UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

# THE BINGHAM MINING DISTRICT, UTAH

A guide prepared for the
Rocky Mountain Section of
The Geological Society of America
33d Annual Meeting
May 16-17, 1980
Weber State College
Ogden, Utah
Field Trip no. 7, May 18, 1980

By W. W. Atkinson, Jr., W. James Garmoe, Laurence P. James,
William J. Moore, and A. Jaren Swensen

U.S. Geological Survey
Open-File Report 80-823
1980

This report is preliminary and
has not been edited or reviewed
for conformity with Geological
Survey standards and nomenclature

# THE BINGHAM MINING DISTRICT, UTAH

A guide prepared for the
Rocky Mountain Section of
The Geological Society of America
33d Annual Meeting

May 16-17, 1980
Weber State College
Ogden, Utah

Field Trip no. 7, May 18, 1980

LEADERS

W. W. Atkinson, Jr.
Department of Geological Sciences, University of Colorado
Boulder, Colorado 80309

W. James Garmoe
Carr Fork Project, The Anaconda Company
Tooele, Utah 84704

Laurence P. James
Consulting geologist, 2525 S. Dayton Way #1406, Denver, Colorado 80231, and
1123 Vista View Drive, Salt Lake City, Utah 84108

William J. Moore
U.S. Geological Survey, 345 Middlefield Road
Menlo Park, California 94025

A. Jaren Swensen
Kennecott Copper Corporation, Geology Department
Bingham Canyon, Utah 84006

Discussions of

(1) the district geologic setting--a Tertiary igneous complex intruding deformed Paleozoic marine sedimentary rocks;
(2) the diverse zones of base-metal and precious-metal mineralization--a porphyry copper center, a contact-metasomatic border, bedded replacement lead-zinc in limestones, and major gold and silver credits in all zones;
(3) the probable geometry of the ore system--possible models for the overall shape and nature of the hydrothermal system, generating ore-forming fluids in a magmatic setting beneath a volcanic sequence.

CONTENTS



## A word of caution

The trip will pass through one of the largest mines in the world. Rapidly moving machinery, live explosives, high voltage power cables, and unprotected rock faces with either loose rocks of steep drop offs are the rule. Please wear safety equipment, and watch carefully for the unexpected. Keep in mind that exposed, overhanging rocks are much less stable than in a typical long-exposed outcrop. Intense, repeated tectonic events, and perhaps even explosive pulses related to magmatic activity, have developed networks of closely spaced fractures in the rocks of the copper mine area.


## Acknowledgments

The mine staffs of Kennecott Copper Corporation, operator of the major porphyry copper deposit, and of the Anaconda Company, a division of Atlantic Richfield Corporation and operator of the newly opened underground Carr Fork mine, have greatly facilitated this field trip. Drs. Fred Pashley and T. Rodney Neff of the Geology Department at Weber State College, Ogden, have contributed countless hours to organizational details. Donald T. McMillan, director of the Utah Geological and Mineral Survey, made available the colored maps, which were purchased with funds from the Geological Society of America. The U.S. Geological Survey provided assistance in editing and assembling this guide. Individuals too numerous to mention have contributed information to the discussions presented.


1/ Insert to field guide available on day of trip.

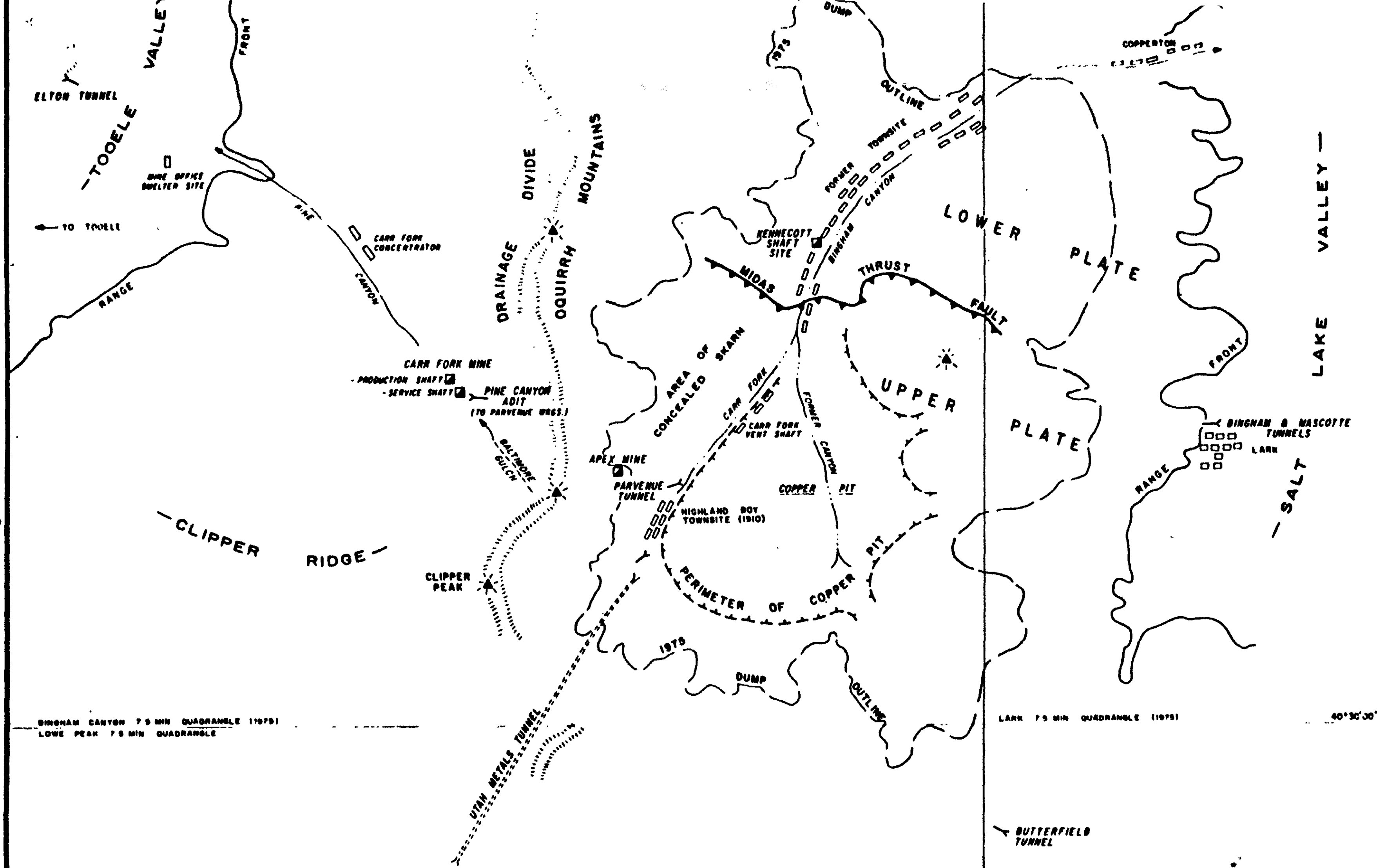
# INTRODUCTION

Laurence P. James

The Bingham mining district, in the Oquirrh Mountains southwest of Salt Lake City, is the largest economic enterprise in Utah. It is among the very largest producers, past and present, of copper, gold, molybdenum, and silver in the United States, and yields important trace metals recovered during copper refining. Lead and zinc production, significant until 1972, will probably resume in the future. Figure B-1 shows the general physiography of the district, and the locations of the major active mines and important drainage tunnels.

