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Mineral Deposit

TEMP-140

GEOLOGY OF THE AREA ADJACENT TO THE FREE ENTERPRISE URANIUM-SILVER MINE, BOULDER DISTRICT, JEFFERSON COUNTY, MONTANA

Trace Elements Memorandum Report 140

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

IN REPLY REFER TO:

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

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AEC 737/2

Dr. Phillip L. Merritt, Assistant Director
Division of Raw Materials
U. S. Atomic Energy Commission
P. O. Box 30, Ansonia Station
New York 23, New York

Dear Phil:

Transmitted herewith for your information and distribution are 6 copies of Trace Elements Memorandum Report 140, "Geology of the area adjacent to the Free Enterprise uranium-silver mine, Boulder district, Jefferson County, Montana," by W. A. Roberts and A. J. Gude, III, March 1952.

We plan to send the dittolith masters of this report to the Technical Information Service for reproduction and distribution according to your Raw Materials Unclassified Distribution List (Limited), and also to include it as part of a Geological Survey bulletin. We are asking Mr. Hosted, by a copy of this letter, whether the Commission has any objection to such distribution and publication.

Sincerely yours,

W H Bradley

W. H. Bradley
Chief Geologist

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Geology - Mineralogy

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Series A

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

GEOLOGY OF THE AREA ADJACENT TO THE FREE ENTERPRISE URANIUM-SILVER MINE, BOULDER DISTRICT, JEFFERSON COUNTY, MONTANA*

By

W. A. Roberts and A. J. Gude, III

March 1952

Trace Elements Memorandum Report 140

This preliminary report is distributed without editorial and technical review for conformity with official standards and nomenclature. It is not for public inspection or quotation.

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

USGS - TEM Report 140

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By W. A. Roberts and A. J. Gude, III

ABSTRACT

Uranium minerals occur in pods associated with cryptocrystalline silica, silver minerals, and scattered sulfide mineral grains in a hydrothermal vein that cuts quartz monzonite and alaskite at the Free Enterprise mine, 2 miles west of Boulder, Mont. The Free Enterprise vein is one of many silicified reef-like structures in this area, most of which trend about N. 60° E.

The cryptocrystalline silica zones of the area are lenticular and are bordered by an altered zone where quartz monzonite is the wall rock. No alteration was noticed where alaskite is adjacent to silica zones. No uranium minerals were observed at the surface, but radioactivity anomalies were noted at 57 outcrops. Underground mining has shown that leaching by downward percolating waters has removed most of the uranium from the near-surface part of the Free Enterprise vein and probably has enriched slightly, parts of the vein and the adjacent wall rock from the bottom of the leached zone to the ground-water level. It is possible that other veins that show low to moderate radioactivity at the surface may contain significant concentrations of uranium minerals at relatively shallow depth.

The quartz monzonite appears to be a more favorable host rock for the cryptocrystalline silica and associated uranium minerals than the alaskite.

The alaskite occurs as vertical dikes,, plug-like masses, and as irregularly shaped, gently dipping masses that are believed to have been intruded into open fractures formed during the cooling of the quartz monzonite.

The nature of the Free Enterprise deposit, the abundance of silicified zones, and the weak to moderate surficial radioactivity of some of these zones suggest that many small deposits of uranium and silver minerals may occur in this area. Cost of exploring for, and mining of many of these small deposits, however, might be prohibitive.

INTRODUCTION

Purpose, location, and accessibility

Uranium minerals occur in a silver-bearing cryptocrystalline silica vein deposit at the Free Enterprise mine in the Boulder mining district, Mont. The area around this deposit was studied to determine the origin, and the mode and extent of occurrence of the uranium minerals. This work is part of a general study of uranium deposits being done by the U. S. Geological Survey on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

The Free Enterprise mine is in sec. 19, T. 6 N., R. 4 W., about 2 miles west of Boulder, Jefferson County, Mont., (fig. 1) and 400 feet south of the graded road between Boulder and Comet.

Boulder, with a population of about 1,000, is the county seat of Jefferson County and is almost halfway between Helena and Butte on U. S. Highway 91 (fig. 1). The Boulder railroad station, on a branch of the Great Northern Railroad, is on the road to Comet about halfway

