Geology of the Eureka Quadrangle Utah and Juab Counties, Utah

By HAL T. MORRIS

CONTRIBUTIONS TO ECONOMIC GEOLOGY

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A study of the principal productive parts of the Tintic and East Tintic mining districts

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By Hal T. Morris

ABSTRACT

The Eureka quadrangle, near the east-central margin of the Great Basin in central Utah, contains the principal productive mines of the Tintic and East Tintic mining districts. It includes the central part of the East Tintic Mountains and the western edge of the Goshen Valley.

The rocks exposed in the quadrangle range in age from Precambrian to Quaternary; all systems of the Paleozoic sequence from Cambrian through Mississippian are represented, but no rocks of late Paleozoic and Mesozoic age are known. The Paleozoic rocks are chiefly miogeosynclinal deposits (dominantly carbonates) whose thickness exceeds 12,000 feet. Tertiary rocks include quartz latite and latite tuffs, lavas, and agglomerates and related intrusive rocks of middle Eocene age, and a prelava conglomerate of Eocene(?) age. The Quaternary deposits consist of talus, alluvium, colluvium, and fanglomerate, but they also include thin lacustrine deposits of Lake Bonneville (Wisconsin) age.

The Paleozoic rocks are asymmetrically folded and cut by thrust and transcurrent strike-slip faults and by transverse normal faults—all older than the volcanic rocks. The lavas are cut by north-northeast-trending normal faults of small displacement, and by longitudinal normal faults, probably of the Basin and Range system.

The principal ore bodies in the quadrangle are large replacement deposits in the Paleozoic rocks, containing lead, zinc, silver, copper, and gold. Of less importance are high-grade argentiferous lead veins in the igneous rocks and auriferous copper veins in the sedimentary rocks. The replacement deposits are localized by faults and favorable stratigraphic units; they are the chief source of the ores from the Tintic and East Tintic mining districts, whose gross production exceeds $428 million.

INTRODUCTION

The Eureka quadrangle is about 20 miles west of the east-central edge of the Great Basin; it includes the central part of the East Tintic Mountains—a typical Basin Range—and the western edge of Goshen Valley (pl. 1). The climate of the area is semiarid and is characterized by hot, dry summers and cold, snowy winters. All streams are intermittent and drain either west, ultimately into the Sevier River, or east into Utah Lake.

The principal communities in the quadrangle are Eureka, with a population of 771 in 1960, Mammoth, with an estimated population of about 100 in 1960, and Dividend, with 11 inhabitants in 1960. Homansville, Knightville, and Diamond formerly were thriving towns, but now only their sites remain.

Parts of two official mining districts are located within the quadrangle boundaries. The area north of an east-west line extending approximately through Packard Peak is in the southwestern part of the North Tintic mining district. The remainder of the quadrangle is in the north-central part of the Tintic district; however, the part of the Tintic and North Tintic districts within the Eureka quadrangle that is east of 112°05′ and between Pinyon Creek and Homansville Canyons and Silver Pass is unofficially but widely designated the East Tintic mining district.

The Eureka quadrangle is bordered on the north by the Allens Ranch quadrangle, on the northwest by the Boulter Peak quadrangle, and on the west by the Tintic Junction quadrangle, all of which have been mapped geologically at scales of 1 : 24,000 or larger by the U.S. Geological Survey. These maps and others of the same group were prepared as part of a comprehensive study of the geology of the northern East Tintic Mountains.

Fieldwork was begun in the Eureka quadrangle early in 1943 and was essentially completed in 1959, after many diversions and interruptions of both short and long duration. From 1943 to 1954 the fieldwork was directed by T. S. Lovering, with whom the writer was associated from 1946 to 1954 in a study of the geology, ore deposits, and hydrothermal alteration of the East Tintic district. Since 1954 the writer has directed the fieldwork in the main Tintic district and in the Tintic Junction and adjoining quadrangles, and has made general studies of the stratigraphy, igneous rocks, and structure throughout the East Tintic Mountains.

Many local residents, mine operators, and mining geologists working in the Tintic and East Tintic districts were helpful during the field study. To list all these people individually is not practicable in this report, but all of them are specifically acknowledged with sincere appreciation in other reports.

ROCKS

The rocks exposed in the Eureka quadrangle include a wide variety of consolidated sedimentary rocks, extrusive and intrusive igneous rocks, and semiconsolidated and unconsolidated sedimentary deposits. The principal lithologic characteristics of these rocks are summarized in Table 1; detailed descriptions and correlations are given in other reports (Lindgren and Loughlin, 1919, p. 22–70, 99–102; Morris, 1957, p. 3–40; and Morris and Lovering, 1961).

The prevolcanic rocks range in age from late Precambrian to Eocene(?) and are chiefly Paleozoic miogeosynclinal deposits about 12,000 feet thick belonging to a Paleozoic section whose total thickness exceeds 25,000 feet. Limestone and dolomite constitute considerably more than one-half of these rocks; quartzite and sandstone are next in abundance; and shale is least abundant. In the general area of the ore deposits, many of the limestone units have been hydrothermally altered to dolomite. Much of this dolomite is in breccia zones adjacent to faults, but some units, notably the Cole Canyon and Bluebird dolomites and the black cherty dolomite unit in the Fitchville formation, are dolomite from base to top in the general vicinity of intrusive rocks and ore, but in outlying areas are chiefly limestone except adjacent to faults; thus, these units are believed to have been completely altered to dolomite in the general vicinity of the intrusive centers.

The extrusive and intrusive igneous rocks underlie the greater part of the Eureka quadrangle; they include two volcanic formations and many plutonic bodies ranging from pipelike masses a few inches in diameter to the Silver City stock, which is about 2½ miles across the widest exposures. In general the igneous rocks can be classified into four general groups: (a) the Packard quartz latite and its intrusive equivalent, the Swansea quartz monzonite; (b) the Laguna Springs latite and its associated monzonitic intrusive bodies, including the Sunrise Peak and Silver City stocks and the smaller intrusions of biotite monzonite porphyry, hornblende monzonite porphyry, and pebble-dike intrusion breccias; (c) quartz monzonite porphyry bodies that cut the Silver City stock; and (d) andesite or latite dikes and intrusion breccias. The age of igneous activity is dated as middle Eocene, based largely on the work of Muessig (1951, p. 234) in the southern part of the East Tintic volcanic field, 27 miles south-southeast of Eureka; here the upper units of the Laguna Springs latite intergrade with the Green River formation and also include a lens of limestone that contains plant fossils of middle Eocene age.

Throughout a large part of the Tintic and East Tintic mining districts, the extrusive rocks rest on a surface of strong relief eroded on folded and faulted Paleozoic rocks. The principal ore deposits of these two districts are replacement bodies in the Paleozoic rocks, but the overlying and adjacent igneous rocks have been intensely altered by hydrothermal solutions (Lovering and others, 1949; Lovering and others, 1960).

