The Messina Mining District, South Africa

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The copper mining district of Messina in the northern Transvaal Province of South Africa has produced a profusion of quartz specimens over the years. In 1985 a single pocket of quartz with inclusions of ajoite yielded spectacular specimens rivalling or even eclipsing older material, which incorporates other copper silicates such as shattuckite and papagoite.

INTRODUCTION

The town of Messina is the most northerly settlement in the Republic of South Africa. It is situated approximately 8 km south of the Limpopo River, which forms the boundary between South Africa and Zimbabwe. The climate of the region is essentially subtropical with summer temperatures reaching up to 40° C. The winter months (June to August) are more congenial, with slightly cooler weather prevailing. Malaria is endemic in the region and, until 1914, it considerably handicapped the copper mining industry (Söhnge, 1946); precautions should be taken if a visit is planned.

Access to the town and surrounding mines is relatively easy; the main national road passes through Messina and up to Beit Bridge, the border crossing to Zimbabwe. The Messina District consists currently of five mines: the Artonvilla, Harper, Messina, Spence and Western Campbell mines. Permission to visit the mines or dumps for collecting must be obtained from the holding company, Messina (Transvaal) Development, which has head offices in Johannesburg. Provided correct channels are followed, permission is generally granted. But the exposure of good quartz specimens showing attractive inclusions is a rare occurrence at the mines, and visitors are liable to be disappointed in what can be collected on an average day.

HISTORY

According to Söhnge (1946) (one of the earliest and most comprehensive reports on the Messina copper mines), the copper deposits in the Limpopo river area were known to ancient indigenous African tribes for centuries. The word "Messina" is a corruption of the word "Musina," which was the name of one of the tribes which moved into the area from the eastern Transvaal (Van Warmelo, 1940). The Musina people had emigrated to escape attacks by Sotho raiders from the south, most likely during the upheavals that accompanied the rise of the Zulu nation in Natal during the early 19th century (Bahnemann, 1986). Prior to the arrival of these migratory tribes, the earlier inhabitants may have had tentative links with the people of the present-day Zimbabwe ruins in southern Zimbabwe. Ancient mine excavations have yielded stone hammers, soapstone artifacts and iron tools and wedges (Rogers and Weber, 1935). "Musina" is believed to mean "Spoiler," because the small amounts of copper tended to spoil or down-grade the iron produced by the early miners. Ancient smelters are still known today along the high ridges and hills within 20 km of the town of Messina, and particularly at the summit of Singelele Kop (hill).

It was the tales of the ancient copper miners that led Lt. Colonel J. P. Grenfell to send a prospecting team to investigate the region, following the South African Anglo-Boer war. The Digby, Harper and Campbell shafts are named after members of this exploration party. The outcome of the expedition was the registration of the Messina (Transvaal) Development Company in 1905. This had an initial capital of £110,000 and £50,000 in debentures. Söhnge (1946), quoting Emery (1930), provides some details on the Grenfell expedition:

> To the courage and foresight of Colonel J. P. Grenfell, the Messina mines owe their existence. The ancient workings at Messina, which were some 80 feet deep (water level) and some 30 feet wide and which contained . . . rich copper sulphides, were investigated by Colonel Grenfell in 1906.
>
> The diary of the first effort to make a profitable venture out of Messina copper was mostly a record of Colonel Grenfell's struggles against lions, malaria and the elements of tropical Africa. The mines produced from 1906 to 1914 a small tonnage of high-grade sorted ore and concentrates which, in the early

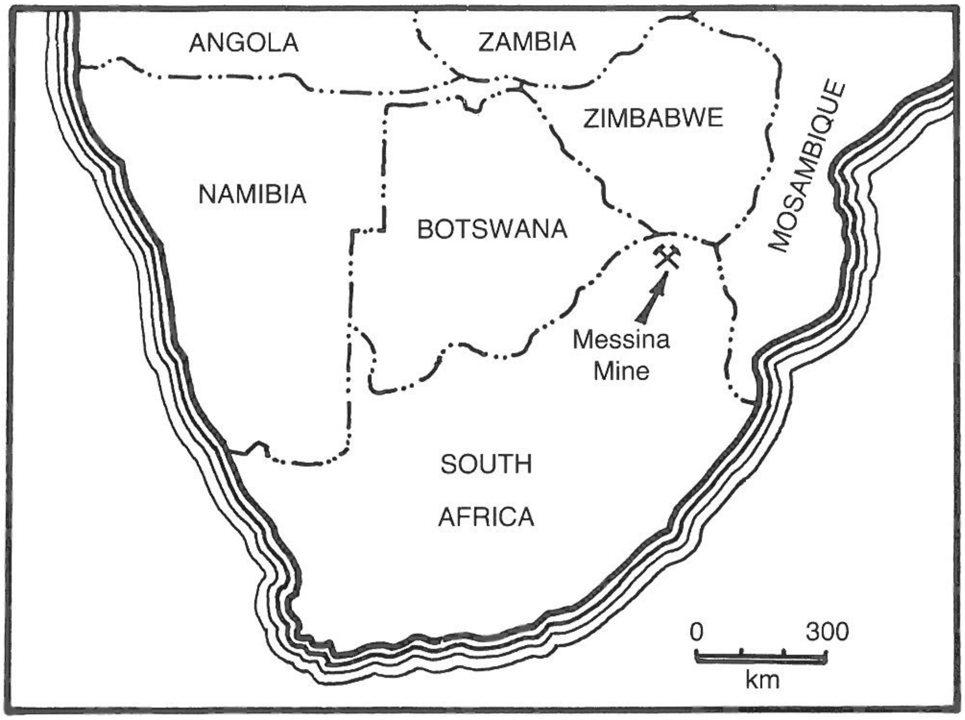

Figure 1. **Location of the Messina mining district in the Republic of South Africa.**

days, were transported by wagon 170 miles to the railhead at Pietersburg.

In 1914 a new reduction works was put into commission, and a small Welsh reverberating furnace turned low-grade concentrates into high-grade matte, which, together with the high-grade concentrations, was shipped overseas to Welsh refineries. In 1920, the Messina mines were closed down pending the erection of the new addition to the concentration plant, and the erection of the new smelting works.

Mining operations were resumed in 1922. Production statistics show that during 1938, 1939 and 1940, the Messina plant was producing 10,000 tons of copper annually. Ore reserves in 1939 were estimated at 2,811,605 tons at a grade of 2.09% Cu (Söhnge, 1946). Since the initial establishment of the Messina (Transvaal) Development Company, 40 million tons of ore have been mined, yielding approximately 700,000 tons of copper (Bahnemann, 1986). It is interesting to note that all of the modern shafts have been sunk on or next to ancient workings.

The discovery of specimen-grade minerals at the mines has been sporadic. All of the specimens are collected either by miners or by other mine personnel, and only appear infrequently on the local market. All specimens are usually labeled "Messina mine," with little or no accurate labeling of material coming out of the adjacent mines. (This seems to be a common local problem similar to the labeling of minerals from the manganese field in the northern Cape Province where individual mines seldom get a mention over and above the N'Chwaning mine). It appears, however, that many of the quartz and papagoite specimens are over 20 years old. The author recently helped unwrap some specimens donated to the Witwatersrand University's Geology Department museum. These represented a donation from a local retired physics professor. Within the trunk was an exceptional group of quartz crystals with inclusions of blue papagoite, shattuckite and brilliant specular hematite crystals. The interesting feature of the specimen was that it was wrapped and sealed in an aged yellow page of a 1955 issues of the S.A. Mining and Engineering magazine, long since out of print, suggesting the specimen was collected well over 30 years ago. The quartz specimens with fine ajoite inclusions are often more recent, many dating from discoveries made in 1985.

