VHMS- AND SEDIMENT-HOSTED BASE METAL OCCURRENCES IN THE COLOMBIAN CORDILLERAS

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INTRODUCTION

Volcanogenic and sediment-hosted base metal deposits from the Colombian cordilleras are considered in the light of tectono-genetic models for these deposit types, integrated into the geology and tectonic assembly of the Northern Andean Block (Cediel et al., 2003). Various distinct metallogenic settings containing important but sub-explored base metal mineralisation are reviewed. Examples include 1) Cu (U) Belt - type mineralisation within the early– middle Paleozoic stratigraphy 2) SEDEX and Sediment-Hosted Zn (Pb-Ag) and Cu (Ag) mineralisation associated with late Mesozoic continental-margin rifting, and 3) Cu-Zn (Pb, Au, Ag) Volcanic-Hosted Massive Sulphide mineralisation associated with intra-oceanic magmatic arc development and accretionary tectonics during the Meso-Cenozoic Northern Andean Orogeny.

FARALLONES GROUP CU OCCURRENCES

Stratiform Cu (U-V-Ag-Zn) mineralisation hosted within red bed-associated meta- arenites, pelites and carbonates, comprising the basal portion of the Devono-Carboniferous Farallones Group, is observed along the eastern-most margin of the Eastern Cordillera and Quetame Massif. Reconnaissance and preliminary exploration in the 1970's and early 1980's resulted in the discovery of dozens of metalliferous geochemical anomalies contained within a NNE-striking belt (Figure 1) reconnoitred for *ca.* 100 km along strike, between the villages of Santa María in the north and Caño Negro in the south. Stratiform Cu mineralisation is observed at numerous localities within the Farallones Group) including in the Cerro del Cobre, Farallones de Medina and Caño Negro areas, where it has been traced during reconnaissance mapping in relatively consistent out croppings for ten's of kilometres along strike. Mineralisation is generally concentrated within a few hundreds of metres of the base of the Farallones Group section, just above the unconformity with the underlying Quetame Group. It consists of disseminations of pyrite, digenite, chalcocite, bornite, chalcopyrite and covellite hosted within meta-quartz arenites, pelites and locally, dolomitic\calcareous rocks. Copper grades as high as 16% are observed locally, often in association with secondary Cu minerals including azurite and malachite and\or, native Cu. Historic analyses returned values as highs 1.6% U, 1.33% V, 0.15% Zn and 44 ppm Ag (Rodríguez and Warden, 1993). Locally enhanced U and V grades show a clear affinity for organic-rich stratigraphic horizons.

SERRANIA DE PERIJÁ VOLCANO-SEDIMENTARY CU (AG) OCCURRENCES

Thick volcano-clastic deposits are associated with Triassic – Jurassic continental margin rifting and back-arc basin formation along the northwestern-most margin of South America. Copper mineralisation is observed regionally, hosted within various intervals of the La Quinta – Girón Formations of Colombia and Venezuela (Figure 1). These formations range from 1,000 to 1,700 m thick and comprise dominantly interbedded arenitic and arkosic sandstones with lessor intercalated conglomerate and shale, mostly of redbed affinity. The sequences are intruded by\intercalated with bimodal igneous rocks, ranging from basalt and hornblende bas-andesite to quartz latite\monzonite in composition. The La Quinta – Girón Formations are correlatable along the eastern and westen margins of the Serranía de Perijá, the eastern margin of the Santander Massif, and the southwestern margin of the Sierra de Merida. Four distinct types of Cu mineralisation, exhibit a distinct spatial relationship with the igneous components of the La Quinta-Girón Formations: 1) amygdaloidal infillings of native Cu (tenorite, malachite, azurite) hosted within mafic volcanic flow tops, 2) disseminated chalcocite (bornite, chalcopyrite, pyrite +\-ashphalt) hosted within coarse-grained arkoses and conglomerates, 3) veinlet-hosted and disseminated bornite (covellite, pyrite) within and surrounding quartz monzonite\latite sills\flows, and 4) minor chalcopyrite-chalcocite (covellite, malachite) within\along the margins of mafic dykes cutting sedimentary rocks. Selected ("grab") samples of conglomerate-hosted Type 2 mineralisation have returned values of over 4% Cu (R. Shaw. Pers. data), whilst arkose-hosted mineralisation has ranged from 0.4 to 0.9% Cu. Representative samples of Type 4 mineralisation reportedly returned values of 0.6% Cu with up to 10 ppm Ag (Maze, 1982).