TABLE 1.—*Rock formations in the Eureka quadrangle, Utah.*

System and series		Formation or unit	Thickness (feet)	Character
QUARTERNARY	Regent	Younger alluvium	0–100+	Gravel, sand, silt.
	Pleistocene	Bonneville formation	20	Gravel, sand, silt.
		Alpine formation	25	Silt.
		Older alluvium	0–250+	Fanglomerate, talus, colluvium, alluvium; includes deposits of Lake Bonneville age in upland areas.
		—Unconformity—		
TERTIARY	Eocene	Andesite or latite dikes and related intrusion breccias.		Narrow, strongly altered dikes containing relict biotite, augite, and labradorite(?). Similar igneous material also forms matrix of intrusion breccias composed in part of fragments of quartzite and biotite monzonite.
		—Intrusive contact—		
		Quartz monzonite porphyry.		Medium-gray, coarse-grained quartz monzonite porphyry containing quartz, orthoclase, oligoclase, and biotite. Intrudes Silver City stock.
		—Intrusive contacts—		
		Pebble dikes		Intrusion breccia of rounded fragments of quartzite and tabular fragments of limestone and shale in a matrix of rock flour or biotite monzonite porphyry.
		Monzonite of Silver City stock and associated biotite monzonite porphyry.		Monzonite: medium- to light-gray, medium- to fine-grained, porphyritic; contains andesine, orthoclase, biotite, augite, and hornblende; xenoliths of sedimentary rocks common. Biotite monzonite porphyry: greenish-gray, coarse-grained; composition similar to monzonite of Silver City stock but ranges from quartz monzonite to basic monzonite.
		Monzonite porphyry of Sunrise Peak stock and associated hornblende monzonite porphyry.		Monzonite porphyry of Sunrise Peak stock: dark purplish- to greenish-gray, medium- to coarse-grained; contains andesine, augite, biotite, orthoclase, and hornblende. Hornblende monzonite porphyry: dark-colored, coarse-grained; contains andesine, augite, hornblende, orthoclase, and hypersthene or biotite.
		—Intrusive contacts—		
		Laguna Springs latite	0–2500+	Flow rocks, welded tuffs, conglomerate, and non-welded tuffs. Flow rocks and welded tuffs: dark-colored, fine- to coarse-grained, porphyritic; contain andesine, augite, hornblende, orthoclase, and hypersthene or biotite. Conglomerate; well-stratified, fine- to coarse-grained; interlayered with latite agglomerate and tuff. Nonwelded tuffs and agglomerate: light-colored, fine- and coarse-grained.
		—Intrusive contact—		
		Swansea quartz monzonite		Medium to light purplish-gray, medium- to fine-grained, porphyritic quartz monzonite. Contains sodic andesine, orthoclase, quartz, and biotite.

			Intrusive contact		
			Packard quartz latite	0-2700+	Vitrophyre, flow rocks, and tuffs. Vitrophyre: gray to black, phenocrysts broken. Flow rocks: pinkish- or bluish-gray, medium-grained, porphyritic; contains andesine, sanidine, quartz, and biotite. Tuffs: light-colored, fine-grained, vitric, and lithic. Flow breccias mark tops of many vitrophyre and flow rock units.
			Unconformity		
TERTIARY(?)		Eocene(?)	Apex conglomerate	0–500+	Brick-red, medium- to coarse-grained, poorly bedded conglomerate; thickness irregular.
			Unconformity		
CARBONIFEROUS	MISSISSIPPIAN	Upper	Great Blue formation	2500–2650	Poker Knoll limestone member: limestone, blue- to brownish-gray, thin-bedded; silty, cherty: total 600 ft, but top eroded. Chiulos member: shale, sooty-black to greenish-gray, fissile; and quartzite, gray-green to brown, medium- to fine-grained, crossbedded; 850–1,000 ft. Paymaster member: limestone interlayered with olive-green shale and brown quartzite; 650 ft. Topliff limestone member: limestone, medium- to dark-gray, medium-bedded; cherty; 400 ft.
			Humbug formation	650	Brown, crossbedded sandstone alternating with light-gray limestone.
			Deseret limestone	860–1100	Uncle Joe member: limestone, medium- to light-gray, coquinoid, sparsely cherty; about 400 ft. Tetro member: limestone, blue-gray, massive, silty, and sandy; much chert; about 450 ft. Phosphatic shale member: phosphorite, shale, limestone, and chert; all black to dark-gray; 10–150 ft.
		Lower	Gardison limestone	450–550	Medium blue-gray, well-bedded, fossiliferous limestone. Upper two-thirds is medium to coarse grained and cherty, especially upper 125 ft; lower third is fine grained, relatively chert free.
			Fitchville formation	275–300	Eight individually distinctive units of limestone and dolomite: sandy at base: Curly limestone: distinctive bed of dense medium- and dark-gray crenulated limestone of algal origin; 1.5 ft. Pink lithographic limestone: dense pinkish-gray limestone of high purity; 7 ft. Sugary dolomite: medium- to dark-gray, medium-grained dolomite with one or more beds of novaculitic quartzite, or locally, green chert, 10 to 20 ft below top; 58 ft.

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TABLE 1.—*Rock formations in the Eureka quadrangle, Utah*—Continued

System and series			Formation or unit	Thickness (feet)	Character
					Black dolomite: dusky blue-gray to black, coarse-grained cherty dolomite with conspicuous almond-shaped pods of white calcite and dolomite 2 to 4 in. long replacing some of the chert nodules; 65 ft. Blue shaly limestone: blue-gray, thin-bedded fossiliferous limestone; 46 ft. White limestone: massive, coarse-grained, light-gray to white limestone; 50 ft. Blue flaky limestone: blue-gray, thin-bedded argillaceous limestone containing numerous small round flakes with dark centers that are probably fossil fragments; 52 ft. Sand-grain marker bed: dull blue-gray, sand-streaked limestone or brownish-weathering calcareous quartzite containing rounded to ovoid grains of frosted quartz from less than a millimeter to 5 mm in diameter; 0.5 ft.
DEVONIAN and MISSISSIPPIAN			Pinyon Peak limestone Disconformity(?)	70–300	Medium to light blue-gray, fine-grained, thin- and massive-bedded, silty limestone.
DEVONIAN		Upper	Victoria formation	125–300	Medium-gray, medium-bedded dolomite interlayered with brown sandstone.
DEVONIAN, SILURIAN, and ORDOVICIAN			Bluebell dolomite	330–600	Light- and dark-gray, fine- and coarse-grained, medium- to massive-bedded dolomite; 10-ft bed of curly, laminated dolomite about 300 ft above base. One or more disconformities is present within this formation.
ORDOVICIAN		Upper	Fish Haven dolomite Disconformity	270–350	Dark-, medium-, and light-gray, medium- and coarse-grained, massive- and thin-bedded dolomite; bed of mottled cherty dolomite at top.
		Lower	Opohonga limestone	300–850	Light blue-gray, thin-bedded, argillaceous limestone containing much flat-pebble conglomerate; nodules of white chert in lower part; thin sandstone unit at base.
		Upper	Ajax dolomite	370–730	Upper member: medium- to dark-gray, faintly mottled, medium-bedded; limy at top; much chert; 265–520 ft. Emerald member: creamy white, medium- and coarse-grained, massive; not cherty; 15–30 ft. Lower member: medium- to dark-gray, massive-bedded; moderate chert; 90–180 ft.

CAMBRIAN		Opex formation	140–350	Limestone, shale, sandstone, and dolomite; mostly thin bedded.
	Middle	Cole Canyon dolomite	830–900	Chiefly alternating beds of Dagmar-type and Bluebird-type dolomite in units 2–20 ft thick; Dagmar-type beds sparse or absent near top; formation is partly limestone in areas remote from ore.
		Bluebird dolomite	150–220	Dusky blue-gray, coarse-grained, medium- to massive-bedded dolomite studded with small twig-shaped rods of white dolomite; formation is partly or wholly limestone in areas remote from ore.
		Herkimer limestone	350–430	Medium to light blue-gray, fine-grained, thin-bedded limestone that is striped with yellow- and red-weathering mudstone; 20-ft bed of green shale 180 ft above base.
		Dagmar dolomite	60–100	Light-gray to creamy-white, fine-grained, laminated, limy dolomite; forms prominent marker bed.
		Teutonic limestone	400	Medium to light blue-gray, medium- and fine-grained, argillaceous limestone; some beds pisolitic.
		Ophir formation	295–430	Upper member: shale, gray-green, sandy; 35–90 ft. Middle member: limestone and shale; limestone, blue-gray, argillaceous; shale, gray-green, fissile; 100–160 ft. Lower member: shale, gray-green, fissile; carbonate marker bed 90 ft above base; base sandy; 160–180 ft.
	Lower	Tintic quartzite	2300–3200	White to buff, medium-grained, well-bedded to massive quartzite; shaly at top, conglomeratic at base; flow of altered basalt 980 ft above base. Complete section not exposed in Eureka quadrangle.
		——Disconformity——		
PRECAMBRIAN		Big Cottonwood formation		Phyllitic shale and medium- to coarse-grained quartzite, both olive-green to brown; occurs only as xenoliths in Eureka quadrangle.

The postvolcanic sedimentary deposits are not important to the study of the mineral deposits of the quadrangle except as they locally conceal the ore-bearing or hydrothermally altered rocks; consequently they are somewhat generalized on the map. These deposits are all of Pleistocene and Recent age and have been described in detail by Goode (1959).