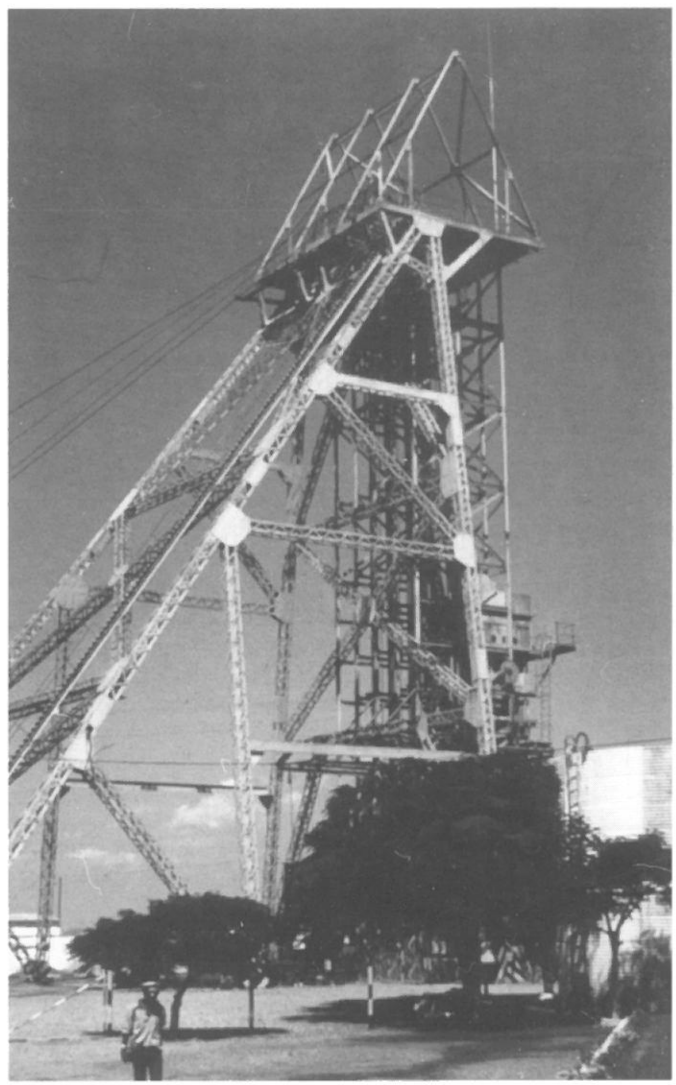

Figure 2. **Headgear of the Campbell shaft, Messina mining district. Photo by Terence S. McCarthy.**

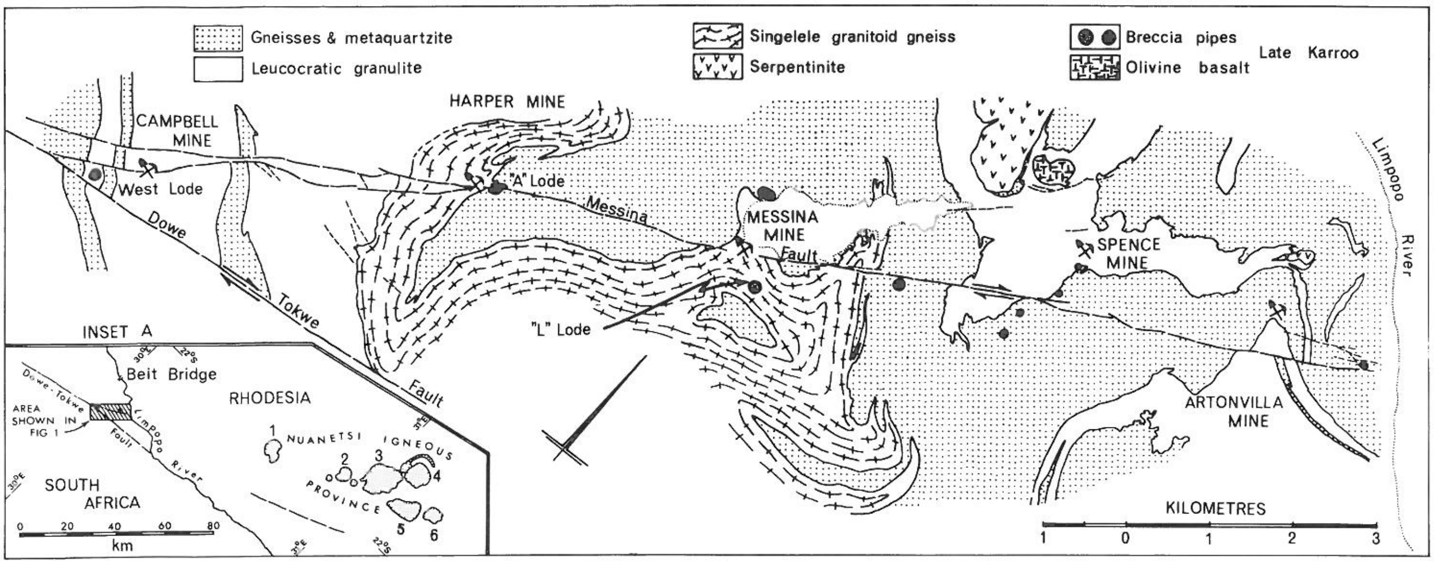

Figure 3. **Location of the various mines in the Messina district, and the regional geology (from Jacobsen *et al.,* 1976).**

GEOLOGY

The copper mines are hosted by gneisses of varying composition (Bahnemann, 1986), forming a structurally complex suite of lithologies resulting from multiple folding and metamorphic recrystallization (Watkeys, 1979).

The basement rocks consist of pyroxene tonalites, overlain by complexly folded metasediments (Bahnemann, 1972). The rocks close to the mines have been metamorphosed to granulite and upper amphibolite facies (Bahnemann, 1972). In contrast, lower-grade metamorphism associated with mineralization resulted in propylitic hydrothermal alteration (Jacobsen and McCarthy, 1976). A number of intrusives of late Karoo age (Triassic/Jurassic) occur close to and within the mine area. These have been called the Nuanetsi Igneous Complex (Cox *et al.,* 1965), thought by some workers to be the intrusive event which introduced the copper mineralization (e.g., Jacobsen, 1967; Jacobsen and McCarthy, 1975 and 1976). Bahnemann (1986), however, has reservations about this theory. He states that the deposition of the Messina copper deposits may pre-date the late Karoo event and that they may be of Waterberg age (1800 million years). The regional tectonic setting of the deposits explains, to a large degree, their structural complexity; the mines are located in the Limpopo Mobile Belt, which delineates the boundary between the Archean Kaapvaal and Rhodesian cratons (Hunter and Pretorius, 1981). The ore deposits occur in part of the Central Zone of the Limpopo Mobile Belt (Cox *et al.,* 1965).

The Messina copper deposits are interpreted as hydrothermal replacement ores (Bahnemann, 1986) forming pipe-like breccia bodies exhibiting collapse features and associated mineralized fractures and fissures. The ore deposition has been primarily structurally controlled (Jacobsen, 1974), frequently by wrench fault systems. The shapes of the individual orebodies are influenced by the fold structure, fracturing and the nature of the lithologies.

Copper is the only economic metal won from the orebodies. It occurs in the primary sulfide minerals chalcopyrite, bornite and chalcocite. Chalcopyrite is present along the peripheries of orebodies and is gradually replaced by bornite, chalcocite and native copper towards

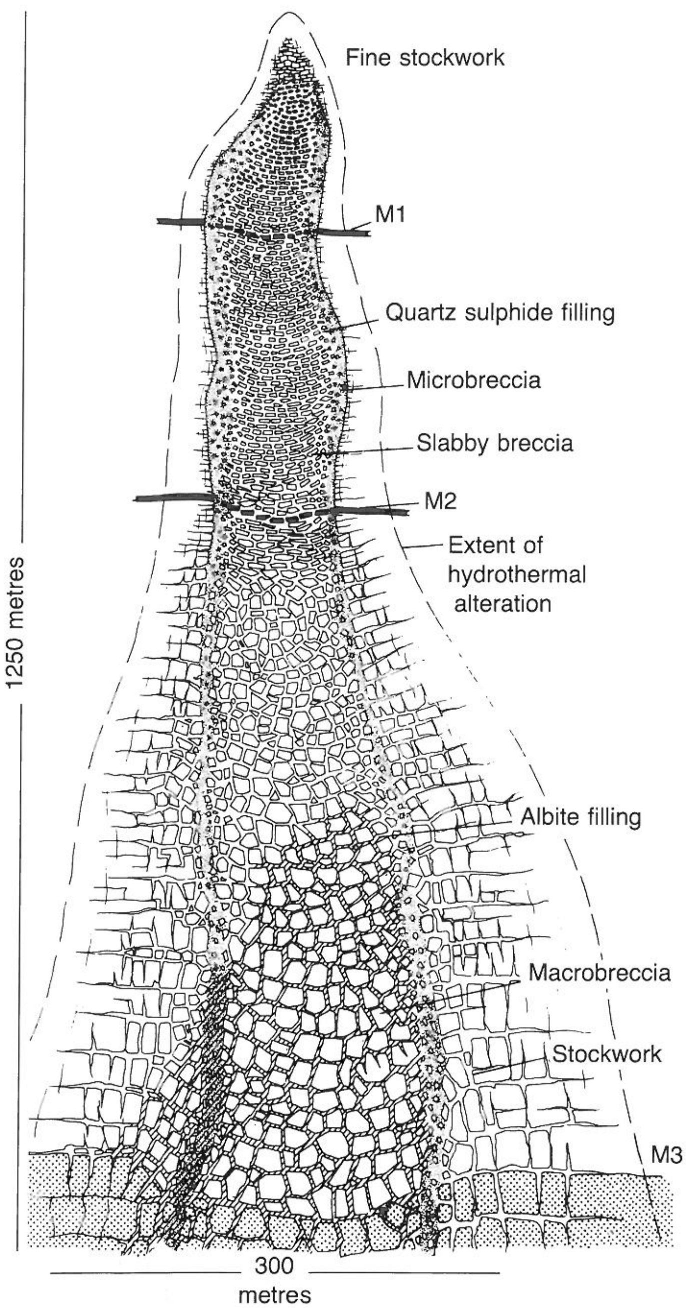

Figure 4. **Graphic representation of the Messina breccia pipes. M1, M2 and M3 are marker zones cut at various levels by the breccia column (from Jacobsen *et al.,* 1976).**

