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ALHAMBRA COBALT-NICKEL-SILVER DEPOSIT, BLACK HAWK DISTRICT, NEW MEXICO

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by

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The title of this paper implies the presence of silver, nickel, and cobalt minerals at the Alhambra mine. Perhaps this should be amplified to include uranium, as pitchblende also occurs, possibly in mineable quantities.

A brief history of the Alhambra mine is of interest, both from a historical angle and as pointing up the importance of geology in the present development.

The Alhambra is one of several mines in the Bullards Peak or Black Hawk district, as it is more familiarly known, in southwestern New Mexico, which was mined for silver in the 1880's and 1890's. Silver valued between $500,000 and $1,000,000 was extracted from the mine in the 10 years prior to 1893, when operations ceased. Almost all the silver mined was native silver, although a small quantity of argentite was produced. Nickel and cobalt were recognized in the ores, but they were thought to be of no consequence.

After lying dormant for about 65 years, the Alhambra was reopened in the spring of 1957. The decision to reopen the mine was based principally upon the results and recommendations of a detailed geologic study of the Black Hawk district made by D. H. Whitebread and myself for the U. S. Geological Survey results of which were published in 1956. Our study revealed the presence of pitchblende in the cobalt-nickel-native silver ores and emphasized the similarity of the deposits, both mineralogically and geologically, to the uranium-silver-cobalt camps of Eldorado, Great Bear Lake, and Joachimstahl, Czechoslovakia. The present owners were influenced by the report, and by the emphasis in old records and reports that the mine was closed, not because it had run out of commercial ore, but because of the drop in silver prices in 1893.

The risk was great, but the gamble was taken. During 1956 and 1957, the mine was dewatered and partially rehabilitated. The old shaft was cleaned to the bottom, and exploration at present is continuing on the lowermost levels of the old workings. Considerable ore of commercial grade has been blocked out. Several faces in the old drifts contain high grade silver, and new shoots have been found. This then seems to be the rare exception where the old stories of ore left in the mine have proved true. Success in the operation may result in the opening of a new district, and encourage the reopening of other old mines, in the Black Hawk district and elsewhere, where the geologic setting is such as to permit the existence of mineable ore. Careful research into the causes for the original shutdown of the mine and careful geologic work, both regionally and in detail, are prerequisites to the reopening of old mines, but new techniques of mining and metallurgy and the present need of metals once thought useless can well make some of the old mines come to life.

The ore at the Alhambra occurs within an open fracture system as much as 15 feet wide in the lower levels of the mine. Within the fracture zone, subparallel slip surfaces lined with or marked by clay gouge, parallel the boundaries of the zone. These slip surfaces are discontinuous laterally and vertically. They bifurcate, pinch out, join again, and in general form an imbricating network much as do the fractures of a wooden board when split. Any section drawn across the vein cuts one to three slip surfaces. Some of these fractures are pre-ore, but others are post-ore, indicating that movement extended over a long period. The boundaries of the zone are not sharp, and no single fracture can be followed on either the footwall or hanging wall of the zone from the collar of the shaft to the lowermost levels.

Cross-fractures, also both pre- and post-ore, cut or displace the vein. Most of these are small and show little displacement. Two, however, one north and one south of the shaft, are of major importance, and displace the vein 30 feet or more.

The host-rock, a Precambrian coarse-grained quartz diorite porphyry, shows disinct gneissoid texture, believed to be due to primary flowage during emplacement. In the vicinity of the mine it is intruded by dikes and small irregular bodies of fine-grained pink granite, diorite, andesite, rhyolite, and monzonite porphyry, ranging in age from probable Precambrian to Cretaceous. The monzonite porphyry is the latest of the intrusive rocks and forms a small stock about ½ mile north of the Alhambra mine. Small dikes and apothyses extend from the stock. Throughout the district, the ore bodies are spatially associated with the monzonite porphyry, but in itself it is a poor host rock. Although almost no metallic ore minerals are present within segments of the veins where they cut the monzonite porphyry, the major ore bodies all occur in close proximity to such areas. At the Alhambra, a dike of monzonite porphyry crops out about 50 west of the vein. North of the shaft, this same dike intersects and probably is displaced by the vein, but relations are not clear. It has not been exposed underground. At Black Hawk Mine, about ½ mile northwest, the vein also cuts and displaces a monzonite porphyry dike. Ore minerals are confined to the portion of the vein in the quartz diorite, and stop abruptly at the monzonite porphyry contact, although the carbonate gangue minerals continue through the dike. The vein is noticeably narrower when it traverses the dike.

