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PRINCIPAL URANIUM DEPOSITS OF THE WORLD

By

V. P. Byers

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ABSTRACT

The geology of the principal world uranium deposits that have identified uranium reserves and production, as described in published literature, is summarized briefly, including such features as type of deposit, host rock and age of host rock, age of mineralization, depositional environment, and mineralogy.

The deposits are located on four maps with the deposits grouped according to age of host rocks - Precambrian, Paleozoic, Mesozoic, and Cenozoic - and further subdivided into types of deposits and size categories. Types of deposits are peneconcordant sandstone, quartz-pebble conglomerate, vein and vein-type, marine black shale, phosphate deposits, coaly carbonaceous rocks, and pegmatic and alaskitic rocks.

The economically most significant deposits of uranium known in 1975 are in quartz-pebble conglomerates and sandstones, which together represented about 75 percent of the world's total production.

The largest deposits occur in quartz-pebble conglomerate at the Elliot Lake-Blind River area, Canada (average grade 0.12 percent U_3O_8), and at the Witwatersrand basin area in the Republic of South Africa (average grade 0.025 percent U_3O_8), where uranium is produced principally as a byproduct or coproduct of gold mining; and in medium-grained sandstones in the Colorado Plateau, U.S.A. (average grade 0.2 percent U_3O_8). Other economically significant concentrations are vein, pegmatite or contact metamorphic types, containing smaller but relatively high-grade tonnages and representing about 20 percent of the world's total production. At Västergotland (Billingen) and Närke in Sweden, uranium has been recovered on a pilot-plant basis from black shale deposits having an uncommonly high grade for black shale of 0.03 percent U_3O_8. "Recoverable reserves" in the near future (40 year period, life time of nuclear plants) is on the order of 50,000 metric tons U.

Over 50 percent of the world's total uranium reserves is located on or near the trend of the iron deposits in the Precambrian iron formation, referred to as the "iron band".

INTRODUCTION

General Statement

Uranium is widespread throughout the world but was one of the last metals to become economically significant. Uranium deposits, prior to the "Nuclear age", were found by accident in the search for copper in the Belgian Congo, for cobalt and silver in the Northwest Territories of Canada, for radium and vanadium in Colorado, and for silver in Czechoslovakia. Most discoveries of large deposits in recent years have been made by geophysical methods, mainly airborne scintillometer, drilling in areal extensions of known areas, or using geologic models as exploration tools.

Uranium deposits occur in three major metallogenic age groups: (1) Laramide and Tertiary, (2) Hercynian and Jurassic, and (3) Precambrian (during which two primary periods of mineralization occurred).

Uranium is a geochemically persistent element. It is isomorphic as U^{4+} with Th, Zr, rare-earth elements (REE), Ca, and Fe^{2+}. As uraninite it is precipitated either at high temperatures and pressures or at atmospheric temperatures and pressures. It is easily oxidized from U^{4+} to U^{6+}, which forms the uranyl ion, $(UO_2)^{2+}$, a unit of sufficient stability to preserve its identity in solution, eventually precipitating as low temperature uranyl minerals.

Uranium is precipitated in clastic host rocks that have high transmissivity to ground water, such as sandstones and conglomerates, or is confined to fracture systems (vein deposits) in less permeable rocks. Primary (dull black, gray, and brown) uranium ore minerals (pitchblende and uraninite) occur either in extensive bedded deposits of pitchblende in sedimentary rocks, or in veins and pegmatites. Refractory primary uranium-bearing minerals are found in placers.

Secondary uranium ore minerals, such as carnotite, tyuyamunite, torbernite, meta-torbernite, autunite, meta-autunite, uranophane, and schroeckingerite, occur in weathered and oxidized zones of primary deposits. Vanadates such as carnotite are major secondary minerals in sandstone deposits. Autunite, torbernite, and uranophane are especially widespread uranyl species found in oxidized vein deposits.

Russell (1956) found that the trace element assemblage in "sedimentary type" uranium ores of the United States included Ag, As, B, Ba, Be, Cd, Cs, Co, Cr, Cu, Dy, Er, Ga, Gd, Ge, Li, Mo, Nb, Ni, Pb, Sc, Sn, Sr, Sm, U, V, Yt, Yb, Zn, and Zr. The elements Ba, Cu, F, Mo, P, Pb, Se, V, and Zn are characteristic associates of uranium (Cathcart, 1956; Finch, 1967; Weeks, Coleman, and Thompson, 1959).

Purpose and Scope of Report

This report is an outgrowth of a primary attempt to show on a map the principal concentrations of uranium known from published sources. In this report, data on the geographical distribution, mode of geologic occurrence, and source references through 1976 are compiled from the literature.

The report covers principal uranium deposits throughout the world exclusive of Eastern Europe, China, and the U.S.S.R. Many new important discoveries are not included. Some small deposits receive greater descriptions than large deposits because more literature is readily available about them. A lack of uniformity in format is somewhat a reflection of published material available. In the brief summaries, no attempt is made to evaluate conflicting interpretations in the literature. Large identified uranium resources plus production, even though they may be presently paramarginal (50-percent to a 5-fold price increase) or submarginal (5-fold price increase) (Finch and others, 1973) are included in this report.

GLOBAL DISTRIBUTION OF DEPOSITS

Parallelism of Precambrian Iron and Uranium Deposits

The distribution of the trend of iron deposits in Precambrian iron formation (Condie, 1976; Goodwin, 1973), referred to as the "iron band", and the present known distribution of the uranium deposits, in host rocks of Precambrian as well as other ages, have an overall spatial parallelism (figures 1a and 1b). Over 50 percent of the world's total uranium reserves are located near the "iron band".

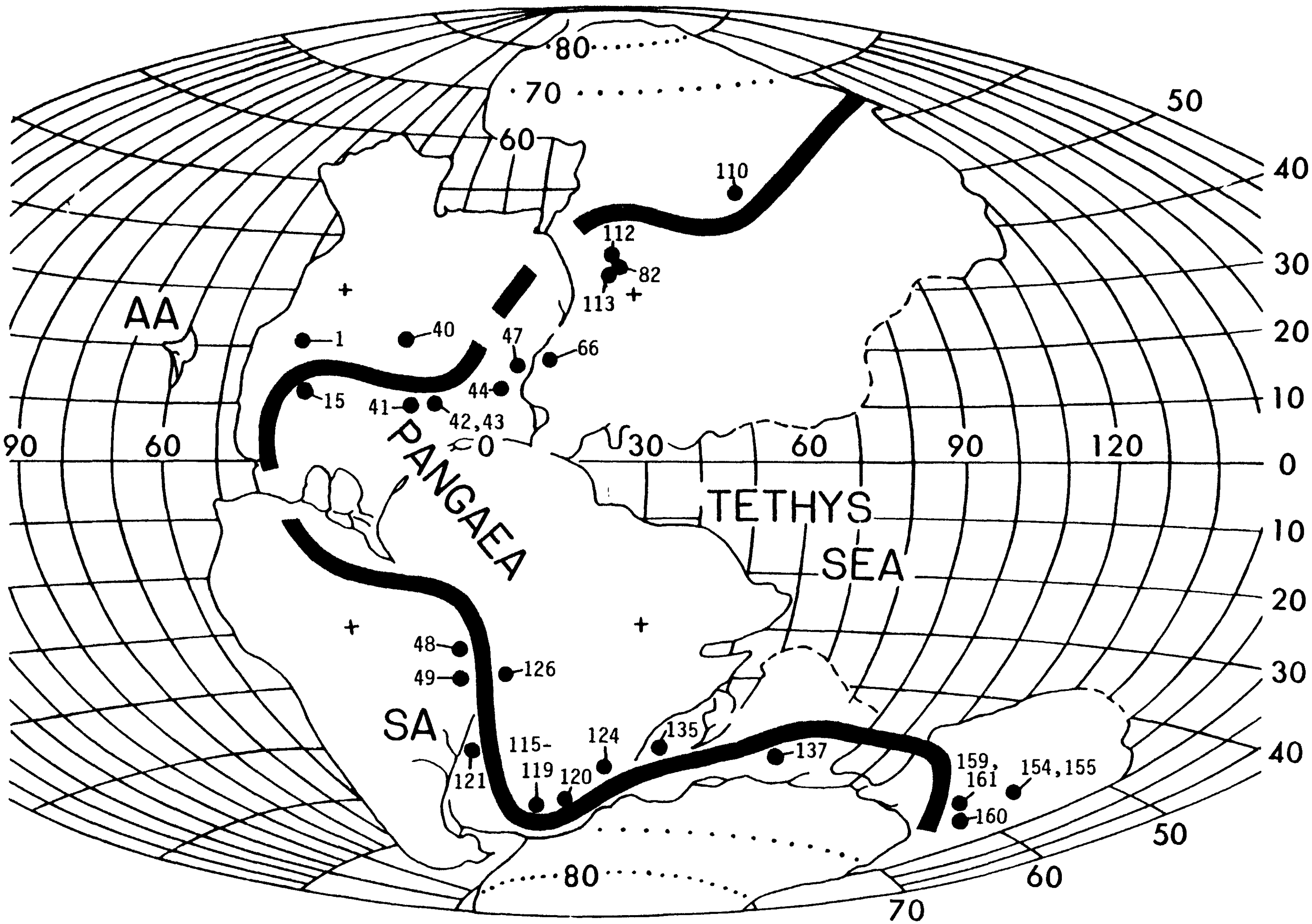


Figure 1a.--Uranium deposits in Precambrian host rocks near the "iron band." More than 50 percent of the world's total uranium reserves (indicated by black circles) (Byers, 1977) is located in host rock of Precambrian age in the vicinity of the iron band (indicated by black band) (Condie, 1976). Figure shows the trend of iron deposits in Precambrian iron formation on reconstruction of the continents into the supercontinent Pangaea at the end of the Permian, 225 million years ago (after Dietz and Holden, 1970). Present positions of the Antilles (AA) and Scotia (SA) arcs are shown for reference. Numbered spots correspond to the numbers on figure 9 and in table 2.

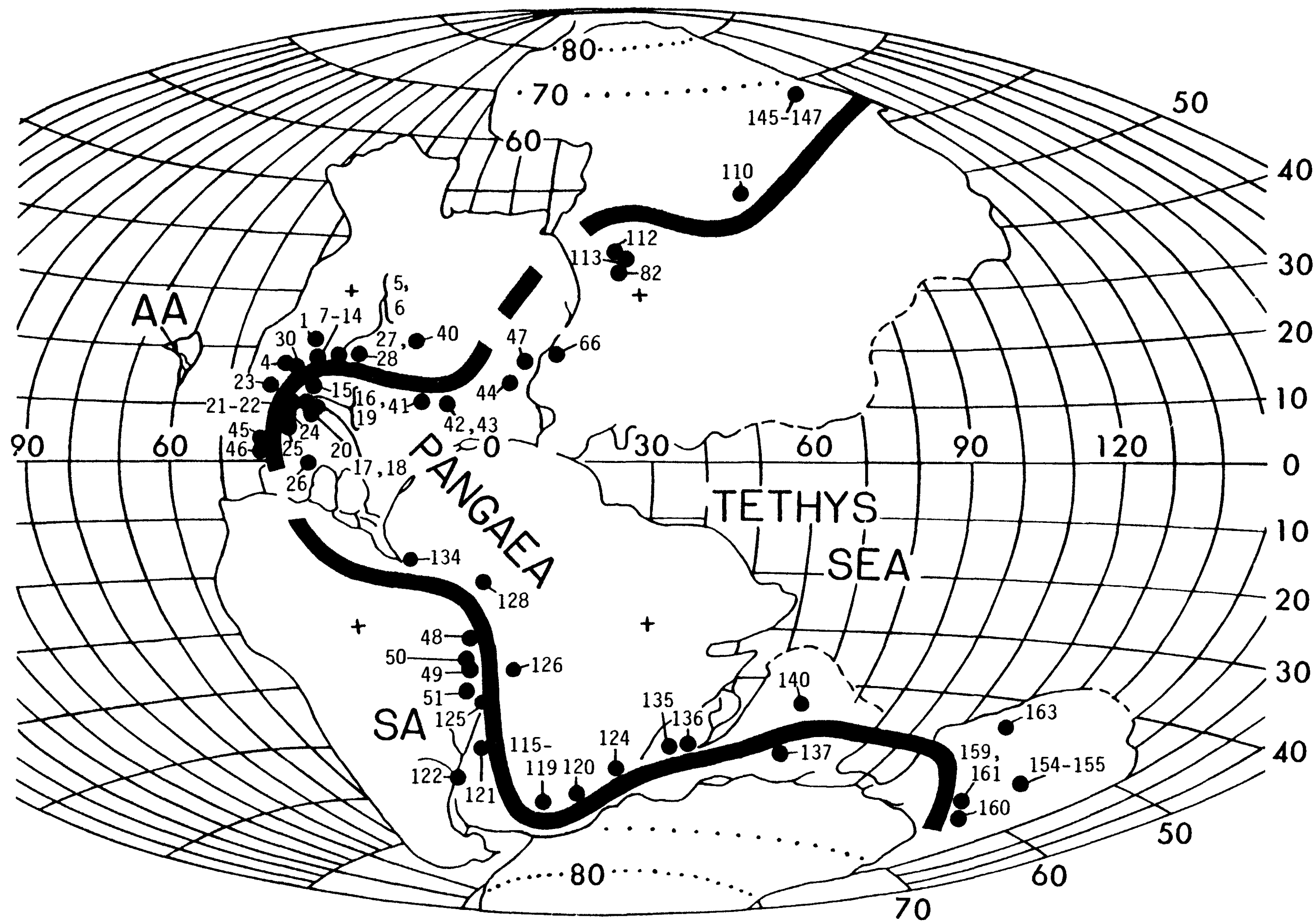


Figure 1b.--Uranium deposits in host rocks of all ages near the "iron band." Numbered spots correspond to the numbers on figures 6,7,8,9 and in table 2.

Uranium Provinces and Districts

Seven principal uranium provinces (Klepper and Wyant, 1956, 1957), as described by Heinrich (1958) are: (1) Colorado Plateau, including adjoining areas and areas in western Idaho and eastern Washington, (2) Canadian Shield-Bancroft district and nearby areas, (3) eastern Brazil areas, (4) Central and Western Europe, (5) southern Africa, (6) northern, eastern, and southern Australia, and (7) Ferghana-Kara Tau region, U.S.S.R. The caliche (or calcrete) deposits of Western Australia, North African phosphate areas, black shale deposits of Sweden, and nepheline syenites of the Illimaussaq massif in Greenland may be considered additional uranium provinces.

Principal productive uranium districts occur primarily in five types of environments: (1) at the margins of Precambrian shield areas where silicic igneous rocks can be as much as five times as radioactive as silicic rocks from the interior parts of the shield areas (Keevil, 1943) (e.g., Blind River-Elliot Lake area and other areas in Canada; Greenland, Australia, Africa, India, Madagascar, Finland, U.S.S.R., and Brazil); (2) at the margins and locally along the axial parts of sedimentary basins, which may be either intermontane basins (e.g., Wyoming, Argentina, and Ferghana, U.S.S.R.), intracratonic basins (e.g., Witwatersrand, South Africa; Blind River-Elliot Lake, Canada; Lake Frome, South Australia; Arlit area, Niger; and Colorado Plateau, U.S.A.), or gulf-type basins (e.g., Texas), and particularly in those basins containing sediments derived from either granitic terranes or volcanic ash; (3) in areas of silicic intrusions in orogenic belts (e.g., Spain, France, Bohemian Massive, and Colorado Rockies); (4) in late magmatic differentiates (alaskites and associated pegmatites) (e.g., Rössing deposit in Southwest Africa); and (5) at unconformities related to paleokarst topography (e.g., Bakouma, Central African Republic, and Tyuya Muyun, Turkistan, U.S.S.R.).

Type of Deposit

Much effort has gone into the classification of uranium deposits (see Cornelius, 1976; Barnes and Ruzicka, 1972; W. D. Chenoweth and R. C. Malan, 1969, written commun.; Petrov and others, 1969; Fomin, 1968; Tananaeva, 1968; "Uranium resources estimates", edited by European Nuclear Energy Agency and the International Atomic Energy Agency, 1967; Wambeke, 1967; Tishkin, 1966; Gotman and Zubrev, 1963; Lang and others, 1962; Little, 1970; Danchev, 1961; Kotlyar, 1961; Surazhakiy, 1959, 1960; Griffith and others, 1958; Robinson, 1958; Ruzicka, 1975; Tishkin and others, 1958; Klepper and Wyant, 1957; and Sullivan, 1957). The geologic classification of deposits as used in this report (table 2) is seven-fold; (1) deposits that are peneconcordant (Finch, 1959a) with the sedimentary structures of the enclosing rocks, which are predominantly sandstones (a single placer deposit is also included in this classification); (2) deposits in quartz-pebble conglomerates; (3) deposits in veins, shear zones, breccia, and fracture zones in rocks of all types, in stockworks, in pipe-like bodies, and of related types (may include disseminated concentrations in fractures, or replacement bodies); (4) deposits in marine carbonaceous black shales; (5) deposits in marine phosphatic rocks, phosphorites, and land-pebble phosphorites; (6) deposits in coaly carbonaceous (coals and lignitic) rocks; and (7) deposits in pegmatite dikes, pegmatoid bodies, alaskite stocks including "porphyry" type bodies, and other igneous rocks. The symbols used in table 2 for categories 1 through 7 are S, G, V, B, P, C, and D, respectively, and are represented in the second alpha character in the symbol.

Peneconcordant deposits (S)

The most economically significant concentrations of uranium known at present in peneconcordant deposits are in host rocks of sandstone, with some deposits occurring in siltstones, conglomerates, and occasionally in limestones, which occur as tabular, lenticular, or roll-shaped bodies, and irregularly shaped masses of widely differing size. Typically these deposits occur in sandstone lenses that are interbedded with mudstone. These strata accumulated under fluvial, lacustrine, sabkha, and near-shore marine conditions in either cratonic or marginal cratonic environments (Finch and others, 1973).

A combination of certain factors is necessary to form peneconcordant uranium deposits in sandstone. These factors include (1) uranium source, (2) transport medium and conduit, (3) reducing agent, and (4) entrapment. Potential source areas for uranium are either granitic or acidic volcanic rocks. Volcanic sources include ash flow tuffs, bedded tuffs, rhyolite lavas, felsitic rocks, zeolitic and montmorillonitic rocks, and calc-alkaline to peralkaline rocks. The transport medium is groundwater, and the conduit consists of permeable rocks such as arkosic sandstones, quartzose sandstones, or porous skarn. The reducing agents include oxide of pyrite, humic material, bacteria, and H_2S, as in formations where gel was formed from alkaline solutions, and in which humates or humic acid provided a fixing environment for precipitation of uranium (e.g., southern San Juan Basin, New Mexico). Squyres (1972) proposed that humic acids were leached from plant detritus in the host rocks, and subsequently flocculated to form a gel, masses of which were transported by ground water and formed lenticular orebodies where the humate masses adsorbed uranium from solution by cation exchange. The traps may be stratigraphic and lithologic or, rarely, they may be structural features such as faults, flanks of anticlines, shear zones, unconformities, fracture systems, and igneous contacts. Areas of sandstone formations that display all or nearly all of these essential factors are favorable for exploration to find new sandstone ores.

The deposition of uranium, molybdenum, and selenium at a reducing barrier has been studied experimentally by Vasil'eva (1972). Microbiologically active gray rock and limonitized rock were permeated by gaseous reducing agents (H_2S and H_2) rising from below, counter to downward-moving metaliferous oxygenated waters. The precipitation of uranium occurred as the Eh of the environment fell to 200 mV and below while the pH ranged from 6.5-8.

Uranium may be concentrated in sedimentary areas in gently folded clastic sequences as thick as 3.5 km that unconformably overlie highly distorted ancient basement rocks (Dunham, 1974) with possible accompanying economic concentrations of Ba, Cu, F, Mo, P, Pb, Se, V, and Zn.

The peneconcordant deposits in clastic sedimentary rocks constitute the greatest known reserves and resources, over 41 percent of exploitable uranium in the western world (OECD/IAEA, 1973), for example: the Colorado Plateau, Wyoming Basins, and Texas Gulf Coast, U.S.A.; Salta and Mendoza Provinces in Argentina; Niger; Ferghana Basin in the U.S.S.R.; and Lake Frome area, Australia.

Placer deposits are extremely rare, and only one significant deposit is included in this report. The deposit is in gravel in gold placers in the Aldan region, Siberian platform, U.S.S.R. The symbol for peneconcordant deposits (S) is used for the Aldan deposits, although placers are not peneconcordant deposits.

Deposits in quartz-pebble conglomerates (G)

Uranium ore occurs in Precambrian sediments in firmly cemented quartz-pebble conglomerates that were deposited under deltaic or fluvial conditions in shallow basins in cratonic or marginal cratonic environments more than 2.3 billion years ago. The matrix surrounding the pebbles consists of common resistate grains and iron sulfide. The ore minerals are either uraninite or brannerite. During early Precambrian time the atmosphere was nearly oxygen-free and reducing in character, which allowed rounded and polished detrital grains of uraninite and pyrite to accumulate with typical detrital placer minerals. Both uraninite and pyrite are generally coextensive with conglomerate beds. Locally the rounded forms of some uraninite and pyrite grains were later modified.

In the Blind River-Elliot Lake district, Canada, deposits are 2.1 - 4.6 m thick and from several hundred meters to 3 km across, in an area of more than 128 km long, and contain more than 5 million tons of ore (Finch and others, 1973). Mineable grade averages 0.12 - 0.16 percent U_3O_8; gold values are 0.02 - 0.03 ounce per ton. The Blind River-Elliot Lake deposits are found in two major structural features, which extend east-west more or less parallel to the north shore of Lake Huron. On the north is a synclinal trough about 40 km long and filled with quartzite. On the south is an eroded anticlinal arch of about the same length that exposes the upwarped basement rock of granite and gneiss.

In the Witwatersrand area, South Africa, the deposits are larger and more extensive than at Blind River-Elliot Lake, but their uranium content is lower, generally 0.03 - 0.07 percent U_3O_8. Uranium is produced mainly as a byproduct of gold mining and locally as a coproduct. Brannerite is a minor amount of ore mineral in the Witwatersrand area.

Uranium reserves and resources in quartz-pebble conglomerates constitute 25 percent of the world's total for countries that have reported resources (OECD/IAEA, 1973) (figure 5).

Vein and vein-type deposits (V)

Uranium-bearing veins are fissure fillings in faults, fracture zones, and joints. Uranium vein-type deposits occur near feeder dikes, in joint sets and along major unconformities, lineaments, and shear zones. Ore occurs as tabular bodies, irregular stockworks, pipelike masses at fracture intersections, and in mineralized gouge and breccia. Veins can be a few centimeters to a few meters wide and extend along strike and downdip as much as several hundred meters. Known vein systems may extend as much as 400 m below the surface in the United States and 1500 m in Canada and may contain 10 tons to millions of tons of ore (Finch and others, 1973). Average mined grade ranges from 0.10 to 1.0 percent U_3O_8.

The uranium-rich vein deposits are commonly rich in sulfides and are found in a variety of host rocks ranging from Precambrian to Tertiary in age, but more commonly of Precambrian age (e.g., the very large deposits at Beaverlodge, in the Goldfields area, Saskatchewan, Canada; the Shinkolobwe, Katanga Province, Zaïre; and the medium-sized deposits at Joachymov, Czechoslovakia, and at Schwartzwalder mine, Colorado, U.S.A.). Uranium deposits have been found in the principal mountain systems (e.g., Schwartzwalder vein deposit, and Central City district, Colorado Rockies) and near or in foreland areas or blocks of earth's crust (massifs) composed mostly of granitic and metamorphic rocks (e.g., Joachimsthal in the Bohemian Massif; Vosges vein deposits of Massif Central, France; and vein deposits of Spanish Meseta, Portugal). Fluorite is a characteristic associate of uranium in moderate-sized deposits at Marysvale, Utah. Uraninite-thorite veins and irregular pods cut and replace bodies of unzoned granitic pegmatite and form fairly large deposits at Bancroft, Ontario, Canada (Robinson and Hewitt, 1958). They contain an average of about 0.1 percent U_3O_8 and 0.025 - 0.2 percent ThO_2.

Uraniferous marine carbonaceous black shales (B)

Uraniferous marine black shales are all of Paleozoic age. The uranium was deposited under anaerobic conditions with the organic fraction of the shale during sedimentation in shallow epicontinental seas. The sapropelic type of uraniferous black shales are commonly more uraniferous than those of the humic type. Most of the black shale resources in the United States are in the upper member of the Chattanooga Shale of Late Devonian and Early Mississippian ages in central Tennessee and adjacent Kentucky and Alabama (Swanson, 1961). This member is 3.7 - 5.5 meters thick over an area of about 10,360 square kilometers, and averages about 0.007 percent U_3O_8. Sweden has uranium ore in uraniferous alum shales (Upper Cambrian and Ordovician) which is 2.7 - 5.5 meters thick, and averages about 0.03 percent U_3O_8. Sulfides are abundant. Shales that yield 10 percent or more distillable oil usually have appreciable uranium. Other deposits of radioactive shale include those in U.S.S.R. near the Baltic Sea.

Uraniferous phosphatic rocks (P)

Marine phosphorite is a dominant source of phosphate and constitutes a very large resource of uranium. Uranium in marine phosphatic rocks is found in formations of early Paleozoic to Tertiary age, but more abundantly in Cambrian, Permian, Upper Jurassic, Cretaceous, and Tertiary rocks. In general beds richest in phosphorites are richest in uranium, but beds leached by surface and ground waters may be enriched in uranium and have a diminished phosphate content. Uranium is produced as a byproduct of phosphorite and phosphate rock. Deposits are found associated with either siliceous carbonate rocks in geosynclinal environments or clay and sand in platform environments. Geosynclinal facies tend to be more uraniferous than platform facies. Uranium was probably deposited from sea water during sedimentation, or possibly later by downward percolating ground water. Extensive uraniferous marine phosphorite deposits (which are commonly 2 - 3 m thick, underlie hundreds of square kilometers, and have uranium content generally ranging from 0.007 to 0.07 percent U_3O_8) occur in the Phosphoria Formation of Permian age in Idaho, Montana, Utah, and Wyoming, in the Bone Valley Formation of Pliocene age in Florida, in countries along the Mediterranean Sea from Morocco to Israel, and near Recife, Brazil.

Uraniferous phosphorite fills large depressions formed by solution of dolomite in the Central African Republic (Mabile, 1968). Uraniferous deposits of aluminum phosphate occur in Senegal and Nigeria.

Uraniferous coaly carbonaceous rocks (C)

Uraniferous lignitic and coaly carbonaceous rocks occur in fluviatile, soft sandy shales and sandstones on the southwestern flank of Williston Basin, North Dakota, South Dakota, and eastern Montana. Uranium probably was introduced by precipitation, chiefly from groundwaters, following coalification. Sources for uranium in the deposits may have been associated silicic volcanic rocks. Uraniferous coaly deposits in Vinaninkarena, Sweden, and Freital, Germany probably had a granitic source. The uranium source in some Hungarian coals may have been the alkalic sills and dikes intruding the coals. Uranium in other coals may have been introduced by uraniferous magmatic solutions. Factors necessary to form the uraniferous coals include: (1) a uraniferous source, (2) groundwater and structures or rocks capable of permitting uranium transport, (3) time for continued movement of uraniferous groundwater, and (4) coaly material of the correct rank, ash content, and permeability, which contains acid organic material capable of precipitating uranium.

Uranium in pegmatite dikes, pegmatoid bodies, alaskite stocks, igneous rocks (D)

Uranium minerals are known to occur in granitic pegmatites, whereas thorium minerals are more likely to be found in syenitic and nepheline-syenitic pegmatites. Several different types of pegmatites and related rock types may occur in the same area (e.g., Bancroft area, southeastern Ontario). Uranium deposits are found around alkalic complexes (e.g., carbonatites around alkalic complexes in dikes and plugs, areas of fenitization, at contacts of granite and schist near plutons (e.g., Mount Spokane alaskite pluton, Washington); and in late-stage differentiates (e.g., Conway Granite of Triassic, Jurassic and Cretaceous age in central New Hampshire). Other areas of uraniferous igneous rocks include alaskitic rocks near Rössing, South West Africa, pyrochlore-bearing alkalic rocks at Araxa, Brazil, sodalite foyaite and nepheline syenite near Julianehaab, Greenland (Bondam and Sörensen, 1958) and riebeckite granite in Nigeria.

FREE WORLD RESOURCES AND PRODUCTION

Uranium resources and production data given in figures 2 to 5 are based on the following sources: "Uranium, Resources, Production and Demand," a joint report by the Organization for Economic Co-operation and Development, Nuclear Energy Agency and The International Atomic Energy Agency, and published by the OECD (1973, 1975); Finch and others (1973); and Bowie (1970).

The Organization for Economic Co-operation and Development NEA/IAEA (1975) estimated world resources of uranium (exclusive of East Germany, Soviet Union, and Chinese Peoples' Republic), which included the totals of reserves and estimated additional resources (in thousand of metric tons uranium) minable at a combined price of less than \$15/lb U_3O_8 and \$15-30/lb U_3O_8. See table 1.

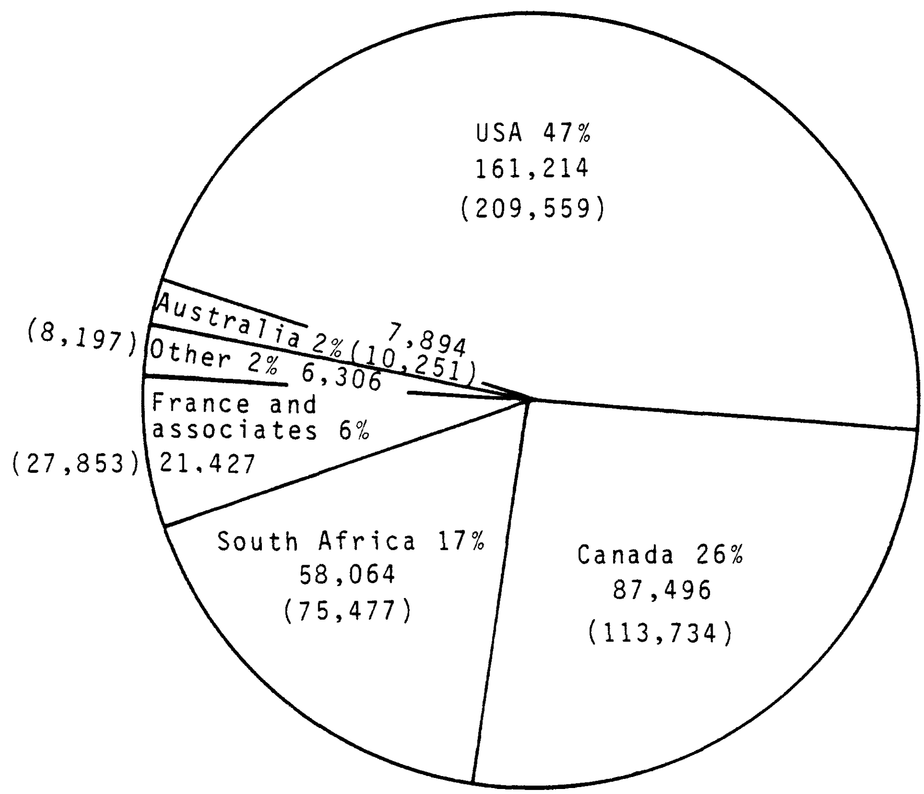


Figure 2.--Uranium production by major producing countries reporting production, 1938-1970 (in metric tons U; short tons U_3O_8 in brackets) (after Davis, 1972, p. 24).

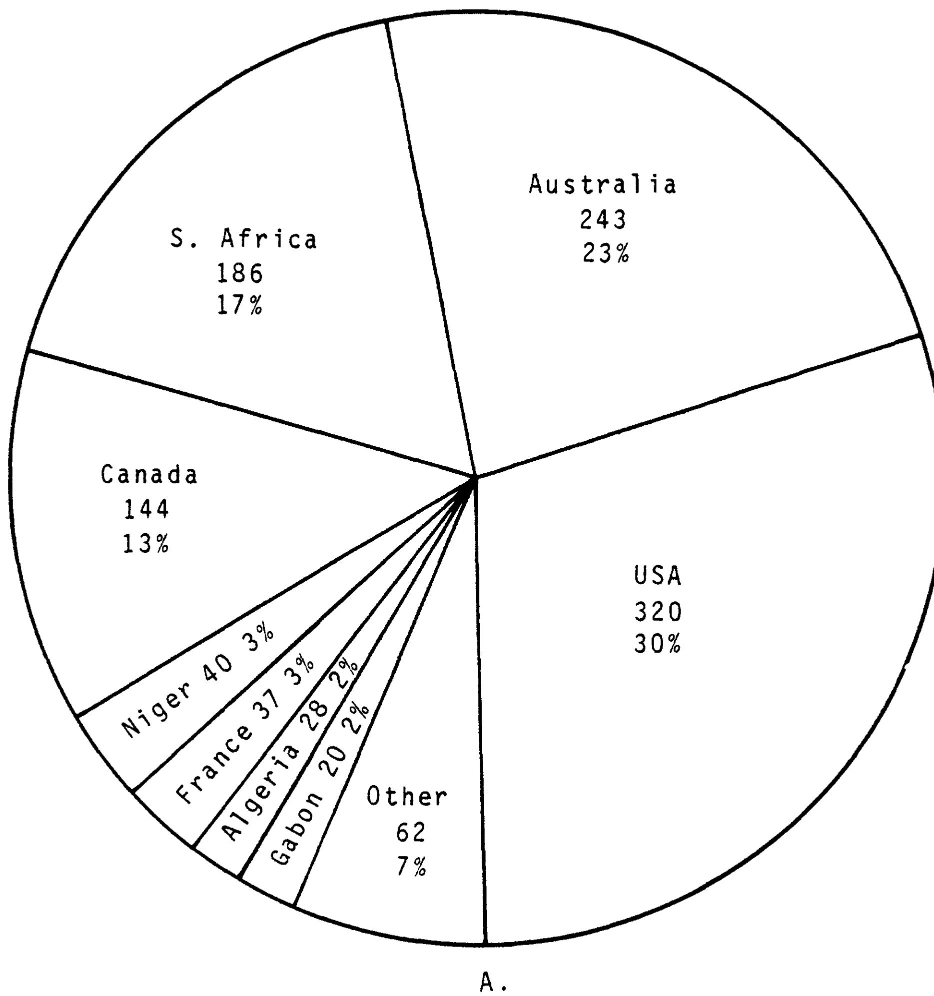
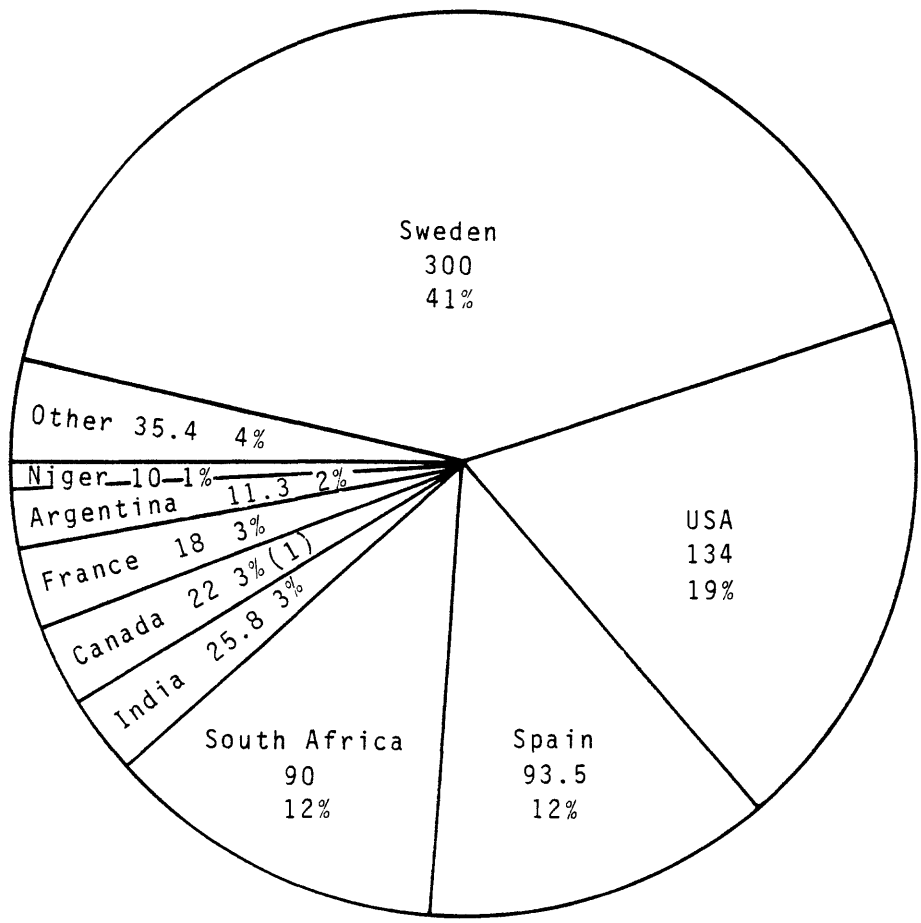


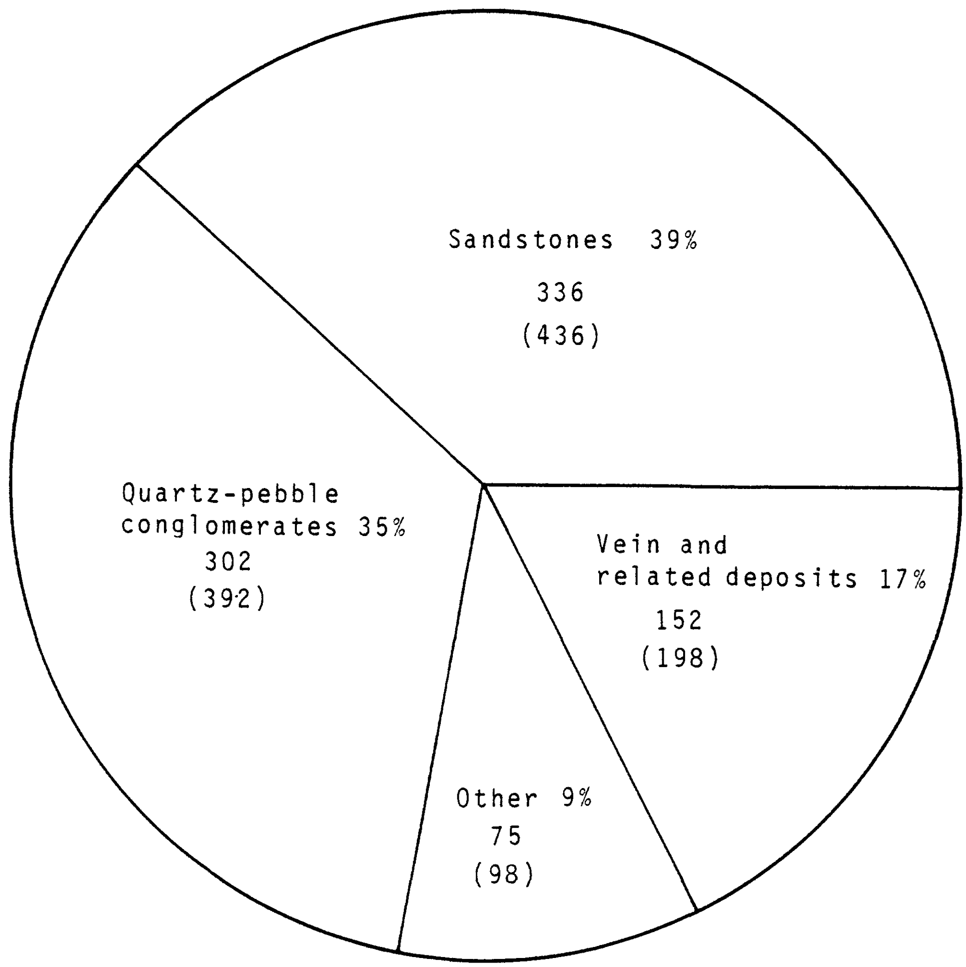
Figure 3.--Uranium: reasonably assured world resources as reported, but excluding estimated additional resources (OECD NEA/IAEA, 1975)
A. Thousand metric tons from ore minable at a price of less than \$15/lb. U_3O_8.
B. Thousand metric tons U from ore minable at a price of \$15-30/lb. U_3O_8.



B.

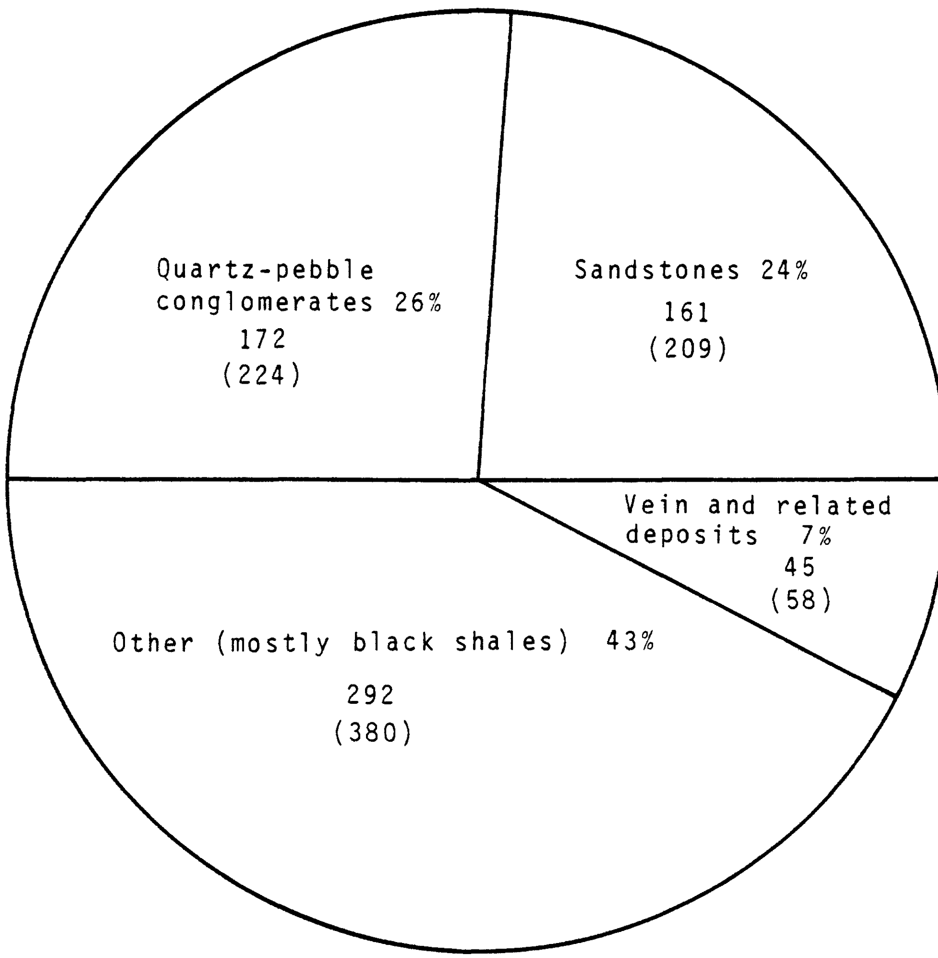
(1) Conservative estimate as restricted to principal deposits.

Figure 3 cont.



A.

Figure 4.--Allocation of world reserves and resources to geological ore types (from OECD NEA/IAEA, 1973, p. 88)
A. Thousand metric tons U (10^3 short tons U_3O_8) reasonably assured resources (reserves) from ore minable at a price of \$10/lb. U_3O_8.
B. Thousand metric tons U (10^3 short tons U_3O_8) reasonably assured resources from ore minable at a price of \$10-15/lb. U_3O_8.



B.

Figure 4 cont.

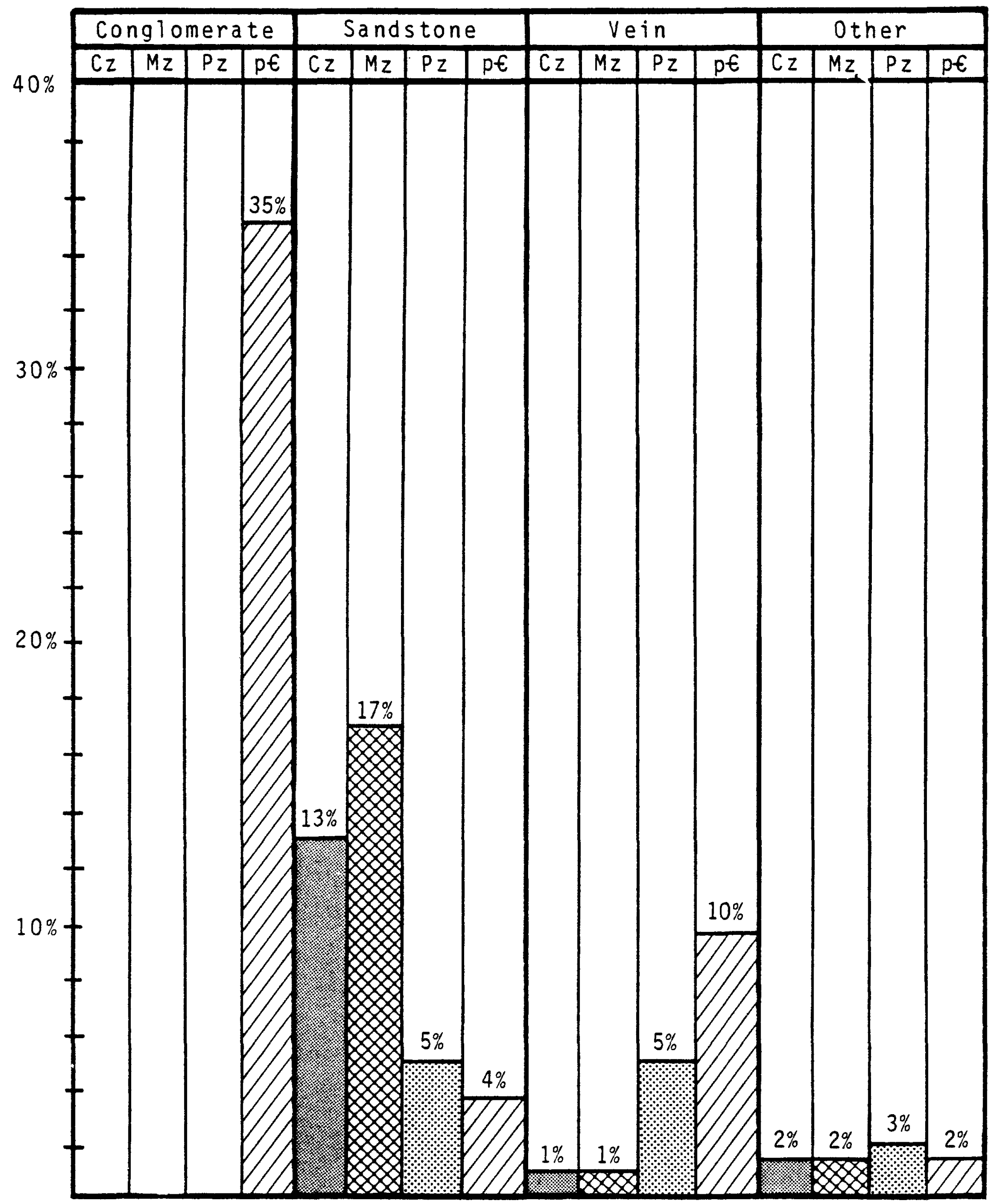


Figure 5.--Allocation of world reserves (reasonably assured resources of ore minable at a price of $10/lb. U_3O_8) (from reporting countries) to ages of host rock within geologic ore types (OECD NEA/IAEA, 1973). Cz, Cenozoic; Mz, Mesozoic; Pz, Paleozoic; and p€, Precambrian.

Table 1. Estimated world uranium resources

Uranium reserves, in thousands of metric tons*	Country
2606.0	USA (includes 69.0 as byproduct from phosphate and copper production)
585.0	Canada
350.0	S. Africa
323.0	Australia
300.0	Sweden
210.3	Spain
95.0	France
80.0	Niger
59.6	Argentina
52.5	India
30.0	Gabon
28.0	Algeria
21.7	Yugoslavia
19.2	Brazil
16.0	Central African Republic
16.0	Denmark (Greenland)
7.7	Japan
6.9	Portugal
6.0	Mexico
5.8	United Kingdom
5.0	Germany
3.5	Zaïre
3.5	Turkey
2.4	Korea
2.2	Italy
1.9	Finland

*These figures from the non-Communist free world total 4,837,200 metric tons U.

SIZE OF DEPOSITS AND DISTRICTS

Both small high-grade uranium deposits or districts (where more than one deposit is present) and large low-grade deposits that have at least 38 metric tons of uranium metal (or 50 short tons U_3O_8) in resources and production together have been selected as "principal deposits." The few relatively high-grade deposits that have been found are not very extensive. Large low-grade concentrations, which are not recoverable profitably under present economic conditions, include such deposits as uraniferous marine phosphorite, black shales, and igneous rocks.

The deposits are divided into three size ranges which are a combination of total production plus reserves, expressed in metric tons of uranium metal (metric tons U), followed by short tons in parentheses. Small size (S) deposits (either single deposit or group where more than one) 770 metric tons U (1,000 short tons of U_3O_8); medium size (M) deposits have 770 to 11,500 metric tons U (1,000 to 15,000 short tons U_3O_8); and large size (L) deposits, more than 11,500 metric tons U (15,000 short tons U_3O_8). The size (S,M,L) of the deposits is shown in the third alpha character of the symbol in table 2.

DESCRIPTION OF LOCALITIES

Geologic descriptions, including type, host rock, age, environment, location by latitude and longitude, and references, are given in table 2 and are keyed by numbers and symbols on the maps in figures 6, 7, 8, and 9, showing principal uranium deposits of the world. The maps have been revised from previous release (Byers, 1977).

Table 2.--Principal uranium deposits of the world.

Map symbol consists of numeric and alpha characters: numeric characters are map and table no. (e.g., 1); first alpha character, age of host rock (A, Precambrian, B, Paleozoic, C, Mesozoic, D, Cenozoic); second alpha character, type of deposit (S,G,V,B,P,C, and D, see seven categories described above) and third alpha character, size of deposit (S,M,L, see above for explanation).

Symbol: 1AVM
Name: Midnite mine, Stevens County, 80 kilometers northwest of Spokane, Washington, U.S.A.
Location: 47° 57' 00" N; 118° 05' 00" W
Description: Uranium occurs in tabular bodies 50 meters or less thick, up to 210 meters wide, and as much as 380 meters long, in metamorphosed steeply dipping Precambrian pelitic and calcareous rocks of a roof pendant adjacent to a Cretaceous(?) porphyritic quartz monzonite pluton. The thickest ore zones invariably occur at depressions in the metasediment-granite contact, and the margins of ore zones generally are steep-sloping granite surfaces (Nash and Lehrman, 1975). At the contact the metasedimentary rocks are mostly phyllite and schist of the Precambrian Togo Formation; the granite is mostly porphyritic quartz monzonite and granodiorite of the Cretaceous Loon Lake Granite. The granite is without visible primary uranium mineralization. The contact is sharp and in detail is extremely irregular. It commonly crosscuts the bedding of the metasedimentary rocks but locally parallels the bedding. The highest grade ore is localized along zones in which the bleached metasedimentary rocks are altered to a rock consisting largely of clay, quartz, and sericite. These zones are at or within a few feet of the contact between the quartz monzonite and the metasedimentary rocks (Becraft and Weiss, 1963). Most ore is in muscovite schist and mica phyllite, but concentrations of uranium sufficient enough to form ore occur in calc-silicate hornfels. Amphibole sills and mid-Tertiary dacite dikes locally carry ore where intensely fractured.

