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The Porphyry Molybdenum Deposit of Compaccha, Peru, and Its Geologic Setting

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Compaccha, in Peru, is a zoned molybdenum, copper, zinc, lead, antimony-arsenic district which has historically been important because of tungsten production derived from all zones. Wolframite, the principal tungsten mineral, is zoned compatibly with the sulfides. Manganese tungstate occurs in the molybdenum zone, while iron replaces the manganese increasingly importantly as distance is gained away from this zone. The alteration zoning in and around the molybdenum zone is typical of that of a porphyry copper deposit, in that fluorite, topaz or other fluorine rich silicates are not common. The molybdenum zone does include a porphyry molybdenum deposit, however, and this is characterized by intense silicification and quartz veining (stockworks). Within the area of the deposit, east of the coastal batholith, no Mesozoic arc type or basic volcanics can be inferred. A cratonic setting is postulated for the deposit.

Introduction

Compaccha is a zoned polymetallic district containing a molybdenum porphyry in its core which is surrounded by tungsten, zinc, lead and antimony deposits in its outer limits. It is located at 77° 59′ W, 8° 02′ S in Santiago de Chuco province, La Libertad Dpto, Peru, via Quiruvilca on the Pasto Bueno (Conzuso) road, an all weather dirt road.

These studies were completed between 1961 and 1964 and no additional exploration has been undertaken since then.

Historically, Compaccha is a wolframite (tungsten) producer, (MALAGA SANTOLALLA 1954) with the production coming from large, individual quartz veins containing minor amounts of tungstates and sulfides. MALAGA SANTOLALLA (1954) refers to Compaccha as Tamboras and Mundo Nuevo. This paper combines both areas into one zoned district. Its future potential, however, appears to be largely as a molybdenum-tungsten producer, with the Mo coming from a molybdenum porphyry present in the heart of the district.

Geologic Setting

Regional Geology

Fig. 1 (after HOLLISTER 1974) shows, in outline form, the general geologic setting of the Compaccha district. It lies in an area of outcropping Mesozoic shelf sediments, though the appearance of pre-Mesozoic to the east, north and northwest suggests that the Mesozoic sedimentary section is erratic in thickness and distribution.

Precambrian metasediments have been identified in the pre-Mesozoic rocks. These are Proterozoic schists to the east and northwest and undated gneisses and schists to the east. Permian phyllites occur in the pre-Mesozoic outcrop to the west of Compaccha, near the coast. Middle Paleozoic as well as Permian sediments have been identified in the pre-Mesozoic to the east. A cratonic basement is therefore inferred to exist for the Mesozoic sedimentary sequence, and the absence of basic volcanics in the vicinity of Compaccha suggests the orogen to be essentially ensialic.

