La Bodega and La Mascota Deposits, California Vetas Mining District, Colombia: Geology, Alteration, Mineralization.

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Introduction

La Bodega (LB) and La Mascota (LM) deposits (inferred resources of 3.47 Moz Au, 19.2 Moz Ag and 84.4 Mlbs Cu at 2 g/t Au cut off; Altmann et al., 2010) are located in the California-Vetas Mining District (CVMD), 35 km NE of Bucaramanga, in the Eastern Cordillera of Colombia (Fig 1).

The deposits have characteristics of epithermal and porphyry-style deposits but are hosted in the Precambrian crystalline basement of the Santander Massif.

The principal host to mineralization is the Bucaramanga Gneiss of Proterozoic age which is cut by Jurassic muscovite-bearing granite dikes and intrusive bodies (Fig. 2). The mineralization exhibits prominent NE-trending, NW-dipping structural control. LB mineralization is mainly composed of porphyry-style veins (Fig. 8) and minor silicified breccias (Fig. 3) while LM mineralization is largely contained in multi-phase hydrothermal breccias (Fig 4) with minor vein zones adjacent to the breccias.

The area has undergone intense exploration in recent years, nevertheless, origin and nature of the hydrothermal fluids have not been yet defined.

This project aims to comprehensively describe of the geology, alteration and mineralization of LB and LM, define the paragenetic sequence for the mineralization events and make a comparison between the two deposits, and define origin and nature of the mineralizing fluids.

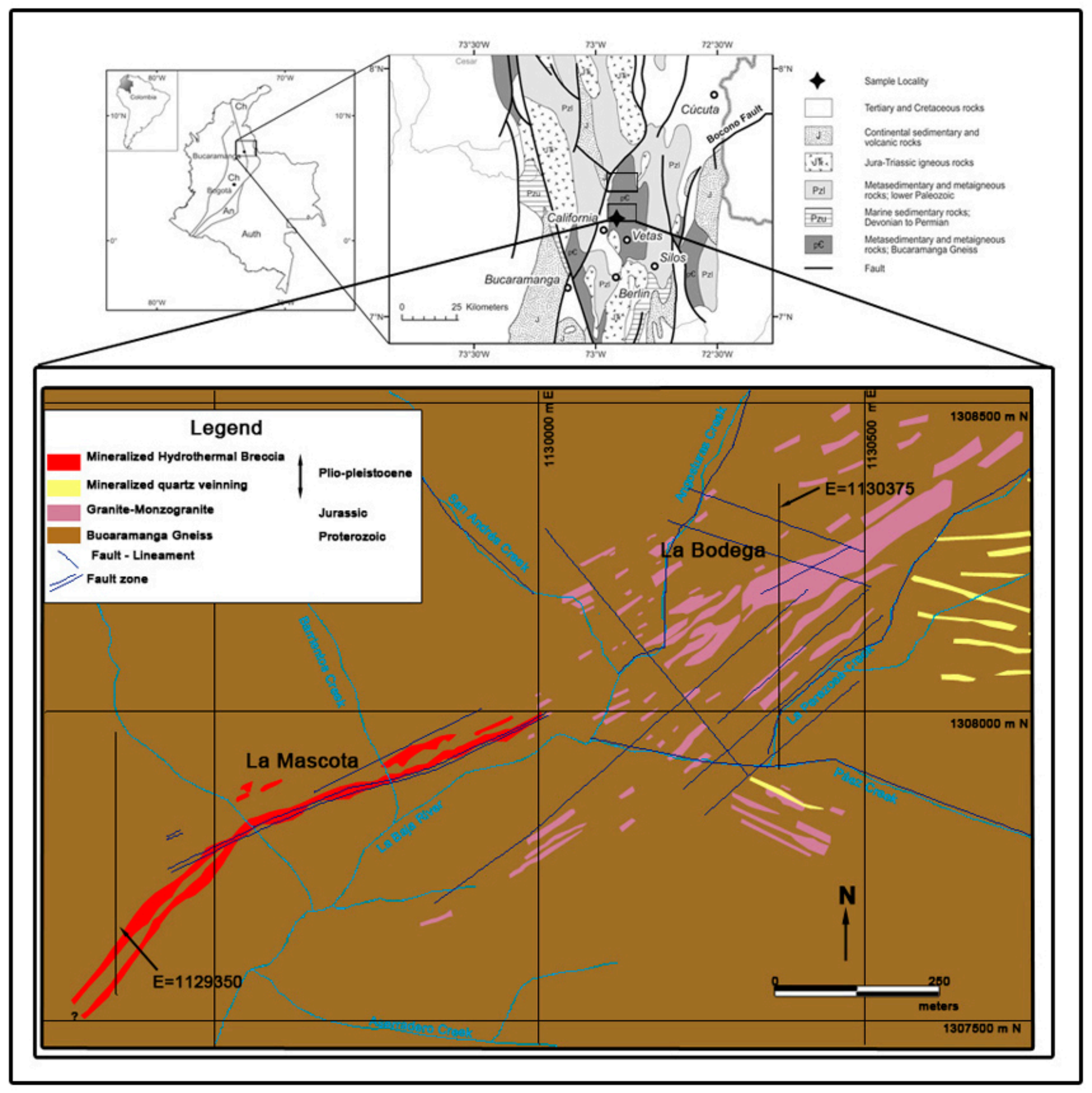
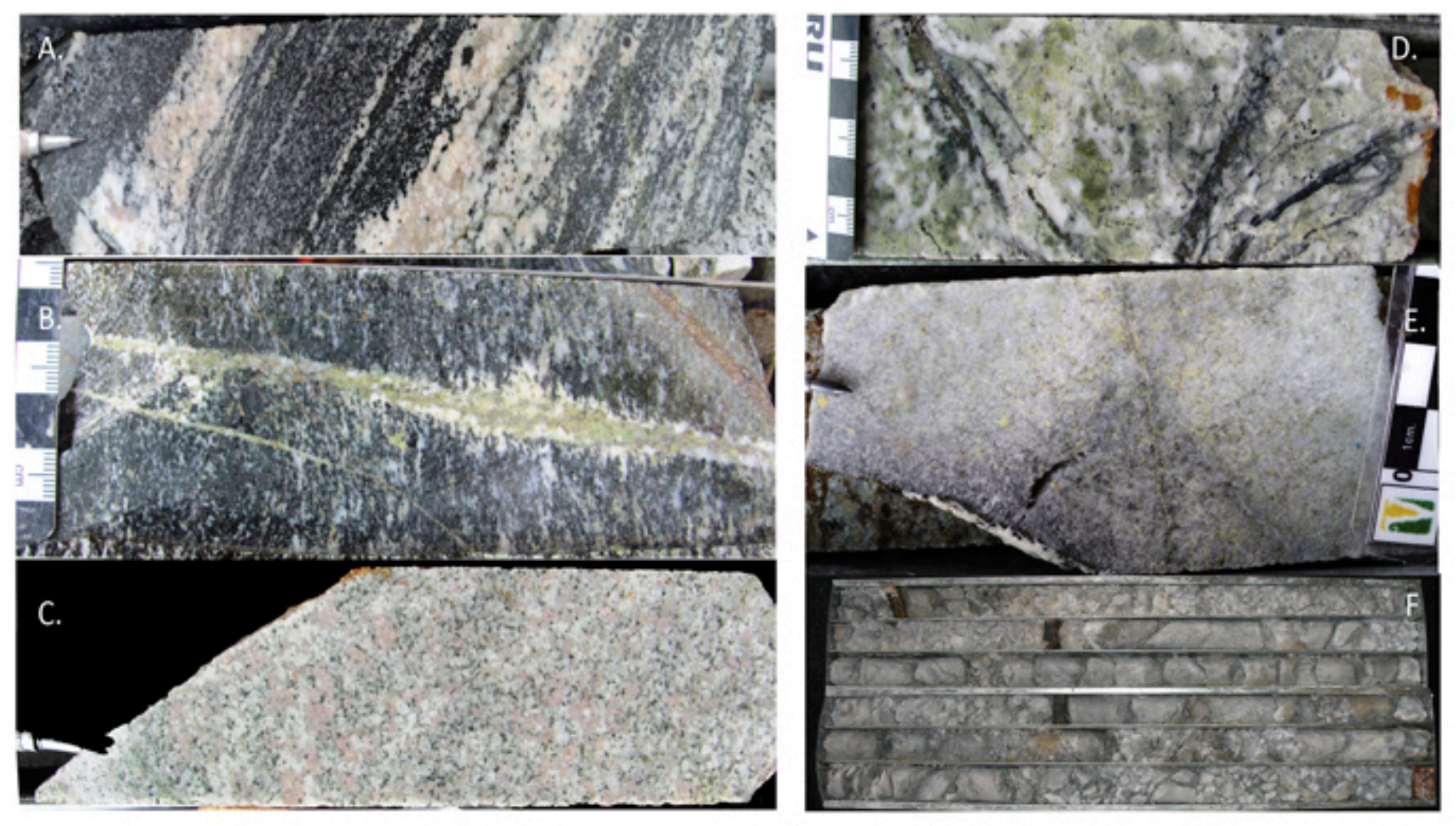


