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URANIUM IN THE METAL-MINING DISTRICTS OF COLORADO*

By

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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 Plateau, 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 and Mesozoic rocks that surround the pre-Cambrian core.

The uranium deposits of Colorado may be classified into eight types: (1) disseminations in sedimentary rocks, (2) veins, (3) replacement deposits in limestone, (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 Plateau; vein-type deposits are the most important in the metal-mining districts.

Pitchblende is the most common uranium mineral in the vein type deposits. In Colorado pitchblende has been found in six types of veins: (1) pyritic gold veins, (2) lead-zinc-silver veins, (3) fluorite veins, (4) telluride veins, (5) pyrite-siderite veins, 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 colors of purple fluorite and smoky 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 primary effort has been in the Colorado Plateau area in the southwestern part of the state (1,2); and secondarily in the metal-mining districts of central Colorado (3). But the search for uranium has included every county west of the meridian passing through Denver, and even a few places in eastern Colorado.

Early field investigation consisted chiefly of radiometric reconnaissance of localities known or reported to contain radioactive materials. Current investigations include radiometric reconnaissance, sampling, search for favorable geologic criteria, and geologic mapping. Detailed geologic studies are then made of localities or districts which appear favorable for uranium.

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 of investigations by reporting radioactive localities and by submitting samples of radioactive rocks and ores.

DISTRIBUTION OF URANIUM DEPOSITS

The main source of uranium ore in Colorado is the Colorado Plateau area in the southwestern part of the state (4) (fig. 1). Ore also has been mined, although in small quantities, in such widely scattered places as La Veta Pass area, Huerfano County; the Skull Creek area, Moffat County (5); the Brush Creek area, Eagle County; the Prairie Divide area, Larimer County (6,7); the Quartz Hill area, Gilpin County (8,9); the Lawson-Dumont area, Clear Creek County (10, 11, 12, 13, 14); the Caribou area, Boulder County (15, 16, 17, 18); near Garo in South Park County (19); and the Ralston Creek area, Jefferson County (20, 21, 22, 23). Localities where uranium minerals are known to occur are shown on figure 1. In all, there are more than 100 known deposits containing radioactive materials in Colorado, and the number increases steadily.

Excluding the Colorado Plateau, the metal-mining districts of the Central Mineral Belt (fig. 1) have been considered to be potentially the most important uraniferous areas. New discoveries of radioactive deposits in 1951 by the Geological Survey in the Alma-Leadville, and St. Kevin districts (24, 25), and in the Upper and Lower Uncompaghre and Red Mountain districts in the San Juan Mountains (26), however, emphasize the fact that metal deposits in these areas have not received sufficient attention.

In the Central Mineral Belt, the potentially important deposits of uranium are in metalliferous veins that cut pre-Cambrian igneous and metamorphic rocks, usually in association with Tertiary intrusive rocks (27, 28, 29). Within and fringing the Central Mineral Belt, uranium deposits also occur in Paleozoic and Mesozoic sedimentary rocks (19, 20, 21, 22, 24, 25, 26). The uraniferous veins generally contain pitchblende in the Lawson-Dumont (10, 11, 12, 13, 14), Central City (8, 9), Ralston Creek (20, 21, 22, 23), and Caribou-Grand Island (15, 16, 18) districts in the Front Range. About 300 tons of high-grade uranium ore has been produced in these districts; most of this was mined between 1872 and 1919 from deposits on Quartz Hill in the Central City district (30).

At the Prairie Divide area, Larimer County (6, 7), pitchblende-bearing ore is being mined from a vein that cuts a deposit of skarn and sulfide minerals in granite. The potential importance of this area is hard to evaluate because little prospecting has been done in this part of the state.

Several areas of late Paleozoic and Mesozoic sedimentary rocks in Colorado appear favorable for finding uranium deposits of both the carnotite type (31, 32, 33), typical of the Colorado Plateau, and the vein type. The country from La Veta Pass, Huerfano County, northward to South Park (19), and eastward to Colorado Springs (34) contains a number of small carnotite-type deposits in Pennsylvanian, Permian, and Jurassic sandstones, and it is possible that further search might result in finding larger and richer deposits. The Placerville district, San Miguel County, well known for its roscoelite ores in the Entrada sandstone (35), also contains veins with uraniferous hydrocarbons and sulfides that cut the sedimentary rocks below the Entrada sandstone (36). In the Skull Creek area, Moffat County, small cupriferous carnotite deposits occur in Mesozoic sandstones (5). In the Ralston Creek area, Jefferson County (20, 21, 22), 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 (37, 38). 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 our 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 (39). Similar deposits have been found in Gunnison County (40).