Uranium minerals occur as disseminations along foliation, replacements, and stockwork fracture-fillings. Secondary, oxidized uranium minerals, principally autunite and meta-autunite, and next abundant, uranophane and phosphuranylite, lie above a fluctuating water table, while below this table there occurs a zone of partially oxidized, sooty and compact uraninite with which sulfides are associated. Coffinite also was observed. Accessory tourmaline and rutile are abundant in the metasedimentary rocks. Adularia, illite, kaolinite, and montmorillonite are present, and indicate hydrothermal action (Tatsch, 1976).

Production during 14 years of operation has been about 3,000 metric tons U from oxidized and reduced ores averaging 0.23 percent U_3O_8 (Nash and Lehrman, 1975).

Economic zones of uranium are interpreted to have been secondarily enriched in late Tertiary time by downward and lateral migration of uranium into permeable zones where deposition was influenced by ground water controls and minerals that could reduce or neutralize uranium-bearing solutions (Nash and Lehrman, 1975). High content of iron and sulfur, contained chiefly in FeS_2, appear to be an important feature of favorable host rocks (Nash and Lehrman, 1975).

Age of uranium is 102 to 108 m.y.; U/Pb ages for the ore (pitchblende) are of the order 100-110 m.y. (Rich and others, 1975, 1977).

References: Barrington and Kerr, 1961; Becraft and Weiss, 1957, 1963; Everhart, 1956; Nash and Lehrman, 1975; Norman, 1957; Osterwald, 1965; Rich and others, 1975, 1977; Sheldon, 1959; Tatsch, 1976; Thurlow, 1957; von Backström, 1974; Walker and Osterwald, 1963; Walker, Osterwald, and Adams, 1963; Weissenborn and Moen, 1974.

Symbol: 2DSM
Name: Peters lease (or Northwest Uranium mine, also known as the Sherwood mine), Stevens County, Washington, U.S.A.
Location: 47° 53' 00" N; 118° 07' 00" W
Description: Uranium is disseminated in a low-grade ore body in gently dipping Oligocene conglomerates. The conglomerate is poorly sorted and very poorly cemented, and except for the large boulders (of mainly quartzite or types of Loon Lake Granite) that must be broken before removal, the rock can be mined in open pit without blasting. The conglomerate occupies a shallow northwest-trending sedimentary trough in the underlying porphyritic quartz monzonite. This trough may be a pre-Gerome stream valley. The maximum thickness of the ore body is believed to be as much as 9 meters. It lies from about 2 meters to as much as 24 meters below the surface. The ore consists of uraninite intimately associated with carbonaceous material near the base of the conglomerate that makes up the basal unit of the Eocene Sanpoil Volcanics (formerly known as Gerome Andesite) in this vicinity. Other radioactive minerals are coffinite, gummite, autunite, sparse metatorbernite. The carbonaceous material, including coalified woody structure, occurs both in small arkosic lenses and in irregular masses distributed sporadically throughout the conglomerate. No carbonaceous material was observed in the conglomerate above the ore zone. Accessory minerals include quartz, potassium feldspar, clay, and calcite. Concentration of arsenic, molybdenum, and zinc were present. Since there is no evidence of hydrothermal activity, the solution that transported the uranium was probably ground water. The source of the uranium in the ground water is unknown. The Sherwood open pit mine is estimated to contain 12 million lb of U oxide in 1966 (Engineering and Mining Journal, 1975, v. 176, no. 9, p. 206).
References: Becraft and Weiss, 1963; Engineering and Mining Journal, 1975, v. 176, no. 9, p. 206; Nash, 1977; Nash and Lehrman, 1975.

Symbol: 3CVM
Name: Mount Spokane area, Spokane County, Washington, U.S.A.
Location: 47° 57' 00" N; 117° 12' 00" W
Description: The mineralization occurs in shear zones along a moderately dipping arcuate contact between an underlying granodiorite phase of the Cretaceous Loon Lake Granite and the overlying Precambrian argillites of the Deer Trail Group on the flank of a major anticline. Both rocks have been altered and contain autunite, uranophane, and gummite. The mineralized zone is 608 meters long and averages 2.4 meters wide. Assays of some parts range from 0.67 to 1.12 percent U_3O_8. Mineralization follows the arcuate contact rather closely. The main Dahl orebody is along a large east-west shear zone dipping 10° to 30° north along the contact. Especially rich shoots appear to lie along intersections with faults that strike northwest and offset the contact. Autunite is found in granite as much as 6 meters from the contact. Some of it occurs in crystals of exceptional size and quality, occurring as vug linings in individuals as much as 37 centimeters thick. Pitchblende and pyrite have been identified from drill cores from a depth of 45 meters. Coffinite also has been reported at depth. The five Daybreak properties are reported to contain reserves of almost 50,610 metric tons proved ore, 418,760 metric tons inferred ore, and about 1,051,120 metric tons potential ore, and the grade ranges from 0.06 to more than 2.0 percent U_3O_8 (Heinrich, 1958).
References: Davis and Sharp, 1957; Heinrich, 1958; Illsley, 1967; Norman, 1957; Thurlow, 1956.

Symbol: 4DVS

Name: White King mine, about 20 km northwest of Lakeview, Lake County, Oregon, U.S.A.

Location: 42° 20' 00" N; 120° 31' 00" W

Description: The uranium mineralization at the White King mine appears to be geologically quite recent and is associated with a flow-banded rhyolite dike(?) that has intruded clayey tuffs, tuff breccias, agglomerates and basaltic lava flows of Pliocene age. Black uranium oxides and associated realgar, stibnite, pyrite, cinnabar, ilsemannite, galena, and chalcedony indicate a relatively low-temperature hydrothermal origin for the deposit. Primary uranium minerals are in veins and disseminated in clayey tuffs and breccias (Peterson, 1969). Opalization and clay alteration are predominant in the orebodies, which tend to be somewhat tabular and are displaced by numerous northwest- and northeast-trending faults. Near the surface, concentrations of a rare, bright yellow-green, secondary uranium mineral, metaheinrichite (barium uranyl arsenate), vivid blue ilsemannite (hydrous molybdenum oxide), and the orange and yellow arsenic sulfides realgar and orpiment make a very colorful mineral deposit (Peterson, 1958, 1959, 1969).

References: Gross and others, 1958; Matthews, 1955; Peterson, 1958, 1959, 1969; Rich and others, 1975; Schafer, 1955, 1956; Walker and Adams, 1963; Walker and Osterwald, 1963.

Symbol: 5CSS
Name: Northern Black Hills area, Crook County, Wyoming, U.S.A.
Location: 44° 46' 00" N; 104° 54' 00" W
Description: The principal host rocks for uranium deposits at the northwest end on the Black Hills uplift are the Inyan Kara Group of Early Cretaceous age. In northeastern Wyoming, the Inyan Kara Group ranges in thickness from about 100 to 200 meters and includes the Lakota Formation and the overlying Fall River Formation. The Lakota is nonmarine, ranges in thickness from 60 to 150 meters, and thickens southward and eastward from the northwestern Black Hills. The rocks make up a sequence of fine- to medium-grained sandstone, siltstone, and clay deposited under fluvial, lacustrine, and paludal conditions. Most of the sandstone occurs as poorly bedded lenses, some of which are of considerable lateral extent (Harshman, 1968a). Carbonaceous shale is present in the lower part of the formation in some areas. The Fall River overlies the Lakota with a marked disconformable contact. It is 38 to 45 meters thick and comprised of mostly fine-grained sandstone with some interbedded siltstone. The Fall River was deposited in a marginal marine environment, and its thin-bedded character contrasts with the more massive character of the nonmarine Lakota (Harshman, 1968a).

The uranium deposits consist of small, irregular, tabular masses that average about 1 meter in thickness and have lateral dimensions that may be measured in 3 to 30 meters; and large deposits, 100 to 300 meters in width (Bergandahl and others, 1961). In gross aspect, the ore deposits have no preferred orientation or trend. One type occurs above the local water table and consists of carnotite-tyuyamunite type of minerals assemblage, and the other type occurs below the water table and is characterized by a uraninite-coffinite assemblage. Both types are associated with finely divided carbonaceous material. Locally both carbonaceous material and uranium minerals are concentrated in sandy or silty seams that appear to be alined along bedding planes and planes of cross stratification; these concentrations constitute the richest parts of the ore bodies (Bergandahl and others, 1961).

References: Bergandahl and others, 1961; Harshman, 1968a; Hart, 1968; Maxwell, 1974; Robinson and Goode, 1957; Robinson and others, 1964; Vickers, 1957.

Symbol: 6CSM
Name: Southern Black Hills area, South Dakota, U.S.A.
Location: 43° 25' 00" N; 103° 50' 00" W
Description: Peneconcordant disseminated uranium deposits are in continental fluviatile channel sandstones of the Lower Cretaceous Lakota and Fall River Formations of the Inyan Kara Group. Sandstone-filled channels in the Inyan Kara are as much as 40 km long and over 30 meters wide. Along their length the deepest scour was completely filled and the stream-borne material then spread over a relatively wide plain, in some places several kilometers wide. The sandstone is fine- to coarse-grained, normally noncarbonaceous, poorly sorted, of extremely variable texture, and cross-stratified. The superposition of fluvial sandstones provided channelways that permit circulation of ground water and influence the location of ore deposits. The Black Hills uplift of Laramide age, an elongate northwest-trending dome about 200 km long and 96 km wide, provided the structural topographic relief necessary for the erosion that exposed Mesozoic and Paleozoic rocks. This erosion resulted in ground water recharge of aquifiers in the formations of Devonian to Permian age. Artesian water ascended along fractures in these aquifers and dissolved evaporites in the Pennsylvanian and Permian Minnelusa Formation. Collapse of beds overlying the evaporite zone resulted in subsidence breccias and breccia pipes. These breccia pipes of Tertiary to Holocene age extend upward from the Minnelusa and permit large volumes of artesian waters carrying relatively low concentrations of uranium to ascend into the Inyan Kara (Gott, Wolcott, and Bowles, 1974). As this calcium sulfate type water from the Minnelusa migrates downdip it is modified by ion exchange and sulfate reduction to either a sodium sulfate or a sodium bicarbonate type water, causing an increase in pH values and a descrease in Eh values. Reduction of sulfate ions in the ground water was the major factor in creating a favorable environment for the precipitation of uranium. Where the water in the Inyan Kara changes from a predominately calcium sulfate water to a sodium bicarbonate water, hydrogen sulfide is abundant. Most likely, the hydrogen sulfide resulted from sulfate reduction by bacteria that depend upon carbonaceous material within the Inyan Kara rocks for their life processes. During erosion, the water table declines, and the zone of artesian recharge, as well as the oxidation-reduction front within the Inyan Kara, migrates basinward. In addition to erosion, structural deformation caused shifting of the sites of uranium deposition. Ore deposits are restricted to fluvial units 1, 4, and 5 and to the sandstones and siltstones of the basal Fall River Formation, which are favorable zones for deposition of uranium because the fine-grained rocks have been removed by intraformational erosion and the geochemical environment is favorable for precipitation.

In the basal part of the Fall River Formation, corvusite, rauvite, carnotite, and tyuyamunite constitute the ore-forming minerals. Aggregates of uraninite are concentrated around pods of green pyritic clay in a quartzose sandstone. In many oxidized uranium deposits uranium minerals are selectively concentrated around carbonized wood fragments and macerated plant remains. In the many other deposits, in which this relation does not exist, the uranium minerals seem to have been precipitated by an ephemeral agent. It is suggested that biogenically derived hydrogen sulfide has been enriched in the ground water in some areas, and this enrichment probably accounts for those deposits not directly associated with organic material (Gott, Wolcott, and Bowles, 1974).

References: Bell and Post, 1971; Braddock, 1955, 1963; Brobst, 1961; Cuppels, 1962, 1963; Gott and Pipiringos, 1964; Gott, Post, Brobst, and Cuppels, 1956; Gott and Schnabel, 1963; Gott, Wolcott, and Bowles, 1974; Hart, 1968; Post, 1967; Ryan, 1964; Schnabel, 1963.

Symbol: 7DSL
Name: Monument Hill area, Powder River Basin, Converse County, Wyoming, U.S.A.
Location: 43° 14' 00" N; 105° 37' 00" W
Description: The stable vanadates, carnotite, and tyuyamunite, disseminated in lensing uncemented sandstone units of the Wasatch Formation, early Eocene age, are the principal ore minerals in the deposits. The ore-bearing sandstone units range in thickness from a few meters to 200 meters. The area is on the west edge of the narrowest part of the red sandstone zone in a region where formation of clay from volcanic ash in some of the sandstone units has bleached out the red color (Sharp and Gibbons, 1964, p. D30). The uranium deposits almost without exception occur near the boundary or edge of the red color in any sandstone unit. Deposits are as much as 30 meters long, 15 meters wide, and 3 meters thick. Small dense concentrations of yellow uranium minerals are common around coalified woody fragments within the body of disseminated material, and fractures may be coated with hydrated uranium minerals. Much of the uranium occurs as uraninite which cements and coats sand grains to form accretionary masses a few centimeters to 2 meters across. All the uraninite accretionary masses are surrounded by a thick halo rich in yellow oxidized uranium minerals. A lead/uranium ratio indicated a maximum age of 13 million years for a uraninite-bearing rock. Vanadium rarely is present in more than a 1:1 ratio with uranium. Manganese occurs almost exclusively in nodules in a highly oxidized state. Concentration of uranium, vanadium, and manganese began with moderate folding along the axis of the basin. The resulting disturbance of the geochemical equilibrium within the Wasatch sediments changed the gray color rock to red (hematitic) or "white" (bleached). The uranium is thought to have been derived from the clastic material which was deposited in the basin and formed the sandstone lenses (Sharp and Gibbons, 1964)--tuffaceous and arkosic debris (Dahl and Hagmaier, 1975). Curry (1976) estimates that uranium resources in tons U_3O_8 of the Powder River Basin, as of January 1, 1976, at a cost of \$30/lb U_3O_8 are: reserves, 107,200; probable resources, 60,000; and possible resources, 18,000. These figures include Highland Flats.
References: U.S. Atomic Energy Commission News Release, 1973, v. 4, no. 13, p. 2; Curry, 1976; Davis, 1969; Dahl and Hagmaier, 1975, 1976; Fischer, 1974b; Granger, 1966; Granger and Warren, 1969, 1974; Harshman, 1968a; Keefer and Schmidt, 1973; Law and others, 1975; Mrak, 1968; Rosholt and others, 1965; Seeland, 1976; Sharp and Gibbons, 1964; Sharp and White, 1957; Sharp and others, 1954; Tatsch, 1976; Warren, C. G., 1972.

Symbol: 8DSL
Name: Highland Flats area, southern Powder River Basin, Converse County, Wyoming, U.S.A.
Location: 43° 05' 00" N; 105° 30' 00" W
Description: Uranium deposits are large roll-type ore bodies in Paleocene sandstone in the upper part of the Fort Union Formation. The sandstones are arkosic, loosely consolidated, very permeable, and contain substantial organic debris and tuffaceous material (Dahl and Hagmaier, 1975). The sandstones were deposited as point bars by a meandering stream, and to a lesser extent as channel bars by sand-laden streams (Dahl and Hagmaier, 1975, p. 1). In cross section the uranium deposits are characterized geometrically by C-shaped or roll-type mineralization. In plan view the deposits are tongue-shaped and best developed near the sandstone margins (Dahl and Hagmaier, 1975, p. 6). Mineralization extends for several kilometers but is not everywhere of economic grade along the tongue. The ore mineral is primarily coffinite with lesser uraninite. Coffinite occurs in the form of thin sooty layers and irregular spherical or botryoidal masses (generally less than 10 micron thickness) on individual mineral grains in the sandstone. High alteration is represented by red hematite-stained sandstone within the oxidized concave interior of a roll. Hematite grades into a narrow brown-colored goethite zone close to and within the roll. The goethite-stained sandstone grades into gray unoxidized sandstone (protore) on the convex side of the roll. Higher-grade ore of minable thickness is most frequently located within a band of varying width (20-200 meters) along the goethite-protore contact. The source of the uranium is considered to be tuffaceous and/or arkosic debris indigenous to the host sandstones, their nearby facies equivalents, and overlying sedimentary units. A master stream system flowed northward into the Powder River Basin depositing clastics in an alluvial complex. Its location was sympathetic with the synclinal axis of the basin. The largest deposits of highest grade occur near the distal margins of permeable, slightly dipping sandstones where they grade laterally into organic-rich siltstones, claystones, and lignites deposited in backswamp or flood basin environments. The deposits are epigenetic in origin, formed by precipitation of uranium from ground-water solutions that moved through the host rocks from a recharge area southwest of the deposits toward a discharge area northeast of the deposits. Oxidation of pyrite, that was formed early through a biogenic process utilizing sulfate-reducing bacteria, caused sulfite to form. Sulfite disproportionation into $SO4^{+}$ and HS- (inorganic bisulfide) developed the final reducing mechanism for uranium precipitation in the ore rolls (Granger and Warren, 1969, 1974).

References: Buturla and Schwenk, 1976; Dahl and Hagmaier, 1975; Denson and Horn, 1975; Granger and Warren, 1969, 1974; Harshman, 1968a, 1968b; Keefer and Schmidt, 1973 Seeland, 1976.

Symbol: 9DSS
Name: Copper Mountain area, Wind River Basin, Fremont County, Wyoming, U.S.A.
Location: 43° 25' 00" N; 107° 54' 00" W
Description: The area is on the north flank of the Wind River Basin in the central part of Wyoming. The host rock for the deposits is a very coarse-grained, arkosic sandstone and boulder conglomerate that was derived from the Precambrian granite upon which it was deposited. The host rock is probably Eocene in age. Near the steep slope of Copper Mountain, it laps onto the eroded surface of the granite or fills old stream channels in the granite. Uranium, in the form of coffinite and various yellow oxides, coats sand grains, fills interstices between grains, and, in many places, forms rinds on boulders. Minor amounts of uranium have been found in tuffaceous rocks interbedded with the arkosic material. Radioactive anomalies and a few low-grade concentrations of uranium exist in the granite, and it is possible that the Copper Mountain deposits represent uranium weathered from the granite, transported in ground water, and deposited in the arkosic sedimentary rocks (Harshman, 1968a).
References: Harshman, 1968a; Finch, 1967; Gruner and Smith, 1955; Love, 1939, 1954; Seeland, 1975a,b; Van Houton, 1964; Wilson, 1960.

Symbol: 10DSL

Name: Gas Hills area, about 95 kilometers east of Lander, Fremont and Natrona Counties, Wyoming, U.S.A.

Location: 42° 48' 00" N; 107° 35' 00" W

Description: The Gas Hills area is on the south flank of the Wind River Basin in an area where a trough-like depression, underlain by rocks of Paleozoic and Mesozoic age, is filled with a sequence of continental rocks of fluvial origin and of Tertiary age. The older rocks dip 10° to 15° N.; the Tertiary rocks dip a few degrees to the south. The uranium deposits are in the upper part of the Wind River Formation of early Eocene age. The ore-bearing beds in the Gas Hills, as in the Shirley and Powder River Basins, are coarse-grained, conglomeratic arkoses, a basin-border facies of the Wind River Formation that contrasts markedly with a fine-grained facies nearer the center of the basin (Harshman, 1968a, p. 829). Roll-type ore bodies are by far the most important source of uranium in the Gas Hills, although blanket-type bodies of reduced black ore, as well as near-surface oxidized ore bodies, have been mined. The deposits are in three belts, trending northerly and about 5 kilometers apart. Two of the belts are aligned with channels, exposed in the Beaver Divide escarpment, that were eroded through the Wagon Bed Formation and subsequently filled with rocks of the White River Formation. In the Gas Hills the ore deposits are related to tongues of altered conglomeratic sand produced by the ore-bearing solutions. Most of the ore occurs along the margins of the altered tongues, in elongate bodies that are C-shaped in cross section. Some ore is emplaced on the top and bottom surfaces of the tongues. Some of the rolls are suspended entirely within a sandstone interval: however, many rolls terminate, top and bottom, at impermeable siltstone beds.

Epigenetic minerals in the orebodies include uraninite, coffinite, pyrite, marcasite, calcite, jordisite, and one or more selenium minerals. Selenium is most abundant near the contact between ore and altered sand, and molybdenum generally is found on the convex side of the roll in a zone between ore and mineralized ground. The ore minerals coat sand grains and fill the interstices between the grains. Most geologists working in the area conclude that the deposits are the result of deposition from ground water moving through the most transmissive parts of the Wind River Formation.

Opinion is diverse regarding the source of the uranium, the hydrodynamics of the ore-bearing solutions, and the factors causing deposition. Stuckless and co-workers (1977) proposed that the source of the uranium deposits in the Crooks Gap, Gas Hills, and Shirley Basin uranium districts, Wyoming, are the granite rocks from Granite Mountains, Wyoming. Investigations by Armstrong (1970) and Cheney and Jensen (1966) indicate that the three belts in the Gas Hills district may all be related to a single large tongue of altered sand, irregular in plan and extending across the district. The deposits have been estimated to be more than 500,000 years old (Cheney and Jensen, 1966).

References: Armstrong, 1970, 1974a; Cheney and Jensen, 1966; Coleman and Appleman, 1957; Dooley and others, 1974; Finch, 1967; Fischer, 1974b; Gruner and Smith, 1955; Grutt, 1956; Harshman, 1968a, 1972a; Sharp and White, 1957; Soister, 1967; Stephens, 1964; Stuckless and others, 1977; Zeller, 1957; Zeller, Soister, and Hyden, 1956.

Symbol: 11DSM
Name: Crooks Gap area, about 88 kilometers southeast of Lander and 40 kilometers south of the western part of the Gas Hills district, Lander County, Wyoming, U.S.A.
Location: 42° 22' 00" N; 107° 50' 00" W
Description: The known deposits are on the north and west flanks of Sheep Mountain, a few kilometers north of the drainage divide between the Great Divide Basin and the Sweetwater uplift. The area is structurally complex. Rocks of pre-Tertiary age are intensely deformed by folding, normal faulting, and overthrusting. Rocks of Tertiary age are only moderately deformed. The host rock for the uranium deposits is the Battle Spring Formation, a sequence of coarse-grained, friable, arkosic sandstones, conglomerates, conglomeratic sandstones, and thin interbeds of carbonaceous siltstone. The formation is 608 meters to 912 meters thick in the mining area. These rocks are of early Eocene age and are partly equivalent to the coarse-grained facies of the Wasatch and Wind River Formations in other Wyoming basins. The Battle Spring Formation rests either on the eroded surface of the Fort Union Formation of Paleocene age or on the eroded surface of the older rocks. According to Eric Newman of Western Nuclear, Inc. (oral commun., 1967), the uranium deposits in the Crooks Gap area are in the lower 243 meters of the Battle Spring Formation. On a regional basis, the ore-bearing zones are concordant with the beds, which dip 20°SE; within the zones, ore may crosscut sedimentary features. Roll-type uranium deposits, associated with slightly altered sand, are thought to be present in the Crooks Gap area, but they are poorly defined and difficult to recognize. Much of the ore appears to be in irregular and/or blanket-type deposits. The complex structural and stratigraphic setting for the Crooks Gap deposits contrasts sharply with the more simple settings in the Gas Hills and Shirley Basin (Harshman, 1968a). A "plumbing" system, complicated by faulting and impermeable siltstone beds, is thought to account for the irregularity of the deposits. The ore-bearing solution is thought to have been ground water; the shape and position of some of the ore bodies suggest that it moved from south to north. Unoxidized ore is black and contains uraninite, coffinite, and pyrite; calcite, selenium, and molybdenum (jordisite) are associated with uranium in the deposits. Near surface ore-bodies, of minor economic importance, contained uranium phosphates, silicates, sulfates, and vanadates.

Granite rocks from Granite Mountains, Wyoming, are proposed as the source of uranium deposits in the Crooks Gap, Gas Hills, and Shirley Basin uranium districts, Wyoming, by Stuckless and his colleagues (1977).

References: Coleman and Appleman, 1957; Finch, 1967; Fischer, 1974a, 1974b; Gruner and Smith, 1955; Grutt, 1956; Harshman, 1968a, 1968b, 1968c, 1972a, 1974a; Sharp and White, 1957; Stephens, 1964; Stuckless and others, 1977; Zeller, 1957; Zeller, Soister, and Hyden, 1956.

Symbol: 12DSL

Name: Shirley Basin area, Carbon, Converse, and Natrona Counties, about 56 airline kilometers south of Casper, Wyoming, U.S.A.

Location: 42° 20' 00" N; 106° 11' 00" W

Description: The uranium deposits in the Shirley Basin area constitute about one-sixth of the uranium ore reserves of the United States. They are in the lower Eocene Wind River Formation in two thick sandstone intervals which are separated by siltstone and silty claystone beds. The deposits bound large tongues of altered sandstone, commonly in so-called roll forms at the margins and as tabular layers on the top and bottom surfaces. This spatial relationship is useful as an exploration guide (Harshman, 1972a, 1972b). Ore bodies range from a few hundred tons to a few hundred thousand tons and in ore grade, as mined, from 0.1 to 0.7 percent U_3O_8. High-grade ore may contain as much as 20 percent U_3O_8. The edge of the altered-sandstone tongues separate oxidized iron minerals within the tongues from reduced iron and uranium minerals in the material surrounding them. Hydrogen sulfide of biogenic origin is believed to have played an important part in forming the ore deposits, although precipitation of the ore minerals may have been caused by nonbiogenic reactions (Harshman, 1972a, 1972b). Ore deposition probably took place at least 150 meters and perhaps as much as 450 meters below the ground surface.

Uraninite, the principal ore mineral, is either fine grained or sooty. It is the only identified ore mineral; accessory minerals are abundant pyrite and minor amounts of marcasite, calcite, hematite, native(?) selenium, and an unidentified sulfate mineral. Altered sandstone contains goethite, limonite, and ferroselite. Uraninite and pyrite coat sand grains and fill interstices between sand grains; there is some replacement of the arkose by pyrite. Many elements in the ore, and in altered and unaltered sandstone near ore, show a systematic distribution about the edge of the altered-sandstone tongue. These elements include uranium, iron, selenium, carbon, beryllium, sulfur, copper, and vanadium. The ore is unoxidized, and it contains no secondary uranium minerals (Harshman, 1972).

The zone of ore deposition is considered to have been a dynamic feature, migrating basinward by oxidation and solution on the updip side of the ore body and reduction and deposition of the downdip side (Harshman, 1972). A rather sharp drop in the pH of the ore-bearing solution probably occurred at the edge of the altered sandstone tongue when pyrite was oxidized by the ore-bearing solutions.

The age of the Shirley Basin uranium deposits is not well documented, but the best evidence suggests that it is about 18 million years (Harshman, 1972).

Some of the larger ore bodies are represented by: the Morton Ranch properties, about 22 miles northeast of Glenrock, which have reserves of 11.4 million lb of U oxide, and are expected to mine for 10 to 12 years (Engineering and Mining Journal, 1976, v. 177, no. 4, p. 148); the Silver Bell properties, which have 1.1 million lb of U_3O_8 in 440,000 tons of shallow ore (Engineering and Mining Journal, 1976, v. 177, no. 4, p. 148); the UJV holdings in the Shirley Basin area, which are estimated to contain 6.9 million tons of in-place reserves with an average grade of 0.19 percent U oxide or 3.8 lb/short ton; the UJV properties in sections 4 and 33, which are estimated to contain 4.5 million tons of ore reserves of 0.23 percent U oxide (Engineering and Mining Journal, 1976, v. 177, no. 6, p. 316); and Getty Oil and Shelly Oil owned properties which have 6.4 million tons of material with average grade of 0.09 percent U oxide or 1.8 lb/ton, containing 5,760 short tons of U oxide (Engineering and Mining Journal, 1976, v. 177, no. 6, p. 316).

Granite rocks from Granite Mountains, Wyoming are proposed as the source of uranium deposits in the Shirley Basin, Crooks Gap, and Gas Hills uranium districts, Wyoming (Stuckless and others, 1977).

References: Buzzalini and Gloyn, 1972; Coleman and Appleman, 1957; Dooley and others, 1974; Engineering and Mining Journal, 1976, v. 177, no. 4, p. 148; Engineering and Mining Journal, 1976, v. 177, no. 6, p. 316; Finch, 1967; Fischer, 1974b; Gruner and Smith, 1955; Grutt, 1956; Harshman, 1968b, 1968c, 1972a, 1972b, 1974a, 1974b; Ludwig, 1975; Melin, 1964; Sharp and White, 1957; Stephens, 1964; Stuckless and others, 1976, 1977; Warren, 1972; Zeller, 1957; Zeller, Soister, and Hyden, 1956.

Symbol: 13DSS
Name: Poison Basin district, about 10 kilometers west of Baggs, Carbon County, Wyoming, U.S.A.
Location: 41° 03' 00" N; 107° 47' 00" W
Description: The district is on the southeast flank of the Washakie Basin. The Browns Park Formation, of Miocene age, is the host rock for the uranium deposits. The formation, which generally is gray to buff, is of continental origin and is at least partly aeolian; it comprises a thick series of fine- to medium-grained, crossbedded, tuffaceous sandstone, tuff, and thin quartzite. Vine and Prichard, 1954, reported the formation to be about 90 meters thick in the Poison Basin area. The low-valent or reduced gray ore consists of uraninite and coffinite that coat sand grains and fill interstices between grains. Considerable pyrite is associated with the ore minerals. Selenium and molybdenum, elements characteristic of many of the Wyoming deposits, are present in appreciable amounts. The upper parts of the deposits have been oxidized, and the brown sandstone contains uranophane, meta-autunite, schroeckingerite, and other high-valent uranium minerals. The contact between oxidized and unoxidized sandstone is generally very sharp. The ore bodies occur in the more permeable parts of the sandstone, and, to some extent, their location appears to have been influenced by faults that are common in the area. Some of the deposits are gently dipping tabular bodies that follow bedding, and, according to R. Rackley (oral commun., 1966), some are roll-type deposits in which oxidation has destroyed the upper limb. The origin of the deposits has been attributed to deposition from circulating ground water, but the source of the uranium is not definitely known. The uranium may have originated in the volcanic ash common in the rocks present in the Poison Basin area. The lack of carbonaceous material in the host sandstone and the presence of natural gas in the Browns Park Formation led Grutt (1957) to propose that the deposits were formed by the precipitation of iron and uranium from circulating ground water by reaction with H_2S in the natural gas.
References: Grutt, 1957; Harshman, 1968a; Keys and Dodd, 1958; Vine and Prichard, 1954.

Symbol: 14DSM
Name: Maybell area, about 8 kilometers east of Maybell, Moffat County, Colorado, U.S.A.
Location: 40° 35' 00" N; 107° 59' 00" W
Description: The deposits are in the Browns Park Formation of Miocene age which contains the largest deposits in rocks of Tertiary age in Colorado. They are in stream-laid arkosic, locally tuffaceous sandstone which forms the uppermost and thickest part of the formation (Bergin, 1957, p. 280-283). The Browns Park Formation filled an ancient basin of considerable relief to a depth of 600 meters in places, and its thickness is very irregular. The main deposits are 150 to 180 meters above the base of the formation. They consist of somewhat overlapping, irregularly tabular mineralized layers (Wright and Everhart, 1960, p. 347). Below the zone of oxidation the introduced minerals are uraninite, coffinite, and pyrite, which in oxidized parts of the deposits alter mainly to meta-autunite, uranophane, and limonite stain (Butler, 1964, p. 140).
References: Bergin, 1956, 1957; Butler, 1964; Woodmansee, 1958; Wright and Everhart, 1960.

Symbol: 15AVM
Name: Schwartzwalder mine, Jefferson County, Colorado, U.S.A.
Location: 39° 50' 38" N; 105° 16' 49" W
Description: The Schwartzwalder mine (Downs and Bird, 1965; Wright and Everhart, 1960), the most productive vein deposit of uranium in the State, is in Precambrian metamorphic rocks in a complexly branching southeastward extension of the Rogers breccia reef fault near the edge of the Front Range (Sheridan, 1956; Sheridan and others, 1958, 1967; Sims and others, 1963). Several fault breccias and high-angle reverse faults cutting metamorphic rocks of the Precambrian Idaho Springs Formation strike northwesterly and dip steeply to the southwest and northeast. The main faults and fault breccias and subsidiary, less steeply dipping faults are mineralized where they cut brittle, competent lime-silicate rock and garnetiferous quartz-biotite gneiss. Sulfides of other metals are common (Sims and Sheridan, 1964, p. 91). The metallic minerals are pitchblende, pyrite, copper sulfides, and some sphalerite and galena. They are accompanied by a gangue of quartz, ankerite, adularia, and sparse garnet. Heyse (1971) recognized siderite occurring as a massive replacement of the breccia fragments, and that it is rather widely distributed in breccia fragments within veins and in altered wall rock. Ore bodies of about 2 meters to about 60 meters in length occur on four principal veins and several subsidiary veins and extend an aggregate vertical distance of at least 275 meters. Several thick podlike bodies occur adjacent to some of the veins where closely spaced subsidiary fractures branching from the main faults are strongly mineralized (Butler, 1964).

Uraninite is the major mineral, coffinite is rare to sparse, small amounts of pyrite and galena are ubiquitous, and sphalerite and copper minerals are sparse; molybdenum values are consistently high, but no molybdenite has been found; silver values are also anomalously high; lead-uranium ages of uraninite are variable but average 65 m.y. (Young and Lahr, 1975).
References: Adams and others, 1953; Bird and Stafford, 1955; Butler, 1964; Downs and Bird, 1965; Heyse, 1971; Rich and others, 1975; Sheridan, 1956, 1958; Sheridan and others, 1958, 1967; Sims, 1956; Sims and Sheridan, 1964; Sims and others, 1963; Walker and Osterwald, 1963; Wright and Everhart, 1960; Young and Lahr, 1975.

Symbol: 16CVM

Name: Los Ochos mine, about 32 kilometers southeast of Gunnison, and others, Marshall Pass area, Saguache County, Colorado, U.S.A.

Location: 38° 22' 06" N; 106° 45' 14" W

Description: In the Marshall Pass area the principal deposits are in or adjacent to a steeply dipping reverse fault along which metamorphic rocks on the east are in contact with sedimentary rocks of Ordovician to Pennsylvanian age on the west. The ores occur mainly as veinlets of pyrite and pitchblende in fractured limestone, arkosic sandstone, and shale and subordinately as replacements of limestone adjacent to the fault (Butler, 1969; Wright and Everhardt, 1960). The Pitch mine (38° 24' 25" N, 106° 17' 53" W) near Gunnison in the Marshall Pass District, may provide under contract to Homestake Mining Co. future deliveries of uranium concentrates exceeding 10 million lb of U_3O_8 (Engineering and Mining Journal, 1976, v. 177, no. 9, p. 224 and 269).

The Los Ochos deposit consists of secondary uranium minerals, pitchblende, and marcasite, a common sulfide in the ore, in fractured and silicified sandstone and mudstone of the Jurassic Morrison Formation or Middle Jurassic Junction Creek Sandstone and adjacent underlying schist and gneiss of Precambrian age where the rocks have been broken by an east-trending fault (Derzay, 1956; Olson and Steven, 1976a, 1976b; Wright and Everhart, 1960). The mine is shown on Sawtooth Mountain quadrangle (Olson and Steven, 1976a). Although the crystalline rocks are mineralized, most of the workable part of the deposit, which is now largely mined out, was in sedimentary rocks (Butler, 1964). Rich and others (1975, 1977) describe the uranium mineralization as being in a large pipe-shaped area which occupies a wide shear zone at the contact between Precambrian granite and Jurassic sediments, and point out that the uranium mineralization post-dates Tertiary faulting. Silicification and brecciation of Morrison and Dakota sedimentary rocks in and adjacent to fault zones controlled uranium deposition (Rich and others, 1975, 1977).

References: Butler, 1964, 1969; Derzay, 1956; Engineering and Mining Journal, 1976, v. 177, no. 9, p. 224 and 269; Gross, 1965; Malan and Ranspot, 1959; Olson, 1976a, 1976b; Olson and Steven, 1976a, 1976b; Wright and Everhart, 1960.

Symbol: 16aCSS
Name: Rifle, Garfield, North Star, Oriole, and other mines, Rifle Creek area, Garfield County, Colorado.
Location: 39° 39' 51" N; 107° 41' 14" W
Description: The Rifle Creek area is on the Grand Hogback monocline which is generally considered to be of late Eocene age. Fractures are abundant. The area is bounded on the north and south by relatively flat structural terraces, but between these terraces the rocks mostly dip southward at angles ranging from 15° to 30°. The Rifle-Garfield vanadium-uranium deposit is in a basin of slight depression relative to small cross flexures.

The Rifle-Garfield deposit, located along East Rifle Creek about 20 km northeast of Rifle, Colorado, is at least 3,000 meters long, and averages about 100 meters in width (Fischer, 1960). Fischer (1960) states that total production of vanadium-uranium ore from the Rifle Creek area, from 1925 through 1954, is about 750,000 tons, containing about 25 million pounds of V_2O_5. The ore contains about 1 to 3 percent V_2O_5 and several hundredths percent U_3O_8. The ore occurs in three tabular layers that partly overlap, but are not concordant with the bedding in detail. Five elements - vanadium, uranium, lead, selenium, and chromium - have accumulated in the deposit. They are concentrated in fairly distinct sheets within or adjoining each of the three ore layers. A thin (generally 3 mm thick) layer of finely disseminated grains of galena and clausthalite and another layer (0.7 m thick) containing a finely micaceous chromium-bearing mineral accompany each layer of ore. All faults displace and brecciate the ore and accompanying layers. The middle layer and accompanying sheets form a vertical S-shaped pattern or ore roll between the upper and lower layers. Fischer (1960) considered reactions at an interface between two solutions to be the most logical explanation for the formation of the Rifle-Garfield vanadium-uranium deposit. Spirakis (1977a, 1977b) theorized that the distinct zonation of authigenic minerals, alteration, and the long-lived interface could all be effects of semipermeable membranes. Changes in the chemical conditions were generated by the semipermeable membrane of vanadium-silicate minerals through which selective diffusion resulted in concentration gradients and pH changes on both sides of the growing ore deposit. LaPoint and Markos (1977) proposed that of the two fluids of very different composition that interacted to cause the Rifle deposit, one was ground water that carried the ore-forming elements from the overlying Jurassic Morrison Formation, and the other could have been a warm chloride brine derived from sediments of the central Colorado basin of late Paleozoic age.

Secondary uranium minerals, tyuyamunite, carnotite, and bayleyite, are disseminated in sandstone of the mostly eolian Navajo(?) Sandstone of Triassic(?) and Jurassic age and in some of the Entrada Sandstone of Jurassic age. Vanadium mica roscoelite, an unnamed variety of a mixed layer mica-montmorillonite, and a chlorite are the principal vanadium ore minerals.

References: Fischer, 1960; LaPoint and Markos, 1977; Ridge, 1972; Spirakis, 1977.

Symbol: 17CSL

Name: Uravan mineral belt, an elongate, slightly curving zone in Mesa, Montrose, and San Miguel Counties, southwestern Colorado, U.S.A.

Location: 38° 22' 00" N; 108° 44' 00" W

Description: The Uravan mineral belt contains about 1,000 mines ranging in size from a few tons to clusters of three quarters of a million tons of unoxidized and oxidized uranium and vanadium ore. The average uranium-vanadium ratio has been about 1:5 but varies widely. Ore bodies have two basic habits; the nearly flat-bedded deposits, tabular but irregular in plan and essentially concordant with bedding; and the roll deposits, which are discordant, prominently elongate in one dimension, but bounded by a variety of curved surfaces. For many years the ore mined consisted only of the yellow uranium vanadates, but now most of the ore is coffinite and montroseite. Associated minerals are iron oxides, gypsum, and calcite. The host rock is light-colored fine- to medium-grained quartzose sandstone and mudstone of the Salt Wash Member (relatively minor amount of ore in the Brushy Basin Member) of the Jurassic Morrison Formation. Faint limonite staining in the form of small specks appear to coincide with broad belts of favorable ground, and individual ore bodies are bounded by a crude halo of somewhat more intense limonitic coloration. The Salt Wash Member was formed as an alluvial fan by a braided system of aggrading streams which flowed and diverged northeastward (Craig and others, 1955). The deposits are in relatively thick lenses of sandstone interbedded with some mudstone which are complexes of sand-filled stream channels. All the deposits in the Morrison Formation are vanadiferous deposits in which the U:V ratio ranges from about 1:3 to about 1:15 and averages about 1:4 in most of the ore mined. Sediments of the Morrison Formation came from the Mogollon highlands and were deposited in large subaerial fans in a broad, northeasterly-trending, trough-like belt; the deposition of the Morrison sediments was significantly affected by the pronounced northwesterly-trending pre-Laramide tectonic grain of the Colorado Plateau and surrounding areas (Saucier, 1975; Downs and Runnells, 1975). This deposition represents a shift of the drainage pattern to the northeast and east from the previous west and northwest patterns (Saucier, 1975).

References: Boardman, Ekren, and Bowers, 1956; Chenoweth and Malan, 1969; Butler and others, 1962; Coffin, 1921; Craig and others, 1955; Downs and Runnells, 1975; Finch, 1967; Fischer, 1942, 1950, 1956, 1968, 1970, 1974a, 1974b; Fischer and Hilpert, 1952; Laverty and Gross, 1956; Motica, 1968; Ridge, 1972; Saucier, 1975; Shawe, 1956, 1974; Shawe and Granger, 1965.

Symbol: 18CSL

Name: Big Indian ore belt (Lisbon Valley), Lisbon Valley anticline, Paradox Basin, San Juan County, Utah, U.S.A.

Location: 38° 12' 00" N; 109° 15' 00" W

Description: In the Big Indian ore belt, almost all of the ore is uraninite which, although it is near the surface, has remained unoxidized due to protection by calcite cement in the sandstone. Other identified radioactive minerals in the deposits are bayleyite, liebigite, coffinite, zippeite, tyuyamunite, corvusite, and pascoite. Associated minerals are vanadium hydromica, montroseite, doloresite, calcite, abundant pyrite; small quantities of barite, fluorite, greenockite, sphalerite, galena, chalcopyrite, and malachite. Uraninite ore deposits of million-ton size are in tabular, irregular masses, usually concordant to the bedding, which dips 5° to 13° to the southwest. Ore minerals occur mainly as disseminations in sandstones, siltstones, and conglomerates and as grains replacing carbonaceous plant material and calcite cement. Localization of ore in channel-fill and other permeable clastic units suggests that transmissivity is a dominant physical ore control. The host rock is feldspathic or arkosic sandstones and bentonitic shales of the Moss Back Member of the Triassic Chinle Formation. In Lisbon Valley, uranium deposits lie within a strip 0.8 kilometers wide which borders the Chinle escarpment and parallels the strike of beds for a distance of 24 kilometers. Most of the known ore bodies are in the northern part of the Lisbon Valley anticline, a salt structure, adjacent to Big Indian Wash. The Rio Algom deposit, the first uranium mine northeast of the Lisbon fault, produces more than 500 tons U_3O_8 per year (Jackson, 1975). Deposits on the southwestern side include Hecla, MiVida, North Alice, and Radon. Semi-arid to arid conditions prevailed throughout a lengthy period of time. Short periods of heavy rainfall and competent drainage were interspersed, during which continental, fluvial, medium- to coarse-grained arkose evolved. The periods were long enough to permit evolution of abundant flora and the accumulation of organic debris in the fluvial sediments but not long enough to evolve a high, stable water table and cause the breakdown of feldspars to clays.

Engineering and Mining Journal (1975, v. 176, no. 10, p. 184), reported that there is a total of 800,000 lbs of U oxide in reserves at the Small Fry mine (38° 14' 12" N, 109° 15' 36" W) near Moab.

References: Brown, 1969; W. D. Chenoweth and R. C. Malan, 1969, written comm.; Engineering and Mining Journal, 1975, v. 176, no. 10, p. 184; Finch, 1967; Fischer, 1974a, 1974b; Isachsen and Evensen, 1956; Jackson, 1975; Rasor, 1952; Schmitt, 1969; Wood, 1968.

Symbol: 19DSS
Name: Yellow Chief mine (or Good Will mine) western Juab County, Utah, U.S.A.
Location: 39° 44' 00" N; 113° 11' 00" W
Description: The Yellow Chief mine, the most important uranium producer in the Basin and Range province, is in a valley that separates Spor Mountain from the main part of the Thomas Range. Upper Tertiary flow-rocks and tuffs in the valley are interbedded with clastic sediments derived from nearby ranges. The host rock for the uranium ore is a massive, tuffaceous, conglomeratic quartz-sanidine sandstone, locally called the Yellow Chief Sandstone (Staatz and Carr, 1964; Hilpert and Dasch, 1964). It was deposited in a fluvial environment and is probably late Miocene or early Pliocene in age (Bowyer, 1963, p. 17-18). The ore mineral is beta-uranophane, which is a secondary uranyl silicate that fills pore spaces and coats the sandstone particles; deposition, for the most part, was stratigraphically controlled. This uranium deposit differs from others in fluvial strata in that carbonaceous matter is inconspicuous or lacking, iron sulfides are sparse, and beta-uranophane is the only mineral present in significant amounts. Bowyer (1963, p. 21) suggests the beta-uranophane may have formed by concentration in the host rock by vadose and ground water, following erosion of the uranium-bearing fluorspar bodies of Spor Mountain; or it may have been altered from coffinite or uraninite after these primary uranium minerals were precipitated from magmatic fluids. Weeksite replaces limestone pebbles in limestone conglomerate of late Miocene or early Pliocene age; schroeckingerite occurs in veinlets. The deposit has been estimated to contain more than 90,700 metric tons of mined and developed ore (Bowyer, 1963, p. 19); shipments have averaged from 0.20 to 0.23 percent U_3O_8 (Dasch, 1967).
References: Bowyer, 1963; Dasch, 1967; Hilpert and Dasch, 1964; Staatz and Carr, 1964; Staatz and Osterwald, 1959; Thurston and others, 1954.

Symbol: 20DVS
Name: Marysvale uranium area, northern Piute County and southern Sevier County, Utah, U.S.A.
Location: 38° 30' 00" N; 112° 12' 00" W
Description: The deposits of the Marysvale area, in a zone about 1.6 kilometers long by 0.8 kilometers wide, are principally in quartz monzonite (but some in granite where the wall rock is granite) of Tertiary age (earliest Pliocene age) (Kerr and others, 1957, p. 60, 61). The ores occur in veins related to the hydrothermal alteration that accompanied the Mount Belknap igneous activity which resulted in the major surges of hydrothermal solutions and which attacked the rocks and resulted successively in alunitic and argillic alteration products. Uranium ores were deposited as an accompaniment of the argillic alteration phase (Kerr and others, 1964). Hypogene uranium occurs as pitchblende associated with black fluorite and fine pyrite in breccia and distributed veinlets along veins. Nearly vertical uranium veins range from about 15 centimeters to about 15 meters in thickness. Veins pinch and swell, and ore shoots are either vertical or exhibit a steep west rake. Supergene uranium minerals occur near the surface (Kerr and others, 1957). The uranium deposits are in the Antelope Range, which lies in a graben between the Sevier fault on the east and the Tushar fault zone on the west. The graben has been disrupted north of the Tushar fault by the invasion of the Mount Belknap Volcanics of Miocene age. The age of the Marysvale uranium is about 10,000,000 years (Kerr and others, 1957). Rich and others (1975) report the age of the pitchblende is on the order of 10 to 13 m.y. Umohite (hydrous uranium molybdate) was first discovered in the Freedom No. 2 mine. Later hydrothermal alteration is associated with the uranium-bearing veins. The Marysvale uranium area contains the most important vein deposits in Utah and provides the outstanding example of fluorite-bearing uranium ores in the United States. The deposits are hydrothermal in origin. In this area, lower to middle Tertiary rocks of the Bullion Canyon Volcanics were invaded by middle Tertiary quartz monzonite, granite, and related intrusive rocks, and covered by upper Tertiary rhyolite of the Mount Belknap Volcanics. Following deposition of the Mount Belknap Volcanics, the uranium deposits were emplaced as veins in the monzonite, as irregular masses at the base of the Mount Belknap Volcanics, and as fracture fillings and coatings in the Bullion Canyon Volcanics. Most important are the deposits, or veins, in the monzonite which consist of the mineralized parts of a set of steeply dipping northwest-trending faults and fractures. The vein material consists of fillings of the open spaces in fault breccia and of fracture coatings by the principal ore mineral pitchblende, by various minor secondary uranium oxides, and by associated fluorite, ilsemannite, quartz, and pyrite. The veins range from about 2.5 centimeters to 0.9 meters thick and pinch and swell along the strike and dip. They have been mined along

the strike for about 300 meters and to a depth below the surface of about 240 meters; they have supplied most of the ore from vein-type deposits. The principal producing mines are within a relatively small area on the southwestern margin of a quartz monzonite intrusive. Ore averages about 0.20 to 0.25 percent U_3O_8. Pitchblende is the major ore mineral, but secondary uranium minerals, namely autunite, torbernite, and schroeckingerite, have been mined. Accessory minerals include quartz or chalcedony, fluorite, pyrite, and andularia. Dominant joint sets have controlled to a large extent the location of the ore bodies, and the uranium ore generally is richest at vein intersections; neither enrichment nor impoverishment are evident with increasing depth (Dasch, 1967). Rich and others (1975) point out that uranium occurs in the center of the area and alunite deposits encircle it, and suggest that alunite may be a capping above alteration zones that contain uranium mineralization.

References: Basset and others, 1960, 1963; Bowyer, 1963; Callaghan and Parker, 1962a, 1962b; Dasch, 1967; Heinrich, 1958; Hilpert and Dasch, 1964; Kerr, 1963, 1968; Kerr and others, 1957, 1964; Rich and others, 1975; Walker and others, 1963; Walker and Osterwald, 1956, 1963; Willard and Callaghan, 1962.

Symbol: 21CSM
Name: Temple Mountain, Delta, and other mines, San Rafael Swell, Emery County, Utah, U.S.A.
Location: 38° 34' 00" N; 110° 57' 00" W
Description: The San Rafael Swell is a large asymmetrical anticline or elongate dome that trends about N. 30° E. and extends over an area about 80 to 96 kilometers long and 32 to 48 kilometers wide. In the Delta mine area, in the south end of the San Rafael Swell, deposits occur in the lower part of the Monitor Butte Member of the Triassic Chinle Formation. The Monitor Butte Member is about 30 meters thick near the mine and pinches out just south of Temple Mountain and Green Vein Mesa. The Monitor Butte Member is considered relatively favorable for large uranium deposits wherever it contains sandstone lenses approaching the thickness (3 to 9 meters or more) of the lens at the Delta mine. The Moss Back Member of the Chinle Formation is considered relatively favorable for significant uranium deposits along the southeastward or northwestward trend of a favorable belt passing through Temple Mountain and Green Vein Mesa and wherever it contains channels in that part of the San Rafael Swell south of Temple Mountain and Green Vein Mesa. The San Rafael Swell is bounded on all sides by the cliff (or "reef", as it is called locally), formed by thick massive sandstone beds of the Wingate Sandstone, Kayenta Formation, and Navajo Sandstone exposed on the flanks of the domal structure. On the ends and flanks of the structure the land surface is rather sharply dissected so that it consists largely of remnants of mesas and steep-walled canyons or cliff-like slopes. Erosion has exposed the central part as a broad, open, gently domed area that is in most places higher than the surrounding reef, even though this reef may stand 450 meters or more above the area immediately adjacent to it. At the Delta mine the ore deposit is in the thickest part of a sandstone unit in the Monitor Butte Member (about 6 meters above the Moenkopi Formation) that interfingers laterally with a purplish-red mudstone of the Monitor Butte. The Monitor Butte Member pinches out northward, and the Delta mine may be near the northern fringe of thick sandstone lenses in the Monitor Butte (Johnson, 1957). At Temple Mountain, the deposits are in the Moss Back Member of the Chinle Formation, and may be as much as 18 meters above the Moenkopi Formation. There is a local thickening of the Moss Back at Temple Mountain, and Johnson (1959, p. 52) believed that the thicker Moss Back probably does represent deposition in a broad shallow channel or channel system. Carbonaceous material is usually present in the ores. Vanadium:uranium ratio at Temple Mountain is about 3 to 1, and the uranium ore is principally uraninite associated with carbonaceous material. Corvusite, rauvite, uvanite, carnotite, tyuyamunite, fourmarierite, abernathyite, and montroseite occur as accessory uranium- and vanadium-bearing minerals (Weeks and Thompson, 1954). Copper is commonly present in amounts less than the uranium content

but in sufficient quantity so that copper minerals are fairly common in both oxidized and unoxidized deposits. On and close to the outcrop the deposits are oxidized, and limonite and yellow, orange, green, and blue secondary uranium and copper minerals call attention to the deposit. A few feet away from the outcrop the ores are largely unoxidized and principal uranium mineral is uraninite. Pyrite, chalcopyrite, galena, and sphalerite are present in small amounts as gangue minerals.