Fig 1. Location of the study area. Top: CVMD general location (Mantilla et al, 2012); Bottom: LB and LM deposits location in Geology map (after Bernasconi et al., 2010) showing geological sections E=1129350 and E=1130375 location.

Figure 2 (left). Main rock Types at La Bodega and La Mascota. A. B. C. Main gneiss types at La Bodega and La Mascota: Banded gneiss (A), mesosome or amphibolite band (B), leucosomes or quartz-feldspar gneiss (C). D. Pegmatitic granite. E. Granite. F. Fracture zone-fault



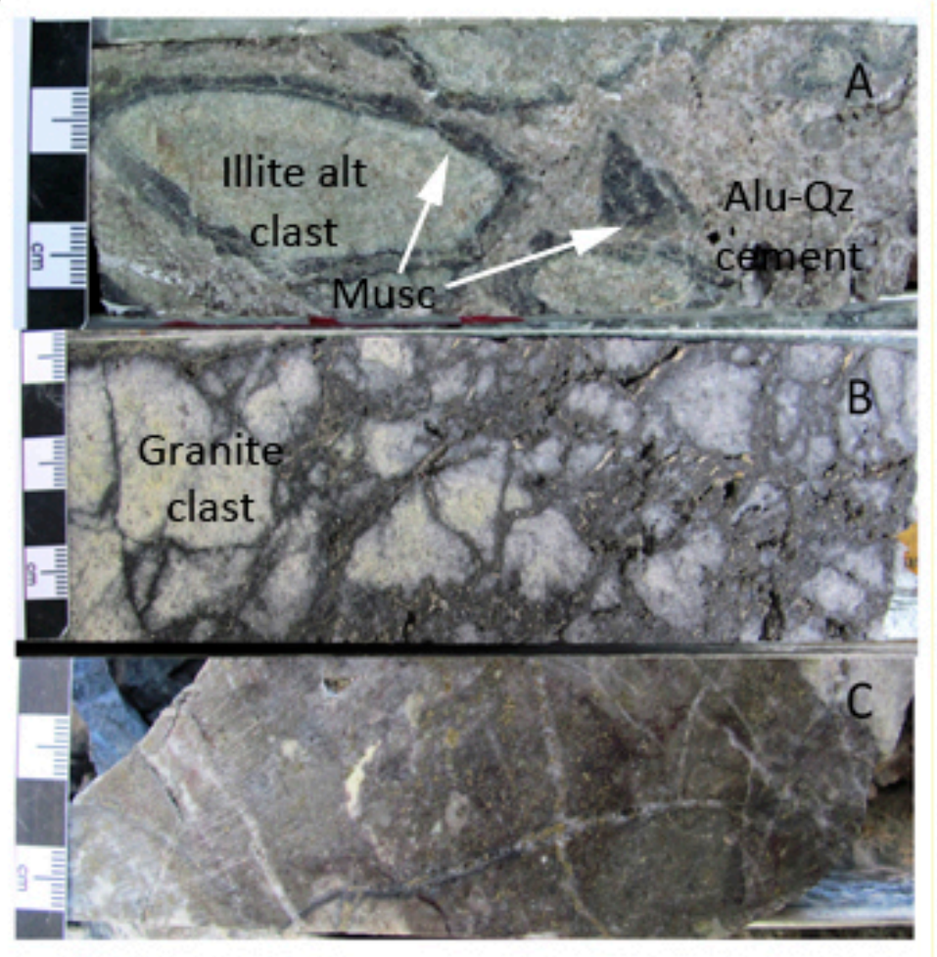


Fig. 3. (Above) La Bodega typical hydrothermal breccias. A. Monomictic breccia with partially resorbed clasts. B. Crackle (monomictic) breccia with granite clasts and Pyrite+Sphalerite+quartz cement. C. Quartz cement breccia: quartz + wolframite veins and cement cut by quartz + pyrite + enargite veins.

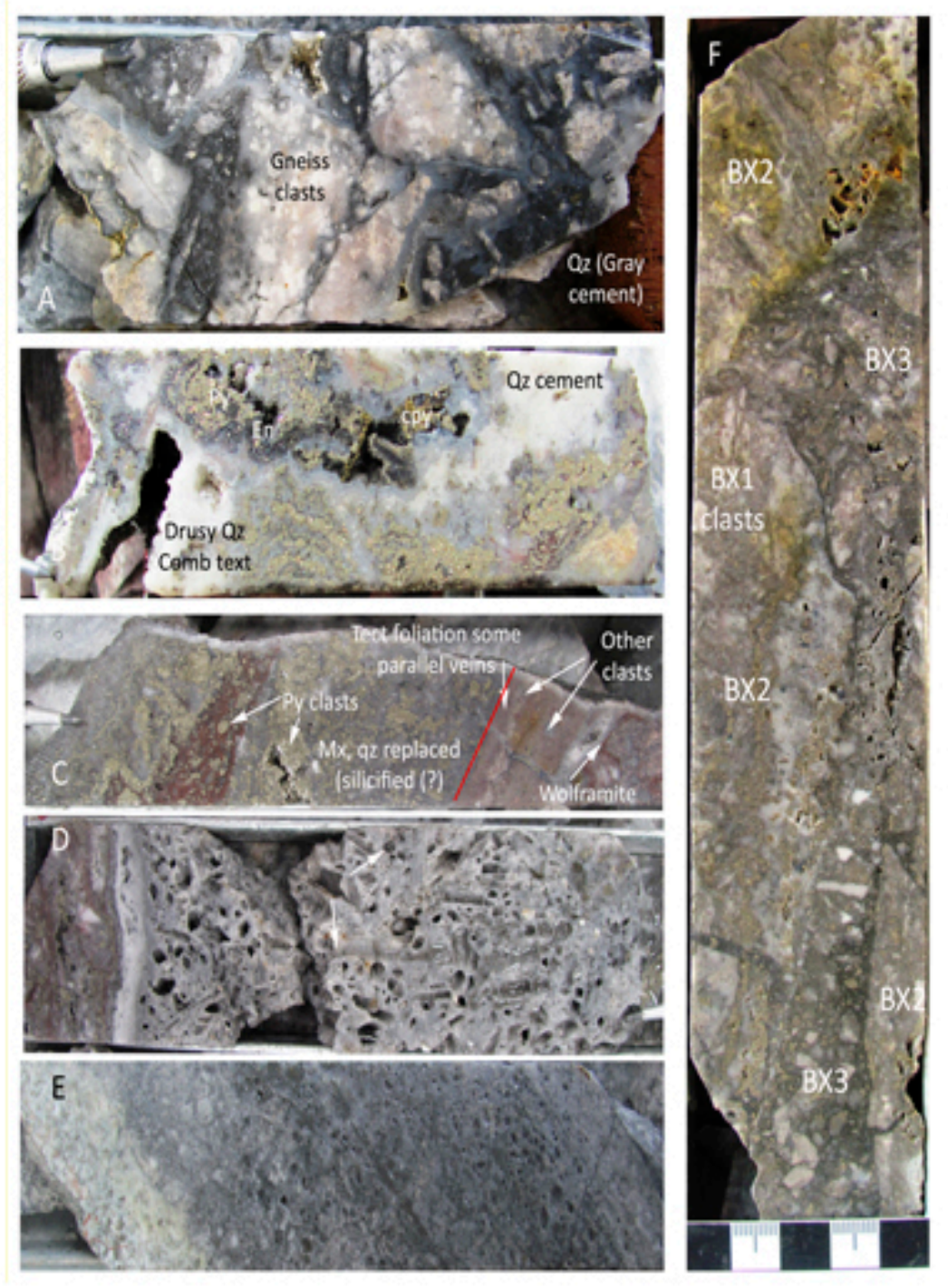


Fig 4. (Left) La Mascota Breccia Types based on breccia physical components and arrange. A. Clast supported breccia. B. Cement supported breccia. Cockade-crustiform texture..C. Matrix to cement supported breccia. Quartz augen clasts (red line). Tectonic foliation. D. Bladed texture , contact to wolframite-Qz bearing breccia. E. Vuggy like silica in wall rock at breccia margin. F. Multiple phases Breccia.

