HASBROUCK MOUNTAIN, NEVADA

PRECIOUS METAL MINERALIZATION IN A FOSSIL HOT SPRING ENVIRONMENT

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INTRODUCTION

Hasbrouck Mountain is an erosional remnant of a fossil geothermal system in which precious metal mineralization was deposited in a shallow hot spring environment.

Hasbrouck Mountain is located in the western part of the Divide District, five miles south of the city of Tonopah in Esmeralda County, Nevada (Fig. 1).

Up to 1980, the Divide District had produced approximately 3.3 million ounces of Ag and 32,000 ounces of Au from 135,000 tons of rock. Most of the Ag production came from replacement veins and lodes from the Tonopah Divide Mine (Fig. 1) during the 1920's. Minor Ag has also been produced from the mining of hydrothermal breccias from the Tonopah Hasbrouck Mine on Hasbrouck Mountain in the early 1900's. Disseminated Au-Ag mineralization on Hasbrouck Mountain was discovered in the middle 1970's by Cordex Exploration Company. Franco-Nevada Mining Corporation is presently evaluating the disseminated mineralization.

The principal publications concerning the geology and ore deposits of the area include a geologic report on Esmeralda County by Albers and Stewart (1972), a geologic report on the Divide District by Knopf (1921), reports and road logs for the Tonopah area by Bonham and Garside (1974, 1979, 1982) and a thesis by Graney (1985). Age dates cited in this article are from Silberman, et al (1978).

GEOLOGIC SETTING

Rocks exposed in the Divide District consist of Tertiary volcanic rocks produced in a caldera collapse/dome field setting.

The oldest unit in the Divide District is 20-18 m.y. old lithic-rich rhyolitic ash-flow tuffs of the Fraction Tuff. The Fraction Tuff is believed to have been deposited from eruptions associated with the collapse of an Early Miocene caldera centered on the Divide District (Bonham and Garside, 1979).

Inception of Basin and Range extensional faulting in the Tonopah area about 17 m.y. ago initiated the deposition of fluvial and lacustrine sediments of the Siebert Formation within fault block basins. Interbedded with these volcaniclastic rocks are subaerially and subaqueously deposited air-fall and ash-flow tuffs. Mineralization on Hasbrouck Mountain is hosted by rocks of the Siebert Formation.

Dikes and domes of 16.4-16.9 m.y. old Oddie Rhyolite and 16.8-16.9 m.y. old Divide Andesite intrude the Fraction Tuff and Siebert Formation in the Divide District. These domes and dikes are commonly altered and believed to be associated with mineralization in the Divide District. Sixteen m.y. old unaltered Brougher Rhyolite domes and flows cut the above units and are believed to postdate mineralization in the Divide District.

Rocks on Hasbrouck Mountain are dominated by Siebert Formation ash-flow, air-fall and waterlain tuffs, volcaniclastic sediments, and sinter produced during hot spring activity (Fig. 2). Table 1 briefly describes the stratigraphic relationships on Hasbrouck Mountain.

ALTERATION AND PRECIOUS METAL MINERALIZATION

Several periods of alteration and associated mineralization are preserved on Hasbrouck Mountain including an early period of hot spring activity which produced disseminated Au-Ag mineralization followed by a weaker period of hot spring activity which produced less alteration and only minor disseminated Au-Ag mineralization. Later, Ag dominant mineralization was deposited during hydrothermal brecciation, with opaline sinter deposition and associated acid leaching concluding hot spring activity at Hasbrouck Mountain.

The disseminated Au-Ag mineralization on Hasbrouck Mountain is concentrated within the volcaniclastic rocks and lapilli tuff units below the chalcedonic sinter horizons (Fig. 2 and 3A). Two zones of disseminated precious metal mineralization are known on Hasbrouck Mountain. The larger is depicted in Fig. 3A whereas the smaller is localized under the collar of drill hole H-2 (Fig. 2). Sinter formation is believed to be coeval with alteration and precious metal mineralization. The two disseminated mineralization zones as well as the thick sinter horizon on the east side of Hasbrouck Mountain are presumed to overlie the intersection of east-west and north-south faults, of little displacement, which localized the hot spring activity.