STRUCTURE

Many of the geologic structures exposed in the Eureka quadrangle extend into adjoining quadrangles and may be more fully analyzed in reference to the structure of the entire East Tintic Mountains than to the small part of the range within the quadrangle boundaries. The external form of the East Tintic Mountains strongly suggests an origin through relatively simple block faulting of large magnitude, but the internal structures record a moderately complex history of crustal movements that considerably antedate the formation of the range block.

The oldest recognized structural events have resulted in several disconformities, the most important of which are between the Big Cottonwood formation and the Tintic quartzite, between the Opohonga limestone and the Fish Haven dolomite, and between the strata of Silurian and Late Devonian age within the Bluebell dolomite. A disconformity may also separate the Victoria formation and the Pinyon Peake limestone. The structural disturbances resulting in these disconformities, and probably others not as readily identified, were apparently broad, gentle upwarps, for the strata above and below the disconformities only rarely show measurable angular discordance.

The dominant structures affecting the prevolcanic rocks of the East Tintic Mountains are a series of north-trending, north-plunging, asymmetrical anticlines and synclines of great width and amplitude. These folds are cut by faults of several types, including thrust faults and high-angle transcurrent faults that were formed at approximately the same time as the folds, and by normal faults that probably developed as extension and release fractures during and following the main period of compression. The age of the principal orogenic movements that produced the folds, thrust faults, and transcurrent faults has been determined from the work of Spieker (1946, p. 149–156) to be late Late Cretaceous, although some of the earliest of these structures may have originated between Late Jurassic and early Late Cretaceous time. The principal movement on most of the normal faults is prelava and probably took place during Late Cretaceous or Paleocene time.

Of considerable economic importance is a system of north-northeast trending fissures and normal faults of small displacement that are occupied by narrow veins in the igneous rocks and appear to have been used as channelways by the solutions that deposited the replacement ore bodies in the sedimentary rocks. These fissures and faults are obviously younger than the larger stocks, but they appear to be the principal structural control for the late preore monzonite dikes and plugs in the East Tintic district. They are probably middle or early late Eocene in age.

The youngest major structural features recognized in the East Tintic Mountains are northward-trending normal faults of the Basin and Range fault system, which are part of a regional fault system that Nolan (1943, p. 183) believes first formed early in the Oligocene epoch, or earlier, and has been intermittently active since that time. The general form and outline of the East Tintic Mountains are attributed to displacement and tilting, chiefly along a zone of these faults at the west edge of the range, beyond the limits of the quadrangle.

FOLDS

Two of the three major folds that dominate the structure of the northern half of the East Tintic Mountains are chiefly within the Eureka quadrangle. The better exposed of the two folds is the Tintic syncline, in the northwest quarter of the map. It is bordered on the east by the East Tintic anticline, which is mostly concealed by volcanic rocks but which is well known from mine openings and drill holes and from scattered exposures of sedimentary rocks in the East Tintic mining district.

The general form and character of the Tintic syncline is indicated by exposures between the upper part of Dragon Canyon and Eureka Gulch. The axis of the fold can be traced northward from a point near the Iron Blossom No. 3 shaft to a point near the Yankee shaft, north of which it is concealed by lava; south of the Iron Blossom No. 3 mine the axial area is concealed by monzonite. The fold is again exposed near the north boundary of the quadrangle, between Tintic Davis and Fremont Canyons. The plunge of the Tintic syncline averages 17° N., but ranges from nearly horizontal to 30° or more, partly because of differential tilting of individual fault blocks. Beds on the west limb generally dip 75° E., although locally they are vertical or even overturned. Beds on the east limb, which is the west limb of the East Tintic anticline, dip about 30° W. Near the north boundary of the Eureka quadrangle, one or more minor folds have developed in the trough of the Tintic syncline, and others are known underground in the Plutus (Tetro) mine.

The East Tintic anticline underlies the greater part of the East Tintic mining district. The crest of this fold is broken by many faults and is largely concealed, but the trace of the axial plane is inferred to underlie Silver Pass Gulch from near the Trump shaft northward to the Eureka Standard fault. North of this fault the axis is offset to the east and in general lies a few hundred feet east of the Apex Standard No. 2 and the Tintic Standard No. 3 shafts, extending northward to the vicinity of the Water Lily and North Standard shafts.

Where the East Tintic anticline is best known in the central part of the East Tintic district, it has the general form of an undulating elongated dome that plunges to the north and south from a point approximately east of Dividend. Near the crest of the anticline in the Tintic Standard mine area, the moderately dipping west limb is crenulated by several small asymmetric folds of diverse trends. These folds are chiefly related to minor thrust faults near the contact between the Tintic quartzite and the Ophir formation.

THRUST FAULTS

Several thrust faults of small to moderate displacement are exposed in the Eureka quadrangle, and others are known from underground workings and drill holes. These faults are closely associated with the folds, and some are themselves folded. In general the thrust faults dip west and show evidence that the upper plates moved relatively eastward.

TINTIC STANDARD THRUST FAULT

The Tintic Standard thrust fault, which is a minor thrust fault localized near the contact of the Tintic quartzite and Ophir formation in the Tintic Standard and North Lily mines, is a major ore-controlling structure at points where it is cut by steep north-northeastward-trending mineralized fissures. It has been described by Lovering and his coworkers (1949) as having been folded into a curving, northwestward-trending asymmetric trough lying just west of the crest of the East Tintic anticline. This trough extends from the Tintic Standard mine to the North Lily mine, and its southern part has been cross-folded into a trough running east-northeast. The cross trough is called the Tintic Standard trough; its eastern end, where it merges with the northwesterly synclinal fold, is very steep and is marked by much broken and highly mineralized ground known locally as the Tintic Standard "pot hole." The northwestern end of the syncline, called the North Lily trough, narrows rapidly at the fissure zone that passes near the North Lily mine, and the western side is vertical or overturned (Lovering and others, 1949, pl. 1). In this part of the folded fault, likewise, the formations between the two limbs of the fold are very much broken and mineralized and this area is known as the North Lily "pot hole." The position and extent of the Tintic Standard fault beyond the limits of the North Lily and Tintic Standard mines are unknown, but the fault is believed to have its root zone in the moderate-dipping east limb of the Tintic syncline.

EAST TINTIC THRUST FAULT

The largest thrust fault recognized in the quadrangle is exposed on the 1050 level of the Burgin mine at a point 1,300 feet west-southwest of the Burgin shaft and possibly also in workings of the inaccessible Independence shaft. In the Burgin mine the plane of this fault is gently folded but in general strikes northward and dips at a low to moderate angle to the west. Rocks of the upper plate include brecciated and deformed beds of the lower member of the Ophir formation that have been overturned and underlie the upper beds of the Tintic quartzite. Rocks of the lower plate in the Burgin mine area are contorted and sheared beds of the lower part of the Opohonga limestone, indicating a stratigraphic separation of about 3,200 feet. The sublava position of the thrust has been traced by drill holes from the Burgin mine generally northward for about 2 miles to a point in the NW¼ of sec. 2 T. 10 S., R. 2 W., and southeastward for approximately half a mile to a point near the west central edge of sec. 14, south of which it was not found. The logs of exploration drill holes south of the Burgin shaft indicate that the thrust probably terminates against a concealed northeastward-trending right-lateral fault, which has been named the Inez inferred fault from the Inez group of claims in this area. The drill logs also indicate that the offset segment of the thrust, if it exists, is displaced at least half a mile to the southwest in the southeast block of the Inez fault. The sublava trace of part of the thrust is indicated by the eastern termination of the pebble dikes near Highway 6–50, the quartzite fragments in these dikes being derived from the Tintic quartzite in the upper plate of the thrust fault.

