Gold in the Eureka Mining District, Nevada

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Abstract

The Eureka district, Nevada, was discovered in 1864; it has since produced about 1.65 million ounces of gold, mostly during the period 1870-1890. Paleozoic shallow-water marine carbonate formations were extensively folded, thrust faulted, and shattered in late Paleozoic and Mesozoic times. The rocks were mineralized during emplacement of Cretaceous stocks. Mantolike replacement bodies rich in gold, silver, and lead formed along or near faults and fractures. Primary ores consist of pyrite, arsenopyrite, galena, sphalerite, and minor quartz in silicified, bleached, and (or) marmorized dolomite. Grades typically are 0.15–0.2 oz Au/ton, 7.0–9.0 oz Ag/ton, 0.1–0.2 percent Cu, 5–7 percent Pb, 9–12 percent Zn, and 20–30 percent Fe. Rich oxidized bonanza ores mined near the surface contained iron oxides, cerargyrite(?), native gold, anglesite, cerussite, mimetite, plumbojarosite, beudantite(?), bindheimite, and some quartz, halloysite, and calcite. These ores accounted for most of the district's production; they averaged about 1.1 oz Au/ton, 27 oz Ag/ton, and 17 percent Pb. Some of the rich ore mined during the period of peak production also contained about 0.12 percent Cu, 24 percent Fe, 1.9 percent Zn, 4.1 percent As, and 0.25 percent Sb.

Oxidized ores were mined southwest of the northwest-trending Ruby Hill normal fault during the early history of the district. Later, large high-grade primary ore bodies were discovered at depth northeast of the fault, and an attempt to mine them was made in the 1940's. A large flow of underground water stopped the attempt, and the resource remains unmined.

Low-grade disseminated gold ore in "sanded" dolomite at the Windfall mine differs markedly from other ores of the district. It is characterized by abundant jasperoid and realgar; it may be of Tertiary age, perhaps a result of reworking of older base metal ores. Mining has recently exploited these resources.

INTRODUCTION

The Eureka mining district is in Eureka County in the east-central part of Nevada; the county seat, Eureka, with a population of less than 500, is about 400 km east of Reno, Nev., and 520 km west of Salt Lake City, Utah (fig. C8). The ore deposits in the district are examples of gold-rich mantolike replacement bodies in Paleozoic carbonate rocks near Cretaceous stocks. In addition to gold, the deposits produced substantial lead and silver.

HISTORY AND PRODUCTION

Ore was discovered in the Eureka district in 1864 during the wave of prospecting that followed the discovery and development of the bonanza ores of the Comstock Lode at Virginia City and, closer at hand, Austin, in what is now the State of Nevada. Discovery of the rich ores resulted in the settlement of the town of Eureka, which at one time in the late 1800's was reported to have a population of some 10,000; similar discoveries elsewhere in the region saw the settlement of such mining camps as Austin, Hamilton, and Pioche. The newly found ores were major factors in the opening of the West through railroad and communication construction.

The initial discovery of ore was made in New York Canyon (fig. C9) south of the present town of Eureka; like most of the ore discovered subsequently, it was oxidized gold-silver-lead ore rich in iron. Initially the ore was not amenable to the beneficiation methods then current, and it was not until 1869, when smelting techniques were improved and when the large rich ore bodies of Ruby Hill (fig. C9) were discovered, that the district became highly productive. The greater part of the district's production took place in the 20 years from 1870 to 1890 and came mostly from the mines on Ruby Hill. Two large smelters, the Richmond, south of Eureka, and the Eureka Consolidated, to the north, produced large quantities of gold, silver, and lead, and their slag piles are still prominent features of the landscape. In addition, several smaller smelters were active during the period.

The production from the Ruby Hill mines decreased after about 1890, but a smaller continuing output was made by lessees from Ruby Hill and from new discoveries in other parts of the district. In 1905, the two major Ruby Hill mines which had been consolidated as the Richmond-Eureka mine were acquired by the U.S. Smelting, Refining, and Mining Co., and considerable