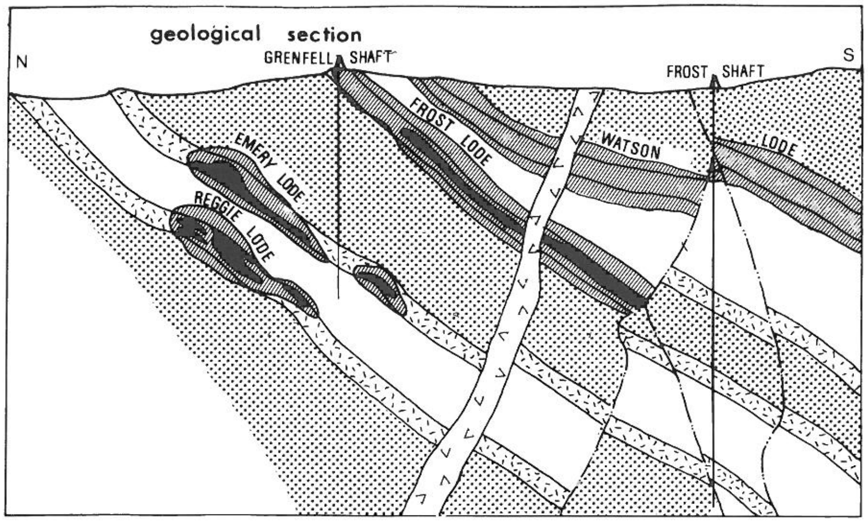

Figure 5. **Geological cross-section through the Frost and Grenfell shafts at Artonvilla mines (from Jacobsen and McCarthy, 1976).**

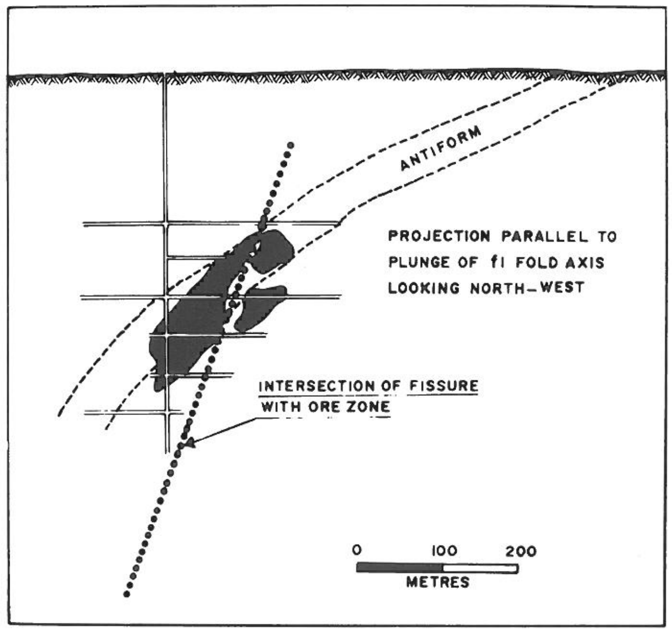

Figure 6. **Longitudinal section through the orebody at the Spence shaft (from Bahnemann, 1986).**

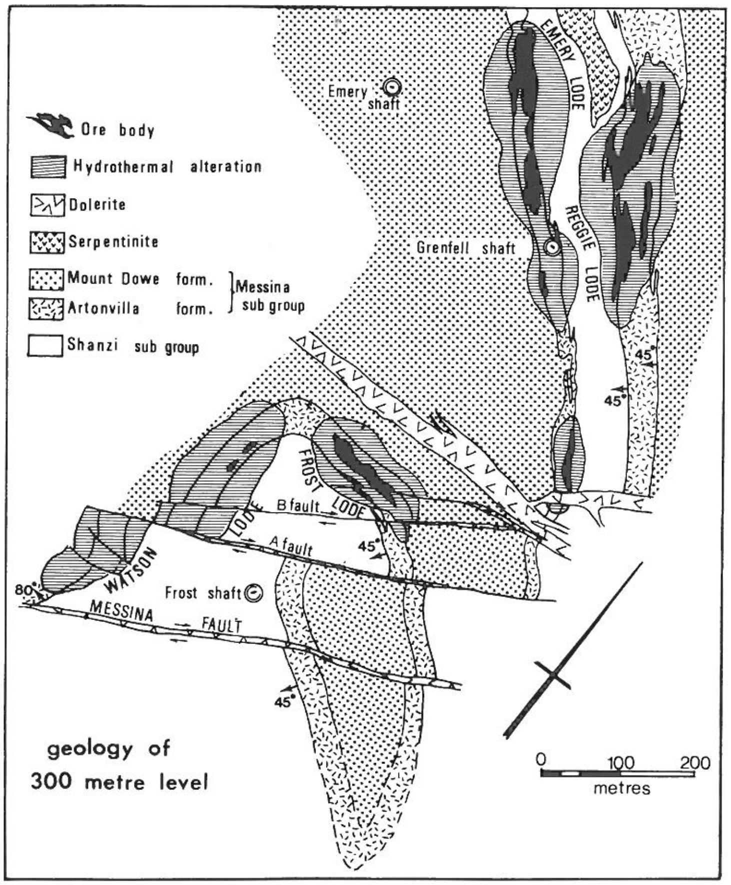

Figure 7. **Distribution of the orebodies on the 300-meter level at the Artonvilla mine (from Jacobsen and McCarthy, 1976).**

the center and downwards. Bahnemann (1986) states that host rock alteration follows the zonation of the sulfides by a general increase in hydration of silicate minerals, leaching of quartz and the development of albite, zoisite and epidote, leading to complete destruction of the host rock.

Jacobsen and McCarthy (1976), in a detailed study of the Artonvilla mine, have observed that disseminated replacement bodies are best developed at this particular mine. Four separate lodes occur where mineralization is accompanied by intense hydrothermal alteration. These disseminated orebodies, such as the Emery lode, show concentric zoning with respect to both the sulfides and the hydrothermal minerals; an outer zone of sericitization is followed inward by zones of albitization, chloritization and epidotization. Concomitant with these stages are sulfide changes which display a zonation from an outer pyrite zone, through chalcopyrite and bornite, to chalcocite and occasional native copper zones in the core (Jacobsen and McCarthy, 1976). These authors conclude that a single hydrothermal fluid was introduced into the Archean host rocks. This fluid entered the structural traps at temperatures in excess of 650° C and passed through the rocks down a temperature gradient which reached about 400° C at the outer extremity, resulting in well-developed mineral zonation. The central parts of the orebody indicate mineral associations equilibrated at temperatures ranging from 140° C to 280° C.

Although the copper mineralization is similar in all five mining areas, certain aspects of the geology differ significantly (Hammerbeck and Schoeman, 1976). Bahnemann (1986) also considered that levels of erosion are thought to have varied, with the deepest levels in the east (Artonvilla) and shallowest in the west (Campbell mine). Each mine is briefly described below, together with the minerals present.