GEOLOGY AND MINERALOGY

The known uranium deposits of Colorado may be classified into eight types: (a) disseminations in sedimentary rocks, (b) veins, (c) replacement deposits in limestone, (d) mineralized volcanic breccia pipes, (e) disseminations in igneous and metamorphic rocks, (f) pegmatites, (g) radioactive inclusions in Tertiary rhyolite, and (h) hot-spring deposits. Of these, only the first two--disseminations in sedimentary rocks and veins--have so far proved of commercial importance.

a) 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 Plateau that are found in the Salt Wash sandstone member of the Morrison formation. These have been adequately described by Fischer and others (4). 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 (35), the carnotite ores of the Morrison formation in the Meeker area (32), and the cupriferous uranium ores in Mesozoic sandstone of the Skull Creek area (5), are similar in structure and mineralogy to the carnotite ores of the Colorado Plateau. The deposits in La Veta Pass area also are similar in structure and habit, but they contain mainly volborthite rather than carnotite.

The deposit near Garo (19) is in sandstones of the Maroon formation of Pennsylvanian and Permian age and contains carnotite associated with volborthite and secondary copper sulfides and carbonates. The absence of plant remains and other carbonaceous material is noteworthy. This blanket-type deposit is in white porous sandstone beds near small cross faults. Such deposits may be oxidized upper parts of pitchblende-sulfide ore bodies.

The carnotite at the Old Leyden coal mine in the Ralston Creek area, Jefferson County, 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 (34), occurs in fractures as well as disseminations in Morrison sandstone.

b) 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: (a) pyritic gold veins, (b) lead-zinc-silver veins, (c) fluorite veins, (d) gold telluride veins, (e) pyrite-siderite veins, and (f) polymineralic-hydrocarbon veins. Most of these veins are in pre-Cambrian granite or metamorphic rocks, but a few are in post-Cretaceous monzonite or in late Paleozoic and Mesozoic sedimentary rocks. The age of the uranium mineralization is inferred 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 (27). 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 are the gangue minerals (15, 16, 18, 29). At the two better-known occurrences of this type, the Caribou (15, 16, 18) and the Jo Reynolds (11, 13, 29) 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 (8, 28, 20) occurs at depths of 40 to 400 feet.

Fluorite veins, represented by deposits at Jamestown (41, 42, 43, 44, 45, 46, 47), contain uraninite and uranothorite as finely disseminated grains in fluorite that is associated with pyrite, galena, sphalerite, and rarely chalcopyrite.

Pitchblende has been tentatively identified in sooty material on the quartz that lines vugs and fractures in gold-telluride veins near Hessie, west of Nederland, Boulder County (48).

The pyrite-siderite vein type of deposit, is at Prairie Divide (6, 7), contains pitchblende in a vein that cuts or follows along the margin of 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 mineralization.

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.

Minor quantities of pitchblende have been found in silver, lead, and zinc replacement deposits in limestone in the Alma district (24).

Pitchblende associated with lead, silver, and copper ores in volcanic breccia pipes occurs in the Red Mountain mining district (26). Because mine workings in the uranium-bearing pipes are inaccessible, the economic significance of the pitchblende has not yet been determined.

Disseminations of uranium minerals in igneous and metamorphic rocks, such as in the San Juan region (26) and near Steamboat Springs (5), are generally too low in grade to be of commercial interest. Scattered samples containing as much as 0.5 percent uranium have been obtained from

No F. (pegmatites) !

slates in the San Juan region (26), but the average grade is low.

G) Inclusions of an earlier phase of the intrusive in Chalk Mountain rhyolite porphyry near Climax, contain small amounts of pitchblende. This occurrence, found by the Geological Survey in 1949, appears to be unique (49).