References: Finch, 1967; Isachsen and Evensen, 1956; Johnson, 1957, 1959; Kerr, 1958; Weeks and Thompson. 1954.

Symbol: 22CSM
Name: White Canyon area, San Juan County, Utah, U.S.A.
Location: 37° 44' 00" N; 110° 16' 00" W
Description: Cupriferous peneconcordant deposits in the basal part of the Shinarump Member of the Triassic Chinle Formation occur in a westerly trending belt. The deposits are in ancient sandstone-filled stream channels (Johnson and Thordarson, 1966). The host rock, present only in the channels, is a coarse-grained to conglomeratic quartzose sandstone which contains abundant carbonaceous material. It is overlain by an intra-channel mudstone unit of the Shinarump and underlain mainly by dense mudstones of the Triassic Moenkopi Formation. The ore is associated with organic matter, sedimentary structures, and deeper areas within the channels. The sedimentary structures include bedding planes, petrological traps, scours within the Shinarump, and basal Shinarump mudstone. Uraninite and copper sulfides cement the sandstone and replace carbonaceous material and secondary overgrowths on quartz grains. The ore minerals are approximately contemporaneous. Oxidized or secondary uranium and copper minerals are minor. In the area of the Happy Jack mine, the normally red sediments have been bleached to green, but there is no other evidence of alteration within the deposit.
References: Finch, 1967; Johnson and Thordarson, 1966; Malan, 1968; Miller, 1955; Trites and Chew, 1955; Young, 1964.

Symbol: 23BVM
Name: Orphan Lode and others, Grand Canyon area, Coconino County, Arizona, U.S.A.
Location: 36° 04' 00" N; 112° 09' 00" W
Description: The Orphan mine ranks among the five most important vein deposits of uranium in the United States (Butler and Byers, 1969). It is on the south rim of the Grand Canyon on a patented claim originally located for copper. The deposit is in a nearly vertical, generally oval, pipelike body of collapse breccia that transects the Coconino Sandstone and Hermit Shale of Permian age and the Supai Group of Pennsylvanian and Permian age (Granger and Raup, 1962, p. A8) and extends downward into the Redwall Limestone of Mississippian age (C. G. Bowles, oral commun., 1968). The rocks in the structure are fractured, disoriented, and displaced from their normal stratigraphic position. Blocks of Coconino Sandstone are displaced downward at least 85 meters. Much of the ore is at the stratigraphic position of the upper, cliff-forming part of the Supai Group. The larger part of the ore is in the arcuate body generally concordant with the north wall of the collapse, where it is partly in fractured rocks of the pipe wall and partly in adjoining pipe filling material. A smaller part of the ore is in more poorly defined bodies in the ring-fracture zone along the southeast wall and in sandstone in the interior of the pipe (Butler and Byers, 1969). Uraninite is the principal ore mineral. It is accompanied by pyrite and other sulfide and sulfosalt minerals that contain copper, silver, lead, zinc, cobalt, nickel, and molybdenum and have been a source of some copper and silver. Gornitz and Kerr (1970) list the minerals and summarize the paragenesis of the Orphan mine. Rich and others (1975) note that this deposit combines many characteristics of both sandstone and hydrothermal uranium mineralization. Rich and others (1975) describe the wall rock alteration associated with the mineralization event as characterized primarily by bleaching of normally red sediments, carbonatization of originally non-calcareous sandstones (sandstones that were originally 90% quartz contain 30-50% carbonate after alteration), and the development of hematitization halos around pitchblende concentrations. Rich and others (1975) state that the minimum age of uranium mineralization is 141 m.y. or Late Jurassic, and that the breccia pipe formed between the deposition of the Permian host rocks and the time of mineralization. Late Cretaceous is suggested as a possible minimum age for the Orphan deposit (Miller and Kulp, 1963, table 6). Bowles (1977) proposed 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, and that secondary enrichment by either supergene or mesogene (mingled descending and ascending) solutions concentrated the metals in medium- to high-grade ore bodies. He suggested that the best ore potential is limited to large breccia pipes that stoped

through the upper part of the Supai Group into overlying formations.

References: Bowles, 1977; Butler and Byers, 1969; Gornitz, 1969; Gornitz and Kerr, 1970; Granger and Raup, 1962; Isachsen and others, 1955; Kofford, 1969; Miller and Kulp, 1963; Rich and others, 1975; Witkind, 1956.

Symbol: 24CSM
Name: Shiprock and Monument Valley areas, Apache and Navajo Counties, Arizona, U.S.A.
Location: 36° 45' 00" N; 109° 50' 00" W
Description: Peneconcordant deposits in the Jurassic Salt Wash Member of the Morrison Formation, lie from near outcrop to 1,000 meters to 2,000 meters below the surface. Most of the deposits in the Shiprock district are clustered in a 16-kilometer strip along the outcrop near the State line west of Shiprock. The U:V ratio averages 1:7. The Salt Wash Member in the Shiprock district consists of very fine- to medium-grained sandstone and about 20-30 percent interbedded sandy and silty claystone (Strobell, 1956). The Salt Wash is a relatively thick, elongate mass that trends eastward and was deposited in a local downwarp between the south depositional margin of the member and a local upwarp that formed about the same time north of the Four Corners area. The Shiprock district is on the northwest flank of the San Juan Basin where the beds dip eastward along the north end of the Defiance monocline, flatten east of the monocline on a structural terrace, and then plunge downward under the San Juan Basin along the northeastward-trending Hogback monocline. The deposits occur largely at the outcrop and are oxidized. They are conspicuous by the prevalence of yellow uranyl vanadates, generally reported as carnotite. These vanadates, however, probably are a mixture of carnotite and tyuyamunite because of the fairly high content of calcium carbonate in the ore and host rock (Weeks and others, 1959). The deposits form blanketlike layers that follow the bedding in general, but cross it locally at low angles. The layers range in thickness from 0 to as much as 4.6 meters and in width and length from about 2 meters to several hundred meters. Channels are less obvious in the Salt Wash Member of the Morrison Formation than in Triassic rocks, and consequently the relation between uranium deposits and channels is less well defined in the Salt Wash Member. The thicker sandstones, in which the ore deposits tend to occur, probably were found in the channel parts of large braided streams (Johnson and Thordarson, 1966).

In Monument Valley the Shinarump Member is the basal unit of the Chinle and the deposits are in the basal part of the Shinarump. Most of the ore-bearing sandstones are stream deposits. Many of these host sandstones are conspicuously lenticular. These lenses were formed by sediments that either filled channels cut into the underlying beds or that laterally interfingered with finer grained sediments that accumulated on flood plains. Sandstone-filled channels or scours cut into less permeable rocks are common loci for uranium deposits in the Chinle Formation, especially in the Shinarump Member. Most deposits are in the lower parts of these filled channels, and they are in irregularly bedded sandstone that contains pebbles and lenses of mudstone and fragments of fossil wood. Some channels can be traced for 10 kilometers, whereas others become shallow and indistinguished within 100 meters. The short channels may represent the deeper scours at the base of a larger, wide, shallow channel (Johnson and Thordarson, 1966).

References: Anthony, Williams, and Bideau, 1977; Dodd, 1956; Finnell, 1957; Finch, 1959b, 1967; Fischer, 1974b; Hilpert, 1969; Isachsen and others, 1955; Johnson and Thordarson, 1966; Strobell, 1956; Tatsch, 1976; Weeks and others, 1959; Witkind, 1961; Witkind and Thaden, 1963.

Symbol: 25CSL

Name: Grants (or Ambrosia Lake), Gallup, and Laguna districts in the southern San Juan Mineral Belt of northwestern New Mexico, in McKinley, Valencia, and Sandoval Counties, U.S.A.

Location: 35° 32' 00" N; 108° 10' 00" W

Description: The deposits are peneconcordant, range in size from small to very large, and lie from near outcrop to about 1-2 kilometers below the surface. They are mostly in relatively thick sandstone masses in structural depressions of Late Jurassic age along or near the south margin of the reconstructed boundary of the old Jurassic basin of deposition. The structural depression (or troughs) and their contained sandstone units range from about 10 kilometers to about 100 kilometers in width and length. Intensive structural deformation during Late Jurassic time is recognized (Hilpert, 1969) as the prime control on the uranium deposits in the Morrison Formation. Flexing took place as the basins received Jurassic sediments and differentially subsided as the highland area rose. This flexing probably was concentrated along the marginal zone of the old Jurassic basin (which has remained in large part as a closed structure since its inception) that probably partly controlled the course of the streams that deposited the Morrison sands. The flexing may also have formed local basins (Hilpert, 1969) in which units like the Jackpile sandstone (an economic term) of the Morrison Formation, accumulated. Such sandstone units contain the largest uranium deposits known in northwestern New Mexico.

Deposits in the Ambrosia Lake district occur principally in the Poison Canyon sandstone of economic usage in the upper part of the Westwater Canyon Member and in sandstone units in the lower part of the Westwater Canyon Member, and much less abundantly in the Brushy Basin Member. The uranium-vanadium ratio averaged 2:1 for ore shipped from 1950 to 1958 (Hilpert, 1969). The principal deposits in the Laguna district occur in the Jackpile sandstone of economic usage in the Brushy Basin Member of the Morrison Formation. The Jackpile is a yellowish-gray to white friable fine- to medium-grained fluvial sandstone that generally grades from coarser grained subarkosic material at the base to finer material at the top. The large open-pit operations of the Jackpile and Paguate mines have yielded 99 percent of all ore produced in the district (Hilpert, 1969). The principal cluster of deposits is elongate northeastward and conforms to the dominant dip direction of the crossbedding and to the axial trends of the Jackpile sandstone body. Most deposits in the Laguna district occur above the water table and most are oxidized to some extent. Ores from the Jackpile and Paguate deposits indicate about 75 percent of the uranium is oxidized (Kittel, 1963, p. 170). Some volcanic activity, possibly to the southwest of the basin of deposition, accompanied the Morrison deposition. The uranium was derived (Hilpert, 1969) from the adjacent highland bedrock or from volcanic debris within the host rocks.

The unoxidized minerals in the prefault deposits (Granger and others, 1961; Granger, 1963) are the ore mineral coffinite and accessory pyrite, jordisite, and ferroselite. The coffinite is exceedingly fine grained and is coextensive with, and intimately associated with, a fine-grained dark-gray or brown carbonaceous material that coats the sand grains and fills the interstices between the grains. The postfault unoxidized ore minerals are coffinite and sparse or local occurrences of uraninite. Carbonaceous material is generally lacking or is quite sparse in the postfault deposits. The oxidized suite of minerals consists of tyuyamunite and metatyuyamunite, and carnotite, autunite, meta-autunite, and other sparse or rare minerals. The prefault deposits are of greatest economic importance. These deposits show no obvious relation to faults, fractures, or folds. They are tabular, elongate masses that are primarily stratigraphically controlled, or strata-bound. They range from thin layers about 2 meters in width and length to bodies as much as 9 meters thick, 200 meters wide, and 2,000 meters long. The long dimensions generally parallel the depositional trends, as marked by current lineations, the dip of cross strata, and the trend of channel scours. The shape and position of the bodies are partly controlled by intraformational disconformities, particularly those at the base of mudstone conglomerates, but away from or between disconformities the deposits may have a variety of shapes. In vertical section, they are the most irregular transverse to the longest dimension and may split and occupy more than one stratigraphic zone, feather out into barren material, or end against a sharply defined curved surface, generally referred to as a "roll" (Hilpert, 1969). The altered hematitic core ranges from pale to intense red. In most places the core is surrounded by a buff-to-orange limonitic rock as much as 100 m thick near the roll front. Near the contact with reduced rock, some pyrite-derived goethite pseudomorphs are found.

Mt. Taylor mine, largest and deepest uranium mine in the U.S., in the Westwater Canyon Member of the Morrison Formation, has a 100-million-lb U_3O_8 orebody at a depth of 1,000 meters (3,500 ft), and commercial production could begin by 1981 (Lapp, 1975; Engineering and Mining Journal, 1976, v. 177, no. 6, p. 313-314). In a 1900 acre area near Crownpoint in McKinley County, Phillips Petroleum Company estimates 25 million lb U_3O_8 in 7 million tons at a depth of 900 to 1000 meters (3,000 to 3,500 ft) (Engineering and Mining Journal, 1976, v. 177, no. 3, p. 9).

In the Grants area some of the ore occurs in the Jurassic Todilto Limestone and is concentrated wherever the limestone has been deformed locally by intraformational folds and intensely fractured. The presence of some fluorite suggests that the Todilto uranium ores were deposited from solutions having a magmatic hydrothermal component (Tatsch, 1976).

References: Adler, 1974; Anderson and Kirkland, 1960; Birdseye,

1955, 1957; Brookins, 1975; Brookins and Lee, 1974; Engineering and Mining Journal, 1976, v. 177, no. 3, p. 9; Engineering and Mining Journal, 1976, v. 177, no. 6, p. 313-314; Finch, 1967; Granger, 1963, 1968; Granger, Santos, Dean, and Moore, 1961; Hafenfeld and Brookins, 1975; Hazlett, 1969; Hazlett and Kreek, 1963; Hilpert, 1969; Kittel, 1963; Lapp, 1975; Lee and others, 1975a, 1975b; Moench and Schlee, 1967; Rawson, 1975; Santos, 1963, 1964a, 1964b, 1970; Santos and Thaden, 1966;
Soc. Economic Geol., 1963; Squyres, 1974, 1975; Tatsch, 1976.

Symbol: 26DSL
Name: Butler-Weddington mines and others, Karnes area, South Texas coastal plain, Karnes, Webb and Live Oak Counties, Texas, U.S.A.
Location: 28° 51' 00" N; 098° 07' 00" W
Description: Both oxidized and unoxidized deposits are present, but the oxidized deposits are now mostly mined out. The oxidized ore occurs near the surface and the unoxidized ore to depths of 60 m. The oxidized deposits were small, lenticular, or irregular sandstone bodies, as much as 24 meters deep, 6 meters thick, 60 to 90 meters wide, and as much as 300 meters long. The host rocks are mainly the Tordilla and Deweesville Sandstone Members of the Whitsett Formation of Eocene age, or beds of approximately the same stratigraphic position in the Whitsett (Eargle and others, 1975). The Tordilla and Deweesville are marine-beach sandstone beds, generally lens shaped in cross section, with long axes that approximately parallel the present geologic strike. These sandstone bodies are fine-grained, light-yellowish-gray, generally well-sorted, arkosic sandstone. They commonly contain burrows of marine crustacean *Ophiomorpha major* near the top and are crossbedded near the base. They are enclosed in finer grained, poorly sorted, lagoonal or paludal mudstone or lignite. The sandstone of the Galen, Butler, and Weddington mines is transected by a fluvial channel, and a coarse-grained well-sorted facies of channel sandstone, and surrounding silty and clayey rocks served as a host for uranium in the Kellner mine. The Falls City fault and the Fashing fault form an imperfect graben.

The unoxidized ore deposits, southeast of the oxidized deposits, are at and directly above the water table, and are larger deposits of generally lower grade ore that is more nearly in equilibrium than the oxidized ore (Bunker and MacKallor, 1973). The true stratigraphic relation between the host rock of the oxidized ore and the host rock of the unoxidized ore, which is downdip, is uncertain. Much of the unoxidized ore in the Karnes area is in ore rolls. The main roll trend is about 10 kilometers long, extending along a scalloped line from the Sickenius mine on the northeast to the Kellner mine on the southwest (Eargle and others, 1975). The concave side of the crescent consists of partly oxidized, leached, or otherwise altered, very pale-gray or buff barren sand; the convex or downdip side consists of unoxidized medium-dark-gray sand that is the thickest and richest ore of the deposit. Thickness and tenor of the ore diminish gradually from the roll front to an assay cutoff 200 or 300 meters downdip (Eargle and others, 1975). The mineralogy of the unoxidized deposits has not been studied in detail, but the chief uranium mineral is apparently uranite (uranous oxide). Both uraninite and coffinite (uranium silicate) have been identified by X-ray diffraction in samples from the mines. Clinoptilolite (a zeolite), authigenic feldspar, opal (cristobalite X-ray diffraction pattern), and montmorillonite are also present, together with the normal detrital minerals, generally quartz and feldspar (Eargle and others, 1975).

The principal source of the uranium is believed to be the post-Eocene rocks, mainly the Miocene Catahoula Tuff of the region. The uranium probably was leached during post-Eocene periods of dry-climate weathering and was carried in oxygenated alkaline ground waters through conduits formed by permeable sandstone beds to subsurface sites where the uranium was precipitated in chemically reducing environments. The uranium deposits at or near the surface apparently are in chemical disequilibrium with their environments and gradually are being dissolved (Bunker and MacKallor, 1973), transported, and possibly redeposited downdip. The host rocks include the highly permeable sandstones and surrounding less permeable rocks. The reducing agent was either hydrogen sulfide or methane gas that seeped from subsurface petroleum deposits and from carbonaceous material in some of the rocks. Altered tuffaceous rocks are present in or near all of the South Texas deposits. The present uranium content of the Catahoula is less than that generally found in tuffs of similar composition (Bunker and MacKallor, 1973) or in igneous rocks of the supposed source area (Gottfried and others, 1962). The marine-sandstone host rock in the Karnes area generally contains less than 0.1 percent organic carbon (E. N. Harshman, oral commun., 1973). The reductant, then, must come from the overlying or underlying rocks, which are in some cases highly carbonaceous. Or, as suggested by several authors (Eargle and Weeks, 1961, 1968; Klohn and Pickens, 1970), the reductant is hydrogen sulfide that seeps upward from petroleum deposits; the proximity of uranium deposits to faults and to oil fields makes this a convincing hypothesis (Eargle, Dickinson, and Davis, 1975). Weathering and soil-forming processes during a relatively dry climate played an important role in the leaching, migration, and redeposition of the uranium (Eargle, Dickinson, and Davis, 1975).

Both uranium and petroleum are found in the shoreline, beach, and fluvial facies of the host rocks of the Jackson Group. Uranium is mined in the Pfeil and Sickenius mines (and intervening area) from beach-shoreface sandstone units parallel to depositional strike; from the Kellner and Weddington mines in fluvial channel facies; and from fluvial sandstone units normal to the strike of the Whitsett Formation (Dickinson, 1976).

The Brysch mine, Karnes County, 5 km east of Falls City, Texas, is in upper Eocene Whitsett Formation at depths of 23-27 m (Dickinson and Sullivan, 1976).

The winged, irregular, crescentic ore roll-type Felder deposit (Klohn and Pickens, 1970), in Live Oak County, is in fluvial sandstones of the Miocene Oakville Sandstone (Klohn and Pickens, 1974). Bruni, 105 km east of Laredo, and Clay West, about 15 km southwest of George West in the Texas Coastal Plain, are being mined by in-situ leaching. Clay West extracts about 250,000 lb/yr of U_3O_8 from sandstones at depths to 170 m (Crawford, 1975; White, 1975). The uranium ranges from 0.05 percent to 0.5 percent in the Oakville Sandstone.

References: Adams and Weeks, 1974; Brooks, 1975; Bunker and MacKallor, 1973; Crawford, 1975; Dickinson, 1973, 1976; Dickinson and Sullivan, 1976; Eargle, Dickinson, and Davis, 1975; Eargle, Hinds, and Weeks, 1971; Eargle and Snider, 1957; Eargle and Weeks, 1961, 1968, 1973; Finch, 1967; Flawn, 1967; Gottfried, Moore, and Caemmerer, 1962; Granger and Warren, 1974; Grutt, 1972; Harshman, 1974b; Klohn and Pickens, 1970, 1974; Tatsch, 1976; White, 1975.

Symbol: 27DCM
Name: Uraniferous lignite, Billings County, North Dakota, U.S.A.
Location: 46° 25' 00" N; 103° 14' 00" W
Description: Uranium occurs in the uraniferous lignite area, southwestern flank of the Williston Basin, in blanket-like deposits and as coatings on fracture surfaces. Uranium is concentrated in or adjacent to permeable formations and beds and in permeable zones within the host rock. The host rocks are the Paleocene Sentinel Butte Member of the Fort Union Formation. The Sentinel Butte Member is composed principally of siltstone and very fine-grained sandstone, and contains in addition, claystone, lignite, and carbonaceous shale. A vertebrate fossil, Champsosaurus sp., was found in the Chalky Buttes area about 55 meters stratigraphically above the base of the Sentinel Butte Member and about 5 meters below the overlying Chadron Formation of the White River Group of Oligocene age (Moore and others, 1959). Champsosaurus is one of the last of a primitive order of water-dwelling reptiles that appeared in Permian time and did not survive the Eocene. The uraniferous coaly rocks are of swamp origin. Woody lignites of the Sentinel Butte Member of the Fort Union Formation of Paleocene age outcrop where these beds are exposed on the flanks of buttes and other topographic highs. The deposits are characterized by a relatively low concentration of uranium and by a relatively large areal extent. A few contain more than 0.1 percent uranium. Uranium content of the lignite is about 0.013 percent (Moore and others, 1959). All uranium-bearing beds closely underlie the base of the Chadron Formation of the White River Group of Oligocene age. Uranium is of secondary origin and probably was leached from volcanic ash in overlying rocks of Oligocene and Miocene age (Moore and others, 1959). Uranium occurs chiefly in a 0.6- to 1.2-meter-thick bed of impure lignite, which is about 207 meters above the base of the Sentinel Butte Member of the Fort Union Formation. As much as 30 meters of sandstone overlies the mineralized bed and protects it from weathering (Vine, 1962). The uranium is disseminated in the carbonaceous material. Carbonaceous material--lignite or carbonaceous shale--is believed to have taken the uranium from solution by ion exchange or by the formation of organo-metallic compounds (Denson and others, 1959). Most of the uranium occurs as organo-uranium compounds absorbed in lignite and other carbonaceous materials (Breger, Deul, and Rubinstein, 1955). Uranium in this form is not present in a visible uranium-bearing mineral and can be detected only by radiometric instruments, or by chemical analyses. Locally, however, green or yellow secondary minerals do occur as films and crusts on joint faces of the lignite. Only uraninite occurs in the unoxidized state; the others (autunite, bassetite, sabugalite-saleeite?, saleeite, and hydrogen-autunite; Vine, 1962) occur in the oxidized or partly oxidized state. The uranium deposits and occurrences in

lignite and carbonaceous rocks in the Fort Union Formation are topographically no more than 60 meters below the unconformable surface on which rocks of Oligocene and Miocene age were deposited (Gott and Pipiringos, 1964).

References: Breger, Deul, and Rubinstein, 1955; Denson, Bachman, and Zeller, 1959; Denson and Gill, 1956; Gott and Pipiringos, 1964; King and Young, 1956; Moore and others, 1959; Vine, 1962.

Symbol: 28DCM
Name: Flat Top Butte claims and others, Harding County, South Dakota, U.S.A.
Location: 45° 35' 00" N; 103° 15' 00" W
Description: Uranium associated with lignite occurs along the southwestern part of the Williston Basin in the continental Fort Union Formation, of Paleocene age. The Fort Union comprises a thick sequence of flat-lying lignite-bearing sandstone, shale, and claystone. The carbonaceous host rocks range in thickness from 15 centimeters to more than 0.6 meters and are characterized by high ash contents and quite high permeabilities. Denson and Gill (1965) believed that volcanic ash in the White River and Arikaree Formations, which once overlay the area, was the source of the uranium, that ground water was the transporting medium, and that the uranium was fixed by the reducing action of the lignite. Uranium deposition was controlled by the proximity of the lignite to the unconformity marking the base of the overlying rocks, the permeability of the beds directly overlying the host lignite, the presence of shallow local troughlike folds, the absence of impervious rocks above the host lignite, and by the permeability of the host material. Most of the uranium occurs as a disseminated amorphous organo-uranium compound, but uraninite and a number of yellow secondary uranium minerals have been identified in the deposits. The grade of the lignite ore is about 0.33 percent uranium.
References: Denson and Gill, 1956, 1965; Harshman, 1968a; King and Young, 1956; Moore and others, 1959; Vine, 1962.

Symbol: 29BBL
Name: Area underlain by Chattanooga Shale, mainly in central Tennessee, U.S.A.
Location: 36° 00' 00" N; 087° 00' 00" W
Description: Uraniferous black shale resources, rich in organic matter, 2 percent or more organic matter, are in the Upper Devonian Gassaway Member of the Chattanooga Shale of Late Devonian and Early Mississippian age in central Tennessee and adjacent Kentucky and Alabama (Swanson, 1960, 1961). This member is 3.6 meters to 5.5 meters thick over an area about 10,400 square kilometers, and averages about 0.007 percent U_3O_8 (Finch and others, 1973). The Chattanooga and its correlatives underlie about 2,080,000 square kilometers extending from Tennessee to Texas and Montana; its uranium-bearing strata average about 12 meters in thickness and about 0.0035 percent U_3O_8 in grade (Finch and others, 1973). Estimates of metallic uranium in black shale indicated that the Chattanooga Shale in east central Tennessee constitutes an enormous reserve (Conant and Swanson, 1961; Kehn, 1955). Processing of the black shale for uranium by countercurrent leaching with sulfuric acid and oxygen pressure leaching may involve costs of $45 and $55, or possibly $36 to $44, per pound of uranium (Columbia University, 1960). The oil content of 100 samples of Chattanooga Shale assayed by the U.S. Bureau of Mines (1955) ranged from a trace to 15.7 gallons per ton (Hickman and Lynch, 1967). The Chattanooga Shale, comprising marine, black, siliceous, low-grade oil shale and gray claystone, has abundant plant remains such as stems, spores, and macerated debris. The Chattanooga was deposited in an area of epicontinental seas. Most of the uranium is in dispersed form.
References: Brown, 1975; Columbia University, 1960; Conant, 1956; Conant and Swanson, 1961; Dennison and Wheeler, 1975; Finch and others, 1973; Hickman and Lynch, 1967; Kehn, 1955; Southern Interstate Nuclear Board, 1969; Swanson, 1960, 1961; U.S. Bureau of Mines, 1955.

Symbol: 30BPL

Name: Area underlain by Phosphoria Formation in Utah, Wyoming, Idaho, and Montana, U.S.A.

Location: 43° 00' 00" N; 112° 00' 00" W

Description: Marine phosphatic rocks with low-grade resources of uranium occur in the Phosphoria Formation of Permian age, and underlie 351,000 square kilometers in Idaho, Montana, Utah, and Wyoming (McKelvey and Carswell, 1956). Their uranium content ranges from 0.001 to 0.075 percent U_3O_8, but beds more than 0.9 meters thick and with more than 31 percent P_2O_5 generally average 0.012-0.024 percent U_3O_8 (Finch and others, 1973). The phosphorites are blanket like. The host rocks are the phosphatic carbonaceous shale and mudstone, phosphorite, chert, carbonate rock and sandstone in the Phosphoria Formation and its close stratigraphic correlatives. Fossil remains, including those originally phosphatic, such as fish scales, teeth, and linguloid brachiopod shells, and those that were originally calcareous and have since been phosphatized, occur. Deposition occurred in marine geosynclines and on platforms. Thinner platform facies lie to the east, and a thicker geosynclinal facies occurs on the west, with the richest phosphate beds occurring in two phosphatic shale members of the formation in the tightly folded and faulted geosynclinal facies. Apart from relatively short-lived periods of emergence during Mississippian times and at the end of the Pennsylvanian, large areas of the western American continent were covered by the Cordilleran geosynclinal sea which occupied much of the Rocky Mountains area and extended northwards into western Canada and into Alaska. It also covered parts of New Mexico and Texas. The Permian phosphate beds were deposited in a long, rather hook-shaped arm of this geosyncline, called the Phosphoria sea. Most of the uranium is in carbonate-fluorapatite, where it probably substitutes for calcium. Tyuyamunite occurs in one area where the rocks are highly weathered. Associated minerals are quartz, chert, hydromica, and other silicates, carbonaceous matter, carbonates, and glauconite; some pyrite.

References: Finch and others, 1973; Maughan, 1975; McKelvey and Carswell, 1956, 1967.

Symbol: 31DPL
Name: Area underlain by Bone Valley Formation, Florida, U.S.A.
Location: 27° 45' 00" N; 082° 00' 00" W
Description: The average uranium content of rock in the Bone Valley Formation of Pliocene age in Florida for phosphate is about 80 ppm. Phosphorite in the Bone Valley Formation of Pliocene age in the land-pebble phosphate field in Florida ranges in thickness from 1.8 to 2.1 meters over about 800 square kilometers and averages 0.012-0.024 percent U_3O_8 and 20-30 percent P_2O_5 (Altschuler and others, 1956). Uranium in marine phosphorite deposits was probably deposited from sea water during sedimentation, or in some places possibly later by downward percolating ground water. The Bone Valley Formation, land-pebble phosphates, has bedded pebbly and clayey phosphatic sands. Leaching or alteration to aluminum phosphates occurs. Some of the material in the Bone Valley Formation is a weathered residuum derived from underlying marine phosphorites and some is the product of marine reworking of the residual mantle. Except for a single trace occurrence of autunite, no uranium minerals have been found in the Bone Valley Formation (Altschuler and others, 1956; Cathcart, 1956). Aluminum phosphate minerals, carbonate-fluorapatite, crandallite, wavellite, and millisite occur as associated minerals. Most rock was deposited in an area of peneplain that was gradually inundated by a sea that had an irregular shore line, scattered islands, a gently sloping bottom, and distinct connections with the ocean; miogeosynclinal platform.

Engineering and Mining Journal, 1976 (v. 177, no. 5, p. 79-89) reported that both U_3O_8 and fluorine are now being recovered from acid plants and sold as commercial by-products of phosphate production; and that 150,000 tons of recoverable U_3O_8 are included in the U.S. Bureau of Mines, 1973, estimated 1.2 billion tons of phosphate rock reserves in the central Florida Bone Valley Formation phosphate area.

References: Altschuler, Jaffe, and Cuttitta, 1956; Cathcart, 1956, 1963; Cathcart and others, 1953; Dennison and Wheeler, 1975; Engineering and Mining Journal, 1976, v. 177, no. 5, p. 79-89.

symbol: 32DPL
Name: Land-pebble phosphates of Beaufort County, North Carolina, U.S.A.
Location: 35° 50' 00" N; 076° 45' 00" W
Description: Miocene land-pebble phosphate deposits are similar to Florida deposits. The Lee Creek phosphate, in a large Miocene phosphorite deposit on the Atlantic Coastal Plain, is uniform over about 50,000 acres and is flat-lying, with an average dip of 2 meters per kilometer southeasterly. Total reserves estimates have been made at 10 billion tons, with an average P_2O_5 content of 18 percent (while other estimates are at only 1.5-2.0 billion tons for the same area) (Caldwell, 1968). The uranium is mainly in the mineral carbonate-fluorapatite. Leaching or alteration to aluminum phosphates occurs. On the basis of 30 ppm (Brown, 1958) there is 0.06 pound of uranium per ton of ore, and on the basis of 80 ppm (Brown, 1958) there is 0.16 pound. A very large, high-cost (byproduct uranium recovery) uranium resource of 160,000 to 800,000 tons is indicated (Southern Interstate Nuclear Board, 1969, p. 85).
References: Brown, 1958; Caldwell, 1968; Dennison and Wheeler, 1975; Southern Interstate Nuclear Board, 1969.

Symbol: 33 DPM
Name: Land-pebble phosphates of South Carolina, U.S.A.
Location: 33° 00' 00" N; 080° 30' 00" W
Description: The uranium is associated with phosphate deposits of the lower Coastal Plain in marine sediments and phosphorite beds. The uranium occurs in the Cooper Marl of Eocene, Oligocene, and early Miocene(?) age in Charleston, Berkley, Dorchester, and Colleton Counties, and in the Hawthorn Formation of Miocene age in Jasper, Beaufort, Colleton, and Hampton Counties. Uranium is mainly in the mineral carbonate-fluorapatite. The uranium content of phosphorite ranges from 0.025 to 0.063 percent equivalent U_3O_8 (Southern Interstate Nuclear Board, 1969). As a byproduct of the phosphate mined for the chemical phosphate fertilizer industry, taking an average of 0.025 to 0.63 percent equivalent U_3O_8, averaging 0.043 percent for the phosphate concentrate (Malde, 1959), the 10 million tons indicated concentrate reserves would contain about 9 million pounds of U_3O_8 (Southern Interstate Nuclear Board, 1969).
References: Malde, 1959; Southern Interstate Nuclear Board, 1969.

Symbol: 34BVL
Name: Conway Granite, New Hampshire, U.S.A.
Location: 44° 00' 00" N; 071° 20' 00" W
Description: It is estimated that about 5,775,000 metric tons U is contained in granitic rocks (fine-grained biotite granite, biotite quartz monzonite) of the Conway Granite of the Triassic, Jurassic, and Cretaceous White Mountain Plutonic Series in northern and central New Hampshire, in an area of more than 780 square kilometers to a depth of 304 meters, in granite that contains 0.001 to 0.003 percent U_3O_8 (Finch and others, 1973) and averages 0.0015 percent U_3O_8 (Billings, 1955; Brown and Silver, 1956; Smith and Flanagan, 1956). Uranium deposits in the Conway Granite are considered paramarginal.
References: Billings, 1955; Brown and Silver, 1955, 1956; Butler, 1967, 1975; Finch and others, 1973; Larsen and others, 1956; Smith and Flanagan, 1956; Smith and others, 1957; Strobell and Cannon, 1975.

Symbol: 35CVS
Name: Ross-Adams mine, and other deposits of Bokan Mountain area, Prince of Wales Island, Alaska, U.S.A.
Location: 54° 54' 15" N; 132° 08' 15" W
Description: Most of the uranium-thorium deposits are genetically related to the peralkaline granite (Cretaceous and Tertiary? Bokan Mountain Granite), an uncommon rock type that forms a boss or small stock about 4.8 square kilometers in areal extent and contains abnormal quantities of many minor elements. The dominant occurrence of the deposits is in veins or local replacements that contain uranium-thorium minerals of hydrothermal origin in or near fractures (MacKevett, 1963). Hydrothermal activity was subsequent to the crystallization of the peralkaline granite, and was facilitated(?) by faults which may have acted as channelways for the vein-forming hydrothermal solutions. The Ross-Adams mine, on the southeast flank of Bokan Mountain, about 56 kilometers southwest of Ketchikan, is within the peralkaline granite boss, about 300 meters from the southeast margin of the boss. It followed a crudely fusiform ore body that trended north, that was exposed over a length of about 55 meters, that averaged about 12 meters in width, and whose maximum vertical dimension was about 15 meters. The few pegmatites in the mine area form quartz-rich dikes as much as 0.3 meters thick that contain subordinate amounts of K-feldspar and albite. The mine produced, between early June and late October 1957, approximately 13,605 metric tons of uranium ore that contained more than 0.80 percent U_3O_8. The ore body consists of a core of high-grade ore that contains more than 0.50 percent U_3O_8 enveloped by a uraniferous zone from 0.6-6 meters thick that contains less than 0.50 percent U_3O_8. A large part of the high-grade ore contains about 1 percent U_3O_8, and local pods contain as much as 3 percent U_3O_8. The ore generally contains slightly more thorium than uranium, but in a few samples the thorium to uranium ratio is as much as seven to one, and the thorium content is as much as 5.66 percent. Even though the ore had a high thorium content, costly extractive processes precluded its profitable recovery. The ore is in numerous ore-bearing veinlets between 0.1 and 0.8 millimeters thick and uranium-thorium minerals scattered throughout the peralkaline host rock. The mine workings consist of a northward-trending open pit about 113 meters long, between 7 and 23 meters wide, and about 9 meters in maximum depth (MacKevett, 1963).

Many radioactive minerals, chiefly uranothorite and uranoan thorianite; a few minerals that contain rare earths, including monazite, zircon, xenotime, parisite(?), and bastnaesite(?); and niobates were identified (MacKevett, 1963). Coffinite, which occurs in minor amounts in the ore has been identified. Besides the uranium-thorium minerals, the veinlets contain abundant hematite and calcite, and lesser amounts of fluorite, pyrite, hydrous iron sesquioxides, galena, quartz, and clay minerals, including nontronite(?) and chlorite(?). Pyrite and galena are locally abundant near the crosscutting faults at the south end of the open pit of the Ross-Adams mine. Fluorite associated with the ore is deep purple and the quartz is gray. Secondary uranium minerals occur in minor amounts in near-surface environments at the deposit. They include gummite, sklodowskite, beta-uranophane, bassetite, and novacekite. The higher grade parts of the ore body are reddish brown because of abundant hematite.

References: Cobb, 1970; MacKevett, 1958, 1959a, 1959b, 1963; von Backström, 1974.

Symbol: 36AVM
Name: Port Radium deposits, Great Bear Lake, district of Keewatin, Northwest Territories, Canada.
Location: 66° 05' 00" N; 118° 02' 00" W
Description: Massive veins of colliform pitchblende, thucolite, with wall rock replacement, occur in the main northeasterly-trending fault and in branching faults (Ruzicka, 1971) in the Archean or Proterozoic Echo Bay Group, which is composed of quartzite, tuff, chert, argillite, limestone, and conglomerate. Age of deposits is 1450 million years. The complex mineralogy of the Eldorado mine, the only large producer, was characterized by the abundance of cobalt-nickel arsenides, bismuth and silver minerals (Jory, 1964), where more than 40 minerals have been identified (Little, 1970, p. 41). Associated metallic minerals are copper-nickel arsenides, hematite, pyrite, sphalerite, tetrahedrite, bornite, chalcopyrite, galena, silver minerals, and bismuth. Associated gangue minerals are quartz and carbonates. Hydrothermal alteration occurs in the form of hematization, carbonatization, chloritization, sericitization, and argillization (Williams and others, 1972). The Great Bear Lake deposits are now worked principally for silver (Robertson and Lattanzi, 1974). The host rocks of the deposits were metamorphosed tuffs and coarse fragmental material interbedded with cherty sedimentary strata, all part of the Echo Bay Group of Aphebian (Proterozoic) age. Masses of feldspar porphyry are interbanded and are at least partly intrusive. The rocks are invaded by granite encountered in the lower levels. Diabase dikes are younger than the granite and are transected by structures associated with the ore. The youngest rocks are flat-lying sheets of diabase, apophyses of which cut ore. The Eldorado orebodies were in an area roughly 600 meters wide and 1.6 kilometers long, mined in places to 500 meters below the surface. The rocks are traversed by a series of steep northeasterly-trending faults, some coalescing and some branching. The orebodies were veins and breccia fillings in faults, individual ore shoots being about 10 centimeters to 4 meters wide and 15 to 213 meters long; one was worked for a depth of 335 meters. The ore shoots were confined almost entirely to the stratified rocks or to places where the fault zones followed controls between them and diabase. They extended only a little way into parts of the fault zones that crossed porphyry, granite, or massive tuff. Ore shoots appeared to be grouped around "noses" of porphyry. Mineralization took place in four stages, the pitchblende apparently being deposited first and at fairly low temperatures and pressures. All evidence indicated that the mineralization was related to the granite. Some veins extend into it, suggesting that the mineralization was a late stage of the intrusion itself rather than redistribution, by metamorphism or granitization, of metals contained in the invaded rocks. Curite, becquerelite, and liebigite also occur.

References: Badham and others, 1972; Douglas, 1970; Jory, 1964; Lang and others, 1962; Little, 1970, 1974; Lloyd, 1973, 1975; Morton, 1974; Robertson and Lattanzi, 1974; Robinson and Ohmoto, 1973; Ruzicka, 1971; Smith, 1974; Thorpe, 1971; Williams and others, 1972.

Symbol: 37AVS
Name: Beta Group of claims, Marian River region, near Maryleer Lake, Great Slave Lake area, Northwest Territories, Canada.
Location: 63° 27' 00" N; 116° 32' 00" W
Description: Pitchblende occurs in veins, breccia zones, stockwork of veins in northeasterly-trending shear zones, in Proterozoic granodiorite, quartzite, dolomite, argillite, chert and mica schist of the Snare Group. Other radioactive minerals that occur are uranophane and thucholite. The mineralogy is relatively simple; exotic minerals are present only in traces. Hydrothermal alteration occurs as hematization, silicification, and chloritization. Associated minerals are hematite, minor pyrite, and chalcopyrite. Associated gangue minerals are quartz and epidote. In southern Bear Province, in the Rayrock mine, pitchblende occurs in shoots in a northeasterly-trending large quartz stockwork. These are locally called "giant quartz veins" and are fairly abundant in the southern Bear Province.
References: Douglas, 1970; Hoffman, 1969; Lang and others, 1962; Little, 1970, 1974; Ruzicka, 1971; Williams and others, 1972.

Symbol: 38AVM
Name: Lake Athabasca district (or Beaverlodge district, or Goldfields, or Uranium City), Beaverlodge Lake area, northern Saskatchewan, Canada.
Location: 59° 30' 00" N; 108° 40' 00" W
Description: In the Athabasca sandstones basins on the north side of Lake Athabasca, the prominent uranium deposits are epigenetic, pitchblende-bearing veins and stockwork, most of simple mineralogy. The deposits are found in various rock types of the Archean or Aphebian Tazin Group (about 1820-2500 million years) and in cover rocks of the Helikian (middle Proterozoic) Martin Formation (about 1630 to 1820 million years). The uranium deposits occur preferentially near the Martin-Tazin contact (Robertson and Lattanzi, 1974). The deposits are all localized by structure, zones of brecciation and mylonitization. Uranium is everywhere dispersed in thousands of small fractures. Only where numbers of these occur in a zone of interconnection do the deposits attain economic size. Deposition of uranium is chiefly by cavity filling of fissures, breccias, and fracture zones, all of which are dilatent systems, suggestive of relatively shallow depths (Robinson, 1955). Pitchblende is the ore mineral, and varies in character from disseminated to massive and colloform. Ninety percent of the uranium is colloform pitchblende, which is usually the oldest and it is frequently brecciated and re-cemented by various minerals, including many stages of younger pitchblende (Robertson and Lattanzi, 1974).

The Gunnar mine, not presently in production, and the Eldorado mine, which will continue to be in production for many years, are the two major ore deposits of the district (Robertson and Lattanzi, 1974). At Gunnar the ore occurred in an albitized monzonite, a metasomatized paragneiss, part of the Archean or possibly Proterozoic Tazin Group. Pitchblende and secondary uranium minerals were disseminated through the monzonite with little evidence of structural control, except for the higher grade zones, which were related to zones of brecciation frequently marked by red hematite. The pipe-like orebody is near the interseection of northeasterly and easterly-trending faults. In the breccia zones, euhedral quartz cemented by calcite and large calcite grains suggested that the brecciated, mylonitized zones were porous and vuggy during mineralization. Secondary uranium minerals, chiefly uranophane, were prominent in the upper part of the body comprising about 60 percent of uranium values. Even at depths of 120 meters, some 30 percent of the uranium was in secondary minerals and secondary mineralization persisted to even greater depths (Robertson and Lattanzi, 1974). Associated metallic minerals are hematite and minor sulfides. Gangue minerals are calcite, dolomite, quartz, chlorite, and kaolin. Calcite and dolomite occurred throughout the rock as irregular grains. Toward the base of the ore unit, carbonates comprised up to 25 percent of the rock, while at higher levels these amounted to about 5 percent. Hydrothermal alteration is in the forms of hematization, carbonatization, silicification, chloritization, and albitization (Williams and others, 1972). The various ore shoots that make up the Eldorado mine system, including the shoots mined from the Fay, Ace, and Verna shafts, lie along the St. Louis fault over a distance of about 4 kilometers. Orebodies are found both in the footwall and hanging wall of the fault in veins and in stockwork breccias, all largely within 60 meters of the fault (Robertson and Lattanzi, 1974). Continuing work by E. E. Smith of Eldorado (Robertson and Lattanzi, 1974) suggests that mineralization everywhere is close to the Tazin-Martin unconformity. There is no great depth to the zone of secondary minerals at the Eldorado mine.

The distribution of the uranium deposits in the area is controlled by regional and local structures and by lithology. The mineralized area is in a belt of folded and faulted rocks with a prevailing northeasterly trend. Faults are of two main ages. Zones of fracturing, brecciation, and mylonitization are commonly associated with the earlier faults that originated after granitization of the Tazin rocks. Some of the later faults, that formed just before and after the deposition of the Martin strata, may have followed the earlier fault traces. The pitchblende deposits lie along the northeasterly-trending faults, particularly at intersections with southeasterly-trending faults and anticlines. They rake or plunge southwesterly, apparently partly because of the angles of intersection between the fault and fracture systems (Robertson and Lattanzi, 1974). Many show preference for rocks easily brecciated and mylonized, and for argillites and mafic rocks.

Most deposits are mineralogically simple--pitchblende with hematite as an alteration product. A vanadium mineral, nolanite, is fairly common in parts of the Ace orebodies. Proven reserves of Fay mine, the main Beaverlodge mine, are almost 3.3 million tons of ore grading 0.20 percent U_3O_8 (Engineering and Mining Journal, 1976, v. 177, no. 7, p. 127).

References: Beck, 1969, 1970; Christie, 1953; Douglas, 1970; Engineering and Mining Journal, 1976, v. 177, no. 7, p. 127; Jolliffe and Evoy, 1957; Koeppel, 1968; Lang and others, 1962; Morton and Sassano, 1972; Robertson and Lattanzi, 1974; Robinson, 1955; Ruzicka, 1971; Tremblay, 1972; Williams and others, 1972.

Symbol: 39AVL
Name: Carswell Dome area, Athabasca basin area, including Cluff Lake (Mokta), and Numac, Saskatchewan, Canada.
Location: 58° 22' 00" N; 109° 30' 00" W
Description: The Cluff Lake uranium orebodies were found by Mokta (Canada) Ltd., who located a train of pitchblende boulders by airborne radiometric survey in 1968. The orebodies lie below the sandstone of the Precambrian (Archean) Athabasca Formation in the Carswell structure, a circular feature 56 kilometers in diameter, variously interpreted as a possible [strata-bound disseminated (diatreme?)] cryptovolcano, a diapiric structure, and an eroded impact crater. Possibly it is a diatreme. At its center, basement rocks are exposed in a circular area with a diameter of about 20 kilometers. The basement is extremely deformed and cut with zones of breccia and beds of rhyolite, and dated at about 470 million years. Around the basement core is a zone of heavily deformed sandstone rubble, followed by a ring of fine-grained sandstone and dolomite, a ring of dolomite, and then the flat-lying Athabasca sandstones. A thin, discontinuous band of pelite, which occupies hollows in the basement, underlies the Athabasca sandstone. It is in this pelite and in the basement rocks that uranium occurs where the basement rocks and the pelite are badly deformed, the basal contact of pelite with gneiss frequently being overturned by structures that appear to be thrust faults (Robertson and Lattanzi, 1974). The basal pelite contains the rich "D" orebody (up to 4.5 meters thick) of massive pitchblende. The ore is essentially monomineralic and carries no thorium, although significant amounts of gold and platinum occur. Pitchblende occurs with shale in a shale-sandstone sequence in coarse hematitic polymictic conglomerate and breccia of the Athabasca Formation. The mineralization is in pitchblende that appears to have an intimate relationship with abundant organic material in the pelite as well as in the fault-controlled ores of the basement (Robertson and Lattanzi, 1974). Primary deposition at between 1100 and 1400 million years ago is indicated by uranium-lead dating. Reworking of uranium through long periods of time is suggested by dates as young as 80 million years (Robertson and Lattanzi, 1974). Robertson and Lattanzi (1974) believed that uranium was emplaced, before the deposition of the Athabasca sandstone, from surficial waters that deposited uranium in pelites and in structural traps in the basement, and that the organic material is oil-derived and remains at the site due to polymerization and fixing in place by the pre-existing uranium. The richest of the deposits averages 10 percent U_3O_8.
References: Little and Ruzicka, 1969; Robertson and Lattanzi, 1974; Ruzicka, 1971; von Backström, 1974.

Symbol: 40AVL
Name: Rabbit Lake deposit, Wollaston Lake area, northern Saskatchewan, Canada.
Location: 58° 12' 00" N; 103° 43' 00" W
Description: The deposit lies under and south of Rabbit Lake, a small lake 4.8 kilometers west of Wollastan Lake, off the east side of the Athabasca Formation in the center of the Wollaston Lake Fold Belt. The host rocks are mainly gneisses and meta-argillites of Precambrian (Aphebian or early Proterozoic) age below a major unconformity overlain by middle Proterozoic sandstone (Helikian Athabasca Formation). Near the mineralized zone they are altered due to argillization, carbonatization, silicification, and some hematitization. Uranium occurs in a crushed and brecciated carbonate, calc-silicate layer which has been down-folded to form a tight recumbent syncline, probably during the Hudsonian event at about 1800 million years. The ore consists of hard, massive, and banded colloform pitchblende accompanied by a minor quantity of sulfides, such as pyrite, galena, and sphalerite, with relatively late quartz and calcite gangue. Spectrographic estimates of chemical composition of the orebody are 10+ percent U_3O_8, 0.01 percent ThO_2, and a trace of V (Knipping, 1974). Continual leaching and redeposition has moved uranium from the upper layers and deposited it as sooty pitchblende in the lower parts of the ore unit. The ores are essentially monomineralic, although secondary uranium minerals, such as uranophane, do occur. The orebody, about 425 meters long and 167 meters in maximum thickness, is roughly a flattened tube plunging gently northeast. Highest grade is in the center of the body and the shape and grade distribution are suggestive of fluid movement through a funnel or tube-like system with greatest uranium precipitation in the most permeable central part. Uranium-lead dates vary from about 1240 million years to 190 million years. Robertson and Lattanzi (1974) believed uranium deposition to be of pre-Athabasca time with some reworking after deposition of the Athabasca, and the source of the epigenetic uranium was the syngenetic uraninite (with thorium) in pegmatites of the gneisses of the Wollaston Lake Fold Belt. Knipping (1974) was of the opinion that present evidence points out that the uranium was deposited by supergene solutions in a regolith acting as a trap, prepared during a long weathering interval after the erosion and peneplanation of the Hudsonian orogen; that uraniferous solutions originated east of the Wollaston Lake area and flowed westward during the deposition of the Athabasca Formation; and that the uraniferous waters percolated through the porous and permeable regolith below the unconformity because structurally the block was in a "high" position. Knipping (1974) stated that after peneplanation of the Hudsonian orogen, surface weathering generated a porous and permeable regolith of varying thickness which later was covered by sandstone and faulted up by a reverse fault. Primary uranium mineralization of massive and colloform

pitchblende occurred about 1000 million years ago and has no relationship to the Hudsonian orogeny (Knipping, 1974).

References: Barnes and Ruzicka, 1972; A. P. Butler, oral commun., 1974; Drozd and others, 1974; Fahrig, 1957, 1961; Hoeve and Sibbald, 1977; Knipping, 1974; Little, 1971, 1974; Little and Ruzicka, 1970; Robertson and Lattanzi, 1974; Ruzicka, 1971; Williams and others, 1972.

Symbol: 40aAVS?
Name: Middle Lake, Saskatchewan, Canada.
Location: 59° 00' 00" N; 106° 00' 00" W
Description: In the Middle Lake deposit, 15 km west of Black Lake, and 16 km east of Stony Rapids, the uranium concentrations are in the Helikian (Precambrian Y) Athabasca Formation near the base (Sibbald, Munday, and Lewry, 1977). Isolated, angular boulders of quartz and some well-rounded quartz pebbles are found side by side in a clay-rich layer in the alteration zone (or "regolith") between the basal contact of the Athabasca Formation and the underlying metamorphosed Archean or Aphebian basement rock. The altered zone formed subaerially and is a true regolith (Ramaekers and Dunn, 1977). In a few places uranium is present in cement between grains in porous fractures. Uranium occurs about three meters above the base of the Athabasca Formation, i.e., above the non-uraniferous sands, regolith, and basement. The uranium bearing solutions moved laterally through the sandstone (Ramaekers and Dunn, 1977). All dates of uranium mineralization in the Athabasca Sandstone are younger than 400 m.y., i.e., post-Early Devonian (Ramaekers and Dunn, 1977).