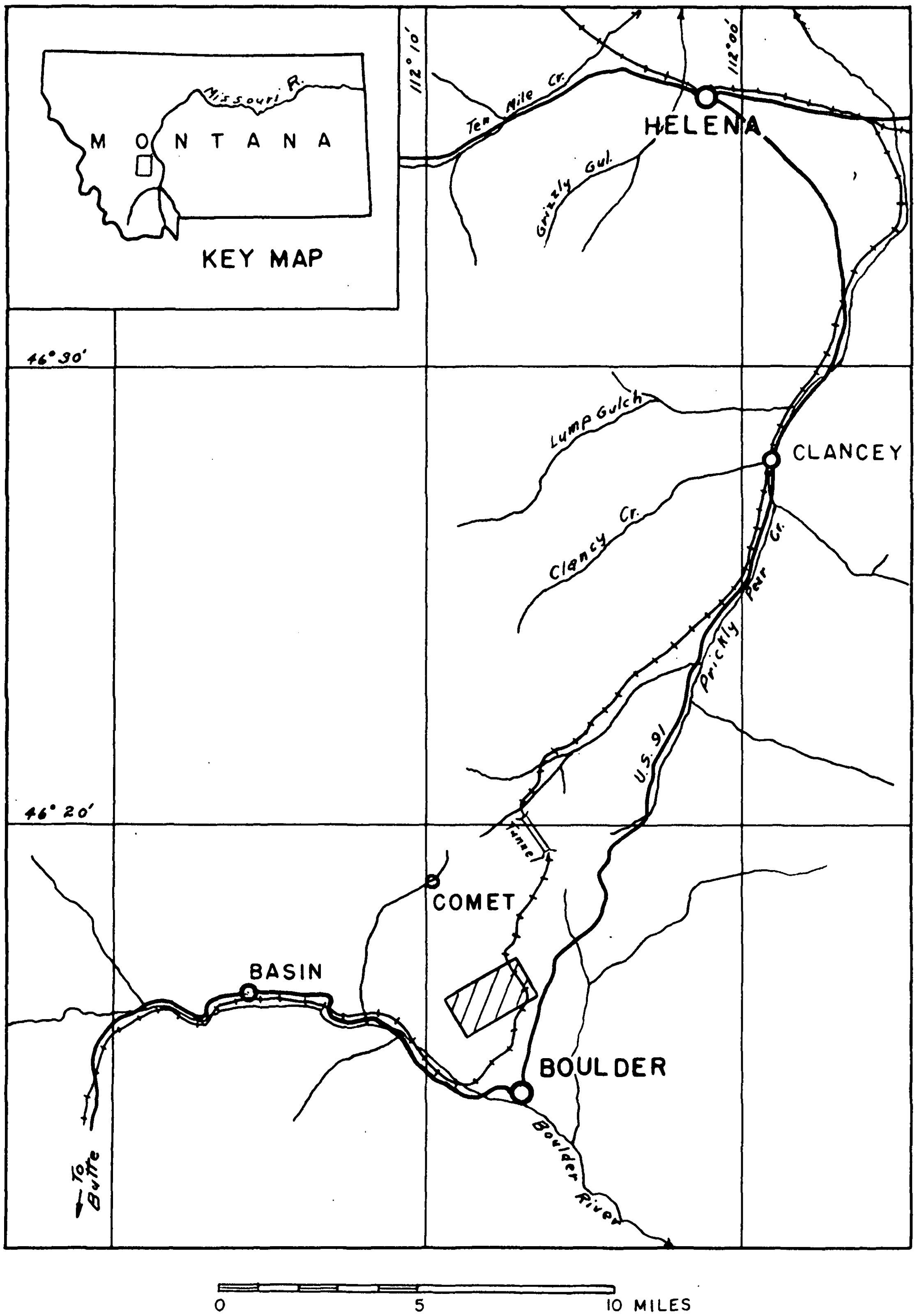

FIGURE 1. INDEX MAP OF AREA MAPPED NEAR BOULDER, JEFFERSON COUNTY, MONTANA.

between the town of Boulder and the Free Enterprise mine.

The relief in the vicinity of the mine ranges from 100 to 300 feet between the ridges and intervening gully bottoms. The Boulder River, a tributary of the Jefferson River, is the nearest perennial stream and is about 2 miles south of the Free Enterprise mine. Although the winter climate is severe, the mine is favorably located and should be able to operate throughout the year.

Previous work

Previous reconnaissance geologic work in the Boulder batholith and the Boulder mining district has been done by several investigators: _/

_/ Knopf, Adolf, Ore deposits of the Helena mining region, Montana: U. S. Geol. Survey Bull. 527, pp. 120-128, 1913.

_/ Pardee, J. F., and Schrader, F. C., Metalliferous deposits of the greater Helena mining region, Montana: U. S. Geol. Survey Bull. 842, pp. 285-299, 1933.

_/ Billingsley, P., The Boulder batholith of Montana: Am. Inst. Min. Eng. Trans. vol. 51, pp. 31-56, 1916.

_/ Billingsley, P., and Grimes, J. A., Ore deposits of the Boulder batholith of Montana: Am. Inst. Min. Eng. Trans. vol. 58, pp. 284-332, 1918.