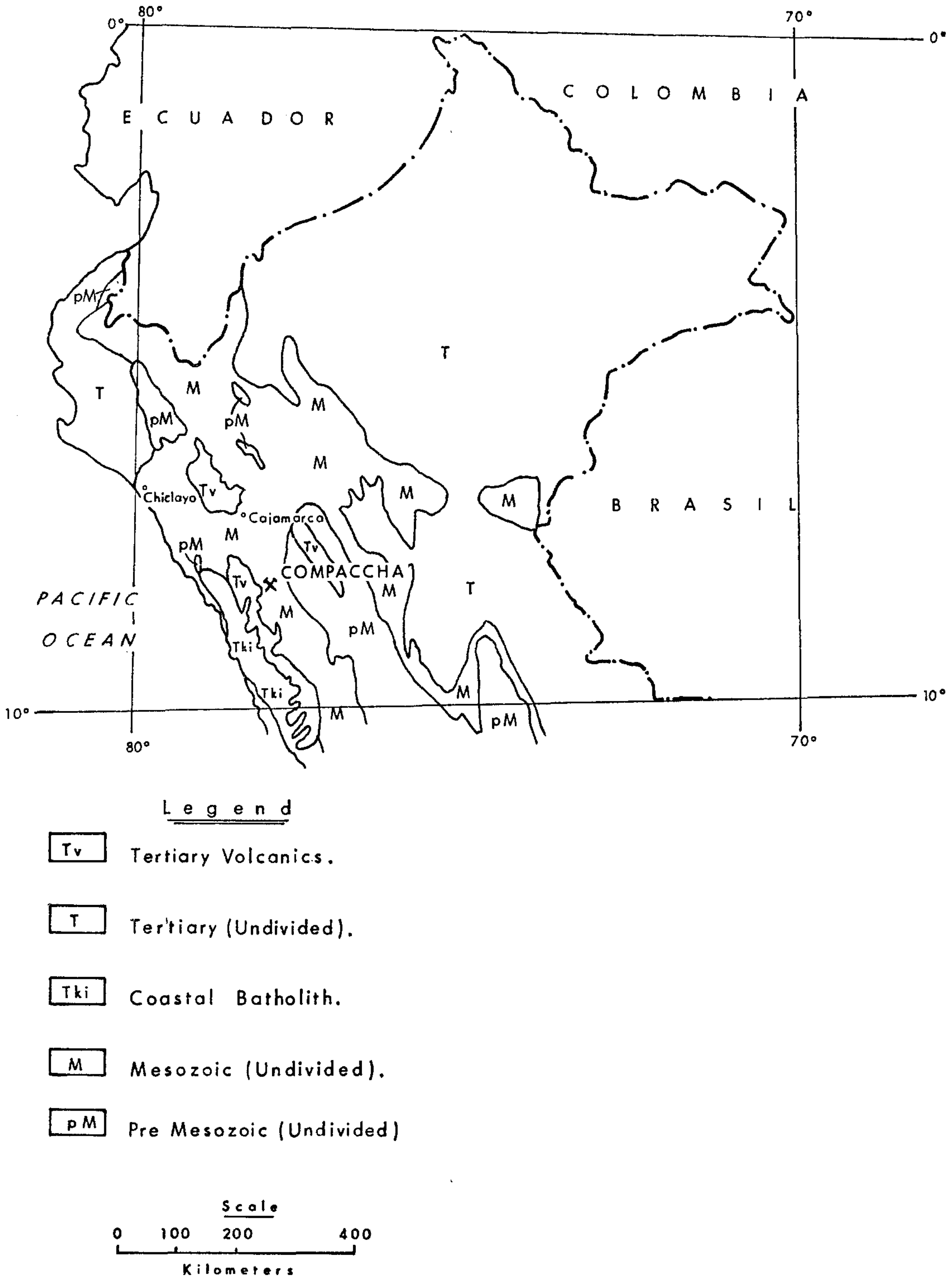

Fig. 1. Geologic Index Map Compaccha, Peru

The region around Compaccha contains strongly folded Jurassic Chicama shales and Cretaceous quartzites and limestones. Both are considered shelf sediments deposited on the pre-Mesozoic basement. Both are variable in thickness, but probably come to less than 20,000 feet (or 7,000 meters) in aggregate near Compaccha. No thick or repeated arc volcanics are indicated to exist east of the Coast batholith in this part of Peru in the Mesozoic, suggesting the absence here of the Mesozoic arch-trench sequences so well developed in Chile and Ecuador. Folding believed to be Upper Cretaceous in age has affected all the Mesozoic rocks. Post folding Tertiary Calipuy (?) andesitic continental volcanics occur between the batholith and Compaccha.

The Compaccha district is localized along a N 50° W trending, multi-strand, strike-slip fault, the Compaccha fault. Generally the Jurassic Chicama shales lie west of this fault, and the Cretaceous lies to the east, though both occur on each side. Flat lying Tertiary andesitic volcanics may also be seen mostly on the east as irregularly shaped erosional remnants. Though not dated, these seem to be Calipuy equivalent (within the useage of Stewart *et al.* 1974). However, Noble *et al.* (1974) note volcanics in central Peru with frequent dates younger than the Calipuy and containing a similar petrography. Tertiary volcanics at Compaccha are thus not well established in age, though a mid-Tertiary age for them is preferred at this time. Stewart *et al.* (1974) also report numerous age determinations on plutons south of Compaccha (Cordillera Blanca) with dates in the 9 to 10 m. y. range. Compaccha may have an age comparable with these dates, or be 9–10 m. y.

Strong compressional folding preceded the development of the Compaccha strike-slip fault, since this fault cuts fold axes in the Mesozoic sediments. The fault trends southeasterly from Compaccha, and the copper-tungsten district (enargite-wolframite-molybdenite) at Pasto Bueno (see Fig. 4) lies on it, 22 km to the southeast. Magistral, (see Fig. 5) a major copper-molybdenum district, lies 30 km southeast of Compaccha, also on the fault. No specific offset has been assigned to the fault, but Tertiary Calipuy (?) volcanics immediately north of Compaccha are identical to other volcanics west of the fault, 10 km to the northwest. Post-volcanic erosion of the volcanics makes correlation hazardous, but a west block north movement appears logical in this setting. The main strand of the fault appears to dip steeply east in Compaccha and Pasto Bueno, though it dips west in Magistral, and in each of these districts, mineralization was accompanied by a complexly shaped, fault controlled quartz monzonite intrusion. For additional details on Magistral, please see Terrones (1958). Malaga Santolalla (1954) provides background on Pasto Bueno (Conzuso).

District Setting

Within the Compaccha district itself, intrusions, alteration and mineralization all are primarily controlled by faulting. The various strands of the Compaccha fault provided most favorable access to the surface; hence the intrusions and hydrothermal products preferentially occupy these fractures.