The East Tintic thrust fault has been interpreted by most geologists who have worked in the East Tintic district in recent years to be the southern extension of the Allens Ranch thrust fault mapped by Proctor and others (1956) in the Allens Ranch quadrangle. The East Tintic thrust fault is similar in trend, attitude, and displacement to the Allens Ranch thrust fault, and its persistence beneath the lava for nearly half the distance between its exposures in the Burgin mine and the southernmost exposures of the Allens Ranch thrust fault 4 miles to the north has been confirmed by exploration drill holes that were drilled by the Bear Creek Mining Co. in 1962 and 1963. However, it is important to note that all the drill holes that penetrate the lavas in the vicinity of the East Tintic thrust are south of the eastward projection of the Homansville fault. If this fault is a postthrust normal fault with large displacement, as is indicated on page K19, and the offset part of the concealed low-dipping East Tintic thrust fault must lie several thousand feet east of the Allens Ranch thrust fault. It might be equally argued that the Homansville fault is a tear fault with little or no vertical displacement that terminates against the continuous plane of the East Tintic and Allens Ranch thrust faults. However, this latter interpretation does not seem to be supported by significant right-lateral displacement of the axis of the Tintic syncline across the projected trace of the Homansville fault.

The segment of the East Tintic thrust in the Burgin mine localizes a lead-zinc-silver replacement ore body of major importance, whose actual size was still being determined at the time of investigation in 1961.

PINYON PEAK THRUST FAULT

The Pinyon Peak thrust fault, of somewhat less apparent displacement than the East Tintic thrust fault, has been traced northeastward from the southeast base of Pinyon Peak to the area of the North Standard mine. A probable northward continuation of this fault extends beneath the volcanic rocks into the Allens Ranch quadrangle, where a fault zone of similar character is recognized about a mile west of the Allens Ranch fault (Proctor and others, 1956). Like the Allens Ranch fault, the Pinyon Peak thrust is cut and displaced by several transverse strike-slip faults. The net slip on the Pinyon Peak thrust fault is unknown, but the stratigraphic throw ranges from a few hundred feet to more than 1,500 feet; it is greatest near the North Standard mine, where the upper part of the Cole Canyon dolomite has been thrust over the basal beds of the Fish Haven dolomite. The fault dips gently west, and drag folds indicate that the upper plate moved relatively eastward.

Other thrust faults recognized in the Eureka quadrangle include the minor thrust just south of Homansville Canyon and the small bedding thrust fault exposed west of the Crown Point No. 3 shaft.

A thrust fault of fairly large magnitude may also have been cut by the Big Hill shaft; this structure, if it exists, is entirely concealed and has not been followed by any mine workings. Its inferred position is shown on structure section *A–A′* (pl. 1).

TRANSCURRENT FAULTS

The transcurrent faults, which are best studied in conjunction with exposures in the Boulter Peak, Allens Ranch, and Tintic Junction quadrangles, form a conjugate system of northeastward- and northwestward-trending fractures that cut the axes of the major folds at angles of 25° to 55°. Most of these faults dip steeply southeast or southwest, but some are vertical and a few dip northwest or northeast.

The dominant displacement on most of them is horizontal or nearly so. Many of those in the Boulter Peak quadrangle, however, show evidence of vertical movement, chiefly with the southeast or southwest sides of the faults relatively down. In general the northeastward-trending faults are more throughgoing than the northwestward-trending faults and are more important as ore-localizing structures.

PAXMAN FAULT

The Paxman fault is prominently exposed near the Paxman shaft about half a mile northwest of Eureka. It strikes approximately N. 45° E. and dips steeply southeast. The upper contact of the Fish Haven dolomite on the northwest side of the fault has been displaced laterally about a thousand feet northeast of the same contact on the southeast side. The fault is concealed by lava a short distance northeast of the Paxman shaft, but a more northward-trending fault underlying Tintic Davis Canyon shows appreciable right-lateral displacement in the Allens Ranch quadrangle (Proctor and others, 1956) and may be the continuation of the Paxman fault north of the lava cap.

BECK, WEST BECK, AND EAST BECK FAULTS

The Beck fault is not exposed at the surface in the Eureka quadrangle, but it has been cut on several levels of the Bullion Beck and Eureka Hill mines. It is close to the surface just south of the Bullion Beck shaft and from this point extends S. 70° W. into the Tintic Junction quadrangle (Morris, 1964), where it is exposed on the south side of Eureka Gulch and on Quartzite Ridge. About 250 feet northeast of the Bullion Beck shaft the Beck fault divides into two strands. The more northward-trending strand, which strikes about N. 25° E. and dips about 80° E., has been named the West Beck fault by the miners. It is recognized in workings of the Gemini mine for 1,300 feet or more north of the point of division, but north of the Gemini shaft it is apparently lost in steeply dipping beds whose bedding planes are chiefly parallel to the fault. The more eastward-trending strand, which is known as the East Beck fault in the Chief No. 1 mine, has a slightly sinuous strike which averages about N. 60° E. to the point where it merges with the Leadville fault and about N. 75° E. beyond it. The East Beck fault dips steeply northwest in the upper levels of the Chief No. 1 mine and steeply southeast in the lower levels. East of the Centennial and Mammoth–May Day faults the Coyote and Baltimore faults may be the faulted extension of the combined East Beck–Leadville fault, but these faults are concealed at the surface by lava and each of them is exposed at only one level of the North Lily mine.

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Near the Bullion Beck shaft the displacement on the Beck fault is about 1,800 feet, the northwest block having moved nearly horizontally to the southwest relative to the southeast block. The distribution of this displacement on the West Beck and East Beck faults is imperfectly known owing to lack of critical exposures, differential folding of the rocks on either sides of the East Beck and Leadville faults, and other structural complexities, but some 500 feet of left-lateral displacement is indicated on the East Beck fault by the offset of steeply dipping beds on the 800 level of the Chief No. 1 mine, and about 1,050 feet of similar displacement is indicated by the dislocation of contacts on the 1800 level. Deep, nearly horizontal mullions on the East Beck fault indicate that most of the movement was strike slip.

Large bodies of ore were found on and near the Beck and East Beck faults in the Bullion Beck and Chief No. 1 mines.

LEADVILLE, INTERMEDIATE, AND MILLIONAIRE ROW FAULTS

Closely associated with the West Beck and East Beck faults are several northeastward-trending faults of smaller magnitude that are known only from exposures underground in the Chief No. 1 mine. The most important of these structures are the Leadville, Intermediate, and Millionaire Row faults. The Leadville is a reverse fault whose principal strand strikes about N. 75° E. and dips steeply southeast. At about the 2000 level of the Chief No. 1 mine, a secondary strand splits off from the main strand of the Leadville fault and dips steeply north (see section *A–A′*). The wedge-shaped block between these strands is dropped relative to the blocks that bound it on either side. The displacement on the Leadville is not uniform along the strike, ranging from a few tens of feet to nearly 300 feet because of complex folding and local faulting of the rocks north of the fault. No ore bodies are found on the Leadville fault itself, but several ore bodies of good size and grade were found on minor structures adjacent to it.

The Intermediate fault is apparently limited by the East Beck and North Centennial faults. Near the Chief No. 1 shaft, where it cuts steeply dipping beds, the Intermediate fault shows 100 to 180 feet of right-lateral displacement. In this area it strikes about N. 77° E. and dips 75° S. Two thousand feet northeast of the shaft on the 1800 level, the fault strikes about N. 60° E. and dips about 70° SE. No ore bodies are localized by this structure.

The Millionaire Row fault is a poorly defined fissure zone that here and there follows earlier faults. In general it has a curving strike that averages about N. 60° E., and dips irregularly to the north. Small bodies of high-grade silver ore, mined chiefly by lessees, are found on the Millionaire Row fault below the 1800 level.

CENTENNIAL FAULT

The Centennial fault crops out from the west boundary of the quadrangle to the dump of the Eagle and Bluebell mine, passing a short distance south of the Centennial Eureka shaft. Underground the fault is exposed on many levels of the Eagle and Bluebell, Chief No. 1, and Chief No. 2 mines. Mine workings have followed it to a point about 2,400 feet northeast of the Chief No. 2 shaft. In the workings of the Centennial Eureka mine the fault strikes about N. 45° E. and dips about 67° SE. from the surface to an elevation of 4,900 feet. In the Eagle and Bluebell and Chief No. 1 mines it strikes about N. 55° E.; in the upper levels of these mines it dips 37° SE., but at an elevation of 5,650 feet the dip steepens and then reverses, becoming about 60° NW. at the elevation of 4,800 feet. About three-fifths of a mile northeast of the Eagle and Bluebell shaft, a strong northeastward-trending fault merges with the Centennial fault, but within a short distance to the northeast, the merging fault becomes nearly parallel with the Centennial. The narrow block between these faults is relatively down-dropped about 1,800 feet, as determined from exposures on the 1600 and 1800 levels of the Chief No. 2 shaft. Southwest of the intersection of these faults the Centennial fault shows 500 to 1,100 feet of left-lateral stratigraphic separation in an area of near-vertical beds.