Recently, Thurlow and Reyner _/ made a detailed study of the uranium

_/ Thurlow, E. E., and Reyner, M. L., Free Enterprise uranium prospect, Jefferson County, Montana: U. S. Atomic Energy Commission unpublished report, April 1950; and Thurlow, E. E., and Reyner, M. L., Supplementary report on the Free Enterprise prospect, Jefferson County, Montana: U. S. Atomic Energy Commission unpublished report, December 1950.

deposit in the Free Enterprise mine for the Atomic Energy Commission. A condensed version of this report containing some new information is included in a report by Thurlow and Reyner on regional reconnaissance for uranium in the Boulder batholith. _/ Uranium-bearing deposits,

_/ Thurlow, E. E., and Reyner, M. L., Preliminary report on uranium-bearing deposits of the northern Boulder batholith region, Jefferson County, Montana: U. S. Atomic Energy Commission unpublished report, March 1951.

similar to the Free Enterprise deposit, occur near Clancey, 15 miles north of Boulder; these deposits were studied by the writers during 1950 and have been described in a previous report. _/

_/ Roberts, W. A., and Gude, A. J., III, Uranium-bearing deposits west of Clancey, Jefferson County, Montana: U. S. Geol. Survey Trace Elements Memorandum Rept. 229, January 1951.

Field work

Radiometric survey

A radiometric survey (fig. 2) was made by A. J. Gude, III, with an El-Tronics portable Geiger counter, model S6M-18A, using six 14-inch gamma tubes connected in parallel as a probe. All major outcrops and most of the intervening mantle were traversed and measured with the counter. The lowest meter reading observed in this area was 6.5 on the 2.0 scale and is designated as background for this area. The only high-intensity radioactivity detected was at the Free Enterprise mine where mineralized rock from the underground workings was on the dump and in ore piles. No anomalies were detected on exposures of the Free Enterprise vein at the surface.

There were 54 low-intensity anomalies (10-15 on the 2.0 scale) observed in this area. In addition to these 54 low-intensity anomalies, three anomalies between 15.0 on the 2.0 scale and 5.0 on the 20.0 scale

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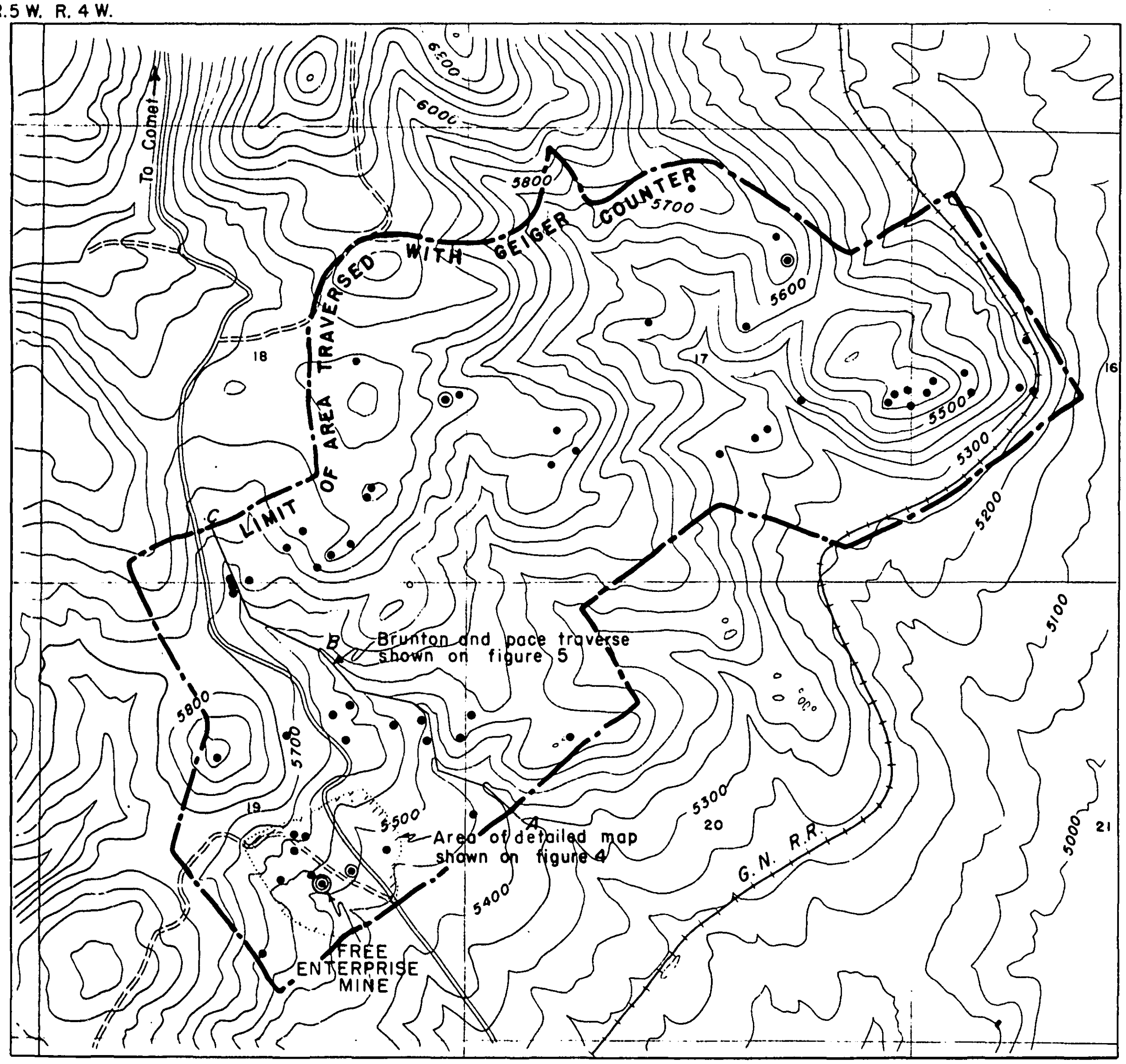