Near surface silica and potassium metasomatism produced funnel shaped alteration envelopes, zoned around the major hydrothermal conduits. The alteration envelopes progress inward from quartz + illite + montmorillonite to quartz + adularia + albite + illite, quartz + adularia + illite to quartz + adularia cores (Fig. 3B). The lapilli tuffs and volcaniclastic rocks acted as permeable aquifers allowing lateral fluid flow and near-surface boiling above the water-lain tuffs and ash-flows of lower permeability. Disseminated electrum + acanthite mineralization accompanied quartz + adularia + pyrite formation in the originally permeable lapilli tuffs and volcaniclastic rocks. Thin section studies suggest several brecciation episodes occurred on a microscale following initial permeability reduction, allowing further gangue and precious metal minerals to be deposited.

The disseminated Au-Ag mineralization formed 30-150 meters below the paleosurface approximately 16.3 $\pm$ 0.5 m.y. ago. The zones of disseminated mineralization are believed to contain 5 million tons of rock averaging 0.04 ounces Au and 0.70 ounce Ag per ton.

The volcaniclastic rocks on the top of Hasbrouck Mountain have also been weakly altered to a quartz + adularia assemblage with only minor precious metal mineralization, suggesting sedimentation and hot spring activity continued after the deposition of the main bodies of disseminated precious metal mineralization.

Multistage sinter deposition and intense near-surface silicification led to self-sealing of the hydrothermal system. Pressure release resulted in the explosive production of breccias within which acanthite + electrum + pyargyrite mineralization was localized. The breccia bodies tend to have east-west orientations,locally occupying zones of normal faulting, cross-cutting earlier alteration and mineralization patterns. The breccia bodies are lensoidal in plan, possibly pipe like in three dimensions. The largest hydrothermal breccia body, the Kernick Vern, has been mined via the Ore Car and Main Adits (Fig. 2). The Northea... and South Adits were also driven to test down-dip extensions of areas of hydrothermal brecciation exposed on the surface.

The breccias range from matrix to fragment supported within the breccia bodies to stockwork brecciation of the enclosing wallrocks. Fragments from the wallrocks have commonly been incorporated into the breccia bodies, with the matrix of the breccias composed of rock flour, quartz, adularia and sulfides. A sample of quartz + illite altered rock adjacent to a hydrothermal breccia in the Main Adit has been dated at 15.8 ± 0.5 m.y. This suggests that there could have been a time lapse of 0.5 m.y. between the deposition of the disseminated Au-Ag mineralization and later hydrothermal brecciation, but overlaps in the uncertainty of the age dates makes this idea conjectural. The mineralized hydrothermal breccias do not seem to be of adequate size or grade to permit exploitation; however, they locally overlap the disseminated zones of Au-Ag mineralization and upgrade the values.

After the several episodes of brecciation, hydrothermal activity on Hasbrouck Mountain apparently waned, perhaps due to the cooling of the near surface rhyolite intrusives which produced volcanic processes controlling the several periods of precious metal mineralization. Deposition of the unconsolidated gray ash near drill hole H-18 (Fig. 2) is the next geologic event recorded, followed by the fault pattern expressed on Hasbrouck Mountain today. Renewed hot spring activity was localized within and above these late fault zones producing the small opaline sinter aprons near the top of Hasbrouck Mountain. Zones of feldspar destructive kaolinite and montmorillonite alteration are localized within the fault zones below the opaline sinter horizons.

CORRELATION OF HASBROUCK MOUNTAIN TO MINERALIZED ACTIVE AND FOSSIL GEOTHERMAL SYSTEMS

The connection between modern geothermal systems and the processes of ore deposition have been emphasized by many authors in explaining the genesis of various types of ore deposits. White (1981), Bonham and Giles (1983), Fournier (1983), White and Heropoulos (1983), Sillitoe and Bonham (1984), Nelson and Giles (1985), and Sillitoe (1985) have provided the most comprehensive discussions comparing modern systems with fossil ore deposits.

