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GEOLOGICAL SURVEY CIRCULAR 215

URANIUM IN THE METAL-MINING DISTRICTS OF COLORADO

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URANIUM IN THE METAL-MINING DISTRICTS OF COLORADO

By R. U. King, B. F. Leonard, F. B. Moore, and C. T. Pierson

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ABSTRACT

Many varieties of abnormally radioactive rocks and ores have been found in Colorado as a result of more than eight years of geologic studies by the U. S. Geological Survey, but only a small proportion of these contain uranium in sufficient quantities to be of possible commercial interest.

The most favorable ground in Colorado for uranium ore deposits, exclusive of the Colorado Plateaus, is the central mineral belt. Here potentially important uranium deposits occur in metalliferous veins in pre-Cambrian igneous and metamorphic rocks, usually in association with Tertiary intrusive rocks. The deposits also occur in Paleozoic, Mesozoic, and Tertiary rocks that surround the pre-Cambrian core of the Rocky Mountains.

Uranium deposits of eight types occur in Colorado: (1) disseminations in sedimentary rocks, (2) veins, (3) replacement deposits, (4) volcanic breccia pipes, (5) disseminations in igneous and metamorphic rocks, (6) pegmatites, (7) radioactive inclusions in rhyolite, and (8) hot-spring deposits. Disseminated carnotite-like minerals in sedimentary rocks constitute the important uranium deposits in the Colorado Plateaus; vein deposits are the most important in the metal-mining districts.

Pitchblende is the most common uranium mineral in the vein deposits. In Colorado pitchblende has been found in six kinds of veins: (1) pyritic gold, (2) lead-zinc-silver, (3) fluorite, (4) telluride, (5) pyrite-siderite, and (6) polymineralic-hydrocarbon veins.

Detailed studies have shown that several geologic guides are useful in prospecting for new deposits. They include (1) stratigraphic position, (2) mineral associations, (3) sedimentary structure, (4) rock alteration, and (5) regional zoning. In addition the following relations may be useful: (1) uranium deposits are commonly associated with post-Cretaceous volcanism; (2) uranium is commonly found in metal-mining districts that have produced gold, silver, lead, and copper; (3) accumulations of radon and helium are theoretically related to deposits of uranium; (4) many uranium deposits are associated with bostonite dikes; (5) uranium deposits seem to occupy a definite place in some types of hypogene zonal patterns; and (6) the purple variety of fluorite and the smoky variety of quartz are believed to be related to radioactivity.

INTRODUCTION

Since 1944 the U. S. Geological Survey has been engaged in the study of uranium deposits in Colorado, first on behalf of the Manhattan Engineer District, and later on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission. The effort has been primarily in the Colorado Plateaus in the southwestern part of the state (Fischer, 1949), and secondarily in the metal-mining districts of central

Colorado (Staff of Reconnaissance Group, U. S. Geol. Survey, 1951). But the search for uranium has been made in every county west of Denver, and even in a few places in eastern Colorado.

Early field work consisted chiefly of radiometric reconnaissance of localities known or reported to contain radioactive materials. Current work includes radiometric reconnaissance, sampling, search for favorable geologic criteria, and geologic mapping, followed by detailed geologic studies of the favorable localities or districts.

This paper summarizes the results of the field studies of the Survey's reconnaissance group and outlines some geologic criteria that may be useful in guiding the search for uranium ore. The writers wish to acknowledge the cooperation of the mining companies and individuals who materially aided the program by reporting radioactive localities and by submitting samples of radioactive rocks and ores.

The writers wish to thank the following Survey geologists for information not specifically credited to them in the text: J. W. Adams, A. J. Gude, 3d, and E. P. Beroni (Nigger Shaft area, Ralston Creek district); J. W. Adams and F. B. Moore (thorium deposits in Gunnison County); E. P. Beroni and F. A. McKeown (scattered deposits in northwestern Colorado); Henry Faul, W. E. Bales, J. E. Harrison, and B. F. Leonard (radon and radioactivity in mines of the Idaho Springs and Lawson areas); Henry Faul and A. Y. Sakakura (radon in some natural gases); E. N. Hinrichs, D. M. Sheridan, and F. B. Moore (pitchblende in gold-telluride veins near Hessie, Boulder County); G. E. Manger (porosity and permeability of radon- and helium-producing horizons); H. T. Schassberger, George Phair, and K. O. Shimamoto (radioactive inclusions in Chalk Mountain rhyolite porphyry); P. K. Sims and George Phair (Copper King deposit); Q. D. Singewald and C. T. Pierson (St. Kevin, Leadville, and Alma districts); and V. R. Wilmarth and D. H. Johnson (Jamestown district). Special acknowledgment is due L. R. Page for his contributions to this report.

DISTRIBUTION OF URANIUM DEPOSITS

The main source of uranium ore in Colorado is in the Colorado Plateaus area (pl. 1) in the southwestern part of the state (Fischer, 1950). Ore also has been mined, although in small quantities, in such widely scattered places as the La Veta Pass area, Huerfano County; the Skull Creek area, Moffat County; the Brush Creek area, Eagle County; the Prairie Divide area, Larimer County (Granger and King, 1951); the Quartz Hill area, Gilpin County (King, 1950b; Armstrong, 1952; Moore and Butler, 1952); the Lawson-Dumont area; Clear Creek County (King and Granger, 1950; King, 1951; Harrison, 1952; Harrison and Leonard, 1952); the Caribou area, Boulder County (Ridland, 1950, King, 1950a; Wright, 1951; Moore and Cavender, 1952); near Garo in Park County (Gott, 1951); and the Ralston Creek area, Jefferson County (Berthoud, 1875; Gott, 1950; McKeown and Gude, 1951). Localities where uranium minerals are known to occur are shown on plate 1. At present, more than 100 deposits in Colorado are known to contain radioactive materials.

Excluding the Colorado Plateaus, the metal-mining districts of the central mineral belt of Colorado (pl. 1) have been considered to be potentially the most important uraniferous areas. Discoveries of radioactive deposits in 1951 by the Geological Survey in the Alma, Leadville, and St. Kevin districts (Pierson and others, 1952), and in the upper and lower Uncompahgre and Red Mountain districts in the San Juan Mountains (Burbank and Pierson, 1953), lend some support to this view. However, recent discoveries of pitchblende outside the central mineral belt suggest that uranium is not confined to those districts from which metal production was high.