Despite the magnitude of production, the volume of rock containing the variety of metal deposits is surprisingly compact. Telltale prospect holes and small mines do not extend for miles from the center of the district, as they do in many western mining camps. The vertical extent of mineralization may prove to be as large as the horizontal extent. The abundance of calcium carbonate, both in relatively thin limestone beds and in calcareous quartzites, appears to have contributed to "telescoping" the distribution of peripheral ores and geochemical haloes.

The enormous open pit "porphyry" copper mine, in a multiphase intrusion at the center of the district, visually dominates the area of this field trip. But limestone beds surrounding this intrusive body (the Bingham stock) contain major contact metasomatic ("skarn") copper ores and bedded replacement lead-zinc ore deposits. The copper deposits west and north of the stock are now under development to great depths. Production from the deposits held by Anaconda commenced recently, and promises to be large. Still further from the center of the district, near-vertical vein or "fissure"-type ore deposits have yielded significant lead-zinc-silver production in the past. In the outermost zones, silver has been the major economic metal.




## FIGURE B-1
## BINGHAM MINING DISTRICT UTAH
### SHOWING MAJOR MINES

Figure B-1. Bingham mining district, Utah, showing major mines. The field trip will enter Bingham Canyon on the east side of the Oquirrh Mountains, near Copperton. General geology will be discussed at stop 1, in this vicinity. Stop 2 will be at the edge of the copper pit, northeast of the Carr Fork vent shaft. Subsequent stops will be in this vicinity, and on a level crossing the copper pit. Because of constant changes in roads and mining sites, exact location of the stops will not be known until the day of the trip.

The ore metals of this large hydrothermal system are distributed within rock types that are rather common in the Great Basin. A mid-Tertiary quartz monzonite-granodiorite intrusive complex was emplaced in a thick sequence of Paleozoic marine sedimentary rocks, which is overlain by remnants of an andesitic volcanic pile. These elements of the Bingham system occur again and again elsewhere in the region, but typically are accompanied by relatively minor mineralization, if any at all.

This field trip addresses the questions: what is the peculiar nature of the Bingham "ore system" that led to such abundances of economic elements? How are the ores, and their accompanying alteration minerals, distributed or zoned within the system? What did the system look like prior to its erosion (and human excavation) to present form? Does the system differ substantially from other intrusive rock-sedimentary rock interactions in the region? These are obviously difficult questions, asked by many geologists. There are much published data available to allow a variety of comparisons.

Two geologic maps (plates I and II), compiled by the staff of Kennecott Copper Corporation and based on many years of field work in the district, are provided for your reference. A smaller, updated map of the mine area will be provided at the second stop. Several guidebooks and publications, listed at the end of this section, summarize at least one man/woman-century of studies in the area. The verbal presentations today, by a few of the geologists now actively continuing work on the district, will scarcely be able to cover the broad scope of available information.

## Selected References


Arrington, L. J., and Hansen, B. B., 1963, "The richest hole on Earth," a history of the Bingham copper mine: Utah State University Monographs, v. 11, no. 1, 103 p.

Boutwell, J. M., Keith, A., and Emmons, S. F., 1905, Economic geology of the Bingham mining district, Utah: U.S. Geological Survey Professional Paper 38, 413 p.

Gay, S. P., and Mardirosian, C. A., 1970, Aeromagnetics and geology of thirty six copper and molybdenum porphyry deposits in the western United States and British Columbia: Privately distributed compilation by Applied Geophysics Inc., Salt Lake City, Utah, 122 p.

Hunt, R. N., 1924, The ores in the limestones at Bingham, Utah: Transactions of the American Institute of Mining Engineers, v. 70, p. 856-883.

James, A. H., Smith, W. H., and Welsh, J. E., 1961, General geology and structure of the Bingham district, Utah, in Cook, D. R., ed., Geology of the Bingham district and northern Oquirrh Mountains: Utah Geological Society, Guidebook no. 16, p. 49-71.

James, L. P., 1978, The Bingham copper deposits, Utah, as an exploration target: History and pre-excavation geology: Economic Geology, v. 73, no. 7, p. 1218-1227.

Koschmann, A. H., and Bergendahl, M. H., 1968, Principal gold-producing districts of the United States: U.S. Geological Survey Professional Paper 610, 283 p.

Moore, W. J., 1973, Igneous rocks of the Bingham mining district, Utah: U.S. Geological Survey Professional Paper 629-B, 42 p.

Rose, A. W., 1967, Trace elements in sulfide minerals from the Central district, New Mexico and the Bingham district, Utah: Geochimica et Cosmochima Acta, v. 31, p. 547-585.

Rubright, R. D., and Hart, O. J., 1968, Nonporphyry ores of the Bingham district, Utah, in Ridge, J. D., ed., Ore deposits of the United States 1933-1967: American Institute of Mining Engineers, p. 886-907.

Society of Economic Geologists, 1975,Guidebook to the Bingham mining district, Utah: R. E. Bray and J. C. Wilson, editors, 156 p.

Society of Economic Geologists, 1978, An issue devoted to the Bingham mining district, Utah: Economic Geology, v. 73, no. 7.

Utah Geological Association, 1976, Guidebook to the geology of the Oquirrh Mountains: Publication 6, 36 p.

# THE BINGHAM CANYON IGNEOUS CENTER, UTAH - A BRIEF REVIEW

## INTRODUCTION

William J. Moore

The mid-Tertiary igneous history figures prominently in conceptual models of hydrothermal mineralization and alteration in the Bingham district. Landmark field investigations and reports by James and others (1961a, b) and Stringham (1953) prepared the way for modern petrologic studies. This review briefly summarizes broad elements of the igneous history, emphasizing premineralization events. Reports published since 1961 provide the principal sources of information for this review; particularly useful were the guidebook (Bray and Wilson, eds., 1975) and issue of Economic Geology (v. 73, no. 7, 1978) resulting from a symposium devoted to the Bingham mining district and sponsored by the Society of Economic Geologists at the 87th annual meeting of GSA (Salt Lake City, 1975).