Both hot water- and vapor-dominated modern geothermal systems exist. Vapor-dominated systems produce extreme near-surface acid leaching that White (1981) believes produce near surface Hg and S deposits with associated porphyry Cu at depths. The hot water-dominated modern systems are believed to have fossil ore deposit equivalents with both acid leaching, argillic, and more alkaline types of alteration. Hasbrouck Mountain qualifies as a near surface alkaline alteration type of hot spring system and it has similarities to other deposits in this class such as Bodie, California (O'Neil, et.al, 1973), Round Mountain, Nevada (Mills, 1982), and Cinola, British Columbia, Canada (Cruson, 1983).

No attempt will be made here to develop a model for mineralization in hot springs systems, for the above references cover that subject adequately. Instead I will cite the following geologic features which I believe contributed to the localization of precious metal mineralization at Hasbrouck Mountain.

(1) Hasbrouck Mountain is located within an area of complex caldera-related Miocene volcanism which deposited tuffs and volcaniclastic sediments within, and around, shallow lakes in fault block basins.

(2) Near-surface rhyolitic intrusives provided the heat necessary to drive the geothermal system.

(3) Several stages of sinter-producing hot springs activity occurred, with associated near-surface formation of disseminated adularia within boiling permeable acquifers.

(4) Near surface disseminated gold and silver precipitation was associated with quartz + adularia + pyrite deposition within 150 m of the paleosurface.

(5) The geothermal system was dynamic, explosive and self-sealing during its later stages which led to multiple periods of hydrothermal brecciation and precipitation of silver dominant mineralization within the breccias.

(6) The solutions from which the precious metals were deposited changed from relatively rich in gold during deposition of the disseminated mineralization to relatively rich in silver during deposition of mineralization associated with hydrothermal brecciation.

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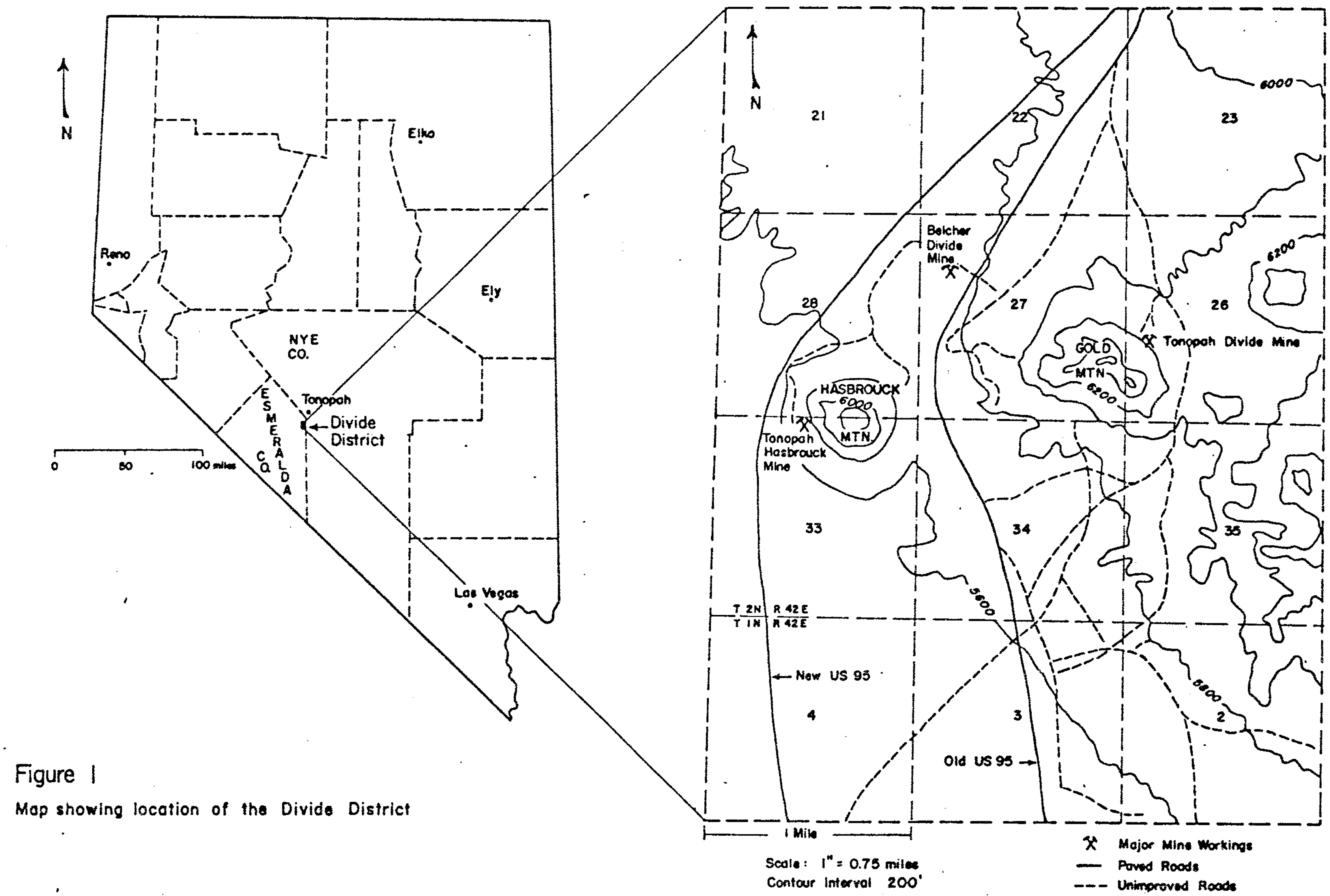