Plutonic Rocks

Within the district, all igneous rocks shown on Figs. 2 and 3 are pyritized and propylitized to some degree, so that compositions of feldspar are not determinable. Two plutonic types are identifiable, however. These are an older andesite, and a younger quartz monzonite porphyry. So that the size of the district may be appreciated, the coordinates in both Figs. 2 and 3 are in meters.

The andesite occurs as small bosses and dikes intruding Chicama shale. Though commonly propylitized, these do not have metamorphic or alteration zones around them. Nor are they frequently associated with vein deposits. These appear to be part of a clearly pre-mineral period of volcanism, and the andesitic Tertiary flows near the district may be comagmatic with these intrusions. The older implied age is compatible with a Calipuy designation for the andesite.

The most irregularly shaped and largest intrusions comprise the younger quartz monzonite porphyry complex of dikes, sills, bosses and stocks. These intrusions also are altered wherever found in outcrop, and fresh specimens are not available. The quartz monzonite is

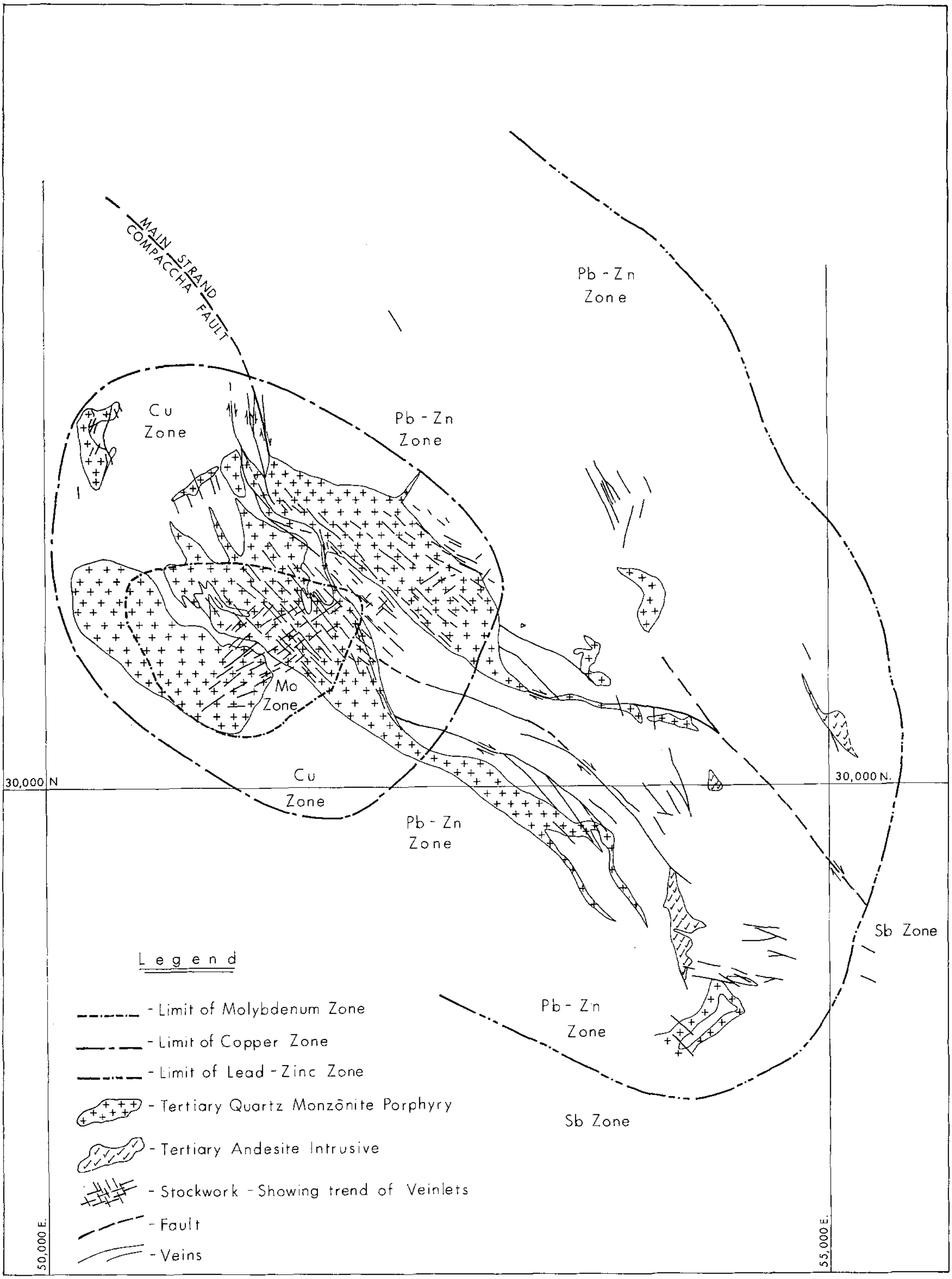

Fig. 2. District Geologic Map, Compaccha

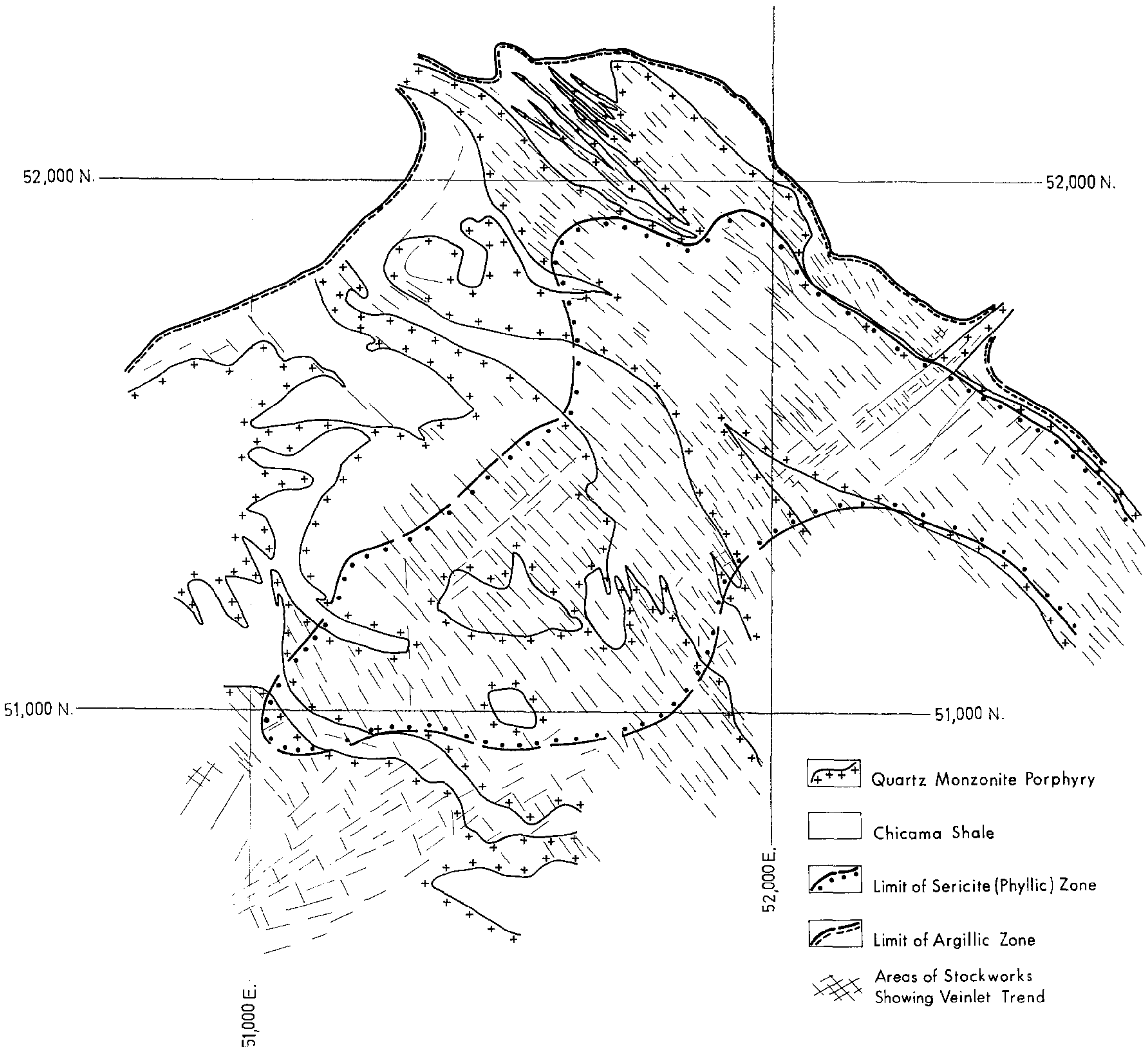

Fig. 3. Stockwork Area, Compaccha

characterized by euhedral to subhedral quartz and euhedral feldspar phenocrysts. Included with the quartz monzonite porphyry are small aplitic and pegmatitic dikes. Thermal metamorphic halos are largely missing around these intrusions.

No volcanics having a composition approaching that of quartz monzonite have been detected. Their absence is considered significant, since andesite extrusives believed to be comagmatic with the pre-quartz monzonite andesite plugs exist, while no such extrusive equivalent of the younger quartz monzonite has been found. This omission in the volcanic sequence suggests the possibility that few, if any, extrusives accompanied the quartz monzonite plutons. The absence of extrusives identifiable as being comagmatic with the quartz monzonites at Pasto Bueno and Magistral conforms to the setting at Compaccha.