Alteration and Mineralization

Hydrothermal alteration assemblages at LB and LM deposits are typical of those found associated with porphyry and epithermal systems and are directly related to mineralization events. The main alteration types and veins related are: 1) propylitic (Fig. 5A), chlorite and epidote alteration, best developed in biotite and amphibole bearing protoliths. This alteration is accompanied by epidote veins cross cutting calcite and specularite veins that may carry minor pyrite and chalcopyrite. These veins are present at both LB and LM. 2) phyllic (Fig 5B), muscovite (sericite) - illite alteration, commonly accompanied by pyrite and fine crystalline quartz as well as quartz+pyrite veins at LB and quartz+pyrite+hematite veins at LM. These contain the early stages of gold mineralization. 3) silicification (Fig. 3, 4) and advanced argillic (quartz+alunite) (Fig 5C) alteration with quartz occurring as cement of breccias and as microcrystalline quartz, mostly as part of the mineralized structures and alunite as vein and replacements of silicate minerals. Breccias and vein include colloform and crustiform as well as cockade textures and no significant vuggy quartz alteration has been observed (Fig. 4), Alunite and quartz deposition is related to brecciation and mineralization events at LB and more prominently at LM and is accompanied by the initial quartz+pyrite+copper sulphide vein emplacement. Chalcopyrite and chalcocite are more common at LB (Fig. 8D) while covelite, bornite, chalcopyrite are more common at LM (Fig. 11). The Copper sulfide stage is followed by the emplacement of quartz+pyrite wolframite veins at LM and the emplacement of quartz+pyrite+enargite and other copper-arsenic sulphides at both, LB (Fig. 8E) and LM (Fig. 12). These assemblages contain the late stages of gold mineralization where gold is found mainly as electrum. Late pyrite+sphalerite+alunite>quartz veins (Fig. 13) and drusy quartz cavity fillings have been found at LM but did not introduce significant amount of gold. In the halos of the mineralized structures, advanced argillic (alunite and quartz) alteration is overprinting the earlier phyllic alteration. At LB phyllic alteration is more widespread whereas at LM it is confined to the proximity of veins and breccias and only occurs within 10-20 m of those mineralized structures. Propylitic (chlorite+epidote) alteration forms a wide envelope around phyllic and quartz-alunite alteration at LM while at LB propylitic alteration is mainly restricted to amphibolite bearing protoliths in the phyllic alteration zone. Epidote in the propylitic assemblage is more common at LM than at LB. The deposits are characterized by repeated events of fracturing during and after mineralization. Post mineralization fault reactivations generated intensely fractured and gouge-rich fault zones.

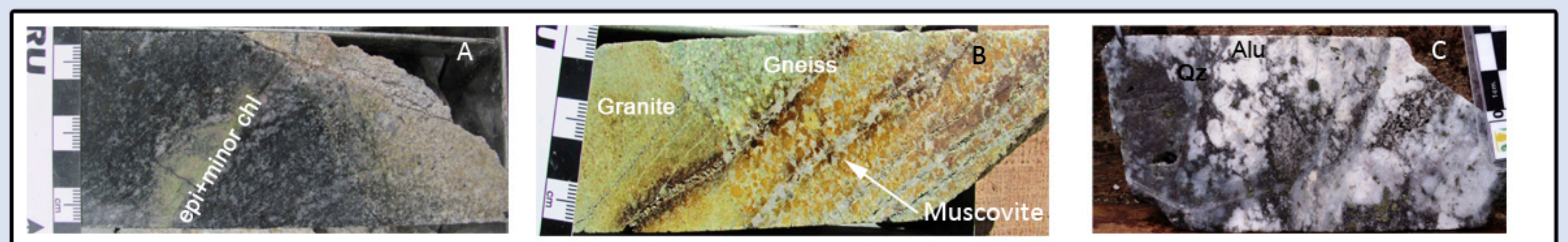


Fig. 5. Alteration at LB and LM. A. Propylitic alteration (chlorite, epidote). B. Phyllic (muscovite-illite) alteration on granite (left) in contact to gneiss (right). C. Alunite-quartz alteration on gneiss.

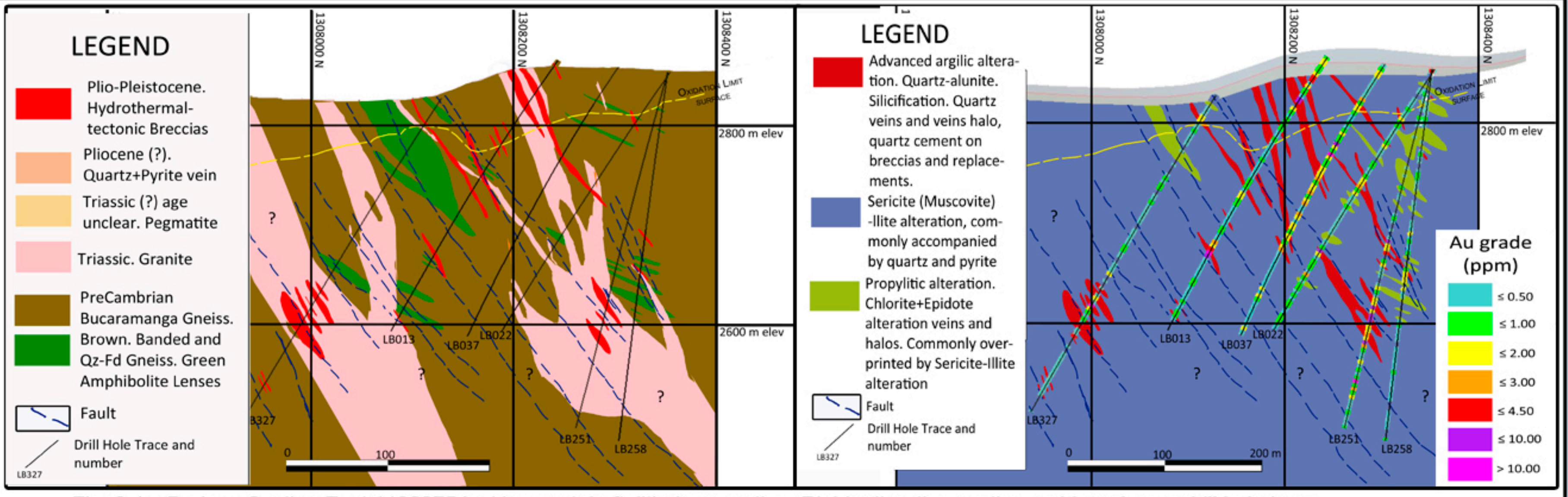


Fig. 6. La Bodega Section East 1130375 looking east. Left: lithology section. Right: alteration section, gold grades on drill hole trace