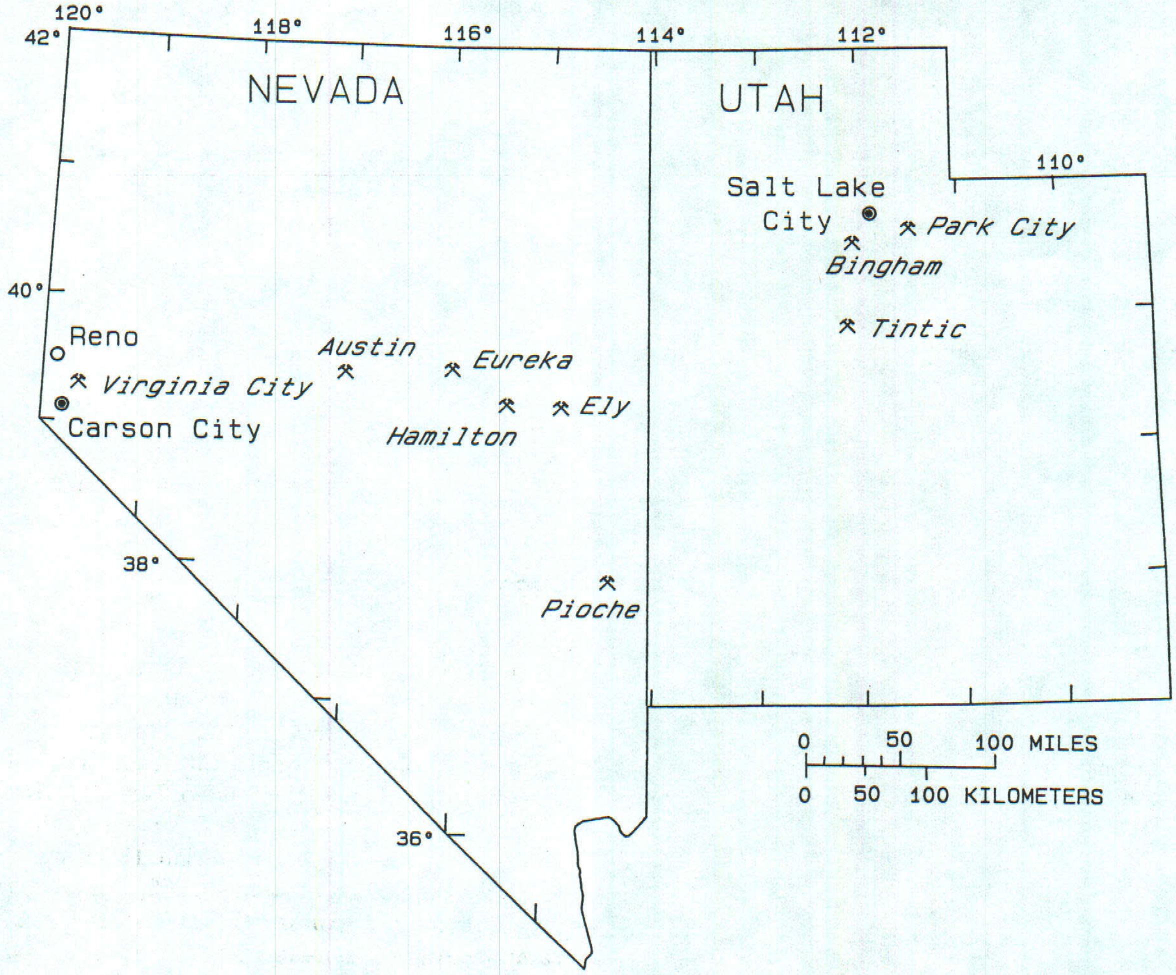


Figure C8. Location of the Eureka mining district, Nevada, and some other significant Nevada and Utah mining districts.

amounts of lower grade ore and stope fillings were shipped to Salt Lake Valley smelters.

Beginning in 1919, extensive exploratory drilling was undertaken in search of extensions of the Ruby Hill ore bodies that had been cut off by the northwest-striking Ruby Hill fault. Several drill holes struck ore of good grade, and a new shaft (the Fad) was sunk in 1941–1946 to a depth of 760 m. In crosscutting to the ore intersections from the shaft, however, a large flow of water was tapped, and the shaft was flooded to within a few hundred meters of the surface. Development of the mine then was abandoned, and despite considerable study of methods to accomplish dewatering of the mine to permit access to the ore bodies, the mine has been idle in recent years.

Other mines in the district with significant production include the Diamond mine of the Consolidated Eureka Mining Co., the T.L. shaft of the Eureka Corp., Ltd. (now the Ruby Hill Mining Co.), the Windfall mine, as well as the belt of old mines extending north from the Hamburg to the Dunderberg (fig. C9). All, however, are now idle, although sporadic exploration continues.

Records of production from the Eureka district for the years prior to about 1900 are fragmentary and in many places conflicting. When such information as appears dependable is pieced together, it suggests that in the neighborhood of 2 million tons of ore were mined, containing about 1,650,000 oz of gold, 39,000,000 oz of silver, and 625 million lbs of lead. These metals had a value (at prices existing at the time of production) of somewhat in excess of $120 million. At present-day metal prices, the total value would, of course, be much greater, substantially more than $1 billion.

In addition to the contribution that the production made to the national economy, the Eureka district significantly advanced mineral technology in several respects. Perhaps the most notable was the development of new and improved smelting methods for the oxidized ores of the district; the district has been characterized as the "cradle of modern lead blast furnace smelting." Less well known is the fact that some of the earliest experiments in geochemical and geophysical prospecting were carried out on Ruby Hill. Finally, the Ruby Hill mines constituted one of the earliest districts, if not *the* earliest, in which the leasing or "tribute" system was utilized in mining the ore. Less notable at the time, perhaps, but of major importance to subsequent mining in the United States was litigation to apply mining law to the irregular "limestone replacement" deposits of the district. The dispute between the Richmond and the Eureka Consolidated mines on Ruby Hill resulted in protracted litigation, finally settled in the U.S. Supreme Court.

GEOLOGY

The Eureka district (fig. C9) was one of the first in the Great Basin to be given detailed geologic study by the newly established U.S. Geological Survey, and the reports on this work by Hague (1892), Walcott (1884), Iddings (in Hague, 1892), and Curtis (1884) were the basis for future work not only in the district but also in adjoining areas in Nevada. Nolan (1962; 1978; Nolan and others, 1956; Nolan and Hunt, 1968) began studies in 1932 in the district; these have continued for a half century, although with decreasing emphasis in recent years.

Rock Formations

The stratigraphic section initially established in the district has, with relatively minor modifications, continued in use to the present time. The section includes marine strata that represent all the Paleozoic system and that have a total thickness of about 9,000 m; Cambrian formations with a total thickness of about 2,300 m, Devonian units (largely dolomite) totaling about 1,500 m, and Carboniferous and Permian beds totaling about 3,000 m constitute the major part of the section.

A sequence of about 300 m of Lower Cretaceous freshwater sediments was deposited unconformably above these rocks. The Cretaceous sediments were overridden by a series of landslides before lithification; these are now exposed as deeply eroded sheets of megabreccia. A small exposure of quartz diorite that crops out a short distance south of Ruby Hill is of Early Cretaceous age (102–99.5 Ma; Marvin and Cole, 1978, p. 9; Silberman and McKee, 1971, p. 30–31); it is the surface expression of a more extensive mass known from deep drill holes and magnetic anomalies.