This review is neither exhaustive nor unbiased. Some interpretive details are influenced by my observations and personal prejudices. Agreement on certain aspects of the magmatic evolution is not unanimous. Such areas of disagreement should guide future research, and questions, comments, or objections are welcomed as important contributions in the process of clarifying and refining the model.

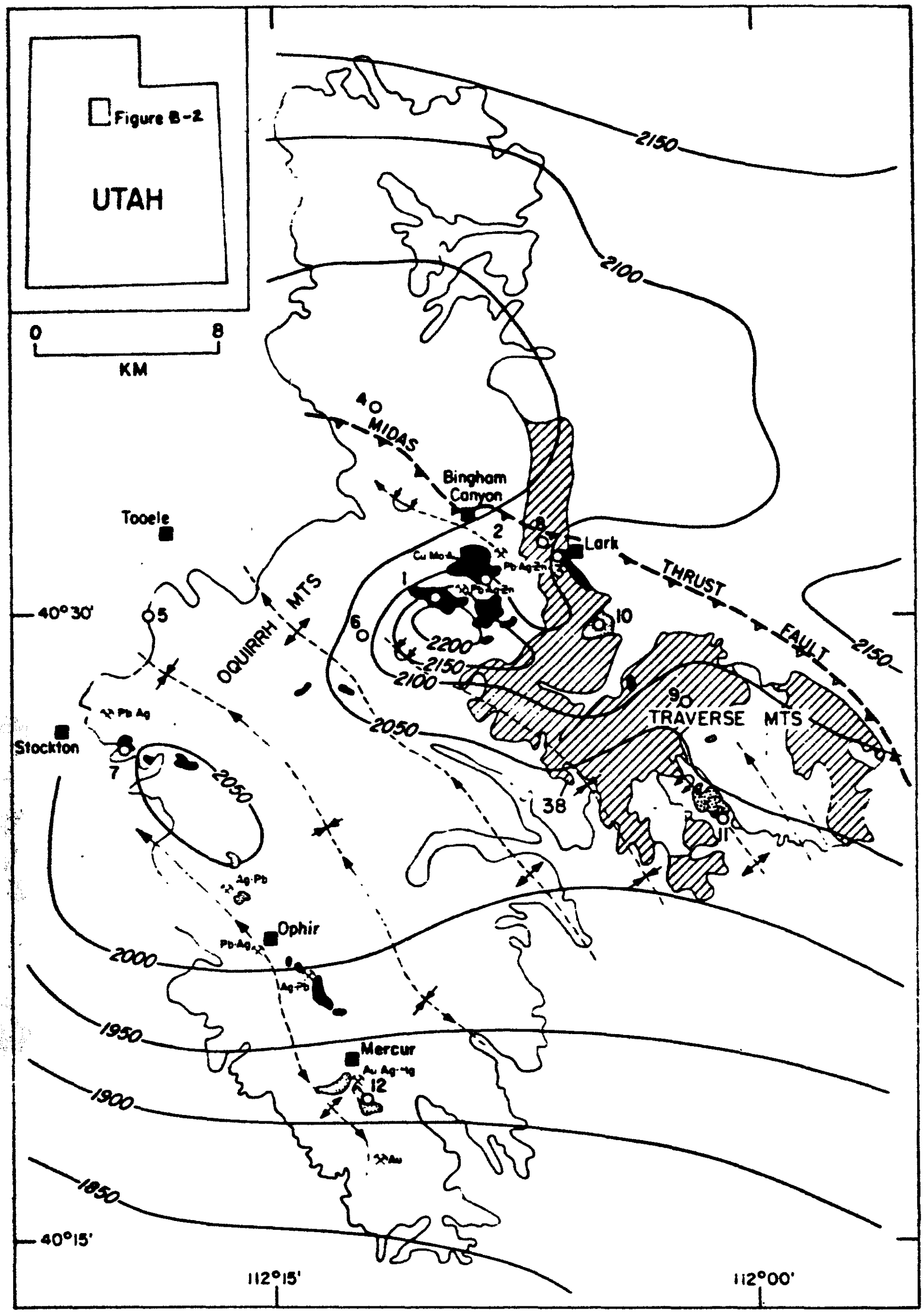
## THE BINGHAM IGNEOUS COMPLEX

Background. Bingham is one of many centers of epizonal, calc-alkaline magmatism in the eastern Great Basin. Others in the region having a history of significant base-metal production include the Park City-Big Cottonwood districts in the central Wasatch Mountains about 50 km to the east and the Tintic district located 70 km to the south. Over the past decade considerable attention has been given to a detailed understanding of the igneous rocks and their mutual relations. Field and petrographic observations by many geologists have been combined with various chemical, radiometric, and isotopic studies to provide an uncommonly comprehensive base for interpretation of the igneous history.

Volcanic rocks. Volcaniclastic rocks, lavas, and related hypabyssal intrusions are widely exposed on the lower flanks of the east-central Oquirrh Mountains and continue southeastward for about 12 km (Plate 1; Figure B-2). Erosion after high-angle range-front faulting and eastward tilting of the mountain block in late Tertiary time has apparently removed any volcanic rocks once present to the west.

The volcanic section is locally variable and laterally discontinuous owing to multiple feeder vents/fissures and considerable relief on the prevolcanic surface. A generalized section for the Traverse Mountains consists of basal laharic breccias (mudflows) 300-500 m thick, overlain by 500-800 m of lenticular lavas and tuff breccias (Moore, 1973b). The eruptive rocks are intruded locally by small domes and necks (c.f. Shaggy Peak and Step Mountain south of Rose Canyon, Plate 1). Latitic to dacitic compositions predominate; notable exceptions include the rhyolites of Shaggy Peak and Tickville Gulch, and the nepheline(?) basalt flow of Oak Spring Hollow (Figure B-2, "38").