H) In the San Juan region (26) and near Steamboat Springs (5) 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. 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 carnotite-type deposits, but we do not know of a single natural exposure containing pitchblende in the Front Range. At best, 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; pitchblende, if it ever was exposed at the surface, has been leached away. Leached outcrops and dumps in which no uranium minerals can now be seen, however, may be radioactive 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 merely a first step in prospecting for uranium in vein-type deposits.

The counter, though the most useful single tool in prospecting for uranium deposits, is only a tool and should be used with geologic know-how.

The use of the counter may be supplemented by geochemical techniques such as sampling vegetation (50) and mine and spring waters for uranium, and sampling mine air for radon (51). Wise use of time and talents requires that the use of all such prospecting aids be concentrated in areas that are geologically most favorable 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 proved their worth in finding carnotite ore on the Colorado Plateau (4). So far, however, systematic prospecting for pitchblende has been difficult. On the basis of preliminary data, we suggest that the following geologic relationships might be useful in the search for uranium outside the Colorado Plateau area: (a) uranium tends to occur in areas of post-Cretaceous igneous activity (52, 53); (b) uranium commonly is found in metal-mining districts that have produced silver, lead, and copper (54); (c) accumulations of helium and radon are theoretically related to uranium and (d) dark-colored fluorite and smoky quartz are believed to have some relation to radioactive minerals.

If the uranium deposits in the western United States are plotted on the geologic map, many of the uranium 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 areas for prospecting than those that contain only the older igneous rocks.

From a tabulation of metal production from 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 we have been studying the relation of helium-rich gases, particularly those containing radon, to the enclosing rocks (55, 56, 57, 58, 59, 60). 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 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 to good advantage in locating those parts of deposits that are radioactive.

In addition to these general guides to uraniferous areas there are guides that we believe may be useful in finding potential pitchblende-bearing deposits. They are: (a) the occurrence of bostonite dikes (27, 28. 29, 61), and (b) the zonal pattern of hypogene mineral deposits (62).

In the Front Range, slightly uraniferous intrusive trachytes of Tertiary age, locally termed "bostonites" (29, 63, 64), occur as dikes and small masses in the areas known to contain pitchblende-bearing veins (fig. 2). 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 that 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 (27, 28, 61, 65). Whether the spatial relationship has genetic significance, we do not know, but association does provide a possible guide to areas where pitchblende may occur.

In recent preliminary studies on the relation of uranium deposits to zoning in the metal-mining districts of the Front Range, it was noted that in the Central City district a small central area containing enargite-fluorite veins is surrounded successively by: (a) an area containing pyritic gold veins; (b) a transitional zone containing veins bearing gold, silver, lead, and zinc; and (c) a rather wide zone containing silver-lead-zinc veins (29, 42, 63, 69) (fig. 3). All the known pitchblende deposits are on the west side of the district in the transitional zone between the areas of pyritic gold veins and the areas of silver-lead-zinc veins (63). One small uranium prospect in the same transitional zone is known on the east side of the district (9). The position of the pitchblende deposits in this zonal pattern strongly suggests that areas around Central City, and similar areas in other districts having the same zonal pattern, are favorable for the occurrence of pitchblende (62).

Many other districts near the Central City district show zones of silver-lead-zinc deposits about a central area of pyritic gold deposits (63). (Enargite-fluorite veins, however, are usually lacking). Among these districts are Georgetown-Silver Plume, Empire, Lawson-Idaho Springs, Alice-Yankee Hill, Caribou-Grand Island, and Ward-Sunset. Several other districts, such as Breckenridge-Montezuma and Jamestown, show similar relations differing in scale or in complexity. The central area in these districts is not as sharply defined as at Central City; the central area and surrounding zones are more likely to be elliptical-shaped, and the pattern may be complicated by the presence of more than one central zone of pyritic gold deposits (61). The pitchblende deposits at Caribou, Lawson, and Jamestown also seem to fit into this hypogene zonal pattern. We feel confident that this guide is worth trying as an aid to finding new pitchblende deposits.