SAN PABLO FORMATION CU (AG, ZN) OCCURRENCES

In the early to middle Cretaceous, the progressively broader and deeper nature of crustal extension\rifting in the northern Andes is recorded within the culminant opening of the Valle Alto rift. Marked by bimodal tholeiitic – alkaline magmatism, growth fault-controlled restricted basin marine sedimentation, and the generation of new oceanic crust, the Cretaceous volcano-sedimentary sequences filling this rift host a variety of Cu and Zn (Pb, Ag) occurrences. The San Pablo Formation (Figure 1) includes a N-S striking belt of early to mid-Cretaceous age. At El Azufral, near the town of Guadalupe, Antioquia, various horizons of massive sulphide containing chalcopyrite, pyrite, pyrrhotite and magnetite, hosted within intercalated siliciclastic and pyroclastic rocks. The largest out crops are observed in the Quebrada Azufral and measure up to 70 m along strike by 12 m in true thickness. Channel samples from this outcrop have returned up to 7% Cu and 19 ppm Ag with less than 0.5% Zn per tonne (R. Shaw, pers. data). The San Pablo Formation extends for some 60 km along strike to the north. Tectonic considerations, litho-stratigraphic relationships and sulphide textures and compositions suggest the occurrences belong to the Besshi-type of volcano-sedimentary hosted Cu (Zn) massive sulphide deposits.

EASTERN CORDILLERA ZN (PB, AG) OCCURRENCES

The Cretaceous-Cenozoic sedimentary sequences of the 35,000 sq. km Eastern Cordillera host over one hundred known base metal manifestations. The most important are Zn (Pb-Cu-Ag-Ba)-dominated, and are hosted within the lower portion of the overall Eastern Cordillera rift-basin. Mineral occurrences include syngenetic stratiform disseminations, lenses and horizons of fine-grained sulphides (sphalerite-galena-pyrite +\- chalcopyrite) hosted within organic shales and siltstones are observed at various localities. Occurrences may be accompanied by barite and Fe-rich carbonate (siderite, ankerite) horizons and\or veining. Another variety of high grade Zn mineralisation is characterised by the occurrence of apparently epigenetic, mantiform bodies and cross-cutting veins of coarsely crystalline sphalerite hosted within organic shales. Known structures, such as at Supatá, Cundinamarca are up to 4 m thick, yielding grades of +55% zinc (R. Shaw, pers. data), and have been locally mined as direct shipping ore. Similarly high Zn grades are also noted in sulphide replacement bodies hosted within Early Cretaceous limestones, including the Rosablanca Formation, where, at Quebrada Cedilla mineralisation grading 57% Zn and 1.33% Pb is recorded.

CAÑAS GORDAS ZN-CU (PB, AU, AG) VHMS OCCURRENCES

The Cañas Gordas terrane (Figure 1) consists of a oceanic volcano-sedimentary sequence of Cretaceous age, containing basalts, andesites and pyroclastic rocks of volcanic arc to continental margin affinity, carbonaceous chert, siltstone and argillite. The sequences host polymetallic massive sulphide deposits of apparently volcanogenic origin, the best known of which include El Roble and Niverengo.