In the central mineral belt, the potentially important deposits of uranium are in metalliferous veins that cut pre-Cambrian igneous and metamorphic rocks, commonly in association with Tertiary intrusive rocks (Alsdorf, 1916; Bastin, 1916; Bastin and Hill, 1917; Phair, 1952). Within and fringing the central mineral belt, uranium deposits occur also in Paleozoic and Mesozoic sedimentary rocks (Berthoud, 1875; Gott, 1950; Gott, 1951; Mckeown and Gude, 1951; Burbank and Pierson, 1953). The uranium generally occurs as pitchblende in the Lawson-Dumont (King and Granger, 1950; King, 1951; Harrison, 1952; Harrison and Leonard, 1952), Central City (King, 1950b; Armstrong, 1952; Moore and Butler, 1952), Ralston Creek, and Caribou-Grand Island (King, 1950a; Ridland, 1950; Wright, 1951; Moore and Cavender, 1952) districts in the Front Range. About 300 tons of high-grade uranium ore has been produced in these districts, most of which was mined between 1872 and 1919 from deposits on Quartz Hill in the Central City district (Moore and Kithil, 1913).

In the Prairie Divide area, Larimer County (Granger and King, 1951), a pitchblende-bearing ore is being mined from a vein that cuts a deposit of skarn and sulfide minerals in granite. The importance of the area is not yet known because little prospecting has been done in this part of the state.

In several areas of late Paleozoic and Mesozoic sedimentary rocks in Colorado, conditions favor the occurrence of uranium deposits of both the carnotite type (Fischer and Hilpert, 1952; Fischer, Stokes, and Smith, 1944; Webber, 1947), such as those found on the Colorado Plateaus, and the vein type. The country from La Veta Pass, Huerfano County, northward to South Park (Gott, 1951) and eastward to Colorado Springs (Beroni and King, 1950) contains a number of small carnotite deposits in Pennsylvanian, Permian, and Jurassic sandstones, and further search may uncover larger and richer deposits. The Placerville district, San Miguel County, well known for its roscoelite ores in the Entrada sandstone (Fischer, Haff, and Rominger, 1947), also contains veins with uraniferous hydrocarbons and sulfides that cut the sedimentary rocks below the Entrada sandstone (Hess, 1913; Wilmarth, 1951). In the Skull Creek area, Moffat County, small cupriferous carnotite deposits occur in sandstones of Mesozoic age. In the Ralston Creek area, Jefferson County (Berthoud, 1875; Gott, 1950; McKeown and Gude, 1951), carnotite has been found in silicified coal and sandstone of the Laramie formation of Cretaceous age.

Uranium-bearing pegmatites are common in such places as Quartz Creek, Trout Creek Pass, and Crystal Mountain (Hanley and others, 1950; Page, 1950). The uranium occurs in complex silicates and oxides, commonly in association with rare-earth and thorium minerals. None of the Colorado or other domestic pegmatites have been found to contain sufficient quantities of uranium minerals to warrant mining for the uranium content alone. It is possible, however, that small quantities of uranium may be recovered from these deposits as byproducts of mining for other pegmatite minerals.

In connection with the search for uranium, several new deposits of thorium have been found in Colorado. In 1950 the Geological Survey investigated thorium-bearing veins in a large area of granitic rocks in the Wet Mountains, Fremont and Park Counties (Dellwig and Gott, 1951). Similar deposits have been found in Gunnison County.

GEOLOGY AND MINERALOGY

The known uranium deposits of Colorado may be classified into eight types: (1) disseminations in sedimentary rocks, (2) veins, (3) replacement deposits, (4) mineralized volcanic breccia pipes, (5) disseminations in igneous and metamorphic rocks, (6) pegmatities, (7) radioactive inclusions in Tertiary rhyolite, and (8) hot-spring deposits. Of these, only the first two—disseminations in sedimentary rocks, and veins—have so far proved to be commercially important.

Disseminations of uranium minerals in sedimentary rocks appear to be of secondary origin. By far the most important deposits of this type are the carnotite ores of the Colorado Plateaus that are found in the Salt Wash sandstone member of the Morrison formation. These have been adequately described by Fischer (1950) and others. These deposits are characterized by fine-grained, disseminated uranium minerals associated with vanadium in or near beds rich in clay pellets and plant remains. Stream channels apparently played an important role in localizing the deposits, but the origin of the carnotite is not well understood.

The roscoelite ores in the Entrada sandstone of the Placerville district (Fischer, Haff, and Rominger, 1947), the carnotite ores of the Morrison formation in the Meeker area (Webber, 1947), and the cupriferous uranium ores in sandstone of Mesozoic age in the Skull Creek area are similar in structure and mineralogy to the carnotite ores of the Colorado Plateaus. The deposits in the La Veta Pass area also are similar in structure and habit, but they contain mainly volborthite rather than carnotite.

The deposit near Garo (Gott, 1951) is in sandstones of the Maroon formation of Pennsylvanian(?) and Permian age; it contains carnotite associated with volborthite, secondary copper sulfides, and carbonates. The absence of plant remains and other carbonaceous material is noteworthy. This blanket-type deposit is in porous white sandstone beds near small cross faults. Such a deposit might be the oxidized upper part of a pitchblende-sulfide ore body.

The carnotite at the Old Leyden coal mine in the Ralston Creek area, Jefferson County (Berthoud, 1875; Gott, 1950; McKeown and Gude, 1951), is associated with silicified, veined, and brecciated coal and sandstone of the Laramie formation. The deposit is thought to be related to hydrothermal activity of post-Cretaceous age. Carnotite at the Mike Doyle prospect, southwest of Colorado Springs (Beroni and King, 1950), occurs as fracture fillings as well as disseminations in sandstone of the Morrison formation.

Uranium in veins—chiefly in the mineral pitchblende—is the source of most of the world's supply. In Colorado, pitchblende has been found in six types of veins: (1) pyritic gold, (2) lead-zinc-silver, (3) fluorite, (4) gold-telluride, (5) pyrite-siderite, and (6) polymineralic-hydrocarbon veins. Most of these are in granite or metamorphic rock of pre-Cambrian age, but a few are in monzonite of post-Cretaceous age or in late Paleozoic and Mesozoic sedimentary rocks. The time of the uranium deposition is thought to be Tertiary.

The pyritic gold veins contain pitchblende in hard, irregular, lenticular masses or pods as much as 1 foot thick and 10 feet in diameter. Streaks of soft, sooty pitchblende usually cut and surround these hard masses. Pyrite, galena, and sphalerite are commonly associated with pitchblende in these deposits, but galena and sphalerite may be absent. Chalcopyrite is present in some deposits but generally is not abundant. Fine-grained, dense quartz is the common gangue. The pitchblende-bearing rock commonly forms an irregular ore shoot within the main shoot of the gold ore. At Central City, however, the miners found that the pitchblende-bearing parts of the vein had a low gold content (Alsdorf, 1916). Hand-cobbed shipping ore from these deposits contained as much as 70 percent U_3O_8.