Recent discoveries of pitchblende with copper- lead- and silver-bearing volcanic breccia pipes of the San Juan region (26), and in replacement deposits of the Alma district (24, 25), have focused attention on two types of ore deposits not previously investigated for uranium. From the very limited data now at hand, it appears that the concept of hypogene zoning may be applicable to some of the replacement deposits, as well as to veins (62). Guides for selecting favorable volcanic breccia pipes have not yet been recognized (49).

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. Few ore bodies of any type have been discovered by pessimists, and fewer still by pessimists who stayed at home.

Table 1.--Uranium deposits in Colorado shown on figure 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	Boulder	Vein	Granodiorite	Pitchblende, torbernite, uranothorite
4	Springdale Springs	Boulder	Spring	Water	Radium-radon
5	Gold Hill	Boulder	Vein	Granite	Pitchblende
6	Copper Rock	Boulder	Disseminated	Schist	Unknown
7	Caribou	Boulder	Vein	Monzonite	Pitchblende
8	Eldora	Boulder	Vein	Monzonite	Pitchblende
9	Nigger shaft	Jefferson	Vein	Granite, schist	Pitchblende
10	Leyden	Jefferson	Disseminated	Silicified coal, sandstone	Carnotite
11	Fall River	Clear Creek	Vein	Schist, pegmatite	Pitchblende, secondary uranium minerals, thucholite (?)
12	Central City	Gilpin	Vein	Gneiss	Pitchblende
13	Golden Gate Canyon	Jefferson	Vein	Schist, gneiss	Pitchblende
14	Bellevue-Hudson	Clear Creek	Vein	Gneiss	Pitchblende
15	Jo Reynolds	Clear Creek	Vein	Gneiss	Pitchblende
16	Lone Star	Clear Creek	Pegmatite	Schist	Uranophane (?)
17	Martha E.	Clear Creek	Shear zones and veins	Schist	Pitchblende (?), torbernite

Table 1.--Uranium deposits in Colorado shown on figure 1--continued

Map No.	Name or locality	County	Type	Rock	Radioactive minerals
18	Spring Gulch-Alps Mountain	Clear Creek	Shear zones and veins	Granite, gneiss	Unknown
19	Georgetown	Clear Creek	Mine water	Schist, gneiss	Radium-radon(?)
20	Steamboat	Routt	Dissem-inated	Tufa	Radium(?)
21	Steamboat Springs	Routt	Pegmatite	Schist	Autunite
22	Steamboat Springs	Routt	Spring	Water	Radium-radon
23	Troublesome	Grand	Spring	Water	Uranium-radium-radon(?)
24	Brush Creek	Eagle	Dissem-inated	Sandstone	Carnotite(?)
25	Rifle	Garfield	Dissem-inated	Sandstone	Carnotite
26	Meeker	Rio Blanco	Dissem-inated	Sandstone	Carnotite
27	Skull Creek	Moffat	Dissem-inated	Sandstone	Carnotite
28	Aspen	Pitkin	Replace-ment	Limestone	Pitchblende(?)
29	Climax	Lake	Dissem-inated	Granite	Torbernite, monazite, brannerite
30	Chalk Mountain	Lake	Inclu-sions	Rhyolite porphyry	Pitchblende(?)
31	Sugar Loaf, St. Kevin	Lake	Dissem-inated, fracture coatings, vein	Granite, schist	Pitchblende(?), torbernite, florencite
32	Leadville	Lake	Dissem-inated	Shale	Pitchblende(?)

Table 1.--Uranium deposits in Colorado shown on figure 1--continued

Map No.	Name or locality	County	Type	Rock	Radioactive minerals
33	Alma	Park	Vein, replacement (?)	Granite, limestone, shale	Uraninite
34	Garo	Park	Disseminated	Sandstone	Carnotite, volborthite
35	Trout Creek Pass	Chaffee	Pegmatite	Granite	Euxenite
36	Manitou Springs	El Paso	Spring	Water	Unknown
37	Duffield	El Paso	Vein	Granite	Kasolite, pitchblende(?)
38	Mike Doyle	El Paso	Disseminated	Sandstone, shale	Carnotite
39	Cripple Creek	Teller	Vein	Granite	Pitchblende
40	Bull Domingo	Custer	Vein	Schist, gneiss	Unknown
41	Rosita-Haputa	Custer	Vein zone	Granite	Thorite
42	McIntire	Huerfano	Disseminated	Sandstone	Secondary uranium-vanadium minerals
43	LaVeta Pass	Costilla	Disseminated	Sandstone	Carnotite
44	Cebolla	Gunnison	Vein zone	Schist and aplite	Unknown
45	Powderhorn	Gunnison	Vein zone	Ultra basic and alkaline intrusive rocks	Thorite
46	Placerville	San Miguel	Vein	Sandstone, limestone	Pitchblende, thucholite (?)
47	Lower Uncompahgre	Ouray	Vein	Shale	Pitchblende(?)

