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GEOLOGY OF THE BLUE STAR GOLD DEPOSIT NEAR CARLIN, NEVADA

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The Blue Star Mine, formerly known as the Number 8 Mine, is located in the Lynn mining district about 23 miles northwest of Carlin, Nevada, in northern Eureka County. The property was first claimed for turquoise in 1929 and the first year 1800 pounds of gem quality turquoise was mined. Gold was first recognized at Blue Star in 1959 and a small cyanide plant was installed. Newmont Mining Corporation acquired the property in 1968 and after an extensive drilling program successfully defined three ore bodies. The total gold ore reserves developed at Blue Star are about 1.8 million tons at an average grade of 0.12 ounces/ton. Carlin Gold Mining Company, a subsidiary of Newmont, began open pit mining operations at Blue Star in 1974.

The Blue Star deposit occurs in the upper plate of the Roberts Mountains thrust fault, a regional structure discussed in the literature by numerous authors. The Roberts Mountains thrust first gained economic significance when the Carlin gold deposit was found a short distance stratigraphically below it in the Lynn Window, one of several uplift blocks exposing Cambrian through Devonian age lower plate miogeosynclinal sediments through a thrust sheet of Ordovician, Silurian and Devonian eugeosynclinal and transitional sediments. More recently, gold deposits have been developed in upper plate rocks at the Bootstrap and Blue Star properties.

The Silurian and early Devonian age Roberts Mountains formation and overlying Devonian Popovich limestone are outcropping 1000 feet south of the Blue Star mine. Although no significant gold mineralization has been found in the lower plate rocks along this extreme northern boundary of the Lynn Window, weak alteration and iron oxide staining are observed. Several substantial veins and pods of barite outcrop and minor production may have come from some old workings on one northwest trending vein.

Upper plate sediments at the Blue Star mine make up a stratigraphic sequence of undetermined thickness that can be divided into two groups, a western assemblage siliceous facies and a transitional assemblage carbonate facies. The siliceous facies consists of cherty shale, quartzitic sandstone and sandy siltstone. The thin bedded cherty shale forms prominent resistant outcrops and occurs at several horizons in the sequence. The quartzitic sandstone occurs in localized lenses 20 to 100 feet thick generally 150 to 250 feet above the base of the sequence. Variably sandy siltstone which acted as the primary host rock accounts for the remainder of the siliceous sequence. The siltstone is composed of major amounts of detrital quartz with minor sedimentary clay. Small amounts of kaolinite and sericite are commonly found due to widespread weak hydrothermal alteration.

The transitional carbonate facies underlies the siliceous facies separated by a thrust plane. This thrust is typically recognized by 5 to 70 feet of intense shearing and fault gouge with strong clay alteration of sediments in both walls. We have adopted the name Blue Star thrust for this local structure that lies entirely within the upper plate of the Roberts Mountains thrust. There is evidence however, that this upper plate thrust fault may be present at other localities in northern Eureka County.

Transitional carbonate rocks are primarily sequences of limestones, dolomitic limestones and sandy calcareous siltstones. One small outcrop of fossiliferous limestone contained a few corals of probable Devonian age based on field examination. Hydrothermal alteration resulting in carbonate removal and clay alteration is widespread among the carbonate rocks making evaluation of their fresh composition difficult. Contact metamorphism of the carbonates is developed along numerous dacite prophyry dikes. Insufficient outcrops have prevented description of the complete aureole. The tactites examined in the mine area consist of diopside, quartz and calcite, a mineral assemblage characteristic of hornblende-hornfels facies metamorphism in siliceous dolomitic limestone. A sample taken from the margin of the east pit dike also contains 12% biotite, reflecting higher temperatures near the dike, while the outer fringes of the aureole are marked only by recrystallization. If progressive metamorphism was active, an intermediate tremolite zone could be expected although one has not yet been documented.

IGNEOUS ROCKS

Igneous rocks of two compositions are known at the Blue Star mine. A prominent dacite porphyry dike swarm striking northeast outcrops just west of Blue Star and appears to converge into a single structure north of the mine area. Several small sills are also known from drill information and pit exposures. The splintering of the dike near the mine suggests the sediments were strongly fractured and open.

The dacite porphyry has been strongly altered and its exact original composition is unknown. Montmorillonite and kaolinite development represent two low temperature alteration types. Remnant plagioclase up to 20% has been found only in samples with montmorillonite type alteration. Sericitic alteration in the dikes probably represents a higher temperature hydrothermal phase which is often associated with gold mineralization. There has not been any recognizable zoning of these alteration types and they frequently overlap.