The great thickness of the Packard quartz latite near the Chief No. 2 shaft shown on cross section *A–A′* (pl. 1) has been attributed by some of the local geologists to postlava vertical displacement on the Centennial fault or the strong fracture parallel to it on the north, but analysis of the fault-lava relations on the lower levels of the Chief No. 2 mine indicate that the fault movement was chiefly prelava, and that the steep contacts of the lava and sedimentary rocks south of the shaft are largely depositional. Northward from this area, however, an increasing amount of postlava displacement may be localized on the Centennial fault comparable to that on the Mammoth–May Day fault.

Large ore bodies were found near the intersections of the Centennial fault and the Gemini and Mammoth ore zones, but the ore does not seem to lie directly within the fault zone.

GRAND CENTRAL FAULT

The Grand Central fault is prominently exposed near the Emerald shaft and on Godiva Mountain, and in the Emerald, Plutus, and May Day mines. According to Lindgren (Lindgren and Loughlin, 1919, p. 202), the course of the fault in the Emerald mine is undulatory, the strike ranging from N. 20° E. to N. 45° E. and the dip from 50° to 70° NW. In the Plutus workings, which in general underlie Gardner Canyon, the average dip is 67° and in the May Day–Chief No. 2 area the dip averages 70°. Displacement on the Grand Central fault is somewhat greater southwest of its intersection with the Victoria fault than northeast of it but, in general the displacement is less than 100 feet or so. The movement on the Grand Central fault was chiefly left lateral, but this may be the result of vertical dislocation of east-dipping strata. This fault is not important as a structural control of ore.

MAMMOTH–MAY DAY FAULT

The Mammoth–May Day fault is conspicuously exposed on Godiva Mountain between the Mammoth and May Day mines. It strikes about N. 30° E. and dips steeply northwest or is vertical. Three periods of movement on the fault are evident: (a) early left-lateral strike slip is indicated by drag folding of the basal beds of the Deseret limestone; (b) late prelava normal displacement on the small segment that is locally followed by the Sioux–Ajax fault; and (c) postlava displacement probably related to Basin and Range fault movement is indicated by displacement of the lava by the fault near the May Day mine and the occurrence of loose breccias adjacent to it in the Mammoth mine (Lindgren and Loughlin, 1919, p. 215). The postlava displacement probably increases northward as the Mammoth–May Day fault approaches the Selma fault, but the evidence for this displacement can only be inferred from a reconstruction of the prelava surface based on scattered penetrations by drill holes and mine workings. Large ore bodies are localized on or near the Mammoth–May Day fault in the Mammoth mine where it is intersected by north-trending mineralized fissures.

IRON KING FAULT ZONE

The zone of eastward-trending faults near the Iron King No. 1 and No. 2 shafts and the displaced segment of this zone on Mineral Hill has been named the Iron King fault zone. The segment of this fault zone west of the Eureka Lilly fault strikes about N. 70° E. and seems to dip steeply north from the surface to a depth of 1,000 feet or so, where the dip changes to south. The segment of the Iron King fault zone east of the Eureka Lilly fault strikes about N. 60° E. and dips moderately to the south. This relation suggests northward or southward tilting of one or the other of the blocks separated by the Eureka Lilly fault. Small pyritic copper-gold ore bodies are found on both the Iron King and Eureka Lilly faults near the Iron King No. 2 shaft.

EUREKA STANDARD FAULT

The Eureka Standard fault is concealed at the surface by lava and alluvium but is well known from exposures in the workings of the Eureka Standard, Apex Standard, and Burgin mines. It lies about half a mile south of the Iron King fault, and the area between these faults is commonly referred to as the Eureka Standard trough. The average strike of the Eureka Standard fault is N. 47° E. and the average dip is about 55° NW. Exposures at the surface near the Trixie prospect and underground in the Eureka Standard, Tintic Standard, and Apex Standard mines show the axis of the East Tintic anticline to be displaced right-laterally about 3,000 to 4,000 feet to the northeast on the northwest side of the Eureka Standard fault.

In workings in the eastern part of the Apex Standard No. 2 mine the Eureka Standard fault may be cut and offset by a northward-trending normal fault that dips west at about 42°. This normal fault, which has a displacement of about 250 feet, also appears to be exposed in mine openings and cut by drill holes in the western part of the Burgin mine and may also cut and displace the East Tintic thrust fault.

In the Eureka Standard, Apex Standard No. 2, and Burgin mines small but comparatively high-grade gold and silver ore bodies were mined on and near the Eureka Standard fault in steeply dipping fractures and pebble dikes in the footwall block close to the fault plane. The gold ores of the Eureka Standard mine consist of hessite, sylvanite and other tellurides with enargite and tetrahedrite. In the Apex Standard No. 2 mine gold was less abundant, although high silver values were recorded. The ore shoots currently being explored on the Eureka Standard fault in the Burgin mine consist of massive argentiferous galena with minor quartz, barite, and sphalerite.

APEX STANDARD FAULT

The Apex Standard fault crops out a short distance southeast of the Eureka Standard fault and trends approximately parallel with it. The straight course of the fault trace across uneven topography suggests that the dip near the surface is essentially vertical. The geologic relations at the surface indicate a displacement of approximately 400 feet, with the south side relatively down. In underground workings off the Apex Standard No. 1 shaft, the only fault correlative with the Apex Standard fault is a reverse fault with similar strike and displacement, cut on the 700 and 900 levels 75 and 130 feet respectively north of the shaft. This relation suggests that the fault plane flattens within a short distance below the surface and cuts the Apex Standard No. 1 shaft at a depth of 500 feet where the upper part of the Tintic quartzite is faulted over the upper part of the lower member of the Ophir formation. It is equally possible, however, that a low-angle fault penetrated by the shaft but not exposed at the surface, cuts and displaces the Apex Standard fault, which maintains a steep to vertical dip. Small stringers and pockets of lead and silver ore were found in the Apex Standard fault zone on the 900 level near the No. 1 shaft.

HANSEN FAULT

The Hansen fault crops out three-fifths of a mile south of the Apex Standard No. 1 shaft but is concealed by lava a short distance northeast and southwest of this area. The average strike of the fault is N. 65° E., but near its westernmost exposure the strike changes to N. 45° E. The fault is cut by the 900 level of the Apex Standard mine, 2,000 feet south-southeast of the No. 1 shaft. The indicated dip of the fault in this area is 55° NW. Three-fifths of a mile south of the Apex Standard No. 1 shaft, the Hansen fault brings the Dagmar dolomite against the lower part of the Teutonic limestone and the upper part of the Ophir formation. This relation indicates a vertical stratigraphic separation of 400 to 500 feet or more, but owing to the complexity of structure on both sides of the fault, the true displacement is not known with any degree of certainty.

FREMONT FAULT

The Fremont fault is chiefly concealed by lava in the Eureka quadrangle but is exposed for a few hundred feet at the west boundary, three-fifths of a mile north of Packard Peak. In the Tintic Junction quadrangle the fault strikes N. 45° W., dips 70° to 75° SW., and shows 2,200 to 3,000 feet of left-lateral separation. It is not known to control ore.

GEMINI FAULT

The Gemini fault crops out about 1,500 feet north of the Gemini shaft and has been cut on many levels of the Gemini mine. In the mine workings it strikes from N. 55° W. to N. 75° W. and dips 55° SW. Approximately 175 feet of left-lateral separation of steeply dipping beds is shown on the fault north of the Gemini shaft. The Gemini fault is not recognized between the West Beck and East Beck faults and has been presumed to terminate against the West Beck fault; however, the Bulkhead fault exposed on the 1800 and adjacent levels of the Chief No. 1 mine has an attitude and displacement similar to the Gemini and may be its offset segment southeast of the East Beck fault. In the Gemini mine, local enlargements of generally northward-trending replacement ore bodies are found near the Gemini fault, but the ore follows the fault laterally for only short distances at best.