EXPLANATION

Low intensity anomaly
(>10 to <15 on 2.0 scale)

Moderate intensity anomaly
(>15 on 2.0 scale, <5 on 20.0 scale)

High intensity anomaly
(>5 on 20.0 scale)

Radioactivity Anomalies

(Readings obtained with an Eltronics portable Geiger counter, model SGM-184, using as a probe six 14" gamma tubes connected in parallel)

Topography from Bureau of Reclamation Upper Missouri Basin Topographic Sheet number 33

INDEX MAP SHOWING RADIOACTIVITY ANOMALIES
OF THE
FREE ENTERPRISE MINE AND VICINITY, JEFFERSON COUNTY, MONT.

0 2000 4000 6000 8000 Feet

Contour interval 50 feet

DATUM MEAN SEA LEVEL

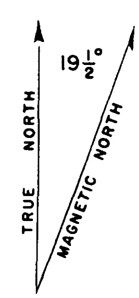

FIGURE 2

were detected (fig. 2).

Geologic studies

Geologic field work was begun September 26, 1950, and was completed October 17, 1950. The geology of an area of approximately 2 square miles extending northeast from the Free Enterprise mine was mapped at a scale of 1:12,000 on a photostatic enlargement of the Bureau of Reclamation, Upper Missouri Basin project advance topographic sheet No. 33 (fig. 3). The geology of the area around the mine shaft was mapped in detail by plane-table methods (fig. 4). A Brunton and pace traverse up the first gully north of the area mapped in detail was made (fig. 5).

Acknowledgments

Valuable help and suggestions were given to the writers by M. R. Klepper of the Geological Survey. Cordial cooperation was extended by Mr. Wade V. Lewis, president of the Elkhorn Mining Company, and operator of the Free Enterprise mine.

In addition, A. F. Trites, Jr., of the Geological Survey, established triangulation stations in this area which were used as control points in mapping the areal geology. J. W. Hosterman of the Geological Survey assisted in making the detailed map of the area around the mine shaft.

History

Metallic minerals were discovered in the Boulder district prior to 1870 and have been mined intermittently from different deposits since that time. Pardee and Schrader _/ do not separate completely the

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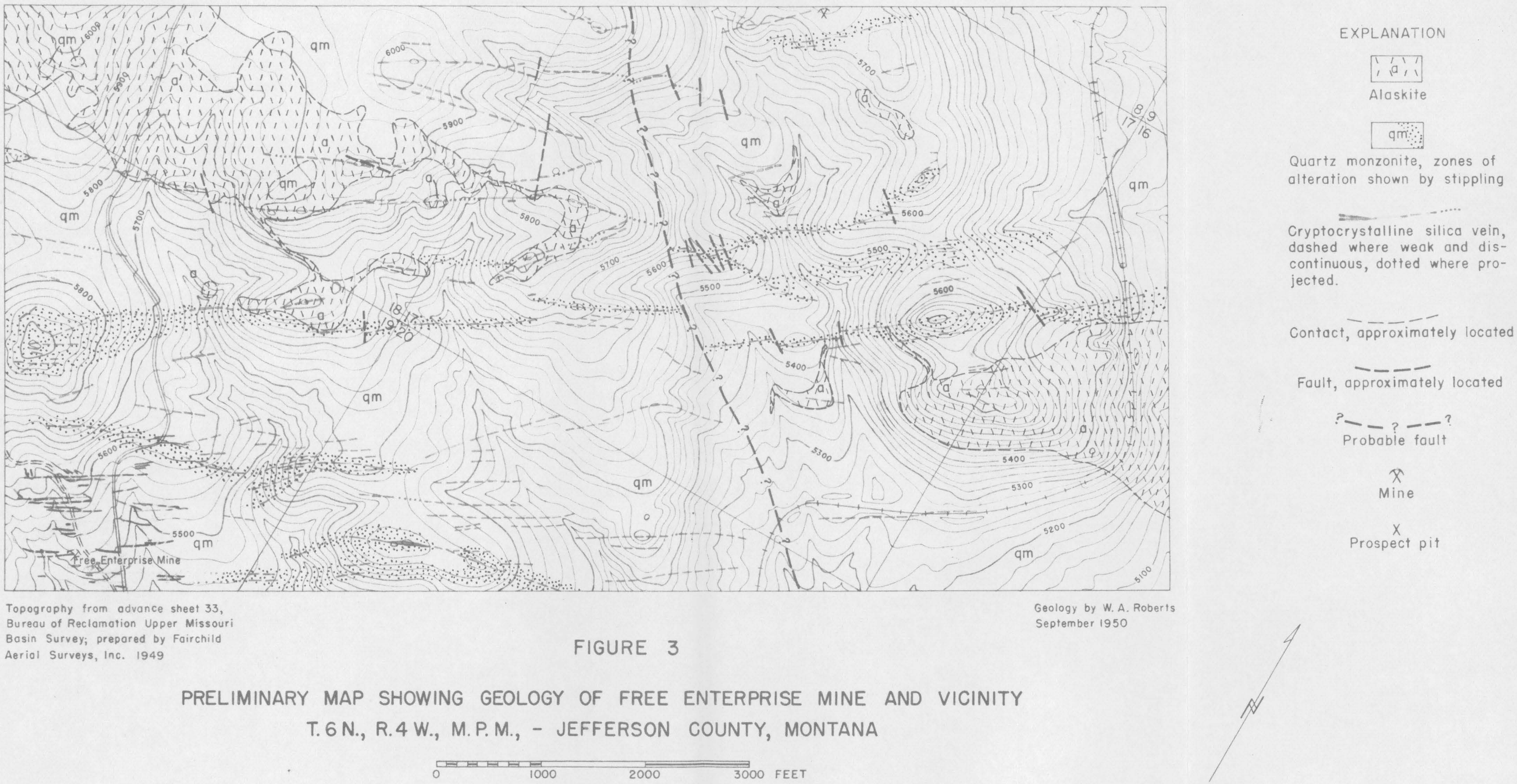