Supergene alteration to a depth of 50 m occurs in the Middle Lake deposit, which is within the Athabasca basin. Balger, east of Verna Lake, is an associated mine. The most common secondary minerals are liebergite and uranophane; the average grade is 0.7 percent U_3O_8 (Tatsch, 1976).

References: Ramaekers, 1975; Ramaekers and Dunn, 1977; Sibbald, Munday, and Lewry, 1977; Tatsch, 1976.

Symbol: 40bAVL
Name: Key Lake area, northern Saskatchewan, Canada.
Location: 57° 17' 00" N; 105° 45' 00" W
Description: The Key Lake area is at the southeastern unconformity between the Helikian (Precambrian Y) Athabasca Formation and the older crystalline basement at the southern edge of the Athabasca basin. The Athabasca Formation unconformably overlies metamorphosed Archean or Aphebian basement rock that is altered to a depth of up to 70 m below the contact. The basement rocks which host the Key Lake mineralization are extensively chloritized and argillized (Sibbald, Munday, and Lewry, 1977). The "regolith", or the altered zone, has at relatively few places, at the contact of the Athabasca, alteration so complete that beds of fairly pure clay often contain only quartz veins. These clays include illite, chlorite, mixed layer lattice clays, quartz, and pyrite, but very little kaolinite (Ramaekers and Dunn, 1977). The Key Lake deposit may be located within a basal Aphebian graphitic pelitic gneiss unit (Ray, 1976). The Athabasca Formation, mostly quartz sandstone with a few thin, discontinuous layers of silt and clay, was deposited 1350± 50 m.y. ago in a fast-flowing braided stream environment characterized by shallow channel sands, local conglomerates, and the near absence of clay deposits (Ramaekers and Dunn, 1977). For at least 30 km down drainage from the Key Lake deposit, an anomalous uranium despersion 'halo' occurs, with the lake sediments locally yielding in excess of 1,500 ppm uranium (Ramaekers and Dunn, 1977). Very high uranium and nickel contents in lake sediments (from 100 ppm to over 700 ppm) were found both in the Zimmer Lake (about 10 km southwest of Key Lake) and Key Lake areas. Anomalous copper (40 ppm) and lead (80 ppm) values in lake sediments were also found. The discovery in 1975 and 1976 of the Key Lake uranium/nickel deposit was a result of a geochemical sampling of particularly organic-rich lake sediments carried out in 1973 and 1974 (Tan, 1977). Most of the anomalous lake sediments, however, are derived from ore boulders and not directly from the ore deposits themselves. Two ore bodies, Deilmann (buried U/Ni orebody) and Gaertner, are about 500 m and 1500 m southwest of Key Lake. The Deilmann orebody has been traced almost as far north as Key Lake. Mineralization is geochemically and mineralogically complex, uranium being associated with a range of other metals including nickel, arsenic, gold and selenium (Watkinson and others, 1975). Lake sediments indicate that vanadium and molybdenum are not associated with the Key Lake ore bodies (Ramaekers and Dunn, 1977).
References: Ramaekers, 1975; Ramaekers and Dunn, 1977; Ray, 1976; Sibbald, Munday, and Lewry, 1977; Tan, 1977; Watkinson and others, 1975.

Symbol: 41AGL

Name: Elliot Lake (Blind River district, <u>sensu stricto</u>) Ontario, Canada.

Location: 46° 30' 00" N; 083° 00' 00" W

Description: Mineralization is confined to the basal Huronian (early Proterozoic) quartz-pebble conglomerate and feldspathic quartzite of the Martinenda Formation of the Elliot Lake Group, mainly on the north and south limbs of the main syncline (Quirke Lake trough) in valleys that may represent channels in the early Huronian drainage system (Ruzicka, 1971; Lang and others, 1962; Robertson, 1974). Robertson (1970, 1974; Robertson and Steenlan, 1960) describes the gravel sheets at both Elliot Lake and Agnew Lake as deltaic deposits of a major stream system. The sheets moving progressively north indicate that the point of debouchment and strand line were moving progressively northward as the sea encroached on the land. Where the quartzite-arkose sequence is clean, well washed, and packed and shows few lateral facies change, as in the Huronian Supergroup, the environment of deposition was marine (Robertson, 1974).

Roscoe (1969) observed mineralogical zoning within the ore zones, and also in a large geological environment and found that the concentration of U_3O_8 was enriched up to 250 times in the upstream part of the conglomeratic member of the deposit in comparison with the U_3O_8 concentration in the hypothetical source area of granite and granitic paleosol, and only four times in the downstream part of the deposit. The deposits are buried placers, and probably required a major drainage system that drew debris from a large area and deposited it on a delta surface on which braided streams played back and forth leaving an interbedded series of long, sinuous lenses and sheets. They probably also required a source area of granite, gneiss, or migmatite, in which the uranium minerals brannerite, uraninite, uranoan monzonite, minor thucholite, coffinite, uranothorite, gummite, and uranothorianite occur. Associated minerals are pyrite, minor hematite, magnetite, zircon, ilmenite, sphene, anatase, and rutile, with gangue minerals of apatite, muscovite, and chlorite. Hydrothermal alteration occurs as local chloritization and albitization. The conglomerates are truncated by unconformity at the edges of basins. Conglomerates are progressively younger northward. The age of mineralization is 2250 to 2400 million years ago (Williams and others, 1972). Robertson (1974) pointed out that pyritic, uranium-bearing quartz-pebble conglomerates found in Canada, South Africa, Brazil, and Australia are similar in lithology, mineralogy, and age (between 2800 million years and 2200 million years); that they were derived from detrital, heavy minerals, carried to and preserved in the rocks because of an anoxygenic atmosphere prior to 2200 million years ago; and that they overlie a contorted greywacke-greenstone sequence, and ores can only be found below the oldest red-colored units of the overlying rock units containing red clastics and shales.

References: Canada Geol. Survey, 1958; Holmes, 1957; Lang and others, 1962; Robertson, J. A., 1970, 1974; Robertson and Douglas, 1970; Robertson and Steenlan, 1960; Roscoe, 1957, 1969; Roscoe and Steacy, 1958; Ruzicka, 1971; Williams and others, 1972.

Symbol: 42AGL
Name: Elliot Lake, *sensu lato*, Agnew Lake, Ontario, Canada.
Location: 46° 26' 00" N; 081° 37' 00" W
Description: The Agnew Lake uranium deposit, a buried placer, occurs in the northern, steeply-dipping limb of an easterly striking syncline built up of quartzites, argillites, conglomerates, volcanic tuffs and flows, and gabbroic intrusions. The ore is in several quartz-pebble conglomeratic beds interlayering the steeply dipping sediments of Huronian age (between 2,500 and 2,200 million years). The contact zone between the granite basement rocks and the unconformably overlying Huronian sediments that dip vertically, is as a rule represented by regolithic material (Ruzicka, 1971). The gravel sheets are described under Elliot Lake *sensu stricto*. The uraniferous conglomerate is composed of quartz pebbles and locally of microcline feldspar fragments in a matrix containing microcline, pyrite, rutile, pyrrhotite, uranothorite, monazite, brannerite (rarely), anatase, chalcopyrite, galena, and zircon. The rare earths occur in relatively high quantities. The $ThO_2:U_3O_8$ ratio varies in various ore types from 1:1 to 6:0 (Carrington and Wilton, 1969). The main ore mineral is uranothorite but many other heavy minerals, including monazite, are present. Associated minerals are pyrite, allanite, and sphene, and gangue minerals are apatite and chlorite. Hydrothermal alteration occurs as chloritization and silicification.
References: Canada Geol. Survey, 1958; Carrington and Wilton, 1969; Holmes, 1957; Lang and others, 1962; Robertson, 1974; Robertson and Douglas, 1970; Roscoe, 1957, 1969; Ruzicka, 1971; Williams and others, 1972.

Symbol: 43ADM
Name: Bancroft area, Ontario, Canada.
Location: 45° 00' 00" N; 078° 00' 00" W
Description: The uranium orebodies occur as discontinuous shoots within pegmatoid bodies, and are mainly concentrated at the edges of contacts. In most cases, the shoots are much more persistent in the vertical sense than in the horizontal. The Grenville Province, in which the deposits lie, is characterized by regionally metamorphosed rocks that are now paragneiss, amphibolite and marble. Intrusive rocks, both stock-like bodies and <u>lit</u>-par-<u>lit</u> injections, include gabbro, diorite, syenite and granite. The area of the deposits is permeated by dikes, lenses and diffuse zones of pegmatitic granite and syenite within which the uranium orebodies lie. The Bancroft area is underlain by three fairly circular masses, called the Cheddar Granite, Cardiff Complex, and Faraday Granite; each is about 9 kilometers in diameter, and is composed of granite, syenite, gneisses, and related rocks. They are separated by metamorphic rocks of various kinds that exhibit concentric structure. These are mainly marble, paragneiss, para-amphibolite, and meta-gabbro of the Grenville Series of Precambrian (late Proterozoic) age. The principal uranium deposits are in bodies of granite and syenite with pegmatitic and metasomatic phases that either cut the wall rocks or replace them. The most favorable rocks were pegmatitic pyroxene granite or syenite, leucogranite, and cataclastic quartz-rich granite-pegmatite. All are fairly high in sodium. Many ore shoots were associated with concentrations of mafic minerals and magnetite. The four productive mines, closed by 1964 (Williams and others, 1972), were the Bicroft mine in paragneiss and amphibolite on the east flank of the Cardiff Complex, the Faraday mine in a belt of metagabbro and amphibolite on the south flank of the Faraday Granite, the Canadian Dyno mine in a belt of paragneiss and other rocks on the east flank of the Cheddar Granite, and the Greyhawk mine in metagabbro on the south flank of the Faraday Granite. The ores were distributed <u>en echelon</u> in a swarm of lenticular dikes (Bicroft mine), or in a series of pegmatitic granite dikes. Deposits of the Faraday mine occur along the limbs of an antiform and synform plunging west (Williams and others, 1972).

The ore minerals are uranothorite and uraninite, mostly averaging 0.1 percent U_3O_8, with additional minor uranophane in the Faraday mine. Cryolite and thorite also are present. Other radioactive minerals are allanite, fergusonite, monazite, betafite (hatchettalite, ellsworthite), and zircon. Hydrothermal alteration occurs as hematite and albitization. Higher grade zones are frequently red in color. Associated metallic minerals are magnetite, pyrite, pyrochlore, and allanite. Gangue minerals are quartz, feldspar, pyroxene, locally gypsum or anhydrite.

Age of deposits is 950 to 1070 million years (Williams and others, 1972). The deposits are of typical syngenetic origin. Their ultimate origin is obscure, but their relatively high pressure content of uranium may be due to rejuvenation of rock and uranium from detrital deposits of Aphebian age which were reworked during the Grenville event (Robertson and Lattanzi, 1974).

References: Bowie, 1970; Cunningham-Dunlop, 1967; Douglas, 1970; Kelly, 1956; Robertson and Lattanzi, 1974; Robinson, 1960; Robinson and Hewitt, 1958; Satterly, 1957; Williams and others, 1972.

Symbol: 44AVS?
Name: Makkovik area, including Kitt's deposit, eastern Nairn geological province of Labrador, Canada.
Location: 54° 59' 53" N; 059° 29' 23" W
Description: Vein deposits with wall rock replacement are along northeasterly trending faults. The host rocks are the Aillik Group of early Proterozoic age, composed of argillite, porphyroblastic feldspathic quartzite, conglomerate, and paragneiss mafic lavas with associated tuffaceous beds. Uranium minerals are pitchblende, minor sodlyite, and kasolite. Associated metallic minerals are pyrrhotite, chalcopyrite, hematite and dispersed pyrite. Gangue minerals are quartz, calcite, feldspar, carbonates, epidote, and apatite. Hydrothermal alteration consists of hematite, carbonatization, silicification, and feldspathization. The age of the deposits is about 600 million years (Williams and others, 1972).
References: Barnes, 1972; Beavan, 1958; Gandhi and others, 1969; Lang and others, 1962; Mining Magazine, 1975; Robertson and Lattanzi, 1974; Ruzicka, 1971; Williams and Little, 1973; Williams and others, 1972.

Symbol: 45CVS
Name: Sierra de la Cal, 70 kilometers southwest of Torreón, and 15 kilometers north of Nazas, including La Preciosa deposit, State of Durango, Mexico.
Location: 25° 20' 00" N; 103° 50' 00" W
Description: Secondary minerals mainly carnotite, autunite, tyuyamunite and torbernite, occur in fracture fillings in calcareous-clayey marine sediments with an average U_3O_8 content of 0.1 percent, in an asymetrical anticline, which is part of the Mexican Geosyncline. The sediments are gray limestone that contains flint nodules, and underlying shales and carbonaceous marls whose thickness varies from 20 to 25 meters. This sequence correlates with the Cuesta de Cura Formation of Early Cretaceous age. Associated minerals are stibnite, cinnabar, fluorite, barite, and kaolin. La Preciosa mine, one of Mexico's most significant deposits, is a replacement and fracture stockwork of uraninite in altered and intruded limestone (Gableman and Krusiewski, 1967). Proven ore reserves for La Preciosa are 335,000 tons minable at a cost between $275 and $412 N.Cy./kg U_3O_8; average grade percent is 0.063, and the mine contains 210 tons U_3O_8 (Gálvez and Vélez, 1976).
References: Antúnez and others, 1962; Gableman and Krusiewski, 1967; Gálvez and Vélez, 1976.

Symbol: 46BVS

Name: Cerro de La Luz del Cobre (or "San Antonio del Cobre") 2 kilometers west of San Antonio de las Huertas, near Soyopa, State of Sonora, Mexico.

Location: 28° 38' 00" N; 109° 40' 00" W

Description: On the western slope of the Western Sierra Madre, 7 km northwest of Tonichi village (Tonichi village is about 180 km east-southeast of Hermosillo), a copper-uranium deposit occurs in a complex pipe structure that pierces the Triassic Barranca Quartzite almost vertically (Gableman and Krusiewski, 1967). The entire pipe is believed to average about 500 m in diameter. The pipe crops out as a nearly conical hill on an east-west hogback spur of the mountain. Rocks in the area include Cretaceous sediments overlain disconformably by rhyolites, andesites, and basalts of Tertiary age, and continental fluvial and lacustrine alluvium. Torbernite is the principal uranium mineral. The average grade of copper-uranium ore is 0.15 percent U_3O_8, and 2 to 5 percent Cu. Associated copper minerals include azurite, malachite, chrysocolla, chalocite and covellite. Marcasite is present. Enclosing the structural pipe is an alteration pipe at least 1 km in diameter. Gableman and Krusiewski (1967) point out that copper minerals, specularite, pyrite, and pyrrhotite, occur together, being most abundant within quartzite breccia in the breccia pipe (the copper mineralization suite generally indicates a hypothermal environment); also that torbernite and marcasite favor argillized dolerite or argillized quartzite. (The marcasite generally indicates an epithermal environment in which the solutions also mingle and have utilized the adsorption quality of clay to precipitate uranium.) Alteration within and peripheral to the brecciated zones occurs as argillization, silicification, and pyritization. The workings reach a depth of 220 meters.

References: Antúnez and others, 1962; Gableman and Krusiewski, 1967.

Symbol: 46aCVM
Name: Villa Aldama area, Chihuahua, Mexico.
Location: 29° 30' 00" N; 106° 00' 00" W
Description: Secondary uranium minerals occur in brecciated rhyolitic rocks in an area 50 km northwest to 100 km north of Chihuahua, Mexico. A reserve estimate of 150,000 tons has been made by scientists from University of Texas and University of Arizona (Engineering and Mining Journal, 1978, v. 179, no. 2, p. 152) confirming the reserves estimate made by government agencies of 1,000 metric tons uranium (1,300 short tons U_3O_8) in the under \$10 per lb category and the 920 metric tons uranium (1,200 short tons U_3O_8) in the \$10-\$15 per lb category of reasonably assured resources (OECD NEA/IAEA, 1973). In the Sierra de Gomez district, tyuyamunite, metatyuyamunite, carnotite, and autunite occur on bedding planes and fractures, and as replacements of Georgetown Limestone (Cretaceous) along the west side of an anticline which is part of a north-northwest-trending block range. The entire linear zone of uranium which parallels the strike along the west side of the anticline, is not more than 100 meters wide, and at any locality of continuous mineralization does not exceed 25 meters in width. The uranium is generally restricted to only one stratigraphic interval of 1 or 2 meters at any locality. Gableman and Krusiewski (1967) point out that ore bodies occur at intersections of major joints or fractures with bedding planes that have been stretched or sheared, and that many uranium ore bodies were found at the three-way intersections of favorable longitudinal fractures, favorable bedding planes, and the surface.
References: Antúnez and others, 1962; Engineering and Mining Journal, 1978, v. 179, no. 2, p. 152; Gableman and Krusiewski, 1967; OECD NEA/IAEA, 1973.

Symbol: 46bDVS
Name: Los Amoles, State of Sonora, Mexico.
Location: 30° 00' 00" N; 110° 15' 00" W
Description: The Los Amoles uranium-gold district is in the western foothills of the Sierra Aconchi, 16 km east of Rayon village on the Rio San Miguel, (Rayon is about 75 km north-northeast of Hermosillo). Uraninite is found in stockwork fractures and replacement disseminations in a silicified metasedimentary roof pendant in a Cretaceous to Tertiary granodiorite (Gableman and Krusiewski, 1967). The area is known for small lean gold veins. Gableman and Krusiewski (1967) pointed out that the deposit is in a regional high-temperature copper zone; and that the suites of alteration and ore minerals, as well as extensive and strong replacement textures, suggest that the uraninite itself was of high-temperature deposition.

Proved ore reserves are 1,000,000 tons minable at a cost between \$275 and \$412 N.Cy./kg U_3O_8, with an average grade of 0.047 percent, which would contain 470 tons U_3O_8 (Gàlvez and Vèlez, 1976).

References: Gableman and Krusiewski, 1967; Gàlvez and Vèlez, 1976.

Symbol: 47AVL
Name: Ilimaussaq massive in Julianehaab district, Gardar province of south Greenland.
Location: 60° 58' 00" N; 045° 57' 00" W
Description: The Ilimaussaq massif, made up mainly of agpaitic or peralkaline nepheline syenites, is the latest major intrusion in the Precambrian Gardar alkaline igneous province, which is made up of a number of major intrusions and many generations of dike swarms and of basaltic lavas. Ilimaussaq measures about 150 square kilometers and its age is approximately 1020 million years (Sörensen and others, 1974). The latest members of the intrusion, lujavritic nepheline syenites, are locally enriched in uranium and thorium. The highest concentrations of uranium and thorium occur at the contact of sheet-like intrusive bodies of a medium- to coarse-grained lujavrite into altered volcanic rocks. These contact zones may be intensively veined by analcime veinlets. The agpaitic rocks of Ilimaussaq contain potential deposits of eudialyte (Zr, Nb, rare earths); steenstrupine, monazite and thorite(?) (U, Th, rare earths); chkalovite (Be); lithium mica; sphalerite; villiaumite (NaF); pyrochlore, epislolite (Nb). The uranium deposits are low-grade ores, characterized by a very heterogeneous distribution of uranium and thorium. The volumes occupied by rocks having more than 400 ppm U are rather small, and future exploration can only be considered in conjuction with the occurrence of Nb, Be, Zr, Li, F., etc. in the same region (Sörensen, 1970a, 1970b). At the mine area at Kvanefjeld the reasonably assured uranium reserves are calculated to be 18,600 million metric tons of ore with 5,800 metric tons of uranium; the ore grade is 310 ppm U. The estimated additional ore reserve comprises 29,400 million metric tons of ore with 8,700 metric tons U, the ore grade being 292 ppm U (Sörensen and others, 1974). Uranium of whole-rock radio-element contents of ore vary from 100-3,000 ppm U, and 300-15,000 ppm Th (Sörensen, 1974); and the average Th:U ratio is 2.6:1. Uranium may be formed by a release of fluorine-rich fluids, perhaps containing UF, from acid magmas (Bohse and others, 1974). The lujavrites were accompanied by hydrothermal veins. In the roof zone there are two small masses of alkali granite. Crystallization of the agpaitic magma took place under a roof of lavas and sandstone, which prevented the escape of volatiles from the magma.
References: Bohse and others, 1974; Bondam and Sörensen, 1958; Bowie, 1970; ENEA/IAEA, 1967; Sörensen, 1970a, 1970b; Sörensen and others, 1974; von Backström, 1974.

Symbol: 48AGM
Name: Serra de Jacobina, State of Bahia, Brazil.
Location: 12° 00' 00" S; 040° 30' 00" W
Description: Uraniferous gold deposits, about 6 kilometers south of Jacobina in north-central Bahia, northeastern Brazil, are stratiform disseminated or replacement deposits in a section geologically more like the rocks at Elliot Lake than in Witwatersrand. Serra de Jacobina is a prominent range that stands out in sharp relief over the adjacent plains. Serra de Jacobina deposits, along with two other localities -- Quadrilátero Ferrifero area near Belo Horizonte, and Pitangui -- are found around the edge of the São Francisco Craton (Robertson, 1974). The conglomerates have a strike distance of about 23 km along the length of the Serra which appears to be a long fault block (Robertson, 1974; White and Pierson, 1974). The deposits occur in oligomictic quartz-pebble metaconglomerates of Serra do Córrego Formation of Aphebian(?) age, 2,200 to 2,500 million years before present. Mafic dikes cut the beds, which strike north and dip 45° to 65° east. The gray, green, or brown metaconglomerate beds range in thickness from 2 centimeters to 2 meters and consist of gray to white quartz pebbles as much as 7 1/2 centimeters long. The gray, green, or brown metaconglomerates, which in zones are heavily pyritized, are richer both in gold and uranium, locally having up to 0.2 percent equivalent uranium and averaging 0.01 percent equivalent uranium, than the white and coarse-grained metaconglomerate that contains a little gold and shows very little radioactivity (less than 0.001 percent equivalent uranium).

Uranium, which increases with pyrite, occurs as pitchblende, some enclosed by pyrite. Hydrocarbon is sparse. Outcrops are strongly limonitic and have been leached of uranium (Heinrich, 1958). Uraninite is the source of uranium in the pyritic gold-bearing reefs (White, 1956). Torbernite, a prominent uranium mineral, occurs disseminated in the ore deposits in close association with sericite, biotite, chlorite, and muscovite in the interstitial mica-pyrite aggregate, and as inclusions in the quartz pebbles, mostly along cleavage planes, cracks, and microfractures (Gorsky and Gorsky, 1962). According to Lemos (1974) the uraninite was deposited as a "placer", whereas the torbernite has a hydrothermal origin. Uraninite is closely associated with pyrite and its ferruginous products of alteration. Johannite also occurs (Gorsky and Gorsky, 1962). Some pyrrhotite, rutile, zircon, hematite and limonite; little magnetite; rare tourmaline, monazite, and clay of the illite group and very rare apatite, epidote, and calcite occur (Gorsky and Gorsky, 1962). The deposits are epigenetic and formed by processes of leaching and concentration. Gross (1968) has suggested that the gold and uranium of the Canavieiras mine were originally detrital and related to foreset beds; that ripple marks and crossbedding indicate sedimentation from the east or southeast. The Huronian uraniferous conglomerates are thought to have formed as the result of erosion of Archean granite surfaces in a delta-like environment off major drainage, at a time after the development of extensive acid crust which carried relatively large amounts of uranium-bearing accessory minerals, but before the development of an oxidizing atmosphere (Bowie, 1970). Hard, gray, light- to dark-green, and chocolate-brown conglomerate beds on the Canavieiras property contain zones of heavy sulfide mineralization--mainly pyrite, and the basal part, called the Piritoso reef, contains the main gold-bearing pyritic orebody of the mine (White, 1956).

Samplings from the Piritoso reef showed the presence of an overall average of 0.01 percent eU (equivalent uranium). The uranium content of the samples range from nil to 0.2 percent eU (White, 1956). Lemos (1974) noted for the Canavieiras mine that the average grade is 100 g/metric ton, and that the present mine production is not sufficient to allow for uranium to be economic as a by-product. Reasonably assured resources are estimated to be 9,000 metric tons U, and estimated additional resources are 1,000 metric tons U minable at a cost of less than $15/lb U_3O_8 (OECD NEA/IAEA, 1975).

References: Bateman, 1958; Bowie, 1970; Davidson, 1957; de Andrade-Ramos and Fraenkel, 1974; Dorr, 1969 [1970]; Gorsky and Gorsky, 1962; Gross, 1968; Guimarães, 1956; Heinrich, 1958; Lemos, 1974; White, 1956, 1961, 1964; White and Pierson, 1974.

Symbol: 49AGM

Name: Quadrilàtero Ferrîfero area, vicinity of Belo Horizonte, Minas Gerais, Brazil.

Location: 20° 00' 00" S; 044° 00' 00" W

Description: The deposits are on the edge of the São Francisco Craton (Robertson, 1974). Uranium and gold occur in metaconglomerates in the lower part of the Moeda Formation, which is the basal part of the Caraca Group of the Minas Series, of early Proterozoic age. The Moeda Formation has a maximum thickness of 1,150 meters and is composed mainly of quartzites of varied grain size intercalated with conglomerate lenses and phyllites (de Andrade-Ramos and Fraenkel, 1974). The mineralized beds have an average thickness of 2.5 meters, and contain about 4,240 metric tons U (5,512 tons U_3O_8), or 5,000 metric tons U_3O_8, in conglomeratic lenses. Uranium (U_3O_8) averages 200 ppm and gold less than 1 ppm. Large iron ore and manganese deposits occur in the area in the Itabira Group, which overlies the Caraca Group. The Itabira Group is also in the Minas Series. The uraniferous metaconglomerates are essentially oligomictic, made up of well rounded quartz pebbles. In some places they are polymictic with phyllitic pebbles. Detrital uraninite and pitchblende are identified. Associated pyrite usually makes up 5 to 20 percent of the whole rock. Monzonite, zircon, coffinite, pyrrhotite, chalcopyrite, rutile, and xenotime are also present in the metaconglomerates. Granites, formed in a central uplift, as well as others situated west and south of the area, are the source of the coarse sediments of the Minas Series. Deposition of the host rock was in paleochannels in a fluvial environment, in the vicinity of the ancient oceanic border, varying from the piedmont (alluvial cones) upstream and passing through typical channel deposits, where the conglomerates are deposited by the scour and fill process, to the deltaic processes in coastal environment, downstream.

References: de Andrade-Ramos and Fraenkel, 1974.

Symbol: 50CVM
Name: Poços de Caldas region, partly in Minas Gerais, partly in São Paulo, Brazil.
Location: 21° 48' 00" S; 046° 33' 00" W
Description: Uranium-bearing zirconium ores occur in the Poços de Caldas region in an alkalic pipe of Late Cretaceous age (60-80 million years, de Andrade-Ramos and Fraenkel, 1974), in a south southeast-north northwest striking volcanic belt, which crops out over an area of about 800 square kilometers near the northeastern part of the Paranå basin in the southwestern part of the Brazilian shield (Tolbert, 1966). The region has rocks comprised of syenites (foyaites), microsyenite (tinguaite), phonolites and associated tuffs. The first known zirconium ores (known variously as caldasite, zirkite, and brazilite) (Tolbert, 1966) consist chiefly of baddeleyite-zircon mixtures together with various amounts of other constituents (Heinrich, 1958). The caldasite occurs in veins and lenses in the alkalic rocks, or in eluvial deposits of broken vein material, or in alluvial deposits of rolled pebbles, which are about one centimeter to seven centimeters in diameter in Recent and older stream beds. The eluvial and alluvial material covers the slopes surrounding the deposits, and are found along the drainages over the area of roughly 450 square kilometers (Heinrich, 1958). The vein caldasite occurs in a dense network of veins, from 5 to 25 centimeters thick, in the nepheline syenite in the central part of the region. Rare earths and thorium minerals, such as urano-thorianite, are present. The uranium is predominantly present in the crystal structure of the zircon, resulting in refractory-type ore that has an average grade of 0.1 percent eU_3O_8 (Heinrich, 1958; von Backström, 1970). Bastnaesite and thorogummite occur in magnetite ore. The nepheline syenite pipe has a topographic expression of a circular plateau, having a diameter of 30 kilometers.

The molybdo-uraniferous deposits of Agostinho and the Cercado mines are in a tectonically disturbed area of the plateau. In the Agostinho deposit uranium is disseminated in the tinguaitic breccia in subvertical veins and also occurs in small quantities as coffinite and uranothorianite. Associated minerals are pyrite, fluorite, and minerals of molybdenum and thorium. The uranium occurs in brecciated subvertical veins, with an average thickness of 2.5 meters, which cut tinguaitic rocks near the contact with foyaites. In the Cercado deposit the uraniferous mineralization occurs in tectonic breccia of hydrothermally altered tinguaite. The zones are subhorizontal, lenticular orebodies with a thickness of up to 8 meters. The alkalic rocks are extensively zeolitized. This type of mineralization is quite different from the classic occurrences associated with caldesite, known since the 1950's and often mentioned in the literature (de Andrade-Ramos and Fraenkel, 1974). The measured and inferred reserves of the Agostinho deposit are 3500 metric tons U_3O_8 or 2968 metric tons U (3858 tons U_3O_8), and those of the Cercado deposit are

5840 metric tons U_3O_8 or 4952 metric tons U (6438 tons U308) (de Andrade-Ramos and Fraenkel, 1974).

In alkaline chimneys of Araxá (19° 45' S; 46° 40' W), Minas Gerais State, associated beds of niobium and uranium occur in Cretaceous rocks in a circular area with a radius of 2.35 km. The rocks are biotite-carbonatite, containing principally calcite magnesia, iron oxides, titanium and apatite. The minerals are pyrochlore and autunite. The grade is 0.01% U_3O_8, with associated apatite, and potential reserves are estimated to be 20,000 metric tons U_3O_8; and at grade 0.01-0.05%, with associated pyrochlore, are 100,000 tons U_3O_8 (Maciel and Cruz, 1973). At Olinda (7° 30' S; 36° 30' W), Paraiba, about 10 km north of Recife, the potential reserve estimate, at grade 0.02% U_3O_8, with associated phosphorite, is 50,000 tons U_3O_8 (Maciel and Cruz, 1973).

References: de Andrade-Ramos and Fraenkel, 1974; de Andrade-Ramos and Maciel, 1974; de Moraes, 1956; Guimarães, 1956; Heinrich, 1958; Koelling and Wessel, 1969; Maciel and Cruz, 1973; Noe and Ransome, 1970; OECD NEA/IAEA, 1973; Tolbert, 1966; von Backström, 1970; Wedow, 1961.

Symbol: 51BSM
Name: The Figueira area of the Paranà Basin in the south of Brazil.
Location: 21° 30' 00" S; 048° 00' 00" W
Description: Reserves of 1696 metric tons U (2205 tons U_3O_8) or 2000 metric tons U_3O_8 have been estimated to be disseminated in sandstone of the lower part of the Rio Bonito Formation (middle Permian) in the vicinity of Figueira, in the Rio do Peixe coal producing region, an area of approximately 700 square kilometers in the middle part of the southeast edge of the Paranà Basin (de Andrade-Ramos and Fraenkel, 1974). De Andrade-Ramos and Fraenkel (1974) pointed out that the sandstone host rock was protected from surface oxidation by two impermeable strata, a coal seam below and limestone bed above, and that, since Permian time, ground-water flow within this confined unit or hydrologic system, has leached uranium from sedimentary rocks of the Itararè Formation and reprecipitated it in favorable locations in the overlying Rio Bonito Formation. The uranium occurs as uraninite in interstices between the quartz grains in sandstone at the base of the Rio Bonito Formation. The basal part of the Rio Bonito is between 15 and 30 meters thick, and is composed of fine to coarse gray sandstones, gray siltstone, and dark shales with coal beds. The average grade for sandstone bodies averaging 1.3 m thick is 0.2 percent U_3O_8 (de Andrade-Ramos and Fraenkel, 1974). The sedimentary environments are fluvial, flood plain coastal swamps, and epineritic (de Andrade-Ramos and Fraenkel, 1974). The paleogeography indicates a complex drainage system with a general northwest orientation. In the relatively deep axial parts of these channels, coarser clastic sediments with a high permeability were deposited; and in the higher parts of the ancient meanders, the relative weakness of the currents resulted in deposition of fine-grained and homogenous sandstones, siltstones and carbonaceous shales, which have a low permeability. In the intermediate area between these two zones, there is an interfingering of the two types of sediments, which presents an ideal locus for later remobilization and subsequent redeposition and concentration of uranium (de Andrade-Ramos and Fraenkel, 1974). Uranium also occurs in the siltstones, dark shales, and coal in the form of organic complexes. Uranocircite, as a result of a secondary process, occurs also. Molybdenum occurs in the form of jordisite. Reasonably assured resources are 2,000 metric tons U with an estimated additional resources of 4,000 metric tons U, minable at a cost range up to \$15/lb U308 (OECD NEA/IAEA, 1975).
References: de Andrade-Ramos and Fraenkel, 1974; OECD NEA/IAEA, 1975; Sàad, 1974.

Symbol: 52CSL
Name: Tónco-Amblayo, Alemanía, and other districts in the Zona Norte, Catamarca, Salta Province, Argentina.
Location: 25° 50' 00" S; 065° 35' 00" W
Description: In the Tónco-Amblayo district, a 100 km by 50 km area with two long and narrow synclines, uranium occurs as disseminations and as inclusions along cleavage planes, cracks, and microfractures in "Middle and Upper Cretaceous" (Stipanicic and others, 1962) calcareous dolomite, argillaceous sandstones, and marl of the Calcáreo Dolomítico and Margas Coloradas Inferiores Formations.

Radioactive minerals include autunite, carnotite, phosphuranylite, metatorbernite, meta-autunite, renardite, schroeckingerite, soddyite, and tyuyamunite. Associated minerals are quartz, calcite, and kaolinite. The dominant mineral is tyuyamunite in the Don Otto and Martín M. de Güemes mines, and carnotite in Los Berthos and Emmy mines. Don Otto mine, the largest in the Tónco-Amblayo district, has a continuous surface mineralization for a length of 2500 m, a thickness of 1 m, and an average grade of 0.15 percent U_3O_8; reserves are 2000 metric tons U_3O_8, minable at a cost of less than \$8/lb U_3O_8, plus 300 metric tons U_3O_8 at \$8-\$10/lb U_3O_8. The ores of the district are economically concentratable by acid leaching (Friz and others, 1965b, p. 46) or heap leaching (Stipanicic, 1972, p. 93).

Known and estimated uranium reserves in the Zona Norte are 34,590 metric tons U_3O_8 (29,332 metric tons U or 38,129 short tons U), of which 14,000 metric tons U_3O_8 are in Tónco-Amblayo and 16,000 metric tons U_3O_8 are in Alemanía (Friz and others, 1965b, table 1, p. 51).
References: Angelelli, 1956; Friz and others, 1965a, 1965b; Stipanicic, 1970, 1972; Stipanicic and others, 1962.

Symbol: 53CSL

Name: Sierra Pintada-La Escondida district and Malargüe district, Mendoza Province, Argentina.

Location: 32° 50° 00" S; 068° 50' 00" W

Description: Epigenetic stratiform deposits are in continental conglomerates and arkosic sandstones of Late Cretaceous age (Diamantian), which near the surface contain carnotite, tyuyamunite, uranophane, and lesser autunite. Sulfides at depth include pyrite, pyrrhotite, sphalerite, galena, chalcopyrite, bornite, and chalcocite, which have been altered to copper carbonates and sulfates and limonite. Associated with the sulfides are uraninite and thucolite. The orebodies are lenticular disseminations chiefly in gently dipping, dark asphaltic sandstones and conglomerates lying between two clayey beds. Permeable zones in the clastic rocks are especially mineralized, but copper-uranium ores also fill fractures and coat fault surfaces. Significant deposits include the Eva Peron (or Cerro Huemul), Agua Botada, Cerro Mirano, and Pampa Amarilla. The Bola Hill vicinity deposit, 25 kilometers west of San Rafael in southern Mendoza Province, described as the richest uranium deposit discovered in Argentina to date (Koelling, 1970), has reserves estimated in excess of 10,000 tons of U_3O_8. The deposit was described as extending 790 meters along a strike with depths exceeding 197 meters in some places. Average U_3O_8 content of the ore was reported at approximately 0.1 percent. The abundant asphaltic material present may have migrated from the infrajacent Mendocian bituminous shales into the Upper Cretaceous rocks, where they could act as a precipitant for uranium. Radioactive minerals include carnotite, uraninite, thucholite, tyuyamunite, autunite, andersonite, bayleyite, cuprosklodowskite, phosphuranylite, gummite, johannite, masuyite, metatorbernite, metazeunerite, metatyuyamunite, schroeckingerite, uranophane, uranospinite, and meta-autunite. Associated minerals include quartz, silicate, bornite, chalcopyrite, goethite, malachite, pyrrhotite, azurite, pyrite, limonite, sphalerite, chalcanthite.

Large, low-grade reserves are estimated by Stipanicic (1972); total reserves including ore minable to $30/lb for Sierra Pintada are 22,000 tons U_3O_8, and for Malargüe, three degrees south of Sierra Pintada-La Escondida district, are 1,550 tons U_3O_8.

References: Belluco, 1956; Bowie, 1970; Friz and others, 1965a, 1965b; Heinrich, 1958; Koelling, 1972; Linares, 1956; Stipanicic, 1972; Yrigoyen, 1958.

Symbol: 54DSL

Name: Valle de Punilla (Rodolfo near Cosquinn), and Sierras Cordoba, Cordoba Province, central Argentina.

Location: 31° 16' 00" S; 064° 25' 00" W

Description: Extensive resources of relatively low-grade epigenetic secondary uranium-vanadium mineralization occur in marls and argillaceous sandstones and clayey and sandy mudstones of early Eocene age, in a zone 6 meters wide and 6.4 kilometers long along the strike. No primary mineral occurred in drilling down to 46 meters, but weathering is deep in the district and it could well be that there is primary mineralization at greater depth (Bowie, 1970). The mineralization includes carnotite, tyuyamunite, and metatyuyamunite associated with quartz, calcite, and kaolinite. Total reserves including ore minable to $30/lb for Punilla are 20,000 tons of U_3O_8, and for Sierras Córdoba are 4,150 tons of U_3O_8 (Stipanicic, 1972).

References: Bowie, 1970; Friz and others, 1965a, 1965b; Stipanicic, 1972; Stipanicic and others, 1962.

Symbol: 55CSM

Name: Paso de Indios, Los Adobes, Sierra Cuadrada, Sierra de Pichinån, Chubut Province, Patagonia, Argentina.

Location: 43° 10' 00" S; 069° 07' 00" W

Description: Uranium occurs in disseminations as well as inclusions along cleavage planes, cracks, and microfractures in Upper Cretaceous continental conglomerates, sandstones, and clays, with associated calcareous tufa and carbonized plants. Deposits are of sedimentary control, epigenetic, and formed by processes of leaching and concentration. Uranium minerals are autunite, carnotite, meta-autunite, metatorbernite, schroekingerite, sklodowskite, uranophane, and fosturanilite. Reserves are discussed by Stipanicic (1972). Total reserves, including ore minable to $30/lb are estimated to be for Paso de Indios 2,900 tons of U_3O_8; for Sierra Cuadrada 1,750 tons of U_3O_8; and for Rio Chico, 1,200 tons of U_3O_8 (Stipanicic, 1972). Friz and others (1965b, p. 51) give reserves, including ore minable to $50/lb, for Tobas Amarilla-Chubut of 24,000 tons of U_3O_8.

References: Friz and others, 1965a, 1965b; OECD NEA/IAEA, 1973; Stipanicic, 1972; Stipanicic and others, 1962.

Symbol: 56BVM
Name: Meseta _s.s._, in a zone from the river Douro in the north to Castelo de Vide in the south, Portugal.
Location: 40° 00' 00" N; 007° 30' 00" W
Description: In the western part of the Spanish Meseta (Plateau), epithermal uranium veins occur in brecciated fault zones in late Paleozoic (Hercynian) granite porphyry that intrudes Precambrian and Silurian schists and is itself intruded by diabase dikes (Heinrich, 1958). The deposits lie within but near the southern edge of the Hercynian granite batholith. The deposits, of suggested supergene (Matos Dias and Soares de Andrade, 1970) origin, are correlated with upper Hercynian (Upper Stephanian to Lower Permian) granites. They have a high background of radioactivity and outcrop in Upper Cretaceous and possibly Triassic peneplains. They occur close to the roof or the walls of the granite bodies, in fractures of variable magnitude (excluding big faults), in metasediments, and throughout an aureole of contact metamorphism of a high degree that does not extend beyond a width of 3 kilometers (contact of metasediments of Precambrian to Late Devonian age with Hercynian granites) (Matos Dias and Soares de Andrade, 1970). Since 1955, about 380 deposits or uranium occurrences have been revealed in the highly tectonized zones, either as veins in monzonitic Hercynian granites, or as veins and impregnations in metamorphic contact schists of the ante-Ordovician complex (OECD NEA/IAEA, 1973). The brecciated structures normally originated under tangential tectonic movements which caused shear faults and mylonitization without any recrystallization of the rock elements. The most common associated wall-rock alterations are hematization, limonitization, and seritization or "green alteration" (Matos Dias and Soares de Andrade, 1970), which all form favorable loci for uranium deposition. Mineralization is also always associated with surfaces of peneplanation, and where these have been destroyed no mineralization occurs (von Backström, 1970).

Uranium deposits occur in the Nisa area, which includes the Portalegre or Nisa mine, in relatively unsiliceous epithermal veinlet systems that are mineralized with pitchblende, secondary uraniferous minerals, and iron sulfides; in highly tectonized zones enclosed in Hercynian granites; or in contact metamorphic rocks (Cavaca, 1965). According to Gowen (1967) Nisa (or Niza) has about 43 percent of Meseta's measured uranium ore reserves.

The Viseu and Guarda (Segaud and Humery, 1913) districts are roughly 240-280 kilometers northeast of Lisbon. In the Viseu region (with reserves estimated at 40 percent; Gowen, 1967), which includes Cunha Baixa and Urgeirica mines, the main controlling fractures are steep and strike north to N. 60° E. with an associated complex system of tension fractures that trend east-west and north-south. The veins, which fill breccia zones, consist of microcrystalline white quartz, reddish jasper, microbotyoidal pitchblende, pyrite, galena, sphalerite, and rarer arsenopyrite and chalcopyrite (Cavaca, 1956; Heinrich, 1958). The veins pinch and swell between 0.5 and 8 meters. The granite wall rock, which has been hematized, sericitized, and silicified near the vein and argillized more than 3 meters from the vein (Everhart and Wright, 1953), locally contains disseminated pitchblende in strongly sheared parts. Exploitation of the Urgeirica mine, near Canas de Senhorini in the Viseu district, was exclusively for the production of radium ore until 1944 when activity ceased. In 1949 when it was resumed, uranium was the main product (Cavaca, 1965). Autunite occurs to at least 95 meters depth (Lepierre and Leite, 1933).

In the Guarda region (with reserves estimates at 17 percent, Gowen, 1969), SRa (Senhora) das Fontas and Guarda mines cut diabase and granite that contain secondary sericite and hematite, that strike N. 40° E. to east, and that consist of white, fine-grained quartz, granular pitchblende, pyrite, and chalcopyrite. Vein breccias are cemented by cherty quartz and pyrite. The deposits of the Beira region south of Guarda, which trend N. 10° to 50° E., are in vuggy fissure fillings and brecciated veins along tension fractures and consist of coarse white and black quartz with microbotryoidal pitchblende in veinlets, in geodes, and as powdery crystal coatings (Heinrich, 1958). The veins are classed as ephithermal of the siliceous type, comparable to those of the Boulder batholith, and their formation is believed to be correlatable with Alpine orogeny (Heinrich, 1958).

The age of mineralization at Urgeiriça and Reboleirs mines has been determined to be 83 million years or 60 to 100 million years (Cavaca, 1965). Primary (Nininger, 1955) veins of pitchblende (found at deeper levels) in the Urgeiriça mine area in the Spanish Meseta (Plateau) are oxidized to autunite. Some of these veins have been traced for a kilometer in a white, coarse-grained granite of Carboniferous age surrounded by folded Precambrian schists (Nininger, 1955). Near the veins the granite usually has been altered to kaolin and fine-grained green sericite. At the surface the veins are marked by zones of kaolin and limonite, and the vein material itself usually has the distinctive dark red jasper, common to most primary uranium deposits, crisscrossed with white quartz veinlets. The uranium mineralization consists entirely of secondary minerals, primary autunite, torbernite, and uranophane, in rocks and cavities in the vein filling to a depth of more than 30 meters. At greater depths in the Urgeiriça mine, fine-grained, black, powdery pitchblende begins to occur with the secondary minerals and becomes more and more common as depth increases, while the secondary minerals gradually diminish. At the deepest levels in the Urgeiriça mine the secondary minerals have entirely disappeared, and the ore is a mixture of red jasper, pitchblende, pyrite, galena, sphalerite, and chalcopyrite, together with white quartz. Other deposits in the area are similar to the Urgeiriça mine, and pitchblende has also been found at depth. The most common uranium minerals are pitchblende and coffinite. These are associated with secondary minerals, of which the most common are autunite, torbernite, uranocirate, and sabugalite. Rarely found are uranophane, beta-uranophane, saléeite, phosphuranylite, parsonite, uranopilite, and zippeite. Pyrite and marcasite are commonly associated, and galena, chalcopyrite, sphalerite, and arsenopyrite are found only sporadically (von Backström, 1970). Gummite, black oxides and colored secondary minerals are abundant in the upper levels (Matos Dias and Soares de Andrade, 1970).

About 100 deposits are in granitic and metamorphic regions of Urgeiriça (35%), Guarda (17.8%), and Alto Alentejo (47.2%), which have an estimated total reasonably assured resources of 6,900 metric tons uranium metal at a cost of under $15/lb U_3O_8; about 90% is mainly vein type in granite; and the dissemination-type Nisa (Alto Alentejo) deposit of secondary uranium ore in metamorphic contact rock contains 2070 metric tons uranium (OECD/IAEA, 1976).

References: Cameron, 1959; Cavaca, 1956, 1958, 1965; Everhart and Wright, 1953; Fernandes, 1971; Ferreira, 1971; Gowen, 1969; Heinrich, 1958; Lepierre and Leite, 1933; Lobato, 1958; Lobato and Ferrao, 1958; Matos Dias and Soares de Andrade, 1970; Nininger, 1955; OECD NEA/IAEA, 1973; Rich and others, 1975; Segaud and Humery, 1913; Thadeu, 1965; von Backström, 1970.

Symbol: 57BVM

Name: Ciudad Rodrigo (Salamanca) and Caceres-Badajoz areas, Spain.

Location: 40° 00' 00" N; 006° 40' 00" W

Description: Uranium deposits very similar to those described as occurring in Portugal also occur in Spain. In the provinces of Salamanca, Zamora, Badajoz, and Caceres, two types of uraniferous deposits occur (Pérez, 1958; Polo, 1970; Ramirez, 1969). One is in granite (including the Valdemascano vein, in which uranium is found associated with lead, zinc, and iron ores, and some copper minerals); and the other is in Paleozoic metasediments (shale, slate). The latter type is large, both in length and width, and is a surface mineralization (including "La Esperanza" zone).

In Salamanca Province deposits near the Portugese border are in primary uranium minerals in schists metamorphosed from Cambrian pelitic sediments during the Hercynian, which also gave rise to or affected adjoining gneisses and biotite granite. Secondary uranium minerals are extensively diffused in the schists near the surface. In the Salamanca area, there is an abundance of radon in the Cambrian slates. Uranium mineralization is associated with acid dikes, impregnations in metamorphic rocks near granitic contacts, or quartz veins oriented mainly along northeast-trending fracture zones. The deposits in Paleozoic metasediments with different degrees of metamorphism (slate, shale) in the Province of Salamanca, located alongside a graben, and in the Province of Cáceres (Badajos) have uranium mineralization mechanisms of supergene origin that are independent of lead, tin, and tungsten mineralization, which preceeded the uraniferous deposits (Polo, 1970). Intermittent, lenticular radioactive deposits occur in Salamanca Province along bedding and joint planes together with some organic material, in the form of stockworks, confined to the metamorphic aureole, which may be from 200 meters to a kilometer wide (Polo, 1970). The thermal aureole, along which spotted slates and hornfels occur in a succession, together with quartzite and limestone, occurs where Hercynian granodiorite and adamelite are intrusive into Cambrian pelitic sediments.

The uranium ore minerals are pitchblende, uranophane, autunite, and torbernite, with minor phosphuranylite, renardite, saléeite, ianthinite, and uranopilite. Associated accessory minerals are pyrite, chalcopyrite, galena, and meinikovite. The gangue minerals are mainly quartz, jasper, barite, and calcite. Reasonably assured resources in granite in the Caceres area (including Ratones mine; 39°15'N., 6°45'W.), in shale in the Badajoz area near Don Benito (Ramirez, 1969) (including "El Lobo" mine), and in the Ciudad Rodrigo (Salamanca) area both in shale (including Fe-1, Fe-3, D, and Alameda mines) and in granite (including Valdemascano and Villar de Peralõnso mines) are reported by OECD NEA/IAEA (1973, p. 67).

References: Alía, 1956; Arribas, 1963, 1964, 1965, 1967, 1970;

ENEA, 1965, 1969; Membrillera and others, 1965; Mineral Trade Notes, 1972, v. 69, no. 1, p. 33; Mineral Trade Notes, 1972, v. 69, no. 8, p. 22; R. D. Nininger, written commun., 1973; OECD NEA/IAEA, 1973; Pérez, 1958; Polo, 1970; Tamaye, 1967.

Symbol: 58CSS
Name: Despeñaperros area and Andugar (Jaén) in the Andalusian Mountains, Spain.
Location: 38° 20' 00" N; 003° 20' 00" W
Description: Pitchblende deposits are disseminated in Ordovician quartzite at grades ranging from 0.03 to 0.07 percent U_3O_8, in slate, greywacke, and sandstone in the Despeñaperros area about 112 kilometers northeast of Cordoba, and in Triassic arkose and limestone in the Andujar area about 275 kilometers south of Madrid and about 70 kilometers northeast of Cordoba of the Spanish Meseta (Plateau). In the Despeñaperros zone the quartzites form an anticlinal fold with many faults, and the outcroppings of the mineralized layers can be followed over 100 kilometers in length and have a possible width of several tens of kilometers. Their mean thickness is one to two meters (Pérez, 1958).
References: Alía, 1956; Pérez, 1958; Ramirez, 1969.

Symbol: 59DSS
Name: Burgos and Logroño districts, of Sierra de la Demanda, and the Madrid, Tajo (or Tagus) rift valley, Spain.
Location: 42° 30' 00" N; 003° 00' 00" W
Description: In or near arkosic or tuffaceous rocks of the Spanish Meseta (Plateau), uranium occurs disseminated in Triassic carbonaceous arkosic horizons of the Burgos and Logona districts, about 225 kilometers north of Madrid, and as tyuyamunite in Miocene sandstone, marly clay, and marl in the Tajo rift valley. Radioactive ores are accompanied by copper carbonates in the Sierra de la Demanda area. Reserves of uranium in granite in the Tajo area, including Navalcan, Carretero, and others, and in shale (Gargüera, Ojaranzo) are reported in OECD NEA/IAEA, 1973, p. 67.
References: Alía, 1956; Alía and others, 1958; OECD NEA/IAEA, 1973.