Plutonic rocks. Plutonic rocks in the Bingham district (Plate II) include two major phaneritic stocks, the Bingham and Last Chance, each having irregular apophyses, and several sets of northeast-trending porphyritic-aphantic dikes that intrude the stocks. The Last Chance stock is a uniformly fine grained pluton, whereas the Bingham stock consists of two small porphyritic variants intruding a larger fine-grained host. One of the porphyries (Tiqmp, Plate II), characterized by a sugary or aplitic quartz-orthoclase groundmass, is the inferred locus of Cu-Mo mineralization.




| SAMPLE NUMBER | K-Ar AGE (m y) |
|---|---|
| 1 | 38.6 ± 0.18 |
| 2 | 37.6 ± 0.07 |
| 3 | 36.9 ± 1.0 |
| 4 | 36.5 ± 1.1 |
| 5 | 38.6 ± 1.1 |
| 6 | 37.1 ± 1.1 |
| 7 | 38.0 ± 1.1 |
| 8 | 38.8 ± 0.9 |
| 9 | 30.7 ± 0.9 |
| 10 | 33.0 ± 1.0 |
| 11 | 31.2 ± 0.9 |
| 12 | 31.6 ± 0.9 |

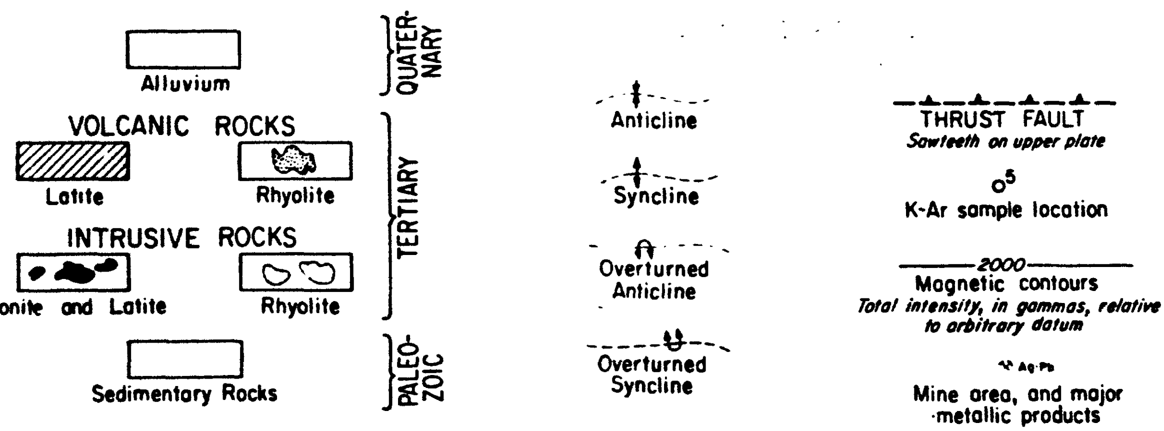
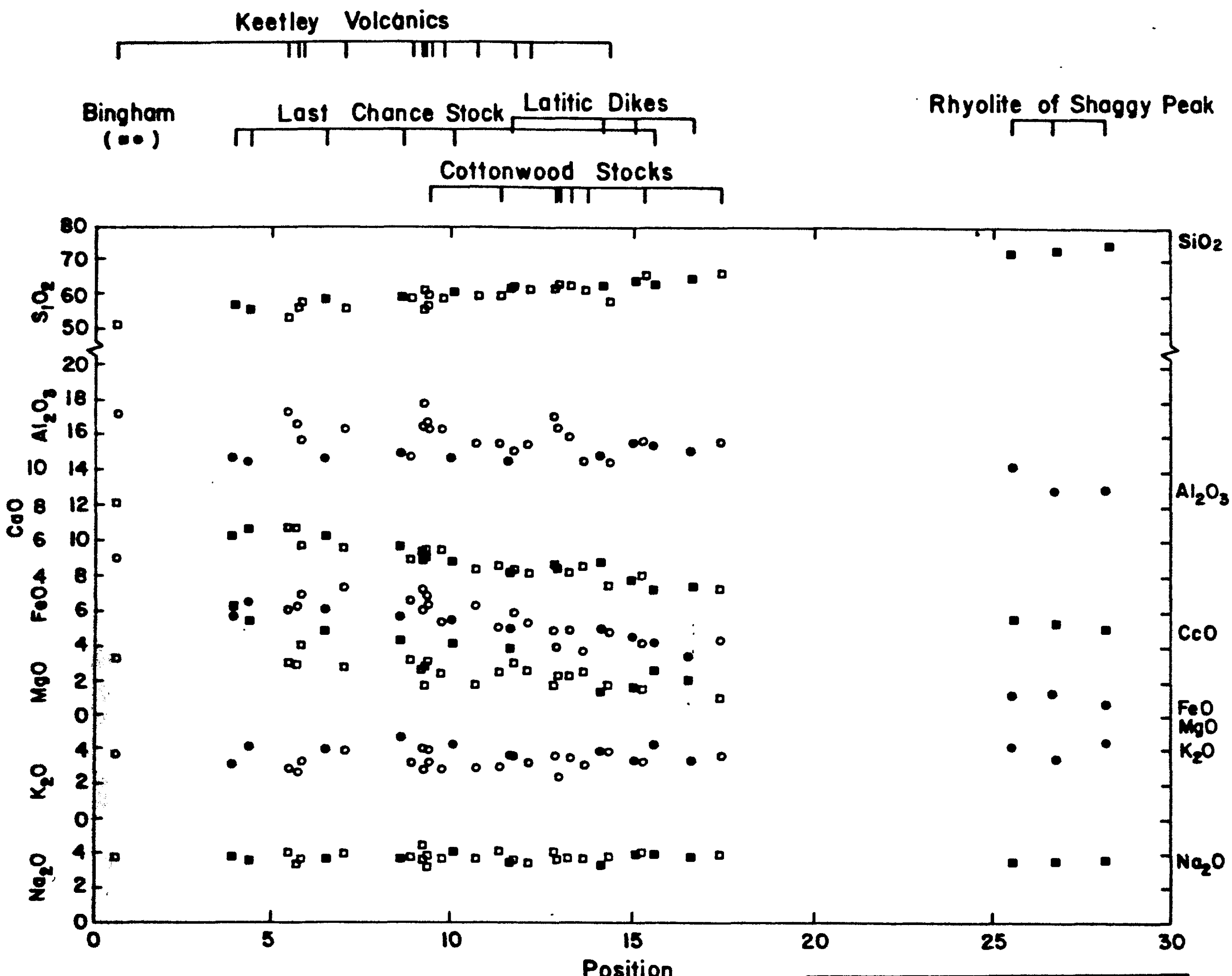



Figure B-2. Generalized distribution of igneous rocks in the Oquirrh Mountains (from Moore, 1973).

The plutonic rocks are dominantly intermediate in composition--monzonite to quartz monzonite for the stocks and latite to quartz latite for the dikes. $SiO_2$ ranges from 58-61 weight percent, and the alkalies, $Na_2O$ and $K_2O$ each range from 3.5-4.0 weight percent. The major-element composition of most of the intrusions is so similar to the latitic eruptive rocks that mutual evolution from a single source magma is highly probable. Furthermore, close similarities in composition and age with igneous rocks of the central Wasatch Mountains (Figure B-3) suggest a common source for each of the bodies indicated in the inset figure.