Younger rocks include a group of Oligocene intrusive rhyolite plugs, ash-flow and air-fall tuffs, and flows; a number of age determinations on this series of volcanics range from 39 to 34 Ma (Blake and others, 1975; Nolan and others, 1974, p. 6; Jaffe and others, 1959). Other units include Miocene ash-flow tuffs and alkali basalt that are 23–21 Ma (Marvin and Cole, 1978, p. 9; Nolan and others, 1974, p. 6); gravel ranging in age from late Tertiary to Holocene; and locally abundant Pleistocene lakebeds.

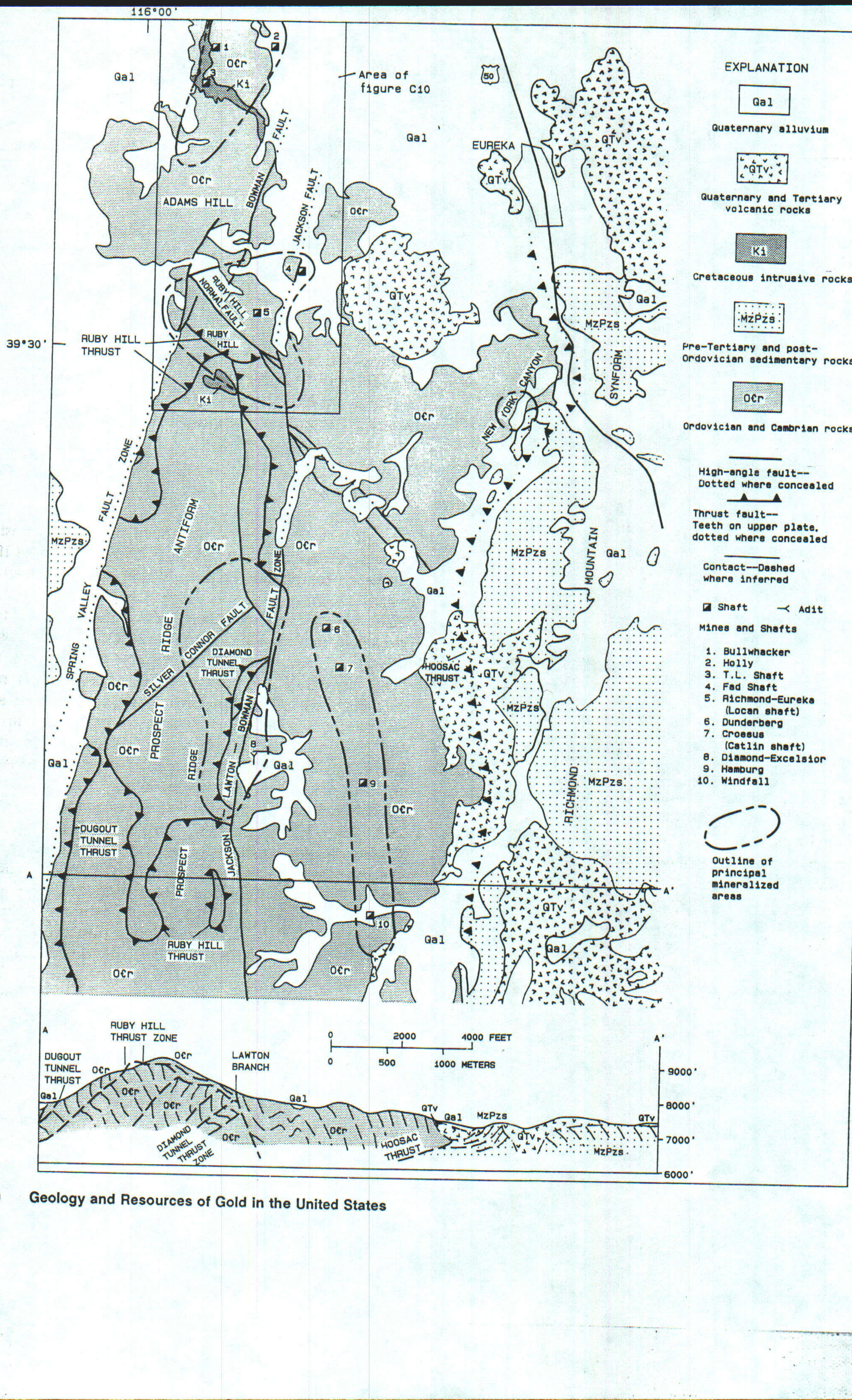
The Cambrian Eldorado Dolomite and Hamburg Dolomite are the host rocks for most of the ores mined in the Eureka district. Limestones in Cambrian and Ordovician formations have also produced some ores, as have calcareous shales in the Secret Canyon and Dunderberg Shales. Characteristically, the ore-bearing dolomites are in part dark gray to black and carbonaceous, although the ores are not known to be directly associated with organic carbon-rich material. The relatively greater brittleness of the dolomitic units is thought to be a more important factor in ore localization than is content of carbonaceous matter. The geologic formations in the Eureka district are summarized in table C4.

Structure

The Eureka district has been the site of crustal unrest over a long period of time. It lies just east of the probably compound Roberts Mountain thrust system which has brought dominantly clastic lower and middle Paleozoic sedimentary rocks ("western facies") from the west over dominantly carbonate rocks of the same age ("eastern facies"). This zone, which has been dated as of Late Devonian and Early Mississippian age, is not recognized within the Eureka district proper, as there are no marked angular unconformities in the section up to the base of the Permian Carbon Ridge Formation. Disconformities and local clastic horizons, however, indicate nearly continuous regional disturbances during the late Paleozoic.

All of the Paleozoic formations, including the Carbon Ridge Formation of Permian age, have been deformed and cut by thrust faults; these faults have been folded into a series of north-trending antiforms and synforms (fig. C9). Like the Roberts Mountains thrust zone to the west, the structurally lower thrust plates have brought into juxtaposition lithologically different facies of time-equivalent rocks, although the degree of foreshortening is less than that involved in the Roberts Mountains thrust zone. After thrusting ceased, folding persisted into Cretaceous time, as shown by deformation of the Newark Canyon Formation of Cretaceous age northeast of Eureka.

