GEOLOGY OF THE BINGHAM MINING DISTRICT

BY

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The Bingham Mining District is associated with major structural zones. Regionally, the Oquirrh-Uinta belt contains the Bingham and Park City mining districts and associated intrusions. Locally, zones of northeast and northwest trending faults intersect in an area of complex folding and thrusting. The central portion contains the contemporaneous Tertiary Bingham and Last Chance stocks, porphyry dikes and sills, and an east-west zone of breccia pipes. The Bingham stock consists largely of two intrusive phases, an earlier fine-grained biotite-granite and a later granite-porphyry, with minor constituents of gradational-granite, rhyolite and quartz-latite porphyries. The Last Chance stock is augite-quartz monzonite. Sedimentary rocks are Pennsylvanian to Permian quartzites and limestones, with sequences upset by the Midas and North Oquirrh Thrust faults. Volcanic rocks consist of andesitic flows and breccias with a few small rhyolitic-latitic intrusions. Ores are zoned in around the Bingham stock, with a copper-molybdenum zone in and around the granite porphyry and a lead-zinc zone outside in sedimentary rocks and in fissures in the Last Chance stock. The two zones are separated by an iron-rich zone. Copper minerals are zoned within the ore body, with bornite in the center and chalcopyrite outside, and occur mostly as small disseminated grains and vein fillings. Lead-zinc occurs as galena-sphalerite replacements and veins. Hydrothermal alteration in intrusive rocks extends zonally outward from the intrusive center and consist of hornblende-augite alteration, feldspar alteration, secondary biotite, sericite, actinolite, chlorite and calcite. All the igneous rocks are the result of differentiation of one magma.

FOREWORD

The following article has been prepared from the authors own experience and also for a larger part from the experience and works of other geologists that have worked in the district during the past 15 years. Major contributions to the geology of Bingham have been used, including those from Kennecott geologists Allan James, John Welsh, Eldon Bray, Edward John, and Paul Mogensen; United States Smelting, Refining, and Mining Co. geologists Richard Rubright and Owen Hart, and Anaconda Co. geologist Leon Hansen. Thus the article represents more of a joint effort and concensus rather than an original paper. Because of the complexity of the subject, no discussion will be permitted at the end of the presentation. Rather than that, ample time will be had for this during the Saturday field trip.

LOCATION AND STRUCTURAL SETTING

The Bingham Mining District in the north-central Oquirrh Mountains is associated with several major structural zones and is located in the center of a structural vortex. In the regional setting, the district occurs on the alignment of the Uinta arch-Cottonwood dome, in the western portion of the Oquirrh-Uinta belt. In this belt occur the Bingham stocks, the Cottonwood stock, the Park City stocks, and the various mining districts associated therewith. The Bingham district occurs in a mountain block which is on the eastern margin of the Basin and Range province, and the fault system responsible for the uplifting of the Oquirrh Mountain block is an integral part of the structural setting. Within the north-central Oquirrh range are two zones of post-Laramide faults, one trending northeast and southwest and comprising the "fissure system" on the United States and associated lead-zinc-copper mines, and the other trending northwest and southeast and comprising the "Bingham Horst" of Allan James et al. The zone of intersection of these two systems marks the major portion of the mining district, including the ore bodies and the igneous intrusions.

This zone of structural intersection occurs in an area of complex folding and thrusting of Laramide age, where a portion of the Oquirrh synclinorium has been locally warped, overturned, and thrusted to produce an intricate pattern of fault blocks. This zone of deformation is the locus for an equally complex group of igneous intrusions, comprised of two major stocks, the Bingham and the Last Chance stocks, which are thought to be nearly contemporaneous and interrelated, and a series of later sills and dikes, many of which occur along the northeast-southwest trending faults. The two stocks are separated by a zone of around 2,000 feet. Associated with this pattern, and not yet fully understood, is an east-west belt of breccia pipes comprised of both igneous and/or sedimentary rocks. These pipes are thought to be contemporaneous with the intrusion of the stocks. They are sometimes composed of intrusive rock as well as diked by intrusives, and are sometimes altered and mineralized. The zone of pipes is aligned roughly with the zone separating the two stocks, but some occur to the south and east of the stocks. A few pipes occur outside of this zone.