Age relations. Relative ages for most units of the igneous complex can be established using crosscutting intrusive relations that, with due allowance for analytical uncertainties, are consistent with available radiometric age determinations. These determinations, some of which are listed in Figure B-2, have been summarized and reviewed most recently by Warnaars and others (1978), who properly emphasize the close temporal relations between mid-Tertiary igneous activity and mineralization; the total duration of magmatic-hydrothermal activity at Bingham was about 3 million years.

The overall duration of magmatism in the Oquirrh Mountains is only slightly greater (about 8 million years); parallel trends from (mafic or) intermediate to silicic compositions with decreasing age are noted in the plutonic and eruptive rocks. These trends are attributed to differentiation of a source magma at a relatively shallow depth; mineralization accompanied residual concentration of fluids in the later stages of differentiation.



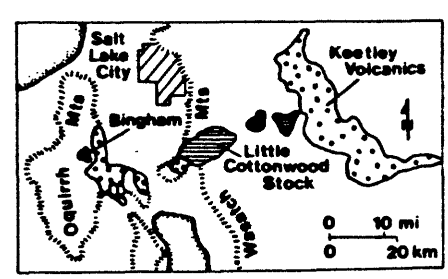




Figure B-3. Larsen variation diagram of igneous rocks along the Uinta-Cottonwood trend. Abscissa 1/3 $SiO_2+K_2O-FeO-MgO-CaO$ (Woodfill, 1972).

## IGNEOUS HISTORY

A condensed history of emplacement and crystallization of the igneous complex (Moore, 1973b) includes the following major elements:

1. Initial magmatism beginning about 38 m.y. B.P. with emplacement of the Last Chance stock, a monzonite under a cover of probably less than 4 km. Because deformed wallrocks, protoclastic textures, schlieren, or partially digested xenoliths are not observed, neither forcible emplacement nor emplacement by assimilation can be invoked. Rather, vertical displacement of previously faulted roof rocks is suggested as the principal emplacement mechanism. Basaltic volcanism occurred concurrently in the Traverse Mountains.
2. The various phases of the Bingham stock were emplaced about 1 m.y. after crystallization of the Last Chance stock. Although recent mapping (Plate II) shows the Phoenix dike as a connecting link between the two, I believe that modal and radiometric age differences are sufficient to treat the stocks as siblings but not Siamese twins.
3. Subsequent tapping of the magma reservoir, in part explosive in nature, resulted in forcible emplacement of the latitic dikes and pebble dikes, and contact brecciation. Venting of the dikes through a roof thinned by uplift and erosion may have supplied clastic debris to the basal laharic breccias.
4. Volcanism continued until 31 m.y. B.P., with quiescent eruption of latitic lavas as the dominant process. Terminal intrusive activity (following hydrothermal mineralization) is marked by the emplacement of rhyolite plugs at several localities in the Oquirrh Mountains (cf Fig B-2).

## SPECULATIONS ON THE NATURE OF THE MAGMA

The process of magma generation is a subject of continuing interest in studies at Bingham. On a regional scale, the east-west distribution patterns of calc-alkaline igneous rocks in Nevada and western Utah (Figure B-4) are not readily explained by plate tectonic models for Cenozoic magmatism in the Great Basin (c.f., Burchfiel, 1979). These patterns are apparently the result of a southwestward-migrating front of igneous activity that may be related to a southward-propagating transverse break in the plate that was being subducted along the western margin of North America at this time (Stewart and others, 1977).

Of more local significance, the east-west localization of mid-Tertiary magmatism and mineralization may be related to deep crustal zones of structural weakness that developed in Precambrian time. The venerable "Cortez-Uinta" axis (Tooker, 1971) is one such inferred zone. Bingham (B) and Park City (PC) (Figure B-4) are key centers of magmatic-hydrothermal activity along the Utah segment of this ancient crustal flaw. The structural, stratigraphic, and aeromagnetic evidence for a Uinta axis, summarized by Erickson (1976), has been augmented by "plumbotectonic" models (Doe and Zartman, 1979), and sulfur isotope (Field, 1966) and strontium isotope studies (Moore and others, 1978).

There is a gratifying convergence of isotopic evidence demanding a deep crustal (or mantle?) source for the magma and lead and sulfur among the ore-forming elements. Details of the magma-generating process and sources of the remaining metals are enticingly obscure and provide challenging topics for future studies.

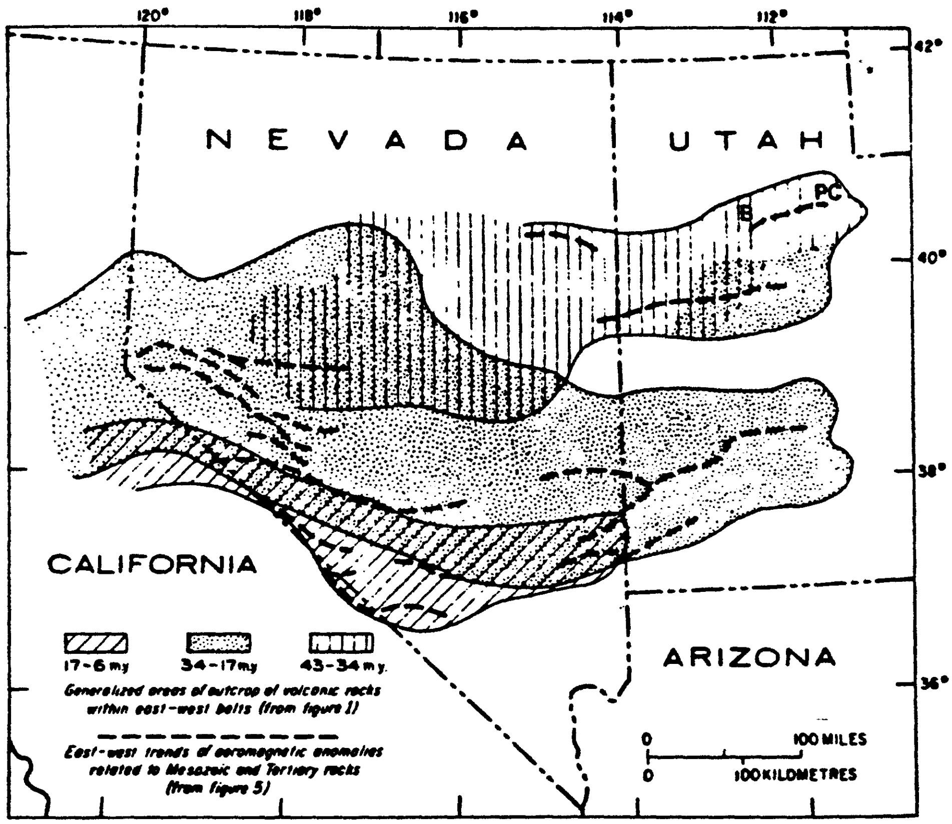



Figure B-4. Generalized east-west patterns of Cenozoic igneous rocks and positive aeromagnetic anomalies showing southward migration of igneous activity in California, Nevada, and Utah. (Stewart and others, 1977)

REFERENCES

Bray, R. E., and Wilson, J. C., eds., 1975, Guidebook to the Bingham mining district, Society of Economic Geologists, October 23, 1975: Bingham Canyon, Utah, Kennecott Copper Corp., 156 p.

