GEOLOGY OF THE RALSTON BUTTES DISTRICT JEFFERSON COUNTY, COLORADO

A PRELIMINARY REPORT

By Douglas M. Sheridan, Charles H. Maxwell,
Arden L. Albee, and Richard Van Horn

Trace Elements Memorandum Report 901

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

IN REPLY REFER TO:

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WASHINGTON 25, D. C.

March 25, 1957

AEC - 375/7

Mr. Robert D. Nininger
Assistant Director for Exploration
Division of Raw Materials
U. S. Atomic Energy Commission
Washington 25, D. C.

Dear Bob:

Transmitted herewith are three copies of TEM-901, "Geology of the Ralston Buttes district, Jefferson County, Colorado,-- a preliminary report," by Douglas M. Sheridan, Charles H. Maxwell, Arden L. Albee, and Richard Van Horn, December 1956.

We plan to publish this report as a Geological Survey mineral investigations field studies map.

Sincerely yours,

John H. Eric
for W. H. Bradley
Chief Geologist

Geology and Mineralogy

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

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JEFFERSON COUNTY, COLORADO
A PRELIMINARY REPORT*

By

Douglas M. Sheridan, Charles H. Maxwell,
Arden L. Albee, and Richard Van Horn

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*This report concerns work done on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

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GEOLOGY OF THE RALSTON BUTTES DISTRICT, JEFFERSON COUNTY, COLORADO

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ABSTRACT

The Ralston Buttes district in Jefferson County is one of the most significant new uranium districts located east of the Continental Divide in Colorado. The district is east of the Colorado Front Range mineral belt, along the east front of the range. From November 1953 through October 1956, about 10,000 tons of uranium ore, much of which was high-grade pitchblende-bearing vein material, was shipped from the district. The ore occurs in deposits that range in size from bodies containing less than 50 tons to ore shoots containing over 1,000 tons. The only other mining activity in the area has been a sporadic production of beryl, feldspar, and scrap mica from Precambrian pegmatites, and quarrying of dimension stone, limestone, and clay from sedimentary rocks.

Most of the Ralston Buttes district consists of complexly folded Precambrian metamorphic and igneous rocks -- gneiss, schist, quartzite, amphibolite, and granodiorite. Paleozoic and Mesozoic sedimentary rocks crop out in the northeastern part of the district. These rocks are cut by northwesterly-trending fault systems of Laramide age and by small bodies of intrusive rocks that are Tertiary in age.

The typical uranium deposits in the district are hydrothermal veins occupying openings in Laramide fault breccias or related fractures that cut the Precambrian rocks. Pitchblende and lesser amounts of secondary

uranium minerals are associated with sparse base-metal sulfides in a gangue of carbonate minerals, potash feldspar, and, more rarely, quartz. Less common types of deposits consist of pitchblende and secondary uranium minerals that occupy fractures cutting pegmatites and quartz veins.

The uranium deposits are concentrated in two areas, the Ralston Creek area and the Golden Gate Canyon area. The deposits in the Ralston Creek area are located along the Rogers fault system, and the deposits in the Golden Gate Canyon area are along the Hurricane Hill fault system.

Two geologic factors were important to the localization of the uranium deposits: (1) favorable structural environment and (2) favorable host rocks. The deposits in each of the two major areas are located where a northwesterly-trending Laramide fault system splits into a complex network of faults. Also, most of the deposits appear to be localized where the faults cut Precambrian rocks rich in hornblende, biotite, or garnet and biotite. The ore controls recognized in this relatively new uranium district may have wider application in areas of similar geology elsewhere in the Front Range.

INTRODUCTION AND ACKNOWLEDGMENTS

The Ralston Buttes district in northwestern Jefferson County, Colo. (fig. 1) has become increasingly significant in recent years as the result of a small but growing production of uranium ores. The discovery of vein deposits of pitchblende in 1949 was followed by steadily increasing amounts of exploration, development work, and mining. The total production of uranium ore from the district from November 1953, when production started,