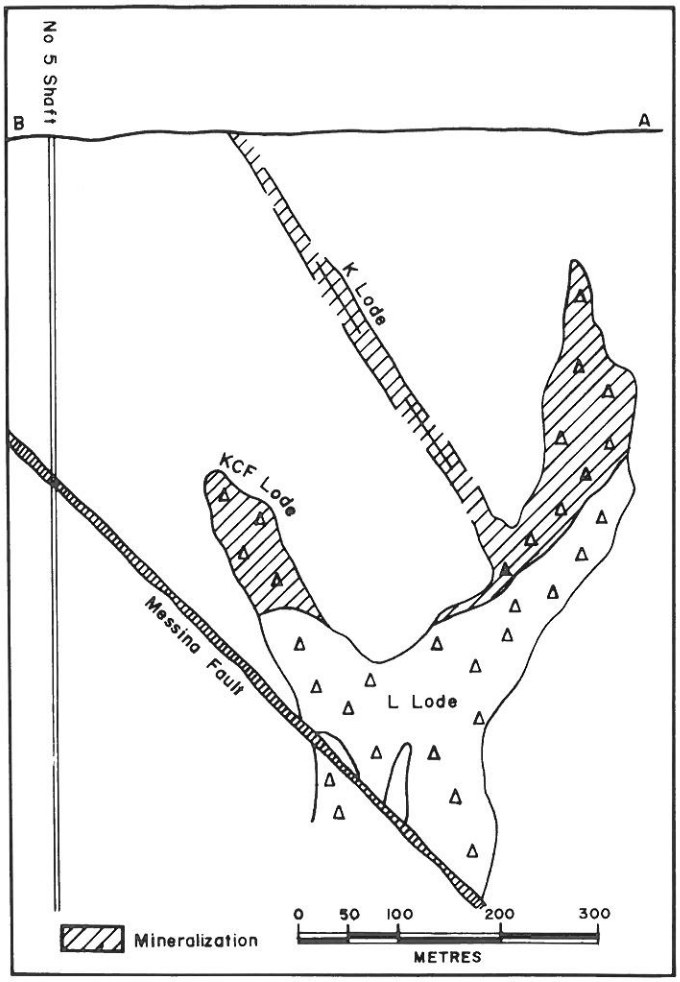

Figure 8. **Cross-section through the L Lode breccia pipe at the Messina mine (from Bahnemann, 1986).**

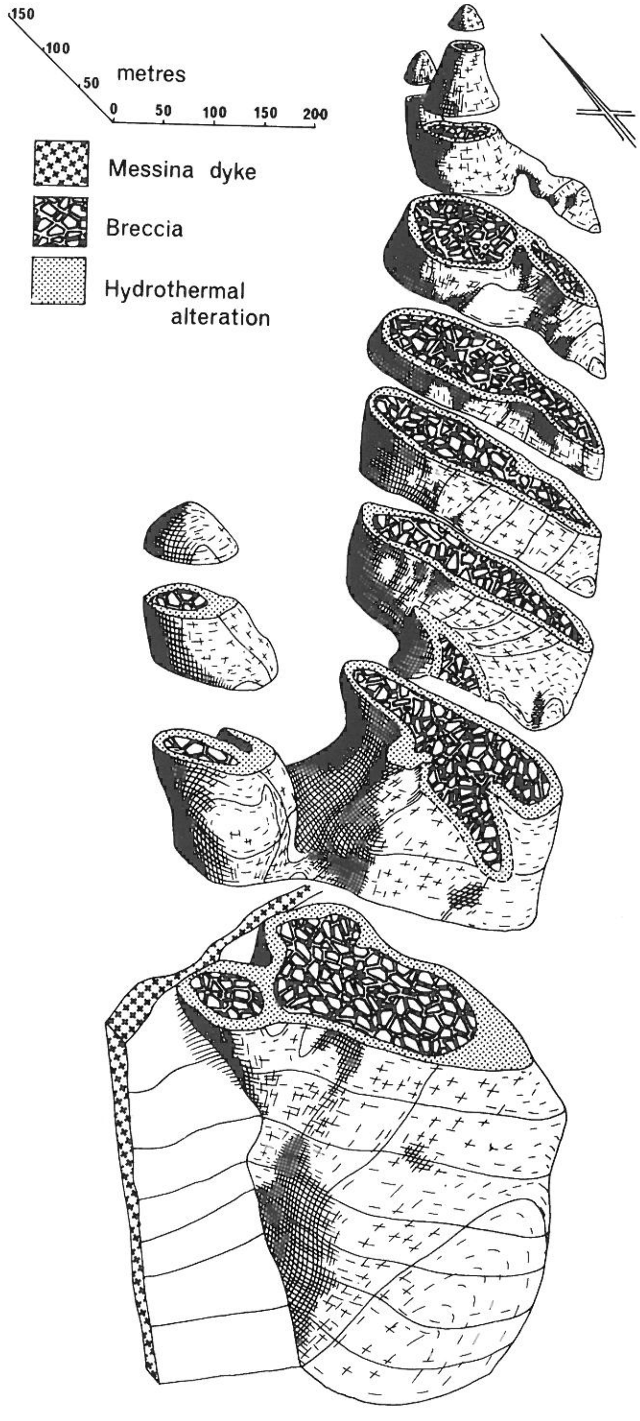

Figure 9. **Three-dimensional construction of the L Lode breccia pipe at the Messina mine (from Jacobsen *et al.*, 1976).**

Artonvilla and Spence mines

The orebodies at Artonvilla are located in bands of biotite-garnet-cordierite gneiss enclosed by leucocratic granite gneiss and meta-quartzite (Hammerbeck and Schoeman, 1976). The orebodies known as the Watson, Frost, Emery and Reggie lodes occur on fold limbs representing three-fold repetition of the gneiss by multiple isoclinal folding.

The Artonvilla and Spence deposits were not yet discovered when Söhnge wrote his memoir in 1946. As a result, the information available on collectible minerals there is limited to the more recent literature.

Bahnemann (1986) described the mineral zoning associated with the hydrothermal alteration at the Artonvilla mine, and concluded it was similar to that observed in the mines to the west. The outer alteration zone of the cordierite-biotite-garnet gneiss consists of "sericite" resulting from the alteration of plagioclase, sillimanite, cordierite, biotite and quartz accompanied by pyrite. Farther inwards, chloritization has occurred and chalcopyrite has replaced pyrite and, in turn, is replaced by bornite. This accounts for the successive coatings of these sulfides on some specimens. Hematite and epidote appear for the first time, together with bornite, and all original feldspar is replaced by albite. In the central zone of alteration, where the host rock is largely replaced by grey-green masses of clay, chalcocite, native copper and goethite occur. In their most altered state, the rocks have been changed completely to an assemblage of epidote, chlorite, goethite, bornite, chalcopyrite, native copper and euhedral quartz crystals (Bahnemann, 1986), and consists of "a vuggy albitite in which minor amounts of prehnite, calcite, epidote and analcite occur. Late quartz crystals line some of the vugs. Most of the albite reveals a fine dusting of iron oxide which may in part account for the red coloration of the altered rock" (Jacobsen and McCarthy, 1976).

Messina mine

The Messina mine (or "Five Shaft" area) forms the nucleus around which the town of Messina developed. The local term "Five Shaft" has been used to distinguish this particular mine from the Messina mining district as a whole. Some confusion has resulted when specimens are labeled "Messina," because this term alone could be taken to mean "Messina mine" or "Messina district."

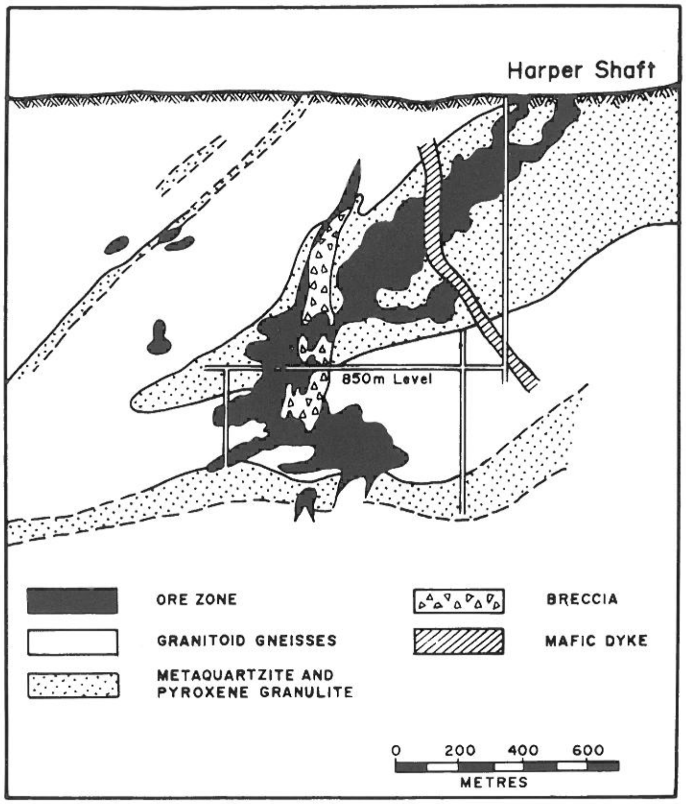

Figure 10. **Geological cross-section looking northwest at the Harper mine. The section is parallel to the Messina Fault (from Bahnemann, 1986).**