Topography from advance sheet 33, Bureau of Reclamation Upper Missouri Basin Survey; prepared by Fairchild Aerial Surveys, Inc. 1949

Geology by W. A. Roberts
September 1950

FIGURE 3

PRELIMINARY MAP SHOWING GEOLOGY OF FREE ENTERPRISE MINE AND VICINITY
T. 6 N., R. 4 W., M. P. M., - JEFFERSON COUNTY, MONTANA

0 1000 2000 3000 FEET

Contour Interval 20 ft.

Brunton-tape base survey and geology by W. A. Roberts, 1950

FIGURE 5.– GEOLOGIC TRAVERSE ALONG UNNAMED GULLY, NORTHEAST OF FREE ENTERPRISE MINE, SEC. 18, 19, and 20, T. 6 N., R. 4 W., JEFFERSON COUNTY, MONTANA

0 100 200 300 400 500 600 700 800 900 1000 Feet

_/ Pardee, J. F., and Schrader, F. C., op. cit., p. 286.

the Boulder and the Basin mining districts but list the value of minerals produced from the Boulder district as $325,000 between 1904 and 1928. The minerals mined during this period presumably contained lead, zinc, gold, silver, and copper.

Mr. Sanford Davis of Boulder recognized uranium minerals on the dump of the old Silver Bell prospect about April 1949. Mr. Davis, Mr. Edward C. Miles of Helena, and Mr. Wade V. Lewis of Boulder visited the property shortly after this with a Geiger counter and detected radioactivity at the dump.

Messrs. Davis, Miles, and Lewis now own the 29 unpatented claims of the Free Enterprise-Boulder Mercury group and have renamed the prospect the Free Enterprise mine. The property was leased to the Elkhorn Mining Company at Boulder, Mont., with whom the Sunshine Mining Company of Coeur d'Alene, Idaho, negotiated an operating agreement and rehabilitated and extended the old workings in late 1949 and early 1950. When the Sunshine Mining Company withdrew, the Elkhorn Mining Company began mining on the 80-foot level and has since shipped a small amount of uranium-silver ore. Thurlow and Reyner _/ report that 2,300 pounds of

_/ Thurlow, E. E., and Reyner, M. L., op. cit., December 1950, p. 5.

selected material containing 1.66 percent U_3O_8 was shipped to Shattuck Chemical Company of Denver, Colo., in July 1950. No reports on the silver assays were available. Two shipments of ore were made to Vitro Chemical Company of Salt Lake City, Utah, prior to April 16, 1951. The first shipment was about 42 tons averaging 0.16 percent U_3O_8 and the second shipment was 40 to 50 tons of ore of an unknown grade.

GEOLOGY

General features

The Free Enterprise mine and the area mapped around the mine (fig. 3) are entirely within the Boulder batholith, a large intrusive body composed chiefly of quartz monzonite. The quartz monzonite is cut by plugs and dikes of alaskite and dacite (?). Many of the alaskite dikes are gently dipping, irregularly shaped, lens-like bodies that crop out over areas that are relatively large compared with the thickness of the bodies involved.