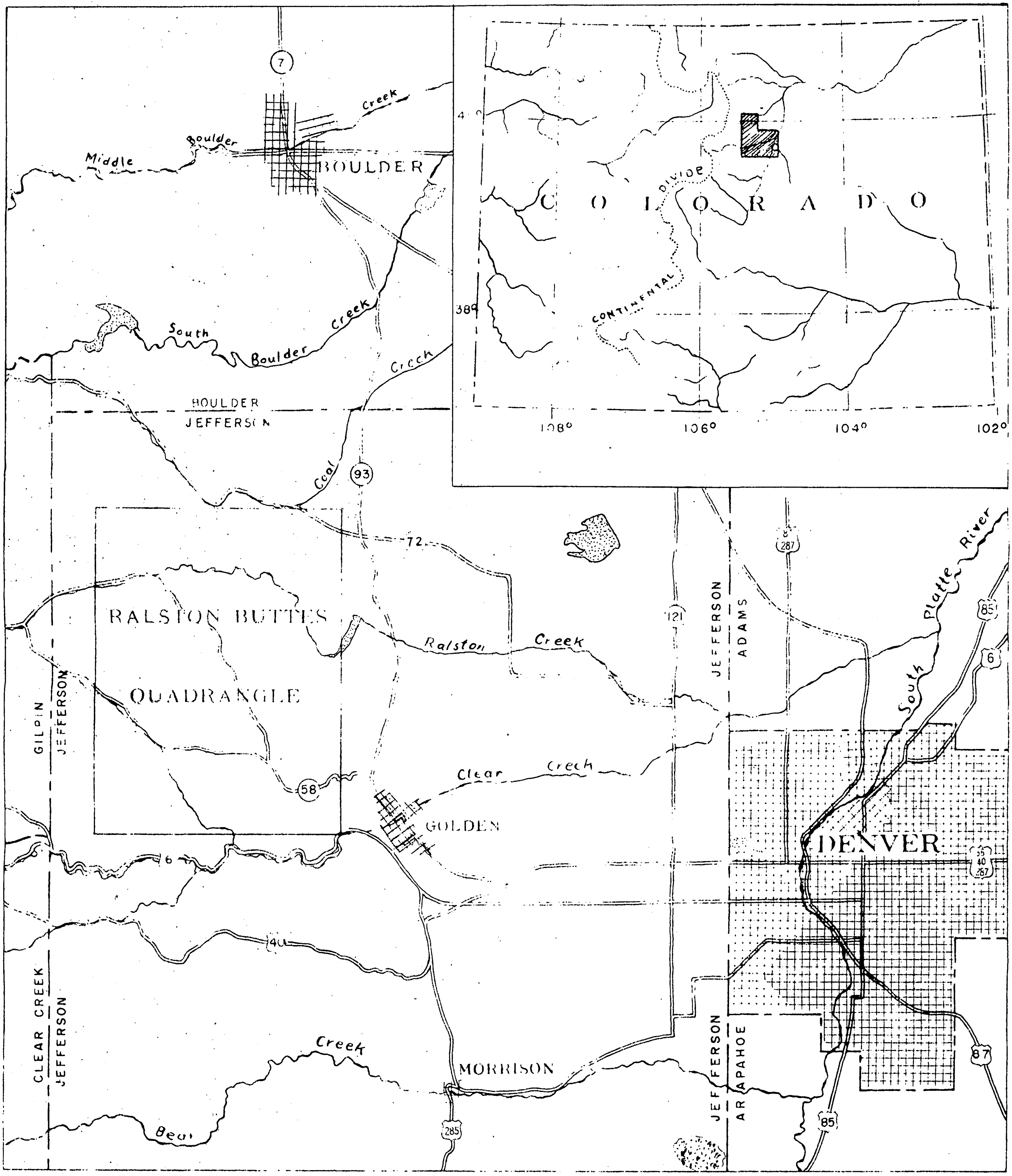


FIGURE 1.-INDEX MAP SHOWING LOCATION OF RALSTON BUTTES QUADRANGLE, JEFFERSON COUNTY, COLORADO

3 0 3 6 9 Miles

through October 1956 was about 10,000 tons, a large percentage of which has been high-grade pitchblende ore. In 1956 four mines were producing uranium ore and several other properties were being explored and developed.

The Ralston Buttes district comprises an area of about 58 square miles on the eastern flank of the Colorado Front Range, and coincides with the limits of the Ralston Buttes quadrangle, shown on the accompanying geologic map (fig. 2). The name of the district is taken from a topographic feature, Ralston Buttes (actually a hogback), in the northeastern part of the quadrangle.

This report consists of a preliminary areal map (fig. 2) and a brief description of the geology of the Ralston Buttes district. A more comprehensive report is currently being prepared.