Because the folded Cretaceous rocks were deposited in the developing synforms, the folding is believed to have continued in the Mesozoic and later time. The volcanic rocks were similarly deposited in


116°00'
39°30'
Area of figure C10
EUREKA
ADAMS HILL
BOWMAN FAULT
JACKSON FAULT
RUBY HILL NORMAL FAULT
RUBY HILL THRUST
RUBY HILL
SPRING VALLEY FAULT ZONE
ANTIFORM
RIDGE
PROSPECT RIDGE
SILVER CONNOR FAULT
DIAMOND TUNNEL THRUST
BOWMAN
LAWTON
JACKSON FAULT ZONE
DUGOUT TUNNEL THRUST
RUBY HILL THRUST
NEW YORK CANYON
HOOSAC THRUST
SYNFORM
MOUNTAIN
RICHMOND
EXPLANATION
Gal
Quaternary alluvium
QTv
Quaternary and Tertiary volcanic rocks
Ki
Cretaceous intrusive rocks
MzPzs
Pre-Tertiary and post-Ordovician sedimentary rocks
O€r
Ordovician and Cambrian rocks
High-angle fault--Dotted where concealed
Thrust fault--Teeth on upper plate, dotted where concealed
Contact--Dashed where inferred
Shaft
Adit
Mines and Shafts
1. Bullwhacker
2. Holly
3. T.L. Shaft
4. Fad Shaft
5. Richmond-Eureka (Locan shaft)
6. Dunderberg
7. Croesus (Catlin shaft)
8. Diamond-Excelsior
9. Hamburg
10. Windfall
Outline of principal mineralized areas
A
A'
RUBY HILL THRUST ZONE
DUGOUT TUNNEL THRUST
LAWTON BRANCH
DIAMOND TUNNEL THRUST ZONE
HOOSAC THRUST
0 2000 4000 FEET
0 500 1000 METERS
9000'
8000'
7000'
6000'

synforms; in the area east of that of figure C9 they were deposited against a steeply dipping fault that forms the boundary between a synform and an antiform.

Basin-Range normal faults, which were responsible for creating the present mountain ranges, appear to have followed in part the older faults that separate antiforms and synforms. Other faults, such as the Ruby Hill and Silver Connor, transgress the older structures at considerable angles. The topographically expressed faults, such as those that border the Diamond Range northeast of Eureka, branch and die out, and at two localities they clearly have curved traces. They also appear to be offset locally by minor east-trending rifts.

The principal thrust faults in the district proper are, from lowest to highest, the Diamond Tunnel thrust zone, the Ruby Hill thrust zone, and the Dugout Tunnel thrust zone (fig. C9). The Diamond Tunnel thrust zone, which is possibly the oldest of the three, underlies a block of ground in which the ore deposits in and around the Diamond-Excelsior mine occur. The Ruby Hill thrust zone underlies a block of dolomitic rocks at Ruby Hill in which the bulk of the district's productive deposits were formed. Folding occurred during development of the Ruby Hill thrust zone as shown by progressively greater warping of earlier strands of the zone. The Dugout Tunnel thrust zone has no significant ore deposits related to it in the vicinity of Eureka; south of the area of figure C9 there has been some production from the rocks below this thrust.

The Silver Connor transverse fault (fig. C9), representative of several northeast-striking faults, is a steep fault with probable right-lateral strike-slip movement. It formed contemporaneously with the thrusting.

The Jackson-Lawton-Bowman normal fault system (fig. C9) is a north-striking, east-dipping system that had both pre- and post-ore movement, aggregating about 120–900 m. It may have contributed in part to uplift of Prospect Ridge, the high topographic form that extends southward from Ruby Hill and that is bounded on its west side by the north-striking Spring Valley fault zone. The Jackson-Lawton-Bowman fault system probably served as a major channelway for mineralizing solutions in much of the Eureka district.

The Ruby Hill fault (figs. C9, C10, C11), a northwest-striking, northeast-dipping fault with about 600 m of normal displacement, is perhaps the best known fault in the district. It truncates near-surface mineralized ground (oxide ores) on the northeast side of Ruby Hill (fig. C11), and thus it was the object of much interest to early-day miners. It had probably both pre- and post-ore movement on it. The possibility of occurrence of ores on the downdropped northeast side of the fault led to exploration in the 1930's that resulted in discovery of extensive and rich deep sulfide deposits (fig. C11). Because of excessive underground water as well as low metal prices these deposits have not been mined.

Figure C9 (facing page). Generalized geologic map and section of the Eureka district, Nevada. Modified from Nolan and Hunt (1968, fig. 1).

Alteration

Carbonate rocks in the vicinity of the ore bodies have been locally bleached and (or) marmorized, but most commonly they are thoroughly fractured. However, at the contact of the Ruby Hill stock (Ki on fig. C9), wallrocks have been converted locally to a hornfels and to a tactite that consists of garnet and diopside and lesser amounts of biotite, chlorite, epidote, pyrite, pyrrhotite, and magnetite. The intrusive rock is locally altered so that biotite has been replaced by chlorite, and feldspars are clouded with alteration minerals. Deep drilling into the stock revealed that the rock contains pyrite and secondary biotite, and it is laced with quartz veinlets that carry sulfides, including molybdenite. Biotite from a sample of such rock has been dated as about 100 Ma (Silberman and McKee, 1971, p. 30–31). The old stopes under Ruby Hill were in many places bordered by jasperoid. Elsewhere, especially along faults, or in other places at the contacts of Dunderberg Shale, irregular podlike bodies of jasperoid have been formed.