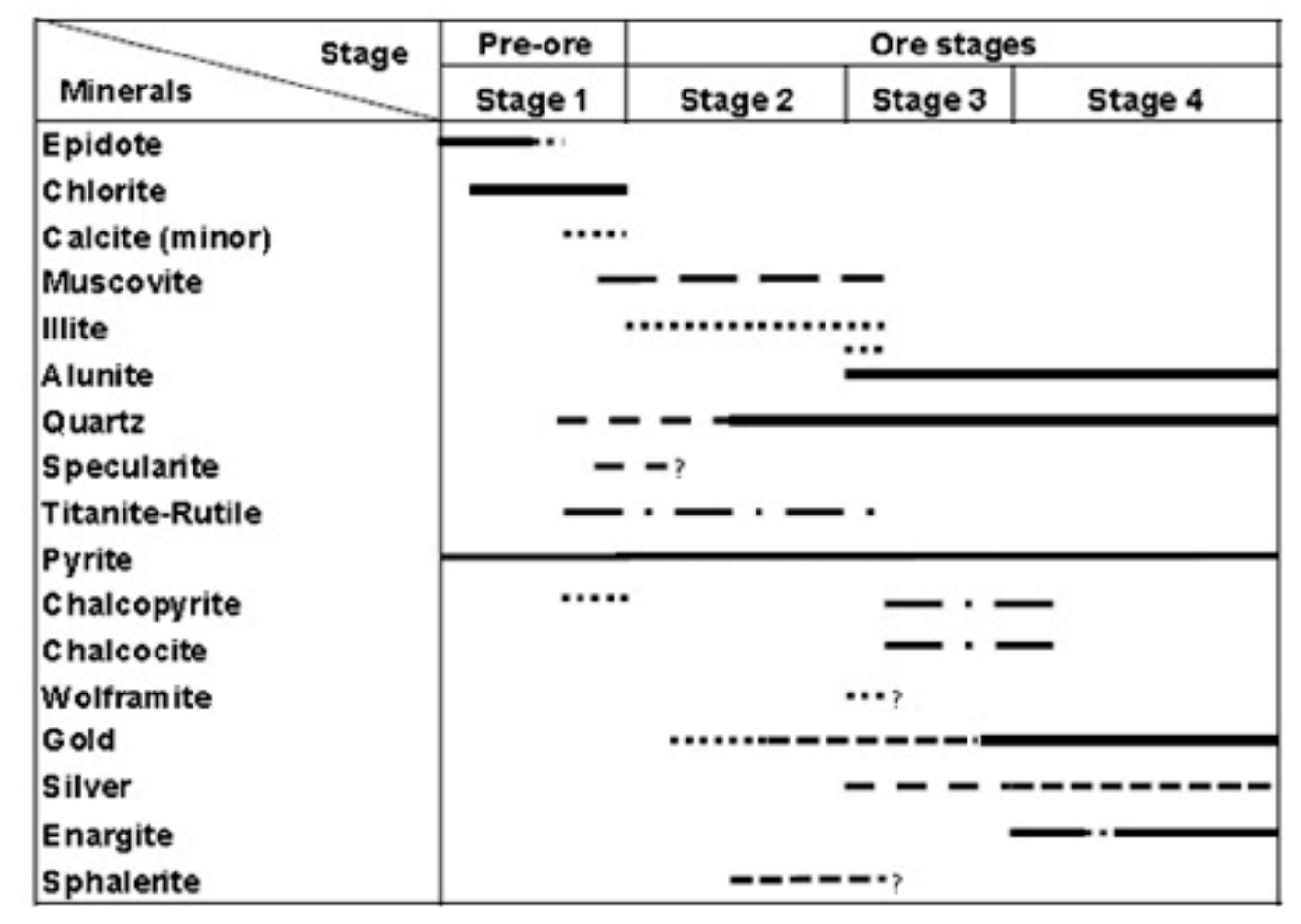


Fig. 7. La Bodega Parageneteic sequence. Solid line: common occurrence of the mineral. Dashed line: low abundance or not common.