District Structure

The various strands of the Compaccha fault may be occupied by plutonic rocks in irregular but elongate bodies. By providing planes of weakness into which the magmas could be injected, the Compaccha fault largely controlled the location and ultimate shape of the igneous intrusions. Fig. 2 shows the main strand of the Compaccha fault and the mineralized strands which are the district's principal veins. Where the fault strands are not occupied by either igneous or vein material, they are not easily detectable in the shales, and are omitted from the figure. Some small quartz monzonite dikes trend N45E in the molybdenum zone, suggesting that a N45E cross fault occurs in this area in addition to the NW trending Compaccha fault. The implication exists that both the N45E cross fault and the Compaccha fault were active during intrusion of the quartz monzonite. Though most dikes are too small to show in Figures 2 or 3, the largest are shown on these figures. Fault straie on the walls of the largest NE trending dike are nearly horizontal, suggesting horizontal fault movement. The molybdenum zone therefore appears to occur at the intersection of N50W and a N45E trending strike-slip faults. This intersection also coincides with the center of magmatic activity.

District Metal Zoning

The core of mineralization in the district is the molybdenum zone. Laterally around this is a zone where occasional enargite, apparently accompanied by lesser tetrahedrite and chalcopyrite, occurs in the quartz vein structures. Adjacent to the enargite zone at the suface is a large area where spalerite and galena occur in the veins. Outside of the zinc-lead zone, antimony (as stibnite) and arsenic (as realgar) can occasionally be seen. The areas where these metals occur as vein constituents are shown on Fig. 2, modified after MALAGA SANTOLALLA (1954).

Wolframite occurs in all metal zones and in the past has been the most important economic mineral produced in the district. In the molybdenite zone it occurs as deep red hubnerite, and in the outer margin of the Zn-Pb zone it occurs as an iron rich ferberite (HOLLISTER 1970). A continuous lateral change from the manganese tungstate to the iron may be observed in moving outward from the core area. The manganese:iron ratio is a function of distance from the core area where the molybdenite occurs. Because of the gradational characteristics of wolframite zoning, it is omitted from Fig. 2.

The molybdenum-hubnerite zone is located at the intersection of the Compaccha fault and the N45E fault. The other zones are elongate with the Compaccha fault, successively surrounding the molybdenum zone.

District Mineralization

Sulfide (molybdenite, enargite, tetrahedrite, chalcopyrite, shalerite, galena, stibnite) and oxide (wolframite) ore minerals are almost entirely found in quartz filled fractures. The quartz:ore mineral ratio normally is 10 or greater. Pyrite also occurs erratically in the quartz veins. Vein walls are always sharp, though they may either be "frozen" or fault bounded. The larger veins usually show repeated openings, while the smaller veins and veinlets may show only one period of opening and filling.

Within the molybdenite and enargite (copper) zones, well developed stockworks outcrop, and the principal trend of the stringers is N50W. A subsidiary trend strikes N45E. Fig. 3 is the detailed map of the stockwork area.

Molybdenum Zone

The molybdenum zone occurs wholly contained within the only place in the district where N45E fractures occur together with the dominantly N50°W fractures. Since each set can be seen cutting and also being truncated by the other set, simultaneity of movement is indicated for each set. Molybdenite occurs as vein filling in the fractures, and since fracture density is adequate to qualify use of the term stockwork, the molybdenum zone is characterized by a stockwork of quartz-sulfide veinlets.

The host rocks, as shown in Fig. 3, consist only of quartz monzonite porphyry intruding Chicama shale. In detail the intrusion is very complex since it is primarily controlled by numerous strands of the Compaccha fault, and it silled out following bedding in the shale as well. The shales appear to have been contorted by forceful injection of the magma as well as by dragging during fault movements.

Alteration Zoning

Fig. 3 presents the alteration zones as indicated on the surface. No readily identifiable potassic zone, consisting of orthoclase, biotite or chlorite has been found at the surface. One may have existed, but supergene alteration, resulting from the oxidation of pyrite, has apparently destroyed any near surface orthoclase and masked such a zone, if it had indeed any surface expression.