The Hamburg Dolomite at the Windfall gold mine was converted to dolomite sand ("sanded") near ore apparently as a result of leaching along dolomite grain boundaries by ore-forming fluids. Small quantities of the arsenic minerals scorodite and realgar are associated with the gold ore. This association suggests that an original Ruby Hill type of arsenic-rich silver-lead ore which replaced the Hamburg Dolomite was altered and leached of its base metals, possibly by hydrothermal fluids derived from the Oligocene dike that cuts through the mineralized zone.

Because of the general spatial association of the Eureka ores with the intrusive rock at Ruby Hill, and the close association of non-economic contact-metasomatic deposits with the Ruby Hill stock, the ores are inferred to be genetically related to the intrusive rocks.

ORE DEPOSITS

Essentially all the mineralized rocks, as well as the small plug of Cretaceous intrusive rock, are restricted to the antiforms. Probably more than three-quarters of the total production of the Eureka district has come from the mines of Ruby Hill, the summit of which is about 3 km west-southwest of the town of Eureka (fig. C9). The

Table C4. Geologic formations present in the Eureka mining district

[Modified from Nolan and Hunt, 1968; leaders (- - -), not applicable]

Age	Name	Stratigraphic thickness (in meters)	Lithologic character
Quaternary	Alluvium	0-150±	Stream and slope alluvium, terrace gravels, and mine and smelter dumps.
------Unconformity------			
Miocene	Alkali olivine basalt	225+	Lava flows; a few dikes and small plugs.
------Tertiary intrusive contact, and unconformity------			
Oligocene	Rhyolite tuff, rhyolite, and andesite.	240±	Welded tuffs; rhyolite flows, plugs, domes, dikes, vent breccias; andesite and rhyodacite flow and dikes; lamprophyre dikes.
------Tertiary intrusive contact, and unconformity------			
Late(?) Cretaceous	Quartz porphyry	---	Sills and dikes.
Early Cretaceous	Quartz diorite	---	Intrusive plug south of Ruby Hill.
------Intrusive contact------			
Early Cretaceous	Megabreccia	---	Landslide sheets.
------Unconformity------			
Early Cretaceous	Newark Canyon Formation	300±	Fresh-water conglomerate, sandstone, grit, shale, and limestone.
------Unconformity------			
Permian	Carbon Ridge Formation	300±	Thin-bedded sandy and silty limestone; some included sandstone and dark carbonaceous shale.
------Unconformity------			
Early Pennsylvanian-Late Mississippian	Ely Limestone	0-500	Massive-bedded bluish-gray cherty limestone, local chert-pebble conglomerate; brown sandstone beds near base.
------Unconformity------			
Late Mississippian	Diamond Peak Formation	0-1,200	Conglomerate, limestone, and sandstone.
	Chainman Shale	1,100± exposed	Black carbonaceous shale with thin interbedded sandstone.
Mississippian	Dale Canyon Formation	575	Grit, sandstone, minor black shale and conglomerate.
------Break in section------			
Late and Middle Devonian	Devils Gate Limestone[1]	220-500 exposed	Thick-bedded limestone, dolomitized at base.
Late Ordovician	Hanson Creek Formation	90± exposed	Dark-gray to black carbonaceous dolomite.
Late(?) to Middle Ordovician	Eureka Quartzite	90	Thick-bedded vitreous quartzite.
Middle and Early Ordovician	Pogonip Group	490-560	Chiefly cherty thick-bedded limestone at top and bottom; thinner bedded shaly limestone in middle.
Late Cambrian	Windfall Formation: Bullwhacker Member	120	Thin-bedded sandy limestone.
	Windfall Formation: Catlin Member	75	Interbedded massive gray to dark carbonaceous limestone, some cherty, and thin sandy limestone.
	Dunderberg Shale	80	Fissile brown shale with interbedded thin nodular limestone.
Late and Middle Cambrian	Hamburg Dolomite	330	Massively bedded gray to dark carbonaceous dolomite; some limestone at base.
Middle Cambrian	Secret Canyon Shale: Clarks Spring Member	150±	Thin-bedded platy and silty limestone, with yellow or red argillaceous partings.
	Secret Canyon Shale: Lower shale member	60-70	Fissile shale at surface; green siltstone underground.
	Geddes Limestone	110	Dark-blue to black carbonaceous limestone; beds 8-30 cm thick; some black chert.
	Eldorado Dolomite	800±	Massive gray to dark carbonaceous dolomite; some limestone at or near base.
Middle and Early Cambrian	Pioche Shale	120-165	Micaceous khaki-colored shale; some interbedded sandstone and limestone.
Early Cambrian and Late Proterozoic	Prospect Mountain Quartzite (base not exposed)	560 exposed	Fractured gray quartzite weathering pink or brown; a few thin interbeds of shale.

[1]Nevada, Lone Mountain, and Roberts Mountains Formations not recognized in mapped area.