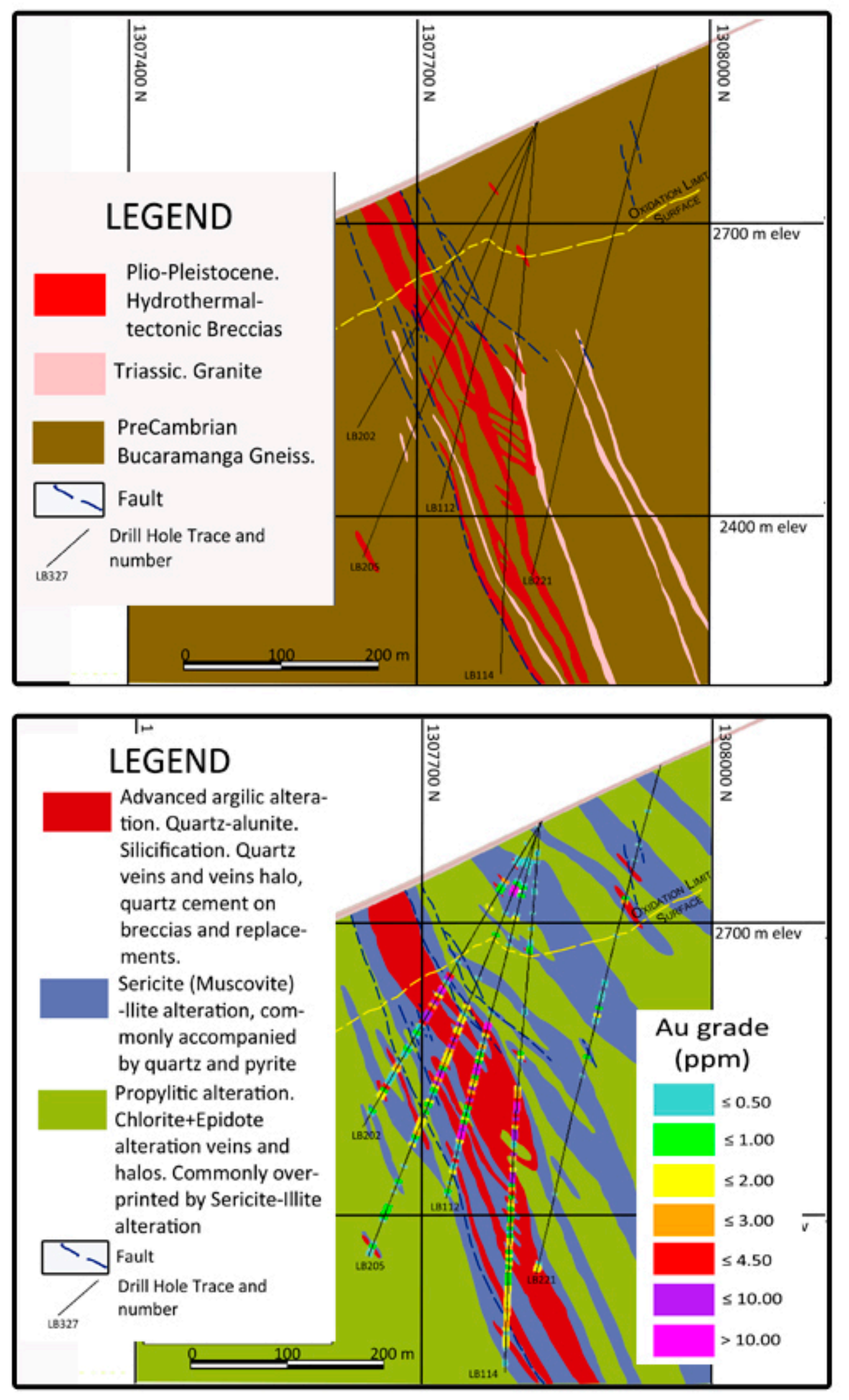


Fig 9. La Mascota Section East 1129350 looking east. Top: Lithology section. Bottom: Alteration section, gold grades in drill hole trace.

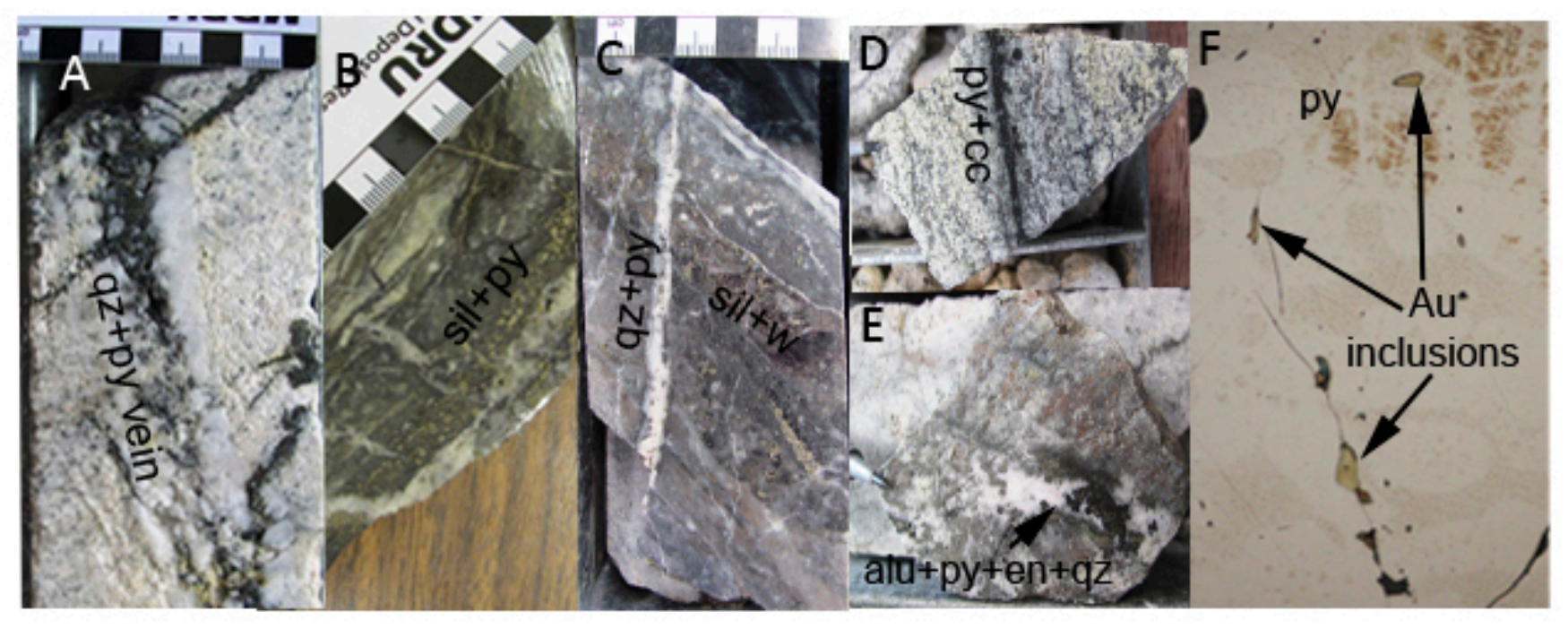


Fig. 8. Typical veins with gold mineralization at La Bodega. A. quartz + pyrite vein. B. Quartz silicified breccia and Quartz+pyrite vein. C. quartz + pyrite + wolframite bearing cement cut by quartz +pyrite vein. D. Pyrite + chalcocite vein. E. Alunite + pyrite+enargite + Quartz. F. Gold inclusions (3-5 μm) in pyrite.

Fig. 9 (left). La Mascota paragenetic sequence. Solid line: common occurrence of the mineral. Dashed line: low abundance or not common.