Symbol: 60DCL
Name: Calaf area, Province of Barcelona, Spain.
Location: 41° 44' 00" N; 000° 31' 00" E
Description: Uranium resources associated with the Calaf basin lignites, about 400 kilometers northeast of Madrid, near Fraga, with a grade of 0.03 to 0.1 percent U_3O_8 (ENEA, 1967), occur in intercalations in lower Oligocene lacustrine lutites. The deposits, discovered in the course of prospecting with carborne equipment, are in the eastern sector of the Ebro Valley. The lignite-bearing zone is 800 m thick, and consists of an alternation of limestones, sandstones, and marls. The limestones, sandstones, and marls separate the different types of lignites (OECD NEA/IAEA, 1975). Other Oligocene basins of the Ebro Valley with uraniferous lignite-bearing layers are in the Fraga, Mequinenza, and Almatrets basins (750 square kilometers) and in the Santa Coloma de Queralt basin. Reasonably assured and estimated additional resources are reported by ENEA (1967) and OECD NEA/IAEA (1973, 1975).
References: Bowie, 1970; ENEA, 1967, 1969; Marton-Delgado-Tamayo and Fernandez-Polo, 1974; OECD NEA/IAEA, 1973, 1975.

Symbol: 61BSS
Name: Huesca district, Montanuy, Spain.
Location: 42° 45' 00" N; 000° 30' 00" W
Description: Uraninite occurs disseminated in Permian continental sandstone about 340 kilometers northeast of Madrid, near Huesca. Veinlets of carbonaceous matter are present. Associated minerals are iron or base-metal sulfides. Copper and vanadium are associated with the deposits.
Reference: Caralp, 1910.

Symbol: 62BSL
Name: Lodève (Hérault) and other basins around the Massif Central, France.
Location: 43° 44' 00" N; 003° 19' 00" E
Description: Uranium is disseminated in continental lacustrine sandstone and shale, impregnating sheets of sand, pebbles, and marl, some coal bearing, of Permian age. In folded zones of the Hérault basin (Gangloff, 1970) deposits overlie beds of shale, sandstone, and dolomite (Autunian) and others of red sandstone and pelites (Saxonian). Uranium is in distinct close association with bituminous organic matters (so-called asphaltites), and analyses show that the main uraniferous mineralization occurs in the shape of carbonized uraniferous products (carburan), but also some massive pitchblende; superficial oxidation products are well developed (Lenoble and Gangloff, 1958). Uranium minerals are uraninite, carbonized uraniferous products (carburan), pitchblende, uranophane, fourmarierite, ianthinite, masuyite, billietite, vandenbrandeite, zeunerite, novacekite. Associated minerals are chalcopyrite, chalcocite, covellite, malachite, azurite, chrysocol, zinc, lead, tin, arsenic, barite. Vanadium mineralization also occurs. Zinc is concentrated along some joints. Permian deposition began with Autunian strata over a dissected pre-Permian basement. A basal conglomerate is overlain by fine-grained sandstone with mudcracks, bituminous limestone, and shale with plant remains. On top of these are reddish and grey psammitic and pelitic deposits (Barthel, 1974). The mineralized zone is lenticular and stratified, and it formed under lithological as well as tectonic control. The syngenetic enrichment was probably supplied by solutions formed during weathering of granite within the Massif Central. In the depositional basin the uranium was precipitated under reducing conditions during sedimentation. In joints and traps subsequent enrichment probably occurred under the influence of migrating bitumen. The depositional environment was initially swampy and had a rich flora. In individual lagoons, sediments accumulated in deep and tranquil water. Temporarily flooded, relatively stable areas are distinguished by terrestrial vegetation (conifers). The climate was tropical, moist, and hot with intermittent drier periods. Another characteristic feature of the Autunian sequence is the occurrence of acid volcanic ash horizons with high alkali contents (Barthel, 1974). Mineralized horizons are found mostly on flanks of channels. They occur as silt-clay intercalations in the region where the sandstone changes from gray to red (Barthel, 1974).
References: Barthel, 1974; Gangloff, 1970; Herbosch, 1974; Lenoble and Gangloff, 1958; OECD NEA/IAEA, 1973.

Symbol: 63BVL
Name: Brittany Massif, Massif Central, and Vosges, France.
Location: 47° 00' 00" N; 002° 00' 00" E
Description: Uraniferous vein deposits, mostly epithermal type as classified by French geologists (Heinrich, 1958), occur in Hercynian tectonic units chiefly in the Brittany Massif and Massif Central.

In the Vendée district of the Brittany Massif, the deposits occur in the Mórtagnē granite massif close to its margins, along granite-schist contacts, or rarely in the matamorphic rocks themselves, not far from the granite contact. The main fluorite vein deposit, L'Ecarpiere, discovered in 1952 (Roubault, 1956), about 7 kilometers east of Clisson, consists of seven west-northwest trending, vertical to steeply south-dipping veins in granite near its contact with amphibolites. Mineralization, along 600 meters, and to a depth of 200 meters, is in veins a few decimeters to 1 to 2 meters thick, with an average grade of 0.5 to 2 percent U, containing black fetid fluorite and chalcedony, with minute nodules and veinlets of pitchblende localized along contacts between fluorite and quartz bands. Pyrite increases in abundance with pitchblende (Heinrich, 1958). Siliceous type veins include the brecciated quartzose veins of the LaChapelle-Largeau group, discovered in 1951 (Roubault, 1956). These veins strike north-northwest, dip steeply northeast, and contain pitchblende, pyrite, marcasite, galena, and uranyl minerals (Heinrich, 1958).

In the Limousin region, Haute-Vienne, western part of Massif Central, deposits occur in coarse-grained granite, which encloses numerous pegmatites, and which is cut by a swarm of lamprophyres trending north-northeast and dipping 55° to 75° northwest (Heinrich, 1958). The first massive pitchblende deposits known in the French territory, La Crouzille deposits, were discovered in November 1948 (Roubault, 1956). La Crouzille deposits include the Henriette vein of massive pitchblende with abundant later pyrite and marcasite and small local amounts of bismuthinite, sphalerite, galena, loellingite, chalcopyrite, bornite, chalcocite, and covellite. Quartz is a very minor mineral, but barite in two generations is abundant in some parts. Pitchblende invariably forms spherulites, some several centimeters across, usually in botryoidal aggregates. In parts of the Henriette deposit massive pitchblende is cut by iron sulfide veinlets, and elsewhere the deposit is banded: botryoidal pitchblende against the walls, overgrown by fibrous iron sulfide bands, and a central filling of fine-grained barite with iron sulfide nodules (Heinrich, 1958).

In the Autunois and Morvan areas low-temperature pitchblende deposits are nearly all localized in the Luzy batholith, a granite massif of granite porphyry, with large orthoclase crystals which vary from light gray to pink, cut by veins of a variety of rocks which may be acid (microgranite), or more alkaline (lamprophyre) (Roubault, 1956). La Faye and

Les Vernays deposits, south of Grury, which follow fractures in granite along the western margin of the Luzy batholith, are chalcedony-fluorite veins with disseminated pitchblende. Some pyrite, marcasite, hematite, and traces of galena, sphalerite, covellite, and chalcopyrite occur in La Faye deposit, which is the northern extension of the Crot-Blanc fluorite vein, exploited from 1930 to 1932 (Roubault, 1956). The veins are 0.5 to 1 meter thick, developed to 80 meters (Heinrich, 1958), strike N. 10° W., and dip 40° to 75° NE. In the near-surface part, torbernite, autunite, and kasolite predominate, but sooty pitchblende, hard pitchblende, and sulfides appear at depth (Roubault, 1956). At Bauzot, pitchblende (also massive), discovered in July 1950, 2 kilometers southeast of Issay l'Evêque (Saône et Loire), led to the discovery of fluorite and disseminated pitchblende at depth (Roubault, 1956). La Borne Pilot, a fluorite-pitchblende vein 20 centimeters thick containing limonite, gummite, autunite, and uranophane, strikes northwest and dips 80° SW. in coarse pyritic granite. Pyrite, galena, and barite also are present. The fluoritic ore at Bauzot contains 1 percent or less uranium and the banded vein contains the following sequence inward: clear quartz, fluorite-pitchblende with ribbons of dark purple fetid fluorite, abundant ferruginous quartz, and minor dolomite with abundant calcite (Roubault, 1956; Heinrich, 1958).

In the Lachaux area, Forez, east-central part of Massif Central, chalcedonic pitchblende veins occur with parsonite veins at Bigay and Gourniand. The Bigay vein, nearly vertical and 20 to 50 centimeters thick, striking west-northwest in its eastern part and deflected toward west-southwest in its western end, occurs in granite (Heinrich, 1958). The pitchblende is spherulitic, crisscrossed by microveinlets of quartz, or replaced zonally by quartz. Sulfides of the assemblage of sphalerite (or blende), galena, pyrite, and chalcopyrite (referred to as B.G.P.C. group by French geologists; Heinrich, 1958) also are present, associated with smoky quartz and other constituents of hematite, covellite, and opal.

The Bois Noirs region, east of the Lachaux district in Forez, contains uranium mineralization along the eastern edge of a granite massif bounded by major faults on both east and west. The Limouzat deposit (drilled to 200 meters) occurs in a micro-granite breccia lens 150 meters long and up to 25 meters thick, which trends northwest and dips northeast adjacent to a hydrothermally altered diabase dike (Geffroy and Sarcia, 1954). The silicified and pyritized breccia contains cementing spherulites and bands of pitchblende in hematitic cryptocrystalline quartz with minor galena, chalcopyrite, covellite, and marcasite. Some pitchblende is brecciated and veined by quartz. Near the surface, torbernite, autunite, ianthinite, and other uranyl species are abundant.

The vein deposits, according to Gangloff (1970), have these major characteristics in common: the veins are embedded in granite; uranium is mainly found in the form of pitchblende and its weathering products; it is accompanied by a paragenesis that is sparse, somewhat lacking in variety and chiefly represented by iron sulfides, lead sulfide (galena), sphalerite and chalcopyrite; the orebodies (1) may be associated with a chalcedonous gangue that is fairly plentiful and of striped appearance, (2) may form intricate networks of smaller veins, or (3) may comprise a mass within the episyenitic rock; the orebodies show preference for location at intersections with lamprophyric dikes; the deposits are associated with granites containing two types of mica; they show a tendency towards albitization and high radioactivity; the granites are usually accompanied by a peripheral aureole of tin-tungsten veins; mineralization occurs in the neighborhood of extensive mylonitic zones; and the age of the fertile granites is of the order of 300 million years, whereas the mineralization is of the order of 250 million years old (Gangloff, 1970). Rich and others (1975) pointed out that the uranium mineralization is Early Jurassic or Triassic by geologic evidence, but isotopic ages range from 290 to 286 m.y. (Carboniferous and Devonian) according to Ranchin (1968). The endogenic weathering theory that uranium in the deposits in "fertile" granites is concentrated by thermal waters, perhaps as a continuation of a certain type of granitic evolution, is favored by Gangloff (1970). Poty and others (1974) indicated that the uranium was transported as uranyl carbonate complexes because of the rich concentrations of CO_2 in the fluids associated with the pitchblende deposition and with the bismuthinite. The average grade is more than 0.10 percent U_3O_8.

References: Arnold and Cuney, 1974; Barbier, 1970, 1974; Barbier and Leymarie, 1972; Barbier and Ranchin, 1969; Barbier and others, 1969; Carlier, 1965; Carrat, 1962, 1971, 1973; Coppens, 1973; Durand, 1963; Faure, 1968; Gangloff, 1970; Geffroy, 1973; Geffroy and Sarcia, 1954, 1955, 1958, 1960; Germain and others, 1964; Gerstner and others, 1962; Heinrich, 1958; Jurain and Renard, 1970a, 1970b; Kosztolanyi and Coppens, 1970; Le Caignec and others, 1964; Lenoble and Gangloff, 1958; Leroy and Poty, 1969; Mabile and Gangloff, 1965; Marquaire and Moreau, 1969; Moreau and Ranchin, 1973; Moreau and others, 1966; R. D. Nininger, written commun., 1973; Picciotto, 1950; Poty and others, 1974; Poughon, 1962; Ranchin, 1968, 1970, 1971; Rich and others, 1975, 1977; Roubault, 1956, 1958a, 1960; Roubault and others, 1962, 1969; Sarcia, 1958; Sarcia and others, 1958; Zechke, 1970.

Symbol: 64BBM
Name: Vosges Mountains, Alsace, France.
Location: 48° 10' 00" N; 007° 30' 00" E
Description: On the Eastern slopes of the Vosges Mountains of Hercynian type, stratiform uranium deposits occur in black shales of Westphalian Age (Pennsylvanian) (Grimbert and Carlier, 1957) in a mineralized area of about 200,000 to 250,000 square meters with mineralized thickness between 1 and 40 meters, and grades of 0.02 to 0.1 percent which average about 0.06 percent (Lenoble and Gangloff, 1958). Tectonic faults have encased the coal-bearing strata in granitic-gneissic rock and in part protected them from erosion. Red Permian and Triassic sandstones partly or intermittently cover the coal-bearing rocks, which are composed of arkoses topped by black shales interspersed with sandstone rich in organic matter. The unrecognizable discrete uranium mineralization has a heterogeneous distribution and is confined to the black shales. It varies according to the absence or presence and the size of the sandstone covering (Lenoble and Gangloff, 1958). Associated minerals are sulfides such as mispickel, galena, and sphalerite in the higher grade layers, and siderose and chalcopyrite in the lower grade layers, with pyrite lining the cracks throughout the formation (Lenoble and Gangloff, 1958).
References: Gangloff, 1970; Grimbert and Carlier, 1957; Lenoble and Gangloff, 1958.

Symbol: 65AVS
Name: Cornwall, Devon, and Somerset, extreme southwest of England.
Location: 50° 30' 00" N; 004° 30' 00" W
Description: Pitchblende mineralization occurs in wrench faults near Hercynian granites and occurs in Cornwall in fissure-filling veins which are younger than the associated main tin and copper lodes, and as a late accessory mineral within tin and copper lodes, where folded lower Namurian slates and greenstones have been intruded, along an east-west line, by five main post-Carboniferous granite plutons around which the cassiterite veins are clustered (Davidson, 1956a; Heinrich, 1958; Ostle, 1970, p. 345). Granite has been tourmalinized, silicified, and kaolinized along the lodes. Pitchblende and its supergene alteration products, principally autunite, torbernite, and zippeite and rarely bassetite and uranospathite are widespread (Davidson, 1956a; Heinrich, 1958). In the high temperature mineral lodes both the metallic and gangue minerals have a zonal distribution, with those formed at higher temperatures and pressures occupying the deeper parts of the mineralized fissures; the order of deposition of the principal ores from below upwards is tin, copper, zinc, lead, iron (Davidson, 1956a).

The primary uranium mineralization in the veins, only exceptionally present, usually occurs in or close to the copper zone; always in pockets of no great size, most frequently occurring at intersections with cross-courses and where the wall rock is greenstone (Davidson, 1956a). Pitchblende was mined from the vein in the Cornwall South Terras deposit (Radium or Green Jim lode) ("Green Jim" or torbernite), which strikes N. 10° W. across the earlier tin-copper lodes, dips 10° to 30° SW, averages 0.6 meters thick, and contains coarse comb quartz and inclusions of slate (Gregory, 1946; Heinrich, 1958). The South Terras property, discovered in 1873 near St. Stephen (before Shinkolobwe was discovered in 1915; Heinrich, 1958, p. 289), ranked next to Jackymov and Urgeiriça as the third most productive source of uranium in the world (Davidson, 1956a). The vein, traced for 300 meters along the strike, split and pinched out against a granite dike to the south. Pitchblende is the principal ore below 36 meters, chiefly in marginal stringers, and its supergene alteration products, chiefly autunite, torbernite, and zippeite, occur to a depth of 18 meters (Davidson, 1956a; Heinrich, 1958). Accessory pyrite, chalcopyrite, mispickel, galena, and traces of smaltite, niccolite, and barite are present (Davidson, 1956a). The pitchblende-bearing part of the vein varied from a knife-edge to 20 centimeters thick and was traced to a depth of about 270 meters (Davidson, 1956a; Heinrich, 1958). At the Trenwith mine, pitchblende impregnated slate and greenstone wall rocks to as much as 12 meters from the lode where the vein strikes east-west and dips very steeply north. Pitchblende also is a late fracture-filling mineral along walls in the copper-bearing parts of the lode, forming lenses 5 to 30 centimeters thick at intersections with cross fractures (Heinrich, 1958). In some deposits pitchblende also occurs as disseminations in slate. Secondary uranium minerals have been found along joints in kaolinized granite and slaty wall rock in the oxidized zone (Heinrich, 1958).

Darnley and others (1965) interpreted the available age data as indicating three periods of uranium mineralization, which are c. 290 m.y., c. 225 m.y., and c. 50 m.y.

Rich and others (1975) pointed out that red staining of the granite is a good indicator of the presence of uranium.

References: Bain, 1950; Darnley and others, 1965; Davidson, 1927; Davidson, 1956a; Dines, 1930, 1956; Dines and Robertson, 1929; Gentile and McGinnis, 1967; Gregory, 1946; Heinrich, 1958; James, 1945; Lamming, 1952; Ostle, 1970; Park and MacDiarmid, 1964; Penrose, 1915; Perutz, 1939; Rich and others, 1975; Rumbold, 1954; Stein, 1952; Stephens, 1906; Taylor, 1966; Toll, 1951; Zachloul, 1960.

Symbol: 66ASM
Name: Caithness and Sutherland Counties, north Scotland, and Orkney Islands, northeast Scotland, including the Island of Stroma in the Pentland Firth, Scotland.
Location: 58° 25' 00" N; 003° 30' 00" W
Description: Uranium occurs as tabular enrichments in phosphatic horizons and along fractures in shaly beds of the Middle Old Red Sandstone (Devonian) in the Northern Highlands beyond the Great Glen fault at Caithness County and Orkney Islands, and as weak disseminations and small veinlets in minor structures in a Caledonian (about 400 million years) granite pluton at Helmsdale (Gallagher, 1972). Caithness County and part of Sutherland County are underlain by metamorphic rocks of the Moine Series intruded by granitic stocks of late Caledonian age, which for the most part in Caithness is covered by gently inclined lagoonal sediments of the Old Red Sandstone--mainly arenaceous, arkosic members, silts, and shales (Ostle, 1970). In the Caithness Flags of the Old Red Sandstone, the uranium content (which averages about 5 ppm but has concentrations up to 0.1 percent U_3O_8) is accompanied by some degree of enrichment in lead, molybdenum and other metals; and the Caithness Flags, 6000 meters of calcareous siltstones, are believed to be present in the central part of the Old Red Sandstone basin (Orcadian cuvette) (Gallagher, 1972). Some of the factors that may account for the uranium concentration in Northern Scotland are deep regional faults that cross the area; basinward movement of uranium from the igneous and metamorphic rocks marginal to the sediments that may have provided a favorable structure for concentration of uranium in the sedimentary rocks; pre-Devonian and Tertiary erosions that could have mobilized uranium from uraniferous granite and concentrated it in permeable strata in the sedimentary basin; and the persisitence of tectonic movements like the coastwise Helmsdale fault at least into Jurassic time (Ostle, 1970). The late Caledonian granite of Helmsdale, Sutherland County, was unroofed prior to the local deposition of Lower Old Red Sandstone sediments (Gallagher, 1972). Small occurrences of autunite, metatorbernite, and kasolite were found associated with fractures in the Helmsdale Granite pluton, which was intruded into Precambrian schist (Davis and others, 1971; von Backström, 1974). Uranium occurs in bituminous shale on the Island of Stroma in the Pentland Firth, Scotland (Gentile and McGinnis, 1967).
References: Davis and others, 1971; Engineering and Mining Journal, 1973, v. 17, no. 8, p. 146; Gallagher, 1972; Gentile and McGinnis, 1967; Heinrich, 1958; Michie, 1972; Ostle, 1970; von Backström, 1974.

Symbol: 67BVS
Name: Monte Bianco, Italian Alps, Italy.
Location: 45° 50' 00" N; 007° 00' 00" E
Description: The pitchblende epithermal veins in the Monte Bianco (Mt. Blanc) Granite of pre-Westphalian age, of the Hercynian period, fill mylonites and tectonic breccias classified as late or post-Hercynian (Mittempergher, 1970a). The veins show two main original parageneses: one with arsenopyrite and the other with galena, sphalerite, pyrrhotite, and chalcopyrite. The uranium mineralization is locally rejuvenated by the early Tertiary Alpine tectonics (Mittempergher, 1970a).
References: Mittempergher, 1970a.

Symbol: 68BVM
Name: Valganna and Novazza, Central Alps, Italy.
Location: 45° 54' 00" N; 008° 50' 00" E
Description: Valganna and Novazza deposits are elongated lenticular masses (economically the most significant found in Italy so far; Mittempergher, 1970a), in Lower Permian silicic volcanic sedimentary series, and are of hydrothermal origin. The Novazza deposit occurs in a volcanite metasomatized to silica, sericite, and carbonates, with adularia, albite, muscovite, and chlorite (Mittempergher, 1970a). The uranium is in paragenesis with Zn; the pitchblende and sphalerite are diffused in micro-fractures and impregnate the groundmass of the host rocks (Mittempergher, 1970a). The uranium in the Valganna deposits is associated with hematite, pyrite, arsenopyrite, and marcasite. In the area, Late-Hercynian magnetism is highly developed which generated thick sheets of ignimbrites, lavas, and acid tuffs. The volcanic effusions took place in a continental or lacustrine environment. The thickness of some series of volcanic layers is often more than 1000 meters. Uranium occurs in both ignimbrites and tuffs (Mittempergher, 1970a). Reasonably assured uranium resources (OECD/IAEA, 1976) of 1200 metric tons (about 900 ppm ore concentrates) have been located in the Novazza (Bergamo) deposit, in the Val Seriana. Val Seriana deposit, scheduled to go on stream in 1979, has an estimated 2.5 million tons of ore at grade of about 0.1 percent U_3O_8 (Tatsch, 1976).
References: D'Agnolo, 1966b; Mittempergher, 1970a; OECD/IAEA, 1976; Tatsch, 1976.

Symbol: 69BSS
Name: Val Daone, Val Rendena, and Val Pescara areas, Italy.
Location: 46° 04' 00" N; 010° 50' 00" E
Description: Epigenetic uranium mineralization occurs in individual basins or parts of basins in stratiform, lens-shaped, and concordant deposits or in thin layers. The deposits are contained in the thick basal gray, silty, pelitic sandstones of coarse to medium-grained arkose of Permian age. The sandstone formation is made up of a basal gray member and a red upper one (Grodener Sandstone), which was formed in a piedmont environment which may have been either continental, fluviatile or deltaic, with lacustrine or lagoonal intercalations (Mittempergher, 1974; Barthel, 1974). The control of the mineralization is linked to the permeability and the reducing environment caused by the presence of organic matter (log remnants more or less carbonized to fusitic material, with which the uranium is in constant association) (Mittempergher, 1970a, 1974). Pitchblende and microcrystalline uraninite (black oxides) are the only uraniferous minerals in the ores; these minerals are often diffused in the sandstone matrix or in the groundmass of small volcanite pebbles (D'Agnolo, 1966a; Mittempergher, 1974). Pitchblende forms layers locally massive and often associated with levels of coal where the sandstone has been subjected to weak metamorphism (Mittempergher, 1974). Associated minerals, in random variable quantities, are chalcopyrite, pyrite, galena, sphalerite, tetrahedrite, arsenopyrite, and tennantite (Mittempergher, 1974; Barthel, 1974). Val Rendena and Val Daone deposits are in areas with very thick sedimentary sequences (6000 to 8000 meters) (like the Lombardy trough) (Barthel, 1974).
References: Barthel, 1974; D'Agnolo, 1966a; Mittempergher, 1970a, 1974.

Symbol: 70BSS
Name: Cuneo zone, near the village of Peveragno, and Preit, Pennide region, Italy.
Location: 44° 25' 00" N; 007° 35' 00" E
Description: Deposits are Alpine synmetamorphic remobilizations on the pre-existent deposits in continental Upper Permian highly folded and fractured chlorite-sericite schists (metaporphyries) (Mittempergher, 1970a). The schists correspond to an original series of argillite-graywackes. In the Pennide zone, where the Permian-Triassic series is very restricted, uranium concentrations are mostly syngenetic and are located in the upper parts of continental sediments at the transition to the epicontinental marine lithologic formations (Mittempergher, 1970a). The deposits in the Cuneo and Preit districts, 96 and 115 kilometers west of Genoa, are stratiform and lenticular, or rather cylindrical with an elliptic cross section (Ippolito, 1958), and are associated with irregular quartz-pyrite-chalcopyrite veinlets, mainly localized in schistose layers near contacts with Lower Triassic marine quartzitic formations that form a transition to Middle Triassic evaporitic and carbonatic strata. At Rio Freddo, pitchblende, which is indicated at the surface by abundant autunite, occurs at a depth of 10 to 15 meters beneath autunite mineralization; grade varied from 2 to 5 percent uranium in about 300 tons of ore mined (Ippolito, 1956; Heinrich, 1958). The primary microcrystalline uraninite is associated with the phyllosilicates, with no trace of gangue minerals; graphites and big masses of phosphorites (apatite) are associated with uranium. Pitchblende is the typical mineral of the synmetamorphic remobilization and occurs in small veins and lenses. The lenses also contain calcite, carbonaceous material, torbernite, autunite, uranophane, and other uranyl species. Kaolinized feldspar and introduced pyrite and hematite are in the adjacent wall rock (Heinrich, 1958). The uranium concentrations are mostly syngenetic and are in very thin beds alternating with the micaceous chloritic layers and lying parallel to the schistosity. Mineralization has been attributed to the action of the synsedimentary genetic processes. Such processes took place in littoral or lagoonal environments, as uranium is associated with pelites and siltites containing large quantities of organic matter, and with phosphorites which are stratigraphically connected with the quartzitic facies formed by a slow and perhaps cyclical marine ingression (Ippolito, 1956, 1958; Mittempergher, 1970a).
References: Heinrich, 1958; Ippolito, 1956, 1958; Ippolito and others, 1956; Mittempergher, 1970a.

Symbol: 71DVS
Name: Vulsini, Vico, and Sabatini volcanic districts of central Italy.
Location: 42° 00' 00" N; 012° 18' 00" E
Description: Uranium exhalative-supergenic mineralization is related to magmatic H_2S exhalations and to supergenic weathering of exhalative pyrite and marcasite (Mittempergher, 1970b). Because the H_2S is of volcanic origin, Mittempergher (1970b) classed the mineralization as exhalative and supergenic. The mineralized areas all exhibit zonation, with thick layers of bleached, silicified, and kaolinized volcanic rocks in the upper zone, and massive or alternate layers of iron sulfides (pyrite and marcasite) and diffused uranium in the lower zone; the richest uranium mineralization (shown below the water table by Mittempergher, 1970b) occurs closest to the source of CO_2 and H_2S cold gases (Mittempergher, 1970b). The ore deposits are controlled by the superficial and underground hydrology; mineralization follows a hydrostatic and not a stratigraphic horizon, and exhibits a regular slope with respect to drainage valleys. The Vico volcano is a central vent stratovolcano, and the Vilsini and Sabatini are fissure volcanoes. The highest concentrations of U and Th occur in the apical parts of magmatic reservoirs; they are probably due to the pneumatolithic action of gases. Common to all mineralized areas is the emission of CO_2 gas with small amounts of H_2S. From a tectonic point of view, the occurrences are related to fault zones with N-S and NW-SE trends representing the two main faults and controlling the distribution of the effusive volcanic structures (Mittempergher, 1970b). The volcanics are represented by some pyroclastic units interbedded with frequent lacustrine deposits. Leucite, kalsilite, and melilite are characteristic feldspathoids of the alkaline-potassic rocks which have built up the Pleistocene in the central area (Mittempergher, 1970b). Ignimbrites and tuffs are more common than lava flows. Volcanites are K-trachytes, undersaturated latites, phonolitic tephrites, tephritic phonolites, tephritic leucitite to leucitite types. The mean uranium content of these volcanites is 25 ppm, with a maximum of 50 ppm; the Th mean is 130 ppm, with a maximum of 240 ppm; concentrations of Zr, Be, and Sr are exceptionally higher than their respective clarkes (Mittempergher, 1970b). The uranium and thorium concentrations are always related to areas with an extended layer of white kaolinized and silicified rocks (Mittempergher, 1970b). Uraniferous bodies between 2 and 3 meters thick, with uranium maxima of 0.2 to 0.3 percent U and averages of 300 to 400 ppm U, have been found around the small rivers; and the content of U decreases away from the exhalative zone. The best and most regular deposits are about 1 kilometer long and some hundred meters wide (Mittempergher, 1970b).
References: Mittempergher, 1970b; von Backström, 1974.

Symbol: 72BSS
Name: Mecsek Mountains, Badacsony area, Hungary.
Location: 46° 25' 00" N; 013° 30' 00" E
Description: The deposits are lenticular epigenetic blanket type, with local accumulations. Their lenticular form derives from the original sedimentation of fine-grained deposits rich in vegetable matter in association with arkose (Barthel, 1974). The ore is found on the flanks or above the axis of the arch of a flat-topped Permian and Triassic anticline, the axis of which dips from west to east, in the western part of Mecsek Mountains. A large fault line toward the north and an overlapping plane toward the south bounds the Permian sediments (Barabȧs and Kiss, 1958). The uranium host rocks are about 500 meters of Upper Permian gray arkosic sandstone, siltstone with clayey-carbonate matrix, and thin-bedded argillites (indicating a low redox potential) (Barthel, 1974). Above is red sandstone with iron-rich argillaceous and calcareous cement (indicating an elevated redox potential). The paleogeographic setting suggests (Barthel, 1974) that deposition was on a fluviatile talus fan. The material must have been transported over a distance of about 10 kilometers. It was derived from the erosion of granitic rocks enriched in Bi, Co, and Ni. The uranium mineralization took place along the banks of a meandering stream with an abundant flora (Barthel, 1974). Migration of the stream bed led to the formation of numerous pools and flooded areas with coarse-grained arkose and fine-grained clays. Low precipitation favored an infiltration of mineralized waters into the border zone (with dead vegetation) and permitted the uranium ore to be precipitated as uranite (Barthel, 1974). The uranium concentrated primarily within arkose intercalations, the detritus of which was derived mostly from granitic rocks. At the same time some basic igneous detritus was also deposited, as is shown by the presence of chromium-containing hydromicas. Barabȧs and Kiss (1958, p. 391) regarded the primary hydrothermal formation of the ore as proven, for Co, Ni, Bi, and Ag are present in trace elements and in allogenic minerals; and they also regarded transport by fluvial water as proven. The uranium was transported partly in mechanical detritus and partly in actual colloidal solution, and then by means of adsorption by minerals of a "montmorillonite-illite" character or perhaps by entering into the lattice of these minerals (Barabȧs and Kiss, 1958). The presence of organic matter formed a reducing environment. An abundance of silicified wood (Araucarites) remains were noted (Barabȧs and Kiss, 1958).

Pitchblende, uraninite, and soddyite predominate in the area. Other uranium minerals are coffinite(?), liebigite, autunite, zippsite, and uranopopilite, and a lemon-yellow uranium-vanadium mineral found in pulverulent incrustations along the rock fissures (Barabȧs and Kiss, 1958). It is the secondary uranium ores, accumulated in sandstone, which were mined (Huvos, 1970, p. 5). Associated ore minerals are pyrite, galena, sphalerite, niccolite, cobaltite, chalcopyrite, and molybdenite (Barabás and Kiss, 1958). Vanadium and chromium are associated with the uranium. The chromium mineral is not an important uraniferous mineral but its role as an accumulator of uranium serves to enrich radioactive elements in psammitic rock (Kiss, 1958). Chromium mica because of its cementing quality has greatly diminished the volume of the sandstone pores, and has thus formed a kind of barrier stratum on both sides of the anticline (Kiss, 1958).

References: Barabás and Kiss, 1958; Barabás and Virag, 1966; Barthel, 1974; Huvos, 1970; Kiss, 1958; Saum and Link, 1969.

Symbol: 73CSS
Name: Northwest shore of Lake Balaton, Hungary.
Location: 46° 45' 00" N; 017° 30' 00" E
Description: In the foothills along the northwest shore of Lake Balaton, concentrations of uranium occur in bituminous phosphoritic substance in fractured zones and horizontally between the stratified layers in dolomites, limestones, and bituminous marls of Triassic age. The Triassic rocks form a basin that is very deeply cut through by oblique faults parallel to the direction of the strata. The bituminous strata are brownish-gray in color, their structure shows thin bands and, when struck with a hammer, they exude a fetid odor. The bituminous marl and bituminous substance appear, for the most part, as tectonic breccia zone cement (Jantsky and others, 1958). Uranium exists only in the bituminous phosphoritic substance; the measurable quantities of these elements are tied in with the fractured zones. Fluorite has developed in the veins and druses in several stages. Associated minerals are fluorite, fluorapatite, malachite, and chalcopyrite. The bituminous substance is in the form of calcareous tufa cement breccia fragments, as well as stalactiform incrustations. Everything indicates that the bituminous phosphoritic substance reached its present site from the primary or surrounding substances, while the uranium and fluorite were brought there by hydrothermal means from the deeper portions (Jantsky and others, 1958). The fluorite probably came from the fluorapatite, and the uranium came from the primary bituminous sediments (Jantsky and others, 1958).
References: Jantsky, Kiss, Lengyel, Szy, and Viragh, 1958.

Symbol: 74AVS
Name: Karlovy Vary Massif, Czechoslovakia.
Location: 50° 23' 00" N; 012° 55' 00" E
Description: The area is 110 kilometers northeast of Praha (Prague) in Krusnė horý (Erzgebirge). The Krusnė horý Mountains are an anticlinorium built up mostly of crystalline schists and granitoids. Jåckumov (or Jåchymov, or St. Joachimstal, or Joachimsthal) deposit is about 4 kilometers east of Eibenstock batholith, which cuts the Joachimsthal schist. Endogenic magmatic and postmagmatic processes formed many mineral deposits within the Krusnė horý Mountains of different types: magnetite deposits, which occur in skarns, are the earliest formed; tin and tungsten deposits occur in greisens; in the polymetallic hydrothermal veins within the Jåckymov area pitchblende is the most abundant mineral; barite-fluorite veins are widely scattered throughout the Krusnė horý area and represent the latest stage of hydrothermal mineralization; and other significant nonmetallic mineral resources are kaolin and lignite (Ruzicka, 1971). In the Jåckymov area of 35 square kilometers, the uranium deposits are located within or close to the old regional tectonic lineaments, along or within which other large ore deposits are located (Ruzicka, 1971). The hydrothermal uranium veins are within the metamorphosed mantle of the granitic pluton and especially within those parts that are close to the younger differentiates of intrusions (Ruzicka, 1971). In the mantle, a metamorphosed complex of Precambrian and Cambrian graphic-muscovite-biotite mica-schists with a pyritic admixture, are characteristic host rocks to the Jåchymov uranium deposit (Ruzicka, 1971). The fault pattern of the Jåchymov area is very complicated. The three main systems within the Klinovec anticline are the northwest, the east, and the northeast systems (Ruzicka, 1971). Of the two systems of veins, a north-south (Midnight) and an east-west (Morning), the north-south system represents the main system of uranium-bearing veins and veins formed during the pitchblende stage of mineralization. The thickness of veins is usually only a few centimeters, but in places may be as much as a few meters. Veins have been followed for 2.4 kilometers and to a depth of 480 meters and are about 15 centimeters to 0.6 meters thick (Heinrich, 1958). Some veins transect granite at the depth where uranium mineralization is inferred to decrease (Heinrich, 1958). The vein filling is mainly quartz and carbonates, with pitchblende lenses and arsenides. The main uranium-ore mineral is pitchblende; other minerals are liebigite, zippeite, and uranopilite. The most favorable host rocks for the deposition of uranium-ore minerals are amphibolites, biotitic, pyritic, and graphitic gneisses, erlans, chloritized and pyritized biotitic mica schists, and skarns (especially amphibole-pyroxene) (Ruzicka, 1971). The pitchblende lenses are at intersections with other faults or in branch faults and fractures (Ruzicka, 1971). Associated minerals are arsenopyrite, pyrite, galena,

sphalerite, chalcopyrite, bornite, ankerite, hematite, native silver, native bismuth, barite, fluorite, quartz, carbonate, and dolomite. Associated commodities are silver-bismuth, cobalt ores, lead, nickel, arsenate, tin, tungsten, copper, and radium. The main stage of pitchblende deposition is 220-230 m.y.; pitchblende regenerations are 5-160 m.y.; and mineralization in the Jáchymov district is predominently of Mesozoic and Tertiary age (Rich and others, 1975).

References: Bernard and others, 1968; Chrt and others, 1968; Everhart and Wright, 1953; Harlass and Schuetzel, 1965; Heinrich, 1958; Leutwein, 1957; Pluskal, 1970; Rich and others, 1975; Ruzicka, 1971; Tischendorf and others, 1965; Zeschke, 1970.

Symbol: 75AVS

Name: Central Bohemian Pluton, Bohemian Massif, Czechoslovakia.

Location: 49° 20' 00" N; 014° 00' 00" E

Description: The Pribram deposits, 50 kilometers southwest of Praha (or Prague), are in the mantle zone of Central Bohemian Pluton built up of Barrandian Proterozoic and early Paleozoic complexes (Ruzicka, 1971). The Barrandian synclinorium trends mainly southwest, and is dislocated by sets of faults that strike northeast, north, and northwest (Ruzicka, 1971). The mantle sediments of slightly metamorphosed pelitic and coarser sediments containing the hydrothermal uranium ore-veins are folded into an asymmetric anticline. Structural control, especially the morphology of fissures as well as the physical-mechanical features of host rocks, is the chief factor influencing the localization of ore mineralization (Ruzicka, 1971). Within the hydrothermal veins are "vein-knots" or complicated vein systems. The orebodies have shapes of regularly and irregularly scattered lenses, ore chimneys, ore bunches, ore stockworks, and many others (Ruzicka, 1971). The trifold sequence of vein mineralization is: (1) polymetallic stage, in which siderite, quartz, sphalerite, Ni-Co minerals, galena, dolomitic carbonate, and arsenopyrite were deposited; (2) second stage, where calcite, dolomite, ankerite, pitchblende, and later calcite were formed; and (3) post-ore stage, where mainly calcite was deposited (Ruzicka, 1971). The uranium mineralization occurs in two main types of veins: (1) carbonate veins with pitchblende and a few sulfides, and (2) quartz-carbonate veins with Pb-Zn-(Ag)-(Cu) (Ruzicka, 1971). Uranium mineralization is present as pitchblende, and less abundantly uranoan-anthraxolite (a product of later phases of the hydrothermal processes) (Ruzicka, 1971). The hydrothermal solutions acquired their organic matter probably from the underlying carbonaceous shales. The metasomatic processes affected the primary pitchblende mineralization especially along the shear zones (Ruzicka, 1971). Chloritization, sericitization, and hematization are evident usually locally for only a short distance from the veins, but in places up to several meters (Ruzicka, 1971). Hematization is most common around pitchblende accumulations within the carbonate vein filling (Ruzicka, 1971). The intrusive phases are dated as Early Carboniferous; age of main pitchblende stage is about 270 m.y. (Rich and others, 1975).

References: Bernard and others, 1968; Frenzel and Ottemann, 1968; Pisa, 1966; Pluskal, 1970; Rich and others, 1975; Ruzicka, 1971.

Symbol: 76BSS
Name: Intra-Sudetic Basin, Czechoslovakia and Poland.
Location: 50° 38' 00" N; 015° 59' 00" E
Description: The Intra-Sudetic Basin, which includes Plzen Basin, Kladno-Slaný-Rakovník Basin and Zaelér-Svatonovice Basin, of Permian to Carboniferous molasse sediments, is located amidst crystalline massifs and is of the intermontane depression type (Ruzicka, 1971; Svobada and others, 1966). The uranium mineralization is epigenetic, localized within bituminous coal seams and partly within their overlying and subjacent beds, which are composed mainly of sandstone, and is associated with vanadium, copper, and germanium, which locally reaches high concentration (Ruzicka, 1971). Included in the region are Stachanov, Rybnícek and Choalec deposits.
References: Pluskal, 1970; Ruzicka, 1971; Svoboda and others, 1966.

Symbol: 77BVS
Name: Rychlebske hory, Czechoslovakia.
Location: 50° 20' 00" N; 016° 55' 00" E
Description: Geologically similar to the Krusné hory region, in that within the region there are Variscan massifs containing several intrusions presumably of post-Bretonian age, and within the ore-aureole of these granitic intrusions there are mainly hydrothermal deposits corresponding to different stages of development of the magmatism; northwest-trending faults or regional lineaments structurally control the uranium mineralization; and host rocks of gneisses, often migmatized, intercalated by amphibolites and erlans (Ruzicka, 1971). Uranium mineralization is mainly pitchblende and, as in the Javorník deposit, occurs in hydrothermal carbonate-veins, and very finely disseminated in orebodies. Copper mineralization, mainly chalcopyrite and bornite, is within irregularly-shaped carbonate bodies and stockworks, and partly in veins (Ruzicka, 1971).
References: Pluskal, 1970; Ruzicka, 1971.

Symbol: 78BVS
Name: Labe Lineament region, Czechoslovakia.
location: 49° 30' 00" N; 016° 15' 00" E
Description: The hydrothermal uranium deposits are spatially related to the disjunctive tectonic system, the Labe Lineament, which is considered to be the northeast boundary of the Tepla-Moldanubian block, and the uranium mineralization is localized along shear zones and fissures (Ruzicka, 1971). The Rozná deposit, in the southeastern part of the Labe Lineament, is on the limb of a refolded mega-anticline in the Variscan (upper Paleozoic) Moldanubian Varied Group, which in the Rozná area is mainly plagioclase-biotite paragneiss and amphibolite (Ruzicka, 1971). The rocks surrounding the deposit are distinctly chloritized and carbonatized. The mineral succession may be observed mainly within the flanks of the deposit where carbonate veins are developed, whereas within the central part of the ore zones, the rocks are strongly crushed, brecciated, and mylonitized and the ore mineralization is finely disseminated and as a rule represented by sooty or microscopic pitchblende (Ruzicka, 1971). In the southeastern part of the Lineament, three main stages of mineralization are developed, from oldest to youngest (post-ore): (1) quartz-hematite or carbonate-hematite with sulfides; (2) carbonate, pitchblende, graphite, hematite, chlorite, and some metallic minerals; and (3) quartz, hematite, carbonates, and pyrite (Ruzicka, 1971). Associated minerals, with pitchblende, are calcite, berzelianite, umangite, eucairite, clausthalite, hematite, chalcocite, bornite, and chalcopyrite (Ruzicka, 1971). In the northwestern part of the Labe Lineament region, most of the deposits are mineralized by uranium-bearing anthraxolite (similar to those of the Prİbram ore district) and only as an exception by sooty or massive pitchblende (Ruzicka, 1971).
References: Pluskal, 1970; Ruzicka, 1971.

Symbol: 79BSS
Name: West Carpathians, region of Spis-Gemer Mountains, Czechoslovakia.
Location: 48° 10' 00" N; 020° 30' 00" E
Description: Upper Permian (Verrucano) uranium ore-bearing rocks are conglomerates, sandstones, and siltstones (or aleurolites), which are folded into the Huta anticline and Hnilcík syncline (Ruzicka, 1971). Uranium ore mineralization is apparently syngenetic, and is in association with Cu and Mo. The ore minerals in tuffites are pitchblende, sooty pitchblende, molybdenite, chalcopyrite, tenatite-tetrahedrite, galena, sphalerite, arsenopyrite, ilmenite, magnetite, hematite, covellite, and the secondary minerals, autunite, torbernite, and tyuyamunite; and the ore minerals in quartz porphyries are pitchblende, sooty pitchblende, chalcopyrite, tenantite-tetrahedrite, pyrite, sphalerite, and molybdenite (Ruzicka, 1971). Quartz-porphyry volcanism was accompanied with hydrothermal activity and exhalatory activity, which occurred during the sedimentation of tuffaceous rocks; and the hydrogen sulfide exhalations caused precipitation of ore elements, the source of which was quartz porphyries (Ruzicka, 1971; Rojkovič, 1968). Uranium deposits of this type are the Novoveská Huta and Murán.
References: Pluskal, 1970; Rojkovič, 1968; Ruzicka, 1971.

Symbol: 80BBL
Name: Province of Scania, Öland, Västergötland, including Billingen-Falbygden district, Sweden.
Location: 56° 30' 00" N; 014° 00' 00" E
Description: Uraniferous alum shale or bituminous shale, and a coal-like substance, "Kolm," which has as its composition a mixture of hydrogen-rich and oxygen-poor organic substances, a highly uraniferous kerogen, occur in an area of about 500 square kilometers in south Sweden, in the Scandinavian Shield, near the landward margin of a submerged shelf or platform that lay between two geosynclinal zones. The shale itself contains 200 to more than 400 grams of uranium per ton, whereas the kolm contains about 3,000 g U/ton; the uraniferous shale averages 3 meters thick, and 300 g U/ton (0.02 percent uranium); the ore reserves are estimated to be about one million tons U_3O_8. Recovery is not expected to be more than 35 percent; however, extraction techniques, possibly bacterial leach, may improve, resulting in higher recoveries at lower cost (Bowie, 1970; Heinrich, 1958). The organo-uranium complex contains abundant organic matter and nodules and small lenses of nearly pure, pitch-black hydrocarbon. The most uraniferous shales begin in the lower part of the *Peltura scarabaeoides* (Wahlenberg) Zone of Late Cambrian age, which also contains the kolm forming lenses as layers in the shale (Svenke, 1956). The carbonaceous shale is the deepest water facies. The thickness of the *P. scarabaeoides* Zone reaches a maximum thickness in the center of the northern embayment of the Late Cambrian sea. Most of the host rocks are Late Cambrian age, but a few are Silurian and Ordovician. Their depositional environment was marine, and a typical area of stagnation sediments. The thickness of the Upper Cambrian is only 10 to 20 meters. Associated minerals are pyrite, quartz, feldspar, illite, kaolinite, carbonate, and phosphate. Radium is an associated commodity. Byproducts, at the Ranstad mine, one of the world's largest mines, include molybdenum, nickel, and vanadium (Tatsch, 1976).
References: Armands, 1972; Barnes and Ruzicka, 1972; Bowie, 1970; ENEA, 1967; Heinrich, 1958; Klinger, 1971; Ruzicka, 1971; Sherman, 1972; Strand and Kulling, 1972; Svenke, 1956; Tatsch, 1976.

Symbol: 81BBL

Name: Närke Province (which includes Kvarntorp district), and Norrland, south and central Sweden.

Location: 58° 45' 00" N; 015° 20' 00" E

Description: Uraniferous alum shale deposits are similar to those in the Province of Scania. Associated commodities are radium, oil shale (minable for its 5 percent kerogen content), sulfur, and vanadium. In the Kvarntorp district the 5- to 6-meter bed contains 220.5 grams uranium per metric ton with reserves of 90,700 metric tons (Heinrich, 1958).

References: Armands, 1972; Bowie, 1970; ENEA, 1967; Heinrich, 1958; Ruzicka, 1971; Sherman, 1972; Svenke, 1956.

Symbol: 82AGL
Name: Finno-Karelia, Finland and U.S.S.R., and Kola Peninsula, U.S.S.R.
Location: 66° 00' 00" N; 033° 30' 00" E
Description: Blanket-type deposits occur in Precambrian metasediments of uranium-bearing quartzite in the Koli region (or Kola or Kol'skiy Poluostrov Province, including Pziukkajanvaara or Paukkajanvaara (68°00'N., 35°00'E.)), along the border area of the Scandinavian Shield of northern Finno-Karelia, a distance of 25 kilometers. The deposits are perhaps about 50 kilometers from the Russian frontier. The deposits are expected to produce about 180 metric tons of concentrates annually from 29,100 metric tons of ore with a content of 0.2 percent U_3O_8 (Davidson, 1960b). The Koli rocks (of the Jatulian Series) are of Proterozoic age and overlie the Archean granite-gneisses. They comprise a basal quartz-pebble conglomerate succeded by a series of medium-grained quartzite, usually 300-400 meters, sometimes 1,000 meters thick, the whole being folded into a synclinal structure. The complex is cut by many large intrusions of metadiabase. There is a close similarity to the Witwatersrand and Blind River deposits, and these deposits may be large (Davidson, 1960b). As early as 1954, the locale of Karelia was expected to be favorable on the assumption that the granitization represented by the uraninite-bearing Karelian pegmatites could give rise to a disseminated uranium mineralization in the ancient conglomerates (Davidson, 1960b). An age of 1,870 million years (determined by the potassium-argon method) for the sericitic cement in a Jatulian quartz-pebble conglomerate from Russian Karelia has been reported (Davidson, 1960b; Krattz, 1960). Bowie (1970) states that in northern Karelia, Finland, mineralization in Precambrian quartzite-conglomerate formations is present as veins and impregnations associated with diabase dikes; and that at Paukkajanvaara, where the main uranium mineral is pitchblende associated with hydrocarbon, and where vanadium and iron are the most important associated elements (Bowie, 1970), the ore zone parallels a dike and is best developed where the dike cuts a conglomerate bed. OECD NEA/IAEA (1973) indicates that at Kolari, north Finland (67°25'N., 23°40'E.), and Paltamo, east Finland (64°31'N., 27°40'E.), deposits in Precambrian sedimentary formations have resources estimated to amount to 1,300 metric tons uranium. Ruzicka (1971, p. 61) states that in conglomerates in the shield region, radioactive uraniferous conglomerates are within Cambrian complexes unconformably overlying the Precambrian basement, which is composed of microcline granite, schists, and gneisses. In the report of Working Group III, on uranium in quartz-pebble conglomerates (IAEA, 1974, p. 707-709), it is suggested that reports of young conglomerates, such as Cambrian conglomerates described in Soviet literature, are in error, and age determinations suggest that the conglomerates form between about 2800 m.y. and 2200 m.y. (Precambrian W or X). Of the

three types of conglomerates, the most productive uranium-bearing zone is represented by monomictic quartz-pebble conglomerate (Ruzicka, 1971; Shcherbin, 1968). The uranium-bearing orebodies may be (1) stratiform and lenticular confined to conglomeratic rocks, (2) veinlets confined to conglomeratic rocks and to the contact zone between them and the adjacent quartzites, and (3) irregular bodies with disseminated and massive ore confined to conglomerates affected by shearing and metasomatism (type 3 is developed only sporadically) (Ruzicka, 1971).

Ore mineralization in the stratiform and lenticular bodies is represented by microcline, malacon (altered zircon), thorite, uranothorite, allanite, ilmenite, rutile, brannerite(?), hematite, magnetite, and secondary autunite, with minor titanium-tantalum-niobates, priorite, monazite, xenotime, pyrite, and chalcopyrite (Ruzicka, 1971). Ore mineralization in veinlets is represented by quartz, ilmenite, hematite, thorite, uranothorite and zircon; and ore mineralization in irregular bodies is mainly allanite (Ruzicka, 1971). Generally uranium is contained in brannerite, allanite, autunite, thorite, thorianite, uranothorite, and hyalite (Ruzicka, 1971). According to Shcherbin (1968) the origin of the uranium mineralization seems to be similar to that in the Elliot Lake area; however, the metamorphic and particularly the hydrothermal processes affected the uranium mineralization (after the diagenetic stage of uranium-bearing conglomerates) and partially caused its redistribution.

References: Bowie, 1970; Davidson, 1960b; IAEA, 1974; Krattz, 1960; OECD NEA/IAEA, 1973; Roubault, 1958a; Ruzicka, 1971; Shcherbin, 1968; Wennervirta and Kauranen, 1960.

Symbol: 83BVS
Name: Ellweiler, on the Nahe River, West Germany.
Location: 49° 40' 00" N; 006° 40' 00" E
Description: The deposit, southeast of Trier, is in a fracture zone of a crystalline massif, a Permian porphyry, Porphyry of Nohfelden (Closs, 1964, after dissertation of H. Mathes, 1963). A great abundance of secondary uranium minerals (such as ellweilerite and paulite) and several primary minerals (pitchblende and probably primary coffinite) of one or more hydrothermal stages were formed (Closs, 1964). Highly uraniferous hydrocarbons occur for which a hydrothermal origin is assumed (Bültemann, 1960; Schwille, 1959). A dike shaped outline for the deposit (of primary origin) is thought probable (Closs, 1964).
References: Bültemann, 1960; Closs, 1964; Emmermann, 1969; Schwille, 1959.