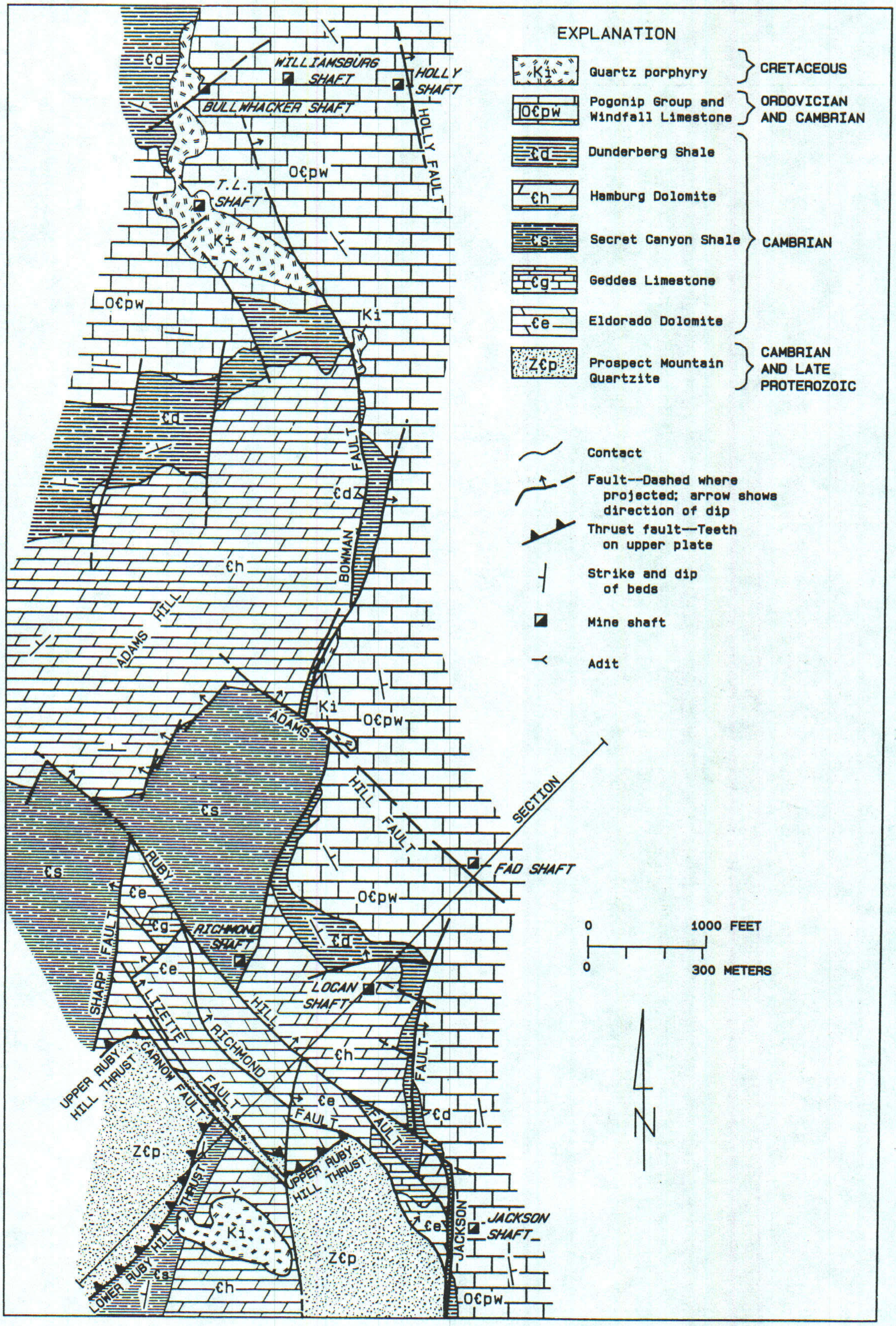


Figure C10. Bedrock geology of Ruby and Adams Hills, Eureka district, Nevada. Modified from Nolan and Hunt (1968, fig. 2). Location of area is shown on figure C9. Cross section, figure C11.