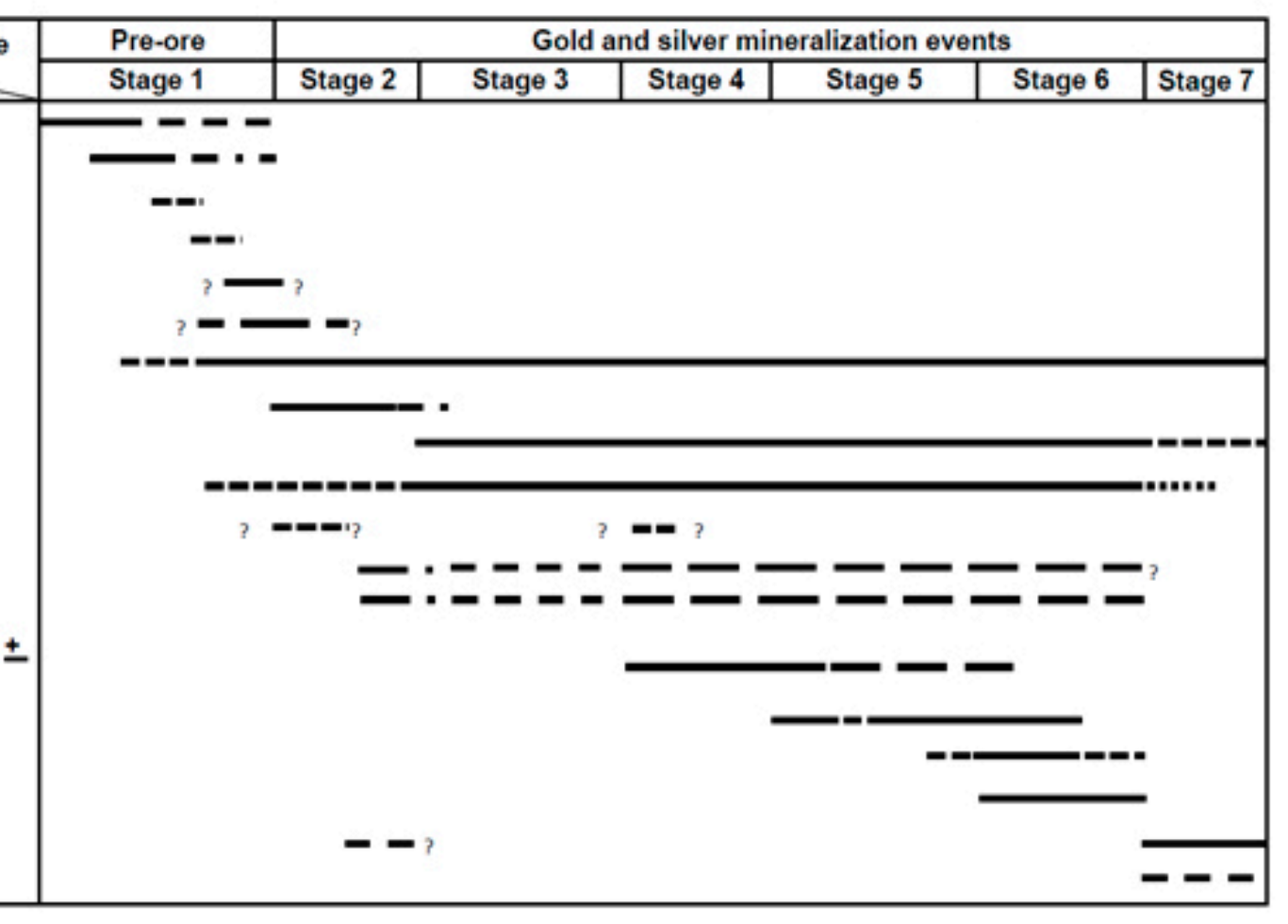
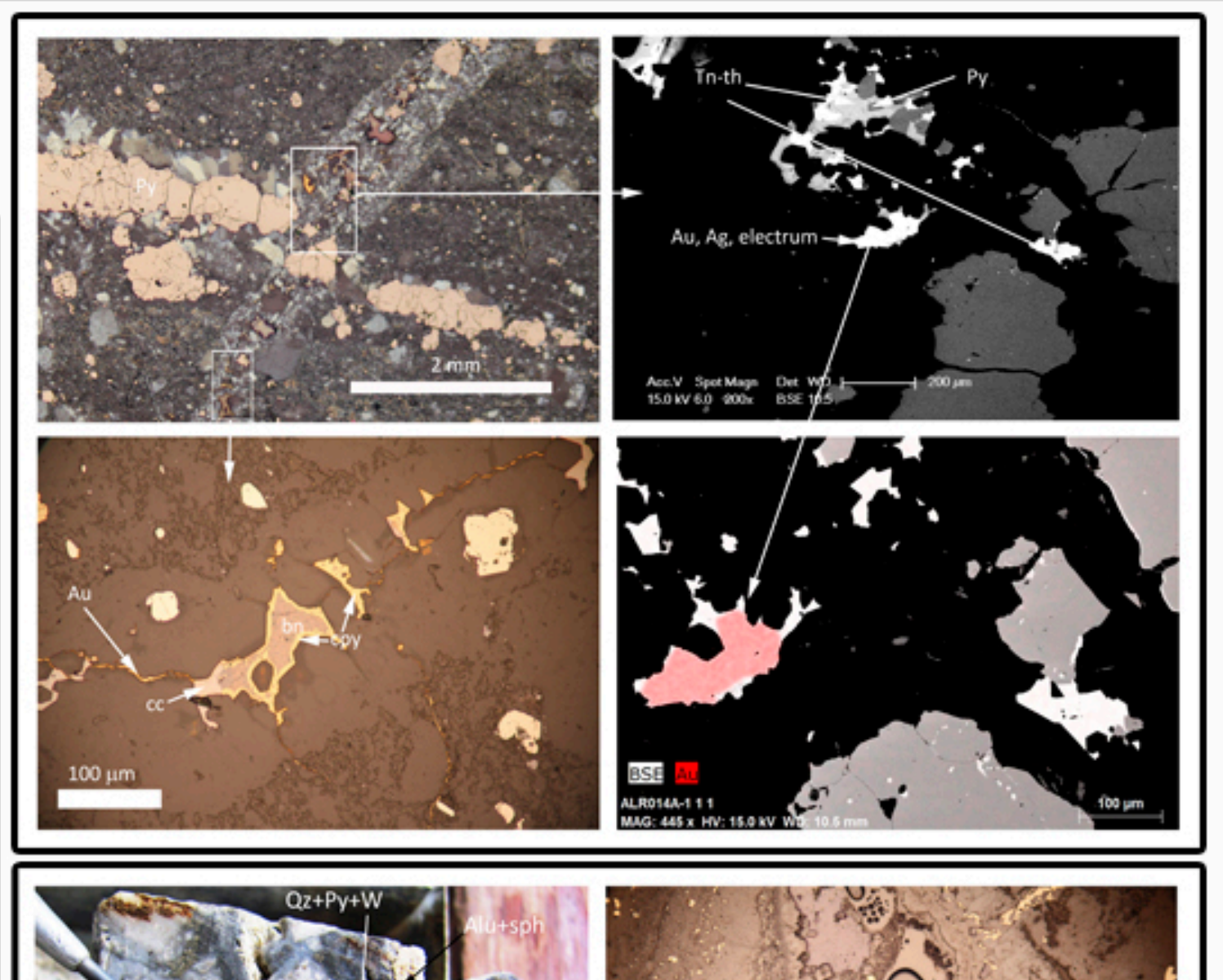