Symbol: 84BVM

Name: Menzenschwand (or Menzengebwand), southern Black Forest, West Germany.

Location: 47° 50' 00" N; 008° 10' 00" E

Description: In a granite southeast of Freiburg on the southern slope of Feldberg massif (Menzenschwand), pitchblende and a little coffinite were found in ore deposits. The Menzenschwand deposit is on a fringe of an Upper Permian granite complex of the Feldberg massif near a gneiss. Associated minerals are hematite and manganese oxide, occasional magnetite, small amounts of various sulfides and some arsenides of iron, copper, nickel, and traces of lead selenides; gangues are chert, quartz, fluorite, and barite. The deposit is of the iron-barite formation type generally considered as very promising for large uranium deposits (Closs, 1964). The age of the katathermal (syngenetic with granitic intrusions) deposit has been determined as 229.4 ± 3.3 million years (Closs, 1964, p. 159). Estimates of the yield lie between 1,000 and 3,000 tons U_3O_8 (Closs, 1964, p. 159). In the Black Forest, deposits of torbernite, autunite, and zeunerite are along fractures in granite, but most are associated with silver-nickel deposits (Heinrich, 1958). A smaltite specimen from the Sophia mine contained 15 percent U_3O_8 in the form of pitchblende (Kohl, 1954). The veins are of the Ag-Co-Ni-Bi-U type with barite-fluorite-quartz gangue.

References: Closs, 1964; Heinrich, 1958; Kohl, 1954; Nahai, 1967; Zeschke, 1970.

Symbol: 85BVM
Name: Bohemian Massif, Saxothoringian area, Erzgebirge, East Germany.
Location: 50° 55' 00" N; 013° 21' 00" E
Description: The Erzgebirge, a mining region of Saxony (Eastern Germany) and Bohemia (Czechoslovakia), includes the districts of Freiberg (lat. 50°55'N., long. 13°21'E.), Marienberg (lat. 50°38'N., long. 13°11'E.), Annaberg (lat. 50°35'N., long. 13°01'E.), Johanngeorgenstadt (lat. 50°26'N., long. 12°44'E.; 19 kilometers northwest of Jochimsthal, or Jáchymov), and Schneeberg (lat. 50°35'N., long. 12°38'E.; 48 kilometers northwest of Jáchymov).

The Erzgebirge, which forms part of a low mountain chain extending across central Germany to the Carpathian Mountains, had been mined mainly for Pb, Ag, Co, Ni, and Bi. However, the Ag-Co-Bi-U hydrothermal fissure veins have been the most important economically (Heinrich, 1958). The area around Jochimsthal, at the intersection of a northwesterly trending mineralized zone with a north-south zone, is underlain by Precambrian paraschists and Paleozoic phyllites and slates into which has been intruded the Upper Carboniferous and Lower Permian Eibenstock granite pluton (Heinrich, 1958; Ruzicka, 1971). Generally the fissure veins are best developed in metamorphic rocks, but at Schneeberg, pitchblende also occurs in veins in granite. Endogenous pitchblende, the chief uranium mineral, forms thin seams, streaks, and irregular patches within dolomitic or dolomitic quartzose veins or rarely along microfractures in schistose wall rock, and is confined essentially to veins with a gangue of reddish dolomite (Heinrich, 1958).

Minerals within the main uranium-bearing strata of quartz-pitchblende-calcite and dolomite-selenides are quartz, fluorite, hematite, coffinite, pitchblende, calcite, anhydrite, gypsum, sulfides, dolomite, goethite, and selenides (Harlass and Schuetzel, 1965). The most favorable host rocks for uranium mineralization are Cambrian skarns and amphibolites, or pyritic chlorite-sericite schists and carbonaceous shales, skarns, and amphibolites of Silurian and Devonian age (Yanishevskiy and Konstantinov, 1960; Ruzicka, 1971). The veins are characterized by a complex suite of minerals. Associated minerals include native silver, argentite, stephanite, the ruby silvers, and rarer sulfosalts, niccolite, smaltite, safflorite, chloanthite, native bismuth, bismuthinite, galena, sphalerite, chalcopyrite, pyrite, wolframite, cassiterite, chlorite, fluorite, arsenopyrite, pyrrhotite, stannite, bornite, hematite, calcite, anhydrite, gypsum, dolomite, clausthalite, umangite, goethite, barite, siderite, kaolinite, skutterudite, loellingite, and rammelsbergite. The gangue consists chiefly of quartz, jasper, calcite, dolomite, other carbonates, barite, and fluorite. Oxidation has resulted in a complex assemblage which includes horn silver, bismutite, beyerite, uranosphaerite, liebigite, schroeckingerite, voglite, zippeite, uranopilite, johannite, autunite, torbernite, metauranoarcite, saleeite, fritzcheite, metazeunerite, uranospinite, troegerite, walpurgite, uranophane, beta-uranophane, and cuprosklodowskite (Harlass and Schuetzel, 1965; Heinrich, 1958).

References: Bain, 1950; Barsukov, 1967; Dymkov, 1960; Frohberg, 1950; Harlass and Schuetzel, 1965; Heinrich, 1958; Ruzicka, 1971; Vinogradov, editor, 1963; Yanishevskiy and Konstantinov, 1960; Zeschke, 1970.

Symbol: 86BCS
Name: Freital and Ronneburg areas, East Germany.
Location: 51° 00' 00" N; 013° 40' 00" E
Description: In the Freital area, bituminous coals of the Lower Permian are irregularly mineralized by uranium tin, germanium, molybdenum, pyrite, galena, sphalerite, and copper (Ziehr, 1961). Such minerals as quartz, pyrite, chalcopyrite, bornite, covellite, fahlerz, and galena, which are fairly disseminated, are in the combustible shales as well as in the fissure fillings (Ruzicka, 1971). Pietzsch (1963) reported uranium enrichments in sediments of the Zechstein Formation in the Ronneburg area.
References: Pietzsch, 1963; Ruzicka, 1971; Ziehr, 1961.

Symbol: 87CSS
Name: Elbtal ore district, Bohemian Massif, East Germany.
Location: 51° 05' 00" N; 013° 45' 00" E
Description: Uranium mineralization of the infiltration type (roll-type) is developed in Late Cretaceous (Cenomanian) sediments in the vicinity of Dresden and elsewhere (Ruzicka, 1971; Loetzsch, 1968).
References: Loetzsch, 1968; Ruzicka, 1971; Samana, 1973.

Symbol: 88?SS
Name: Vathi district, northern Greece.
Location: 40° 59' 00" N; 022° 51' 00" E
Description: A uranium deposit near Kilkis is in a volcanic formation which covers an area of about 50,000 square meters and averages 100 grams of U_3O_8 per ton of ore (Corrick, 1970).
Reference: Corrick, 1970.

Symbol: 89BSS
Name: Kitzbühel and other areas, Austria.
Location: 47° 20' 00" N; 012° 30' 00" E
Description: Uraninite and pitchblende(?) occur at Kitzbühel in Permian and Lower Triassic Buntsandstein or sandstone, Austrian Alps; near Fieberbrunn (Tyrol or Tirol) in the "Oberostalpin" Buntsandstein, at the base of the Northern Limestone Alps; in the "Unterostalpin" sericite quartzites of Forstau (Salzburg); and in the Semmering (Styria) area, in the Penninic schists near Mayrhofen (Tyrol); as well as in the Grödener Sandstein of the Gailtaler Alpen and Karawanken (Carinthia), in stratiform deposits, conformable to the layering. These beds are terrestrial, formed under semiarid conditions, and lagoonal in origin, while their upper parts are of shallow marine origin (Petrascheck, Erkan, and Neuwirth, 1974). The comparatively larger uranium layers are in or near the Permian troughs, the areas of greater thickness. Uranium is in layer- or lense-shaped orebodies, 10 to a few hundred meters long, in zones a few kilometers long, elongated in the alpin east-west direction. Ore content ranges between 0.05 and a maximum of 2 percent uranium. Almost all the Permian deposits with uranium contain porphyritic intercalations or volcanic detritus, but there is no correlation between the intensity of mineralization and the frequency of volcanics. In the Buntsandstein, volcanics are scarce, and in the Skythian Werfener Schigfer, where occurrences of ore exist, silicic volcanics are absent (Petrascheck, Erkan, and Neuwirth, 1974). Uranium has remobilized and reconcentrated in areas where younger hydrothermal solutions have penetrated into uraniferous sandstones. At Mühlbach near Bischofshofen, small stratiform layers of very fine-grained uranium ore (uraninite and brannerite) occur in Lower(?) Permian quartzites which overlie schists that have been cut by a hydrothermal copper (chalcopyrite-ankerite) vein (Petrascheck, Erkan, and Neuwirth, 1974). Some radioactive anomalies have been found in the vicinity of hydrothermal ankerite near Permian sandstones in Western Tyrol (Petrascheck, Erkan, and Neuwirth, 1974).
References: Broderick, 1970; Mittempergher, 1970a; Petrascheck, Erkan, and Neuwirth, 1974.

Symbol: 90BVS
Name: West-central and extreme southwestern Romania.
Location: 45° 30' 00" N; 022° 30' 00" E
Description: Veins occur where metamorphic or metasomatic iron deposits, lead, zinc, molybdenum, and copper, are associated with younger veins, and perhaps with disseminations that contain a complex assemblage, and locally include minerals of cobalt, nickel, and bismuth in Paleozoic rocks (Nitu, 1974). Pitchblende also occurs in bitumen-associated deposits in Upper Carboniferous or other Paleozoic conglomerates, greenstones, gritstones, siltstones, and sandstones, which were formed in alluvial and lacustrine environments; most ore bodies are stratified, lenticular, and lie concondantly with the strata (Kornechuk and Burtek, 1974).
References: Bain, 1950; Gerard, 1956; Kornechuk and Burtek, 1974; Nitu, 1974; Roubault, 1958a; Ruzicka, 1971.

Symbol: 91BVS
Name: Eastern part of Rhodopy (or Rhodope) Mountains (Massif) between Madan and Zilatograde, Bulgaria.
Location: 42° 00' 00" N; 024° 08' 00" E
Description: Endogenous base-metal veins occur in Hercynian rocks in the area which is along the lineament of Jȧchymov and Pribrian in Czechoslovakia and Mecsek in Hungary. The massif consists largely of Precambrian and lower Paleozoic metamorphic rocks cut by large granitic plutons, possibly of several ages. Associated minerals are pyrite, galena, sphalerite, and chalcopyrite.
References: Bain, 1950; Foose and Manheim, 1975; Heinrich, 1958; Ruzicka, 1971.

Symbol: 92BVS
Name: Bukhovo or Goten deposit, Bulgaria.
Location: 42° 46' 00" N; 023° 34' 00" E

Description: Goten (or Bukhovo) deposit, 7 kilometers from Bukhovo and 20 kilometers north of Sofia, is a lens, 4 to 15 meters wide, 50 to 70 meters long, explored to about 10 meters deep, of uranyl minerals (torbernite, metatorbernite, autunite) and limonite along a highly fractured brecciated zone in sandstone at the contact of monzonite with Silurian metamorphosed shales or schists(?) (Heinrich, 1958; Konjarov, 1938; Kostov, 1943; Roubault, 1958a). There is no evidence of a true vein, or of primary minerals (Konjarov, 1938; Nininger, 1955). Uranium may have been carried down from an overlying source (now denuded), the Jurassic oil shale still preserved at nearby Breznik (Heinrich, 1958; Sundius, 1941).

References: Bain, 1950; Foose and Manheim, 1975; Heinrich, 1958; Konjarov, 1938; Kostov, 1943; Nininger, 1955; Roubault, 1958a; Sundius, 1941.

Symbol: 93BSM
Name: Zirovski Vrh, Yugoslavia.
Location: 46° 04' 00" N; 014° 05' 00" E
Description: Zirovski Vrh uranium deposit, in the Gorenja Vas region, on the southern flank of Julian Alps about 30 kilometers west of Ljubljana, in Slovenia, a region of Permian and Triassic sediments, northwest Yugoslavia, occurs in an ore-bearing horizon of greenish-grey sediments, 30-60 meters thick, of the lower part of the Permian Gröden Sandstone (Lukacs and Florjancic, 1974). According to Lukacs and Florjancic (1974), all known uranium occurrences in northwest Yugoslavia are in the greenish-grey sediments (mostly sandstones, but also siltstones and conglomerates) of the lower part of the Gröden. According to Pantić and others (1972), uranium, as indicated from surface exploration, occurs in a zone up to 150 meters wide by almost 7 kilometers long, and the lens-like orebodies, elongated in the direction of the fold, have dimensions from several hundred up to several thousand square meters, and thickness up to several meters; also the uranium content is not uniform but varies from one hundredth of one percent up to 1.0 percent, but usually is between 0.05 and 0.23 percent U_3O_8. In 1974, Markov and Ristić reported the concentration of uranium as 0.01-5 percent, amounting to over 10 percent in a very few places. The prevalent types of orebodies are bands or lenticles up to 20 centimeters thick, parallel to the bedding, and disseminations where concentrations from high to barren are randomly distributed (Lukacs and Florjancic, 1974). Ore in joints has been found to represent partial secondary mineralization along cleavage planes. Most orebodies are of several types. Lukacs and Florjancic (1974) concluded that the deposit was syndiagenic or that uranium was transported into the sediments during their deposition in a fluvial environment and later redistributed; they assumed that the source of the sediments and the uranium was the keratophyric basement.

The most important mineral of the deposit is pitchblende, which is localized in the cement of sandstone and conglomerate in the form of fine-grained aggregates; the largest concentrations of uranium are in formations characterized by a wide variety of reduction and precipitation conditions (Lukacs and Florjancic, 1974; Pantić and others, 1972). Secondary uranium minerals of dumantite, torbernite, autunite, the series phusphuranylite-renardite, and gummite occur and have been found down to 200 meters below surface (Lukacs and Florjancic, 1974; Markov and Ristić, 1974).

The main ore-controlling feature is bedding. Cyclic sedimentation is recognizable in the mineralized sandstone; the tendency of finer grading of sediments in the upward direction can be a proof of alluvial origin; obliquity and crossbedding are rare; and schistosity has obliterated the original sedimentary structure (Barthel, 1974; Lukacs and Florjancic, 1972; Pantić and others, 1972). The composition of the sediments suggests that volcanogenic detritus and intercalations of tuffite are present locally (Barthel, 1974). Carbonized vegetal remnants are present either as cement or as small grains or lumps of anthracite (Pantić and others, 1972). Copper, zinc, lead, arsenic, yttrium, and other elements, most of which were precipitated epigenetically, occur in the uraniferous sandstones and conglomerates where carbonates, organic matter, and sulfides also occur. Markov and Ristić (1974) believed that the uranium and other metals were precipitated from underground waters and deposited at the limit of the oxidation and reduction media, which represented the geochemical barrier; and that gradual metamorphism of the sandstones led to the transformation of the argillaceous cement into chlorite and sericite and of the organic matter into anthracite, with the fractionation and deposition of uranium. An association of uranium with galena and chalcopyrite is rare. Sphalerite, tetrahedrite, bornite, realgar, marcasite, arsenopyrite, covellite, ilmenite, Cr-spinels, and pyrrhotite occur independently of uranium. Zirovski Vrh deposit has 4000 metric tons U and indicated reserves of 1540 metric tons U (Pantić and others, 1972, p. 79).

References: Barthel, 1974; Lukacs and Florjancic, 1974; Markov and Ristić, 1974; Nininger, 1955; Pantić and others, 1972; Ristic, 1956; Samana, 1973.

Symbol: 94DVM
Name: Zletovska Reka, Yugoslavia.
Location: 42° 05' 00" N; 022° 15' 00" E

Description: Zletovska Reka uranium deposit, 75 kilometers northeast of Skopje on the eastern boundary of the Kratovo-Zletovo volcanic complex, in the vicinity of the contact with the crystalline schists of the internides, has uranium mineralization, mainly "soft" pitchblende, in two forms: (1) dispersed through the cataclysed and kaolinized material of the tectonized zone in mainly volcanic breccia and (2) concentrated in veinlets, films, and fractures in mainly compact andesite (Pantić and others, 1965, 1972). Uranium mineralization occurs mainly within the predominant structural feature in the area, a tectonized zone about 250 meters by 2500 meters characterized by intensive mechanical and hydrothermal alterations (kaolinization, silicification, chloritization, carbonatization, zeolitization, and alunitization) (Pantić and others, 1965). The immediate vicinity of the deposit is composed of Tertiary hornblende-biotite andesites, andesitic tuffaceous breccias and tuffs, ignimbrites of hornblende-biotite dacitic origin, and hornblende-biotite dacite lavas (Pantić and others, 1965).

The main mineral is pitchblende; and secondary minerals identified include autunite, torbernite, kasolite, and uranophane (Pantić and others, 1965). The uranium content varies from 0.03 to 1.17 percent (Pantić and others, 1965). Very small quantities of sphalerite, pyrite, galena, marcasite, bravoite, and tetrahedrite are present; only the sphalerite intergrows with the pitchblende; the gangue minerals are siderite, barite, chalcedony, and fluorite in insignificant quantities (Pantić and others, 1965). The majority of the deposits of lead, zinc, copper, and uranium are in the Tertiary extrusives, in the faults and tectonized zones, rarely in the rim zone of the mainly Paleozoic crystalline schists. Lead, zinc, and copper are strongly interrelated, but the uranium appears not only in association with these metals but also on its own (Pantić and others, 1965). According to Radusinović (1974) the uranium has most probably originated from a deep-seated magmatic source, activated after the consolidation of volcanites; and uranium mineralization was deposited subsequent to the main phase of sulfide mineralization.

References: Pantić, Radusinović, Sikosek, and Obrenović, 1965; Pantić, Simić, Jokanović, and Antonović, 1972; Radusinović, 1974.

Symbol: 95CVS
Name: Bukulja, Yugoslavia.
Location: 44° 20' 00" N; 020° 25' 00" E
Description; Paun Stena, a vein-type deposit, is controlled by a shear zone striking east-west in the southern part of the granite massif of Bukulja of Early Cretaceous(?) age. The shear zone, up to 100 meters by several kilometers, is intensively kaolinized with granite fragments of different size. The vein-type mineralizations are from 1.0 up to 4.0 meters thick. The main uranium mineral is "soft" pitchblende localized mainly in the clayish part of the zone, and the content ranges from 0.03 up to 0.08 percent U_3O_8.
References: Pantić, Simić, Jokanović, and Antonović, 1972.

Symbol: 96CVS
Name: Stara Planina, Yugoslavia.
Location: 43° 25' 00" N; 022° 25' 00" E
Description: Mesdreja and Inovska Reka are the most economic uranium deposits at Stara Planina. These deposits are vein-type and are controlled by northwest-southeast shear zone in granite. The shear zones are filled with kaolinite, chlorite, and sericite, and less often by quartz and carbonates. Pitchblende occurs in veinlets and fracture coatings, as well as fine disseminations in the altered zones. Mineralized zones are up to 2000 meters by 350 meters; and thickness of vein-type mineralizations ranges from several centimeters up to 6 meters. The uranium content ranges from 0.02 to 0.17 percent.
References: Pantić, Simić, Jokanović, and Antonović, 1972.

Symbol: 97DCS
Name: Istria and Dalmatia, Yugoslavia.
Location: 44° 00' 00" N; 016° 00' 00" E
Description: Uraniferous coals of Tertiary age in the northwestern part of Yugoslavia (Istria and Dalmatia regions) contain usually 0.01 to 0.04 percent U_3O_8 and occasionally 0.1 percent, with reserves up to several hundred metric tons.
References: Pantić, Simić, Jokanović, and Antonović, 1972.

Symbol: 98CVM
Name: Western (Lower) Silesia in southwestern Poland.
Location: 50° 10' 00" N; 016° 00' 00" E
Description: Hydrothermal veins, similar to Erzgebirge of east Germany and Czechoslovakia, contain uraninite; pitchblende and sooty pitchblende; schroeckingerite; autunite; sklodovskite; uranophane; and uranium carbonates, phosphates, and silicates; as well as pyrite, pyrrhotite, marcasite, galena, sphalerite, arsenopyrite, chalcopyrite, bornite, tetrahedrite, loellingite, native arsenic, bismuthite, quartz, magnetite, hematite, fluorite, barite, and calcite (Ruzicka, 1971).
References: Morawiecki, 1960; Roubault, 1958a; Ruzicka, 1971.

Symbol: 99BSM
Name: Lower Silesian field, southwestern Poland.
Location: 50° 30' 00" N; 106° 00' 00" E
Description: Uranium occurs in carboniferous conglomerates, sandstones, and coal seams not in mineral form; and in sediments in Silurian shales, Permian and Triassic sandstones, and Cretaceous sediments as sooty pitchblende and secondary uranium minerals accompanied by pyrite, marcasite, calcite, limonite, galena, gypsum, and barite (Ruzicka, 1971).
References: Morawiecki, 1960; Morozewics, 1918; Roubault, 1958a; Ruzicka, 1971.

Symbol: 100DSL
Name: Ferghana Basin, U.S.S.R.
Location: 41° 00' 00" N; 072° 00' 00" E
Description: In the Ferghana Valley (40° to 41° N., 70° to 73° E.) of Russian Central Asia, in Tertiary gray arkosic sandstones containing carbonized plant remains, uranium-vanadium deposits have been found scattered over about 2600 square kilometers in the semiarid mountainous region in Uzbekistan, around the towns of Kokand and Ferghana (or Fergana), near the borders of Afghanistan, India, and Sinkiang (Heinrich, 1958; Nininger, 1955; Shimkin, 1949; Strishkov, 1967). The principal mineral is carnotite, with some tyuyamunite, other vanadium-bearing minerals, and varying amounts of copper minerals (Nininger, 1955). Yuigur Say (or Yuigur Sai, or Uigar-Sai, or Uysur-Say, or Uigur-sai, or Athash) deposits (41° 02' N., 71° 12' E.) (50 kilometers west and 15 kilometers north of Namangan) are in a continental sandstone in the Papsk region of northern Ferghana, Uzbek S.S.R. (Bain, 1950; Popov, 1939; Shimkin, 1949). These stream-deposited carnotite deposits closely resemble those in the Colorado Plateau (Bain, 1950; Heinrich, 1958; Shimkin, 1949). Popov (1939) pointed out that the uranium deposits are located in the confluences of the small lateral paleostreams; that the uranium occurs at the boundary of sulfate and carbonate zones; that ore elements were brought in by sulfate solutions and were precipitated by carbon remains; and that helium might be found in Ferghana Valley or elsewhere near carnotite deposits, similarly to helium found near carnotite deposits in Utah and New Mexico. Of the small explored area (Bain, 1950), favorable sandstone extends under a section of 250 square kilometers; at 2 metric tons per 2.6 square kilometers, the region may be expected to furnish 200 metric tons. Heinrich (1958) states that carnotite forms disseminations, lenses, cavity linings, and coatings along minor faults in a continental Miocene sandstone; and that concentrations occur near fossil logs and carbon trash associated with mudstone lenses. Carnotite deposits, discovered in 1934 (Golubkova, 1934), occur on the right shore of the Maili-Su (or Mayli-Su, or Mailisu) (41° 18' N., 72° 27' E.), 50 kilometers north of Andishan, as impregnations in a Tertiary sandstone bed 0.8 meters thick, and along a known distance of 150 kilometers (Heinrich, 1958; Shimkin, 1949; Volfson, 1940). Popov (1939) called Ferghana Valley a province of U, V, Bi, Ni, Co, and Sr; in southern Ferghana, radioactive vanadates, Ni, and Cu occur in fissures of siliceous schists of Late Silurian age. Bain (1950) stated that one of the highest U_3O_8 contents of secondary sedimentary deposits is in southern Ferghana, where less than 10 meters represents the accumulation for most of the Silurian. Tertiary intrusives are exposed at the extreme southern edge of the province and may lie at depth within the province. The uranium is believed to have been introduced into the sediments at the close of the Mesozoic.

References: Bain, 1950; Danchev and others, 1969; Golubkova, 1934; Heinrich, 1958; Mashkovtsev, 1928; Modnikov and Lebedev-Zinov'yev, 1969; Nininger, 1955; Popov, 1939; Shimkin, 1949; Volfson, 1940.

Symbol: 101BVS
Name: Tyuya Muyun area, Uzbek S.S.R., U.S.S.R.
Location: 40° 21' 00" N; 072° 35' 00" E
Description: Tyuya Muyun deposit is an "ore pipe" in a narrow but irregular and generally cylindrical ore body in a limestone hill, about 50 kilometers east of Ferghana (or Fergana), and 23 kilometers south of Andijan (or Andizhan) (Heinrich, 1958). The hill is bisected by the north-flowing Avavgn River, on the north side of Alai Mountains. Tyuyamunite (type locality of tyuyamunite, named for two knobs or "camel's humps") and thorium occur in fissure veins and in karst caverns in Carboniferous coarse-grained and reddish- or brownish-violet, highly fractured, highly soluble, metamorphosed limestone, which has interlayered volcanic breccias and tuffs, and is associated with extensive karst channels and caves developed in Tertiary time. Bain (1950) stated that the karst deposits end at 170 meters depth, that only a thin film of ore marble coats the joints below the karst zone, and that even it disappears or is not obvious at 20 meters greater depth. It has generally been stated that the tyuyamunite or carnotite in these deposits are oxidized ores, concentrated from a thick series of black shales (Silurian and Cambrian) that crop out in the Alai Mountains (or Range), and contain as much as 0.05 percent U_3O_8 (Bain, 1950; Heinrich, 1958; Nininger, 1955). Bain (1950, p. 312) stated that this grade is almost certainly due to surface enrichment in the desert climate. Bain (1950) also stated that at Potekhina and the Julie mine northeast of Minussinsk, the source might have been a gray Devonian shale but more probably was sparse carnotite in the Devonian red sandstones. Shimkin (1949) believed the history of the ore to be more complex. Deep, relatively low-temperature hydrothermal processes, possibly connected with the Variscan revolution of the upper Paleozoic, appear to have been the primary agents of deposition; and orogenic movements (Alpine?) faulted the deposit subsequent to the primary uranium deposition; then post-Eocene karst formation redistributed the deposit, partly destroying veins, partly reconcentrating ores. Chirvinsky (1925) also stated that the deposit was formed by postvolcanic hydrothermal solutions. Heinrich (1958) pointed out that it seems unlikely that the barite veins with their dolomitized wall rocks are anything but hydrothermal; that there is no compelling evidence that the source of uranium must have been the black shales; and that the karst deposits may represent supergene reworking of material derived from the oxidized baritic veins. Associated minerals are calcio-volborthite, turanite, volborthite, calcite, malachite, chrysocolla, barite, goethite, quartz, ferghanite, radiobarites, radiocarbonates, sphalerite, galena, cerucite, wulfenite, and crocoite. Associated commodities are radium, vanadium, copper, barite, nickel, iron, manganese. Almalyk vein deposit, about 6 kilometers from Tyuya Muyun, and other veins, are in Carboniferous limestone and contain Cu, Ni, Fe, Mn, and

radioactive minerals in a barite-calcite or barite gangue (Heinrich, 1958; Kohl, 1954).

The Tyuya Muyun uranium deposit was discovered in 1900 to 1903 (Shimkin, 1949) but was worked for copper by the Chinese using stone implements (Alexandrov, 1922). The vein field consists of five barite ore veins bearing U, V, and Cu minerals and over 30 pure barite veins (Shimkin, 1949). Productive veins, at a maximum depth of 500 m, are found near the center of the deposit; the ore bodies range from 1.5 m to a few cm in thickness and length; and the ore grade averages about 1.5 percent U_3O_8 with the range being 0.6 to 4 percent (Shimkin, 1949).

Gorunov (1934) suggested zoning of radioactive elements with other metals, along a row of points from Tyuya Muyun westward to Karachagir, Tash-bulak, Tul Char-ky, Mazar, Agalyk, and Kizil-Kum, because they occur along folds and fractures characteristic of Central Asia.

References: Alexandrov, 1922; Bain, 1950; Chirvinsky, 1925; Fersman, 1928b, 1930; Gorunov, 1934; Heinrich, 1958; Kohl, 1954; Nininger, 1955; Shcherbakov, 1941; Shimkin, 1949.

Symbol: 102BSL
Name: North flank of Alai Range, south of the Ferghana Basin, U.S.S.R.
Location: 39° 30' 00" N; 072° 30' 00" E
Description: The Alai Range, Central Asia, south of Ferghana (or Fergana) has thick black slates and shales of Silurian age. Bain (1950) stated that a series of secondary oxidized deposits occur for 100 kilometers along a line following the margin of the Alai Range (or Mountains) south of Ferghana, that their uranium almost certainly comes from the Silurian black slates and shales, that the bedded occurrences may be expected to have the usual 0.01 percent U_3O_8, and that if 1/2 kilometer from the outcrop is considered accessible, the rock may be expected to have 19,225 to 23,070 metric tons U (25,000 to 30,000 tons of U_3O_8). According to Heinrich (1958), the deposits along the north flank of the Alai Range are thick black shales and slates (Silurian) that contain up to 0.05 percent U_3O_8, but supergene enrichment under desert condition probably has increased the grade near surface.
References: Bain, 1950; Heinrich, 1958; Nalivkin, 1960.

Symbol: 103BBL
Name: Kara Tau (or Karatau) Range area, Kazakh S.S.R., U.S.S.R.
Location: 44° 30' 00" N; 067° 30' 00" E
Description: Uraniferous vanadium ores occur in the Kara Tau area, 90 kilometers northeast of Chiili, in the western part of Ferghana district, disseminated in Cambrian black shale or slate interstratified with dolomite (Tyurin, 1944). The ore horizon is 8 to 14 meters thick under an area of 40 to 50 square kilometers and has roscoelite and carnotite (Bain, 1950; Shimkin, 1949; Tyurin, 1944). Bain (1950) stated that the occurrence is in a marine series and therefore indicates that the deposit is not the Colorado Plateau type but a surface enrichment of the bituminous shale type. Althausen (1956) pointed out that the Kara Tau carnotite deposit is a geosynclinal facies of the Cambrian-Ordovician black shales and contains relatively high concentrations of Mo, V, P, Ba, and Sr. The Kara Tau carnotite deposit extends over 70 to 80 kilometers, varies in thickness from 0.6 to 6.0 meters, and ranges in grade from 28 to 32 percent P_2O_5 (Heinrich, 1958). Bain (1950) stated that the Kara Tau deposit follows a 10- to 14-meter siliceous black shale zone for 25 to 35 kilometers (from Tyurin, 1944); that the tyuyamunite and metatorbernite are in fissure zones localized by fold structures; that dolomite and marble are interstratified with the black shale; and that the ores are confined fairly close to the source stratum. The deposits were discovered in 1940-1941 (Tyurin, 1944; Shimkin, 1949).

Tyuyamunite and torbernite occur in bright, greenish-yellow coatings in rock fractures along a narrow band in Cambrian, highly folded black shale and slate; roscoelite is the principal mineralization in the slate, and uranium is in scattered irregular pockets in the vanadium-rich band (Nininger, 1955). Other minerals present are calcite, gypsum, barite, quartz, and limonite. The uranium is believed to have been deposited by ground waters which removed it from adjacent very low-grade uranium-bearing shales similar to the Chattanooga Shale (Nininger, 1955). At Suleytan Say the uranium is leached from the shale and precipitated by a lead ore as a uraniferous vanadinite. Suleytan Say may have 460 metric tons U (600 tons) in surface enriched ore of grade 0.05 percent U_3O_8 along about 10 kilometers of outcrop and 7,690 metric tons U (10,000 tons of U_3O_8) in rock of grade 0.01 to 0.02 percent U_3O_8 (Bain, 1950).

References: Althausen, 1956; Bain, 1950; Borkov and others, 1971; Kohl, 1954; Nininger, 1955; Shimkin, 1949; Tyurin, 1944.

Symbol: 104BPL
Name: Kara-tau phosphates, Kazakh S.S.R., U.S.S.R.
Location: 43° 30' 00" N; 070° 30' 00" E
Description: Paleozoic uraniferous phosphorite deposits, similar to the Permian Phosphoria Formation of Western United States and the phosphorite deposits of North Africa, occur about 300 kilometers southeast of Chiili, southern Kazakstan.
References: British Sulphur Corp., Ltd., 1971.

Symbol: 105ASL
Name: Krivoi (or Krivoy) Rog iron deposit area, Ukrainian S.S.R., U.S.S.R.
Location: 48° 23' 00" N; 034° 10' 00" E
Description: Uranium mineralization is within the border facies of the iron ore deposits ("iron-uranium formation"), and occurs in quartzites and similar rocks of the Precambrian (Kotlyar, 1961; Ruzicka, 1971). The host rocks are migmatized and altered by aegirinization, rhodusitization, albitization, and carbonatization, and they carry also hematite-magnetite mineralization, according to Ruzicka (1971), who also states that the orebodies are (1) stratiform bodies within albitites comprising uraninite, magmatite, hematite, aegirine, rhodusite, malacon, pitchblende, uranium silicate, aragonite, and graphite; (2) lenticular accumulations of magnetite, hematite, carbonate, and uraninite; (3) irregular accumulations of albite, dolomite, and uraninite; or (4) irregular accumulations of albite, amphibole, aegirine, and malacon. The Novaya uranium mine at Zheltya Vody in Dnepropetrovsk Oblast' is a large producer (Baroch, 1967). Uranium occurs as impregnations and coatings on sand grains and in fractures in quartzites and related rocks of Precambrian age. Uranium minerals are uraninite, pitchblende, and nenadkevite; associated minerals are magnetite, hematite, aegirine, rhodusite, malacon, aragonite, graphite, pyrite, galena, marcasite, quartz, and carbonates (Ruzicka, 1971). Uranium mineralization is related to the alkaline-silicate and carbonate metasomatism (Ruzicka, 1971). Iron-rich formation occurs in the Krivoy Rog Group in the basal conglomerates of the Skelevatka Formation; the Pb-isotope age of the uranium-bearing sulfides is 2,600-2,700 m.y. (Tugarinov and Voytkevich, 1970).
References: Barnes and Ruzicka, 1972; Baroch, 1967; Gershoyg and Kaplun, 1970; Kotlyar, 1961; Ruzicka, 1971; Tugarinov, 1975; Tugarinov and Voytkevich, 1970.

Symbol: 106BBL
Name: Popovka River region, Russian Platform, U.S.S.R.
Location: 59° 00' 00" N; 031° 30' 00" E
Description: The Popovka River region east of Leningrad is reported to have by radiometric measurement up to 0.21 percent U_3O_8 in secondary sedimentary deposits in marine uraniferous shales that accumulated slowly in oxygen deficient bottom water, but the chemical assays give only a tenth of this amount (Bain, 1950; Shimkin, 1949; Westergard, 1944), with 0.008 to 0.03 percent U_3O_8. The Leningrad shales are not enriched, have great regularity, and are amenable to open pit mining over 100 square kilometers (Bain, 1950). Black carbonaceous marine <u>Dictyonema</u> shales of Late Cambrian age may contain 76,900 metric tons U (100,000 tons U_3O_8) (Bain, 1950; Roubault, 1958).
References: Bain, 1950; Heinrich, 1958; Orlov and Kurbatov, 1934, 1935, 1936; Popov, 1939; Roubault, 1958a; Westergard, 1944.

Symbol: 107BDL
Name: Novograd Volynskii and Berdyansk-Mariupol', Ukranian S.S.R., U.S.S.R.
Location: 47° 00' 00" N; 037° 00' 00" E
Description: The uranium magnetite-allanite pegmatites, particularly in the areas of Novograd Volynskii (50°30' N., 27°40' E.) and Berdyansk-Mariupol' (46°40' N., 36°50' E. to 47°N., 37°30' E.), and the Paleozoic carbonatite veins in the alkalic hornblende granite pluton, Mariupol Massive, have deposits similar to the Mountain Pass, California, rare-earth deposits (Pecora, 1956). Radioactive minerals are allanite, wiikite, euxenite, and zircon. Associated minerals are parisite (carbonates), fluorite, quartz, chalcedony, sphalerite, galena, chalcopyrite, argentite, cerrussite, covellite, limonite, calcite, and mariupolite.
References: Fersman, 1940; Pecora, 1956; Shimkin, 1949; Tsarov'skiy, 1939.

Symbol: 108BSS
Name: Agalyk, Uzbek S.S.R., Central Asia, U.S.S.R.
Location: 39° 32' 00" N; 066° 52' 00" E
Description: Uranium-vanadium ores, principally tyuyamunite, are of primary deposition, and possibly secondary hydrothermal deposition (Gotman, 1937; Shimkin, 1949). Zilberminte and Somoilo (1934) pointed out that tyuyamunite (67° 15' E., 39° 30' N.), discovered in 1933, occurs finely disseminated and in spots in cracks and cavities in dark gray Paleozoic limestone; uranium persists to at least 2 m; and reddish granitic and aplitic veins cut limestone and overlying schist nearby.
References: Gotman, 1937; Shimkin, 1949; Zilbermints, 1935; Zilbermints and Somoilo, 1934.

Symbol: 109DSM
Name: Aldan gold fields, Siberian platform, U.S.S.R.
Location: 58° 00' 00" N; 125° 00' 00" E
Description: In gold placers of the Aldan region, on the Aldan River of the South Yenessei, monazite occurs (Heinrich, 1958). Davidson (1953) has reported that the radioactivity of Russian gold placer samples average 0.005 percent eU_3O_8. The radioactive minerals are monazite, thorite, xenotime, samarskite, blomstrandine, and zircon. Bain (1950) estimates that 3,000 tons of monazite could be obtained annually as byproduct to recovery of 56,700,000 grams of placer gold.
References: Bain, 1950; Davidson, 1953; Heinrich, 1958; Kazarinov, 1967; Shimkin, 1949.

Symbol: 110ADS
Name: Khamar-Daban Range, Siberian Platform, U.S.S.R.
Location: 51° 40' 00" N; 103° 35' 00" E
Description: At Slyudyanka (or Skjudyanka) at the western edge of Lake Baikal (or Lake Baykal), a phlogopite mica deposit in upper Proterozoic (Nalivkin, 1960, p. 36) pegmatite veins, mendelyeevite (a titanian, betafite, niobium-tantalum-uranium mineral) has been identified (Luchitsky and his collaborators, 1939). Paone (1959) reported that in 1958 betafite deposits containing uranium, calcium, columbium, and tantalum were mined at Slyudyanka. The productive sector, Zayavka No. 5, consists of a large mass of Precambrian crystalline limestones, penetrated by a 200-meter-thick band of biotite and biotite-granitic gneisses, which in turn are interlaced by a thick pattern of pegmatite veins in which mendelyeevite is found (Shimkin, 1949). The bulk of phlogopite veins in the sector Zayavka No. 5 are associated with the pegmatite-gneiss zone of contact. The mendelyeevite is strikingly similar to betafite and allied niobium-tantalum-uranium minerals of Madagascar. Radioactive minerals are betafite, allanite, and zircon. Total uranium-oxide content in samples from Slyudyanka ranged from 19.70 to 28.90 percent (Shimkin, 1949). At Emeldzhik (approx. 58°22' N., 126°40' E.), Kuranakh (58°46' N., 125°35' E.), and Chuga or Ust Nelyuka (58°06' N., 123°00' E.), major phlogopite mica deposits in the Aldan gold field area have been found (Shimkin, 1949). The South Africa Mining and Engineering Journal (1957) predicted 2,000 tons of metal per year would be produced in southern Siberia by 1960.
References: Luchitsky, 1939; Nalivkin, 1960; Paone, 1959; S. Africa Min. and Engr. Jour., 1957; Shimkin, 1949.

Symbol: 111BSM
Name: Ukhta, North Russia, Russian Platform, U.S.S.R.
Location: 63° 35' 00" N; 053° 40' 00" E
Description: The Ukhta reserves in permeable sediments might well be producing 2,000 tons of metal a year; the Uchta (or Ukhta) plant (Bain, 1950; Nikitin, 1936), using radioactive waters, had about 1 gram radium capacity. Bain (1950) pointed out that Fersman (1928a) held the opinion that the radium in Ukhta salt water and petroleum came from the pre-Devonian crystallines of the Timan Range; but that it seems much more probable that the radium came from uranium in the petroleum source rocks and left them not more than a millennium ago. The Paleozoic oil-bearing marine formations, including those of Ukhta, have an interesting parallel with the Ferghana (or Fergana) uranium deposits as a group, and with the Tyuya Muyun deposit in particular, in that all three have high concentrations of radium, meso-thorium, and barium (Shimkin, 1949; Osipov, 1941).
References: Bain, 1950; Fersman, 1928a; Nikitin, 1936; Osipov, 1941; Shimkin, 1949.

Symbol: 112ADL
Name: Kola Peninsula, U.S.S.R.
Location: 67° 50' 00" N; 035° 00' 00" E
Description: Apatite, rare-earth, and vanadiferous titanium deposits occur in Paleozoic alkalic rocks and Precambrian pegmatites. Pyrochlore occurs as disseminated grains in alkali granite, syenite, nepheline syenite, and various other alkalic, silica-deficient dike rocks at Khibina Tundra, Kola Peninsula (Heinrich, 1958). In the Khibina (or Khibiny) igneous complex intrusion and in associated plutons of nepheline syenites, carbonatites, and related rocks in the Kola Peninsula, carbonate veins and mineralogically famous pegmatite contain minerals of low radioactivity which include lovchorite (or khibinite or rinkite), loparite, vudyavrite, calciorinkolite, fersmite, eudialyte, yuksporite, steenstrupine, sphene, and zircon. Uncommon rare-earth silicates also occur at the Lovozero Tundra area of the Kola Peninsula, in nepheline syenite, in the Baltic part of Scandinavian Shield (Heinrich, 1958; Pecora, 1956; Roubault, 1958a). Associated minerals are albite, pectolite, lepidomelane, sodalite, calcite, fluorine, chalcopyrite, pyrrhotite, sphalerite, galena, cancrinite, apatite, lamprophyllite, astrophyllite. Associated commodities are thorium, phosphate, rare earths. British Sulphur Corporation Limited (1971) states that the Khibiny nepheline-syenite complex, in the approximate center of the Kola Peninsula, is the source of 60 to 70 percent of all Russia's phosphatic raw materials. In the Murmansk area of the Kola Peninsula, uranium is associated with thorium in the alkalic rocks (Bulakh and others, 1974).
References: Bain, 1950; British Sulphur Corp., Ltd., 1971; Bulakh and others, 1974; Heinrich, 1958; Pecora, 1956; Roubault, 1958a; Sheldon, 1969; Sorensen, 1970b.

Symbol: 113ADS
Name: Northern Karalian A.S.S.R., U.S.S.R.
Location: 66° 30' 00" N; 033° 00' 00" E
Description: At Chupa district, about 275 kilometers south, and Louchsk, 135 kilometers southeast of Murmansk (or Mourmansk) in Northern Karalia and in the Kola Peninsula, uraniferous pegmatites (feldspar and mica deposits) occur (Roubault, 1958a, fig. 125) in Precambrian quartz-oligoclase-biotite gneiss and massive amphibolite. The structure of some of the pegmatites is quartz cores, feldspathic intermediate zones and wall zones with oligoclase (Borisov, 1937; Fersman, 1940; Grigoriev, 1935; Heinrich, 1958). Ores occur in an area of acidic paleo-volcanism and intrusive rock complexes of the Baltic Shield. Radioactive minerals include pitchblende, uraninite, allanite, thucolite, zircon, xenotime, monazite, and gummite. Associated minerals are tourmaline, garnet, magnetite, apatite, and pyrite.
References: Borisov, 1937; Fersman, 1940; Grigoriev, 1935; Heinrich, 1958; Roubault, 1958a; Ruzicka, 1971.

Symbol: 114BBS

Name: Lake Onega area, south Karelia, Karelian A.S.S.R., U.S.S.R.

Location: 62° 00' 00" N; 034° 00' 00" E

Description: Uraninite(?), uraniferous turquoise(?), kolorratite, volborthite, and molybdenum (up to 46 percent) and vanadium minerals occur in black, carbonaceous, graphitic marine shales, asphaltite, and uraniferous peat (shungite, 98.77 percent carbon) (Roubault, 1958) of late or middle Paleozoic age.

References: Prigorovskiy, 1939, 1940; Roubault, 1958a.

Symbol: 115AGL
Name: East Rand, Witwatersrand, Transvaal, Republic of South Africa, Africa.
Location: 26° 25' 00" S; 028° 40' 00" E
Description: Peneconcordant uranium deposits, associated with pay amounts of gold in the Witwatersrand Basin, a wide shallow basin formed by an inland sea, occur in a number of horizons throughout the Precambrian System in the Dominion Reef, Witwatersrand, Ventersdorp, and Transvaal (rock) Systems. Ridge (1975) described the Witwatersrand Basin, in the South-central Transvaal and the northern Orange Free State, as having the shape of a curved sausage, convex to the northwest, that is just over 290 km long in a north-northeast direction, with the ends of the sausage wider than its central part. Pretorius (1974) stated that the Kaapvaal craton, one of the two ancient Archean nuclei that are made up of granite-greenstone terranes and are located to the east and northeast of the Witwatersrand Basin, underwent its last metamorphism between 3000 and 3250 m.y. ago; that most of the Archean (pre-Witwatersrand) formations on the Kaapvaal craton were deposited under marine conditions; that in the Proterozoic, however, the basins were shallow; and that the Witwatersrand Basin is one of the 5 that were formed on the craton between 3250 and 1750 m.y. ago. Crustal instability in the craton area is shown by volcanic beds that are associated with the Proterozoic rocks (Ridge, 1975).

Within the Witwatersrand Basin are six major goldfields; these are, from southwest, clockwise around the basin: Welkom (Orange Free State), Klerksdorp, Carltonville (Far West Rand or West Wits line), West Rand, East Rand, and Evander. The uranium in the Witwatersrand reefs is so low in grade (280 ppm) that to be mined profitably it had to be mined and crushed in the process of gold recovery. The number of reefs that are mined in a given field (fan) ranges from 1 in the Evander to 10 in the Klerksdorp and West Rand fields. Ridge (1975) pointed out that the term "reef" or "banket" is applied in South Africa to a stratified quartz-pebble conglomerate in which valuable minerals, mainly gold and uraninite, are confined largely to the conglomerate matrix; and explained that the minor amounts of gold in fractures in the pebbles or in quartz veins associated with or included in the reef are not considered to vitiate this definition.

Pretorius (1974) indicated that all of the gold fields are confined to fluvial fans that are intermediate in character between alluvial fans and classic deltas; that each of these fluvial fans was developed at the interface between a fluvial system and a shallow-water, lacustrine, or inland-sea environment; and that the fluvial fans were deposited in an enclosed continental basin that had no connection to the open ocean. All the fluvial fans were developed south or southeastward from the fault-bounded (northwest) margin of the basin in which deposition took place; the southeastern rim of the basin was much less active tectonically and was downwarped rather than downfaulted; the sediment source was to the northwest; and sedimentation was by northwest-to-southeast-flowing rivers (Ridge, 1975). In the coarser portions of the fans, braided stream patterns generally were developed, with the channel usually containing the coarsest materials. The average channel is less than 60 cm deep. Arenaceous sediments in the channels are crossbedded, the units range between 5 and 100 cm thick, and the foresets dip between 18° and 25°.

The three periods of basin infilling in the Witwatersrand were, in order, 1) volcanic materials, with only limited amounts of interbedded continental shallow-water sediments, 2) dominantly shallow water and continental, and 3) mainly volcanic material during renewed crustal instability (Ridge, 1975). In the over 12,000 m of sediment in the stratigraphic column of the basin, the sand:shale ratio is 1.9:1, and that of volcanics to sediment is 0.8:1 (Ridge, 1975).

The chief uranium mineral is uraninite except in the Dominion Reef Systems. The mineralization of the Dominion Reef is typically placer, with a heavy mineral assemblage consisting of monazite and cassiterite with smaller amounts of chromite, garnet, zircon, and ilmenite; the uranium-bearing minerals are thorianite, uraninite, brannerite, uranothorite, and weakly active columbo-tantalite (Bowie, 1970). Overlying the Dominion Reef System is the Witwatersrand System, which is nearly 7,700 meters thick in the Central Rand. Uranium occurs in five main uranium-bearing horizons in the form of pitchblende grains which average 50 micromillimeters in diameter and are associated with gold, pyrite, various sulfides, sericite, chlorite, chloritoid, and oxyhydrocarbon. Smaller amounts of pitchblende occur in the Contact Reef at the base of the Ventersdorp System and in the Black Reef, which is at the base of the Transvaal System (Bowie, 1970). In the Witwatersrand System ore occurs in about a dozen thin conglomerate beds, mainly in the Upper subdivision (predominately quartzite), the chief ones being in the Main-Bird series, which has three payable members--Main Reef, Main Reef Leader, and South Reef--each 0.3 to 3 meters thick. In the Witwatersrand System the distribution of gold and uraninite is clearly related to sedimentary features. Most commonly the ore horizons are in quartz-pebble conglomerate beds, continuous over considerable areas, that rest on unconformities or intraformational breaks in sedimentation; but not infrequently the higher grade concentrations are at the top of the conglomerate bed (Bowie, 1970). All exploitable reefs occur on, immediately above, or immediately below an unconformity (Ridge, 1975). Concentrations occur too in stream-channel fillings and in isolated lenticular bodies of conglomerate (Bowie, 1970). Other uranium minerals present in the Witwatersrand area are gummite, schoepite, uranophane, zippeite, schroekingerite, thucolite, brannerite, uranothorite, columbo-tantalite, davidite, thorian uraninite, and also uranium-bearing leucoxene and zircon. Associated minerals are pyrite, monazite, cassiterite, chromite, garnet, zircon, ilmenite, sericite, chlorite, and chloritoid.

In a particular area, usually only one or two beds are ore-bearing. The beds are folded, faulted, and cut by dikes and numerous quartz veins. The pebbles, averaging 70 percent of the conglomerate and under 2.5 centimeters in size, are quartz, quartzite, jasper, quartz porphyry, tourmaline rock, and rare slate and schist. The ore is mineralized conglomerate matrix consisting mostly of pyrite (3 to 12 percent), gold, sericite, chlorite, chloritoid secondary quartz, and pitchblende and thucolite. The conglomerates, in elongated shoots as much as 300 meters wide and 1,500 meters long, are considered to be deposited in well-defined channels in which material was transported from the northwest and west, with the axes in a fan-shaped arrangement, open to the east and southeast in the Central and East Rand (Heinrich, 1958).

Three general theories (Heinrich, 1958; Liebenberg, 1958) advocated for the origin of Rand ores are (1) gold is of direct placer origin; (2) gold, uraninite, and most of the other metallic minerals were introduced by hydrothermal solutions under mesothermal conditions; and (3) gold was initially deposited with the gravels together with hydrocarbons, iron minerals, and detrital species, sulfur was introduced subsequently to form sulfides, and gold was recrystallized and somewhat redistributed. Miholič (1954) suggested that the destruction of an accumulation of uranium-concentrating microorganisms under anaerobic conditions gave rise to thucolite, uraninite, and pyrite; and gold was precipitated later by the organic material from "thermal waters." Ridge (1975) pointed out that conceivably the Buschveld and Vredefort igneous rocks well may be the top of a huge igneous mass that centers under the basin and could have provided a source for the gold-bearing hydrothermal solutions; and that heated magmatic and connate waters could have moved through the conglomerate and deposited not only the irregularly shaped gold but also the rounded forms of pyrite and uraninite, the latter two by replacement of quartz pebbles. Ridge (1975) classified the gold in the conglomerate, as well as the gold in the carbon derived from the algal mats, as mesothermal. He further suggested that because of the association of uraninite with the higher-temperature minerals rather than directly with the gold, the uraninite should be classified as hypothermal in non-calcareous rocks, but he stated that the problem is still unresolved. Whiteside (1970a) discussed the age and distribution, characteristics and mineralogy of the conglomerates which occur in the four systems: Transvaal, Ventersdorp, Witwatersrand, and the Dominion Reef.