INTRUSIVE ROCKS

The Last Chance stock was the first intrusion in the Bingham area, and consists of a fine-grained equigranular augite-quartz monzonite. The Bingham stock is a complex intrusion with five mappable phases. The first phase was a fine grained equigranular rock thought to be equivalent to the augite-quartz monzonite of the Last Chance stock, but now altered to a biotite-granite. The two types grade progressively along connecting dikes, especially the Phoenix dike. Porphyritic phases consisting of granite porphyry, rhyolite porphyry, and quartz-latite porphyry intrude the biotite-granite and the surrounding sediments. The granite porphyry phase is the largest of the three, and is actually a small stock within the biotite-granite, which it displaces. The granite and granite porphyry are separated in places by a hybrid of the two or a gradational-granite phase. Dikes of rhyolite porphyry and quartz-latite porphyry extend at least three miles from the intrusive center in northeast and southwest directions. Mineralization is related to the granite porphyry phase of the Bingham stock. All of the phases become monzonitic in composition away from the central potassium-silica alteration zone.

SEDIMENTARY ROCKS

Sedimentary rocks are lower to upper Pennsylvanian and lower Permian in age, the Pennsylvanian rocks are mostly ortho-quartzites with a few members of cherty and fossiliferous marine limestones and shallow water siltstones. The Permian rocks are mostly sandstones with intercalated and irregular limy siltstones and impure shallow water limestones with a few fusulines and some unidentifiable carbonaceous "worm tracks". This series is known as the Oquirrh formation or group, and earlier was called the "Bingham quartzites" and the "intercalated series". The Pennsylvanian has a thickness of around 16,000 feet, ranging from mostly limestone in the lower to mostly quartzite in the upper. These were folded into a series of asymmetrical synclines and anticlines, trending northwest-southeast with steeper northeast limbs. The Bingham syncline, which Gilluly describes in the southern Oquirrhs as part of this system, becomes warped broadly in the Bingham area, with one component, the Z-fold limb known as the Middle Canyon syncline to the west and the other the southeast limb of the Bingham syncline to the east. The axis of the Middle Canyon syncline continues northwesterly along the western edge of the mining district, the axis of the Bingham syncline curves sharply northeastward and then loops around to the north and northwestward, terminating against the Midas thrust fault, which cleaves the district roughly east-west. This thrust juxtaposes the south Oquirrh Pennsylvanian and lower-most Permian section and synclinorium over a similar uppermost Pennsylvanian and Permian series of the North Oquirrh range. In this lower-plate section there is about 5,000 feet of sandstones, impure quartzites and limestones, with the pratially overturned Copperton anticline to the east and the Flood and Pass Canyon "chaos area" to the west. Structures on the lower and upper plates of the thrust cannot be readily correlated. To the extreme northern limits of the district, in the vicinity of Televison Ridge and Nelson Peak, middle-Pennsylvanian rocks are again juxtaposed over the Permian by the east-west trending, northerly dipping North Oquirrh thrust (which is not a part of the Midas).

VOLCANIC ROCKS

Volcanic rocks consist mostly of andesitic flows, breccias, and agglomerates. There are some latitic flows as well as a few basaltic. A large portion of the volcanic suite is agglomerate composed of andesitic to dacitic lithic material in a variable coarse to fine matrix of crystal tuff, and is thought to be derived from a long north-south belt of andesite-breccia dike-vents and plugs beginning with Step Mountain on the south and ending with the Clay Hollow plug on the north. The agglomerates are younger than the adjacent flows, and at one time probably covered most of the mountain range. The mode of emplacement was by ash-flow avalanche. Some post-volcanic hornblende-andesite dikes cut through the flows and agglomerates. A few latitic to rhyolitic "light porphyry" bodies occur in the Lark-Butterfield area, these were very late in the igneous cycle and either during or after the agglomerate emplacement. There is a suggestion that the rhyolites may have been associated with a small buried and partially exhumed caldera. There is also evidence that these bodies were once covered by the agglomerates.