The batholithic rocks have been fractured, sheared, and brecciated along narrow zones that trend about N. 60° E. and in general, dip steeply to the northwest. Some zones have been recurrently silicified and brecciated. The topographic expressions of these silicified zones have been called reefs because they usually stand above the adjacent ground surface. Small, high-angle faults trending northwest offset the silicified zones as much as several hundred feet.

The only sedimentary rocks in the area mapped are Recent deposits of alluvial and colluvial material. Small terraces occur in the gullies several feet above the present bottom. A thin veneer of hillwash and mantle blankets most of the area. The alluvial gully fills and terraces are too small to map at a scale of 1:12,000 (fig. 3).

Igneous rocks

Quartz monzonite

The principal rock type of the Boulder batholith has been described as quartz monzonite. _/ The quartz monzonite is a light-gray medium-

_/ Knopf, Adolf, op. cit., p. 10

_/ Pardee, J. F., and Schrader, F. C., op. cit., p. 3.

grained equigranular rock that consists, in order of decreasing abundance, of plagioclase, quartz, orthoclase, biotite, and hornblende. Orthoclase occurs as large scattered pink phenocrysts about 1 inch long. Typically, the rock weathers into large rounded boulders. The finer-grained detritus formed by weathering is usually granular and iron stained and contains conspicuous biotite.

Wherever cryptocrystalline silica cuts the quartz monzonite an altered zone occurs on both sides of the silica vein; however, altered zones are present that are not cut by visible cryptocrystalline silica. This altered facies differs from the unaltered rock in the following ways: the altered facies appears to be slightly finer grained; ferromagnesian minerals are sparser in the altered facies, although biotite occurs locally as scattered flakes; there appears to be more orthoclase in the altered facies; some of the feldspar in the altered facies have been altered to clay minerals. Locally sericite occurs in the zone of alteration adjacent to cryptocrystalline silica, especially in the northwestern part of the area mapped, but the age of the sericite with respect to that of the silica has not been determined. Contacts between the unaltered and altered country rock are gradational through an interval ranging from 1 inch to about 1 foot. The altered facies generally weathers to angular blocks instead of the granular detritus formed by the weathering of the country rock.

The altered part of the quartz monzonite is believed to be facies of the unaltered country rock rather than a separate intrusive rock, principally because of its close association with the cryptocrystalline silica and also because of its gradational transition into quartz monzonite.

Alaskite

Alaskite dikes and plug-like masses cut the quartz monzonite and are believed to occupy tension fractures formed during the cooling of batholithic quartz monzonite. Many of these dikes are gently dipping irregular-shaped, lenticular sheet-like masses that crop out over areas as much as a quarter of a square mile. Some of the dikes have a vertical or steep dip. The alaskite commonly weathers to blocky material and the soil derived therefrom is relatively free from biotite.

Mineralogically, the alaskite, which is composed essentially of quartz and potash feldspar with very subordinate amounts of plagioclase and rare biotite, is very similar to the alaskite bodies near Clancey, Mont., but texturally the alaskitic rocks of these two areas differ significantly. In the Free Enterprise area the principal variety of alaskite has a saccharoidal to granitic texture in a variety of grain sizes from about 0.1 mm to 4 mm. The bulk of the rock is a mediumgrained alaskitic granite with a grain size of 1 to 2 mm. The distinctly porphyritic facies which is common near Clancey was not observed in the Free Enterprise area, and the pegmatitic facies is rare and probably comprises less than 1 percent of all alaskite outcrops.

Although the contacts with the quartz monzonite are sharp, and locally, the grain size of the alaskite may be slightly finer at the borders of a body, chilled selvages of alaskite have not been found. This suggests that the alaskite was emplaced in fractures that formed while the quartz monzonite was still cooling and that the alaskite came from a quartz- and potash-rich magmatic residuum of the main batholithic mass.

A large body of quartz-poor alaskite that appears to contain an appreciable amount of plagioclase, as well as abundant orthoclase, is exposed in a railroad cut in the southeastern part of the area mapped. Black tourmaline rosettes occur in the alaskite about 4 feet above the railroad bed for 20-30 feet along the northwestern side of the cut. For purposes of mapping, this rock type was not distinguished from the plagioclase-poor alaskite.

Cryptocrystalline silica veins and stringers cut the alaskite, as well as the quartz monzonite, but altered zones bordering the veins usually are not evident megascopically in the alaskite. Locally, however, sericite has been recognized in alaskite adjacent to silica veins.

Dacite (?)

One small aphanitic dike of dacite (?) cuts quartz monzonite at the eastern edge of the area shown in figure 4. The age relationship of the dacite (?) and the alaskite could not be determined within this area, but studies in nearby areas indicate that the dacite (?) is younger.