The age of the Witwatersrand System is between 2800 m.y. and 2500 m.y. (Ridge, 1975). The age range of the Witwatersrand uraninites is between 2250 and 1820 m.y. (Burger and others, 1962). Ridge (1975) considered the age of the Witwatersrand uraninites as the best evidence as to the age of the gold-uraninite mineralization -- some 2085 m.y. or the latter part of the middle Precambrian. Included in the East Rand is Daggafontein.

References: Bain, 1950; Bosazza, 1959; Bowie, 1958, 1968, 1970; Brabers, 1971; Brock and Pretorius, 1964; Brock and others, 1957; Burger and others, 1962; Coetzee, 1965; Cousins, 1972; Davidson, 1953, 1955, 1956b, 1957, 1959, 1960a, 1962, 1964, 1964-1965, 1966; Davidson and Bowie, 1951; Davidson and Cosgrove, 1955; de Kun, 1965; Du Toit, 1954; Emmons, 1937; Engr. and Mining Journal, Nov. 1972; Fisher, 1938-1939; Fuller, 1960; Graton, 1930; Heinrich, 1958; Hoefs and Schidlowski, 1967; Koen, 1958, 1961, 1964; Liebenberg, 1955, 1957, 1958, 1960; Louw, 1954; McWhirter, 1956; Miholič, 1954; Myers, 1971; Nel, 1958, 1959, 1960; Nicolaysen and others, 1962; Pelletier, 1964; Pretorius, 1964a, 1964b, 1974; Schidlowski, 1966, 1966a, 1966b, 1966c, 1966d; Strauss and Truter, 1951a, 1951b; Toens and Griffiths, 1964; Villiers and others, 1958; Wagener, 1972; Whiteside, 1964, 1970a, 1970b.

Symbol: 116AGL
Name: West Rand, Witwatersrand, Transvaal, Republic of South Africa, Africa.
Location: 26° 13' 00" S; 027° 48' 00" E
Description: Includes Randfontein and West Rand Cons. See No. 115.
Reference: See No. 115.

Symbol: 117AGL
Name: West Wits Line, Witwatersrand, Transvaal, Republic of South Africa, Africa.
Location: 26° 25' 00" S; 025° 35' 00" E
Description: Includes Blyvooruitzicht, W. Driefontein. See No. 115.
Reference; See No. 115.

Symbol: 118AGL
Name: Klerksdorp, Witwatersrand, Transvaal, Republic of South Africa, Africa.
Location: 26° 56' 00" S; 026° 47' 00" E
Description: The Klerksdorp area (Klerksdorp town is 26°52' S., 26°39' E.) is 160 km southwest of Johannesburg and 112 km northwest of the Welkom goldfield (Ridge, 1975).

Ridge (1975) reported that as in the Central Rand, the Upper Division of the Witwatersrand System is divided into the Main-Bird Series (below) and the Kimberly-Elsburg Series (above); and the rocks of the Upper Division are thickest in the southeast part of the Klerksdorp area and thin toward the northwest and north. The Main-Bird Series is divided into, from bottom to top, the following stages: 1) the Main Reef, 2) the Livingston Reef and 3) the Vaal (Bird) Reef. The Vaal Reef zone is from 182 meters to 274 meters thick overall, and probably correlates with the Basal Reef in the Orange Free State and with the Bird Reefs of the West Rand, possibly the Monarch Reef (Ridge, 1975). The Vaal Reef at the base of the Vaal Reef zone ranges from a carbon parting in the northeast part of the district to a 1.2-meter-thick, well-developed reef in the southeast. The pebbles are from 0.6 to 1.2 centimeters in diameter, are closely packed, and have a strongly pyritic matrix. Carbon generally is present, and visible gold is rare. Uraninite is uniformly disseminated throughout the reef. Quartz pebbles are sheared in many places, and these contain flakes of pyrite and minor gold. The Vaal Reef proper is consistently mineable over a large part of the district (Ridge, 1975).

The greater portion of the area underlain by the Vaal Reef forms an elliptical basin that is elongated in a northeast-southwest direction; this elongation is generally parallel to the axis of the much larger regional Transvaal syncline. On the northwest and southwest margins, the basin is cut off by the Buffelsdoorn and Kromdraai faults, respectively (Ridge, 1975).

Ridge (1975) pointed out that if the ores are reworked placer minerals, the age of the placer deposits probably is late early Precambrian, but if it is epigenetic, it is almost certainly middle Precambrian.

Total production to 1964 was 21.5 million pounds of U_3O_8. The production of uranium oxide (as U_3O_8) is far larger in the Klerksdorp reefs than in any other area on the Rand; in 1971, about 4.93 million pounds of U_3O_8 were recovered from the ores of five Klerksdorp mines, Buffelsfontein, Hartebeestfontein, Vaal Reefs, Western Reefs, and Zandpan, with a weighted average grade of 0.593 pounds per ton of ore (Ridge, 1975). See No. 115.
References: Hiemstra, 1968a, 1968b; Krige, 1966; Nel and others, 1937; Ridge, 1975; Wilson and others, 1964. Also see No. 115.

Symbol: 119AGL
Name: Witwatersrand, Orange Free State, Republic of South Africa, Africa.
Location: 28° 06' 00" S; 026° 55' 00" E
Description: The gold-uranium mines of the Welkom (Orange Free State) field lie in an area south of the town of Allanridge (27°45' S., 26°40' E.) that extends southeast through Odendaalsrus and Welkom to about 8 km south of Virginia (28°06' S., 26°53' E.) (Ridge, 1975). The actual mining area is about 30 km in length, and the 11 producing mines in 1969 included Harmony, President Brand, and Virginia. In the entire Welkom area, the rocks of the Upper Division of the Witwatersrand System are divided into the Main-Bird Series (below) and the Kimberley-Elsburg Series (above). The broad north-south syncline along the west margin of the district appears to be the oldest structural feature; its formation predated the folding, thrusting, and reverse faulting of which the Merriespruit fault is the major example (Ridge, 1975).

Gold ore in the Welkom area (Schidlowski, 1968) is mostly in the bottom parts of the reefs in a layer only 2 to 3 mm thick. The gold ore is associated with thin layers of carbon that immediately underlie the conglomerate of the Basal reef. The carbon, known as thucolite, is a form of once mobile hydrocarbons, polymerized by the ionized radiation coming from the uraninite in the banket. The gold is associated with pyrite, arsenopyrite, zircon, uraninite, and the carbon. Gold is later than the grains it penetrates or surrounds.

Ridge (1975) discussed the theories of origin of the gold and uraninite, including works by Schidlowski, Davidson, and Graton, and considers that the gold in the Welkom reefs, and in the Witwatersrand proper, was deposited hydrothermally and under mesothermal conditions, but that the uraninite was deposited in the hypothermal range in non-calcareous rocks. Further, if either gold or uraninite is to be considered detrital, Ridge would prefer to consider uraninite to be detrital, as he accepts the concept that the atmosphere was sufficiently oxygen-free at the time the placers were formed to allow uraninite to be water-transported without the uranium oxidizing to U^{+6}. Ridge (1975) pointed out that if the modified placer concept of the origin of the ores, favored by most South African geologists, is adopted for the Welkom (Orange Free State) portion of the Witwatersrand gold-uranium ores, they must be early Precambrian in age; but if the gold, uraninite, and the possible non-detrital minerals associated with them are thought to have been introduced hydrothermally, their age probably is middle Precambrian.

As of September 1974, President Brand mine had built up an inventory of 841,463 metric tons of uranium-bearing slimes grading an average of 0.14 kg of uranium per ton (Engineering and Mining Journal, 1975, v. 176, no. 9, p. 216).
References: Engineering and Mining Journal, 1975, v. 176, no. 9, p. 216; Hugo, 1963; Nicolayson, 1962; Ortlepp, 1962; Ridge, 1975; Schidlowski, 1966; Siems, 1961; Simpson, 1951, 1952;

Winter, 1962, 1963, 1964a, 1964b. Also see No. 115.

Symbol: 120ADM
Name: Palabora (or Phalaborwa), Transvaal, Republic of South Africa, Africa.
Location: 24° 01' 00" S; 031° 08' 00" E
Description: The deposit is located 112 kilometers west of the Mozambique border, near Phalaborwa, Letaba district, northeastern Transvaal. Small concentrations of baddeleyite and uranothorianite occur in the phoscorite and carbonatite of the Palabora Igneous (carbonatite) Complex, a vertical pipe, intrusive into the granite gneiss of Archean age. The complex includes pyroxenite, feldspathic syenite, olivine-diopside-phlogopite, pegmatoid fenite, and carbonatite. The pyroxenite was intruded first, followed by the syenite and lastly by a centrally located core of a transgressive carbonatite, which is surrounded by a serpentine (olivine)-magnetite-apatite rock to which the name "phoscorite" has been given. Associated minerals are zircon, magnetite, apatite, orthoclase, diopside, phlogopite, olivine, chondrodite, chalcopyrite, chalcocite, and bornite. Associated commodities are phosphate, copper, apatite, vermiculite, magnetite, and thorium. The uranium, mined as a by-product, averages about 0.004 percent (von Backström, 1974).
References: Bowie, 1970; British Sulphur Corporation Limited, 1971; de Kun, 1965; Engineering and Mining Journal, 1972, p. 125; Hanekom and others, 1965; Hiemstra, 1955; Strauss and Truter, 1951a, 1951b; von Backström, 1974.

Symbol: 121ADL
Name: Rössing, Namib desert, Namibia (formerly South West Africa), Africa.
Location: 22° 41' 30" S; 014° 15' 10" E
Description: Rössing, about 55 kilometers northeast of Swakopmund, on the Namib Plain, near the edge of the Khan River canyon, is an alaskite pluton, "porphyry" type, in which the uranium host rocks of Precambrian Lower Hakos Stage are alaskite, graphic granite, and biotite granite that intrude metamorphic rocks and are cut by numerous alaskitic pegmatites (Armstrong, 1974; Smith, 1965; von Backström, 1970). Where pegmatites transgress across biotite-rich (quartz-biotite and biotite-amphibole) schist bands, they are commonly uraniferous (von Backström, 1970). The mineralized area is irregular in shape and about 700 meters in diameter. The ore occurs finely disseminated in the host rocks and in occasional small stringers; uraninite is the principal ore mineral in unweathered rock, and occurs in grains a few microns to 0.3 millimeters in diameter as inclusions in quartz, feldspar, and biotite, and also as free grains (von Backström, 1970). Uraninite of primary origin constitutes about 55 percent of the radioactive minerals present, and unleachable betafite is less than 5 percent; secondary minerals (40 percent) are mainly beta-uranophane, metatorbernite, metahaiweeite, uranophane, carnotite, thorogummite and gummite, which are present mainly along joints, cracks, and boundaries in the quartz and feldspar and between the flakes of biotite (Hiemstra, 1969; von Backström, 1970). Uraninite, betafite, and biotite from the host rock have all been dated provisionally as 510 ± 40 million years old (Nicolayson, 1962; Armstrong, 1974; von Backström, 1970). Most of the radioactive minerals are exposed and easily leachable (von Backström, 1970). Von Backström (1970) reports that several million tons of low grade (0.05 weight percent U_3O_8) mineralization were proven; and Ruzicka (1975) estimates that the Rössing mine contains reserves of about 150,000 tons of U_3O_8 in ore grading 0.7 lb./ton.

Louw's and S J Claims (22°29' S., 15°03'03" E.), Namib desert, are large pegmatite bodies. In the Louw's claim, davidite occurs at the contact zone of two quartz lenses intruded along the schistosity planes of a lit-par-lit biotite-muscovite gneiss derived from highly metamorphosed Damara sediments (von Backström, 1970). Associated minerals are tourmaline, aquamarine, cassiterite, zircon, monazite, minor pyrite, chalcopyrite, molybdenite, ilmenite, magnetite, rarely fluorite, and hematite.
References: Armstrong, 1974; de Kun, 1965; EM/J, 1975, v. 176, no. 1, p. 31; Hiemstra, 1969; Nicolayson, 1962; Pelletiere, 1964; Rich and others, 1975; Ruzicka, 1975; Sherman, 1972; Smith, 1965; von Backström, 1970; Williams, 1974; World Mining, 1974.

Symbol: 122DSL
Name: Namib desert, Namibia, Africa.
Location: 22° 50' 00" S; 015° 00' 00" E
Description: In an area more than 25,000 square kilometers in the vicinity of the Rössing uranium deposit, secondary uranium minerals, oriented around the included grains, impregnate Holocene(?) calcrete, recemented granitic material derived from basement rocks, weathered biotite gneiss, pegmatite, quartzite, granulite, and biotite schist (von Backström, 1970). Calcrete consists of pebbles of surface limestone; grains of quartz, feldspar, muscovite, and biotite derived from pegmatite; and chips from the basement rocks, all cemented by lime and gypsum (von Backström, 1970). Carnotite is the only uranium mineral present as encrustations, fracture fillings, and joint coatings (von Backström, 1970). Associated minerals are minor amounts of zircon, magnetite, apatite, and secondary carbonates; the feldspars are all highly altered to kaolinitic and sericitic material (von Backström, 1970).
References: Smith, 1965; von Backström, 1970.

Symbol: 123AVL
Name: Shinkolobwe (Kasolo), Swampo, and Kalongwe in Zaïre, Africa.
Location: 11° 07' 00" S; 026° 30' 00" E
Description: At Shinkolobwe deposit, in the southeastmost part of the Republic of Zaïre, about 100 km west-northwest of Lubumbashi (Elizabethville), about 20 km west of Likasi (Jadotville), and 20 kilometers south of Kambove, the uranium minerals and associated cobalt, silver, nickel, bismuth, and arsenic assemblages occur as veins of massive sulfide ore up to 1 meter in thickness but usually much less; frequently as narrow but closely spaced veinlets giving rise to stockworks along fractures, bedding planes, joints, and minor faults; as breccia cement; as replacement masses and nodules; and as disseminated grains in chiefly dolomitic shale and siliceous dolomite in the lower bed of the Precambrian Mine Series (Série des Mines). The Mine Series has been folded into a generally northwest-trending series of asymmetric anticlines and synclines in an arc known as the Katanga synclinorium, about 320 kilometers by 105 kilometers at its widest. The deposit is located where the folding is close and isoclinal in the fault-bounded structural blocks within the Mine Series wedge where the axis trend changes from northwest to west and even slightly south of west. Talc and chlorite in the Mine Series are the result of low-grade metamorphism. Silicification in the Mine Series is a common feature. The ascending uraniferous solutions penetrated along a zone of inclined dolomitic shales, and expanded sub-horizontally under a nappe, the dome of the R.A.T. (Roche Argilotalqueuse) (de Kun, 1965, p. 339), which crosscuts the Mine Series (Derricks and Vaes, 1956). At depth, the deposits consist partly of massive uraninite and partly of uraninite which is associated with nickel and cobalt sulfides. The uraninite always is crystalline (colloform not observed) (Derricks and Vaes, 1956). Cubes of uraninite, generally not over 1 centimeter but occasionally 4 centimeters, are fairly common in the open fissures of the massive veins or in the wall rock. In the uraninite veins there are few associated minerals. Several veins contain native gold. Toward the surface, the uraninite is altered to secondary minerals, and the majority of these secondary minerals occur only as replacements of the uraninite in situ (Derricks and Vaes, 1956). The ore minerals are very varied and include, in addition to uraninite or pitchblende, sulfides of copper, cobalt, and nickel together with molybdenite, pyrite, gold, and minerals of the platinum group. Many new uranium minerals which were recognized for the first time at Shinkolobwe, include ianthinite, becquerelite, schoepite, curite, fourmaierite, masuyte, vandendriesschéite, richetite, bielietite, kasolite, soddyite, sklodowskite, cuprosklodowskite, dewindtite, dumontite, renardite, parsonsite, saleite, sharpite, studtite, and diderickite (Derricks and Vaes, 1956). Before World War II Shinkolobwe supplied most of the world's radium, and it was largely from

uranium from this deposit that the first atomic bombs were manufactured (Pellitier, 1964). The gangue consists of dolomite, magnesite, chlorite, and subordinate quartz. Primary minerals include cattierite (CoS_2) and vaesite (NiS_2), which were recognized for the first time at Shinkolobwe (Derricks and Vaes, 1956). Copper is present almost everywhere in Shinkolobwe, but in such minute quantities that Shinkolobwe is not regarded as a copper-bearing deposit; but cobalt is abundant (Derricks and Vaes, 1956), as is nickel.

Swampo deposit, 36 kilometers west of Shinkolobwe, and Kalongwe, 120 kilometers west of Shinkolobwe, are also vein deposits in Precambrian metamorphic dolomites, shales, and quartzites associated with cobalt, nickel, and copper, but smaller in size than Shinkolobwe (E.N.E.A., 1967). At Swampo, uraninite is disseminated in a transverse crush zone which cuts an ecaille of anticlinal remnants that extends from Shinkolobwe to Kalongwe (de Kun, 1965).

At Kalongwe, uranite impregnates a fault zone intersecting the Mine Series at the beginning of a three phase cycle in which cobalt, then cobalt-copper, and finally copper sulfides followed uranium. The age of this uraninite is 600 million years (de Kun, 1965), whereas the age of the mineralization at Shinkolobwe is 630 million years (Derricks and Vaes, 1956). Ridge (1975) thought that the presence of large amounts of secondary uranium (and radium-bearing) minerals formed under supergene conditions, probably in Holocene time, required that the deposits be classified also as ground water formed as well as hypothermal in calcareous rocks.

The Shinkolobwe mines, which were discovered in 1915 and began to be mined in 1921, were closed in 1960 because of the exhaustion of the ore (Ridge, 1975).

References: Bain, 1950; Bowie, 1970; Cahen and others, 1971; Darnley, 1961; de Kun, 1965; Derricks and Oosterbosch, 1958; Derricks and Vaes, 1956; ENEA/IAEA, 1967; Everhart and Wright, 1953; Gerasimovsky, 1956; Heinrich, 1958; Ledent, 1956; Malu, 1970; Oosterbosch, 1970; Pelletier, 1964; Rich and others, 1975; Roubault, 1958a, 1958b; Thoreau and du Trieu de Terdonck, 1933, 1936; Vaes, 1946-1947a, 1946-1947b.

Symbol: 124AVS
Name: Mavuzi district, Mozambique, Africa.
Location: 15° 45' 00" S; 033° 30' 00" E
Description: About 48 kilometers north of Tete, davidite, many individual crystals of which exceeded a foot in diameter, occurs as variously reported magmatic (segregation) or late magmatic replacements, epigenetic and hydrothermal, formed at high temperatures (Heinrich, 1958). The deposits were formed during the latter stages of a period of shearing that followed emplacement and complete solidification of the noritic mass, an intrusive body 48 kilometers by 128 kilometers (Heinrich, 1958). The mineralization is mainly intimately associated with shear zones, the largest of which, at Mavuzi, is about 800 meters long by 1.5 to over 12 meters wide. Along these shears the fine-grained norite has been converted to gneissic epidiorites commonly showing augen structure, in which feldspar has been extensively scapolitized, and the coarser norite converted to streaked hornblende gneisses (Heinrich, 1958). In some places the norite is cut by syenitic and pegmatitic dikes, the latter in some places injected lit-par-lit into the sheared epidioritic norite (Heinrich, 1958). The Pb-U age is 565 m.y. (Heinrich, 1958). Associated minerals are scapolite, calcite, massive white quartz, diopside, pyrite, pyrrhotite, chalcopyrite, molybdenite, rutile, sphene, magnetite, ilmenite, apatite, traces of siderite and tourmaline, vermiculite, hornblende, and albite. Thorium is present.
References: Bannister and Horne, 1950; Cavaca, 1956; Davidson and Bennett, 1950; Heinrich, 1958.

Symbol: 125DPL
Name: Cabinda and southwest Angola, Angola, Africa.
Location: 08° 00' 00" S; 014° 00' 00" E
Description: Uraniferous phosphate deposits in the Upper Cretaceous (Maestrichtian) and Eocene rocks occur in broad belts in Cabinda and southwest Angola. The deposits are typically lenticular, with a variable uranium content ranging between 0.05 and 0.20 percent U_3O_8, and resources about 11,535 metric tons U (15,000 tons U_3O_8) (Bowie, 1970).
References: Bowie, 1970; Cavaca, 1965; ENEA/IAEA, 1967; Robertson, 1970.

Symbol: 126ASL

Name: Oklo mine and others, Republic of Gabon, Africa.

Location: 01° 45' 00" S; 013° 07' 00" E

Description: The uranium deposits in southeastern Gabon, which include Mounana (or Mouhana, or Mounan) (Franceville), 90 kilometers northwest of Franceville, Oklo, Boyindzi, and Mikouloungou, Gabon (formerly French Equatorial Africa), occur in the Precambrian Francevillian Series, 1.7-1.9 billion years old, which fills a 35,000-square-kilometer basin with alternating sandstones, shales, and some conglomerate. The Francevillian Series and its uranium deposits are similar in some respects to the much younger Mesozoic sedimentary uranium deposits of the Colorado Plateau. The Francevillian Basin has remained essentially undisturbed by post-formational tectonism. Stratigraphic and tectonic controls are most apparent. The tectonics appears to have played a role in the distribution of the sedimentary deposits and then to have been a determining factor in the formation of the tectonic-sedimentary traps which conceal the concentration of economic interest. Radioactive minerals include uraninite or pitchblende, francevillite (a uranium and barium vanadate, the latter in part replaced by lead), vanadinite, melanovanadinite, corvusite, roscoelite, ferghanite, carnotite, uranopilite, and bassetite. Associated minerals are chalcocite, pyrite, galena, chalcopyrite, sphalerite, bornite, barite, calcite, wulfenite, and molybdenum mineral. Most of the ore at the Oklo mine, which is the site of a fossil sustained nuclear reactor (Brookins, 1975; Maurette, 1976), contains 0.1-0.5 percent uranium of normal ©^{235}U content. The very high grade ore, the uranium of which was apparently derived from sandstone of lower ore grade, is formed in shale which has been faulted into zones between broken and disconnected parts of a sandstone layer; all these events presumably took place relatively soon after sedimentation. Precambrian organic carbon is associated with uranium and chlorite and/or illite (or mixed layer clay minerals) in the low-grade nonreactor ore. In the high-grade reactor zones, much of the carbon has been removed and what is present has undergone extensive radiation damage. Estimates of the age of the reaction at Oklo range from approximately 100,000 years to approximately 1 million years (Brookins, 1975a).

Maurette (1976) described the Oklo deposit as having been buried most of the time under a thick layer of sediments; quite distant (about 150 km) from the nearest magmatic chamber so far identified that could both trigger the matamorphism of the sediments and inject into them hydrothermal solutions; and having ores only brought into a near-surface position in recent times but protected from extensive weathering by top layers of impermeable sediments (pellites).

The Oklo deposit is stratiform, but the Mounana and Boyindzi deposits are clearly discordant (Rich and others, 1975). Bourrel and Pfiffelmann (1972) suggested that the source of the uranium is either the nearby granitic basement (averaging 4 ppm U) or the overlying acid tuffs (average 5.7 ppm U).

The Oklo orebody measures about 900 m by 600 m by 5 to 8 m thick (Gilbert Nouet, oral comm., May 6, 1977). The uranium ores average more than 0.1 percent U_3O_8 for Mikouloungou and 0.4 percent U_3O_8 for Mounana (Sherman, 1972).

Production of uranium concentrates from the Oklo mine will be increased from the 700 metric tons of 1974 to 1,000 metric tons by 1978, according to Minister of Mines Alexis Mbouy Boutzit; and reserves at the Oklo mine are estimated at 15,000 metric tons uranium concentrates (Engineering and Mining Journal, 1975, v. 176, no. 8, p. 162).

References: Apt and Bryant, 1977; Ampamba-Gouerangue, 1970; Barnes and Ruzika, 1972; Bernazeaud, 1959; Bîgotte, 1964; Bourrel and Pfiffelmann, 1972; Bowie, 1970; Brookins, 1975a; de Kun, 1965; des Ligneris and Bernazeaud, 1960; Drozd and others, 1974; Engineering and Mining Journal, 1975, v. 176, no. 8, p. 162; ENEA/IAEA, 1967; Gabon, Dir. Mines, 1965; Gangloff, 1970; Geoffroy and others, 1964; Hagemann and others, 1974; Kuroda, 1975; Lancelot and others, 1975; Lenoble and Gangloff, 1958; Maurette, 1976; Nininger, 1973; Nouet, Gilbert, oral comm., May 6, 1977; Pfiffelman, J. P., written commun., 1974; Rich and others, 1975; Sherman, 1972.

Symbol: 127DPL
Name: Bakouma, Central African Republic, Africa.
Location: 06° 10' 00" N; 024° 30' 00" E
Description: About 100 kilometers north of Bangassou, in karst topography, in a Precambrian basin similar to that at Mounana (Franceville), Gabon. Eocene phosphorite, uncommonly rich in uranium, fills large depressions formed by solution of dolomite (Mabile, 1968). The uraniferous ores average about 0.10 percent U_3O_8.
References: Finch and others, 1973; Mabile, 1968; Nininger, 1973; Sherman, 1972.

Symbol: 128DPS
Name: Adeta and others, Togo, Africa.
Location: 08° 00' 00" N; 001° 30' 00" E
Description: Middle and lower Eocene uraniferous phosphatic rocks occur at Adeta, Kpomė (northeast of Lomė and west of Lake Togo), Hahotoė, Dagbati, and Momė (northeast of Lake Togo) (de Kun, 1965).
References; de Kun, 1965.

Symbol: 129CSL
Name: Arlit-de-l'ar and others, Republic of Niger, Africa.
Location: 19° 00' 00" N; 007° 30' 00" E
Description: Stratiform uranium ore deposits with secondary minerals occur in Jurassic and Carboniferous rocks mostly fine-grained carbonaceous, argillaceous, sandstone interbedded with lenticular sandstone (Bîgotte and Obellianne, 1968). Volcanic tuffs which accumulated in abundance in the Triassic and which carry up to 100 ppm U_3O_8 are thought to be the source of the Jurassic uranium deposits; and Precambrian gneiss and granite provided the arkose from which the Carboniferous ores were derived (Bîgotte and Obellianne, 1968; Robertson, 1970). The environment of deposition was fluviatile to marginal marine, channels and river meanders. Abundant organic remains are present in the Carboniferous deposits which are immediately below overlying clays (Robertson, D. S., 1970). The uranium is believed to be moved by ground water and precipitated and concentrated by abundant organic matter (Robertson, D. S., 1970). The deposits, mainly in sandstone formations, are "Western States" type of deposits. Deposits of Azelisk (or Azelik or Azelick) (17°30' N., 07°00' E.), Madaouela (or Madouela), Agadez (17°00' N., 07°45' E.), Akokan (19 kilometers south of Arlit), and Imouraren (48 kilometers south of Arlit) are in the area. Production of Niger in 1974 was 123,000 tons of U. The deposits of Arlit are estimated to contain, in the price range below $10, 12,000 short tons U_3O_8 of reasonably assured resources, and 13,000 short tons of estimated additional resources (ENEA/IAEA, 1967). The Azelisk contains over 5000 tons of ore averaging more than 0.10 percent U_3O_8. Madaouela uranium ores contain over 6000 tons of ore averaging more than 0.10 percent U_3O_8. Copper is an associated commodity. Beulaygue (1972) stated that 750 metric tons of sodium uranate has been produced since the start of 1971, and this rate will be doubled shortly. Deposit consists of a concentration of 0.25 percent (U_3O_8?) in clay and sandstone under 35 to 50 m of overburden. It is mined by open-pit.
References: Baudet and Bizard, 1971; Beulaygue, 1972; Bîgotte and Obellianne, 1968; Bowie, 1970; ENEA/IAEA, 1967; Gangloff, 1970; Mining and Minerals Engineering, 1970, v. 6, no. 11, p. 49; Mining Magazine, 1968, v. 118, no. 1, p. 4-9; Robertson, D. S., 1970; Sherman, 1972; Tatsch, 1976; Woodmansee, 1970.

Symbol: 130CPM
Name: Safaga and others, Egypt, Africa.
Location: 25° 00' 00" N; 034° 00' 00" E
Description: At Safaga and Quseir (or Kosseir, or Quoseir), in the eastern desert to the south of Safaga near the Red Sea coast, and at Sibaiya, Mahmid, Kharga, and Dakhla, uraniferous phosphorite beds occur in Cretaceous marls, limestones, and cherts.
References: Davidson and Atkin, 1953; Heinrich, 1958; Hume, 1927; Mining Journal, 1965, p. 231.

Symbol: 131DSM
Name: Gebel Quatrani, western desert, Egypt, Africa.
Location: 30° 00' 00" N; 030° 15' 00" E
Description: Uranium mineralization occurs in Oligocene sediments (of Quatrani Formation) at Quatrani (or Katrany), 90 kilometers west of Cairo in the northern part of the western desert, in various medias, all uraniferous, of phosphatic sandstone, ferruginated sandstone, carbonaceous clay, clay, limestone, tubes, and fossil wood (El Shazly and others, 1974). El Shazly and coauthors (1974) theorize that the uranium has been carried by acidic oxidized thermal brines initiated by Oligocene subvolcanic activity, as indicated by the presence of relics of geysers. In the Quatrani area, which was the site of a delta under temperate climatic conditions with abundant fauna and flora during the time of deposition of the uranium host rock, the depositional environment was dominantly fluviatile to fluviomarine, with sediment transported by a river system which drained higher areas to the southeast or east-southeast, in which the uranium was laterally distributed in favorable stratigraphic lithologies and structures (El Shazly and others, 1974).
References: El Shazly and others, 1974; Higazy and others, 1958; Tatsch, 1976.

Symbol: 132DPL
Name: Chott el Djerid and others, Tunisia and Algeria, Africa.
Location: 34° 00' 00" N; 005° 00' 00" E
Description: Uraniferous phosphatic beds occur in lower Eocene limestone, marl, conglomerate, and pseudo-oolitic phosphorite at Chott el Djerid, west of the Gulf of Gabès, in Rèdeyel-Mellasui basin, at Aïn Moulares, M'dilla and Djebel Berda, in Djebel Ank-Djebel Chemsi basin, Tunisia; and at Boràj, Redir, and Zhadia (35°54' N., 4°55' E.), Algeria. Deposits at Hoggar Mountains, Algeria, are estimated to contain at least 16,000 tons of uranium oxide, or possibly 30,000 tons, which could be mined at a cost of about $16 to $18 per ton (Engineering and Mining Journal, 1976, v. 177, no. 5, p. 150).
References: British Sulphur Corporation Limited, 1971; de Kun, 1965; Engineering and Mining Journal, 1976, v. 177, no. 5, p. 150.

Symbol: 132aAVL
Name: Ahaggar massif, Algeria.
Location: 05° 00' 00" E; 023° 30' 00" N
Description: OECD NEA/IAEA (1975) estimates for Algeria reasonably assured resources minable at a price of less than \$15/lb U_3O_8 are 28,000 metric tons U, which is divided between vein-type deposits (26,000 metric tons U) and stratiform deposits (2,000 metric tons U).

Vein-type (vein or stockworks) deposits are in the Precambrian Ahaggar massif in a series of Precambrian migmatic gneiss (Suggarian and Pharusian), which consists of Precambrian horsts traversed by several quartzite, pyroxenite, cipolin and amphibolite formations lying roughly parallel to the direction of foliation in a NNE-SSW direction (OECD NEA/IAEA, 1975). Pitchblende, uraninite, autunite, torbernite, uranophane, fourmarierite, and andersonite occur; as well as galena, hematite, purite, marcasite, chalcopyrite, blende, magnetite, and molybdenite.

Reference: OECD NEA/IAEA, 1975.

Symbol: 132bBSM
Name: Tassilis and other deposits, Algeria.
Location: 05° 00' 00" E; 022° 00' 00" N
Description: Stratiform-type deposits occur in the Tassilis, Ougarta, and Tindoof Basin areas, in the Tassilian Series south of Ahaggar at the contact of crystalline Precambrian (Suggarian) rocks of gneiss and schists and overlying Cambrian and Ordovician conglomerates and sandstone (OECD NEA/IAEA, 1975).

The ore bodies are nearly horizontal and vary from 1 to 8 m thick. The most concentrated bodies occur in paleo-depressions in the basement crystalline Precambrian rocks.

References: OECD NEA/IAEA, 1975.

Symbol: 133DPL

Name: Sidi Daoui and others, Morocco, Africa.

Location: 32° 00' 00" N; 008° 00' 00" W

Description: Uraniferous phosphatic beds occur in sandy phosphorite, limestone, and chert of early Eocene and Cretaceous (Maestrichtian) age at Sidi Daoui (33° N., 6°55' W.), Oulad Abdoun Plateau; at Kourigha (or Khouribga) (33°N., 7°5' W.), 120 kilometers southeast of Casablanca; at Youssoufia (formerly Louis Gentil in the Ganntour) (32°5' N., 8°28' W.), Ganntour Plateau; at Chichaoua (31°30' N., 8°45' W.); at Imi N'Tanout (31° N., 8°50' W.) 70 kilometers east of the port of Safi; at Oued Erguita (30°7' N., 9° W.); and at Shouradu Dades (31°8' N., 6°13' W.), Morocco. The uraniferous marine phosphate rocks comprise about 30 billion tons, and contain about 0.015 percent U_3O_8 (Tatsch, 1976).

References: Agard and others, 1952; Bowie, 1970; British Sulphur Corp. Ltd., 1971; de Kun, 1965; ENEA/IAEA, 1967; Leconte, 1956; Royaume Du Maroc, Direction Des Mines et de La Geologie, 1962, Carte Metallogenique du Maroc, Feuille 3: Gites Sédimentaires 1962, scale 1:2,000,000; Salvan, 1952; Tatsch, 1976.

Symbol: 134DPS
Name: Taïba, Lam-Lam, Senegal, Africa.
Location: 15° 00' 00" N; 016° 00' 00" W
Description: Uraniferous phosphate occurs northeast of Dakar in middle or lower Miocene phosphatic clays, marls, argillaceous sand. Aluminum may be an associated commodity.
References: de Kun, 1965; Heinrich, 1958; Hume, 1927; von Backström, 1974.

Symbol: 135ADS
Name: Fort Dauphin, Mandrarė Valley, Belafa, Malagasa Republic (Madagascar), Africa.
Location: 24° 15' 00" S; 046° 15' 00" E
Description: Uranothorianite (with 5 to 30 percent uranium) in concentrations of disseminated grains in flat-lying lenticular masses and lenses, up to several hundred meters long and 20 to 30 meters thick, of pyroxenite interlayered with Precambrian crystalline schists, occur in a north-south arc, 150 kilometers long and between 30 to 40 kilometers wide, from Fort Dauphin north to the Mandrarė River basin (Bain, 1950; Roubault, 1956). Enclosed in the pyroxenite are associated lensoid masses of calcite-wernerite, phlogopite, or anorthite (Heinrich, 1958). The deposits are controlled by folds, and impregnated lenses are concordant to schistosity, but they are less foliated than barren strata; and lenticular bodies of acid intrusives are adjacent to concentrations (de Kun, 1965). Uranothorite is believed to have precipitated from marls or crystallized during pegmatitic-hydrothermal phases generated during regional metamorphism (de Kun, 1965; Moreau, 1959). Zoned ultrabasics are gneisses, quartzites, plagioclase, and diopside pyroxenites, and cover 52,000 square kilometers of southeastern (Madagascar) Malagasa Republic (de 'Kun, 1965). The average grade of the orebodies is generally less than 0.1 percent U_3O_8, and according to Bain (1950) the deposits are largely worked out. Secondary alluvial and eluvial deposits of uranium probably have been derived from earlier deposits (von Backström, 1974). Showing scapolite remnants, thorogummite is present in pyroxenite (Moreau, 1959).
References: Bain, 1950; Bowie, 1970; de Kun, 1965; Moreau, 1959; Roubault, 1956; von Backström, 1974.

Symbol: 136DSS?
Name: Antsirabé at Vinaninkarena, Malagasa Republic (Madagascar), Africa.
Location: 19° 00' 00" S; 047° 00' 00" E
Description: Uranocircite and autunite in disseminated flakes and as fracture coatings and as wormhole fillings has been found near and south of Antsirabé at Vinaninkarena in a 1 square kilometer area in a zone about 1 meter thick, in Quaternary lacustrine beds of gravel, sand, and peaty clay and silts about 20 meters thick (Heinrich, 1958; Roubault, 1956; de Kun, 1965). The uranium was derived by late volcanic activity from an adjacent granitic complex (basement) (rich in pegmatites that are themselves locally rich in a variety of radioactive minerals such as fergusonite, samarskite, ampangabeite, euxenite, priorite, betafite, allanite, chevkinite, uraninite, thorite, monazite, xenotime(?), zircon, pyrochlore, and microlite) and reprecipitated in the marly clays and sandstones of ancient (Quaternary) Vinaninkarena Lake (de Kun, 1965; Heinrich, 1958). The uranium apparently has been precipitated by the peaty organic material in certain of the beds (Heinrich, 1958). Native bismuth and its alteration minerals are associated with the pegmatites in the adjacent granitic complex (Heinrich, 1958). Uranothorianite production was small in 1967, and the deposit continued to be progressively depleted, with no indication of discovery or development of additional reserves (Engineering and Mining Journal, 1968, v. 169, no. 3, p. 119).
References: Bain, 1950; de Kun, 1965; Engineering and Mining Journal, 1968, v. 169, no. 3, p. 119; Heinrich, 1958; Nininger, 1955; Roubault, 1956, 1958a.

Symbol: 137AVL
Name: Jaduguda deposit and others, Singhbhum district, South Bihar, India.
Location: 22° 39' 00" N; 086° 21' 00" E
Description: Deposits are hydrothermal vein-type, disseminated mainly along shear zone of hanging wall of thrust, and in crush and breccia zones in an arcuate thrust zone 160 kilometers long around the northern margin of the cratonic block of Precambrian (Archean) Singhbhum Granite in South Bihar. Bhola and others (1965) described the east-west-trending Singhbhum Thrust Belt, well known for its copper, apatite-magnetite, and kyanite deposits, as traversing Precambrian metasediments comprising closely folded mica schists, quartzites, conglomerates, and metamorphosed basic lavas. The rocks have been overfolded and sometimes overthrust, accompanied by severe crushing and mylonitization along a zone from 100 meters to 300 meters wide (von Backström, 1974; Ghosh, 1972). Uranium occurs as lenses in <u>en echelon</u> pattern both along the strike as well as at depth; workable concentrations of uranium are observed only where cross folding and later fractures are dominant (von Backström, 1974). At Jaduguda, uranium mineralization is present in disseminations in a 120-meter-wide zone in quartzite breccia (von Backström, 1974). The main ore minerals are uraninite, torbernite, and autunite which occur frequently in the surficial zone. The average grade is 0.067 percent U_3O_8 (von Backström, 1974). Mineralization along the thrust belt took place over a long period of time, with the first stage being the formation of apatite and magnetite, closely followed by uranium mineralization, and the second and last stage, the sulfides including chalcopyrite (von Backström, 1974).

Sarkar and others (1971) believed that wall-rock alteration was only a result of retrograde metamorphism. Sen Gupta (1964) had pointed out that the mineralization was a two phase process: 1) the apatite-magnetite and uraninite mineralization and 2) the sulfide mineralization; both with associated tourmalinization, sericitization, biotitization, and chloritization. The uraninite ores associated with the apatite-magnetite mineralization seem definitely to be hypothermal (Ridge, 1975).

The source of the ores, copper and other, derived from hydrothermal fluids, is thought to be the younger soda granite of late Precambrian age (about the time of the 900-m.y.-old Singhbhum orogeny), and not the Singhbhum Granite (Archean) as originally considered (Sen Gupta, 1964; Ridge, 1975). Other deposits include Narwapahar (or Narapahar) (22°42' N., 86°17' E.), 8 kilometers northwest of Jaduguda; Turamdih (22°44' N., 86°09' E.), 11 kilometers west-northwest of Narwapahar; Bhatin (22°40' N., 86°19' E.), about 3 kilometers northwest of Jaduguda; and Bagjata-Kanyaluka (22°29' N., 86°31' E.), 25 to 26 kilometers southeast of Jaduguda. Associated minerals are chalcopyrite, magnetite, molybdenite, pyrite, hematite, azurite, millerite, pentlandite, quartz, apatite, chlorite, and tourmaline.

Mining originally began in the copper area as early as 200 B.C. (Ridge, 1975).

References: Bhola, Chatterji, and others, 1958; Bhola and Rama Rao, 1966; Bhola, Udas, and others, 1958; Bhola and others, 1965; Bowie, 1970; Dar, 1972; Darr and others, 1972; Ghosh, 1972; Sarkar, 1970; Sarkar and Deb, 1974; Sarkar and Saha, 1962; Sarkar and others, 1971; Sarkar and others, 1967; Sen Gupta, 1964; Sharma, 1970; Ridge, 1975; Udas and Mahadevan, 1974; von Backström, 1974; Wadia, 1956.

Symbol: 138AVS
Name: Rajasthan, India.
Location: 24° 45' 00" N; 074° 00' 00" E
Description: In the Udaipur district of Rajasthan (or Rajputana), 9 to 12 kilometers east of Udaipur city, and at Umra, uranium is deposited in veinlets and stringers along the lower limbs of anticlines in the tightly folded zone of the Aravalli Range. The deposits occur along shear zones in Precambrian (Archean) breccia consisting of white clay gangue and fragments of feldspar, quartz from Udaisa-gar Granite, and black carbonaceous shale of the Aravalli Formation. The Aravalli Formation consists of conglomerates, chlorites, and biotite phyllites, impure limestone, quartzites, black carbonaceous phyllites, and breccias intruded by granites. The Aravalli is rich in kaolin that shows patches of radioactivity, is also rich in iron and copper sulfides, and is the most important uranium-bearing host rock in the area. The carbonaceous material contains heterotrophic, chemoautotrophic, and anaerobic flora. The anaerobic flora indicate a relatively higher reducing environment. The chemoautotrophic bacteria indicate a favorable oxidation environment for leaching and a favorable reduction environment for refixation of uranium.

Radioactive minerals are uraninite, autunite, uranophane, torbernite, metatorbernite, formaricrite, johannite, zippeite, kesolite, clarkeite, gummite, and sooty pitchblende. Associated minerals are pyrite, chalcopyrite, malachite, azurite, and siderite.

References: Bhola, Udas, and others, 1958; Bhola and others, 1965; Dar, 1972; Darr and others, 1972; Jayaram and others, 1974; Udas, 1958; Udas and Mahadevan, 1974; Wadia, 1956.

Symbol: 139BVS
Name: Himachal Pradesh, India.
Location: 31° 00' 00" N; 077° 30' 00" E
Description: In the Kulu district of Himachal Pradesh, in the Himalaya, uraninite and pitchblende occur in vein-type uranium mineralization (as fracture fillings and coatings or replacing quartz grains) intermittently in a quartzite member of the possible Jaunsar (lower Paleozoic) rocks over a distance of about 45 kilometers from Chhinjra in the north to the Skakirandhar Range in the south (Dar and others, 1972). Cross folding occurs in the quartzite, which forms a doubly plunging fold system overturned to the west, and uraninite veins up to 10 meters long, 0.3 meters wide, and 1.5 meters deep (from surface) occur most often at bumps of cross folds. Secondary uranyl minerals (vandendriesscheite, uranogummite, betauranophane) and malachite are observed at places (Dar and others, 1972). In fold fractures in quartzites, veins are often oriented parallel to the fold axes. Chalcopyrite, pyrite, galena, quartz, and malachite are associated minerals.
References: Dar, 1972; Darr and others, 1972; Parthasarathy, 1971; Udas and Mahadevan, 1974.

Symbol: 140CPM
Name: Uttar Pradash, Himalaya, India.
Location: 30° 19' 00" N; 078° 03' 00" E
Description: Uranium deposits with a grade of 0.02 to 0.04 percent U_3O_8 have been found in 0.46- to 1-meter-thick phosphorite beds at the transition zone between the underlying Permian and Triassic Krol Limestone and the overlying carbonaceous shales and sandstones of the Jurassic and Cretaceous Tal Formation, over a strike length of 5500 meters from Bandal in the southeast to Jhanda Dhar in the northwest (Darr and others, 1972). The phosphorite also carries the following values of rare metals: Mo, 100-1,000 ppm; and Ni, 500-5,000 ppm (Dar and others, 1972). In comparison with Permian phosphorites of the United States, these have a higher enrichment of nickel, molybdenum, vanadium, cobalt, barium, and manganese; less amounts of chromium, scandium, and lanthanum; and comparable amounts of thorium, zircon, yttrium, and scandium.
References: Darr, 1972; Dar and others, 1972; Udas and Mahadevan, 1974.

Symbol: 141DSM
Name: Dera Ghazi and others, Pakistan.
Location: 30° 00' 00" N; 070° 00' 00" E
Description: Blanket-type uraniferous lenses up to 90 meters in length (north-south-direction) and width (conglomerate lenses which pinch out rapidly in an east-west direction that mark paleochannels) and 2.1 to 2.7 meters thick, occur in a single horizon, more or less conformable with the host rocks, the fluviatile Tertiary and Quaternary (middle Miocene to lower Pleistocene) Siwalik Formation (Krishnam, 1956), near the base of the middle member in brown and hard gray sandstones. The deposits occur in the foothills of the Sulaiman Range in the Dera Ghazi district of Pakistan over a strike length of more than 160 kilometers (Basham and Rice, 1974; Moghal, 1974). The best exposures are at Baghal Chur (30°20' N., 70°15' E.) (40 kilometers north-northwest of Dera Ghazi Khan, and about 16 kilometers south of the edge of the Barthi Basin; on the western flank of a long asymmetrical syncline), where mineralization also is metatyuyamunite and tyuyamunite in the oxidized zone and apparently uraninite or coffinite in the unoxidized zone (Moghal, 1974). The host rock is composed dominantly of metamorphic rock fragments and quartz, accompanied by feldspar, hornblende and biotite; in addition rare red sandstones, dolerites, porphyries, highly altered (igneous?) rocks, and serpentinite also occur. The detrital components in places are cemented by calcite, heulandite, hägggite, and an expanding clay mineral (possibly vanadiferous) that occur as coatings on detrital grains in the most radioactive sample (Basham and Rice, 1974). According to Moghal (1974), at Baghal Chur there are very rare vegetal remains, almost always completely limonitized to soft and earth-colored ochre; silicified, frequently mineralized bone occurs; H_2S gas, dead oil, and structureless humic compounds are not present. Uranium concentrations are also found associated with goethite, hematite, martite, biotite, and plant debris (Basham and Rice, 1974). No ore controls have been recognized (Moghal, 1974). Tatsch (1976) commented that the controls and transport appear to have been facilitated by the vestiges of "seismotectonomagmatic-belt activity" found in that area, particularly those associated with the "Aleutians-Bengal-Bouvet wedge-belt of activity." The source of the Siwalik sediments is the area to the north composed predominantly of low-grade schists and slates (Basham and Rice, 1974; Moghal, 1974). The hypothesis of ground-water movement transporting the uranium from the original source in the Himalayas is discussed by Moghal (1974). A possible source of the uranium is detrital uranium minerals derived from the rising Himalayas, but Basham and Rice (1974) pointed out that this hypothesis does not account for the presence of vanadium in the oxidized minerals. Moghal (1974) discussed the similarities and differences between these deposits and the sedimentary deposits of the United States. The uranium content ranges from 0.05 percent to over 0.5 percent U_3O_8.

References: Basham and Rice, 1974; ENEA/IAEA, 1967; Krishnam, 1956; Mining Magazine, 1972, v. 127, no. 3, p. 199; Moghal, 1974; Tatsch, 1976; Zeschke, 1970.

Symbol: 142DSM
Name: Salihli-Köprübasi and Usak-Güre regions, west Turkey.
Location: 38° 30' 00" N; 029° 00' 00" E

Description: Included in these regions is the secondary uranium mineralization in poorly consolidated Neogene sediments in deposits at Kasar, 150 kilometers northeast of Izmir (Smyrne); Tasharman (phosphate), 25 kilometers northeast of Kasar in the Salihli-Köprübasi region; and Esme and Fakili, about 50 kilometers west of Usak in the Usak-Güre region (Ayan, 1972; Kaplan and others, 1974; OECD NEA/IAEA, 1973). The radioactive minerals are autunite and meta-autunite; associated minerals are quartz, albite, almandine, and muscovite. The Fakili deposits occur in the Fakili facies, which lacks marl but contains secondary gypsum and sedimentary pyrites. According to Kaplan and others (1974), the Neogene lake was rich in dissolved uranium, and as evaporation progressed, the sulfate compounds were concentrated to the point they precipitated, and the uranium was also concentrated in waters that were first acidic, then neutral, and syngenetic precipitation of uranium resulted; the second phase of uranium precipitation occurred as epigenetic concentration of uranium took place after the lake receded, vadose waters acted upon the sediments and uranium again was passed into solution, and uranium was then precipitated as sulfate compounds in the heterogeneous zones above the contact at the base of the Fakili facies. These deposits are at the edge of long-standing metamorphic crystalline massifs (i.e. Menderes Massif, Rhodope Massif). The Fakili deposits, in the Aegean region, contain an average concentration of 0.044 percent U_3O_8 (Tatsch, 1976).

References: Ayan, 1972; Kaplan and others, 1974; Lang and others, 1962; OECD NEA/IAEA, 1973; Tatsch, 1976.

Symbol: 143DSS
Name: Eskine, Giresun-Sebinkarahisar, Turkey.
Location: 40° 00' 00" N; 038° 20' 00" E
Description: About 100 kilometers south of Giresun, uranium deposits with an average grade of 0.03 percent uranium occur in Eocene sediments (sandstone, andesite, dacite, rhyolite, and basalt) formed around granite masses (Ayan, 1972; OECD NEA/IAEA, 1973).
References: Ayan, 1972; OECD NEA/IAEA, 1973.

Symbol: 144DPS
Name: Ayvaik-Kücükkuyu region, Turkey.
Location: 39° 20' 00" N; 026° 30' 0C" E
Description: About 100 kilometers south of Canakkale (Dardanelle), deposits occur in Tertiary lacustrine volcanic tuffaceous rocks and bedded tuffs and ignimbrites (andesite, dacite, latite, rhyolite, spilite), phosphorite, and dolomite (Ayan, 1972). Bayleyite and ningyoite are within the dolomite. The grade of U_3O_8 in the phosphorite is greater than 0.1 percent. Uranium is found with phosphorite in dahllite (Ayan, 1972). Some pyrite and azurite are present. The average grade is about 0.07 percent U_3O_8 (OECD NEA/IAEA, 1973).
References: Ayan, 1972; OECD NEA/IAEA, 1973.

Symbol: 145DSM
Name: Tônô mine, Japan.
Location: 35° 20' 00" N; 137° 15' 00" E
Description: Tônô mine, which is composed of four groups of uranium deposits (Jorinji, Tsukiyoshi, Misano, and Utozaka), in Gifu Prefecture, occurs in the middle Miocene basal part of the Toki Group of middle Miocene to Pliocene age, and the deposits are in the tributaries or at the head of channels on the plane of unconformity above the basement (mainly Upper Cretaceous to lower Tertiary granite with considerable amounts of leachable uranium) against which the Toki Group abuts. Broad main channels, which are hundreds of meters wide and several kilometers in length, are usually barren. The lacustrine (mostly non-marine, but some marine) Toki Group is composed of conglomerate, sandstone, shale, tuffaceous sandstone, and volcanic ash. It was deposited in small sedimentary basins and has coaly material at the margins where the river flowed into the lake. The typical ore mineral is a zeolite of the heulandite-clinoptilolite group (Katayama and others, 1974). The matrices of conglomerate and sandstone of the Toki Group usually contain tuffaceous material, diagenetically zeolitized or montmorillonitized. Montmorillonitization preceeded zeolitization. Impermeable barriers (rocks in which montmorillonite predominated), or the reverse Tsukiyoshi fault, as well as channel structures, controlled the conduits of uranium-bearing ground waters that migrated from the basement granites into the Tertiary sediments; and uranium was adsorbed on heulandite-clinoptilolite zeolite from waters that became rather stagnant (Katayama and others, 1974). According to Katayama and others (1974), enrichment of uranium took place as pyrite was oxidized to produce sulfuric acid solutions which leached the uranium that had been adsorbed on zeolite; during migration as the pH of the uranium-rich solution became higher and reached about 4, the uranium was again adsorbed on zeolite, and the uranium content may have been enriched up to 0.9 percent; coffinite has been formed where uranium was accumulated over the adsorption capacity of zeolite or where strongly reducing conditions were maintained by carbonaceous matter. Radioactive minerals include coffinite, uraninite, autunite, uranocircite, phosphuranylite, uranium calcite, and zeolite. Associated minerals are pyrite, calcite, montmorillonite, kaolinite, halloysite, limonite, siderite, and barite.

