The Mineralogy of the Black Hawk Arsenide 5-element Deposit

Jakob Newcomer[1,2*], Virginia Mclemore[2], Zohreh Kazemi Motlagh[2,3], Evan Owen[1,2], William Chavez[3], Nicole Hurtig[1]

[1]Dept. of Earth and Environmental Science, New Mexico Institute of Mining and Geology

[2]NM Bureau of Geology

[3]Dept. of Mineral Engineering, NMT

Abstract

The unusual arsenide five-element-vein deposits of the Black Hawk district in the Burro Mountains, Grant County, New Mexico is one of only a few examples of these types of deposits in the United States. These are unusual deposits due to their scarcity, unusual metal association, and uncommon mineral textures. The typical metal assemblage consists of silver-nickel-cobalt-arsenic-bismuth mineralization, with varying amounts of uranium, copper, antimony, mercury, and zinc. These deposits have been long produced for high grades of silver, and more recently cobalt, nickel, and bismuth, but they are not well studied. The Black Hawk deposits appear to be late Cretaceous in age, and occur within faults of Proterozoic granites, diorites, and metamorphics. Production from the Black Hawk district from 1881-1960 amounts to 1,286,000 oz Ag, 3,000 lbs. Cu, 1,000 oz Au, 4,000 lbs. Pb, and minor tungsten and fluorite. The mineralogical and textural relationships are very similar to those observed from the 5-element system in Cobalt, Ontario, Canada. These include early precipitation of dendritic and skeletal native silver, followed by nickel and cobalt arsenides, such as nickeline, skutterudite, nickelskutterudite, safflorite, and rammelsbergite. This is followed by a sulfide stage and precipitation of minor base metals, such as galena, sphalerite, and chalcopyrite. The last minerals to precipitate are gangue minerals, typically calcite or siderite, with some quartz. The Black Hawk district shows early uraninite precipitation, whereas the Cobalt, Ontario system shows no such uranium mineralization. This assembly of highly reduced metallic phases indicates a reducing agent component to precipitation, and it is theorized that methane or other organic fluids could have caused this rapid crystallization, leading to the development of the observed dendritic and uneven vein filling mineral textures. A better understanding of the mineralogy of this deposit in comparison to other 5-element deposits around the world will better inform the pursuit of the critical minerals cobalt, nickel, arsenic, zinc, and bismuth.