Figure 1

Map showing location of the Divide District

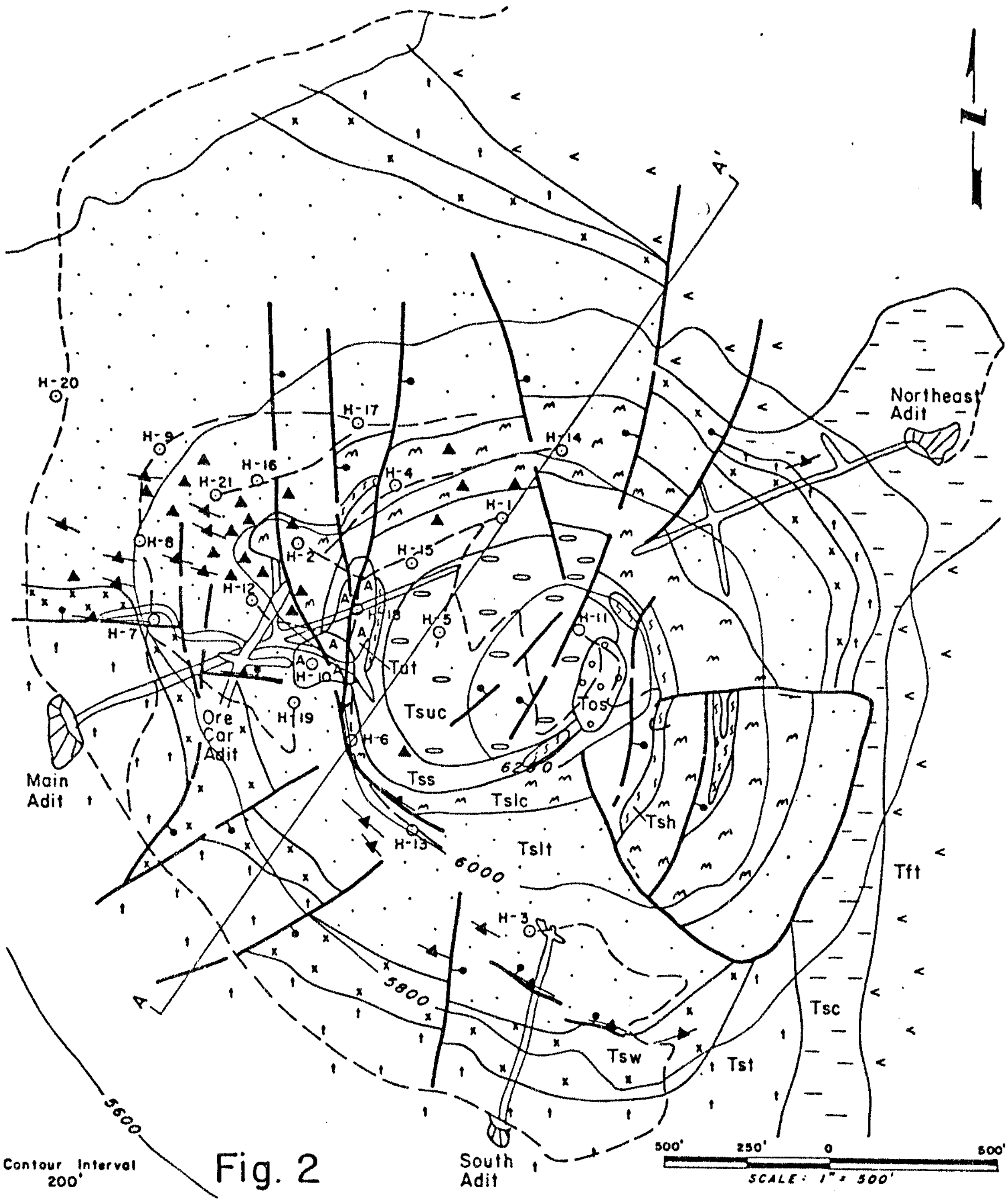


Fig. 2

GEOLOGIC MAP OF HASBROUCK MOUNTAIN

	Fault		Road
	Contact		Linear hydrothermal breccias