The writers gratefully acknowledge the generous and courteous cooperation given by numerous ranchers in the district, by geologists of the U. S. Atomic Energy Commission, by officials, geologists, and miners of the Denver-Golden Oil and Uranium Company and the Yellow Queen Uranium Company, by geologists of the Union Pacific Railroad Company, by Mr. Fred Schwartzwalder, by Mr. J. W. Walsh, and by numerous prospectors and miners.

GEOLOGIC INVESTIGATION

The Ralston Buttes district lies southeast of the northeast-trending Front Range mineral belt, the geology of which has been described by Lovering and Goddard (1950). Pegmatite deposits in the Ralston Buttes district have been described by Waldschmidt and Gaines (1939), Waldschmidt and Adams (1942), and Hanley and others (1950). Uranium deposits in the district have been discussed by Bird and Stafford (1955) and by Bird (1956). The geology of post-Precambrian rocks in the district and adjacent areas has been described by Van Tuyl and others (1938), Waldschmidt (1939), LeRoy (1946), Waagé (1955), and Van Horn (in preparation). /

/ Van Horn, Richard, in preparation, Bedrock geology of the Golden quadrangle, Colo.

A series of uranium investigations in the Ralston Buttes district has been conducted by the U. S. Geological Survey on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission. Adams, Gude, and Beroni (1953) described the results of preliminary studies of the uranium deposits. More detailed studies pertaining to wall-rock control of certain pitchblende deposits in the district were made by Adams and Stugard (1956a; 1956b; 1956c). A brief summary of the uranium deposits in the Colorado Front Range, including those in the Ralston Buttes district, is given in a report by Sims (1956).

A comprehensive study of the entire Ralston Buttes district was started by the U. S. Geological Survey in 1953. Field work in the Precambrian part of the quadrangle was done by Sheridan (about 12 months, 1953-56), Maxwell (about 9 months, 1953-56), and Albee (about 6 months, 1955-56). K. R. Everett and W. E. Willging assisted in 1955. Van Horn mapped the geology of the Paleozoic and Mesozoic rocks in about 6 months in 1955-56.

The geology shown on the accompanying preliminary map was mapped in the field on U. S. Forest Service aerial photographs at a scale of about 1:23,000 and then was transferred to an enlarged base (1:20,000) of the 1944 edition of the Ralston Buttes topographic map.

GEOLOGIC SETTING

Precambrian metamorphic and igneous rocks, including gneiss, amphibolite, schist, quartzite, and granodiorite, form ninety percent of the bedrock of the Ralston Buttes district (fig. 2). Precambrian rocks not shown on the map include dikes, sills, and irregular bodies of pegmatite and aplite and small dikes and sills of hornblende-biotite metasyenite. Aside from some of the pegmatites, all the Precambrian rocks have been metamorphosed and contain mineral assemblages characteristic of the upper part of the amphibolite facies.

Sedimentary rocks of Paleozoic and Mesozoic age crop out in the northeastern part of the district. The sedimentary rocks range in age from Pennsylvanian to Cretaceous and in lithology from conglomerate to limestone.

Tertiary igneous rocks intrude both the Precambrian rocks and the younger sedimentary rocks. Quaternary deposits, not shown on the map, include thick deposits of gravel mantling the pediments in the northeastern part of the district and thin deposits of alluvium in most of the valleys.

The predominant trend of compositional or lithologic layering, schistosity, and major folds in the Precambrian rocks is east to northeast, whereas the trend of bedding in the Paleozoic and Mesozoic sedimentary rocks is north to north-northwest. An angular unconformity separates the complexly folded Precambrian sequence from the overlying sedimentary rocks.

Northwesterly-trending Laramide breccia-reef faults and fracture zones cut all the rocks ranging in age from Precambrian to Cretaceous (fig. 2). Characteristically the faults and fracture zones cutting the Precambrian rocks are marked by breccia zones and are similar in character to the faults and fracture zones in the Front Range that have been termed "breccia dikes" or "breccia reefs" (Lovering and Goddard, 1950, p. 79; Lovering and Tweto, 1953, p. 30). According to Lovering and Goddard (1950, p. 79) these northwesterly-trending fault systems represent one of the early stages of the Laramide revolution in this region.