CALIFORNIA FAULT

The northwestward-striking left-lateral fault that is mostly concealed by the dump of the Centennial Eureka mine is named the California fault from the large columnar ore body of that name adjacent to it between the 600 and 1400 levels of the Centennial Eureka mine. The dip of the fault underground is 60° to 75° SW., and the horizontal separation of steep beds along it is 200 to 500 feet; the principal movement is probably horizontal with possibly some later vertical displacement, north side relatively down. Restoration of the prefaulting relations across the Centennial fault indicates that the California fault may be the displaced segment of the zone of northwesterly faults that crop out a short distance southwest of the Victoria shaft. The average trend of this fault zone is N. 67° W., but the faults die out within a few hundred feet southeast of the Victoria shaft. In the near-surface workings of the Eagle and Bluebell mine, the general dip of this fault zone is about 65° SW.; the left-lateral separation is about 350 feet but apparently diminishes downward.

EARLY NORMAL FAULTS

Two sets of normal faults that cut the folded sedimentary rocks but do not cut the lavas are recognized in the Eureka quadrangle. Faults of the dominant set, which includes the Homansville and Sioux-Ajax faults, in general strike eastward and dip steeply north. Faults of the other set, including the Victoria, Addie, Eureka Lilly, and others. in general strike northward and dip steeply or moderately west. The vertical displacement recognized on many of the transcurrent faults also may be contemporaneous with the development of these faults.

HOMANSVILLE FAULT

The Homansville fault is exposed on the south side of Lime Peak between the Homansville shaft and the edge of the Packard quartz latite about half a mile to the east. Its extension to the east beneath the lava is indicated by the termination of quartzite-bearing pebble dikes in Pinyon Creek Canyon on projection of the strike of the fault. To the west the Homansville fault is correlated with the eastward-striking Dead Horse fault exposed three-fourths of a mile southwest of Packard Peak in the Tintic Junction quadrangle. The Homansville fault strikes N. 75° E. and dips steeply to the north. Rocks north of the fault are relatively downdropped about 3,000 feet near the Homansville shaft; the displacement diminishes to the west, inasmuch as the maximum displacement on the Dead Horse fault is about 1,700 feet.

SIOUX-AJAX FAULT

The Sioux-Ajax fault cuts the backbone ridge of the East Tintic Mountains a mile east of Mammoth. The fault zone consists of several strands, which in general strike east and dip 80° or more north. Steeply dipping beds on the west limb of the Tintic syncline north of the fault are dropped against gently dipping beds in the trough of the syncline south of the fault, indicating a vertical displacement near Mammoth Peak of about 1,600 feet. The position of the Sioux-Ajax fault east of the Iron Blossom No. 3 shaft is not known with any degree of confidence, but displacement on it may be distributed on the

Hansen fault and on concealed faults that may underlie lavas near the South Standard shaft. The Sioux-Ajax fault is also concealed west of the Mammoth mine, but scattered exposures indicate that it may be deflected to the southwest on the northwest side of the Mammoth-May Day fault, and underlie the alluvium in Mammoth Gulch.

VICTORIA FAULT

The poorly exposed fault that follows the east side of Gardner Canyon has been cut at depth in the Plutus and Victoria mines, where it was named the Victoria fault. It strikes nearly due north and has an average dip of 70° W. Displacement on this fault is normal, with the west side relatively down about 175 feet. The Victoria fault apparently is limited between the Grand Central and Centennial faults and is not known to localize any commercial ore bodies.

YANKEE AND ADDIE FAULTS

Mine workings driven eastward at the 2000 level of the Yankee shaft cut two large northward-trending faults that are entirely concealed by lava or alluvium in the upper part of Burriston Canyon. The fault nearest the Yankee shaft has been named the Yankee fault; the other has been named the Addie fault from the Addie group of claims. On the 2000 level of the Yankee mine the Yankee fault strikes about N. 20° W. and dips about 50°–70° SW. The type of displacement on the Yankee fault is unknown, but underground maps show the upper part of the Bluebell dolomite in the hanging-wall block to be faulted against the lower part of the Opohonga limestone, indicating an apparent normal displacement of about 1,200 feet.

The Addie fault, which was followed for 1,800 feet on the 2000 level of the Yankee mine, trends N. 10°–12° E. The dip is vertical or very steep to the west, and the displacement is apparently normal, with the west side relatively down about 1,100 feet.

Little is known of the general extent of the Addie and Yankee faults, but they apparently join near the Maple shaft and extend southeastward beneath alluvium in the middle part of Burriston Canyon. Near the Zuma shaft the northwestward-trending Yankee-Addie fault appears to cut and offset a northward-trending, west-dipping steep reverse fault and to extend to the area of the Eureka Standard fault. No actual exposures of the Yankee-Addie fault are known in this area, however, either at the surface or underground.

Mineralized breccias were found along the Addie fault throughout the full distance explored on the Yankee 2000 level, but no large ore bodies were discovered.

SELMA AND EUREKA LILLY AND ASSOCIATED FAULTS

The zone of north-trending normal faults extending from the north boundary of the quadrangle along the western base of Pinyon and Lime Peaks to the Homansville fault is known as the Selma fault zone from exposures in and near the Selma mine in the Allens Ranch quadrangle. The general southward continuation of this fault zone from the Homansville fault to the Eureka Standard fault is named the Eureka Lilly fault from exposures near the Eureka Lilly mine. A southward continuation of the Eureka Lilly fault is inferred to extend south of the Eureka Standard fault to Silver Pass and possibly farther south to the Diamond fault. The displacement on this zone of faults is dominantly postlava in age, although important prelava displacement is evident on the Eureka Lilly segment in the Eureka Lilly and North Lily mines. The postlava displacement increases in magnitude northward and southward from a point near the Eureka Standard fault, the lava showing little displacement near the Iron King No. 2 shaft, 300 feet of displacement near the Eureka Lilly mine, about 800 feet of displacement near the wells south of Homansville, and 1,200 to 1,400 feet or more displacement on the Selma fault segment north of the Homansville fault. The Eureka Lilly segment is well known from exposures in the North Lily mine, where it strikes N. 10° to 35° W. and dips 50° to 70° SW. The total displacement on the fault near the North Lily shaft is about 750 feet. A few relatively small ore bodies were found on the Eureka Lilly fault in the Iron King No. 2 and North Lily mines, indicating that the latest displacement on this segment of the fault preceded the deposition of ore.

MINERALIZED FAULTS AND FISSURES

The pebble dikes, monzonite dikes, and veins that cut both the sedimentary and igneous rocks along a wide zone extending north-northeastward through the Eureka quadrangle occupy faults and fissures of considerable persistence but small displacement. Where these fractures cut monzonite, thick lavas, and massive low-dipping quartzite and limestone, they trend within 10° or 15° of N. 30° E. and dip steeply west. Where they cut steeply dipping sedimentary rocks, as in the west limb of the Tintic syncline, they commonly deviate locally from this strike to follow northward-trending bedding-plane faults. In the flatter beds in the trough of the syncline, however, they maintain the north-northeastward trend.

BASIN AND RANGE FAULTS

A late normal fault, named the Diamond fault from exposures near the site of Diamond in the southern part of the quadrangle, cuts lava and intrusive rocks and has physiographic expression; thus it is probably part of the system of Basin and Range faults that define the western border of the south central part of the East Tintic Mountains. In general this fault strikes northward and dips steeply west. It can be followed with some confidence as far north as Ruby Hollow, but it appears to die out near Silver Pass. In general the Diamond fault is alined with the Eureka Lilly and Selma faults, but relatively undisturbed ore bodies on the Eureka Lilly fault indicate little if any displacement on this fault since middle Eocene time, although physiographic relations in the Allens Ranch quadrangle suggest that the Selma fault may have been reactivated as a Basin and Range border fault at the western edge of the main northeast spur of the East Tintic Mountain during the Pleistocene epoch.