A small quartz diorite plug outcropping about two miles north of Blue Star has an early Cretaceous age of 121 $\pm$ 5 million years determined by the K-Ar method on biotite (Hausen, 1967). Gold mineralization, is known to occur within the altered quartz diorite at the Gold Strike property. The similar composition and association of gold mineralization with both the quartzdiorite plug and dacite porphyry dikes suggest that they may be related to a common magmatic source. Hausen had previously suggested this same relationship for the dikes at the Carlin deposit.

The second igneous type recognized from drilling in the mine area was a rhyolite porphyry with 27% K-feldspar, minor quartz, biotite and plagioclase in a ground mass of cristobalite and glasses. Its fresh, unaltered appearance can be attributed only to post mineralization intrusion. This rhyolite does not outcrop and is probably related to the extensive rhyolite flows a few miles to the west thought to be miocene-pliocene in age (West, 1976). Roen's description (1961) of these flows is compatible with the Blue Star rhyolite sample.

STRUCTURAL SEQUENCE

The oldest structures in the area are remnants of the Paleozoic thrusting. The Blue Star thrust is thought to be sympathetic with the Mississippian age Roberts Mountains thrust and therefore related in time. Although absolute ages are not known for the high angle faulting at Blue Star, three periods of activity are recognized. An east-west trending set represents the earliest period of faulting. Two other fault sets which have been mapped are the northeast and northwest sets. Some field data would indicate that the northeast faults are youngest and displace the northwest set. This is contrary to the accepted relationships in the Lynn district where the northwest faults are recognized as the youngest (West, 1976). The issue may be resolved as mining progresses.

The east-west fault set is comprised of four high angle, north dipping faults ranging in strike from N 70° E to N 85° W. The major fault of the set, about 1000 feet south of the mine, forms the northern boundary of the Lynn Window bringing upper plate rocks into high angle contact with the Roberts Mountains formation. Total displacement is not known but must be more than 1200 feet. Of the three remaining east-west faults occurring within a mile north of the major fault, two are exposed in pit walls and are known to have offset in the range of 100 to 200 feet. The aggregate effect of the entire east-west fault system creates a wedge of upper plate rocks thickening to the north.

The northeast faults strike between N 20° E to N 30° E near the mine but farther north they bend and strike N 40° E to N 60° E. The two most prominent northeast faults bound a horst block northwest of the mine. Upper plate rocks within this block are folded into a northwest plunging syncline. The bedding in the horst is striking about N 25° W, almost perpendicular to that in the mine area where sediments are folded into a series of southwest plunging folds.

Of the northwest fault set, only one example is known in the mine area. Displacement on it appears to be about 200 feet and suggests rotational movement. Other northwest faults occur both north and south of the mine.

BASE METAL MINERALIZATION

The most prominent base metal occurrence at Blue Star is copper in the south and east ore bodies where copper values range from .08 to 1.0%. The absence of copper in the north pit suggests it has been localized along the oldest east-west structures near the major fault bounding the window. Our current feeling is that the copper mineralization is probably older than the gold, however evidence concerning the relative ages is not well developed.

Although most of the copper contaminating the gold ore is not visible in hand speciman, a number of copper minerals have been identified. Turquoise, a by product of the gold mining generally occurs as nuggets and stringers within the Blue Star thrust zone. Chrysacolla and malachite are more frequently associated with altered carbonate rocks along fractures. Euchroite, a copper-arsenic oxide has been identified by x-ray diffraction. In some samples, a substantial fraction of the copper is found occupying positions in the montmorillonite clay lattice.

Other base metal occurrences include zinc and antimony. A small veinlet of sphalerite was found in thin section cutting cherty shales north of the mine but no megascopic occurrences have been reported. Small hand samples of stibnite have been reportedly taken from west of the mine, however this occurrence has not been confirmed.

GOLD MINERALIZATION

The age of gold mineralization is known to be bracketed between the intrusions of the dacite porphyry and rhyolite dikes. It is presumed to be a late period of hydrothermal activity. A reasonable age for the gold mineralization would be middle to late Tertiary.

Hydrothermal solutions responsible for gold deposition at Blue Star have produced quartz-sericite alteration in the host rocks. This alteration phase is very prominent in strongly mineralized rocks but becomes less noticeable as strength of mineralization decreases. Hydrothermal quartz associated with gold mineralization occurs as fine quartz veinlets, overgrowth rims on detrital particles and recrystallized quartz. Sericite has formed often at the expense of other pre-existing clays.