On the small index map (fig.3) accompanying this report the fault systems in the Ralston Buttes district are shown in a simplified form and are correlated by name with the persistent "breccia reefs" or "dikes" that extend for many miles across the Front Range mineral belt (Lovering and Goddard, 1950, pl. 2). From southwest to northeast in the Ralston Buttes district these are the Junction Ranch, Hurricane Hill, Rogers, and Livingston fault systems. The largest apparent fault displacement in the Ralston Buttes district is along the Junction Ranch fault system, which shows an apparent horizontal movement of 4,000 feet (fig. 2). Less displacement is shown along other breccia-reef faults in the district, and no displacement of the wall rocks was recognized along some of the breccia-reef fracture zones.

A generalized zoning of the mineralogic character of the breccia along the fault and fracture systems was recognized from northwest to southeast in the district. In the northwestern part of the district

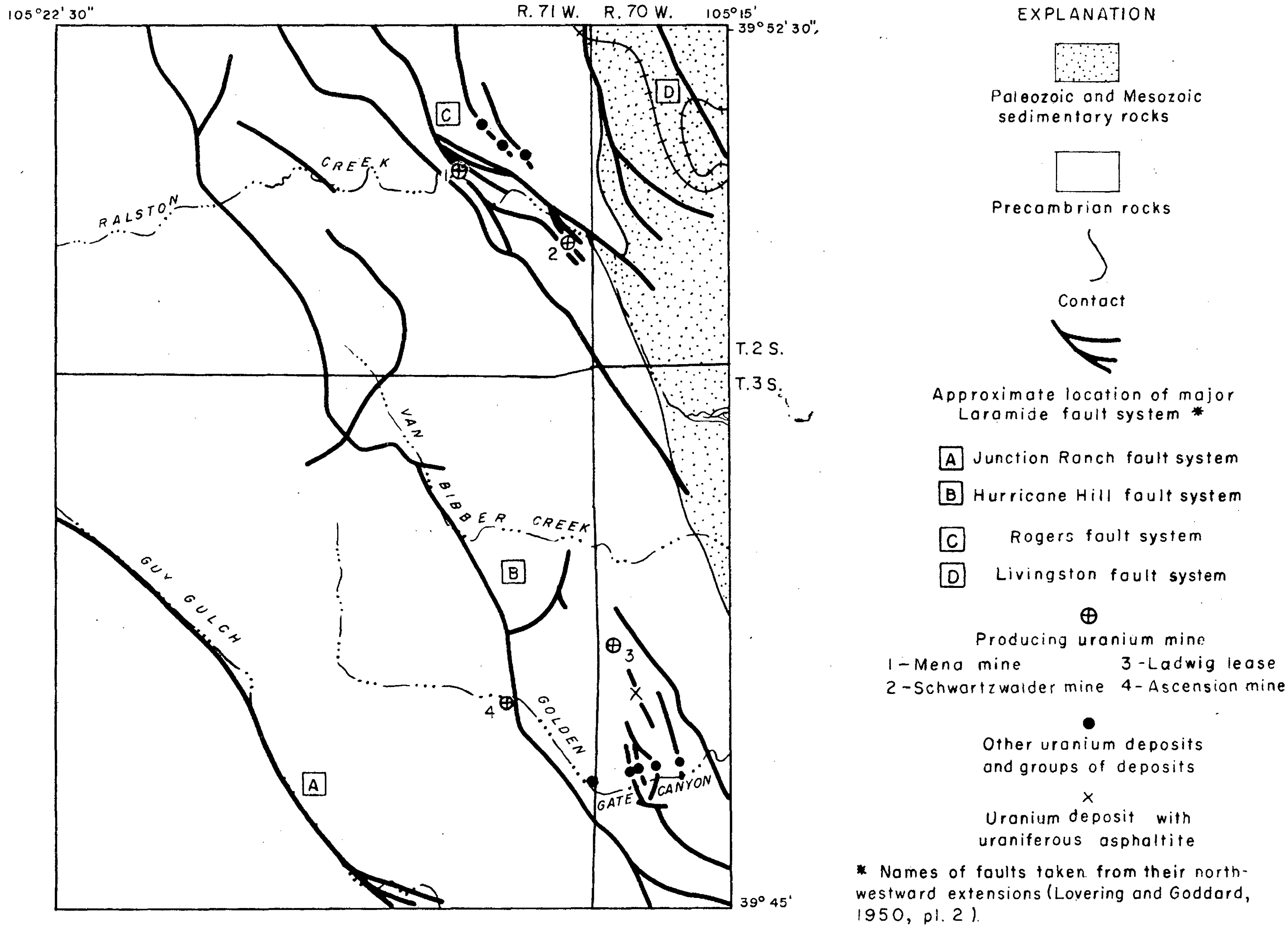
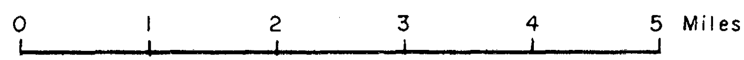