The general straightness of the eastern edge of the East Tintic Mountains suggests that a late border fault delimits the range on this side. However, no exposures of such a fault are known, and geophysical evidence does not strongly indicate faulting of large displacement.

MINERAL DEPOSITS

From 1869 to 1955 the mineral deposits of the Eureka quadrangle produced metalliferous ores valued in excess of $428 million (U.S. Bureau of Mines, 1958) and nonmetallic mineral products valued at several million dollars. Continued production of halloysite clay from the Dragon mine is expected to add materially to the total value of nonmetallic products, and exploitation of the newly discovered lead-zinc-silver deposits in the Burgin mine and adjacent areas will substantially increase the overall value of the metalliferous ores.

METALLIC MINERAL DEPOSITS

The metallic mineral deposits in the quadrangle (fig. 1) may be classified into three general groups: (a) narrow veins of pyritic silver, lead, and copper ores that cut the intrusive and adjacent volcanic rocks; (b) replacement veins that cut sedimentary rocks in both the main Tintic and East Tintic districts; and (c) extensive replacement ore bodies found exclusively in the Paleozoic rocks. The veins and replacement ore bodies are parts of virtually continuous ore zones that can be traced almost without interruption from one type to another, but which are sufficiently distinctive to justify individual description. Of these various deposits, the replacement ore bodies have accounted for more than 90 percent of the total value of the ores produced.

FISSURE VEINS

The pyritic base-metal and silver veins cut the Silver City stock and adjacent rocks within the north-northeast-trending belt of fissures, veins, and dikes. These veins have sharply defined walls, and range in width from knife-edge seams to about 10 feet, averaging about 2

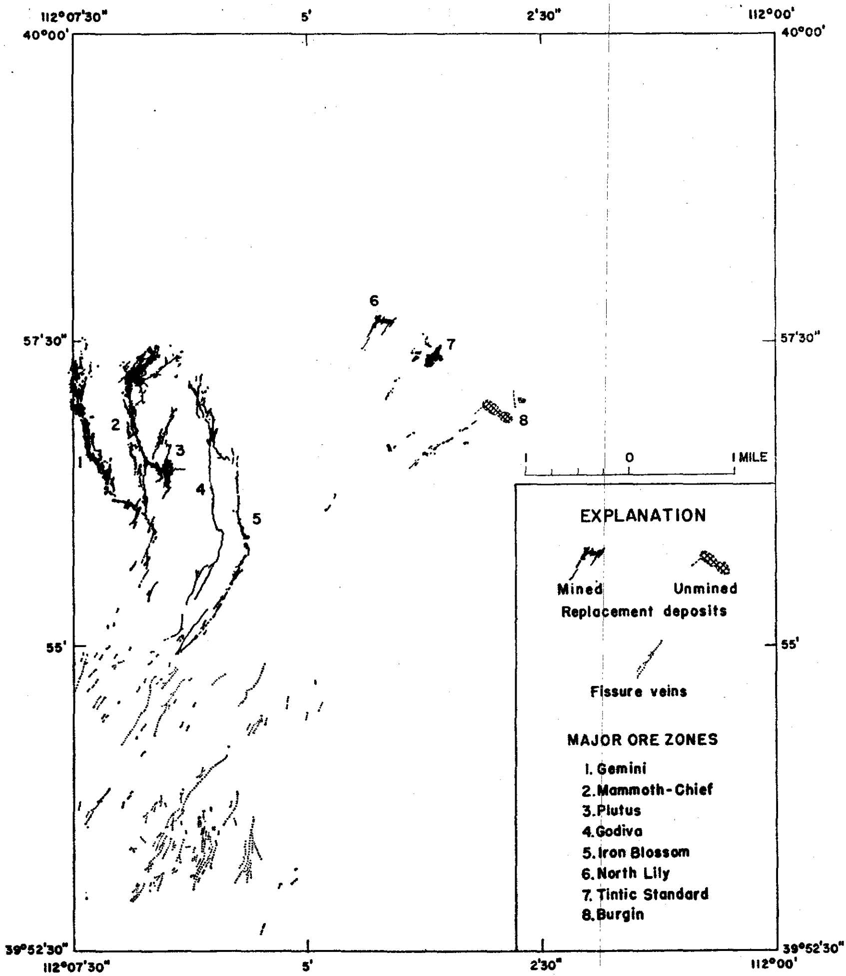

Figure 1.—Generalized plan of ore bodies, Eureka quadrangle.

feet. Most of them are less than a few hundred feet long, although the Sunbeam vein has been followed as a nearly continuous fissure filling for about 4,000 feet. The structures occupied by the veins seem to be small normal faults with an average strike of N. 20° E. The average dip is 75° to 85° W., but some of the veins are vertical and others dip east. They are widest and longest where they cut massive intrusive rocks, and tend to form groups of short, subparallel veins or disappear entirely, except for linear altered zones, in thick tuffs and incompetent flow rocks more than a few hundred feet from the intrusive bodies.

The principal primary ore minerals of the veins are pyrite, argentiferous galena, and enargite, with minor chalcopyrite, sphalerite, and arsenopyrite. The gangue is chiefly quartz and barite, both commonly coarsely crystalline. In the oxidized zone the ore consists of jarosite and iron oxides, copper carbonates, silicates, and arsenates, cerussite and residual galena, cerargyrite, and some native silver. Owing to heavy inflows of water at depths of 350 to 500 feet, none of the veins in the Eureka quadrangle was extensively mined below the water table; consequently, little is known about the character and shape of the primary ore bodies. The ore shoots in the oxidized parts of the veins are described by Tower and Smith (1899, p. 712) as being lens shaped and without definite pitch, although the longest axis is commonly horizontal.

REPLACEMENT VEINS

The veins in sedimentary rocks are similar to those in igneous rocks except to the extent that they replace their wallrocks and are transitional with the replacement ore bodies. The replacement veins in the southern part of the main Tintic district cut pyrometasomatized carbonate rocks near the Silver City stock and merge with podlike and columnar replacement ore bodies near the Sioux-Ajax fault. The veins of the East Tintic district are found chiefly in the Tintic quartzite downrake from the main replacement ore bodies in the Ophir and younger formations. Most of the replacement veins follow minor faults that strike north-northeast, dip steeply west, and show relatively little displacement. The replacement veins are less than a thousand feet long, with the exception of the Dragon–Iron Blossom vein, which has been followed continuously for 5,600 feet. Veins that cut carbonate rocks are characterized by irregular walls and range in width from mere seams to 50 to 60 feet. They are largest where they intersect cross-trending fractures or more thoroughly brecciated dolomite beds, commonly developing columnar ore shoots. Veins cutting quartzite in the East Tintic district are somewhat more uniform in width, most of them being 2 to 8 feet wide. Ore shoots in these veins are localized chiefly at changes in strike or dip, or at intersections with other fractures. Only rarely are the quartzite walls replaced to any extent.

The principal ore minerals of the replacement veins are pyrite, enargite, tetrahedrite, galena, sphalerite, and bismuthinite, or their oxidation products. The chief gangue minerals are quartz and barite. Many of the baritic copper ore bodies in the replacement veins contain important quantities of gold, in contrast to similar ore shoots in veins that cut igneous rocks, which in general contain little or no gold. Gold in the oxidized ores is native, whereas that in the primary ores is either native or is in various gold-silver tellurides. In the veins of the East

Tintic district the gold-copper ore shoots are found almost exclusively between quartzite walls. This relation has been regarded by some as evidence of a lithologic control of ore deposition, but the occurrence of copper-gold ore shoots in the veins cutting carbonate rocks in the Iron Blossom No. 1 mine and elsewhere in the quadrangle casts some doubt on the validity of this interpretation.

REPLACEMENT DEPOSITS

All of the highly productive replacement deposits of the Tintic and East Tintic mining districts are within the Eureka quadrangle. The deposits of the Tintic mining district are along five linear zones or "ore runs" that in general underlie Eureka Ridge and Godiva Mountain, extending northward from the Sioux-Ajax fault zone to points north and east of Eureka. The replacement deposits of the East Tintic district are centered near Dividend, and occur in several localized ore centers that lie within a zone of still unresolved dimensions that was actively being explored in 1962 and 1963.