A very large quartz-sericite-pyrite zone exists over much of both the copper zone and molybdenum zone. As shown in Fig. 3, it is irregular in outline and includes hydrothermally sericitized shales as well as quartz monzonite. The sericite zone associated with molybdenum does not appear to carry prominent fluorite, topaz or other fluoro-silicates typical of greisens. Fluorine may be present in the sericite, but the lack of topaz or other fluoro-silicates does not qualify this phyllic zone as a greisen. Silicification, as a pervasive replacement alteration product, is variable in the quartz-sericite-pyrite zone. The eastern part of zone carries the most intense, widespread silicification in the district though other parts of the sericite zone are also silicified. Most silica added to the rocks, on the other hand, occurs in veins as quartz, apart from the pervasive silicification. Pyrite accounts for about 4% of the phyllic zone rocks, as a dissemination in the sericite-quartz matrix. It occurs both in altered shale as well as altered quartz monzonite porphyry.

An argillic zone consisting mostly of bleached but not sericitized shale surrounds the sericite (phyllic) zone.

A propylitic zone beyond that consists mostly of partly bleached shale or chloritized intrusive.

The core of the alteration sequence is clearly the intersection of the Compaccha and the N45E faults. This intersection is now encompassed by the sericite-quartz-pyrite zone, with the other zones occurring peripheral to it.

Structure

In the molybdenum zone, the stockwork of quartz-sulfide veinlets dominates and tends to mask all other structure. For the most part it consists of two sets of veinlets, most of which are under one cm wide, and most of which are less than 10 cm apart. The veinlets appear to be sub-parallel in each set. Veinlet intersections suggest that the N50°W set may terminate veinlets in the N45°E set, though the reverse is also true. The logical conclusion of this observation is that the two sets formed simultaneously. Most of the veinlets trending NW dip steeply east, and where fault straie are visible, are nearly horizontal. A few of these veinlets do have visible vertical striations, suggesting some vertical movement at some time on a few stringers.

Fault straie on the NE trending set also are nearly horizontal, and one possible interpretation of the intersections visible in outcrop between the NE and NW trending veinlets is that the north side of the mineralized fracture moved east horizontally.

Clearly the two principal veinlet sets do not make a conjugate pair. Each is a shear, rather than a tension fracture, that has opened and been filled with mineral, and for most of the veinlets, the opening occurred only once. The set trending N50W appears to be an integral part of the Compaccha fault, with each veinlet a separate strand of the fault itself. In this case, the mineralization is clearly part of a major transcurrent structure.

The stockwork occupies the intersection of the two major faults, and it is the heart of igneous activity, mineralization and alteration. The stockwork is a product of mineralization during simultaneous, repeated movement on the two faults over a prolonged period of time.

Mineralization

Within the molybdenum zone, molybdenite and pyrite appear to constitute about 90% of the total sulfide, though partial oxidation to 300 meters or more below the surface makes a precise figure difficult to construct. Enargite appears to have constituted much of the remainder of the sulfide. Occasional copper staining in some veinlets are all that now remain of this mineral at the surface.

Hubnerite occurs erratically with the molybdenite in the quartz veins. The average ratio of Mo to WO_3 appears to be 10, where the stockwork will average more than 0.2% Mo. The vast predominance of quartz in the veinlets does not permit frequent exposures of molybdenite in contact with hubnerite, but those noted suggest the hubnerite to be younger.

The molybdenite occurs as gray smears on walls of veinlets, as very fine grained material clouding vein quartz, and occasionally as continuous veinlets of very fine grained sulfide wholly within the quartz.

The stockwork extends beyond the molybdenum zone to the east. In this area, the sulfide content of the veins increases, though complete oxidation at the surface prohibits a precise description of the hypogene mineralogy. It would seem likely that enargite would be one of the principal hypogene minerals present in this area. The stockwork may also be very well developed, giving the rock an overall quartz content of 80%, but the molybdenite may be almost entirely missing at the surface.

Discussion

The Compaccha fault is mineralized in three areas: Compaccha, Pasto Bueno and Magistral. Each district contains mineralization associated with a calc-alkalic, quartz phenocryst porphyry, and in each district, volcanics that may be assigned a role comagmatic with the quartz monzonite are missing. All three plutons intrude Mesozoic sediments, and in each district mineralization may be closely tied to the pluton spatially and temporally through a structural interpretation of the setting of the pluton, distribution of the ore minerals and alteration zoning. From the northwest to the southeast these are dominantly molybdenum-tungsten, tungsten-copper-molybdenum and copper-molybdenum. Some speculation is justified to explain the change in metallogeny along the fault, since both a molybdenum porphyry (Compaccha) and a porphyry copper (Magistral) occur along it.

The regional geologic setting of Compaccha and the area to the north, east and west is that of a craton with a thin cover of folded but unmetamorphosed Mesozoic sediments. Erratic but small exposures of Tertiary andesite near Compaccha indicate a short period of pre-mineral, arc type volcanism may have existed in the middle Tertiary.

The Compaccha fault offsets granite porphyry (granite of MALAGA SANTOLALLA 1954) and is mineralized as large quartz veins at Pasta Bueno, as shown in Fig. 4. The quartz veins carry minor wolframite and enargite, and lesser amounts of sphalerite and pyrite. Molybdenite also occurs in quartz veins in this district. Mineralization closely followed intrusion.