ORE ZONING

Bingham is undoubtedly one of the largest ore mineral assemblages in the world. The center of this is in and around the granite porphyry portion of the Bingham stock, with the ores zoned in an orderly sequence around the center. The ore occurrences are complex and suggest more than one cycle of deposition. In the center, and almost entirely within the stock, is the molybdenum zone. The copper zone is superimposed on the molybdenum and is much larger in areal extent and reaches outward in the adjacent sedimentary rocks. The lead-zinc zone occurs outside the copper zone and is separated from it by an iron-rich zone roughly 2,000 feet wide. This is actually a transition zone between the copper and lead-zinc zones, for the most part it is barren, but in certain areas where favorable host-rock limestones and transverse faults, or "fissures" occur, vein type deposits of copper and lead are found, and these are sometimes good enough to be mined as pit ore, and in earlier years supported a number of underground mining operations. Beyond this transition zone the lead-zinc zone extends for over a mile, to the edge of the ore producing area. While there is no apparent zoning of the lead and zinc minerals throughout this zone, there is a notable increase in silver values near the outer periphery.

The vertical zoning is much more complicated. The copper zone, before stripping and mining, consisted of a leached and oxidized capping of from 100 to 200 feet thick, followed by an enriched zone of from 750 to 1,000 feet thick. Below this and through a transitional zone the primary or sulfide zone occurs, and the present pit is almost entirely within this zone. The copper and molybdenum zones break up with depth, and become roughly concentrically arranged around a low-grade core. The top of this core occurs about 1,000 feet higher in the copper zone than it does in the molybdenum zone, and suggests similar but separate controls for the emplacement of each. The lead-zinc deposits are controlled by limestone beds which in most areas dip toward the stock. Thus the lead-zinc arrangement is roughly conical, and diminishes in areal extent with greater depths. As with the copper, the lead-zinc zone breaks up with greater depths, and with extreme depths the lead-zinc shoots disappear into pyrite and the copper diminishes into root-like downward extensions. The factors responsible for the diminution of ore minerals with depth are numerous. Less fracturing in the core of the stock at greater depths was responsible for the breakup of the copper and the molybdenum. This was due to the cooling sequence during the solidification of the granite porphyry. The top of the intrusion and the Bingham ore body roughly coincide, and both were very near the top of the mountain when open pit operations began. Evidence from old maps indicate this to have been a roof-pendant situation. The top of the stock cooled more rapidly than the core, and became well fractured throughout, whereas only the edges of the core became well fractured. Fracturing may have been due also to water or steam pressure. The presence of fractures is one of the major controls for the emplacement or copper and molybdenum. Another factor for diminution of ore minerals with depth is the gradual increase of iron and silica with depth. This is especially notable in the lead-zinc zone where sphalerite becomes iron-rich, pyrite increases and silica in the form of silicates and silica flooding becomes pervasive. Another factor is the plunging of the ore shoots toward the stock, largely controlled by the attitude of the host limestones.

MINERAL ZONING

Bingham is known as a dissemminated ore body. Bornite, chalcopyrite, and molybdenite occur as grains within the granitic rocks and even at times in the sedimentary rocks. These grains are replacements of original constituent grains of magnetite, and not syngenetic with the magma forming the stock. Roughly 50 percent of the copper and 10 percent of the molybdenite occur as dissemminated grains. The rest of the ore minerals occur as fine vein fillings. Copper minerals are zoned within the ore body, with bornite in the center and chalcopyrite surrounding the bornite. Vein fillings of molybdenite seldom occur together with copper, veinlets of chalcopyrite intermixed with pyrite are most common, and usually contain no other ore mineral. Bornite and molybdenite veinlets usually occur in quartz filled fractures. Pyrite is the most common gangue mineral, and occurs rarely in the bornite zone, is more prominent in the chalcopyrite zone, and is predominant in the transition zone.

In the transition zone, galena and enargite occur together, in varying ratios, usually higher copper in the inner portion, and increasing in lead toward the outer fringe. In the lead-zinc zone galena and sphalerite occur together, with no radical changes in ratio throughout the zone. Pyrite occurs throughout the zone and is found outside of the mineralized area in veins and in porphyry dikes. The arrangement of the pyrite in the lead-zinc zone is such as to indicate separate and overlapping cycles of pyrite and lead-zinc deposition.

Gold and silver, as by-products to the ores and accessories to the ore minerals, occur throughout the district, but in varying quantities. In the copper ore body they occur in higher amounts in association with the inner bornite zone, and diminish toward the outer edge of the chalcopyrite zone. In the transition and lead-zinc zones the gold values are higher near the inner periphery or iron-rich zone, and the silver values are highest near the outer periphery of the lead-zinc zone. Manganese and barite occur in the veins at and beyond the outer edge of the lead-zinc-silver zone.