The ore bodies in both districts replace several different types of sedimentary rocks of Paleozoic age, but are chiefly in areas of hydrothermally dolomitized limestone and recrystallized syngenetic dolomite. The deposits of the main Tintic district occur in all of the stratigraphic units between the Cole Canyon dolomite and the Humbug formation, the largest being in the Cole Canyon, Ajax, Fish Haven, and Bluebell dolomites, the Fitchville formation, and the Deseret limestone. The ore bodies in the East Tintic district replace parts of probably all of the carbonate units between the Tintic quartzite and the Cole Canyon dolomite, but most have been found in the limestone beds of the Ophir formation.

The linear ore zones of the main Tintic district consist of columnar and podlike ore bodies connected by pipelike, tabular, and irregular masses of ore, forming continuous ore "runs" that have great horizontal persistence. These "runs" have many features in common with the great limestone replacement chimney and manto ore deposits of north-central Mexico. In the Tintic district, however, owing to abundant cross faults and abrupt changes in the attitude of beds, many of the larger ore bodies have irregular branching shapes and in general cannot be classified as either chimneys or mantos. The ore bodies of the East Tintic district are similar in many respects to those of the main district, but these do not occur in persistent linear zones. However, the East Tintic ore bodies are generally elongated in the direction of the northeastward-trending fissures and veins with which they are associated.

Structural controls are apparent for some of the individual replacement ore bodies, are obscure for others, and seem to be lacking for at least a few. The East Tintic deposits are chiefly localized where zones of steep, north-northeastward-trending fissures intersect carbonate beds that were brecciated along faults. The replacement ore bodies of the main Tintic district are not obviously localized by fissures, but appear to have been deposited by solutions that worked their way through many different types of openings, some of them not readily apparent. The largest mantolike ore body follows a coarse-grained bed in the upper part of the Deseret limestone at the trough of the Tintic syncline; it apparently originates at a chimney of jasperoid and low-grade ore in the wide zone of the Sioux-Ajax fault and extends horizontally 5,000 feet northward to the Beck Tunnel No. 2 shaft following obscure tension fractures. The irregular ore bodies of the Chief No. 1 and adjacent mines show more obvious structural control and generally are found near faults at places where competent carbonate beds—most commonly dolomite—have been extensively brecciated. Mantolike projections extend from these ore bodies along beds, and veinlike, pipelike, and small irregular masses of ore extend from the main ore mass along faults and fissures. Like the larger ore bodies, the small connecting ore bodies of the main Tintic district are controlled by steep crosscutting faults, bedding-plane faults, fissures, and other local features, but the fundamental controls of the major ore zones of the main Tintic district and the reason for the north-northeastward trend of these zones across major structures are unknown.

The principal primary minerals of the replacement ore bodies are galena, sphalerite, enargite, and ubiquitous pyrite. Much of the galena is rich in silver, which probably occurs as blebs of argentite. Some native silver occurs in sulfide ore bodies as much as 900 feet below the water table and also must be considered a primary mineral. Some small ore shoots near the water table contain wurtzite, pearceite, proustite, stephanite, freibergite, tetrahedrite, and other sulfo-salt minerals; some of these minerals are also found with the native silver ores in the sulfide ore bodies well below the water table. Completely or partly oxidized ores extend to a maximum depth of about 1,900 feet in the main Tintic district and about 1,400 feet in the East Tintic district; they contain many secondary minerals, including cerargyrite, native silver, anglesite, cerussite, smithsonite, complex copper arsenates, and other minerals, some of which are valued for their rarity or spectacular appearance. Native gold occurs locally in some of the copper ores. The gangue minerals include jasperoid, quartz, barite, and minor dolomite and calcite. Jasperoid, the most abundant gangue mineral, is a mixture of chalcedony and fine-grained quartz, which apparently crystallized from gelatinous silica that replaced limestone and dolomite. Crushing of early jasperoid produced breccias which were the hosts for successive deposits of jasperoid, quartz, barite, and ore minerals. The last minerals deposited in the ore bodies were predominantly base-metal sulfides and sulfosalts and native silver.

A general horizontal zonation is evident in the composition and, to a lesser degree, the texture of the ore bodies of the linear ore "runs" of the Tintic district. A less obvious zonation of the more massive ore bodies of the East Tintic district has also been suggested by Billingsley and Crane (1933, p. 118). The replacement ore bodies of the main Tintic district that occur within a mile or so of the more even-grained facies of the Silver City stock are valuable chiefly for copper and gold, although important shoots of lead ore have been mined in this area. The mines 1 and 2 miles from the stock have produced chiefly lead and silver ores, although some chimneylike ore bodies contained notable amounts of copper and some gold. The northernmost ore bodies in the district are preponderantly zinc bearing and carry significantly smaller quantities of silver than those in the area of predominantly lead deposits. Some zinc ores have also been mined, however, near the contact of the Silver City stock in the zone containing chiefly copper ores.

The more localized ore centers of the East Tintic district show a similar if less regular zonation. Copper is an abundant constituent only in the lower southwestern parts of the ore bodies and is virtually absent from the lead-silver ore bodies that make up the great bulk of the deposits. As in the main Tintic district, zinc ores have been noted both in the zones of copper-gold ores and upward or outward beyond the zone of lead-silver ores. The predominant zinc ores, however, are the extensive rhodochrosite-sphalerite deposits in the Burgin mine and adjacent areas, which appear to lie on the outer fringe of argentiferous lead deposits.

A textural zonation of the gangue minerals outward from the Silver City stock is perhaps as evident as the chemical zonation, although it is less spectacular and not of direct commercial significance. As noted by Lindgren (Lindgren, and Loughlin, 1919, p. 127), the quartz in the veins cutting the igneous rocks is in well-developed crystals, some several inches long. The siliceous gangue of the copper ore bodies that occur in the sedimentary rocks near the Silver City stock consists of granular aggregates of small quartz crystals and medium-grained jasperoid, both containing medium to coarse plates of barite and druses filled with quartz crystals a centimeter or so long. The jasperoid associated wih the silver-lead ore bodies farther north is fine grained, resembling chert, and contains smaller barite plates and tiny quartz crystals filling fractures and shrinkage openings. The fine-grained jasperoid continues into the zinc-rich areas, but barite and crystalline quartz cease to be abundant. In the East Tintic district, rhodochrosite rather than jasperoid is the gangue of the principal zinc ore bodies. Transitions between these textural and compositional zones are virtually imperceptible.

NONMETALLIC DEPOSITS

The nonmetallic materials produced in the Eureka quadrangle include halloysite clay, high-purity limestone, road metal, and construction materials. Of these, the halloysite deposits currently being exploited at the Dragon mine (Kildale and Thomas, 1957, p. 94–96) are by far the most important, the processed mineral being a highly efficient filter-catalyst used in the refining of certain crude oils. The Dragon mine is at the south tip of the large reentrant of sedimentary rock that extends into the north side of the Silver City stock. The halloysite, which in the undisturbed deposits is actually in the hydrated form, endellite, occurs as a massive irregular replacement of the upper part of the Ajax dolomite on both sides of the Dragon fissure vein at the point where it crosses the monzonite-dolomite contact. The dolomite beds are completely replaced by the clay, which commonly retains original bedding features, including layers of unreplaced chert nodules. The adjacent monzonite is also partly to wholly argillized. The purest clay is white and has a waxy lustre; most of it contains finely disseminated pyrite and some contains manganese oxides. Associated with the clay deposit are large bodies of iron oxides that lie near the Dragon vein and divide the clay body into two parts. Shoots of oxidized silver, lead, gold, and copper ores also occur in the fissure zone. From 1949 to 1958 the deposit produced nearly 500,000 tons of halloysite (Kildale and Thomas, 1957, p. 94), and it still contains large developed and undeveloped reserves.

High-purity limestone has been produced in past years from massive pink sublithographic beds near the top of the Fitchville formation on Lime Peak near Homansville. The broken rock was calcined in an underground kiln at the quarry site, partly rehydrated, ground, and bagged at a plant nearby, and the finished product was sold chiefly as plaster and metallurgical lime. The quarry and lime plant were closed in 1949.

Construction materials and road metal have been exploited for local use only.

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