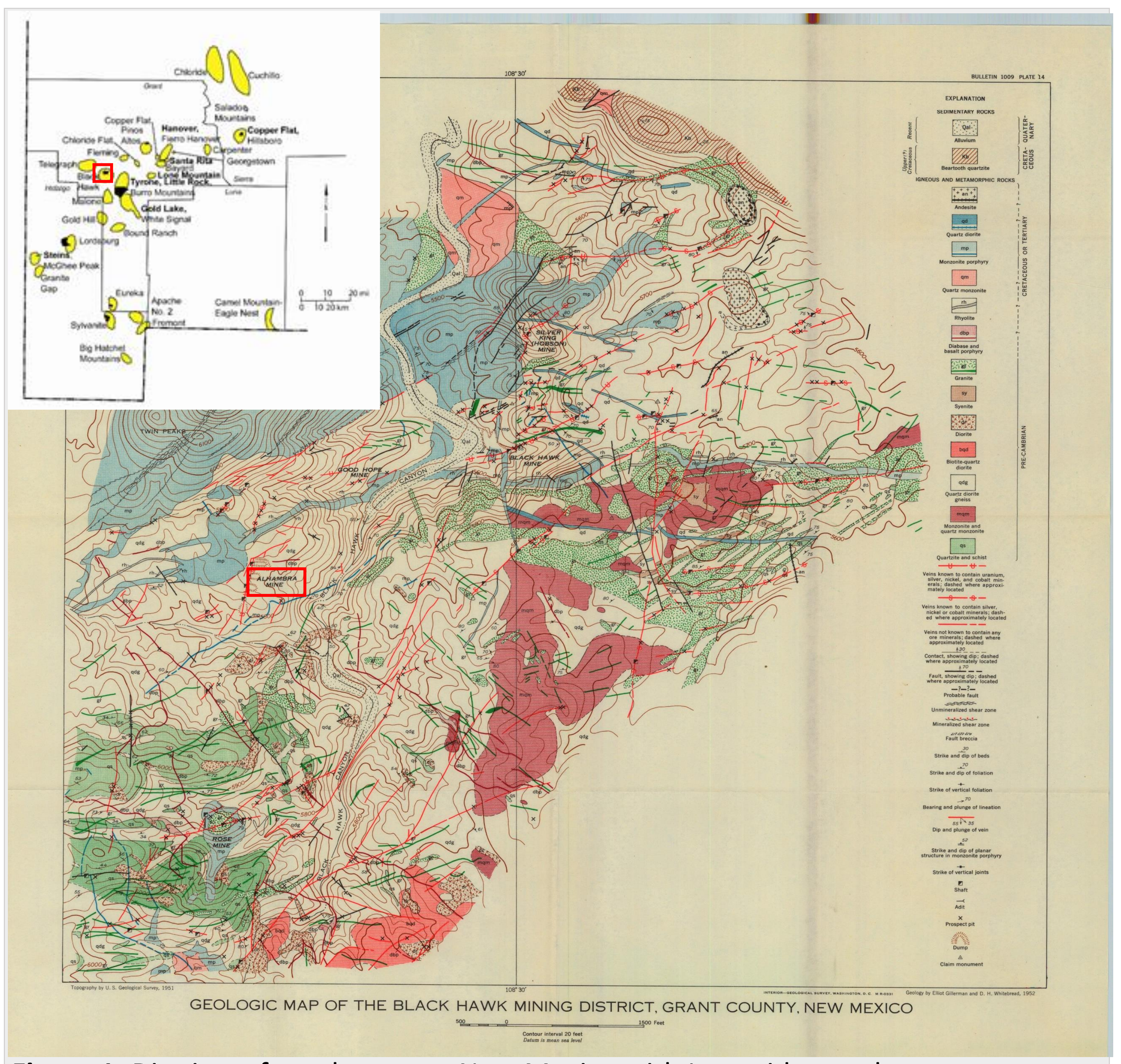

Figure 1: Districts of southwestern New Mexico with Laramide porphyry copper deposits, polymetallic veins, skarns, and plutons, and geologic map of Black Hawk district [2]. Quartz Diorite Gneiss (White), Monzonite (Red), Quartzite and schist (Green), Quartz diorite (Blue), Biotite-quartz diorite (Light Red).

Geologic Setting

- The predominant rock unit is the Burro Mountain Batholith Complex monzodiorite gneiss.
- The area has been intruded by several Laramide stocks, including the Twin Peaks diorite porphyry.
- The northern part of the district is overlain by Tertiary volcanics of the Datil-Mogollon volcanic field. [1]

References

[1] Gerwe, J. E., (1986) Ag-Ni-Co-As-U Mineralization In The Black Hawk Mining District, Grant County, New Mexico, Master of Science in Geology Thesis, New Mexico Institute of Mining and Technology

[2] Gillerman, E.G. and Whitebread, D.H., 1956, Uranium-bearing nickel-cobalt-native silver deposits, Black Hawk district, Grant County, New Mexico: U.S. Geological Survey, Bulletin, v. 01009-K, p. 283-313.

5-Element Arsenide Veins

- Hydrothermal systems typically with an Ag-Co-Ni-Bi-As assemblage.
- Variable mineralization of U, Cu, Pb, Zn, Sb, Hg.
- Typically show dendritic and skeletal native metals and Co-Ni arsenides.
- Redox-sensitive metals reduced in a sulfur-poor environment.
- Mineral and vein textures indicate rapid precipitation.
- Possible source for critical minerals such as Co, Ni, As, Bi, Ba, Zn, Sb, Mn, and Sn