Burchfiel, B. C., 1979, Geologic history of the central western United States, in Ridge, J. D., eds., Papers on mineral deposits of western North America: Nevada Bureau of Mines and Geology Report no. 33, p. 1-12.

Doe, B. R., and Zartman, R. E., 1979, Plumbotectonics, The Phanerozoic, in Barnes, H. L., ed., Geochemistry of hydrothermal ore deposits, 2d ed.: New York, Wiley and Sons, 798 p.

Erickson, A. J ., Jr., 1976, The Uinta-Gold Hill trend - an economically important lineament, in Hodgson, R R., ed., Proceedings of First International Conference on the New Basement Tectonics: Utah Geological Association, p. 126-138.

Field, C. W., 1966, Sulfur isotope abundance data, Bingham district, Utah: Economic Geology, v. 61, p. 850-871.

James, A. H., Smith, W. H., and Bray, R. E., 1961a, Bingham district--A zoned porphyry ore deposit, in Geology of the Bingham mining district and northern Oquirrh Mountains: Utah Geological Society Guidebook to the Geology of Utah, no. 16, p. 81-100.

James, A. H., Smith, W. H., and Welsh, J. E., 1961b, General geology and structure of the Bingham district, Utah, in Geology and structure of the Bingham district, Utah, in Geology of the Bingham mining district and northern Oquirrh Mountains: Utah Geological Society Guidebook to the Geology of Utah, no. 16, p. 49-69.

Moore, W. J., 1973a, A summary of radiometric ages of igneous rocks in the Oquirrh Mountains, north-central Utah: Economic Geology, v. 68, p. 97-101.

_____1973b, Igneous rocks in the Bingham mining district, Utah: U.S. Geological Survey Professional Paper 629-B, 42 p.

Moore, W. J., Hedge, C. E., and Sorensen, M. L., 1978, Variations in $^{87}Sr/^{86}Sr$ ratios of igneous rocks along the Uinta trend, northwestern Utah [abs.]: Geological Society of America, Rocky Mountain Section, 32d Annual Meeting, Fort Collins, Colo., May 24-25, 1979, Abstracts with Programs, v. 11, no. 6, p. 297.

Stewart, J. H., Moore, W. J., and Zietz, Isidore, 1977, East-west patterns of Cenozoic igneous rocks, aeromagnetic anomalies, and mineral deposits, Nevada and Utah: Geological Society of America Bulletin, v. 88, p. 67-77.

Stringham, Bronson, 1953, Granitization and hydrothermal alteration at Bingham, Utah: Geological Society of America Bulletin, v. 64, p. 945-991.

Tooker, E. W., 1971, Regional structural controls of ore deposits, Bingham mining district, Utah, USA: Society of Mining Geologists of Japan, Special Issue 3 (Proc. IMA-IAGOD vol.), p. 76-81.

Warnaars, F. W., Smith, W. H., Bray, R E., Lanier, G., and Shafiqullah, M., 1978, Geochronology of igneous intrusions and porphyry copper mineralization at Bingham, Utah: Economic Geology, v. 73, no. 7, p. 1242-1249.

Woodfill, R. D., 1972, A geologic and petrographic investigation of a northern part of the Keetley volcanic field, Summit and Wasatch Counties, Utah: Purdue University, Lafayette, Ind., Ph. D. thesis, 157 p.

MOVEMENT OF HYDROTHERMAL SOLUTIONS AT BINGHAM, UTAH

W. W. Atkinson, Jr.

Studies of the Carr Fork area of the Bingham district have shown the presence of mineral gradients and boundaries, which suggest the shape of thermal gradients during the period of ore deposits (Fig. B-5). These boundaries are subparallel with the western contact between the Bingham quartz monzonite porphyry and enclosing sedimentary rocks. The dominant host rock of the western contact is calcareous quartzite, with subordinate limestone beds. Mineral gradients and boundaries are remarkably planar in quartzite, but are highly irregular in limestone. Zones of higher permeability, such as the fault zone illustrated in Figure B-5, have only a local effect on the shapes of the boundaries. The quartzite was strongly fractured during tectonic movements prior to intrusion, and additional fractures were formed during and immediately following intrusion. It appears that the quartzite had sufficient fracture density to present a nearly isotropic, easily permeable medium to the invading solutions.

The patterns observed were probably not produced by a large circulating hot springs-type hydrothermal system. Rather, they were produced as the thermal gradients expanded, before the system had cooled appreciably. The solutions therefore consisted of magmatic water, perhaps with admixed meteoric water.

One boundary most indicative of expanding isotherms is that between orbicular and fracture-controlled actinolite alteration of dipside. Orbicular alteration appears to have formed under metastable conditions. The boundary between orbicular and fracture-controlled alteration appears to have been produced by solutions below a temperature at which equilibrium nucleation of the alteration phases could take place. The boundary, then, represents an