At Magistral, the N45W trending Compaccha fault intersects the east-west striking Magistral fault, with the intrusion elongated along the Magistral fault. TERRONES (1958) notes that the Compaccha fault (though unnamed in his description) has reverse movement. Chalcopyrite-molybdenite mineralization occurs most importantly in a skarn which surrounds the pluton, though ore occurs in the stock as well. Fig. 5 shows evidence for closely associated fault movement, intrusion and mineralization at Magistral.

Pre-Mesozoic rocks are unknown southwest, west or south of Magistral, which itself is surrounded Upper Cretaceous limestone. A wide surface cover of Cretaceous shelf sediments is exposed, however, with only a small percentage of the surface covered with Tertiary igneous rocks. A cratonic setting which includes Precambrian cannot be demonstrated to exist on the basis of surface exposures. The same period of middle-late Tertiary volcanism present to the north of and near the Compaccha exists to the south of Magistral.

The difference in metallization along the fault from Compaccha to Magistral may possibly be ascribed to a change in the composition or thickness of the crust where it is penetrated by the Compaccha fault, providing the fault had the same depth of penetration in each district. If the crust thinned significantly from Compaccha to Magistral, then the fault could have tapped a different source of fluids in each case. Had the Compaccha fault a different depth of penetration at Magistral than at Compaccha, then conceivably the products of metallization would also be different. The structural link binding the two deposits together, the Compaccha fault, conceivably may have had a different depth of penetration in each district, though such a speculation is not favored in such a short distance for a major strike-slip fault. A distance of only 30 km separates the Magistral porphyry copper, a chalcopyrite dominant Cu-Mo porphyry with well developed skarn mineralization, from the Compaccha porphyry molybdenum deposit.

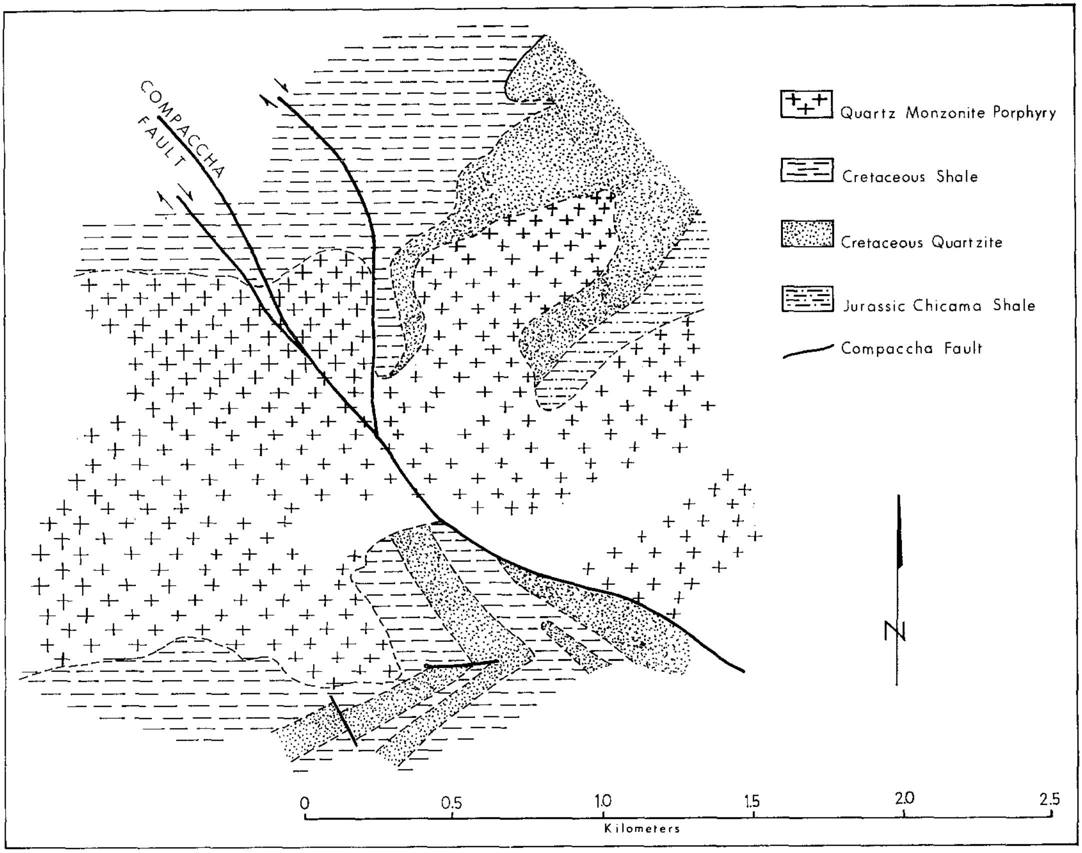

Fig. 4. District Geologic Map, Pasto Búeno

Another factor could be the relative ages of the deposits, though at present neither are radiometrically dated. On stratigraphic evidence both are considered Miocene or younger, and to be penecontemporaneous.