The occurrence of pitchblende in lead-zinc-silver veins is similar to that in the pyritic gold veins. Pods of hard pitchblende, with accompanying sooty pitchblende, form shoots in parts of the main sulfide ore bodies. In addition to galena, sphalerite, and silver minerals, some pyrite and chalcopyrite are present. Quartz and carbonates comprise the gangue (Bastin and Hill, 1917; King, 1950a; Ridland, 1950; Wright, 1951; Moore and Cavender, 1952). At the two better-known occurrences of this type, the Caribou (King, 1950a; Ridland, 1950; Wright, 1951; Moore and Cavender, 1952) and the Jo Reynolds (Bastin and Hill, 1917; King, 1951; Harrison and Leonard, 1952) mines, the known pitchblende occurs at depths of about 900 to 1,050 feet below the surface; in contrast, the pitchblende in the pyritic gold veins at Central City (King, 1950b; King and others, 1952) occurs at depths of 40 to 400 feet.

Fluorite veins, such as the deposits at Jamestown (Beroni and others, 1950; Goddard, 1946; Goddard, 1947; Phair and Onoda, 1950; Phair and Shimamoto, 1952; Wilmarth and others, 1952) contain uraninite and uranothorite as finely disseminated grains in fluorite associated with pyrite, galena, sphalerite, and, rarely, chalcopyrite.

Pitchblende has been tentatively identified in sooty material on quartz that lines vugs and fractures in gold-telluride veins near Hessie, west of Nederland, Boulder County.

A pyrite-siderite vein deposit at Prairie Divide (Granger and King, 1951) contains pitchblende in a vein that cuts or borders a massive copper-zinc sulfide body. The sulfides—pyrite, chalcopyrite, sphalerite, and pyrrhotite—are believed to have been formed by a much earlier, probably pre-Cambrian, period of ore deposition.

Polymineralic-hydrocarbon veins in the Placerville district contain galena, sphalerite, erythrite, tetrahedrite, molybdite, chalcocite, azurite, and malachite in a gangue of calcite and barite. The uranium is in a solid hydrocarbon, perhaps thucholite, that forms rounded to irregular masses as much as 6 inches across in the veins and adjacent limestone (Wilmarth, 1951).

Black uranium minerals have been reported from several metalliferous replacement deposits in Colorado. Virtually nothing is known about such occurrences of uranium.

Pitchblende associated with lead-silver-copper ores in volcanic breccia pipes occurs in the Red Mountain mining district (Burbank and Pierson, 1953); however, the mine workings in the uranium-bearing pipes are inaccessible, and the amount of pitchblende present is not known.

Disseminations of uranium minerals in igneous and metamorphic rocks, such as in the San Juan region (Burbank and Pierson, 1953), and near Steamboat Springs, are generally too low in grade to be commercially important. Scattered samples containing as much as 0. 05 percent uranium have been obtained from slates in the San Juan region (Burbank and Pierson, 1953), but the average grade is lower.

Inclusions of an earlier phase of the Chalk Mountain rhyolite porphyry intrusive near Climax contain small amounts of beta-uranophane and pitchblende(?). This occurrence, found by the Geological Survey in 1949, appears to be unique.

In the San Juan region (Burbank and Pierson, 1953) and near Steamboat Springs, pre-Pleistocene spring-deposited tufa has been found to contain uranium, but the deposits are small and low in grade.

Secondary uranium minerals are quantitatively unimportant in the pitchblende-bearing veins of Colorado, and they are rarely abundant enough to serve as a guide to primary ore.

GUIDES FOR PROSPECTING

Prospecting for uranium deposits by looking for uranium minerals in outcrops or float is practicable in areas containing deposits of the carnotite type, but we do not know of a single natural exposure containing pitchblende in the Front Range. The only surface indications of the pitchblende deposits are scattered flakes of green or yellow secondary uranium minerals, such as torbernite and autunite, or radioactive gossan. Leached outcrops and dumps in which no uranium minerals can now be seen may be radioactive, however, from residual radium or other radioactive decay products. Consequently, the examination of outcrops, dumps, and mine workings, using a Geiger counter or other radioactivity-detecting apparatus, is a first step in prospecting for uranium in vein deposits.

A radiation detector, though the most useful single aid in prospecting for uranium deposits, is only a tool. Its use may be supplemented by geochemical techniques, such as sampling vegetation (Cannon, 1951a, 1951b) and mine and spring waters for uranium, and sampling mine air for radon. Such tools and techniques, however, attain their maximum effectiveness only when they are applied in areas which seem to be most favorable, geologically, for the occurrence of uranium deposits.

Stratigraphic position, mineral associations, plant remains, favorable sedimentary structures, rock alteration, geochemical studies of vegetation, and broad regional zoning have been successful guides in the search for carnotite ore on the Colorado Plateaus (Fischer, 1950; Weir, 1952). So far, however, systematic prospecting for pitchblende has been difficult, perhaps chiefly because of the smaller size of the target and the greater complexity of the geologic environment of pitchblende deposits. On the basis of preliminary data, we suggest that the following geologic relationships might be useful in the search for uranium outside the Colorado Plateaus: (1) uranium tends to occur in areas of post-Cretaceous igneous activity (Kaiser and Page, 1952; Phair, 1952; Waters and Granger, 1952); (2) uranium commonly is found in or near metal-mining districts that have produced gold, silver, lead, and copper; (3) accumulations of helium and radon are theoretically related to uranium; and (4) the dark-colored variety of fluorite and the smoky variety of quartz in some instances are believed to be related to radioactive minerals. One may expect the utility of these general guides to vary widely, depending on local geologic conditions.

If the uranium deposits in the western United States are plotted on the geologic map (Kaiser and Page, 1952), many of the occurrences in veins and sandstones appear to have a relatively close spatial relation to post-Cretaceous volcanic and intrusive rocks. Therefore, we believe that the areas subjected to igneous activity in post-Cretaceous time are more favorable for prospecting than those that contain only the older igneous rocks.

From a tabulation of the metal production of western mining districts, it was noted that uranium was most commonly present in those districts from which gold, silver, lead, and copper had been produced.

For more than three years the Geological Survey has been studying the relation of helium-rich gases, particularly those containing radon, to the enclosing rocks (Faul and others, 1951; Hill, 1950; McNeal, 1950). Both helium and radon are decay products of uranium. Uraniferous hydrocarbons recently were found in well cuttings from a helium-bearing gas well outside of Colorado. The presence of these hydrocarbons has provided a clue to the possible source of the helium and radon found in the natural gas. This suggests that prospecting in such helium-rich areas of Colorado as the Model dome, in Las Animas County, and North Park, Jackson County, might be rewarding.