O_{H-2}	Drill hole		Stockwork breccias
	Underground workings	A – A'	Cross section line

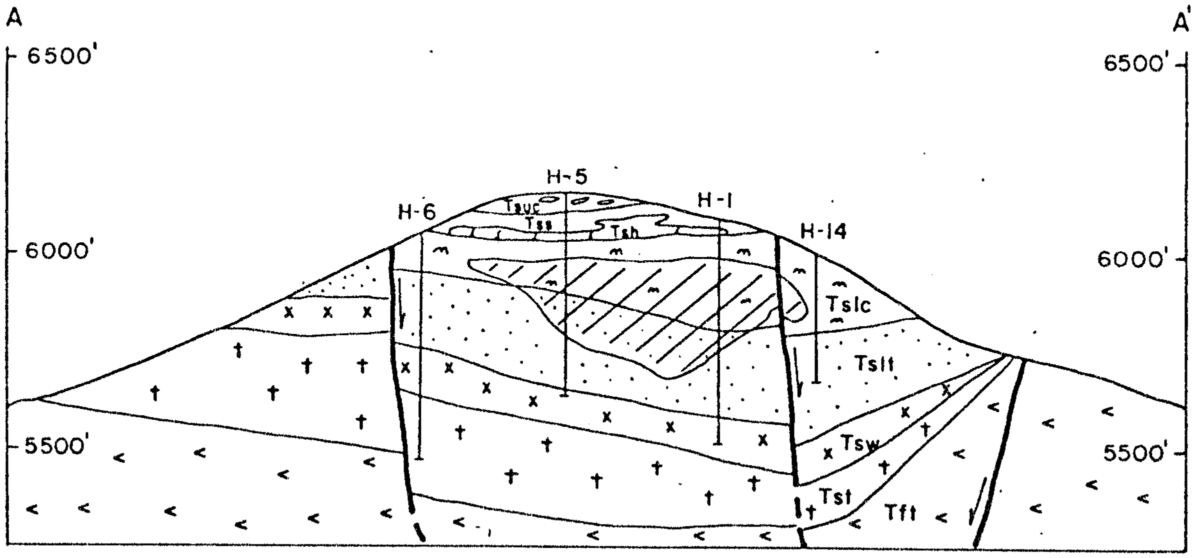


Fig. 3A Geologic Cross Section

(See Fig. 2 and Table I for unit explanation)