Silicification

Within the area mapped both the quartz monzonite and alaskite are cut by numerous zones composed in part of many stringers and veins of cryptocrystalline silica. The silicified zones are within a zone of fracturing and alteration in quartz monzonite or within a zone of fracturing without recognizable alteration in alaskite. Most silicified zones are somewhat lenticular, and generally the stringers and veins within them are arranged in a sub-parallel to en echelon fashion. The stringers and veins are roughly parallel to the elongation of the zones. The silicified zones, which include the veins and stringers, range in thickness from a few inches to several tens of feet.

Contacts of the cryptocrystalline silica veins and stringers with the altered quartz monzonite and alaskite are sharp. Disseminated cryptocrystalline silica also has impregnated the wall rock of quartz monzonite from a fraction of an inch to several feet adjacent to veins and altered it by replacement. Locally, closely spaced iron-stained joints occur in the marginal parts of silica reefs and altered zones, and also in the adjacent country rock. Brecciated silica fragments cemented by silica are common in the veins, and brown opaline silica is commonly found as fracture-filling in the silica, indicating that there were either at least two ages of hydrothermal, or primary and secondary silicification.

The reefs weather less rapidly than either the quartz monzonite or alaskite, and usually occur as ribs or low ridges that stand from 6 inches to 20 feet above the surrounding surface.

The quartz monzonite was the better host rock for the cryptocrystalline silica because apparently it was more fractured and thus more susceptible to silicification than the alaskite. Silica veins that cut both quartz monzonite and alaskite are generally thicker and more continuous in the quartz monzonite. This observation also has been made in the Free Enterprise mine by Thurlow and Reyner. _/

_/ Thurlow E. E., and Reyner, M. L., op. cit., April 1950, p. 11.

Structure

The numerous steeply-dipping silica zones, most of which trend about N. 60° E., and dip northwestward, are the most striking structural features in the Free Enterprise area. Brecciation has occurred in many of these silicified veins, and gouge or microbreccia is found at the margins or within some veins.

The veins are offset as much as several hundred feet (fig. 3) by high-angle northwest-trending cross-faults. These faults are probably normal faults along which the northeastern blocks generally moved down. Faults in the batholithic rocks are difficult to detect --- the discontinuity of silicification, irregularity and discontinuity of the alaskite dikes and plugs, and the lack of key units for correlation obscure all but the most obvious ones.

The principal gullies and intervening ridges are transverse to the veins and are roughly parallel to the northwest-trending normal faults.

MINERAL DEPOSITS

General geologic features

The only occurrence of uranium minerals as yet discovered in this area is at the Free Enterprise mine. Although no uranium minerals were noted in surface outcrops, low-intensity radioactivity anomalies on veins in the area suggest that uranium may occur beneath the surface in many of them.

Uranium occurs as a primary constituent of a silicified vein on the 80-foot level of the Free Enterprise mine. Weathering has altered most of the primary uranium minerals above the 80-foot level to secondary gummite-type uranium minerals. Metatorbernite and autunite occur disseminated in the wall rock adjacent to the vein. The geology of the underground workings at the Free Enterprise mine has been mapped by geologists of the Atomic Energy Commission.

A series of twelve or more nearly parallel silicified zones, one of which is the Free Enterprise vein, that strike on the average about N. 60° E. and dip 85° NW, are shown on the detailed map (fig. 4). These zones cut both the quartz monzonite and the vertical and gently dipping alaskite dikes. Several sheet-like gently dipping alaskite dikes crop out near the mine shaft and at least two of these have been intersected by the underground workings. _/ The steeply dipping alaskite dike that

---

_/ Thurlow, E. E., and Reyner, M. L., op. cit., pl. II, March 1951.

---

crops out about 100 feet west of the shaft is offset slightly by the Free Enterprise vein indicating that some movement has occurred along this zone. Underground studies by Thurlow and Reyner _/ indicate that

_/ Thurlow, E. E., and Reyner, M. L., op. cit., pl. II, March 1951.

this dike may be connected with the alaskite body that crops out about 130 feet east of the shaft by a gently dipping alaskite mass exposed in the mine workings (fig. 4, section BB'). A dacite (?) dike 25 feet thick shown in the southeastern part of the detailed map strikes roughly parallel to the silicified zones.

Intense weathering has left only short discontinuous outcrops of the silicified zones, commonly less than 10 feet long, in the vicinity of the Free Enterprise shaft. In mapping, judicious projections of these zones were made (fig. 4); however, only physical exploration such as bulldozing, drilling, or driving of underground workings can demonstrate the continuity of these structures.