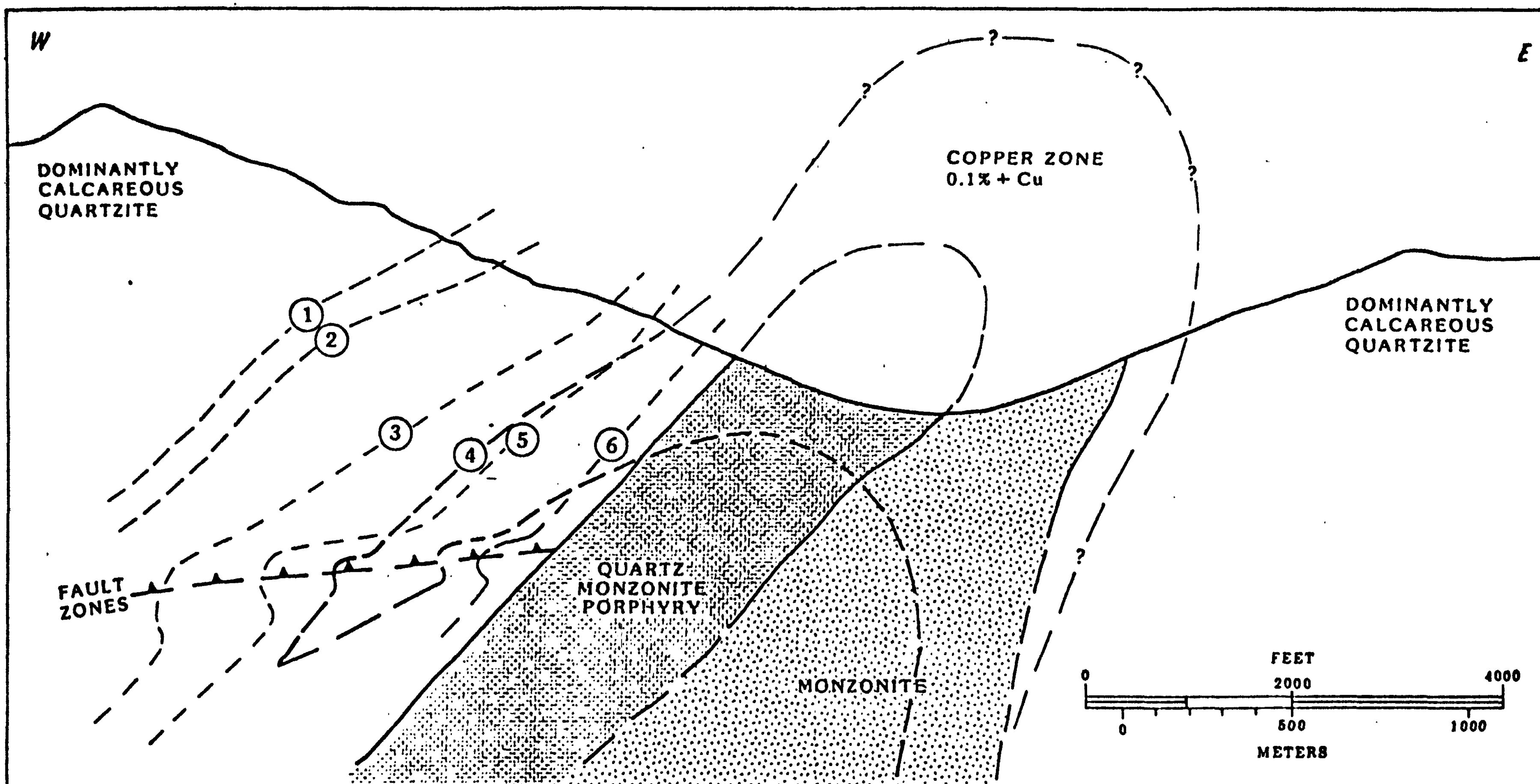



Figure B-5. East - West section looking north, through the Bingham district, showing zonal boundaries on the west side of the district. Boundaries are: 1. Outer limit of orbicular alteration. 2. Outer limit of actinolite envelopes on fractures. 3. Inner limit of orbicular alteration. 4. Limit of 0.1% Cu. 5. Outer limit of molybdenite and secondary biotite. 6. Outer limit of bornite.

Modified from Atkinson & Einaudi, 1978, Econ. Geol., p. 1361, Fig. 18, and p. 1356, Fig. 15.

E

isotherm at the time of its formation. It appears that the boundary moved outward with time, because a zone of overlap occurs between the two types of alteration. Crosscutting fractures demonstrate that fracture-controlled alteration is younger than orbicular alteration.

Early sulfide veinlets show a continuous gradation in sulfur and copper content. From the outside inward, sulfides show a continuous variation in ratios from pyrite to chalcopyrite to bornite. The innermost zone, containing molybdenite, expanded outward, so that molybdenite-bearing veins cut copper and iron sulfides.

Calc-silicate zones apparently expanded outward at the same time. Interstitial calcite in the quartzite was replaced sequentially by dolomite, talc, tremolite, and diopside. Iron was introduced later, producing actinolite, then biotite, alteration of diopside. Limestones were altered to garnet as copper was deposited. It is probable that both magnesium and iron were released simultaneously from the porphyry, but iron was less mobile in the calcareous environment. These alteration events correlate with chlorite, actinolite, and biotite alteration of the Bingham quartz monzonite on the east side of the porhyry.

Unequivocal evidence on the direction of movement of hydrothermal solutions is not available. However, the surfaces of the many mineral boundaries suggest that the solutions were not moving upward parallel with the porphyry contact. If they were, we might expect elongated irregularities parallel with the contact, pointing upward. Rather, the surfaces are nearly planar, with a prominent bulge along the illustrated fault, in both plan and section. The shapes suggest movement outward from the intrusive contact, although the exact vector is not known.

A well-defined zone of sericitic alteration at Bingham is lacking. Locally, strong sericitic and clay alteration occurs along late, strong fault, where it is accompanied by abundant pyrite. These features are most common within 1,000 feet of the porphyry, much closer in than the edges of the early mineral boundaries, which extent out as far as 3,000 feet. They are also limited to vertical faults. This type of alteration and mineralization was probably produced by circulation of hot meteoric water.

## METAL PRODUCTION AND METAL ZONING

Laurence P. James

The immense total metal production of the district, from its discovery in 1865 to the most recent publication of data, is summarized in table 1, from James (1978). The precious metals have been derived largely as byproducts of base-metal production, though the district is listed by Koschmann and Bergendahl (1968) as the fourth largest gold producer in the nation.

Table 1. Production from Bingham mining district, 1865-1972

| | |
|---|---|
| Copper, lb | 21,511,566,050 |
| Lead, lb | 4,486,218,827 |
| Zinc, lb | 1,884,205,351 |
| Gold, oz | 14,717,731 |
| Silver, oz | 245,568,577 |

Utah Copper data from Arrington and Hansen (1963) and annual reports of Kennecott Copper Corp.
District data from Stowe, 1975.

Metals are distributed in the district in a definite zoned pattern. The porphyry copper ores at its center, containing chalcopyrite, pyrite, and molybdenite, commonly show lead and zinc contents of a few hundred parts per million or less. Metal production from these deposits is summarized in table 2, from James (1978). The lead-zinc ore bodies which roughly encircle the copper center contain only minor visible copper minerals, and may contain less than 1,000 ppm copper. In these ores, galena and sphalerite are closely intergrown. The zoned distribution of ores is not perfectly annular, as it is controlled in part by the distribution of limestone beds and structures.