The quartz diorite porphyry has not been intensely altered. Adjacent to the vein the feldspars are bleached and partly sericitized, biotite is now chlorite, and small veinlets of pyrite permeate the rock, but the rock is hard and retains its texture, and in many places the biotite and feldspar are only slightly altered. Fragments and large masses of the rock ~~enclosed~~ within the fracture zone are more intensely altered, and in some places within the vein the original character of these breccia fragments is obscure. The presence of irregular grains of quartz randomly distributed throughout the white clayey mass serves to identify the rock.

The ore minerals are native silver, argentite, pitchblende, and nickel and cobalt aresenides, of which skutterudite, nickel skutterudite, niccolite, and probably rammelsbergite are the most common. Sphalerite, chalcopyrite, galena, and pyrite are present as well as millerite and various unidentified cobalt, nickel, and silver arsenides, sulphides, and sulpharsenides. The gangue minerals are carbonates, and minor amounts of quartz. Barite is rare and fluorite has not been definitely identified. This association of primary native silver with nickel and cobalt arsenides and sulphides and with pitchblende is duplicated at relatively few other places in the world, and adds great interest to the deposit mineralogically.

Silver is by far the most important of the ore minerals. It constitutes well over half of the total weight of ore minerals, and a considerably large fraction of the value. It is present as blebs, flakes, plates, dendrites, and skeletal crystals disseminated through the carbonate gangue or concentrated in sheets and arborescent masses containing as much as 50 percent silver. In places the silver is tarnished black, and less commonly golden yellow, flesh pink, or purple. These later tarnish colors seem to be due to thin films of copper or cobalt minerals. The skeletal crystals are commonly rimmed by a hard brittle silvery-white arsenide, which is either rammelsbergite or one of the minerals of the skutterudite series. Elsewhere coatings of argentite enclose the flakes or skeletal crystals.

The nickel and cobalt minerals are intimately associated, and detailed mineralogical investigation has not progressed far enough as yet to ascertain just which minerals are present or what the various relationships are. Nicollite is one of the common arsenides, and much of the nickel values is carried by it. It occurs in large and small masses, in many places intimately intergrown with a silvery white mineral that has been tentatively identified by x-ray diffraction as rammelsbergite. Minerals of the skutterudite series are the most abundant of the cobalt-nickel minerals. Shutterudite and nickel-skutterudite have both been identified, and members of the smaltite-chloathite series may be present. Most of the cobalt values, and much of the nickel values is contained in these minerals. The skutterudite and nickel skutterudite form border zones surrounding dendritic masses of silver as well as enclosing or partly enclosing the individual silver dendrites. Elsewhere euhedral to subhedral zoned crystals of skutterudite and nickel skutterudite occur in the carbonate gangue. These crystals are cut by carbonate-filled fractures, some of which displace portions of a single crystals slightly more than 1 mm.

Argentite fills seams within the native silver and coats some of the skeletal crystals. In many places thin plates of argentite fill fractures in the carbonate; some of these are coated on both sides by thin films of chalcopyrite. The chalcopyrite seems to have been deposited on the argentite.

Pitchblende is present as blebs and small masses disseminated through that part of the ore rich in nickel and cobalt, and as distinct veinlets and coatings on fracture surfaces. The pitchblende coating fractures consists of numerous minute rounded, possibly colloidal, particles resembling oolites. More than anything else this looks like black caviar spread on cracker. In the wider veinlets the pitchblende is dark ashy gray, structureless, and extremely fine grained. The veinlets are discontinuous and lenticular and are as much as 2 inches wide.

The relationships of the various arsenides to one another and to the native silver and the sulphides present need still to be determined, and many challenging problems exist. The coating of chalcopyrite on argentite, anomalous with reference to the normal order of deposition of these two minerals, is one such problem. The recognition of many still unidentified minerals is another. A study of the various members of the skutterudite series and of their zoned crystals is another, and the intimate association of the niccolite and rammelsbergite is still another. Preliminary evidence, however, indicates that the native silver is one of the earliest if not the earliest ore mineral. It is clearly primary, and was emplaced by replacement of carbonate gangue. The rammelsbergite and skutterudite series minerals that envelop the silver were deposited on the silver, hence later than it. Many of the arsenite-silver contacts reflect the original outlines of the isometric silver by arsenides. Elsewhere the arsenides replace the earlier carbonate. Argentite is a late mineral, filling seams and fractures in the silver and in the arsenides, but more than one generation of argentite may be present. Chalcopyrite postdates at least some of the argentite and seems to be late in the sequence. Pitchblende coats and traverses the earlier minerals and is one of the last to be deposited. Late euhedral calcite and clear quartz crystals fill vugs and coat the earlier minerals, and late calcite has also replaced some of the silver within some of the arsenide envelopes. Arsenide envelopes within which the filling is partly silver and partly calcite or is entire calcite, are common, and in the latter case the calcite-arsenide contacts preserve the isometric outlines of the former silver crystals.