The Cretaceous El Roble deposit, located near the town of Carmen de Atrato, Chocó, was explored by Kennecott Minerals Co. from 1981 to 1983, and eventually placed into production at 300 tpd by the Colombo-Japanese consortium EERESA. Initial proven and probable reserves were quoted as 1.1 million tonnes grading 4.9% Cu, 3.7 g Au and 9.8 g Ag per tonne. The main deposit forms a steeply dipping lense, some 200 m long and up to 45 m in thickness. It is hosted within a structurally complex, isoclinally folded and faulted series of carbonaceous black, grey and white cherts, near the faulted contact with tholeiitic basalt to the west. Mineralisation appears as fine grained admixtures of high-grade massive to finely laminated sulphides and low-grade siliceous and chloritic stringer and breccia ore. The mineralogy consists of pyrite, chalcopyrite and pyrrhotite with electrum and minor sphalerite. Recent exploration has been successful in discovering additional resources and prospects in the area. The El Dovio – Sabanablanca occurrences located some 150 km to the south demonstrate some similarities to El Roble.

The Niverengo-Pastorera massive sulphide occurrence is located in the Quebrada Niverengo valley, near the town of Anza, Antioquia. The occurrence was discovered in 1999, during development of a gypsum mine by the company Exman Ltda. of Medellín. Subsequent excavations revealed polymetallic and pyritic sulphide mineralisation over an *ca.* 400 m strike length, in horizons up to 10 m thick. The host sequence consists of a deformed series of Cretaceous andesitic to dacitic (?) flows and pyroclastic rocks, with lessor mudstone, chert and volcano-sedimentary breccias in thrust fault contact with basalt, chert and mudstone to the west. Mineralisation occurs as a series of tectonised horizons of fine-grained, laminated to massive exhalitive sulphides dominated by sphalerite, galena and chalcopyrite, surrounded by and structurally intercalated with abundant pyritic exhalations and replacements, grey to white gypsum, anhydrite, barite and silica\exhalative chert. Selected samples of mineralisation returned grades as high as 29% Zn, 22.5% Pb, 2.3% Cu, 216 ppm Au and 29 ppm Ag per tonne (R. Shaw, pers. data). Recent drilling has demonstrated various zones containing high-grade mineralisation distributed over a >1.5 km strike length. Gypsum resources exceed 1,000,000 tonnes, and are considered indicative of the, long-lived nature of the hydrothermal system.