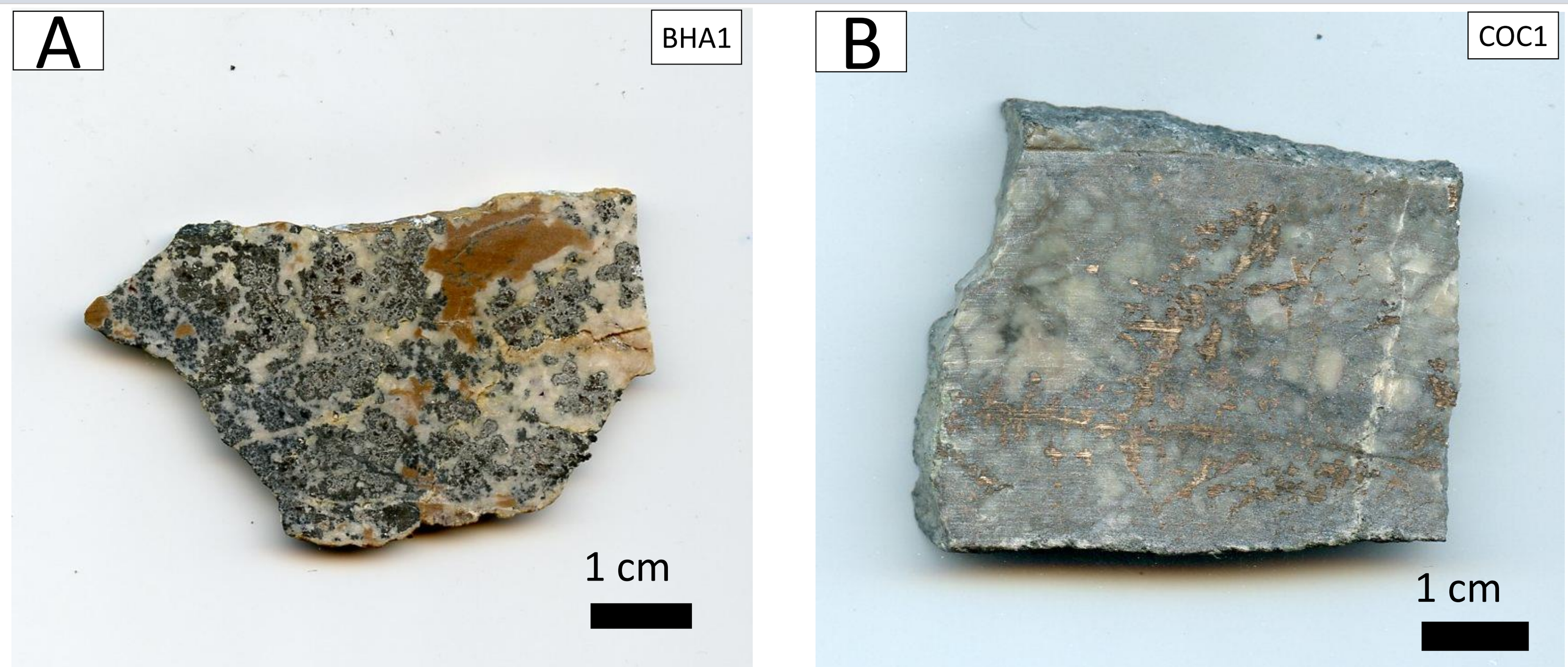

Figure 2: Hand samples of mineralized veins from 5-element systems. A) Skeletal and colloform native silver and skutterudite series mineralization from the Alhambra Mine, Black Hawk District, NM (sample BHA1) Shown in Figure 1. B) Skeletal native silver, nickeline, skutterudite, and safflorite from the O'Brien Mine, Cobalt, Ontario, Canada (sample COC1).