FIGURE 3.–INDEX MAP OF RALSTON BUTTES DISTRICT, COLORADO, SHOWING LOCATION OF MAJOR LARAMIDE FAULT SYSTEMS AND URANIUM DEPOSITS



the fault breccia commonly is cemented by quartz, fluorite, and hematite. Most of the faults and fracture zones in the remainder of the district are characterized by breccia cemented by ankerite and potash feldspar, with varying amounts of quartz and silicified fragments of wall rock.

Characteristically the breccias weather to a reddish-brown or yellowish-brown color. Outcrops of breccia containing ankerite and associated potash feldspar commonly weather to a knotty surface, with wall rock fragments and grains of potash feldspar standing out as resistant knots. Dike-like outcrops of breccia occur along some of the faults and fracture zones but are less common than in the Front Range mineral belt. More commonly in the Ralston Buttes district the faults or fracture zones are marked by low rounded outcrops of breccia, topographic depressions on ridges, or by scattered floats of breccia.

Fluorite, hematite, and sulfide minerals are distributed irregularly in the breccias along the Laramide faults and fracture zones. Vein deposits of pitchblende with associated base-metal sulfides fill openings in some of the breccia-reef faults and fractures.

ECONOMIC GEOLOGY

Uranium was the principal commodity of the mining industry in the Ralston Buttes district in 1956. Other materials that have been produced from time to time include feldspar, scrap mica, and beryl from Precambrian pegmatites, and limestone, dimension stone, and clay from the younger sedimentary rocks.

Uranium deposits

Summary statement

The typical uranium deposits of the Ralston Buttes district are hydrothermal veins that occupy openings in Laramide fault breccias or related fractures that cut the Precambrian rocks. Pitchblende and lesser amounts of secondary uranium minerals are associated with sparse base-metal sulfides in a gangue of carbonate minerals, potash feldspar, and, more rarely, quartz. Less common types of deposits consist of pitch-blende and secondary uranium minerals in fractures cutting pegmatites and quartz veins.

The uranium deposits are concentrated in two main areas: (1) the Ralston Creek area in the northeastern part of the district, and (2) the Golden Gate Canyon area in the southeastern part of the district. The deposits in the Ralston Creek area are located along the complexly faulted southeastward extension of the Rogers fault system (fig. 3). The deposits in the Golden Gate Canyon area are located in a similar zone of complex faulting along the southeastward extension of the Hurricane Hill fault system (fig. 3).

Two geologic factors were important to the localization of the uranium deposits: (1) structure and (2) favorable host rocks. The deposits in each of the major areas are located where a northwesterly-trending Laramide fault system splits into a complex network of numerous faults. Also, most of the deposits appear to be localized where the faults cut Precambrian rocks rich in hornblende, biotite, or garnet and biotite.

History and description

Active interest in uranium deposits in the Ralston Buttes district began in 1949 when Mr. Fred Schwartzwalder of Golden, Colorado, brought uranium samples to the U. S. Atomic Energy Commission from deposits he had discovered near Ralston Creek. In 1951-52 additional discoveries of uranium were made in the Ralston Buttes district by members of the U. S. Geological Survey (Adams and others, 1953, p. 2). Since that time, interest and exploration have increased greatly in the district. The first shipment of uranium ore from the district was made by Mr. Schwartzwalder in November 1953. In 1956 uranium ore was produced at four mines (fig. 3): the Mena mine, operated by J. W. Walsh; the Schwartzwalder mine, operated by the Denver-Golden Oil and Uranium Company; the Ladwig lease, operated by the Denver-Golden Oil and Uranium Company; and the Ascension mine, operated by the Yellow Queen Uranium Company. Other deposits in the district are undergoing active exploration.

The typical uranium deposits in the Ralston Buttes district are hydrothermal veins that occupy openings in Laramide fault breccias and related fractures. Pitchblende, the main uranium mineral, and minor amounts of secondary uranium minerals are associated with base-metal sulfides. The gangue consists typically of carbonate minerals (commonly ankerite) with associated potash feldspar, but less commonly it is quartz. In addition to the deposits directly associated with fault breccias, one deposit occurs in a fractured zone along and near a pegmatite contact and another deposit occurs in fractures that cut a sulfide-bearing quartz vein.