Dark-purple to black varieties of fluorite and black or smoky quartz have been noted in many radioactive deposits throughout the United States. These color variations in fluorite and quartz have been used with some success as a guide in locating the radioactive parts of the deposits.

In addition to these general guides to uraniferous areas, the following may be useful in finding pitchblende deposits: (1) the occurrence of bostonite dikes (Alsdorf, 1916; Bastin, 1916; Bastin and Hill, 1917; King and others, 1952; Phair, 1952), and (2) the zonal pattern of hypogene mineral deposits (Leonard, 1952).

In the Front Range, slightly uraniferous intrusive trachytes of Tertiary age, locally termed "bostonites" (Spurr and Garrey, 1908; Bastin and Hill, 1917; Lovering and Goddard, 1950), occur as dikes and small masses in areas known to contain pitchblende-bearing veins (fig. 1).

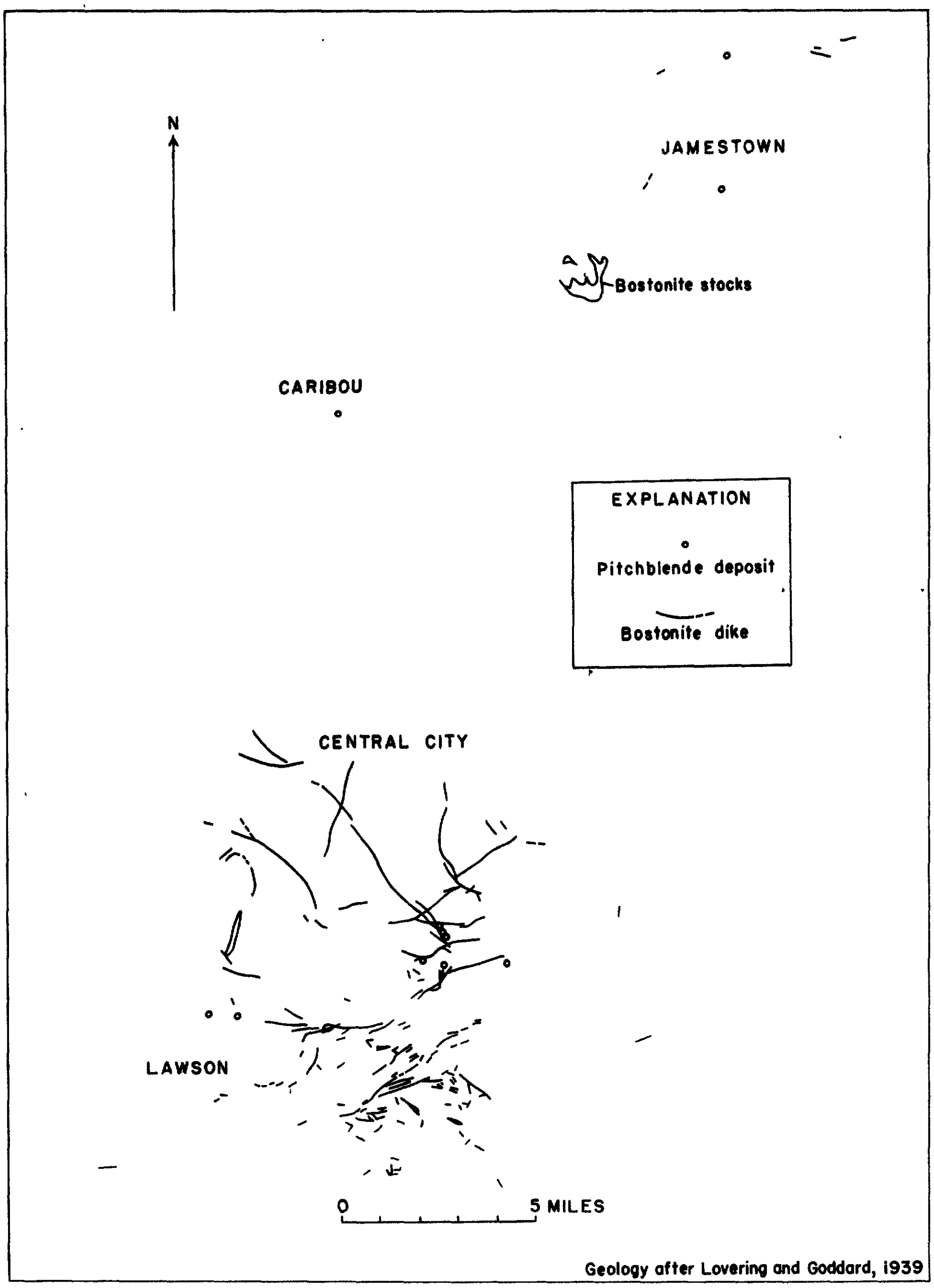

Figure 1. — Relation of pitchblende deposits to bostonite dikes in the Front Range mineral belt, Colorado.

The bostonite dikes are only one member of a complex series of Tertiary igneous rocks occurring in a zone that trends diagonally across Colorado. In part, this zone coincides roughly with the Front Range mineral belt, which includes many of the Tertiary mineral deposits of Colorado. In the principal pitchblende-bearing areas of the Front Range, pitchblende deposits and bostonite dikes are closely associated (Alsdorf, 1916; Bastin, 1916; King and others, 1952; Phair, 1952). Whether the spatial relationship has genetic significance, we do not know; but the association does provide a possible guide to areas where pitchblende may occur.

Recently, preliminary studies have been made on the relation of uranium deposits to zoning in the metal-mining districts of the Front Range (Leonard, 1952). In the Central City district, for example, a small central area containing enargite-fluorite veins is surrounded successively by (a) an area containing pyritic gold veins; (b) an intermediate or transitional zone containing veins bearing gold, silver, copper, zinc, and lead; and (c) a rather wide zone containing silver-lead-zinc veins (Collins, 1903; Bastin and Hill, 1917; Goddard, 1947; Lovering and Goddard, 1950). (See fig. 2.) All the known pitchblende deposits are in the transitional zone (b) (Leonard, 1952). Most of them are on the west side of the district, but at least one small uranium prospect is on the east side. Three other pitchblende deposits, found since figure 2 was prepared, are also in the transitional zone. The distinctive position of the pitchblende deposits in this zonal pattern suggests that the transitional zone (b) in the Central City district, and perhaps in other districts having the same zonal pattern, is especially favorable for the occurrence of pitchblende (Leonard, 1952).