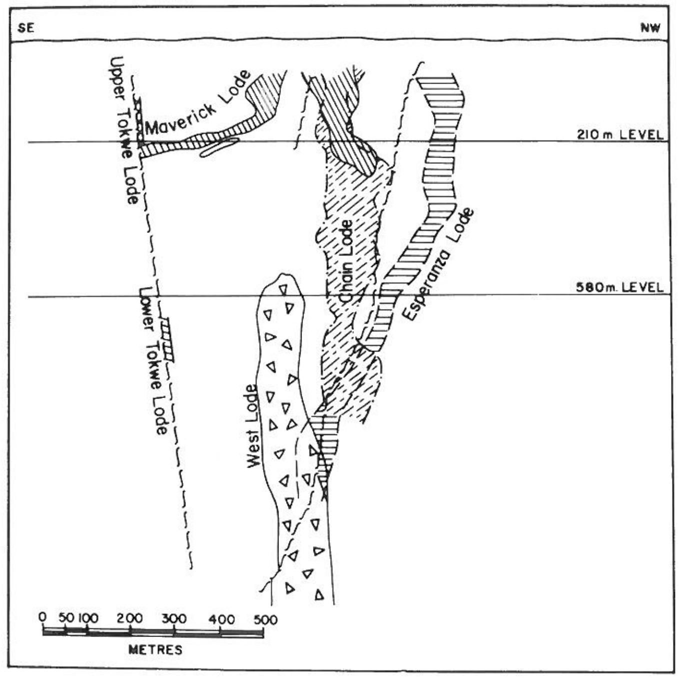

Figure 11. **Cross-section of the Campbell mine transverse to the Messina fault; view towards the southwest (from Bahnemann, 1986).**

In contrast to the Artonvilla and Spence mines, the Messina mine orebodies occur in granite gneiss of the older basement rocks (Hammerbeck and Schoeman, 1976). The various ore lodes have, in the past, been given a variety of names so numerous that eventually an alphabetical categorization of the orebodies became necessary. The Messina mine contains the KCF lode, K lode and L lode. These are breccia pipes with mineral zonation similar to that described previously for the Artonvilla and Spence mines. Söhnge (1946) observed that the K and L lodes consist of brecciated zoisite rock that is host to quartz-copper veins. Epidote, piemontite, talc and sericite are common accessories. Quartz crystals enclosing and coated by specular hematite are widespread and common as fillings in vugs and open fissures. The brecciation in the pipes is spectacular, with variations in sizes from microbrecciated material infilling between larger slabs up to 20 meters in size. The size of the fragments tends to increase downwards and inwards, and at deeper levels and pipes tend to grade into a stockwork of breccia and quartz veins dissecting the country rock (Bahnemann, 1986).

It is these breccia zones, particularly at the Messina mine, that have produced the great variety of quartz crystals. Bahnemann (1986) states that:

> Altered fragments of country rock are cemented by an interlocking mass of quartz crystals which have grown inwards into the voids between the fragments. In still-open vugs, these quartz crystals may reach spectacular sizes. Native copper is present as inclusions in quartz crystals.

Bahnemann (1986) makes a further observation with regard to the presence of prehnite at the Messina mine:

> Porcelaneous white prehnite is a conspicuous mineral, giving the wall rock a distinctly "bleached" appearance. It forms scallopy white rims around quartz and chlorite, and it lines fissures and vugs. The distribution of prehnite . . . appears to be tied to the areas where basement rocks host the mineralization. It is absent at Artonvilla and is found only sporadically at the Harper and Campbell mining areas in or close to basement rocks.

Harper mine

The orebodies of the Harper mine show combined characteristics of the stratiform ore sheets of Artonvilla and the breccia pipe of the Messina mine. The clear zonation of sulfides and associated alteration of the host rocks is absent at the Harper mine, and quartz is scarcer at the Harper mine than at the Messina mine (Söhnge, 1946). Another feature of the orebody is the predominance of bornite and chalcocite, particularly in the central core zones of the pipe.

Campbell mine

Several isolated orebodies occur in the Campbell mine area, and these have been given names such as the Line Lode, Snake Lode, Esperanza Lode, Tokwe Lode (situated on the Dowe Tokwe fault) and the West Lode. The Esperanza Lode is richly mineralized and has been termed an enlarged branch fissure by Van Graan (1964). The fissure consists of fractured and altered host rock dissected by vein quartz but with little breccia. Reddish albite, mustard-colored epidote and zoisite, together with white quartz and the copper sulfides, chalcopyrite, chalcocite and bornite, give the ore an attractive, colorful appearance different from ore in the breccia pipes. The structure, lithology and mineralization of the West Lode are similar to those of the L Lode at the Messina mine.

MINERALS

By far the most abundant and attractive mineral, from a collector's standpoint, is quartz. The habits and varieties of sizes and groups, together with several colorful secondary mineral inclusions, make the Messina mines quartz specimens interesting items. Minerals that occur associated with the orebodies and breccia zones are listed in Table 1.

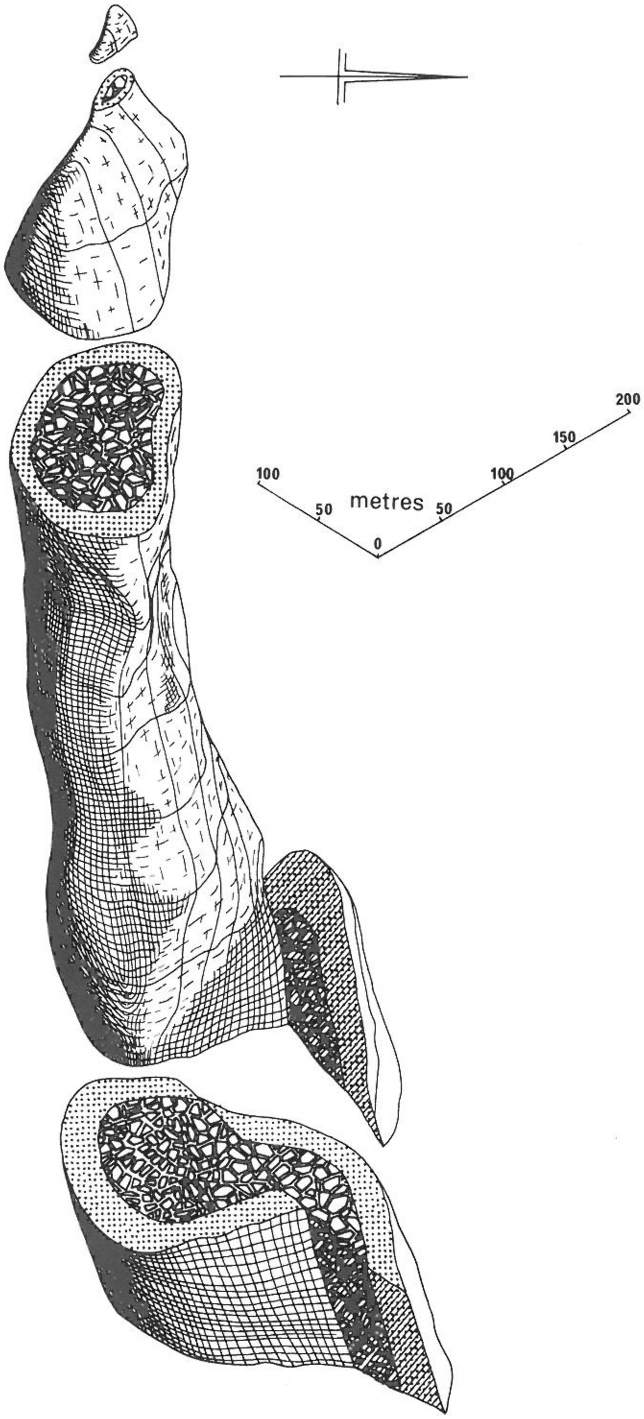

Figure 12. **Three-dimensional diagram of the West Lode at the Campbell mine (from Jacobsen *et al.*, 1976).**

Ajoite $(K,Na)Cu_7^{+2}AlSi_9O_{24}(OH)_6 \cdot 3H_2O$

In July of 1985 a pocket of several dozen quartz crystals was discovered in the Messina mine. These have inclusions of chrysocolla-colored (blue-green) material which commonly delineates phantom faces at or near the terminations of the quartz. This blue material was analyzed by X-ray diffraction (Rob Smith, personal communication) and found to be ajoite (Schaller and Vlisidis, 1958; Chao, 1981). The majority of specimens are individual loose crystals in thumbnail to miniature sizes. Some larger groups were also found; the largest and finest single crystal specimen consists of an undamaged quartz crystal 25 cm long, rimmed at the base by smaller quartz crystals also containing ajoite. In this particular specimen, the ajoite inclusions are present in the central parts of the specimen rather than at the terminations.