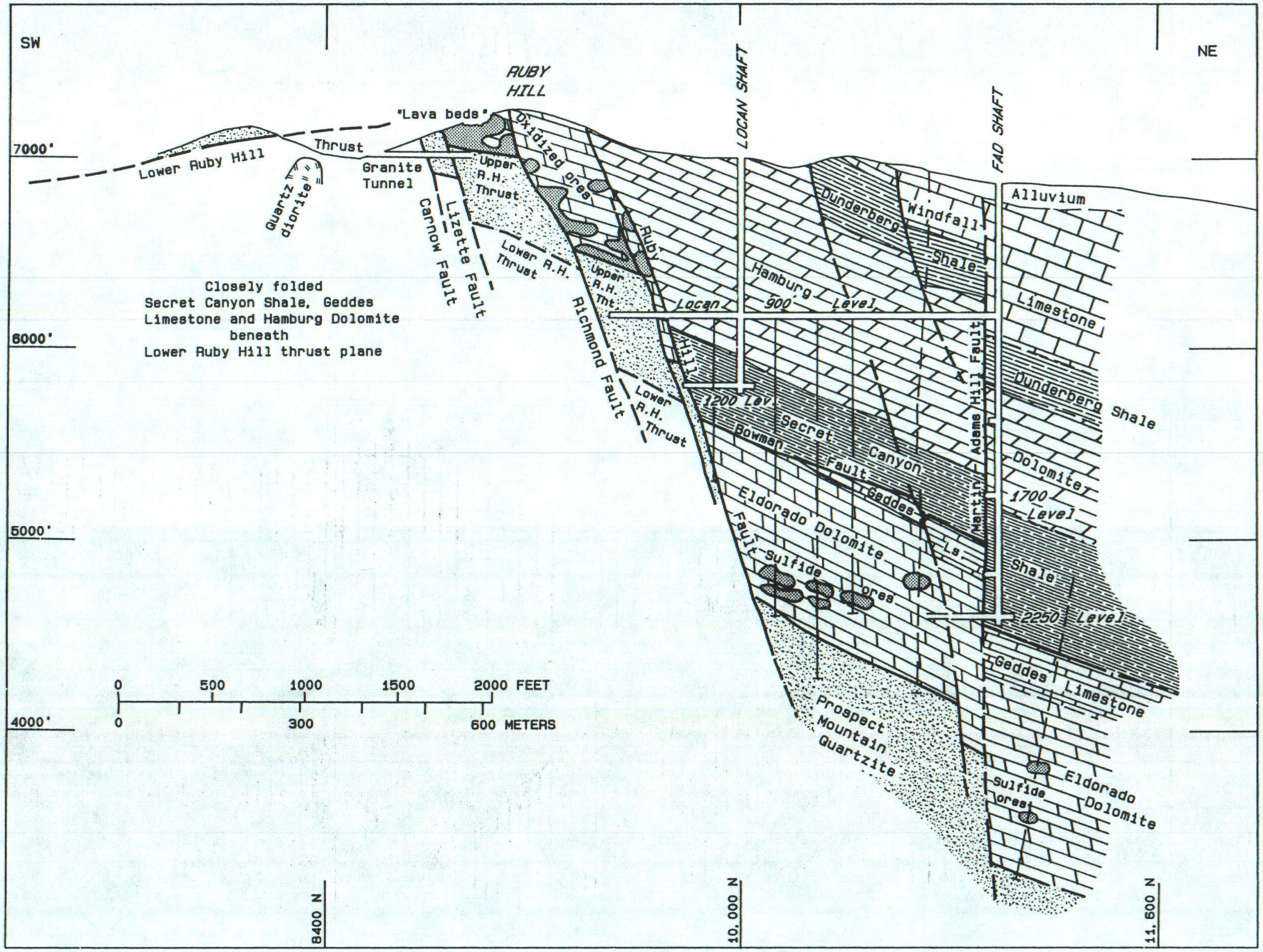


Figure C11. Geologic cross section N. 45° E. through Ruby Hill. Modified from Nolan and Hunt (1968, fig. 3). Line of section shown on figure C10. Contacts and faults dashed where inferred. R.H., Ruby Hill. Drill holes shown by vertical or nearly vertical lines (dashed where projected to the plane of section).

Ruby Hill ore deposits form one of five clusters of deposits in the district that are separated by unproductive ground (fig. C9; Nolan, 1962, p. 29).

The Ruby Hill ore bodies were found in a northwest-trending wedge-shaped mass of Eldorado Dolomite (Middle Cambrian). The base of the dolomite mass was truncated by the branching Ruby Hill thrust zone that subsequently was folded into a north-plunging antiform. To the northeast, both the dolomite and the ores were cut off by the more steeply dipping Ruby Hill normal fault (figs. C9–C11); to the west, the ore zone was terminated by a branch of the Basin-Range fault (Spring Valley fault zone) that forms the west boundary of Prospect Ridge (fig. C9).

Individual ore bodies were formed by replacement of the dolomite. Their location, for the most part, was controlled by fractures or faults; the nearly complete oxidation of the original sulfide ores, however, has obscured the important lithologic or structural features. Although some of the ore shoots in the Diamond mine have been characterized as "mantos," most of the Ruby Hill ore was found in irregular replacement bodies, the forms of which were pipelike to more tabular or veinlike. These bodies varied greatly in size, ranging from small podlike bodies a meter or so across to chambers a hundred meters or more in extent. Many of the larger shoots were associated with open caves as much as 50 m high which had formed directly above the large oxidized ore bodies, leading to the speculation that the caves resulted from the leaching action of sulfuric acid formed during supergene oxidation of sulfides. The ground-water table is at various levels in the district, dependent in part at least on impoundment by fault zones, and it almost certainly varied greatly in the past as a result of climatic changes or tectonism.

Most of the ore mined at Eureka was nearly completely oxidized. The oxidized ore in most places contained considerable amounts of iron oxide, anglesite, cerussite, mimetite, plumbojarosite (and probably the arsenic analog, beudantite), bindheimite, and some quartz, halloysite, and calcite. Cerargyrite and native gold were probably present also. Bulk analyses of early-day ore sent to the local smelters suggest that plumbojarosite (and (or) beudantite) may have been abundant constituents.

The oxidized ores on Ruby Hill (fig. C11) were of extremely high grade. Mining during the years 1869–1901 produced 1,317,388 tons of ore that averaged about 1.1 oz Au/ton, 27 oz Ag/ton, and 17 percent Pb. A composite sample of all the Ruby Hill ores treated at the Richmond smelter in 1877 contained 1.59 oz Au/ton, 27.55 oz Ag/ton, and (in percent) 0.12 Cu, 33.12 Pb, 24.07 Fe, 1.89 Zn, 4.13 As, 0.25 Sb, 1.67 S, and 2.95 SiO_2. In later years, lower grade ores were produced. For example, about 2,500 tons shipped from Ruby Hill in the years 1920–1925 averaged 0.305 oz Au/ton, 4.21 oz Ag/ton, and (in percent) 0.32 Cu, 6.63 Pb, 34.0 Fe, 5.32 Zn, 2.90 As, 0.51 S, 2.34 CaO, and 12.3 insoluble. (Data are from Nolan and Hunt, 1968, p. 981–982.)

Sulfide ore from the T.L. mine north of Ruby Hill, and from various drill-hole intersections, is probably similar to the original or primary mineralized material. It is made up of pyrite, arsenopyrite, galena, sphalerite, and minor quartz.

Sulfide ores, based on drill-core data from deposits at depth northeast (in the hanging wall) of the Ruby Hill fault (fig. C11), also are of high grade. Large tonnages of mineralized material have a grade-in-place in the range of 0.15–0.2 oz Au/ton, 7.0–9.0 oz Ag/ton, and (in percent), 0.1–0.2 Cu, 5–7 Pb, 9–12 Zn, and 20–30 Fe (Nolan and Hunt, 1968, p. 984). Mineralized material through one diamond drill core interval of 11.1 m assayed 1.33 oz Au/ton, 20.3 oz Ag/ton, 12.6 percent Pb, and 9.37 percent Zn. Mineralized rock through another diamond drill core interval of 20.1 m assayed 0.16 oz Au/ton, 10.5 oz Ag/ton, 7.72 percent Pb, and 9.78 percent Zn. (Data are from Nolan, 1962, pl. 8.)