The known uranium deposits are grouped in two main areas: the Golden Gate Canyon area in the southeastern part of the district and the Ralston Creek area in the northeastern part. The locations of the four producing uranium mines and nine other uranium deposits and groups of deposits that have been explored are shown on figure 3. The uranium-bearing deposits near Golden Gate Canyon are associated with the complexly branching southeastward extension of the Hurricane Hill fault system, and the deposits along Ralston Creek are associated with a similar complex fault system, the southeastward extension of the Rogers fault system. In addition to the deposits shown on figure 3, numerous radioactivity anomalies and several other smaller occurrences of uranium minerals are known elsewhere along the Rogers and Hurricane Hill fault systems. Radioactivity anomalies have also been found along the Junction Ranch fault system; but, to date, no potentially significant uranium deposits have been found along this structure in the Ralston Buttes district. The Livingston fault system largely cuts sedimentary rocks in the Ralston Buttes district, and no uranium deposits are known in its vicinity within the district.

The uranium deposits range in size from thin mineralized veinlets or fault breccias less than an inch thick to major uranium ore shoots as much as 6 or 8 feet in thickness. Commonly the pitchblende-bearing ore shoots are confined either to the hanging wall or to the footwall of a mineralized fault breccia, with lower grade material occupying adjacent parts of the breccia. Typically the uraniferous material forms lenses or shoots that are discontinuous along strike. Individual ore bodies range in size from small pods or lenses containing 50 tons or less to large shoots containing over a thousand tons of ore. Although development and exploration work have progressed rapidly in recent years, the present stage of development has not approached that which is common in the older mining districts of Colorado. Consequently, the structure and persistence of the deposits in the Ralston Buttes district are not known completely.

Pitchblende is the main uranium mineral. Secondary uranium minerals at some of the deposits include torbernite, metatorbernite, uranophane, autunite, uranopilite, and meta-autunite. The secondary minerals are commonly found along the fault breccias and in fractures in the wall rock in the near-surface, oxidized portions of the deposits.

Copper minerals and other base-metal sulfides commonly are associated with the pitchblende in the uranium deposits but are not present in sufficient quantities to be valuable constituents of the ore. The suite of other metallic minerals includes chalcopyrite, bornite, chalcocite, covellite, sphalerite, galena, tetrahedrite-tennantite, pyrite, marcasite, malachite, azurite, and hematite. Native bismuth occurs at one pitchblende deposit, and emplectite (?) and molybdenite (?) have been tentatively identified at other uranium deposits. Samples from some of the deposits contain as much as 0.14 percent vanadium oxide but no vanadium mineral has been identified yet; the vanadium may be present as a trace element in the vein minerals or in the brecciated host rock. Pyrrhotite has been found in the immediate vicinity of two of the pitchblende deposits but it may not belong to the same period of mineralization. Uraniferous asphaltite is associated with base-metal sulfides in a carbonate-bearing fault breccia in Halfmile Gulch north of Golden Gate Canyon. The asphaltite may be related to known oil seepage in the vicinity, the oil presumably coming from sedimentary rocks underlying the westward-dipping Golden reverse fault. The trace of the Golden fault is east of the Ralston Buttes district.

In a detailed study of the paragenesis of the minerals in the Union Pacific prospect (sec. 19, T. 3 S., R. 70 W.) immediately north of Golden Gate Canyon, Adams and Stugard (1956a; 1956b; 1956c) found that pitchblende preceded the deposition of sulfide minerals. In their detailed sequence, pitchblende, hematite, some ankerite, and minor pyrite were deposited first, prior to the deposition of base-metal sulfides and the bulk of the ankerite vein filling; the last phase of the deposition is represented by calcite and fine-grained pyrite. Megascopic evidence and preliminary microscope studies of material from other pitchblende deposits in the district suggest that this same paragenetic sequence is generally consistent. Post-mineral shearing and rebrecciation of vein material have been common in some of the deposits.

As mining, exploration, and mapping have progressed in the Ralston Buttes district, it has become increasingly evident that most of the pitchblende deposits were controlled primarily by two geologic factors: (1) a favorable structural environment and (2) favorable host rocks.