ALTERATION

Hydrothermal alteration in intrusive rocks consists largely of alteration products of feldspars, hornblende and augite, which are chiefly calcite, chlorite, actinolite, sericite, secondary biotite and orthoclase, and are zoned in that order from the periphery of alteration about three miles distant, to the center of the stock. The five stages of intrusion of the Bingham stock were accompanied by five stages of hydrothermal alteration, with the youngest quartz-latite the least altered and the older biotite-granite the most altered. The augite quartz-monzinite of the Last Chance stock, however, is relatively unaltered, and it is apparent that this stock remained inert during the succeeding intrusive cycles and during the alteration cycles, alteration was restricted to the wall-rocks of the veins, and mineralization was restricted to vein-fillings and limestone replacements. This alteration zoning in the igneous rocks can be traced away from the center of the Bingham stock along the porphyry dikes.

In the lead-zinc and transition zones were transverse fissures and/or limestone horizons control ore deposition, wall-rock alterations have been described by Rubright and Hart as being distinctive as regards the locale, but generally containing some or all of the following minerals. talc, saponite, montmorillonite, chlorite, micas, vermiculite minerals, mixtures of calcite and dolomite, epidote, diopsitic pyroxene, and other minor minerals. In locations where limestone septae and xenoliths occur within the granite, the predominant minerals are garnet chlorite and montmorillinoid clay. Most of the silicate minerals are the result of tactitic alteration of carbonate minerals in place. However, Rubright recognizes some areas deep in the lead-zinc mines where the mobilization and migration of silicate solutions has taken place. In the transition zone between the two stocks the sedimentary rocks are intensely metamorphosed by silicatization, silicification, and marmorization. Where the transition zone is away from the stocks, the metamorphic processes were silicatization, silicification and bleaching, for a distance of 3,800 feet from the center of the Bingham stock.

SOURCE

All of the igneous rocks of the district were derived from a single magma, from the earliest monzonites to the latest agglomerates and rhyolites. The sulfide mineralization which accompanied the igneous activity had almost the same time span, beginning with pyrite, followed by molybdenum and copper, and then lead-zinc-silver-gold and followed by pyrite. The very last pyritic surge occurred very late, accompanying some subsidence faulting along the Lark Vein which cuts the volcanic-breccia which is contemporaneous with the latest volcanic agglomerates.

Some of the physical relationships are not yet clear, due to the lack of outcrops to reveal the contacts: (1) There is a suggestion of a time lag between the Last Chance stock, which appears to be deeply eroded and which may be earlier, and the Bingham stock, which appears to be shallowly eroded and thus possibly later. (2) The possibility of venting of the monzonitic magma is a moot question. No evidence has yet been found to correlate the emplacement of the stocks with extrusion of the lava flows, but the idea cannot be dismissed because of this lack of evidence. The fine grained to aphanitic texture of the stocks is quite suggestive of very rapid cooling, such as could be brought about by sudden venting resulting in release of heat and pressure. (3) Some of the earlier flows seem to overlap the later intrusive dikes, indicating not only a time lag between the emplacement of the stocks and the volcanics but an intervening uplift and erosion cycle. The fact that some of the later volcanics fill the channels of some of the deeper canyons indicate that the present drainage system had been established before at least some of the volcanics were laid out. Some small volcanic remnants or outliers, combined with numerous occurrenses of contact related phenomena observed at higher elevations indicate that the range was mostly covered with volcanics at one time. (4) The attitude of the layering of the agglomerates, the attitude of the volcanic contact itself, and the distribution of the mountain block came after the volcanic cycle, and that during this tilting the bulk of the volcanic cover was removed, the major canyons exhumed, and the pediment area largely covered by sedimentary gravels.

The inescapable conclusion is that the emplacement of the stocks and the ore mineralization was multi-cycled, and was accompanied by a succession of orogenic events which resulted in the original uplifting and later tilting of the mountain block, and these intrusions, mineralizations, and uplifts were interrelated. These orogenic events occurred between short periods of quiesence when extensive erosion took place, with seven and possible eight uplift-erosion cycles between the first post-Laramide uplift and the present.

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