Several thin sections were cut perpendicular to the *c*-axis of a smaller thumbnail specimen, and the distribution of the ajoite within the crystal examined in detail. At and near the termination, the ajoite completely fills and extends across the internal portion of host crystal. Further down towards the point of attachment, the central core regions of the host crystal no longer contain ajoite. Instead, the included material forms an outer rim which parallels the external hexagonal form of the quartz.

The amount of ajoite present within the quartz varies. Some specimens may be almost completely included with the blue material while others have only faint veils scattered in the specimen. No ajoite has been reported as occurring in free-growing crystals not included in quartz. Since the find in 1985, no other similar specimens have been found.

Albite $NaAlSi_3O_8$

Albite is a common constituent of the alteration zones in the orebodies, particularly at the Artonvilla mine (Jacobsen, 1967). The Messina and Harper mines have a higher degree of prehnitization and zoisitization than seen at the Artonvilla mine.

Albite occurs as rust-red to mustard-brown to white crystals. The red coloration of the albite has been attributed by Poldervaart and Gilkey (1954) to the addition of ferrous ions to the structure after the albite had formed. The red albite was identified using X-ray diffraction (Jacobsen, 1967). This mineral often occurs as small crystals up to 4 mm, studding the surfaces of the abundant secondary quartz crystals. In addition, both red and white varieties of albite are common in the host rock alteration zones.

Almandine $Fe^{+2}Al_2(SiO_4)_3$

Almandine constitutes up to 70% of the garnet crystals occurring in the host rock and amphibolite. Pyrope comprises 20% and the remaining 10% consists of grossularite (Jacobsen, 1967). These volumetric percentages differ in the biotite-garnet-quartz granulites where almandine constitutes 55%, pyrope 30% and grossularite 15%.

Analcime $NaAlSi_2O_6 \cdot H_2O$

This species of the zeolite group occurs as a pink to white, soft, almost clay-like material occurring in veinlets, veins and irregular masses in the more highly feldspathic rocks (Jacobsen, 1967). At Artonvilla, analcime occurs exclusively in the higher altered albitic rocks, suggesting that it represents the decomposition product of earlier hydrothermal albite. Analcime is frequently associated with calcite, chalcocite, chlorite, native copper and epidote.

Azurite $Cu_3^{+2}(CO_3)_2(OH)_2$

Azurite is a widespread oxidation product of the copper deposits and commonly occurs with malachite. No large crystals have been reported to date. The azurite occurs as encrustations of microcrystals along joint planes and partings in outcrops of the country rock.

Barite $BaSO_4$

Barite occurs sporadically as flattened, orthorhombic crystals of a habit resembling wulfenite crystals. The color of the barite is light beige to tan. Crystals may occur as floater groups. In some cases, spear-shape terminations of larger (>1 cm) crystals may be rimmed with an overgrowth of barite microcrystals of similar habit and color. The barite is a late-stage mineral commonly found to exist on top of the secondary quartz crystals.

Biotite $K(Mg,Fe^{+2})_3(Al,Fe^{+3})Si_3O_{10}(OH,F)_2$

Biotite occurs in the host rocks, particularly the granulites. Hydrobiotite may also be present within the ore zones as hydrobiotite (Jacobsen, 1967) where it occurs in association with sericite.

Figure 13. Ajoite inclusions in quartz crystals to 3.5 cm in diameter, from the Messina mine. Rob Smith collection.

Figure 14. Ajoite inclusions in a quartz crystal, 20 cm, from the Messina mine. Rob Smith specimen.

Figure 15. Hematite inclusions in a quartz crystal, 4.4 cm, from the Messina mine. Don Olson specimen.

Figure 16. Ajoite inclusions in quartz crystals to 5 cm, from the Messina mine. Rob Smith specimens.

Figure 17. **Ajoite, papagoite and epidote inclusions in quartz group 11 cm tall, from the Messina mine. Rob Smith collection.**

Figure 18. **Cuprite and papagoite inclusions in a quartz crystal, 10.4 cm, from the Messina mine (old specimen). Cal and Kerith Graeber specimen.**

Figure 19. **Ajoite inclusions in quartz crystals to 3 cm, from the Messina mine. Cal and Kerith Graeber specimens.**

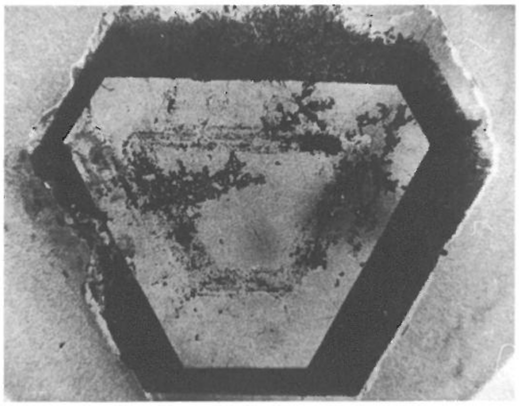

Figure 20. **Thin section of ajoite-bearing quartz. The section is perpendicular to the *c*-axis. The ajoite appears as a black band parallel to the hexagonal crystal form. Diameter of crystal is 9 mm. Author's collection; photo by Mark Hudson.**

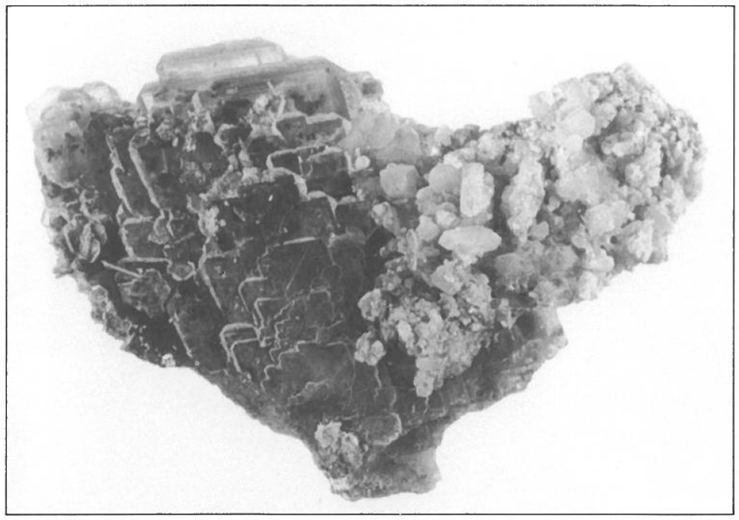

Figure 21. **Group of light brown, parallel barite plates. Small, doubly terminated quartz crystals are attached on the right side of the specimen, which is 10.5 cm long. Messina mine. Rob Smith collection; photo by Mark Hudson.**

Bornite Cu_5FeS_4

Bornite is the most common copper sulfide and is frequently associated with chalcocite. It occurs predominantly as massive peacock-colored ore infilling breccia cavities, and only very rarely forms crystals.

Calcite $CaCO_3$

White to colorless calcite is common as fillings in the breccia voids and is one of the few carbonates present in the orebodies—the others being disseminated malachite and azurite. At Artonvilla, calcite occurs in association with late-stage minerals such as chalcocite, native copper, chlorite and epidote. Jacobsen (1967) suggests that the calcite originated from alteration of the original calcic plagioclase. In thin section, native copper is seen to occur along the intergranular borders between chalcocite and calcite.

Calcite occurs as well-formed crystals, which are usually scalenohedral and in some cases doubly terminated, in all of the mine workings (Söhnge, 1946). Rhombs and scalenohedrons are commonly perched on ore and incorporate quartz, epidote, specularite, chlorite, sericite and the sulfides. Rosettes of calcite 3 to 5 cm in diameter (Söhnge, 1946) are locally present. The light brown color of some calcite is most likely due to limonite staining.