The two known areas of uranium deposits, one near Golden Gate Canyon and the other along Ralston Creek, are each located where a major north-westerly-trending Laramide fault system consists of a complex network of numerous faults and fractures rather than a simple, discrete fault. In the uraniferous area along Ralston Creek the complexity of faulting is also characterized by a general change in trend of the faults from northwest to west. The combination of these geologic conditions -- splitting of a fault into a complex network of intricate fractures and a change of trend of the faults -- was favorable for uranium ore deposition, presumably because ample open space was provided for uranium ore deposition.

Probably equally important as faulting and fracturing in the localization of the uranium deposits was the other major factor - a favorable host rock. Within the district most of the uranium deposits occur where the faults cut Precambrian rocks that contain abundant hornblende, biotite, or garnet and biotite. The favorability of certain rock types in the district was first recognized by Adams and Stugard (1956a; 1956b; 1956c), who found that pitchblende deposits in the Golden Gate Canyon area are located where faults cut beds of hornblende gneiss, whereas the same faults are barren where they cut adjacent rocks of other mineralogic types. The favorable beds cited by Adams and Stugard are the amphibolite of the present report and are included in the map unit (ahb) of interlayered amphibolite and biotite-plagioclase-quartz gneiss (fig. 2) near the contact with quartz monzonite gneiss (gqm).

Some of the pitchblende deposits in the Ralston Creek area (fig. 2) are located in the amphibolite unit (a) and in or near amphibolite layers in the undifferentiated gneiss unit (g). The Schwartzwalder mine (sec. 25, T. 2 S., R. 71 W.) is located where fault breccias cut a zone of garnetiferous biotite-rich gneiss that forms the contact between the mica schist unit (s) and the amphibolite unit (a). The Ascension mine (NW¼ sec. 24, T. 3 S., R. 71 W.) is located where faults and fractures cut interlayered amphibolite and biotite-quartz-plagioclase gneiss (ahb), layered lime silicate gneiss (al) including garnetiferous layers, and pegmatite (not shown on the map). The fault and fracture system near the Ascension mine has been greatly simplified on the preliminary geologic map (fig. 2). Recent detailed mapping at the mine indicates that at least two breccia-reef faults lie immediately west of the breccia-reef fracture zone shown on fig. 2; there are also other branching zones of breccia in the vicinity. The uraniferous asphaltite in Halfmile Gulch (NW$\frac{1}{4}$ sec. 19, T. 3 S., R. 70 W.) occurs where a fault breccia cuts garnetiferous rock which forms the contact between a layer of lime silicate gneiss (al) and sericite-biotite schist (als). At the Ladwig lease (SW$\frac{1}{4}$ sec. 18, T. 3 S., R. 70 W.) ore was found originally near the surface in and near the fractured contact between pegmatite and garnetiferous biotite-rich gneiss. This garnetiferous rock occurs at the contact of the mica schist unit (s) and layered lime silicate gneiss (al), a stratigraphic relationship similar to the geologic setting at the Schwartzwalder mine. More recently, mine workings at a level 80 feet below the surface on the Ladwig property have exposed fractures and irregular zones of coarse breccia that cut the garnetiferous gneiss and contain pitchblende and secondary uranium minerals.

That certain wall rocks appear to have been more favorable for ore deposition than others may be explained by their physical or chemical character. Hornblende-rich and garnet-rich gneisses, for example, are relatively more competent than sericite-biotite schist and upon fracturing yield more open space, whereas much of the fault movement in schist is dissipated along the schistosity planes. The chemical nature of the wall rock may have been equally effective in localizing ore, because certain minerals in the wall rock may have reacted with the mineralizing solutions in such a way as to cause the deposition of uranium as pitchblende. It is difficult to determine which characteristic of a favorable rock -- physical or chemical -- is of prime importance, but is likely that both characteristics influenced the genetic history of the uranium deposits in the Ralston Buttes district.

The location of the series of deposits in amphibolite in the Golden Gate Canyon area strongly suggests that the chemical nature of the wall rock was a strong factor in ore localization in that area. Adams and Stugard (1956a; 1956b; 1956c) believe that ferrous iron was released by the alteration of hornblende in these rocks by mineralizing solutions and was oxidized and partly deposited as hematite; at the same time uranium was reduced in the solutions and deposited as pitchblende. They concluded that wall rocks rich in ferrous iron provide the most favorable host for ore deposition and emphasized that rocks rich in biotite, magnetite, tourmaline, or iron sulfides could be equally effective as hornblendic rocks. Chemical control may also be an important factor at the Schwartzwalder mine, because rich ore is especially abundant where fault breccias cut the zone of garnetiferous biotite-rich gneiss, but the physical competence of the garnetiferous rock may also be a contributing factor.