Table 1.--Uranium deposits in Colorado shown on figure 1--continued

Map No.	Name or locality	County	Type	Rock	Radioactive minerals
48	Ouray	Ouray	Dissem-inated	Tufa	Radium, ura-nium
49	Upper Uncompahgre	Ouray	Dissem-inated	Slate	Pitchblende(?)
50	Ouray Springs	Ouray	Spring	Water	Radium(?)
51	Red Mountain	Ouray	Vein, volcanic breccia pipe	Rhyolite, latite	Pitchblende(?)

REFERENCES

1. Fischer, R. P., Federal exploration for carnotite ore: Colorado Mining Association, February 1949.

2. Fischer, R. P., Use of geology in guiding exploration for carnotite deposits on the Colorado Plateau: American Mining Congress, October 1951.

3. Staff of the Reconnaissance Group, U. S. Geological Survey, Progress report, Colorado Front Range area: U. S. Geol. Survey Trace Elements Memorandum Report 97A, August 1951. (Prepared for U. S. Atomic Energy Comm. Tech. Information Service.)

4. Fischer, R. P., Uranium-bearing sandstone deposits of the Colorado Plateau: Econ. Geology, vol. 45, pp. 1-11, 1950.

5. Beroni, E. P., and McKeown, F. A., Reconnaissance for uraniferous rocks in northwestern Colorado, southwestern Wyoming, and northeastern Utah: U. S. Geol. Survey Trace Elements Report, in preparation.

6. Granger, H. C., and King, R. U., Uranium in the Copper King mine, Black Hawk No. 1 claim, Larimer County, Colorado: U. S. Geol. Survey Trace Elements Memorandum Report 128-A, May 1951.

7. Sims, P. K., and Phair, George, Petrography and petrology of the pitchblende deposit at Copper King mine, Prairie Divide, Larimer County, Colorado: U. S. Geol. Survey Trace Elements Report, in preparation.

8. King, R. U., Investigations in the Wood mine, Colorado: U. S. Geol. Survey Trace Elements Memorandum Report 102 February 1950.

9. Armstrong, F. C., Pitchblende and related ore deposits at Quartz Hill, Justice Hill, and Iron and Pewabic mines, Central City mining district, Gilpin County, Colorado: U. S. Geol. Survey Trace Elements Report, in preparation.

10. King, R. U., and Granger, H. C., Torbernite occurrence at the Robineau claims, Clear Creek County, Colorado: U. S. Geol. Survey Trace Elements Memorandum Report 24, June 1950.

11. King, R. U., Radioactivity in the Jo Reynolds mine, Clear Creek County, Colorado: U. S. Geol. Survey Trace Elements Memorandum Report 5, January 1951.

12. Harrison, J. E., Geology of the Martha L. area, Clear Creek County, Colorado: U. S. Geol. Survey Trace Elements Report, in preparation.

13. Harrison, J. E., and Leonard, B. F., Geology of the Jo Reynolds area, Lawson-Dumont district, Clear Creek County, Colorado: U. S. Geol. Survey Trace Elements Investigations Report 153, in preparation.

14. Harrison, J. E., and Leonard, B. F., Geology of the Bellevue-Hudson area, Lawson-Dumont district, Clear Creek County, Colorado: U. S. Geol. Survey Trace Elements Report, in preparation.

15. Ridland, G. C., radioactivity at the Caribou silver mine, Boulder County, Colorado: Mining Eng., vol. 187, No. 1, pp. 98-101, 1950.

16. King, R. U., Vein deposits of uranium at the Caribou mine, Boulder County, Colorado: U. S. Geol. Survey Trace Elements Memorandum Report 13, June 1950.