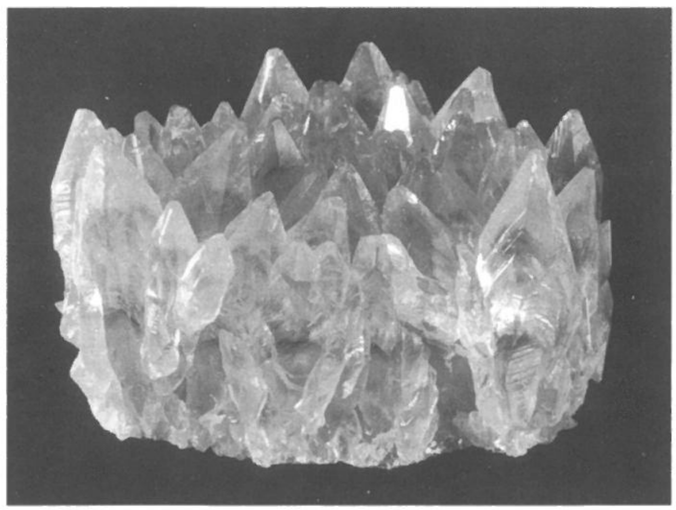

Figure 22. **A group of colorless calcite crystals from the Messina mine. The specimen is 7 cm across. Rob Smith collection.**

Chalcocite Cu_2S

Chalcocite is one of the primary copper minerals in the Messina district orebodies, and occasionally forms euhedral crystals. Chalcocite is generally closely associated with bornite, with maximum concentrations present in the central cores of the lodes. It occurs as discrete, disseminated grains as well as larger, irregular masses and veins parallel to the banding of the host rock (Jacobsen, 1967).

Euhedral and subhedral chalcocite crystals have been found in vugs in some of the underground workings, but mostly in Messina mine (Söhnge, 1946). In one such cavity, a zoned quartz crystal from the Messina mine was found to contain perfect pseudohexagonal crystals of chalcocite, each 1 mm in diameter and closely resembling thick, stubby crystals of biotite. Euhedral chalcocite crystals have also been found perched on chalcopyrite crystals (Söhnge, 1946).

Chalcopyrite $CuFeS_2$

Chalcopyrite was one of the earliest copper sulfides to form in the ores, and it is associated with almost the entire paragenetic range. Chalcopyrite is most commonly associated with bornite, pyrite, pyrrhotite, magnetite and specularite. Euhedral crystals of chalcopyrite are found attached to quartz crystals, and are commonly coated by a dusting of calcite microcrystals.

Beautiful crystal clusters have been recovered from many vugs (Söhnge, 1946). Supergene chalcopyrite stalactites up to 1 cm long and 2 mm across came from a small stope on the 6th level in the Messina mine; the hollow cores are filled with chalcocite and bornite.

Chlorite Group

Chlorite is a prominent alteration mineral commonly associated with epidote and secondary quartz (Laing, 1973). Detailed analytical work in all of the species of chlorite found in the ore lodes has not been conducted, although Jacobsen (1967) lists clinochlore $(Mg,Fe^{+2})_5Al(Si_3Al)O_{10}(OH)_8$ and pennantite $Mn_5^{+2}Al(Si_3Al)O_{10}(OH)_8$ as the most common species.

Chlorite occurs abundantly in the lodes and imparts a gray-green color to many of the quartz specimens, either as external coatings or as inclusions. Laing (1973) states that the pale green color of specimens can be attributed to a mixture of chlorite and sericite.

Clausthalite PbSe

Clausthalite, which forms a series with galena, has been described by Jacobsen (1967) from the Artonvilla mine as "a very minor constituent of the ore." It is found in close association with bornite, chalcocite, specularite and digenite.

Copper Cu

Native copper is relatively common in the Messina deposits, particularly in the central chalcocite zones. Native copper often occurs as inclusions in quartz crystals, generally as flattened copper platelets up to 5 mm in diameter and less than 1 mm thick. Alternatively, the native copper forms extremely fine wires or threads dispersed within the quartz crystals, imparting a very pale, cloudy, copper color to the quartz. Only under high-power magnification can the wire-like habit of the native copper be identified. Native copper also occurs independently as irregular masses and occasionally as aesthetic wires and dendrites.

Söhnge (1946) described elongate, multiple hopper crystals of native copper on chalcocite, quartz, calcite and other silicates. In some cases, the copper projects through scalenohedra of later-formed calcite. Arborescent copper in the form of distorted, polysynthetic octahedral growths, botryoidal clusters and long wires, occurs in cavities between quartz and epidote crystals.

Cordierite $Mg_2Al_4Si_5O_{18}$

Cordierite occurs in most of the garnet-biotite-quartz rocks as anhedral grains containing numerous biotite inclusions. In hand specimens, cordierite is gray-blue in color, but in areas where hydrothermal alteration has occurred, the mineral becomes distinctly greenish.

Covellite CuS

Jacobsen (1967) states that covellite is very rare, and is restricted to zones of late hydrothermal activity at Messina. Covellite and goethite are commonly developed in supergene replacement ores.

Cuprite Cu_2O

Bright red inclusions with native copper in quartz have been qualitatively identified by electron microprobe analysis as "copper oxide," presumably cuprite (Tod Solberg, personal communication).

Digenite Cu_9S_5

Digenite is found only as exsolution lamellae in association with chalcocite and clausthalite.

Epidote $Ca_2(Fe^{+3},Al)_3(SiO_4)_3(OH)$

Epidote is a common hydrothermal mineral in the ore lodes, where it occurs as emerald-green to yellow-green crystals (Laing, 1973). These can partially coat quartz crystals or may be present as isolated lath-like inclusions. Jacobsen (1967) observes that a light-colored apple-green variety associated with chlorite, calcite and albite is common in the Emery Lode. A second occurrence in the lower portions of the lode consists of bright lime-green to yellow-green crystals. These have a slightly lower refractive index than the apple-green variety, but both have been identified by X-ray analyses.

The size of epidote crystals which either fill vugs or adhere to quartz crystals is generally less than 1 cm in length. Individual crystals can however reach dimensions in excess of 5 cm.

Fluorapatite $Ca_5(PO_4)_3F$

Fluorapatite is referred to by Jacobsen (1967) as being rare and found only in the lower levels of the Emery Lode at Artonvilla. Pyrite and chalcopyrite are the only associated sulfides.

Goethite $Fe^{+3}O(OH)$

Jacobsen (1967) states that goethite is the most common iron mineral in the more central portions of the orebodies, where it is characterized by a reddish coloration in hand specimens.

Hematite Fe_2O_3

Hematite forms as an alteration product of hornblende (Laing, 1973) and, to a lesser degree, biotite (Jacobsen, 1967). The early hematite occurs as a fine dust and replacement mineral whereas the later hematite (specularite) frequently replaces magnetite.

The hematite in the Messina district ore lodes imparts a red coloration to many of the minerals, particularly as inclusions in quartz crystals. Specular hematite is commonly associated with quartz as masses of fine platelets either coating the crystal faces or as inclusions. The specular hematite also forms rosettes ("eisenrosen") which, when grouped on specimens, can be very aesthetic. These may also be present as individual rosette-like balls included in quartz crystals.

Hematite is common in the bornite-chalcocite zones of some orebodies. The Harper and Messina mines commonly carry specularite, whereas iron oxide is scarce at the Campbell mine (Söhnge, 1946). In some lodes of the Campbell mine, tabular specular hematite crystals 3 cm in diameter have been found. Similar crystals 3 cm in diameter and 8 mm thick came from a vug in the 21-760 stope in the Messina mine. Locally aggregates of flaky specularite fill vugs up to 2 meters in length at the same mine.

Kaolinite $Al_2Si_2O_5(OH)_4$

Many underground fissures are lined with gray kaolinite, minute flakes of which also coat pyrite and other sulfides. Zoned quartz crystals contain hollow spheroidal aggregates of gray-white kaolinite, attesting to the formation of the quartz during and following kaolinite generation. Cloudy white phantoms in other quartz crystals are defined by thin kaolinite crystals. Söhnge (1946) remarked that beidellite, a member of the smectite group, may also be present but has not been confirmed.

Magnetite $Fe^{+2}Fe_2^{+3}O_4$

Magnetite is one of the primary constituents of the country rock and is usually not associated with the ore zones. In the envelope surrounding the orebodies, magnetite is partially replaced by early iron and copper sulfides.

Malachite $Cu_2^{+2}(CO_3)(OH)_2$

Malachite is a ubiquitous oxidation mineral of the copper sulfides; surface stains and veinlets are found in all of the ancient workings (Söhnge, 1946). Radial clusters of malachite needles up to 2 cm long have been found in crevices in chalcocite ore. Under magnification, the slender prisms show twinning. Malachite crystals grouped in parallel arrangements of prismatic crystals are also found attached to quartz crystals. In thin section, malachite has been seen to form pseudomorphs after prehnite (Söhnge, 1946). In these cases, the malachite assumes an olive-green color rather than the more common bright green.

Molybdenite MoS_2

Söhnge (1946) states that he was told of molybdenite in the K Lode at the Messina mine. Laing (1973) states that "in the foyer of the mine offices a molybdenite sample is indicated as coming from the 19th level of the West Lode, Campbell mine."