The ore minerals occur in segration of extremely high grade ore, or as scattered flakes and small grains disseminated in the carbonate gangue. The high-grade segregations consist mostly of native silver but include subordinate amounts of nickel and cobalt minerals and pitchblende. They range from the size of a baseball to shoots extending 50 feet vertically, 30 feet horizontally, and as much as 3 feet wide. These pods and shoots occur indiscriminantly through the vein, with no apparent pattern, and may be likened to plums in a plum pudding, although additional geologic studies, as work in the mine progresses, may point up some obscure control.

Boundaries of the ore segregations are sharp; there is little gradation between extremely high grade ore and barren wall rock, vein rock, or carbonate containing disseminated ore minerals. Seemingly there is no replacement of wall-rock, of breccia boulders within the fracture zone, or of vein material other than carbonate. Emplacement of the carbonate gangue seems to have been entirely by filling of open spaces along fractures and between breccia boulders. Ore minerals in the high-grade segregations were emplaced by late replacement of carbonate.

In the large segregations, a zonation of the ore minerals within the observable shoots is characteristic. Whether this was also true of those shoots that have been mined out is of course unknown. A horizontal section perpendicular to the walls of one of the ore shoots now exposed would show an inner core of silver, bounded on each side by a zone of predominantly nickel and cobalt minerals, and a thin veneer of pitchblende concentrated on the outer margins next to the barren wall rock or gangue. Within the zone of high silver content pitchblende is absent, and the arsenides are present only as thin incomplete rims around some of the silver dendrites and skeletal crystals. In the outer zones, the nickel and cobalt minerals predominate. Silver dendrites are present, but they are almost completely rimmed by the arsenides, the envelope of nickel and cobalt minerals is thicker, and in many places no silver is present at all, and solid masses of the arsenides occur. Pitchblende is associated with the arsenides, but is most abundant along the outer boundaries, and in many places forms thin veinlets between the rest of the ore minerals and the barren gangue or wall rock. The ratio of silver to nickel and cobalt is about 10:1 in the inner zone of the shoot and approaches 1:1 in the outer zone, where in many places there is even an excess of nickel and cobalt.

The outer zone of arsenides around the central silver-rich portion of the shoot duplicates the envelopes of nickel and cobalt arsenide around the silver dendrites and skeletal crystals. It represents a later phase of the metallogenic epoch. Solutions carrying nickel and cobalt moved along the fractures that bound the previously formed native silver ore shoots, and permeated inward from these bounding fractures toward the center of the ore shoot. Replacement was most extnesive adjacent to the fissures and incomplete or non-existent in the central part of the ore mass. Silver, which had earlier replaced calcite, was in turn replaced by skutterudite, nickel skutterudite, rammelsbergite, niccolite, and similar minerals, resulting in rims of arsenides around the silver crystals. The thickness and completeness of the arsenide envelopes was inversely related to the distance outward from the bounding fractures of the ore mass. Later, uranium-carrying solutions penetrated along the same channelways, and pitchblende was deposited adjacent to and in these fractures.

As mentioned earlier, no definite pattern or arrangement of these high-grade segregations has as yet been determined, but the individual shoots and the ore body as a whole have a northward rake. The veins dip irregularly, and known ore shoots are confined to the less steep portions of the veins. The widest part of the vein is the lowermost level, and here the dip is 80-85°.

The scattered grains and flakes of ore minerals disseminated through the carbonate are mostly native silver, argentite, and probably nickel and cobalt arsenides, although few of these have been identified. In some areas within the vein, these are concentrated enough to constitute reliable ore bodies -- of lower grade than the segregations discussed previously, but of economic value. Silver values of 25 ounces per ton are not exceptional in carbonate rock that megascopically appears barren, and in many places the values are greater.

Estimates of importance of the disseminated ore and its abundance and grade must await the results of the current sampling program. Determination of the mode of emplacement of this ore, its character, and its relationship to the high-grade masses also must await future study.