Table 2. Production from Utah copper ore deposit

| | |
|---|---|
| 1,240,186,675 tons ore mined 1904-1972 | Weighted mean grade--0.912 percent copper |
| 399,505,485 lb molybdenum recovered 1938-1955 | Mean grade, calculated: 0.036 percent Mo for this period |
| 1,804,185 oz gold recovered 1908-1938 | Mean grade, calculated from this: 0.00654 oz/ton Au |
| 16,944,796 oz silver recovered 1908-1938 | Mean grade, calculated from this: 0.0580 oz/ton Ag |

The general geology of the district in relation to metal zoning is summarized on Figure B-5. A sequence of Tertiary intrusive rocks, largely unmineralized, comprises the center of the district. A volcanic pile, probably derived from volcanic necks that once overlay the intrusive rocks, flanks the district on the east (Tvhl and Tvlb). The barren intrusive rocks now comprise a topographic and aeromagnetic high.

The zoned distribution of metals centers on the relatively small, northernmost body of quartz monzonite porphyry (Tiqmp). This rock unit is illustrated on Figure B-4. Most current students of district geology view this complex body as an orthomagmatic "source" of the copper and molybdenum mineralization. As in many "porphyry" deposits, the chalcopyrite and molybdenite tend to occur in separate fractures, perhaps formed at different times.

While precious metals occur as trace elements in base-metal sulfides, they are not as distinctly zoned as copper, lead, and zinc. Thin veinlets dominated by native gold have been found in many areas of the district, and placer gold in Bingham Canyon led to the district's discovery. The writer well remembers watching a leaser, deep underground in a lead-rich fissure vein in the Last Chance stock, pull out a specimen that was half galena and half native gold. Small, rich deposits of telluride ores were reported on the northwest periphery of base-metal ore bodies (James, 1978).

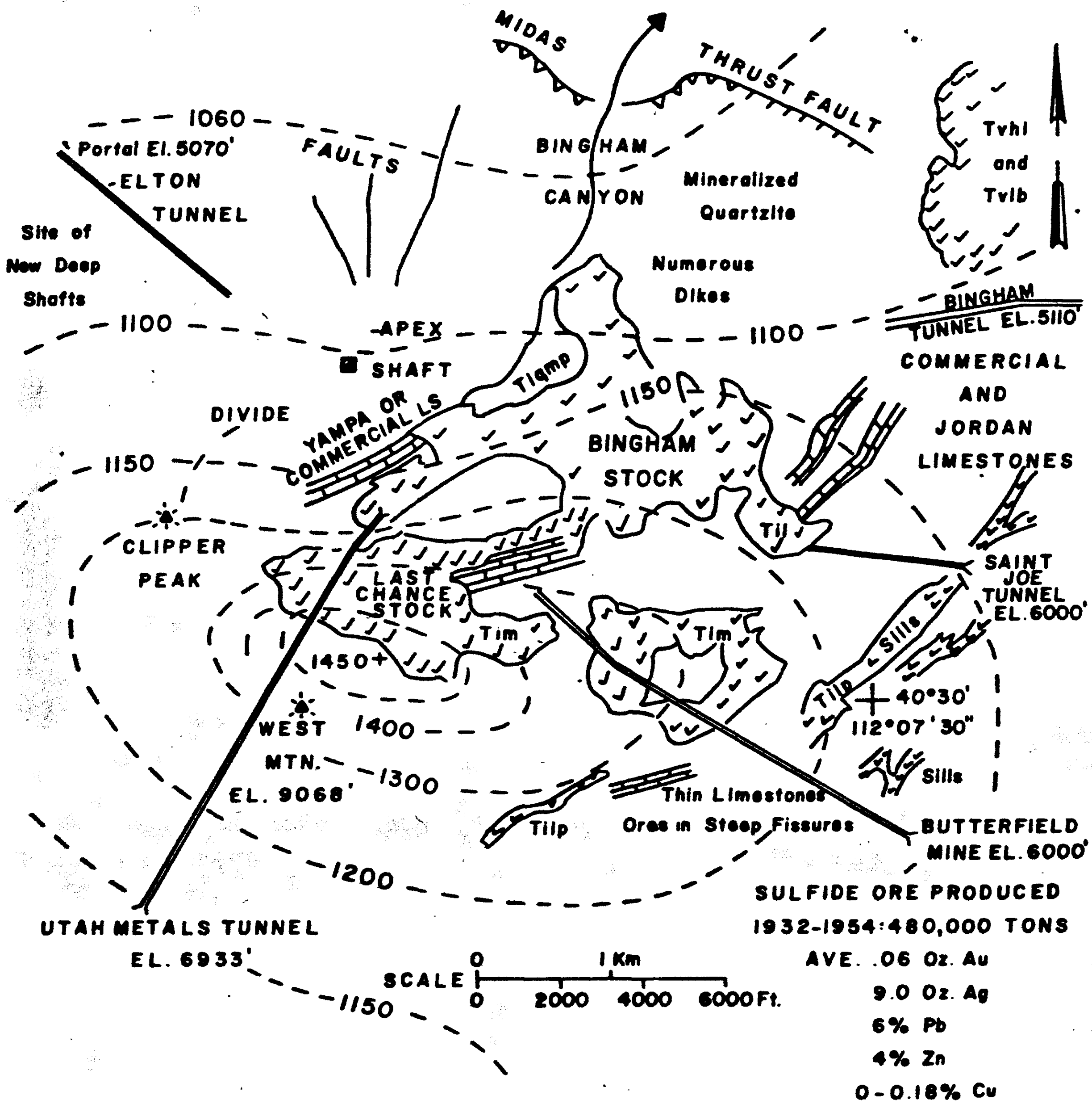



Figure B-6. Highly generalized geologic map of the Bingham area, showing some of the deep adits penetrating the periphery of the district. Aeromagnetic contours (dashed lines) from Gay and Mardirosian (1970), superimposed on the geology, reveal a magnetic response centered on the barren intrusive rocks. Values contoured are in gammas above an arbitrary datum.

A series of low-elevation adits eventually penetrated the district at depth. Some of these are shown of Figure B-6. Peripheral, vein-dominated ore bodies developed by these and other workings tended to be small, discontinuous, and to lack great vertical extent. The metal content of ore produced from the Butterfield Tunnel, which mined several peripheral veins valuable chiefly for silver, is shown on Figure B-6. These data were compiled from the records of the old Combined Metals Reduction Company.

The best explanation for the zoning of metals appears to be temperature gradients around the central quartz monzonite porphyry. The large quantities of lead, zinc, and silver cannot be unequivocally attributed to a magmatic source, however.