Muscovite $KAl_2(Si_3Al)(O_{10}(OH,F)_2$

Two varieties of muscovite occur in the Messina district. Sericite is a common coating on quartz and epidote crystals. Scales and clustered aggregates of sericite deposited on earlier hydrothermal minerals are invariably a glistening white, whereas the sericite derived from wall-rock alteration is, in general, a pale green color. Chromian muscovite occurs as bright green micaceous crystals in all of the host rock meta-quartzites.

Papagoite $CaCu^{+2}AlSi_2O_6(OH)_3$

Papagoite has been observed as cloudy, pale blue inclusions in quartz crystals, and also occurs as massive, isolated lumps. Some samples recently analyzed (R. Turner, personal communication) appear to be plancheite. Although ajoite may have a more blue-green coloration than papagoite, determinative chemical techniques would be needed to confirm the identification.

Figure 23. **Piemontite crystals to 2.4 mm, on quartz from the Messina mine. Don Olson specimen; photo by Dan Behnke.**

Piemontite $Ca_2(Al,Mn^{+3},Fe^{+3})_3(SiO_4)_3(OH)$

The manganese-bearing member of the epidote group, piemontite (referred to as *withamite* by Söhnge), is also present. The crystals range from distinctive, transparent wine-red to opaque rust-red varieties. Some quartz crystals contain inclusions of isolated piemontite crystals up to 5 mm in length.

Prehnite $Ca_2Al_2Si_3O_{10}(OH)_2$

Söhnge (1946) remarks that prehnite may be regarded as a diagnostic accessory of many copper prospects in the fault zones of the district. Distinct crystals of prehnite have not been found.

Pyrite FeS_2

At the Campbell mine, pyrite is restricted to the upper parts of the breccia pipe (Laing, 1973). In thin section, pyrite is seen to have replaced the alteration minerals chlorite, sericite, epidote and secondary quartz. Pyrite can itself be replaced by younger pyrrhotite. Söhnge (1946) notes that pyrite is common in the upper portions of the L Lode at the Messina mine. Apart from these two occurrences, pyrite is comparatively rare in the Messina district lodes.

Pyrrhotite $Fe_{1-x}S$

Pyrrhotite is an uncommon constituent of the ores and generally occurs in the chalcopyrite-rich zones.

Quartz SiO_2

The Messina district is best known for the abundance of quartz crystals that have been produced over the decades. Due to the brecciation of the orebodies, a multitude of cavities, vugs and fissures provided the space for growth of crystals up to almost 1 meter long. Many researchers have remarked on the abundance and diversity of quartz crystals; for example, Laing (1973) observed that:

> a notable feature . . . throughout the breccia pipe (Campbell mine) . . . is the development of vugs which are often lined with well-formed crystals of quartz and calcite.

He later added:

> The early stage of open space filling is dominated by the deposition of quartz which grows from the breccia fragment surfaces outwards, encrusting succeeding layers of quartz forming a typical "cockade" (phantom) texture. In some cases, well-formed prismatic crystals are formed . . . where permeability of the breccia fragments was low and (sulfide) mineralization scarce, open spaces . . . contain well-terminated prismatic crystals.

Table 1. **Minerals reported from the Messina mining district.**

Ajoite	$(K,Na)Cu_7^{+2}AlSi_9O_{24}(OH)_6\cdot 3H_2O$
Albite	$NaAlSi_3O_8$
Almandine	$Fe_3^{+2}Al_2(SiO_4)_3$
Analcime	$NaAlSi_2O_6\cdot H_2O$
Azurite	$Cu_3^{+2}(CO_3)_2(OH)_2$
Barite	$BaSO_4$
Biotite	$K(Mg,Fe^{+2})_3(Al,Fe^{+3})Si_3O_{10}(OH,F)_2$
Bornite	Cu_5FeS_4
Calcite	$CaCO_3$
Chalcocite	Cu_2S
Chalcopyrite	$CuFeS_2$
Clausthalite	PbSe
Clinochlore	$(Mg,Fe^{+2})_5Al(Si_3Al)O_{10}(OH)_8$
Clinozoisite	$Ca_2Al_3(SiO_4)_3(OH)$
Copper	Cu
Cordierite	$Mg_2Al_4Si_5O_{18}$
Covellite	CuS
Cuprite	Cu_2O
Digenite	Cu_9S_5
Epidote	$Ca_2(Fe^{+3},Al)_3(SiO_4)_3(OH)$
Ferrohornblende	$Ca_2(Fe^{+2},Mg)_4Al(Si_7Al)O_{22}(OH,F)_2$
Fluorapatite	$Ca_5(PO_4)_3F$
Goethite	$Fe^{+3}O(OH)$
Hematite	Fe_2O_3
Kaolinite	$Al_2Si_2O_5(OH)_4$
Magnetite	$Fe^{+2}Fe_2^{+3}O_4$
Malachite	$Cu_2^{+2}(CO_3)(OH)_2$
Molybdenite	MoS_2
Muscovite	$KAl_2(Si_3Al)O_{10}(OH,F)_2$
Papagoite	$CaCu^{+2}AlSi_2O_6(OH)_3$
Pennantite	$Mn_5{}^{+2}Al(Si_3Al)O_{10}(OH)_8$
Piemontite	$Ca_2(Al,Mn^{+3},Fe^{+3})_3(SiO_4)_3(OH)$
Prehnite	$Ca_2Al_2Si_3O_{10}(OH)_2$
Pyrite	FeS_2
Pyrrhotite	$Fe_{1-x}S$
Quartz	SiO_2
Shattuckite	$Cu_5^{+2}(SiO_3)_4OH_2$
Sphalerite	(Zn,Fe)S
Zoisite	$Ca_2Al_3(SiO_4)_3(OH)$

Table 2. **Minerals observed as inclusions in quartz from the Messina district.**

Ajoite	Chalcopyrite	Epidote	Papagoite
Azurite (rare)	Chlorite	Hematite	Pyrite
Bornite	Clinozoisite	Kaolinite	Shattuckite
Calcite	Copper	Malachite	Zoisite
Chalcocite	Cuprite	Muscovite	

Söhnge (1946) remarked that the Messina mine is noted for its wealth of beautiful quartz crystals ranging from microscopic size to individual crystals half a meter long. He further noted that doubly terminated crystals up to 10 cm in length have been found in many vugs. The larger crystals are, almost without exception, zoned internally with over a dozen phantom layers occurring in some crystals. Söhnge (1946) observed that the zones can consist of minute inclusions of specular hematite, epidote and chlorite. It is common to find an outer euhedral layer of clear quartz that has grown on the zoned core after the latter has been coated by hematite, epidote, talc, sericite, chlorite, zeolites, malachite or azurite. The presence of flaky specular hematite imparts a striking sheen to well-formed clear crystals. Söhnge (1946) also stated that hollow kaolinitic spherules are sometimes incorporated in the core of quartz crystals from some localities.

The growth habit of the quartz has produced specimens of unusual shapes. Tabular crystals have been formed by the excessive growth of two parallel prism faces or predominant development of three rhombohedral faces at each end of the short prism, producing disc-shaped crystals.

A feature of the quartz crystals is that many are doubly terminated, even individuals in subparallel groups. Another attractive aspect of some quartz specimens is the circling of the base of a large crystal by a peripheral halo of smaller crystals. This often gives an appearance of the larger crystal rising out from a nest of smaller basal crystals.

The included minerals in the quartz specimens cover a wide diversity of species. These have all been described in detail under the individual species subdivisions, but are also listed for reference in Table 2.

Shattuckite $Cu_5^{+2}(SiO_3)_4(OH)_2$

Shattuckite occurs as royal-blue to dark navy-blue inclusions in quartz crystals. The habit may be formless aggregates or may occur as small (<1 cm) circular haloes defined by the parallel arrangement of minute crystals. Shattuckite is usually distinguishable from papagoite and ajoite by its darker blue color.

Sphalerite (Zn,Fe)S

Jacobsen (1967) stated that sphalerite is a rare constituent at the Artonvilla mine while Söhnge (1946) affirmed that sphalerite is a rare accessory found at the Campbell mine. At both of these localities, the sphalerite was only visible in thin section.

Zoisite and **Clinozoisite** $Ca_2Al_3(SiO_4)_3(OH)$

Zoisite and clinozoisite are present in the orebodies although in variable amounts. They are far less abundant at the Artonvilla mine than in the westerly orebodies, and at the Messina mine in particular, where zoisitization is the dominant alteration. Laing (1973) states that zoisite and clinozoisite are usually present as columnar aggregates of pale brown to gray-brown crystals. At the Messina mine, zoisite is white to very pale gray in color and cleaves with a splintery to flaky fracture (Söhnge, 1946).

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