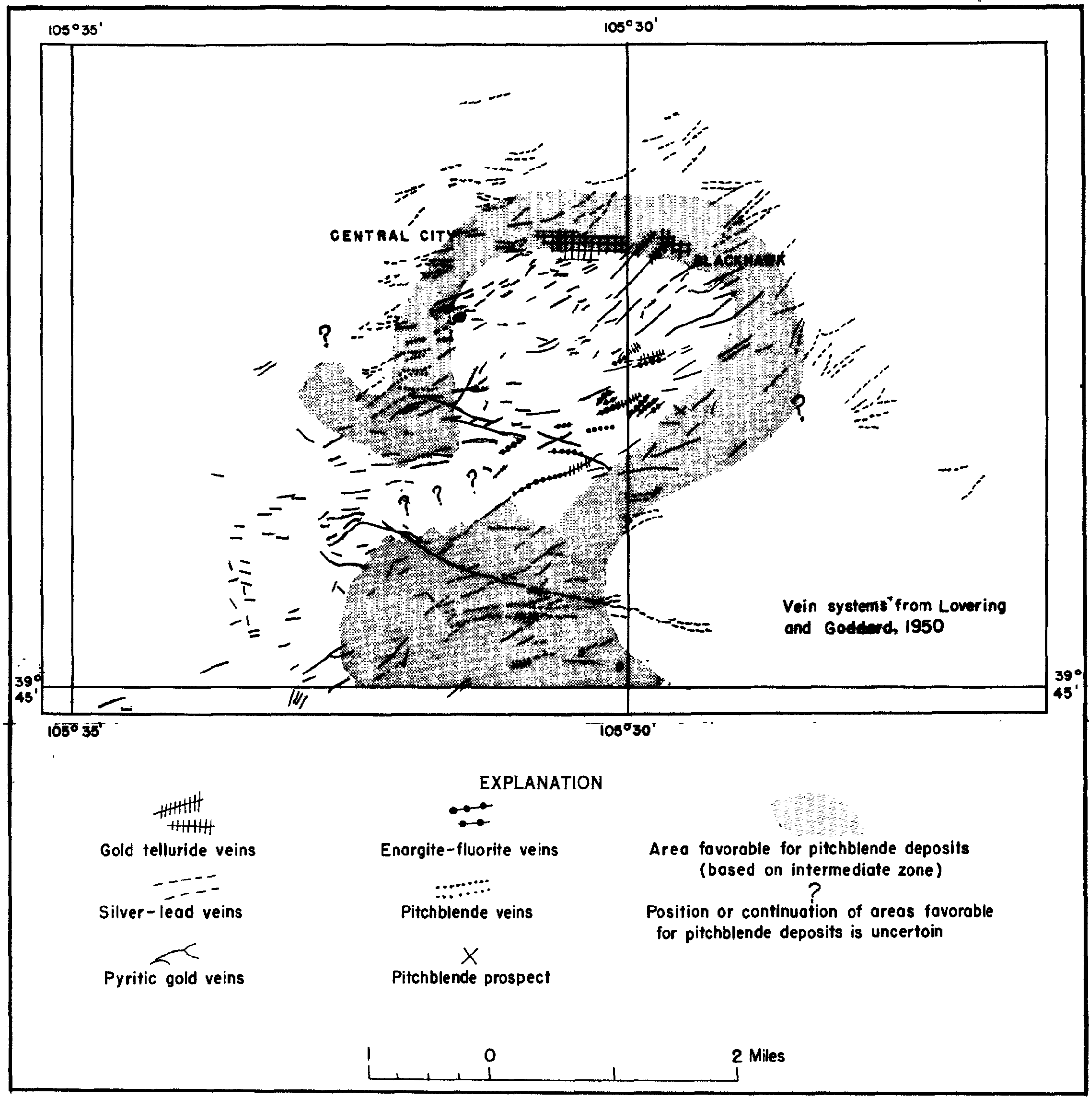

Figure 2. --Relation of pitchblende deposits to mineral zoning in the Central City district, Colorado.

Other districts near Central City show zones of silver-lead-zinc deposits about a central area of pyritic gold deposits, though enargite-fluorite veins are usually lacking (Lovering and Goddard, 1950). Among these districts are Georgetown-Silver Plume, Empire, Lawson-Idaho Springs, Alice-Yankee Hill, Caribou-Grand Island, and Ward-Sunset. Several others, such as Breckenridge, Montezuma, Michigan Hill, and Jamestown, show similar relations differing in scale, complexity, or dominant type of mineralization. In these districts, the central area is not so sharply defined as it is at Central City; the central area with its surrounding zones is likely to be irregular, the pattern complicated by the presence of more than one central area of pyritic gold deposits. Nevertheless, the pitchblende deposits at Caribou, Lawson, Michigan Hill, and Jamestown seem to fit a variant of the pattern of hypogene zoning.

The recent discovery of pitchblende with copper-, lead-, and silver-bearing volcanic breccia pipes of the San Juan region (Burbank and Pierson, 1953) has focused attention on a type of ore deposit not previously investigated for uranium. Guides for selecting favorable volcanic breccia pipes have not yet been recognized.

Many mining districts of the central mineral belt have not yet been systematically prospected for uranium deposits. Districts that have produced gold, silver, lead, and copper remain favorable places to look for uranium. Where appropriate geologic guides can be recognized and applied, every effort should be made to test their usefulness.

Table 1.--Uranium deposits in Colorado shown on plate 1.