17. Kerr, P. F., Mineralogical studies of uraninite and uranium-bearing deposits (appendix by H. D. Wright), 1950. (Unpublished Interim report for Atomic Energy Commission)

18. Moore, F. B., Geology and ore deposits, as related to uranium, of the Caribou Mining district, Boulder County, Colorado: U. S. Geol. Survey Trace Elements Report, in preparation.

19. Gott, G. B., Garo uranium deposits, Park County, Colorado: U. S. Geol. Survey Trace Elements Memorandum Report 222, July 1951.

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

21. Gott, G. B., The Leyden uranium prospect, Jefferson County, Colorado: U. S. Geol. Survey Trace Elements Memorandum Report 132, November 1950.

22. McKeown, F. A., and Gude, A. J. III, Preliminary report on the carnotite deposits of the Old Leyden coal mine, Jefferson County, Colorado: U. S. Geol. Survey Trace Elements Memorandum Report 308, September 1951.

23. Gude, A. J. III, Geology of the Nigger Shaft area, Ralston Creek district, Jefferson County, Colorado: U. S. Geol. Survey Trace Elements Report, in preparation.

24. Singewald, Q. D., and Pierson, C. T., Occurrences of radioactive minerals in the Alma district, Colorado: U. S. Geol. Survey Trace Elements Report, in preparation.

25. Singewald, Q. D., and Pierson, C. T., Occurrences of radioactive minerals in the St. Kevin district, Lake County, Colorado: U. S. Geol. Survey Trace Elements Report, in preparation.

26. Burbank, W. S., and Pierson, C. T., Preliminary results of radiometric reconnaissance of parts of the northwestern San Juan Mountains, Gunnison, Ouray, San Juan, San Miguel, and Dolores counties, Colorado: U. S. Geol. Survey Trace Elements Memorandum Report 310, in preparation.

27. Alsdorf, P. R., Occurrence, geology, and economic value of the pitchblende deposits of Gilpin County, Colorado: Econ. Geology, vol. 11, pp. 266-275, 1916.

28. Bastin, E. S., Discussion, occurrence, geology, and economic value of the pitchblende deposits of Gilpin County, Colorado: Econ. Geology, vol. II, pp. 681-685, 1916.

29. Bastin, E. S., and Hill, J. M., Economic geology of Gilpin County and adjacent parts of Clear Creek and Boulder counties, Colorado: U. S. Geol. Survey Prof. Paper 94, 379-pp., 1917.

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

31. Fischer, R. P., Stokes, W. L., and Smith, L. E., Geology of the Rifle Creek vanadium area, Garfield County, Colorado: U. S. Geol. Survey Strategic Minerals Investigations Preliminary Report, 1944. (Mimeographed, limited distribution.)

32. Webber, B. N., Report on Coal Creek anticline district, White River uplift area, Rio Blanco County, Colorado: Union Mines Development Corp. Report, June 1947.

33. Cater, F. W., and Fischer, R. P., Geology and ore deposits of the Uravan quadrangle, Colorado: U. S. Geol. Survey Quadrangle Map series, in preparation.

34. Beroni, E. P., and King, R. U., The Mike Doyle carnotite deposit, El Paso County, Colorado: U. S. Geol. Survey Trace Elements Memorandum Report 133, October 1950.

35. Fischer, R. P., Haff, J. C., and Rominger, J. F., Vanadium deposits near Placerville, San Miguel County, Colorado: Colorado Sci. Soc. Proc., vol. 15, No. 3, pp. 115-134, 1947.

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

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

38. Page, L. R., Uranium in pegmatites: Econ. Geology, vol. 45, pp. 12-34, 1950.

39. Dellwig, L. F., and Gott, G. B., Radioactive deposits on the Haputa Ranch, Custer County, Colorado: U. S. Geol. Survey Trace Elements Memorandum Report 285, November 1951..

40. Adams, J. W., and Moore, F. B., Personal communication, 1950.

41. Goddard, E. N., and Glass, J. J., Deposits of radioactive cerite near Jamestown, Colorado: Am. Mineralogist, vol. 25, pp. 381-404, 1940.