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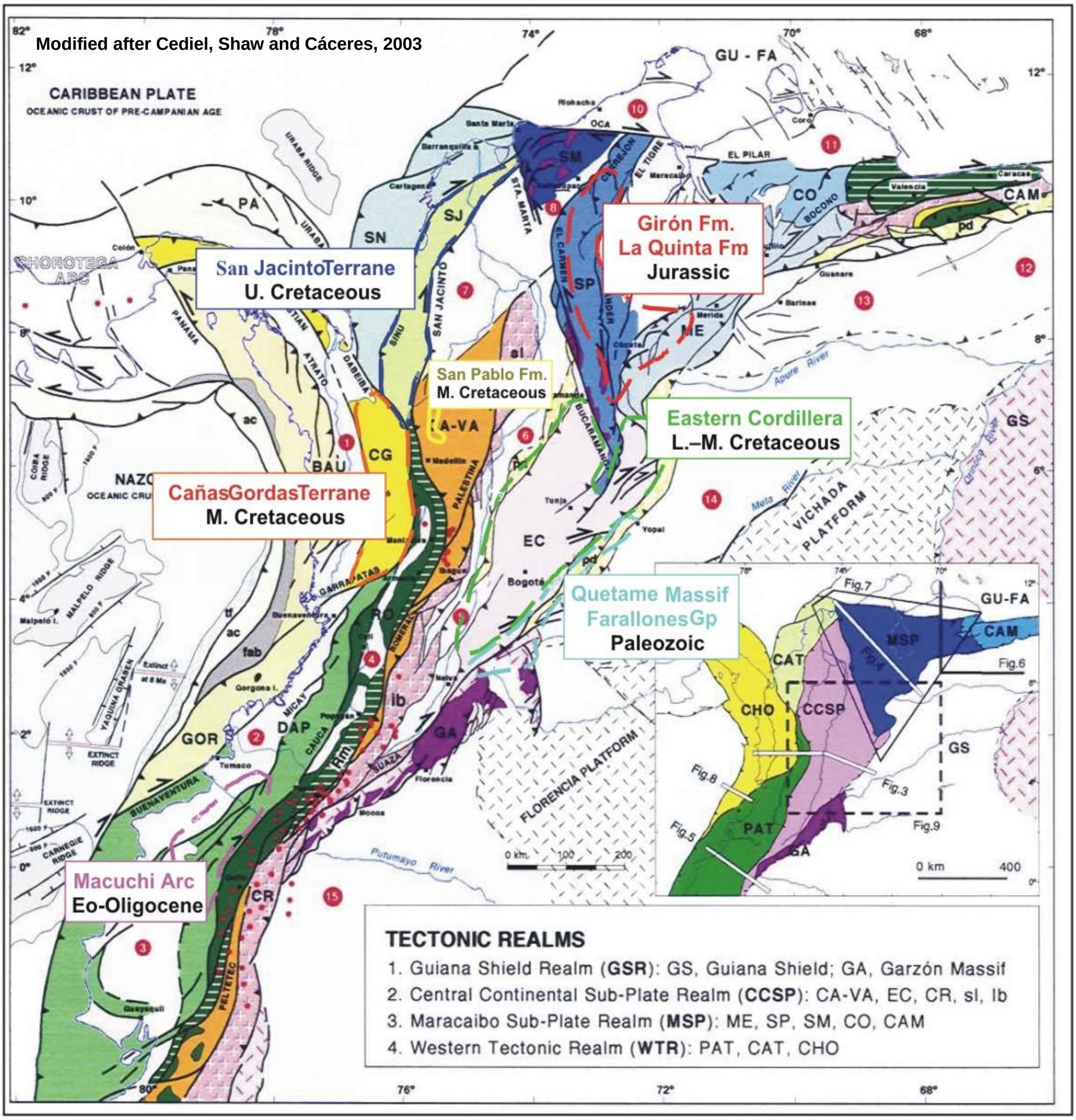

Figure 1: *Litho-tectonic and morpho-structural map of northwestern South America highlighting tectonic assemblages hosting known volcanogene and sediment-hosted base metal occurrences. Base image after Cediel et al. (2002). GS = Guiana Shield; GA = Garzón massif; SP = Santander massif – Serranía de Perijá; ME = Sierra de Mérida; SM = Sierra Nevada de Santa Marta; EC = Eastern Cordillera; CO = Carora basin; CR = Cordillera Real; CA-VA = Cajamarca-Valdivia terrane; sl = San Lucas block; ib = Ibagué block; RO = Romeral terrane; DAP = Dagua Piñón terrane; GOR = Gorgona terrane; CG = Cañas Gordas terrane; BAU Baudó terrane; PA = Panamá terrane; SJ = San Jacinto terrane; SN = Sinú terrane; GU-FA = Guajira-Falcon terrane; CAM = Caribbean Mountain terrane; Rm = Romeral melange; fab = fore arc basin; ac = accretionary prism; tf = trench fill; pd = piedmonte; 1 = Atrato (Chocó) basin; 2 = Tumaco basin; 3 = Manabí basin; 4 = Cauca-Patía basin; 5 = Upper Magdalena basin; 6 = Middle Magdalena basin; 7 = Lower Magdalena basin; 8 = Cesar-Ranchería basin; 9 = Maracaibo basin; 10 = Guajira basin; 11 = Falcon basin; 12 = Guarico basin; 13 = Barinas basin; 14 = Llanos basin; 15 = Putumayo-Napo basin; Additional Symbols: PALESTINA = fault\suture system; red dot = Plio-Pleistocene volcano; Bogotá = town or city. Inset map: PAT = Pacific Terranes; CHO = Chocó arc; CAT = Caribbean terranes. Base image modified after Cediel et al., 2003.*