Map no.	Name or locality	County	Type	Rock	Radioactive minerals
1	Prairie Divide------	Larimer------	Vein------------	Granite----------	Pitchblende.
2	Rusty Gold-Cerite---	Boulder------	Pegmatite-------	Granite, schist.	Cerite, uraninite.
3	Jamestown-----------	----do--------	Vein------------	Granodiorite-----	Uraninite, torbernite, uranothorite.
4	Springdale----------	----do--------	Spring----------	Water------------	Radium-radon.
5	Gold Hill-----------	----do--------	Vein------------	Granite----------	Pitchblende.
6	Copper Rock---------	----do--------	Disseminated----	Schist-----------	Unknown.
7	Caribou-------------	----do--------	Vein------------	Monzonite--------	Pitchblende.
8	Eldora--------------	----do--------	---do------------	----do------------	Do.
9	Nigger shaft--------	Jefferson----	---do------------	Granite, schist.	Do.
10	Leyden--------------	----do--------	Disseminated----	Silicified coal, sandstone.	Carnotite.
11	Fall River----------	Clear Creek--	Vein------------	Schist, pegmatite.	Pitchblende, secondary uranium minerals, thucholite(?).
12	Central City--------	Gilpin-------	---do------------	Gneiss-----------	Pitchblende.
13	Golden Gate Canyon.	Jefferson----	---do------------	Schist, gneiss.	Do.
14	Bellevue-Hudson-----	Clear Creek--	---do------------	Gneiss-----------	Do.
15	Jo Reynolds---------	----do--------	---do------------	----do------------	Do.
16	Lone Star-----------	----do--------	Pegmatite-------	Schist-----------	Uranophane(?).
17	Martha E.-----------	----do--------	Shear zones and veins.	----do------------	Pitchblende(?), torbernite.
18	Spring Gulch-Alps Mountain.	----do--------	---do------------	Granite, gneiss.	Unknown.
19	Georgetown----------	----do--------	Mine water------	Schist, gneiss.	Radium-radon(?).
20	Steamboat Springs---	Routt--------	Disseminated----	Tufa-------------	Radium(?).
21	Steamboat Springs---	----do--------	Pegmatite-------	Schist-----------	Autunite.
22	Steamboat Springs---	----do--------	Spring----------	Water------------	Radium-radon.
23	Troublesome---------	Grand--------	---do------------	----do------------	Uranium-radium-radon(?).
24	Brush Creek---------	Eagle--------	Disseminated----	Sandstone--------	Carnotite(?).
25	Rifle---------------	Garfield-----	---do------------	----do------------	Carnotite.
26	Meeker--------------	Rio Blanco---	---do------------	----do------------	Do.
27	Skull Creek---------	Moffat-------	---do------------	----do------------	Do.
28	Aspen---------------	Pitkin-------	Replacement-----	Limestone--------	Pitchblende(?).
29	Climax--------------	Lake---------	Disseminated----	Granite----------	Torbernite, monazite, brannerite(?).

Table 1.--Uranium deposits in Colorado shown on plate 1--Continued

Map no.	Name or locality	County	Type	Rock	Radioactive minerals
30	Chalk Mountain-------	Lake---------	Inclusions-------	Rhyolite porphyry.	Beta-uranophane, pitchblende(?).
31	St. Kevin-----------	----do--------	Disseminated, fracture coatings, vein.	Granite, schist.	Metatorbernite, torbernite, florencite.
32	Leadville-----------	----do--------	Disseminated-----	Shale-------------	Pitchblende(?).
33	Alma----------------	Park---------	Vein, replacement(?).	Granite, limestone shale.	Pitchblende, secondary uranium minerals.
34	Garo----------------	----do--------	Disseminated-----	Sandstone---------	Carnotite, volborthite.
35	Trout Creek Pass-----	Chaffee------	Pegmatite--------	Granite-----------	Euxenite.
36	Manitou Springs------	El Paso------	Spring-----------	Water-------------	Unknown.
37	Duffields-----------	----do--------	Vein-------------	Granite-----------	Kasolite, pitchblende(?).
38	Mike Doyle----------	----do--------	Disseminated-----	Sandstone, shale.	Carnotite.
39	Cripple Creek--------	Teller-------	Vein-------------	Granite-----------	Pitchblende.
40	Bull Domingo---------	Custer-------	Vein-------------	Schist, gneiss----	Unknown.
41	Rosita-Haputa--------	----do--------	Vein zone--------	Granite-----------	Thorite.
42	McIntire------------	Huerfano-----	Disseminated-----	Sandstone---------	Secondary uranium-vanadium minerals.
43	La Veta Pass---------	Costilla-----	---do------------	----do------------	Carnotite.
44	Cebolla-------------	Gunnison-----	Vein zone--------	Schist and aplite.	Unknown.
45	Powderhorn----------	----do--------	---do------------	Ultrabasic and alkaline intrusive rocks.	Thorite.
46	Placerville---------	San Miguel---	---do------------	Sandstone, limestone.	Pitchblende, thucholite(?).
47	Lower Uncompahgre----	Ouray--------	---do------------	Shale-------------	Pitchblende(?).
48	Ouray---------------	----do--------	Disseminated-----	Tufa--------------	Radium, uranium.
49	Upper Uncompahgre----	----do--------	---do------------	Slate-------------	Pitchblende(?).
50	Ouray---------------	----do--------	Spring-----------	Water-------------	Radium.
51	Red Mountain---------	----do--------	Volcanic breccia pipe, vein.	Rhyolite, latite.	Pitchblende(?).

REFERENCES

Alsdorf, P. R., 1916, Occurrence, geology, and economic value of the pitchblende deposits of Gilpin County, Colo.: Econ. Geology, v. 11, p. 266-275.

Armstrong, F. C., 1952, Pitchblende deposits on Quartz Hill, Central City district, Gilpin County, Colorado [abs.]: Geol. Soc. America Bull., v. 63, p. 1232.

Bastin, E. S., 1916, Discussion. Occurrence, geology, and economic value of the pitchblende deposits of Gilpin County, Colo.: Econ. Geology, v. 11, p. 681-685.

Bastin, E. S., and Hill, J. M., 1917, Economic geology of Gilpin County and adjacent parts of Clear Creek and Boulder Counties, Colo.: U. S. Geol. Survey Prof. Paper 94, 379 p.

Beroni, E. P., and King, R. U., 1950, The Mike Doyle carnotite deposit, El Paso County, Colo.: U. S. Geol. Survey Trace Elements Memo. Rept. 133. (TEM-133A, 1952, U. S. Atomic Energy Comm., Tech. Inf. Service, Oak Ridge, Tenn.)

Berthoud, E. L., 1875, On the occurrence of uranium, silver, iron, etc., in the Tertiary formation of Colorado Territory: Acad. Nat. Sci. Philadelphia Proc., v. 27, p. 363-365.

Burbank, W. S., and Pierson, C. T., 1953, Preliminary results of radiometric reconnaissance of parts of the northwestern San Juan Mountains, Colorado: U. S. Geol. Survey Circ. 236, 11 p.

Collins, G. E., 1903, The relative distribution of gold and silver values in the ores of Gilpin County, Colorado: Inst. Mining and Metallurgy Trans., v. 12, p. 480-499.

Fischer, R. P., 1949, Federal exploration for carnotite ore: Colorado Mining Assoc.

__________, 1950, Uranium-bearing sandstone deposits of the Colorado Plateau: Econ. Geology, v. 45, p. 1-11.

Fischer, R. P., Haff, J. C., and Rominger, J. F., 1947, Vanadium deposits near Placerville, San Miguel County, Colo.: Colorado Sci. Soc. Proc., v. 15, no. 3, p. 115-134.

Fischer, R. P., and Hilpert, L. S., 1952, Geology of the Uravan Mineral Belt: U. S. Geol. Survey Bull. 988-A, 13 p.

Goddard, E. N., 1946, Fluorspar deposits of the Jamestown district, Boulder County, Colo.: Colorado Sci. Soc. Proc., v. 15, no. 1, 47 p.