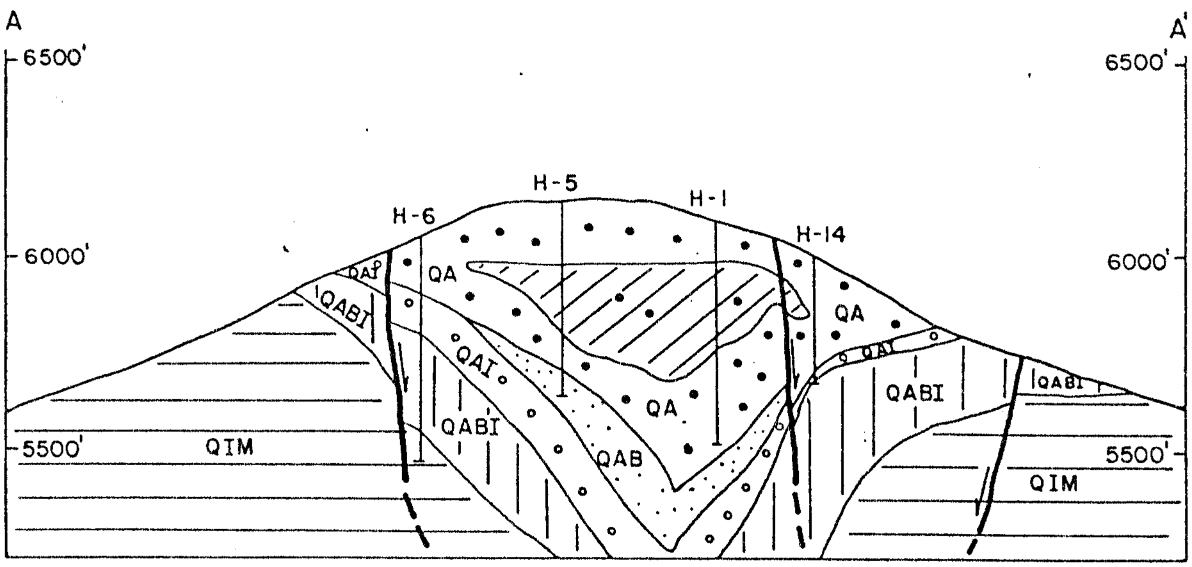


Fig. 3 B Alteration overlay for Fig. 3 A

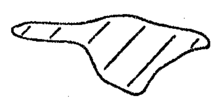
Q - Quartz

A - Adularia

B - Albite

I - Illite

M - Montmorillonite



Outline of potential orebody with greater than 0.03 oz Au/ton and 0.06 oz Ag/ton.

Scale 1" = 500'

TABLE 1

STRATIGRAPHIC RELATIONSHIPS AT HASBROUCK MOUNTAIN

Tos	Opaline sinter, locally containing plant fragments
Tut	Unconsolidated gray ash

SEIBERT FORMATION

Tsuc	Epiclastic volcanic conglomerate with local interbeds of sandstone and ash-flow tuff
Tss	Epiclastic volcanic sandstone and siltstone with local accumulations of plant fragments
Tsh	Chalcedonic sinter
Tslc	Epiclastic volcanic conglomerate containing lenses of sandstone and local basal breccias
Tslt	Ash-flow tuff with abundant pumice lapilli
Tsw	Thin bedded water-lain tuff containing interbeds of epiclastic volcanic siltstone and sandstone
Tst	Ash-flow tuff rich in crystal and lithic fragments locally includes water-lain tuffs in its lower part
Tsc	Sandstones and conglomerates of fluvial origin and ash-flow tuff

UNCONFORMITY

FRACTION TUFF

Tft	Tonopah Summit Member. Ash-flow tuff rich in lithic fragments

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