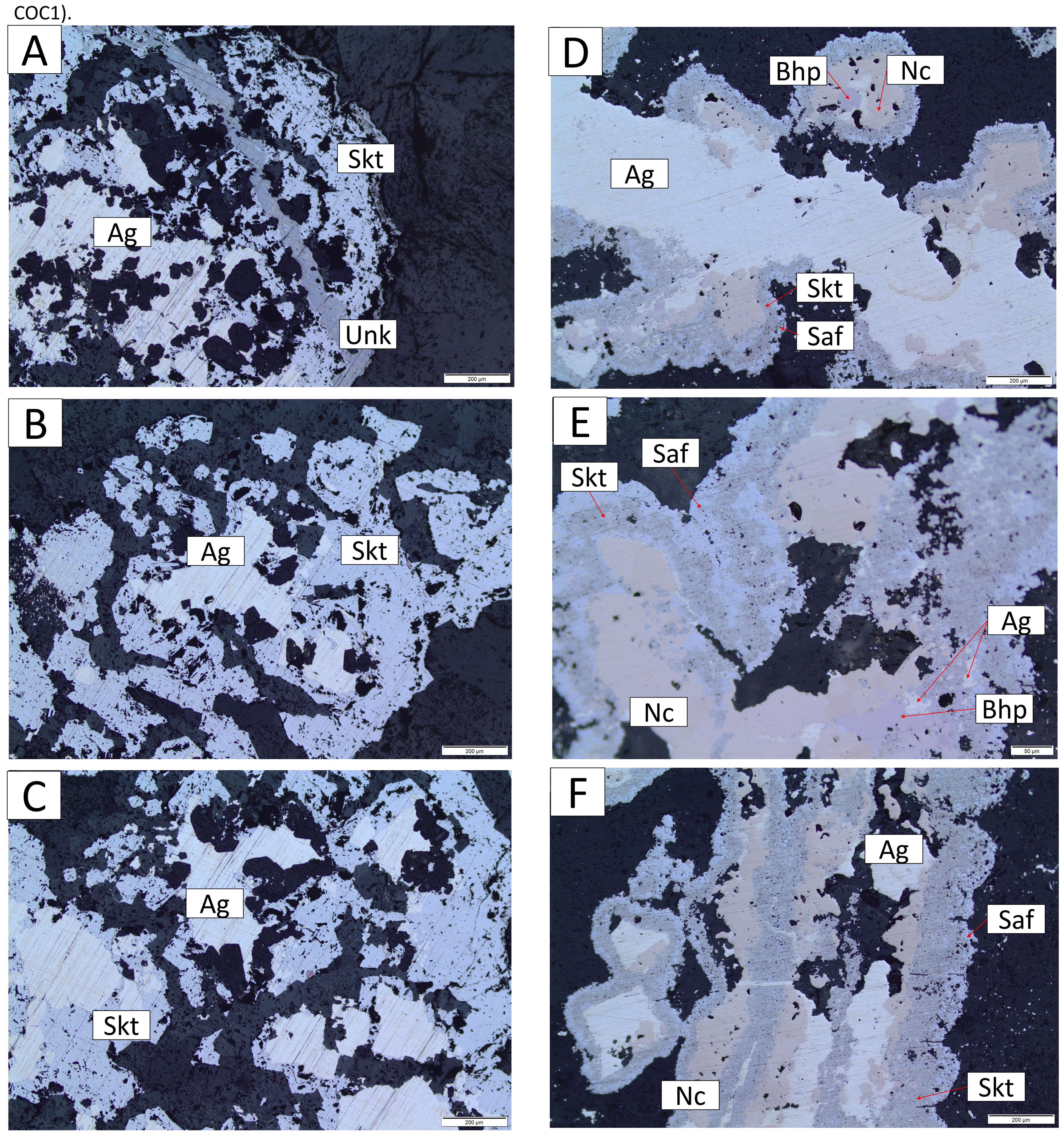

Figure 3: Reflected light photomicrographs of native metals and Co-Ni arsenides from the Alhambra Mine, Black Hawk District (A, B, C) and the O'Brien Mine, Cobalt District (D, E, F) from hand samples in Figure 2. A) Native silver (Ag, white) rimmed by skutterudite series (Skt, light grey) and crosscut by unknown mineral vein (grey). B,C) Native silver and skutterudite series showing complex textures. D,E,F) Native silver (Ag, white) with nickeline (Nc, orange) and breithauptite (Bhp, violet) rimmed by colloform skutterudite series (Skt, grey) and safflorite (Saf, blue-grey).

Table 1: Select mineralogy comparison between minerals reported from the Black Hawk District, NM, and the Cobalt District, Ontario, Canada. **Minerals observed in early petrography.** *Mineral species discredited by International Mineralogical Association IMA.