__________, 1947, The Front Range mineral belt, in Mineral resources of Colorado, p. 294-327: Denver, Colorado Mineral Resources Board.

Hanley, J. B., Heinrich, E. W., and Page, L. R., 1950, Pegmatite investigations in Colorado, Wyoming, and Utah, 1942-1944: U. S. Geol. Survey Prof. Paper 227, 125 p.

Harrison, J. E., and Leonard, B. F., 1952, Preliminary report on the Jo Reynolds area, Lawson-Dumont district, Clear Creek County, Colo.: U. S. Geol. Survey Circ. 213, 9 p.

Hess, F. L., 1913, Notes on the vanadium deposits near Placerville, Colo.: U. S. Geol. Survey Bull. 530, p. 142-156.

Kaiser, E. P., and Page, L. R., 1952, Distribution of uranium deposits in the United States, in Kaiser, E. P., and others, Selected papers on uranium deposits in the United States: U. S. Geol. Survey Circ. 220, p. 1-7.

King, R. U., 1950a, Vein deposits of uranium at the Caribou mine, Boulder County, Colo.: U. S. Geol. Survey Trace Elements Memo. Rept. 13. (TEM-13A, 1952, U. S. Atomic Energy Comm., Tech. Inf. Service, Oak Ridge, Tenn.)

__________, 1950b, Investigations in the Wood mine, Colo.: U. S. Geol. Survey Trace Elements Memo. Rept. 102. (TEM-102A, 1951, U. S. Atomic Energy Comm., Tech. Inf. Service, Oak Ridge, Tenn.)

King, R. U., and Granger, H. C., 1950, Torbernite occurrence at the Robineau claims, Clear Creek County, Colo.: U. S. Geol. Survey Trace Elements Memo. Rept. 24. (TEM-24A, 1952, U. S. Atomic Energy Comm., Tech. Inf. Service, Oak Ridge, Tenn.)

King, R. U., Moore, F. B., and Hinrichs, E. N., 1952, Pitchblende deposits in the United States, in Kaiser, E. P., and others, Selected papers on uranium deposits in the United States: U. S. Geol. Survey Circ. 220, p. 8-12.

Leonard, B. F., 1952, Relation of pitchblende deposits to hypogene zoning in the Front Range mineral belt, Colorado [abs.]: Geol. Soc. America Bull., v. 63, no. 12, pt. 2, p. 1274-1275.

Lovering, T. S., and Goddard, E. N., 1950, Geology and ore deposits of the Front Range, Colorado: U. S. Geol. Survey Prof. Paper 223, 319 p.

Moore, F. B., and Butler, C. R., 1952, Pitchblende deposits at the Wood and Calhoun mines. Central City mining district, Gilpin County, Colo.: U. S. Geol. Survey Circ. 186, 8 p.

Moore, F. B., and Cavender, W. S., 1952, Pitchblende deposit at the Caribou mine, Boulder County, Colo. [abs.]: Geol. Soc. America Bull., v. 63, no. 12, pt. 2, p. 1281.

Moore, R. B., and Kithil, K. L., 1913, A preliminary report on uranium, radium, and vanadium: U. S. Bur. Mines Bull. 70, p. 43-47.

Page, L. R., 1950, Uranium in pegmatites: Econ. Geology, v. 45, p. 12-34.

Phair, George, 1952, Radioactive Tertiary porphyries in the Central City district, Colorado, and their bearing upon pitchblende deposition: U. S. Geol. Survey Trace Elements Inv. Rept. 247. (TEI-247, 1952, U. S. Atomic Energy Comm., Tech. Inf. Service, Oak Ridge, Tenn.)

Phair, George, and Shimamoto, K. O., 1952, Hydrothermal uranothorite in fluorite breccias from the Blue Jay mine, Jamestown, Boulder County, Colorado: Am. Mineralogist, v. 37, p. 659-666.

Pierson, C. T., Burbank, W. S., and Singewald, Q. D., 1952, Some uranium occurrences in the central and southwestern parts of the Colorado mineral belt [abs.]: Geol. Soc. America Bull., v. 63, no. 12, pt. 2, p. 1368.

Ridland, G. C., 1950, Radioactivity at the Caribou silver mine, Boulder County, Colorado: Mining Eng., v. 187, no. 1, p. 98-101.

Spurr, J. E., and Garrey, G. H., 1908, Economic geology of the Georgetown quadrangle (together with the Empire district), Colorado, with general geology by S. H. Ball: U. S. Geol. Survey Prof. Paper 63, 422 p.

United States Geological Survey, Staff of Reconnaissance Group, 1950, Progress report, Colorado Front Range area: U. S. Geol. Survey Trace Elements Memo. Rept. 97. (TEM-97A, 1951, U. S. Atomic Energy Comm., Tech. Inf. Service, Oak Ridge, Tenn.)

Waters, A. C., and Granger, H. C., 1952, Volcanic debris in uraniferous sandstones, and its possible bearing on the origin and precipitation of uranium: U. S. Geol. Survey Circ. 224, 26 p.

Weir, D. B., 1952, Geologic guides to prospecting for carnotite deposits on Colorado Plateau: U. S. Geol. Survey Bull. 988-B, 27 p.

Wilmarth, V. R., Bauer, H. L., Jr., Staatz, M. H., and Wyant, D. G., 1952, Uranium in fluorite deposits, in Kaiser, E. P., and others, Selected papers on uranium deposits in the United States: U. S. Geol. Survey Circ. 220, p. 13-18.

Wright, H. D., 1951, Memorandum on the study of certain Colorado and Ontario uraninite deposits, p. 70-86, in Kerr, P. F., and others, Mineralogical studies of uraninite and uraninite-bearing deposits—Annual report for July 1, 1950 to June 30, 1951: U. S. Atomic Energy Comm. RMO 797, 86 p.

UNPUBLISHED REPORTS

Beroni, E. P., Granger, H. C., and King, R. U., 1950, Radiometric examination of the Williamson and General Chemical fluorite deposits, Jamestown district, Boulder County, Colo.: U. S. Geol. Survey Trace Elements Memo. Rept. 25.

Cannon, H. L., 1951a, Preliminary report on geobotanical prospecting studies on the Colorado Plateaus: U. S. Geol. Survey Trace Elements Memo. Rept. 199.

__________, 1951b, The effect of uranium-vanadium deposits on the vegetation of the Colorado Plateaus: U. S. Geol. Survey Trace Elements Inv. Rept. 160.

Dellwig, L. F., and Gott, G. B., 1951, Radioactive deposits on the Haputa Ranch, Custer County, Colo.: U. S. Geol. Survey Trace Elements Memo. Rept. 285.