42. Goddard, E. N., The Front Range mineral belt, in Mineral resources of Colorado: State of Colorado Mineral Resources Board, Denver, Colorado, pp. 294-327, 1947.

43. Phair, George, and Onoda, Kiyoko, Verification of uraninite in fluorite breccias from the Blue Jay mine, Jamestown, Colorado: U. S. Geol. Survey Trace Elements Memorandum Report 173, October 1950.

44. Phair, George, and Onoda, Kiyoko, Hydrothermal uranothorite in fluorite breccias from the Blue Jay mine, Jamestown, Boulder County, Colorado: U. S. Geol. Survey Trace Elements Investigations Report 144. (In press, for publication by Am. Mineralogist.)

45. Wilmarth, V. R., Bauer, H. L., Jr., Staatz, M. H. and Wyant, D. G., Uranium in fluorite deposits: U. S. Geol, Survey Circular, in preparation.

46. Wilmarth, V. R., and Johnson, D. H., Radiometric studies in the Jamestown district, Boulder County, Colorado: U. S. Geol. Survey Administrative Report, 1951.

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

48. Hinrichs, E. N., Sheridan, D. M., and Moore, F. B., Personal communication, 1950.

49. Pierson, C. T., Personal communication, 1951.

50. Cannon, H. L., Final report on geobotanical prospecting methods in the Yellow Cat area, Grand County, Utah, the Gateway district, Mesa County, Colorado, and the northern Carrizo Mountains, Apache County, Arizona: U. S. Geol. Survey Trace Elements Report, in preparation.

51. Faul, Henry; Leonard, B. F.; Harrison, J. E., and Bales, W. E., Radon in the Lawson-Dumont district, Colorado, and its significance in exploration for uranium deposits: U. S. Geol. Survey Trace Elements Report, in preparation.

52. Kaiser, E. P., and Page, L. R., Distribution of uranium deposits in the United States: U. S. Geol. Survey Circular, in preparation.

53. Waters, A. C., Personal communication, 1951.

54. King, R. U., and Page, L. R., Personal communication, 1950.

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

56. Faul, Henry, and Sakakura, A. Y., Radon in some natural gases: Address before the Geological Society of Washington, D. C., 1951.

57. Faul, Henry, and Sakakura, A. Y., Radon and helium in the natural gas of the Texas Panhandle, comprehensive report: U. S. Geol. Survey Trace Elements Report, in preparation.

58. Hill, J. W., Radon-bearing gas in the Amarillo helium district, Texas: U. S. Geol. Survey Trace Elements Memorandum Report 131, August 1950.

59. Manger, G. E., Porosity and permeability of radon and helium-producing horizons: U. S. Geol. Survey Trace Elements Report, in preparation.

60. McNeal, R. P., Reconnaissance in oil fields in Lea County, New Mexico: U. S. Geol. Survey Trace Elements Memorandum Report 107, June 1950.

61. King, R. U., Moore, F. B., and Hinrichs, E. N., Pitchblende deposits in the United States: U. S. Geol. Survey Circular, in preparation.

62. Leonard, B. F., Concept of mineral zoning applied to Front Range pitchblende deposits: U. S. Geol. Survey Trace Elements Report, in preparation.

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

64. Spurr, J. E., and Garrey, G. H., 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-pp. 1908.

65. Phair, George; Personal communication, 1951.

66. Emmons, W. H., The principles of economic geology, pp. 368-372, McGraw-Hill Book Co., New York and London, 1940.

67. Sales, R. H., Ore deposits of Butte, Montana: Am. Inst. Min. Met. Eng. Trans., vol. 46, pp. 3-127, 1913.

68. Lindgren, Waldemar, Loughlin, G. F., and Heikes, V. C., Geology and ore deposits of the Tintic mining district, Utah: U. S. Geol. Survey Prof. Paper 107, 282-pp. 1919.

69. Collins, G. E., The relative distribution of gold and silver values in the ores of Gilpin County, Colorado: Am. Inst. Min. Met. Trans. vol. 12, pp. 480-499, 1903.

70. U. S. Atomic Energy Comm. and U. S. Geol. Survey, Prospecting for uranium; Gov't Printing Office, 1949.