Minerals by Chemistry	Black Hawk, New Mexico	Cobalt, Ontario, Canada
Native Metals	Gold, **Silver**	Arsenic, Allargentum, Antimony, Bismuth, Copper, Gold, Mercury, **Silver**
Arsenides (Antimonides)	Chloanthite*, Nickeline, **Nickelskutterudite**, Rammelsbergite, **Skutterudite**, Smaltite*	**Breithauptite**, Clinosafflorite, Dyscrasite, Lollingite, Maucherite, **Nickeline**, **Nickelskutterudite**, Orcelite, Pararammelsbergite, Rammelsbergite, **Safflorite**, **Skutterudite**
Sulfides	Acanthite, Argentite, Bismuthinite, Bornite, Bravoite*, Chalcopyrite, Covellite, Cubanite, Digenite, Galena, Gersdorffite, Jalpaite, Marcasite, Mckinstryite, Millerite, Molybdenite, Pearceite, Proustite, Pyrargyrite, Pyrite, Pyrostilpnite, Pyrrhotite, Siegenite, Stannite, Stromeyerite, Tennantite, Tetrahedrite	Acanthite, Aikinite, Alloclasite, Arsenopyrite, Bismuthinite, Bornite, Chalcocite, Chalcopyrite, Cobaltite, Cosalite, Covellite, Djurelite, Emplectite, Freieslebenite, Galena, Gersdorffite, Glaucodot, Larosite, Lindstromite, Marcasite, Matildite, Mckinstryite, Millerite, Molybdenite, Pavonite, Pearceite, Pentlandite, Polybasite, Proustite, Pyrargyrite, Pyrite, Pyrrhotite, Samsonite, Smythite, Sphalerite, Stephanite, Sternbergite, Stromeyerite, Ullmanite, Wittichenite, Xanthoconite
Gangue, Other	Calcite, Dolomite, Manganocalcite, Rhodochrosite, Siderite	Aragonite, Calcite, Dolomite, Rhodochrosite, Siderite, Spherocobaltite

Table 2: Select cobalt and nickel arsenides reported from Black Hawk, NM, and Cobalt, Ontario, Canada, with mineral symmetry group and redox state of metals and metalloids. *Mineral species discredited by International Mineralogical Association IMA.

Mineral	Mineral Formula	Symmetry Group	Valence
Arsenopyrite	$FeAsS$	Monoclinic	Fe^{3+}, As^{-1}, S^{2-}
Bravoite*	$(Fe,Ni)S_2$	Isometric	Fe^{2+}, Ni^{2+}, S^{1-}
Chloanthite*	$(Ni,Co,Fe)As_{2-3}$	Isometric	Ni^{3+}, As^{-1}
Clinosafflorite	$CoAs_2$	Monoclinic	Co^{2+}, As^{-1}
Cobaltite	$CoAsS$	Orthorhombic	Co^{3+}, As^{-1}, S^{2-}
Gersdorffite	$NiAsS$	Isometric	Ni^{3+}, As^{-1}, S^{2-}
Lollingite	$FeAs_2$	Orthorhombic	Fe^{2+}, As^{-1}
Maucherite	$Ni_{11}As_8$	Tetragonal	Alloy
Nickeline	$NiAs$	Hexagonal	Ni^{3+}, As^{-3}
Nickelskutterudite	$(Ni,Co,Fe)As_3$	Isometric	Ni^{3+}, As^{-1}
Orcelite	$Ni_{5-x}As_2$, $x \sim 0.25$	Hexagonal	Alloy
Pararammelsbergite	$NiAs_2$	Orthorhombic	Ni^{2+}, As^{-1}
Rammelsbergite	$NiAs_2$	Orthorhombic	Ni^{2+}, As^{-1}
Safflorite	$(Co,Ni,Fe)As_2$	Orthorhombic	Co^{2+}, As^{-1}
Siegenite	$CoNi_2S_4$	Isometric	Co^{2+}, Ni^{3+}, S^{2-}
Skutterudite	$CoAs_3$	Isometric	Co^{3+}, As^{-1}
Smaltite*	$CoAs_{2-3}$	Isometric	$Co^{2,3+}$, As^{-1}

Preliminary Conclusions

- Initial petrography of mineralized samples shows textural and compositional similarities between the Black Hawk District and the Cobalt, Ontario district.
- Mineralogy of native metal and arsenide phases shows increased variation of Co+Ni/As ratios in Cobalt, Ontario samples than in Black Hawk samples, and will be further explored.

Acknowledgements

This work is part of ongoing research of the economic geology of mineral resources in New Mexico at NMBGMR, Nelia Dunbar, Director and State Geologist. This study was partially funded by the USGS Earth MRI Cooperative Agreement No. G23AC00054-00 as a subcontract with the Arizona Geological Survey and student grants from the NMGS and New Mexico Tech Brightstar Scholarship.