Faul, Henry, Manger, G. E., and Sakakura, A. Y., 1951, Radon in the helium-bearing natural gas of the Texas Panhandle: U. S. Geol. Survey Trace Elements Memo. Rept. 239.

Fischer, R. P., Stokes, W. L., and Smith, L. E., 1944, Geology of the Rifle Creek vanadium area, Garfield County, Colo.: U. S. Geol. Survey Strategic Minerals Inv. Prelim. Rept. [Mimeographed, limited distribution.]

Gott, G. B., 1950, The Leyden uranium prospect, Jefferson County, Colo.: U. S. Geol. Survey Trace Elements Memo. Rept. 132.

Gott, G. B., 1951, Garo uranium deposits, Park County, Colo.: U. S. Geol Survey Trace Elements Memo. Rept. 222.
Granger, H. C., and King, R. U., 1951, Uranium in the Copper King mine, Black Hawk no. 1 claim, Larimer County, Colo.: U. S. Geol. Survey Trace Elements Memo. Rept. 128-A.
Harrison, J. E., 1952, Geology of the Martha E. area, Clear Creek County, Colo.: U. S. Geol. Survey Trace Elements Memo. Rept. 291.
Hill, J. W., 1950, Radón-bearing gas in the Amarillo helium district, Tex.: U. S. Geol. Survey Trace Elements Memo. Rept. 131.
King, R. U., 1951, Radioactivity in the Jo Reynolds mine, Clear Creek County, Colo.: U. S. Geol. Survey Trace Elements Memo. Rept. 5.
McKeown, F. A., and Gude, A. J., 3d Preliminary report on the carnotite deposits of the Old Leyden coal mine, Jefferson County, Colo.: U. S. Geol. Survey Trace Elements Memo. Rept. 308.
McNeal, R. P., 1950, Reconnaissance in oil fields in Lea County, N. Mex.: U. S. Geol. Survey Trace Elements Memo. Rept. 107.
Phair, George, and Onoda, Kiyoko, 1950, Verification of uraninite in fluorite breccias from the Blue Jay mine, Jamestown, Colo.: U. S. Geol. Survey Trace Elements Memo. Rept. 173.
Webber, B. N., 1947, Report on Coal Creek anticline district, White River uplift area, Rio Blanco County, Colorado: Union Mines and Devel. Corp. Rept. (In files of U. S. Atomic Energy Comm.)
Wilmarth, V. R., 1951, Summary report on the thucolite deposits near Placerville, San Miguel County, Colo.: U. S. Geol. Survey Trace Elements Memo. Rept. 307.

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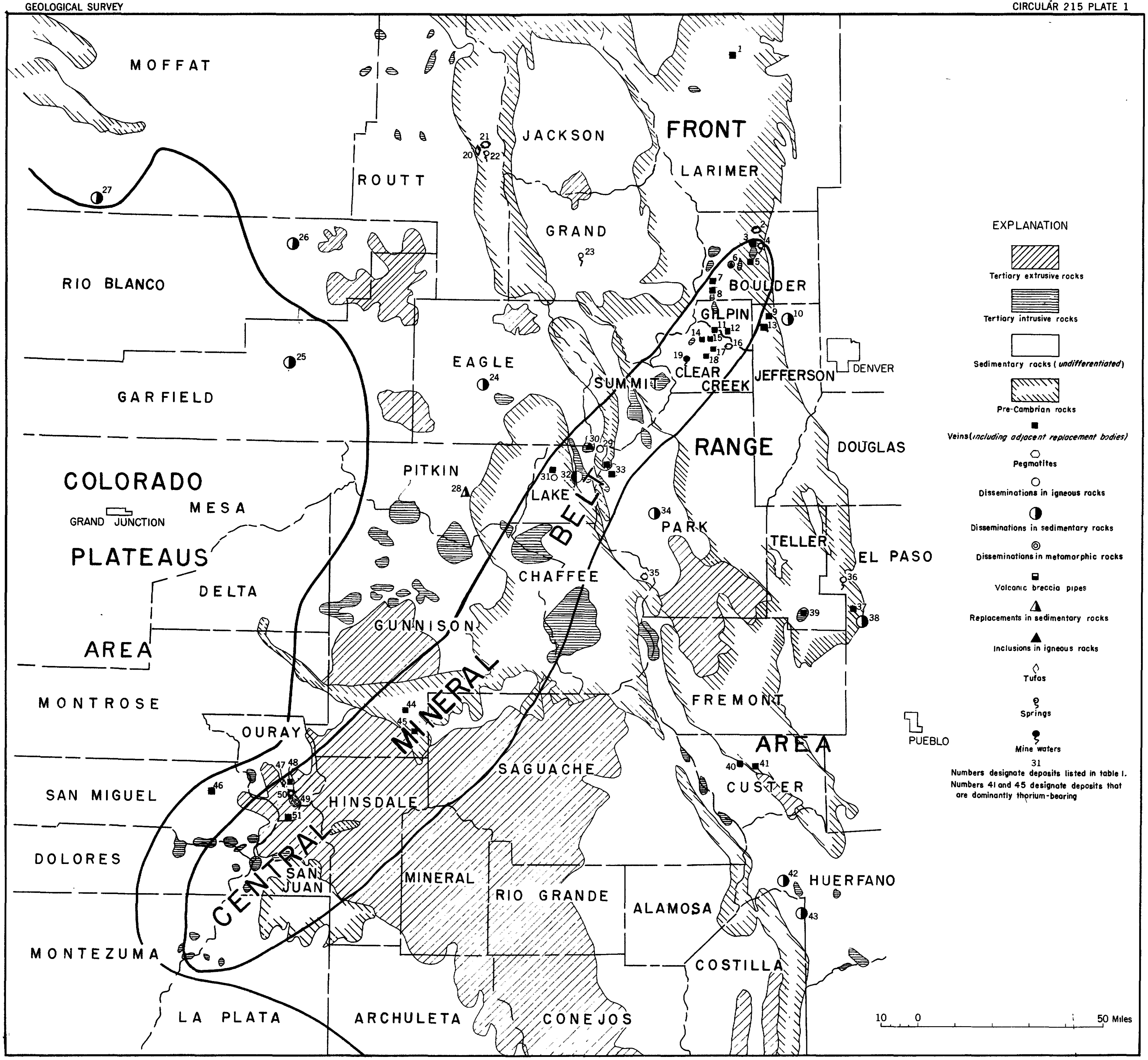

INDEX MAP SHOWING DISTRIBUTION OF URANIUM DEPOSITS IN COLORADO, GENERALLY EXCLUSIVE OF THE COLORADO PLATEAU