Gold ore at the Windfall mine differs markedly from the other ores of the district. Windfall ore occurs in altered "sanded" dolomite at the contact of the Hamburg Dolomite with the overlying Dunderberg Shale. The gold ore is relatively low in grade (at the present time about 0.04 oz Au/ton according to A.B. Wallace and J.S. Livermore (written commun., 1983), though grades mined early in the century were higher). Nolan and Hunt (1968, p. 989) indicated that about 65,000 tons of this ore was mined in the years 1908–1916, and A.B. Wallace and J.S. Livermore (written commun., 1983) suggested an overall current tonnage (production and reserves) of about 2.5 million tons of ore. Ore mined in the earlier period was in shoots 15–50 m across that were localized by cross faults that displaced the Hamburg-Dunderberg contact. Gangue minerals, sulfides, and silver are nearly absent. Sparse small pods of jasperoid are present near the Windfall mine and in the ore zone; one mass of jasperoid contains abundant realgar and much fine-grained pyrite.

Low-grade gold ore in the Dunderberg Shale was being mined in 1987 by Eureka Ventures, Inc. at the Lookout Mountain mine in Ratto Canyon south of the area of figure C9 (R.G. Luedke, oral commun., 1987).

Exploration in recent years, cited previously, has demonstrated the presence of relatively unoxidized sulfide ore in the Eldorado Dolomite in the hanging wall of the Ruby Hill fault. This ore, which contains substantial amounts of gold, silver, lead, and zinc, has not as yet been exploited, in large part because of the problems presented by the large quantities of water, and also because of depressed metal prices. Drilling marginal to the lead-silver ore has indicated a considerable area of iron-zinc-mineralized ground that suggests a possible zonal arrangement of the ores relative to the quartz diorite intrusive body.

Other mines productive in the past in the Eureka district include the T.L., Bullwhacker, and Holly to the north, and the Diamond, Silver Connor, Dunderberg, Croesus, Hamburg, and Windfall to the south. Except for the Windfall mine, most of these mines produced oxidized gold-silver-lead ore from replacement bodies in dolomite. However, the host dolomite in most of the southern mines was the younger Hamburg Dolomite rather than the Eldorado Dolomite; most of the production from the mines north of Ruby Hill has come from deposits in the Windfall Formation and Pogonip Group.

SUMMARY AND CONCLUSIONS

Marine carbonate formations and minor amounts of clastic sediments were deposited in Paleozoic time on an extensive shelf at the west margin of what is now west-central North America. Formations that were to become significantly mineralized at Eureka are characteristically shallow water deposits, now dolomite. Their more westerly correlatives are limestone. During late Paleozoic and Mesozoic time extensive thrust faulting transported plates of carbonate rocks eastward, such that at Eureka three prominent faults juxtaposed previously separated lower Paleozoic formations. Folding accompanied and followed the thrust faulting, and the folded thrust faults (themselves antiforms and synforms) act as bounding faults to the complexly folded sedimentary rocks that also constitute antiforms and synforms, and that are such prominent features of present-day geology. Folding of the antiforms and synforms continued long after the major thrust faulting ceased probably in late Paleozoic or early Mesozoic time. The synforms became the locus of deposition of the non-marine Newark Canyon Formation of Cretaceous age. The Newark Canyon was itself folded, and the Oligocene volcanic rocks were deposited in the continually rejuvenated synforms.

The Ruby Hill stock, following its intrusion, became a center of hydrothermal activity probably in later Cretaceous time. Although it is exposed only in the north part of the district, airborne magnetic measurements indicate that the intrusive mass is a linear body underlying the antiform of Prospect Ridge. The stock has "cupolas," such as the one at Ruby Hill, and it is possible that each cluster of ore deposits in the district (fig. C9) represents a separate mineralized system focused on an individual "cupola." Extensive mineralization took place in such localities, forming the rich gold-silver-lead ores for which Eureka is renowned. Mineralizing fluids were directed to favorable host rocks primarily along the north-trending Jackson-Lawton-Bowman fault system and the Ruby Hill normal fault. The brittle Eldorado and Hamburg Dolomites were extensively fractured and hence favorably permeable for passage of ore fluids, whereas less brittle limestone beds in these formations are in many places marmorized and barren. Galena is more abundant near the Ruby Hill stock and the Ruby Hill fault, and sphalerite is more abundant farther from them, suggesting that the ore-forming solutions may have changed by reaction with the host rock as they flowed outward from the stock and main conduits; decreasing temperature presumably also played a role in the zoning.

The Windfall mine gold ore is quite different from the base metal ores in the other properties on Prospect Ridge. As noted above, it may represent reworking of an original base metal-rich ore by solutions from an Oligocene dike that cuts through the ore body. The presence of realgar in a mass of jasperoid within the ore body suggests that these younger mineralizing solutions may also have been responsible for a gold-rich ore body at the Oswego mine south of Prospect Ridge (south of area of fig. C9). It too contains small amounts of realgar and orpiment; a dike of the Oligocene-Eocene Ratto Spring Rhyodacite is exposed nearby.

Geochemical anomalies suggest that undiscovered ore deposits in the Eldorado Dolomite and the Hamburg Dolomite may occur at moderate depths in the vicinity of the mineralized clusters. Higher metal prices are probably needed to encourage exploration of these anomalies and of other structurally favorable areas.

The presence of widespread jasperoid in areas in the vicinity of the Oligocene rhyodacite, coupled with the speculative correlation of the gold deposits at the Windfall mine and the mines south of Prospect Ridge to these younger rocks, suggests that low-grade gold deposits may exist in formations adjacent to the jasperoids. The inconspicuous character of such deposits could easily hinder their discovery in a district where high-grade ores provided a much more obvious target for mining. Some caution is needed in such exploration, however, as jasperoid also has been formed in the areas of older deposits.

Known sulfide deposits intersected by drilling in the downthrown block north of the Ruby Hill fault remain an attractive target, but their exploitation will depend on solution of both the economic and technical problems that the depth and the large flow of water present.

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