Mineralogy

Scattered specks of pyrite are found in most of the cryptocrystalline silica veins at the surface. In the Free Enterprise mine pyrite, galena, ruby silver, argentite, native silver, molybdenite, chalcopyrite, arsenopyrite, and barite are found in the vein. _/ All are sparse

_/ Thurlow, E. E., and Reyner, M. L., op. cit, March 1951, p. 24.

components. Uranium minerals found in the vein are uraninite, gummite-type hydrous oxides, autunite, metatorbernite, and some zeunerite and uranophane. _/ Autunite and metatorbernite occur along fractures in

_/ Thurlow, E. E., and Reyner, M. L., op. cit., March 1951, pp. 24-25.

and adjacent to the vein and disseminated in the wall rock as much as

2 feet from the vein. A dark-brown primary uranium mineral resembling samarskite, but as yet unidentified, has been found at the southeast end of the drift on the 80-foot level.

Wade V. Lewis _/ reported that cinnabar was collected from a prospect pit on a cryptocrystalline silica vein about 1,500 feet north of the Free Enterprise shaft. Although a search was made, no cinnabar was found by the writers. Cinnabar is also reported by E. S. Larsen _/ to occur in a cryptocrystalline silica vein about half a mile north of Boulder Station and about 100 yards west of the railroad tracks. This pit is 1,500-2,000 feet east of the mapped area (fig. 3) and was not visited.

_/ Oral communication from Wade V. Lewis.

_/ Mineral Resources of the U. S., 1917, p. 415.

General character and classification

Uranium minerals occur in and adjacent to a vein-type deposit of cryptocrystalline silica in fractures in the batholithic rock. The primary minerals occur as pods in the Free Enterprise vein and the secondary minerals occur as fracture linings and as scattered crystals in and adjacent to the vein. The Free Enterprise vein is one of many silicified and altered zones that occur in this area (fig. 3), but it is the only one in which uranium minerals have been found, although a number of others show weak to moderate radioactivity anomalies..

Although the zones of alteration and probably the fractures in which the silica has been deposited are traceable for hundreds to thousands of feet, the actual veins and stringers of cryptocrystalline silica characteristically swell and pinch out over distances of several feet to several hundred feet. Altered zones border the silica veins in the quartz monzonite country rock and may extend beyond the visible silica stringers and veins. Disseminated cryptocrystalline silica probably has impregnated most of the rock in the altered zones but is most noticable adjacent to the silica veins.

Thurlow and Reyner _/ have classified the vein as a mesothermal

_/ Thurlow, E. E., and Reyner, M. L., op. cit., April 1950, pp. 9-10

fissure filling on the basis of the mineralogic assemblage. The writers feel, however, that the mass of brecciated cryptocrystalline silica, the reported occurrence of cinnabar at two localities, one about 1,500 feet north and the other about half a mile east of the Free Enterprise shaft in veins similar to the Free Enterprise vein, and the occurrence of argentite and primary ruby silver in the Free Enterprise vein, indicate that this deposit and all other cryptocrystalline silica veins in the area are probably epithermal. This deposit is also believed to be related to the magma which formed the batholithic mass.

Alteration by meteoric solutions

By the process of weathering, the primary minerals in the Free Enterprise vein have been converted to hydrous oxides, silicates, and uranyl phosphates. The phosphates, autunite and metatorbernite, are the most widespread of the secondary uranium minerals. They occur as fracture- and cavity-fillings in the wall rock, thereby indicating that some depletion of parts of the vein deposit has occurred. The gummite-type secondary uranium minerals are usually within or very near the vein; most of them apparently were formed in place.

Thurlow and Reyner state "Extensive near-surface leaching coupled with selective precipitation along favorable zones within and adjacent to the vein have combined to form enriched pockets of secondary uranium minerals. These zones may be related to the former water level ....". _/

_/ Thurlow, E. E., and Reyner, M. L., op. cit., December 1950, p. 4.

They report that below the water level on the 140-foot level the radioactivity is slight and that only minor amounts of secondary uranium minerals are found in vugs and on fracture surfaces.

Suggestions for prospecting

The present study has revealed several guides that may be useful to the prospector. Radioactivity, which may indicate the presence of uranium, is associated principally with cryptocrystalline silica that crops out as reefs, most of which stand 6 inches to 20 feet above the surrounding surface. Studies at the Free Enterprise mine show that leaching by downward percolating water has removed most of the uranium from the near-surface silicified zones; accordingly a radiation detector must be used in this area for efficient prospecting, but this may fail to give reliable results if thorough leaching of uranium has extended downward more than a foot or so. Quartz monzonite country rock appears to have been a more favorable host rock than alaskite for the formation of silicified zones and deposition of associated uranium minerals. No abnormal radioactivity has been detected in any of the dacite (?) dikes tested in either the Boulder area or in the Clancey area to the north.

The suggestions for prospecting in the Clancey area are believed to be useful to the prospector not only near Boulder and Clancey but in the Boulder batholith as a whole. _/ Intersections of small spur-like

_/ Roberts, W. A., and Gude, A. J., III, op cit., pp. 29-30.

reefs with the larger reefs appeared to be favorable at Clancey. At many places in the Clancey and Free Enterprise areas gray cryptocrystalline silica is indicative of radioactivity.