Gold in the Blue Star deposit has been recognized in thin section as discrete metallic grains in the size range of 1 to 13 microns. The most commonly observed gold occurrence has been at the borders of detrital quartz grains and within quartz overgrowths on detrital grains. Gold in mineralized dikes was found to be associated with sericite. A sample of mineralized jasperoid contained gold particles in a secondary calcite veinlet.

The quantity of gold appearing microscopically can account for only a fraction of the total gold content therefore a large proportion of the gold must be of submicroscopic size, less than 0.5 microns. Undoubtedly some submicron gold has the same occurrences discussed above. Hausen (1967) discussed the role of clays in precipitation of colloidal gold. It is likely that some gold was also deposited as colloidal particles associated with sericite and kaolinite. Finally, field observations indicate that, at least in certain areas, gold is related to iron oxides in the ore.

The Blue Star deposit also has localized megascopic gold occurrences. Gold has been seen in hand speciman without magnification and particles up to one millimeter have been panned from drill cuttings. Two types of megascopic gold occurrences are recognized. The first is along a fault or fractures in strongly argillized limestone. Copper carbonates and silicates are usually abundant in the same area. The second occurrence is in strongly silicified, sericitized, kaolinitic, iron stained siltstone at the margin of a dike. One gold particle was observed on the face of a goethite pseudomorph after pyrite.

The primary ore controls are structural. The south and east ore bodies are both genetically related to one east-west fault. This is the same fault which controlled the copper mineralization. In the north pit gold mineralization is also found in the hanging wall of an east-west fault although to a lesser degree. Strong fracturing was important in all of the ore bodies.

The northeast trending dike system provided the important structural control for gold mineralization in the north pit. The main feeder dikes are not mineralized, however several dike stringers and small sills injected into the footwall rocks are mineralized. Traces of gold mineralization have been found 2000 feet away from the established ore body along this dike system.

Stratigraphy plays a secondary nevertheless effective role in ore deposition. The most favorable host rocks are the sandy siltstones. They supply some degree of porosity coupled with an abundance of detrital quartz, the preferred site of gold deposition. Quartzitic sandstones also work well as host rocks. The limestones however, are poor hosts for ore deposition without extensive favorable hydrothermal ground preparation.

Ground preparation is the result of two mechanisms, hydrothermal alteration and contact metamorphism. The favorable effect in both cases was to enhance the porosity of the rock. Hydrothermal alteration in the siltstones included kaolinitic alteration and some recrystallization. In limestones the important process was carbonate removal leaving a slightly to noncalcareous siltstone.

Contact metamorphism associated with dike intrusion caused quartz recrystallization in cherty shale sediments in the north pit. The zone is up to 50 feet wide with several dike strands penetrating it. Recrystallization and kaolinitic alteration left the rock sufficiently porous for later gold mineralization. Contact metamorphism had a negative effect in areas where the tactites have resisted hydrothermal alteration and restricted gold deposition to some degree.

GEOCHEMICAL EXPRESSION

Arsenic and gold have been the most effective surface geochemical indicators of gold mineralization found to date and are strongly influenced by structural controls. The strongest arsenic anomaly lies directly over the south and east ore bodies where soil samples contained more than 1000 parts per million reflecting the influence of the east-west fault. Arsenic values are spotty and less conclusively associated with gold mineralization along the northeast dike system. High angle faults and the Blue Star thrust zone often carry high arsenic values. The arsenic threshold in the Blue Star mine area is estimated to be approximately 2½ times that normally found in the Lynn district. Gold frequently accompanies arsenic in soil anomalies near the mine.

Mercury has not been regularly employed as a geochemical indicator. Although high mercury values in the range of 2000 parts per billion are associated with the metal rich south and east ore bodies the limited mercury data available correlates poorly with north ore body gold mineralization. Anomalous mercury is crudely aligned with the major fault structures.

CONCLUSION

The Blue Star gold deposit in one of several known upper plate (western assemblage) gold occurrences in northeastern Nevada. Unlike the stratabound Carlin Gold deposit, they exhibit very strong structural controls on ore deposition. Dike systems are usually recognized in close association with the gold mineralization as at the Blue Star, Bootstrap and the Big Six deposits. Upper plate host rocks are sandy or silty members with the ore bodies characteristically found as aggregates of several smaller pods of mineralization. The overall grade is typically less than in the known lower plate deposits although they frequently have coarse gold associated with them as at Blue Star, Big Six and Gold Quarry. Arsenic and gold are the most reliable geochemical indicators known for this type gold deposit.

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