NOBLE (1974) suggests a sub-crustal source for metals such as are found in Compaccha, Pasto Bueno and Magistral, while MITCHELL and GARSON (1972) tie such metal zoning to a subduction zone. The speculation involved in linking metallogenic change to an implied change in crustal thickness should be considered, however, since LOWELL (1974) finds much difficulty in applying the subduction oriented hypothesis of MITCHELL and GARSON (1972) to the Cordilleran orogen in North America. Should the lithophile elements be derived from the crust, while the copper is subcrustal, the speculations concerning penetrations of the Compaccha fault are strengthened. No support for any hypothesis of metal source may be decisive, however, until rubidium-strontium ratios for the plutons are obtained, and until stable isotope data are available for the ore minerals.

Conclusions

The Compaccha district occurs where a N 45 E trending cross fault intersects the N 50 W trending Compaccha fault. The core of igneous intrusion, the center of hydrothermal activity, and the area of stockwork development are all geographically associated with the intersection and appear to be genetically related to it. All were developed during continuing simultaneous movement on both faults. Mineral zoning suggests that the heart of mineralization is the

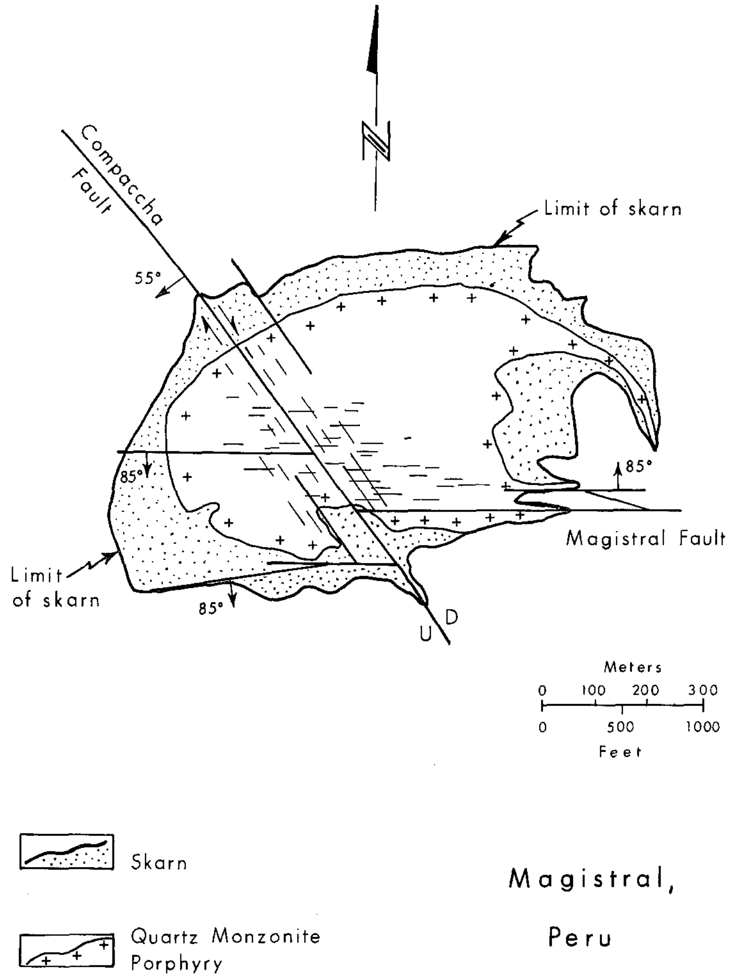

Fig. 5. District Gealogic Map, Mapistral

intersection, and the structure present indicates that mineralization closely followed intrusion of the quartz monzonite as one continuous igneous-hydrothermal event.

Magistral, a Cu–Mo porphyry copper deposit with a large skarn developed around its mineralized intrusive, lies 30 km southeast of Compaccha's porphyry molybdenum-tungsten deposit. Both occur on the Compaccha fault, and no ready explanation exists for the occurrence of two contrasting porphyry types on one regional structure so close together. The Pasto Bueno tungsten district lies between the two and is only 8 kilometers from Magistral. Differences in mineralization between Magistral on the one hand and Pasto Bueno and Compaccha on the other most logically seem explained by different levels of the crust or mantle serving as the metal source in the two contrasting types of deposits. Whether this is a product of different depth of penetration of the Compaccha fault in each case, or whether it is a result of a change in the thickness of the crust or of its composition is not known.

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