Other mineral deposits

Precambrian pegmatites in the Ralston Buttes district have been the source of minor quantities of feldspar, scrap mica, and beryl. The locations of many of the pegmatite mines and prospects are shown on the geologic map. Production has been intermittent, and no large-scale mining of pegmatite is currently in progress in the district. A pegmatite in the SE$\frac{1}{4}$ sec. 30, T. 2 S., R. 71 W., has been explored for rare earths, but no production has been reported.

A prospect containing molybdenum (SE$\frac{1}{4}$ sec. 21, T. 3 S., R. 71 W.) and a prospect containing tungsten (NW$\frac{1}{4}$ sec. 24, T. 3 S., R. 71 W.) are indicated on the geologic map. The minerals scheelite, molybdenite, and pyrrhotite occur in very small quantities in deposits of this type and are not minable on the basis of present exposures. Although these 2 deposits are located along and near Laramide fault systems, the evidence is not conclusive that they are definitely Laramide or Tertiary in age. It is possible that these deposits may be Precambrian, or at least pre-Laramide, in age.

Clay has been mined from the Fountain, Dakota, and Benton formations in the quadrangle. Refractory-grade clay occurs only in the upper part of the Dakota (Waagé, 1952). Small amounts of common clay have been mined from mudstone beds in the Fountain formation and from the lower part of the Benton shale. A small clay pit, 2 miles north of the Ralston Buttes quadrangle, was being mined for common clay from the upper part of the Lykins formation in 1956.

Limestone beds in the Lykins formation and Fort Hays limestone member of the Niobrara formation were extensively quarried for mortar many years ago. The only limestone being quarried in this area in 1955 came from a small quarry in the Lykins formation just east of the Ralston Buttes quadrangle. This material is crushed and used to surface private driveways.

The Lyons sandstone has been quarried in the Ralston Buttes quadrangle for use as dimension stone, but no quarries have been in operation in this area for many years.

Several quarries, just east of the Ralston Buttes quadrangle, have produced rock from Precambrian gneiss in Clear Creek Canyon. The rock is suitable for use as concrete aggregate, riprap, and ballast. Similar rock is abundant in the Ralston Buttes quadrangle.

Sand and gravel have been extracted from the Quaternary pediments east of the quadrangle. The material covering the pediments in the Ralston Buttes quadrangle is silty and contains many cobbles and boulders that would require crushing. It is probably inferior to material that can be obtained from the terraces and flood plain of Clear Creek east of the Ralston Buttes quadrangle.

SUGGESTIONS FOR PROSPECTING FOR URANIUM

Most of the uranium deposits in the Ralston Buttes district are located in or near northwesterly-trending fault systems of Laramide age. Furthermore, the main groups of uranium deposits are located where such fault systems are complex or show changes in trend. Copper minerals and other base-metal sulfides are associated with pitchblende in many of the deposits. Favorable host rocks include relatively dark-colored Precambrian rocks rich in hornblende, biotite, or garnet and biotite. Rocks of this type are particularly abundant in the amphibolite unit.

By using the above-mentioned guides together with evidence of radioactivity, copper stain, traces of secondary uranium minerals and other guides that may develop in the future, it is probable that additional deposits will be discovered in the district. Laramide faults and favorable Precambrian rocks such as amphibolite, biotite-rich gneiss, garnetiferous rocks, and lime-silicate gneiss are common in other parts of the Front Range. Much of the information pertaining to the Front Range mineral belt is shown by Lovering and Goddard (1950, pl. 2). Uranium deposits are already known within the mineral belt (King and others, 1953; Sims and others, 1955; Hawley and Moore, 1955, Sims and Tooker, 1956; Moore and others, in preparation 1/; Harrison and Wells, in preparation 2/, and in areas fringing

1/ Moore, F. B., Cavender, W. S., and Kaiser, E. P., in preparation, Geology and uranium deposits of the Caribou area, Colorado.

2/ Harrison, J. E., and Wells, J. D., in preparation, Geology and ore deposits of the Chicago Creek area, Clear Creek County, Colorado.

the belt (Sims, 1956, fig. 1). The adjacent areas east and west of the mineral belt have received less attention from prospectors over the years, and additional prospecting in these areas and in parts of the mineral belt may result in new discoveries of economic significance.

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