Since 1973 additional ore of 800 metric tons uranium has been found in a fault zone at the Tônô mine, Gifu Prefecture, and the reasonably assured resources up to \$30/lb U_3O_8 amounts now are 7,700 metric tons uranium (OECD/IAEA, 1976).

References: Bowie, 1970; Doi and others, 1975; Hayashi, 1965, 1970; Katayama, 1958; Katayama and others, 1974; Katayama and Sato, 1957; Murakoshi and Koseki, 1958; OECD/IAEA, 1976; Sato, 1958; Sato and others, 1965.

Symbol: 146DSM
Name: Ningyo-togė mine, Japan.
Location: 35° 00' 00" N; 134° 10' 00" E
Description: The Ningyo-togė (or Nungyo-togė) mine includes about twelve individual uranium deposits in a 20 by 20 kilometers area around the boundary of Tottori and Okayama Prefectures, 33 kilometers southwest of Tottori city, in the western part of Honshu (Hayashi, 1970). The Ningyo-togė deposits were discovered in late 1955 (Ridge, 1975). The deposits in the basal part of the Neogene (Tertiary) rocks in small sedimentary basins underlain by Cretaceous granitic rocks are of the epigenetic sedimentary type, similar to those of the Tônô mine, Japan, and the Colorado Plateau, United States, with pitchblende and coffinite as the main primary minerals occurring mainly in conglomerate horizons (Bowie, 1970; Hayashi, 1970). The uranium host rocks are upper Miocene to lower Pliocene non-marine lake sediments of conglomerate, arkose, and sandstone of the Misasa Group on the peneplaned Cretaceous granitic Chugoku Massif. According to Hayashi (1970), the sediments seem to be accumulated in a closed basin which might be dammed up by volcanic rocks; the presence of channel structures in basement granitic rocks, and a non-marine conglomeratic facies in the Neogene (Tertiary) are favorable criteria for uranium concentrations. A representative orebody is approximately 1,000 meters long, 100 meters wide, and 1 to 2 meters thick (Hayashi, 1970). The ores are confined to two main ore-bearing channels: the Ningyo-togė, which trends generally east-west and has a very flat, U-shaped cross section that has a width of 300 to 400 m and an average slope of 1° or less; and the Kan'nokura channel, which is quite steep, with the ore bodies being confined to its tributaries, and the uraninite concentrated in the central part where the carbonaceous matter is most abundant (Katayama, 1960; Katayama and Fukuoka, 1970; and Ridge, 1975).

Primary uranium minerals are ningyoite, uraninite, and coffinite in the unoxidized zone; and secondary minerals are abundant autunite and a small quantity of zippeite, uranophane, and others, with organic substances, clay minerals, and iron compounds (Hayashi, 1970). Katayama and Fukuoka (1970) believed that the ningyoite was formed by reaction between the allogenic apatite and uranium-bearing solutions. Ningyoite precipitates in reducing environments from acidic to neutral conditions, but not under such alkaline conditions as are true of oceans or salt lakes (Muto, 1965; Ridge, 1975). Ningyoite (Muto, 1961) occurs as fine-grained crystals several microns in size with pyrite and gypsum cementing vugs or cracks in the arkose, or coating the surface of pebbles like a skin. Muto and others (1962) found the uranium-lead age to be 10 m.y., and they suggested that the ningyoite mineralization took place not long after the deposition of the Ningyo-togė Member, that is, in Miocene-Pliocene time.

Ridge (1975) stated that probably the ores should be classified for all uranium-bearing minerals as produced by ground water, but that it is possible that the ore-bearing solutions ultimately obtained their uranium from magmatic sources rather than from leaching it from neighboring igneous rocks. The total ore reserves (grade of 0.051 percent U_3O_8) reported in April 1969 were 2533 tons of U_3O_8 (Hayaski, 1970).

References: Bowie, 1970; Fukuoka and Kubo, 1969; Hayashi, 1970; Kamiyama and others, 1973; Katayama, 1958; Katayama and Fukuoka, 1970; Katayama and others, 1974; Katayama and Sato, 1957; Murakoshi and Koseki, 1958; Muto, 1962a, 1962b; Muto and others, 1959; Ridge, 1975; Sato, 1958; Sato and others, 1965; Suginokara, 1967, 1968.

Symbol: 147DSM
Name: Tarumizu area, Japan.
Location: 31° 30' 00" N; 130° 45' 00" E
Description: Deposits, similar to, but smaller than, the Tônô and Ningyo-togé deposits (See nos. 145 and 146), are in nonmarine conglomerate, sandstone, and tuff of Pliocene(?) age. The principal mineral is an unidentified yellow mineral, and hydrated halloysite is associated with it (Sato and others, 1965). The Tarumizu uranium deposits (about 2 kilometers south of the Tarumizu mine of stannite-cassiterite-quartz vein deposits where uranium occurred in uranophane, clay minerals, and limonite) are typical of bedded-type uranium deposits, whose source is trace amounts of leachable uranium of the basement granite, which is enriched in the suitable beds by ground-water circulation (Hida and others, 1969). The uranium occurs in Pliocene to Pleistocene arkosic sandstone and sandy clay beds which are intercalated in the uppermost horizon of the Onobaru sandstone and conglomerate, in a zone 300 to 400 meters east-west, 25,000 meters north-south, and 30 to 60 centimeters thick, which follows a paleo-stream, the paleo-Tajiake lake. The grade varies mostly from 0.00n to 0.03 percent U_3O_8, but high grade ores have between 0.25 and 0.28 percent U_3O_8. Ranquilite was identified, and uranium seems to be absorbed in clay minerals, most of which are composed of hydrohalloysite (Hida and others, 1962). A cap rock of Onobaru welded tuff overlies the uranium deposits, and a permeable bed of Onobaru conglomerate underlies the deposits. The beds seem to have been mineralized in a relatively short time after the Pleistocene volcanism (Hida and others, 1969).
References: Bowie, 1970; Hayashi, 1970; Hida and others, 1969; Katayama, 1958; Katayama and others, 1974; Katayama and Sato, 1957; Murakoshi and Koseki, 1958; Sato, 1958; Sato and others, 1965.

Symbol: 147aASM

Name: Koesan, Chungchon-pukto, and Taejon areas, Goesan province, Republic of Korea (South Korea).

Location: 36° 15' 00" N; 127° 30' 00" E

Description: Uranium deposits (nonproductive as of 1974) of unstated extent and grade occur widely in the carbonaceous beds of the Proterozoic (late Precambrian) Okchon System in the Okchon paleogeosynclinal zone within the Kyonggi-Ryongnam massif in central South Korea in the Goesan province (Kim, 1976).

Reasonably assured resources (minable at a price of \$15-30/lb U_3O_8) for South Korea are estimated as of January 1, 1975, as 2,400 metric tons U (OECD NEA/IAEA, 1975), but it is not stated if all or part of this applies to the uranium in the carbonaceous beds of the Goesan province.

Engineering and Mining Journal, 1975 (v. 176, no. 8, p. 165-166) stated that Korean uranium ore contains only 0.03 percent to 0.04 percent uranium, and comes from the Koesan, Chungchong-pukto, and the Taejon areas; known deposits are estimated at 6 million tons, with another 2 million tons inferred.

References: Engineering and Mining Journal, 1975, v. 176, no. 8, p. 165-166; Kim, 1976; OECD NEA/IAEA, 1975; Yun, 1956.

Symbol: 148AVM
Name: Rum Jungle, Northern Territory, Australia.
Location: 13° 00' 00" S; 131° 00' 00" E
Description: The five small uranium deposits are in lower Proterozoic schist, siltstone, and shale of the Golden Dyke Formation of the Goodparla Group, which was deposited in a shallow marine, partly euxinic environment (Dodson and others, 1974). The lode (replacement, disseminated) deposits include White's (12°59'25" S., 131°00'25" E.); Dyson's (12°59'15" S., 131°00'50" E.), 60 kilometers southwest of Darwin, between Stuart highway and the railway; Mount Burton mine (12°58'50" S., 131°57'50" E.), 4.8 kilometers west of White's mine; and Rum Jungle Creek South mine (13°02'30" S., 130°59'40" E.); all of which are in shears and faults except the Rum Jungle Creek South which is in a tight fold, the host rock being carbonaceous sediments (quartz pebble conglomerate) or chloritic slate, near the contact with the underlying Coomalie Dolomite (Dodson and others, 1974). The uraniferous lower Proterozoic sediments were deposited in the Pine Creek Geosyncline, a fairly shallow trough, on an Archean basement, which crops out as the Rum Jungle Complex (which has 10-28 ppm U in the leucocratic granite). The steep dip of the sediments away from the complex and a sheared contact between the Rum Jungle Complex and the lower Proterozoic sediments indicate post-Archean updoming of the complex at the close of sedimentation in the Pine Creek Geosyncline (Dodson and others, 1974). The complex is cut by the Giant's Reef Fault, which strikes northeast and has a horizontal displacement of about 6 kilometers (Dodson and others, 1974). The Goodparla Group is folded, sheared, and dragged by faulting. There is pronounced stratigraphic or lithologic control of the uranium concentrations, as the Golden Dyke correlates with the host rock, the Koolpin Formation of the South Alligator River Valley, and with host rock Koolpin equivalent at Nabarlek, Jabiluka, Ranger, and Koongarra (Dodson and others, 1974). The pitchblende deposits caught in structural traps in Archean or lower Proterozoic metasediments and granites are spatially located close to or along the unconformity with the overlying Middle Proterozoic rocks.

Rich and others (1975) reported that the U/Pb age of the pitchblende is 650 m.y.; and the K/Ar and Rb/Sr ages of the granite are 1700 m.y. and 1760 m.y., respectively.

Radioactive minerals are oxides of uraninite and pitchblende, and secondary minerals are torbernite, saleeite, autunite, gummite, phosphuranylite, johannite, and sklodowskite. Associated minerals are sulfides of copper and lead (including pyrite, chalcopyrite), and cobalt and nickel minerals.

Spratt (1965) theorized that two possible sources exist for the uranium in the Rum Jungle·deposits: 1) the pryite black slates of the Golden Dyke Formation and 2) the magma chamber from which also came the granites of the granite complexes. Ridge (1975) pointed out that no evidence has been presented so far that the slates contained uranium in sufficient quantities to have supplied the uranium (primary pitchblende) in the Rum Jungle deposits; that what evidence is available seems to favor hydrothermal deposition of the ores; and that the suite of primary ore minerals is typical of the mesothermal range. The secondary (mainly oxidized) minerals were produced by ground-water action.

King (1976) gave production from the Rum Jungle uranium, uranium-copper, copper, and lead concentrations in Proterozoic black shales as 5,000 short tons U_3O_8 and 26,000 short tons Cu. No production was reported in 1971, and recent exploration failed to find any significant deposits (Ridge, 1975).

References: Berkman, 1968; Condon and Walpole, 1955; Corbett and McLeod, 1965; Crohn, 1968; Dodson, 1972; Dodson and others, 1974; Fisher and Sullivan, 1954; Heier and Rhodes, 1966; Heinrich, 1958; Liddy, 1972; Mining Magazine, 1974, July, p. 11-23; Rhodes, 1965; Rich and others, 1975; Ridge, 1975; Roberts, 1960; Smart and others, 1975; Smith, 1974; Spratt, 1965; Sullivan and Matheson, 1952; Walpole and others, 1968; Warren, 1972; Woodmansee, 1970.

Symbol: 149AVS
Name: South Alligator River valley, Northern Territory, Australia.
Location: 13° 30' 43" S; 132° 31' 07" E
Description: The valley area includes El Sherana mine (13°30'45" S., 132°31'10" E.) 85 kilometers northwest of Pine Creek and 175 kilometers southwest of Rum Jungle; and El Sherana West mine (13°30'40" S., 132°31'05" E.), northwest of El Sherana mine. Almost all the uranium ore in the thirteen small deposits, mostly high-grade, distributed along a 19-kilometer section of a fault zone, are in lodes in the form of veins, stringers, or pods in shears and crossfractures along the main fault zone, which strikes north-northwest, in the black carbonaceous shale of the steeply dipping lower Proterozoic (1800 to 2400 m.y.) Koolpin Formation (in part pyritic, with discontinuous algal bioherms) (Dodson and others, 1974). Uranium is also contained in volcanics and sandstone of the Carpentarian (1400 to 1800 m.y.) Edith River Volcanics (acid) of the transitional phase at Coronation Hill and Saddle Ridge, and in sandstone of the Carpentarian Kombolgie Formation at Palette. Where pitchblende occurs in sandstone the host rock is mostly in contact with carbonaceous shale of the Koolpin Formation deposited in the Pine Creek Geosyncline, a shallow intracratonic basin (Dodson and others, 1974). A zone of faulting parallel to the mineralized zone was active during sedimentation. Chloritization and kaolinization, bleaching of wall rock is present. The lower Proterozoic sediments of the South Alligator River valley area are lithologically similar to and stratigraphically relatable to the lower Proterozoic sediments of the Rum Jungle area, and these deposits also have pronounced stratigraphic and lithologic control (Dodson and others, 1974). (See No. 148, Rum Jungle).

Radioactive minerals indicate a remarkable development of secondary minerals in the oxidized zone (phosphuranylite, metatorbernite, autunite, uranophane, soddyite, and the ochre, gummite; phosphates being dominant). The primary minerals consist generally of uraninite as massive segregations, veins, and disseminations mostly in fractures. Associated minerals are gold, tellurium, and various sulfides, such as galena and pyrite.
References: Ayres and Eadington, 1975; Dodson and others, 1974; Dodson and Prichard, 1975; Ferris, C. S., written commun., 1973; Heinrich, 1958; Liddy, 1972; McLeod, 1965; Mining Magazine, 1974, v. 131, no. 1, p. 11-23; Prichard, 1965; Rich and others, 1975; Smart and others, 1975; Taylor, 1968; Walpole and others, 1968; Warren, 1972.

Symbol: 150AVL
Name: Nabarlek, Alligator Rivers area, Northern Territory, Australia.
Location: 12° 18' 30" S; 133° 22' 30" E
Description: Nabarlek is about 275 kilometers northeast of Darwin, and about 35 kilometers east of Oenpelli Mission, in the area between South Alligator River and Cooper Creek known as the Alligator Rivers area (Dodson and others, 1974). The narrow veinlets of secondary minerals follow joint planes and cleavage planes in quartz-chlorite muscovite schist of the lower Proterozoic Koolpin equivalent, the Myra Falls Metamorphics, close to their unconformity with the upper Proterozoic Kombolgie Sandstone of Carpentarian Age. The main deposit is two high-grade lensoid lodes composed of ore richer than 10 percent U_3O_8, surrounded by a zone of lower-grade ore 230 meters long and up to 20 meters wide. Reserves are estimated as 9,540 metric tons U_3O_8, average grade of 2.37 percent U_3O_8, by Dodson and others (1974). Reserves are estimated at 10,500 metric tons U_3O_8, average grade 2.35, by Mining Magazine (1974, v. 131, no. 1, p. 17). Massive pitchblende (disseminated ore) coated with secondary minerals in the lode extends over a north-northwest strike length of about 270 meters, dips to east at 30 to 45 degrees, and is concordant with the schistosity of the host rock. Granite was intersected about 500 meters below the surface in two deep drill holes (Dodson and others, 1974). Taylor (1968) suggested a hydrothermal epigenetic origin for uranium deposition in the South Alligator Valley. It is suggested that the uranium was syngenetically deposited before 1880 m.y. and remobilized(?) at 1700 m.y. (Dodson and others, 1974). Anthony (1975) stated that the orebody localized in a discordant local structure appears to have been remobilized (pitchblende dated at about 900 m.y. by J. H. Hills and J. R. Richards, unpublished; see Anthony, 1975), and the regional mineralization event (850 m.y. ago) may represent one of the latest of perhaps a series of episodes.

Nabarlek is in a crush zone transgressing tightly folded lower Proterozoic (Dodson and Prichard, 1975) Myra Falls quartz-muscovite schist, and cut off at depth by a dolerite dike or sill of Oenpelli Dolorite, at about 70-85 meters. Concentrations of anomalies occur where recently exposed basement rocks adjoin mesas or tablelands of shallow-dipping cover. There is extensive wall rock alteration where hematization and sericitization produce a halo around the uranium mineralization. Chloritization is heavier at Nabarlek than at Jabiluka, Ranger 1, or Koongarra. Chlorite may be an alteration product or a regular metamorphic mineral, depending on timing and sequence of events. Chlorite is a favorable sign in all the deposits. There is a high proportion of uraninite surrounded by zones of disseminated uraninite (massive pitchblende) and coated with secondary uranium mineralization: gummite, autunite, saleeite, and rare torbernite. Associated minerals are hematite, minor galena and copper, and traces of pyrite and gold.

References: Anthony, 1975; Ayres and Eadington, 1975; Cooper, 1973; de Ferranti, 1971; Dodson, 1972; Dodson and others, 1974; Dodson and Prichard, 1975; Engineering and Mining Journal, 1975, v. 176, no. 10, p. 165; Ferris, C. S., written commun., 1973; Gordon, 1976; Lloyd, 1973; Mineral Trade Notes, 1972, v. 69, no. 4, p. 23-24; Mining Magazine, 1974, v. 131, no. 1, p. 11-23; Montgomery, 1972; Prichard, 1965; Smart and others, 1975; Taylor, 1968; Tipper and Lawrence, 1972; Walpole and others, 1968; Warren, 1972; Woodmansee, 1970.

Symbol: 151AVL

Name: Ranger Nos. 1-6, Alligator Rivers area, Northern Territory, Australia.

Location: 12° 41' 15" S; 132° 56' 15" E

Description: Ranger No. 1 is also known as Jabiru, and Ranger No. 3 is also referred to as Jacana. The six radiometric anomalies are grouped in a roughly north-trending arc-like zone about 6.5 kilometers long and up to 1 kilometer wide, about 220 kilometers east of Darwin, 48 kilometers southwest of Nabarlek, and 25 kilometers south of Jabiluka. The host rocks, sheared metasediments, at Ranger No. 1 are known to the company geologists as Mine Series, and considered (Dodson and others, 1974) to be part of the lower Proterozoic Koolpin Formation equivalent. The uranium occurs mostly as primary pitchblende-rich chloritic veinlets infilling cracks and fissures, mainly in the Lower Mine Series of biotite-feldspar-quartz schist, which is overlain by a discontinuous band of dolorite and biotite-quartz schist; but also in the Upper Mine Series. In the Upper Mine Series, uraniferous veinlets tend to be concentrated around fragments of brecciated chlorite schist. Pitchblende is also present as fine grains disseminated through veins and in mineralized zones in chloritic host rocks. Minor copper, lead, and gold are erratically distributed through the ore. Ore reserves for Ranger Nos. 1 and 3 are estimated at 82,500 metric tons U_3O_8 in Dodson and others (1974). Reserves for Ranger No. 1 (Jabiru) are 51,500 metric tons U_3O_8, and those for Ranger No. 3 (Jacana) are 31,000 metric tons U_3O_8, as given in Mining Magazine (1974, v. 131, no. 1, p. 17). Carbonaceous schist is locally present in the sequence. Associated minerals are chlorite, graphite, and garnet. Extensive chemical analyses of the cores for rare earths, copper, lead, and gold showed no anomalous amounts; only minor pyrite, galena, copper minerals, gold, and hematite. Eupene and others (1975) stated that the mineralization is epigenetic; that a hypogene origin is favored by most geologists at present working in the field; and that the uranium anomalies at depth within the Lower Mine Sequence carbonates may prove to be due to residual uranium from ore-forming fluids which passed through the zone en route to the more favorable structural environment above, or perhaps to remobilization and local reconcentration of syngenetic uranium.

References: Ayres and Eadington, 1975; de Ferranti, 1971; Dodson, 1972; Dodson and others, 1974; Dodson and Prichard, 1975; Eupene and others, 1975; C. S. Ferris, written commun., 1973; Gordon, 1976; Liddy, 1972; Mineral Trade Notes, 1972, v. 69, no. 4, p. 23; Mining Magazine, 1974, v. 131, no. 1, p. 11-23; Prichard, 1965; Ryan, 1972; Smart and others, 1975; Smith, 1974; Taylor, 1968; Walpole and others, 1968; Warren, 1972; Woodmansee, 1970.

Symbol: 152ASL
Name: Koongarra deposit, Alligator Rivers area, Northern Territory, Australia.
Location: 12° 52' 30" S; 132° 51' 15" E
Description: The Koongarra (means Early Rising Bird) (formerly known as Jim Jim) deposit, is about 200 kilometers east of Darwin, and about 20 kilometers south-southwest of Ranger No. 1, close to the southern side of the Mount Brockman Massif, an outlier of Kombolgie sandstone. The orebodies consist of a series of en echelon zones of disseminated uranium minerals, which enclose cores of higher grade ore, quasi-concordant(?) with the schistosity of the host rock, the lower Proterozoic quartz-chlorite-muscovite schist of the Koolpin Formation equivalent. The ore zones are parallel to a major reverse fault dipping at about 60° to the southeast (Dodson and others, 1974). The fault plane coincides with the southeastern margin of the Mount Brockman Massif, and has brought the lower Proterozoic host rock into contact (intensely brecciated) with unmineralized sandstone of the Kombolgie Formation. This contact marks the footwall of the mineralized zone; the hanging wall is a carbonaceous horizon some 70 meters above and nearly parallel to the fault (Dodson and others, 1974). Graphite and garnet are accessory minerals. In the primary ore the uranium mineral is pitchblende; minor pyrite, chalcopyrite, galena, and a trace of gold are associated with the ore (Dodson and others, 1974). Foy and Pederson (1975) stated that the primary ore mineral is uraninite, which occurs 1) as a hard, dark grey crystalline form in thin veinlets or in well formed grains and botryoidal masses within a chlorite matrix, or 2) as a sooty amorphous mass, which coats fracture surfaces. The secondary ore, according to Foy and Pederson (1975), consists of the weathered zone above the primary zone, extends as a horizontal tongue in weathered rock downslope from the primary zone as much as 100 m to the southeast, and includes sklodowskite, kasolite, renardite, metatorbernite, saleeite, and curite minerals. The main uranium province is reported to be 670 meters long by 30 to 75 meters wide and as much as 107 meters deep; it is thought that the deposit is intermediate in size between the Ranger and Nabarlek deposits; reserves are estimated at 40,000 metric tons U_3O_8 (Mining Magazine, 1974, v. 131, no. 1, p. 19).
References: Ayres and Eadington, 1975; de Ferranti, 1971; Dodson, 1972; Dodson and others, 1974; Dodson and Prichard, 1975; C. S. Ferris, written commun., 1973; Foy, 1975; Foy and Pederson, 1975; Gordon, 1976; Mining Magazine, 1974, v. 131, no. 1, p. 11-23; Prichard, 1965; Smart and others, 1975; Taylor, 1968; Walpole and others, 1968; Warren, 1972; Woodmansee, 1970.

Symbol: 153AVL
Name: Jabiluka, Alligator Rivers area, Northern Territory, Australia.
Location: 12° 29' 00" S; 132° 52' 30" E
Description: Jabiluka Nos. 1 and 2 are about 20 kilometers north of Ranger No. 1 and about 50 kilometers southwest of Nabarlek, close to the Arnhem Land Plateau, in an east-west-striking, open asymmetrical syncline. Jabiluka No. 1 was discovered in 1971 by ground reconnaissance spectrometry, and Jabiluka No. 2 was discovered in 1973, during exploration drilling to test the favorable host rocks along the strike east of Jabiluka No. 1 (the 20 to 70 m of overlying sandstones masked any geochemical or geophysical expression of Jabiluka No. 2's presence) (Roundtree and Mosher, 1975). Primary ore pitchblende occurs in quartz-chlorite carbonaceous schist of the lower Proterozoic Koolpin Formation equivalent in the Jabiluka lode, which trends west-southwest away from the Arnhem Land Plateau and dips south at about 45°. The ore zone is up to 30 meters thick and about 150 meters long, and extends to a depth of about 105 meters (Dodson and others, 1974). Secondary uranium ore is disseminated through a narrow zone in the Kombolgie Formation, possibly deposited by hypogene enrichment (Dodson and others, 1974). Roundtree and Mosher (1975) indicated that the secondary uranium minerals -- autunite, sklowdowskite, and saleeite -- have been formed in the zone of oxidation which extends to a depth of 15 m at Jabiluka No. 1. Jabiluka No. 2, similar geologically to, but much larger than Jabiluka No. 1, is about 480 meters east of Jabiluka No. 1, beneath the Kombolgie Formation; the orebody covers an area of 15 acres and the ore zone is up to 49 meters thick, at a depth of between 61 meters and 192 meters below the surface (Dodson and others, 1974; Mining Magazine, 1974, v. 131, no. 1, p. 11-23). The uranium mineralization is associated with sulfides, including pyrite and chalcopyrite, with rare chalcocite, covellite, and galena (Roundtree and Mosher, 1975). Evidence of slicification and chloritization is present, and Roundtree and Mosher (1975) suggested that Jabiluka No. 1, with an isotopic age date of approximately 900 m.y., could represent a second episode of chloritization and mobilization of uranium mineralization in the Alligator Rivers area. Ore reserves as of December 1973 are 3,490 metric tons U_3O_8 and 19,580 metric tons U_3O_8 for Jabiluka Nos. 1 and 2, respectively (Dodson and others, 1974). Engineering and Mining Journal (1975, v. 176, no. 8, p. 36) reports that Jabiluka has gold mineralization at depths of 99 m to 294 m, localized in a limited area of 3 hectares of uranium ore body, that is promising and which could be brought into production within 18 months; the gold in 8 drill holes ranged from 0.18 to 5.05 oz per long ton; and the thickness of the mineralized interval ranged from 3 to 6 m.
References: Ayres and Eadington, 1975; Dodson, Needham, Wilkes, Page, Smart, and Watchman, 1974; Dodson and Prichard, 1975; Engineering and Mining Journal, 1975, v. 176, no. 1, p. 37;

Engineering and Mining Journal, 1975, v. 176, no. 8, p. 36; C. S. Ferris, written commun., 1973; Gordon, 1976; Mining Magazine, 1974, v. 131, no. 1, p. 11-22; Prichard, 1965; Roundtree and Mosher, 1975; Smart and others, 1975; Taylor, 1968; Walpole, Crohn, Dunn, and Randal, 1968; Warren, 1972.

Symbol: 154AVS
Name: Pandanus Creek mine area, Northern Territory, Australia.
Location: 17° 35' 00" S; 137° 50' 00" E
Description: Included in the area are Pandanus Creek mine (or Eva prospect) (17°45' S., 137°50' E.), about 160 kilometers west of Burketown, in the Pandanus Creek area; Wollogorong (17°35' S., 137°50' E.), about 16 kilometers north of Pandanus Creek; and Cobar II (Blackwell's mine) (17°30' S., 137°50' E.) about 25 kilometers north of Pandanus Creek, in the Milestone area. The mineralization is a core of massive secondary minerals with remnants and veinlets of uraninite surrounded by a zone of replaced secondary uranium minerals. The principal minerals are sklodowskite, boltwoodite, and betauranophane with lesser saleeite, autunite, and torbernite in shear zones at the contact of the lower Proterozoic acid volcanics and the overlying Westmoreland Conglomerate of platform cover. The mineralization is in the Nicholson Block and extends from (interbedded with) the porphyritic lavas and acid volcanics of the Cliffdale Volcanics into the overlying sericite-epidote quartzite and argillaceous sandstone of the Westmoreland Conglomerate, and into basic volcanics. The Nicholson Block, which lies across the northern part of the boundary between Northern Territory and Queensland, consists of metamorphosed geosynclinal (marine Carpentaria Geosyncline) pelitic and quartz-feldspathic sediments and volcanics, isoclinally folded about an east-west axis and intruded by granite. The metamorphic grade is greenschist, and the granite has foliated margins. Copper and gold are associated commodities.
References: Corbett and McLeod, 1965; Dodson, 1972; Liddy, 1972; McLeod, 1965; Mining Magazine, 1974, v. 131, no. 1, p. 21; Morgan, 1965; Newton and McGrath, 1958; Warren, 1972.

Symbol: 155AVL
Name: Redtree and others, Queensland, Australia.
Location: 17° 30' 00" S; 138° 06' 00" E
Description: Area includes Redtree Nos. 1, 2, and 3 (17°31' S., 138°05'15" E.), about 400 kilometers north-northwest of Mount Isa and about 11 kilometers east of Northern Territory border; Namalangi (17°31'05" S., 138°05'45" E.), about 1 kilometer east of Redtree; Huarabagoo (17°30'15" S., 138°06'20" E.), about 3 kilometers northeast of Redtree; Huarabagoo East (17°29'30" S., 138°07' E.), about 5 kilometers northeast of Redtree; and Long Pocket (17°28'10" S., 138°13'15" E.), about 15 kilometers east-northeast of Redtree, Westmoreland district. The deposits are vein-type, primary uranium mineralization associated with major joint zones; stratiform secondary uranium lenses in gritty, ferruginous sandstone adjacent to the joint zones, and pore fillings, and coatings around mineral grains. The radioactive minerals are carnotite, metatorbernite, pitchblende, and some brannerite. The host rocks are acid Cliffdale Volcanics and Norris Granite, Westmoreland Conglomerate, and basic volcanics in Nicholson Block (see No. 154, Pandanus Creek description). The Westmoreland deposit has reserves of 3200 metric tons of U_3O_8 or 2714 metric tons U (Engineering and Mining Journal, 1976, v. 177, no. 3, p. 274).
References: Brooks, 1971; Carter, Brooks, and Walker, 1961; Engineering and Mining Journal, 1976, v. 177, no. 3, p. 274; Mining Magazine, 1974, v. 131, no. 1, p. 21; Morgan, 1965; Warren, 1972; Woodmansee, 1970.

Symbol: 156AVM
Name: Valhalla and Skal deposits, Queensland, Australia.
Location: 20° 24' 00" S; 139° 24' 00" E
Description: Valhalla (20°22'20" S., 139°21'30" E.), about 40 kilometers northwest of Mount Isa adjacent to the Barkly Highway, and Skal lease (20°26'45" S., 139°27'15" E.), about 32 kilometers north of Mount Isa, Paroo Creek, Mount Isa area, are vein-type deposits in lower Proterozoic Eastern Creek Volcanics in the Western Trough of Mount Isa Geosyncline. The Western Trough (Warren, 1972) is thought to be deposited on continental crust of highly deformed metamorphic rocks, granite, and acid volcanics (Carter, Brooks, and Walker, 1961). Warren (1972) pointed out that the basement is now considered to be an extension of the Nicholson Block to the northwest. Ore is somewhat refractory. Brooks (1975) described the uranium deposits as stratabound, with host rocks being a variety of metasedimentary and metavolcanic rock type in the Eastern Creek Volcanics, where the primary mineral is very fine-grained disseminated brannerite. Uranium mineralization at Valhalla occurs in a 60-m-thick ferruginous tuff bed. Metatorbernite is present at Valhalla in a weathered zone to a depth of 35 m, and this zone is underlain by substantial primary mineralization (Brooks, 1975). At the Skal, substantial amounts of jasperoid material and vein quartz are also present. Brooks (1975) indicated (Queensland Mines Ltd estimates, February 1973) reserves for the Valhalla deposits are 3,810 metric tons U_3O_8 probable, grade 0.19 percent, and 1,633 metric tons U_3O_8 possible, grade 0.20 percent; and Skal reserves are 3,447 metric tons U_3O_8 probable, grade 0.13 percent.
References: Brooks, 1971, 1975; Carter, Brooks, and Walker, 1961; de Ferranti, 1971; Howard, 1972; Warren, 1972; Woodmansee, 1970.

Symbol: 157AVM
Name: Counter lease, Queensland, Australia.
Location: 20° 40' 00" S; 139° 36' 30" E
Description: Counter lease (or Anderson's lode), about 15 kilometers northeast of Mount Isa, George Creek, is a vein-type deposit in slightly metamorphosed greywacke in lower Proterozoic Eastern Creek Volcanics in the Western Trough of Mount Isa Geosyncline on continental crust (Carter, Brooks, and Walker, 1961; Warren, 1972). The Anderson's Lode main pipe-like oreshoot increases in size from the surface to a maximum of 90 m by 27 m at a depth of 60 m, and tapers gradually to a depth of 300 m (Brooks, 1975). The oreshoot is in a greywacke lens 35 m thick, interbedded with altered basalt. The greywacke has been mylonitized and carbonated, and contains abundant magnetite. Brooks (1975) indicated (Queensland Mines Ltd. estimate, February 1973) reserves for Anderson's Lode stratabound deposits are 1,179 metric tons U_3O_8, probable grade 0.20 percent.
References: Brooks, 1971, 1975; Carter, Brooks, and Walker, 1961; Corbett and McLeod, 1965; Mining Magazine, 1974, v. 131, no. 1, p. 21; Warren, 1972.

Symbol: 158AVL
Name: Mary Kathleen deposit, Queensland, Australia.
Location: 20° 45' 00" S; 140° 01' 00" E
Description: The deposit, about 52 kilometers east of Mount Isa, and about 50 kilometers west of Cloncurry, is vein-type, pyrometasomatic; metasomatized by a deep-seated differentiated granite some 3 kilometers to the east. The ore host rock is a breccia skarn composed mainly of quartzitic and feldspathic fragments in a fine-grained matrix composed mainly of garnet, scapolite, and feldspar, which were deposited in the Eastern Trough of Mount Isa Geosyncline. The orebody, primarily a rare-earth orebody, is confined to a richly garnetiferous portion of the breccia-conglomerate of the predominantly calc-silicate upper part of the lower Proterozoic (Carpentarian) Corella Formation near the axis of a north-pitching syncline and is bounded by two roughly north-south shears. Carter and others (1961) indicate that the Corella Formation was deposited in the eastern of two major lower Proterozoic depositional basins (or geosynclines, Ridge, 1975). Dikes, sills, and porphyry intrusions are common. The mineralization is considered to be the result of deposition of late-phase metasomatic emanations from the Mt. Burstall Granite--an environment unique in Australia (Dodson, 1972). The orebody is an irregular shape at the surface, 360 meters long by 230 meters wide, has been mined by open pit down to 61 meters; and follows the 40° north pitch of the syncline to the north; strong oxidation took place down to 15 m, with uraninite altered to uranophane and gummite; and semi-oxidization down to 36 m involved microhalos of secondary uranium around cores of uraninite (C. S. Ferris, written commun., 1973). The hypothermal deposit can be described as a honeycomb of connected ore shoots that range between 45 m and about 2 m wide, separated by barren blocks of waste (Ridge, 1975). The Mary Kathleen minerals are typical of high-intensity deposition in calcareous rocks (Ridge, 1975). Hawkins (1975) pointed out that the metamorphosed sedimentary sequence, in which the Mary Kathleen uranium deposit occurs, has the characteristics of a mixed carbonate -- clastic shoreline and near-shore environment. The primary mineral is disseminated uraninite, generally accompanied by the rare-earth minerals allanite and stillwellite, and occasionally with iron and copper sulfides. U/Th ratio of 5:1 is constant throughout the ore body (Rich and others, 1975). Galena, sphalerite, molybdenum, and pentlandite occur as trace amounts. Secondary uranium minerals developed in the oxidized zone include uranophane and gummite (Matheson and Searl, 1956; McLeod, 1965). Mineralization controls are (1) favorable host rock (principally well-jointed calcareous granulites and breccia conglomerate), (2) a system of north-trending, west-dipping joints, and (3) garnet replacement of the host rock (Matheson and Searl, 1956; McLeod, 1965). The Mary Kathleen deposit was discovered in 1954 (Chem. Eng. and Min. Rev., 1954). The Mary Kathleen mine has been shut down for

several years, but it should be reopened in the near future since it has contracts for the delivery of over 7700 tons of U_3O_8 by 1981 (Ridge, 1975). King (1976) stated that the reserves of the Mary Kathleen are around 10,000 short tons U_3O_8; and that the mine is not now in production. According to Hawkins (1975), back stockpiled ore and previously mined ore, plus current minable reserves (estimated to be 6,430,000 metric tons at a grade of 0.119 percent U_3O_8, or 7,660 metric tons of U_3O_8) total 9,483,000 metric tons at grade of 0.131 percent U_3O_8. Mary Kathleen reserves have been reported as 7,000 metric tons of U_3O_8 (Bull. B.R.G.M., 1976, (2) II, 2, p. 276).

References: Australian Mining, 1972, v. 64, no. 5, p. 40-44; Brooks, 1958, 1960, 1971; Carter, Brooks, and Walker, 1961; Chem. Eng. and Mining Rev., 1954; Condon and Walpole, 1955; Corbett and McLeod, 1965; Gordon, 1976; Hawkins, 1975; Heinrich, 1958; Hughes and Munro, 1965; King, 1976; Lawrence and others, 1957; Liddy, 1972; Matheson and Searl, 1956; Mining Magazine, 1974, v. 131, no. 1, p. 11-23; Ridge, 1975; Warren, 1972; Whittle, 1960; Woodmansee, 1970.

Symbol: 159AVM
Name: Mount Painter, Flinders Range, South Australia, Australia.
Location: 30° 10' 00" S; 139° 55' 00" E
Description: Uraninite, torbernite, autunite, fergusonite, and uranophane occur in brecciated ferruginous zones in gneisses, crushed granite, and pegmatite of the Mount Painter Block, which consists of metamorphosed sediments and acid volcanics intruded by two phases of granite, one Proterozoic and the other Paleozoic. Mount Painter Block is a correlative of the Willyama Block of the Radium Hill area (Warren, 1972). Thorium is an associated commodity. The environment of deposition was a miogeosyncline (Liddy, 1972). The Mount Painter uranium deposits are scattered over an area of about 80 square kilometers in the northern Flinders Ranges centered on lat. 30°12' S., long. 139°23' E., in the Mt. Painter Precambrian Province (Youles, 1975). Drilling to date in the area by Oilmin Group and Transoil N. L. during the period 1968 to 1971 has located, in probable north-east trending anticlines and synclines, four layered breccia deposits of primary uraninite and one irregular deposit of primary and secondary uraninite, with an indicated 3.8 million metric tons of ore at grade 0.1 percent U_3O_8 (Youles, 1975). Youles (1975) pointed out that the breccias, 1 m to 70 m thick, predominately granite and granitic gneiss (some schist, quartzite, carbonate rocks and siltstone), are thought to have provided pathways for the mineralizing solutions, probably of alkaline igneous origin; and that the age of the mineralization probably corresponds with the early Paleozoic orogeny (or similar to the 580$\pm$ 30 m.y. for the absite from Crockers Well).
References: Coats and Blissett, 1971; Dickinson and others, 1954; Liddy, 1972; McLeod, 1965; Nininger, 1955; Warren, 1972; Woodmansee, 1970; Youles, 1975.

Symbol: 160ADM
Name: Crockers Well and Mount Victoria, South Australia, Australia.
Location: 31° 47' 30" S; 139° 57' 00" E
Description: Crockers Well (31°50' S., 139°57' E.), about 64 kilometers northwest of Olary; and Mount Victoria (31°45' S., 139°57' E.), 9 kilometers north of Crockers Well, are pegmatitic-pneumatolylic type, fracture-fill deposits in Archean brecciated rock, adamellite. Adamellite is the host rock for all the important absite deposits (Armstrong, 1974b). Absite, a complex uranium-thorium titanite, averages about 32 percent UO_3. Radioactive minerals are davidite, thorium brannerite (with nearly 13 percent ThO_2), and "absite" (rich in uranium and titanium). Armstrong (1974) considered the Crockers Well deposit a possible "porphyry" uranium deposit. The leucocratic biotite adamellite (quartz monzonite) intrudes metamorphic rocks and is intruded by alaskite, alaskite-pegmatite, and granitic pegmatite (Armstrong, 1974). Associated minerals are biotite, albite, rutile, apatite, blue quartz, zircon, monazite, and xenotime. The ore averages about 0.10 percent U_3O_8. Associated commodities are rare earths.
References: Armstrong, 1974b; Australian Mining, 1972, v. 64, no. 5, p. 40-44; Campana and King, 1958; Corbett and McLeod, 1965; Dickinson and others, 1954; Heinrich, 1958; King, 1954; Liddy, 1972; McLeod, 1965; Warren, 1972; Whittle, 1954.

Symbol: 161AVM
Name: Radium Hill mine, South Australia, Australia.
Location: 32° 20' 45" S; 140° 37' 45" E
Description: The deposit, about 32 kilometers east-southeast of Olary and about 96 kilometers southwest of Broken Hill, or about 515 kilometers northeast of Adelaide, Radium Hill area, Olary Province, is vein-type, fracture, or shear-zone lodes. The distribution of the ore within the lode channels is in irregular shoots, though with some suggestion of overall pitch. The lode fractures are confined to the south limb of the major anticline and also are found only on the southern limb of the minor folds (Parkin and Glasson, 1954; Ridge, 1975). The Whip, Geiger, and Old Main are the three major lodes. Beyond the limits of economic mineralization, the lode channels persist for a few kilometers along strike, and the best ore is found where local changes in strike have increased the open space along the fracture zone where the lode was developed (Ridge, 1975). Ore has been mined to depths of 300 meters, and ore has been intersected in drilling down to 450 meters beneath the surface (Ridge, 1975). The host rocks are Archean feldspathized gneisses, aplitic gneisses, and schists of the Willyama Complex intruded by basic and acid bodies. The variety of igneous rocks that invaded the Archean beds ranges from mafic to silicic (Ridge, 1975). The silicic intrusives comprise a number of pegmatite phases, one of which was a sodic aplite that Parkin and Glasson (1954) think is most closely related in time to the ores, and is probably related to them genetically as well (Ridge, 1975). Whittle (1954) indicated that the aplites were intruded between the early non-uraniferous mineralization and the later introduction of davidite, an iron-uranium-rare-earth mineral. Davidite extensively replaces the ilmeno-rutile-hematite amphibolite pegmatite, and quartz dikes. Other radioactive minerals are carnotite, autunite, torbernite, and absite(?). Associated minerals are rutile, ilmenite, hematite, magnetite, quartz, biotite, pyrite-chalcopyrite, orthite, xenotime, and zircon. Associated commodities are radium, gold, copper, iron, titanium, scandium, lanthanum, cerium, and yttrium.

The geologic setting of the deposit is the Adelaide Miogeosyncline (Warren, 1972). Lodes are in a set of northwest-southwest shears and fissures developed between two ancient northwest-southeast-trending regional faults (MacDonald and Ley lineaments) spaced about 4.8 kilometers apart, which are marked by later amphibolite dikes. The major anticlinal structure is also the locus of greatly increased igneous activity.

The lead isotope age determinations of 1730 m.y. for the ores (in Archean rocks) places the age in the late middle Precambrian (Ridge, 1975). Uranium mining ceased in late 1961 (Ridge, 1975).

References: Butler and Hall, 1960; Campana and King, 1958; Dickinson and others, 1954; Greenhalgh and Jeffrey, 1959; Heinrich, 1958; Liddy, 1972; McLeod, 1965; Parkin, 1965;

Parkin (ed.), Firman, Johns, Ludbrook, Thomson, and Wepfner, 1969; Parkin and Glasson, 1954; Ridge, 1975; Sprigg, 1953, 1954; Warren, 1972; Whittle, 1954.

Symbol: 162DSL
Name: Lake Frome area, South Australia, Australia.
Location: 30° 30' 00" S; 140° 00' 00" E
Description: Beverly prospect (30°12' S., 139°37' E.), and 37A prospect, about 500 kilometers north of Adelaide and about 75 kilometers south of Mount Painter, occur in the Frome Embayment, the most inland of the Eastern Basins, with marine, fluvio-lacustrine deposition. The great Lake Frome depression is north of Willyama Block-Precambrian crystalline basement rock (host for the highly economic Broken Hill silver-lead-zinc deposits), and is bounded on the west by the Paralana Fault system, which is part of a lineament zone extending from the Great Artesian Basin to the eastern side of Eyre Peninsula. Cambrian sediments underlie the Frome Embayment below the thin Tertiary and Cretaceous cover; Wopfner (1966) suggested a continuous Cambrian basin across the Frome Embayment. The uranium (including finely divided pitchblende) is disseminated in flat-lying sedimentary rocks, sandstones, carbonaceous siltstones, metamorphosed black shales, siltstones, and consolidated gravels of Tertiary age. The host rock sediments are derived partly from granite and metamorphic rocks near Mount Painter, which contain uraniferous breccia deposits, and partly from slightly metamorphosed and unmetamorphosed rocks of Adelaidian (1400-500 m.y.) (Precambrian to Cambrian) Age. The deposits are about 100 meters below the surface. Roll-front forms occur similar to deposits on the Colorado Plateau, U.S.A. Haynes (1975) suggested that it is likely that the present Lake Frome, which lies 30 km to the east of the Beverley, was previously much larger, and that the area progressively became a lacustrine plain. Reserves are estimated by Petromin No Liability at 15,800 metric tons U_3O_8, of which 11,000 metric tons are considered recoverable under present conditions; grade of recoverable material is 2.4 kg/metric ton U_3O_8 (Haynes, 1975).

King (1976) indicated reserves are 11,000 metric tons U_3O_8; and Dodson (1972) estimates 17,500 short tons U_3O_8 for the Beverley stratiform deposit.

References: Dodson, 1972; Gordon, 1976; Haynes, 1975; King, 1976; Liddy, 1972; Mineral Trade Notes, 1972, v. 69, no. 4, p. 24; Mining Magazine, 1974, v. 131, no. 1, p. 11-23; Parkin (ed.), Firman, Johns, Ludbrook, Thomson, and Wopfner, 1969; Warren, 1972; Woodmansee, 1970; Wopfner, 1966.

Symbol: 163DSL
Name: Yeelirrie deposit, Western Australia, Australia.
Location: 27° 07' 00" S; 119° 53' 00" E
Description: The Yeelirrie deposit, about 80 kilometers southeast of Wiluna; about 670 kilometers northeast of Perth, and about 450 kilometers north of Kalgoorlie, is an evaporative, channel-sediment, more or less tabular-shaped orebody at the water table. The main ore zone is 6,000 meters long, 500 meters wide and eight meters thick, elongated parallel to the channel. The post-Pliocene uranium host rock is calcrete (caliche zone) or a conglomerate of calcium magnesium clays, sand, and gravel cemented into a hard mass by calcium carbonate precipitated from solution and redeposited through the agency of infiltrating waters. Host rocks are mostly derived from Archean granite or gneiss, but some are metavolcanics and metasediments ("greenstones," which some workers think is primitive oceanic crust) and basic volcanics. The environment of host rock deposition had an arid climate, with salt lakes or playas, following a tropical Pliocene humid lateritic depositional period. The hydrologic axis of the salt lake basin overlies Archean granite or gneiss from which the uranium host rock was derived. Secondary minerals and carnotite are the principal radioactive minerals. The carnotite occurs as thin films in horizontal layers lining the voids and cavities along 45 km of the channel, a filled ancient river bed, at a depth rarely more than 8 m below the surface (Langford, 1974). Zippeite is present on the mine dumps. No associated commodities reported, but in adjacent areas there are lignite, vanadiferous iron, gold (10 kilometers to the west and 25 kilometers to the north), and antimony and arsenic (about 25 kilometers to the north) occurrences. The average grade is about 0.15 percent U_3O_8.

Yeelirrie, an example of modern stratiform deposition, originated from deposits in old drainage channels, and if left alone for geologically long periods, would appear as stratiform concentrations deposited on an unconformity (King, 1976).

References: Brooks, 1971; Dall'Aglio and others, 1974; C. S. Ferris, written commun., 1973; Gordon, 1976; King, 1976; Langford, 1974; Lloyd, 1973; Mineral Trade Notes, 1973, v. 70, no. 2, p. 10, and 1972, v. 69, no. 4, p. 23; Mining Magazine, 1974, v. 131, no. 1, p. 11-23; Morton, 1977; Sanders, 1972.

Symbol: 164BPL
Name: Georgina Basin, Queensland, Australia.
Location: 21° 30' 00" S; 139° 30' 00" E
Description: In the Burke River (Duchess) area (22°30' S., 140°15' E.), about 200 kilometers south-southeast of Mount Isa, and in the Thorntonia (Lady Annie) area (20°30' S., 138°45' E.), about 110 kilometers north-northwest of Mount Isa, Mount Isa area, uraniferous phosphate rocks of the bedded type occur in the Georgina Basin, where, during the Middle Cambrian, the phosphate was dissolved and redeposited in layers, in rather deep water where oxygen was absent. The Georgina Basin, elongated in a northwesterly direction, extends from Western Queensland into the Northern Territory to the vicinity of Daly Waters. The northern half of the basin is a blanket, 304 meters thick, of undeformed marine Middle Cambrian shales, limestones, and sandstones, strongly faulted against the Precambrian basement along its northern margin. The sequence in the southern half of the basin extends from Middle Cambrian to Upper Devonian, and is thicker and more disturbed, having been subjected to faulting and folding during a Late Devonian or Carboniferous orogeny.
References: Brooks, 1971; Clarke, Prider, and Teichert, 1967, p. 143; de Ferranti, 1971; Howard, 1972; Warren, 1972; Woodmansee, 1970.

Symbol: 164aBSM
Name: Maureen deposit, near Georgetown, northern Queensland, Australia.
Location: 18° 00' 00" S; 143° 30' 00" E
Description: The Maureen deposit lies 290 km southwest of Cairns, Queensland. The ore mainly occurs in two flat lenticular zones to a depth of about 60 meters in the basal Permian-Carboniferous sedimentary volcanic sequence, which rests on an Archean basement (Australian Mines Handbook, 1977). Many secondary minerals are present in the oxidized zone of complex mineralization. Primary uranium mineralization includes uraninite accompanied by phosphates, fluorite and molybdenum, down to a considerable depth. Discovery was in 1971. In April, 1976, indicated reserves were 2,020 metric tons of contained uranium oxide at a grade of 0.18 percent and inferred reserves were 1,650 metric tons of contained uranium oxide grading 0.13 percent. Total reserves were 3,670 metric tons (8.1 million lbs). It is a possible open-cut mine.
References: Apt and Bryant, 1977; Australian Mines Handbook, 1977; Engineering and Mining Journal, 1976, v. 177, no. 5, p. 181; Ranford, 1977.

Symbol: 165CSS
Name: Lower Buller Gorge, South Island, New Zealand.
Location: 41° 50' 00" S; 171° 40' 00" E
Description: Uranium deposits 24 kilometers east of the rail and shipping center of Westport, are bedded type and are mineralized along an intrusion of porphyry in middle(?) Cretaceous coarse-grained arkosic sandstone, siltstone, conglomerates, and breccias of the Hawks Crag Breccia, which were deposited in a continental foreland depositional basin. The uranium mineralization is restricted to the arkosic facies of the Hawks Crag Breccia. Carbonized plant remains are present. The grade is about 0.05 percent U_3O_8. Radioactive minerals are autunite, coffinite, uranophane, and pitchblende. Associated minerals are pyrite, carbonate, hematite, and clastic feldspar (abundant secondary carbonate, mainly ferroan dolomite). Associated commodities are beryllium, copper, and lead.
References: Beck, Reed, and Willett, 1958; Bowie, 1970; Cohen and others, 1969; ENEA/IAEA, 1967; Grange, 1955.

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