Fig 11 (right). Gold found as electrum (Au>>Ag) Quartz+bornite-chalcopyrite vein (Hydrothermal stage 4) cross cutting quartz+pyrite vein parallel to tectonic foliation in quartz cemented breccia.



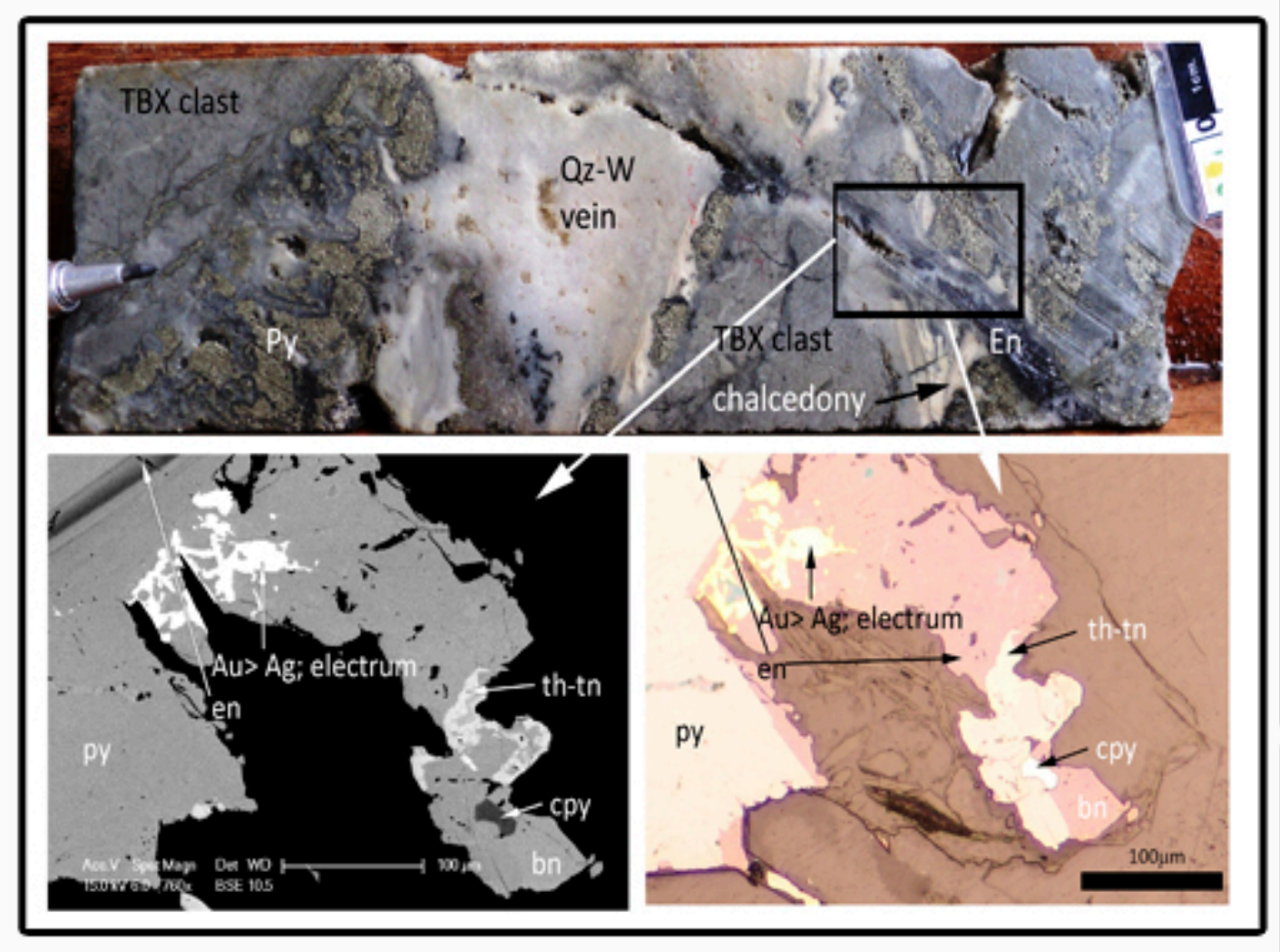


Fig 12 (above). Hydrothermal breccia. Silicified tectonic breccia clasts (TBX) cut by quartz+wolframite (W) (Hydrothermal stage 5) with pyrite vein cross-cut by enargite (luzonite?) vein. In thin section: Gold found as electrum related to copper sulphides: enargite, tetrahedrite-tennantite, bornite, chalcopyrite; gold seem to be more related to enargite in this case. (Hydrothermal stage 5-6).

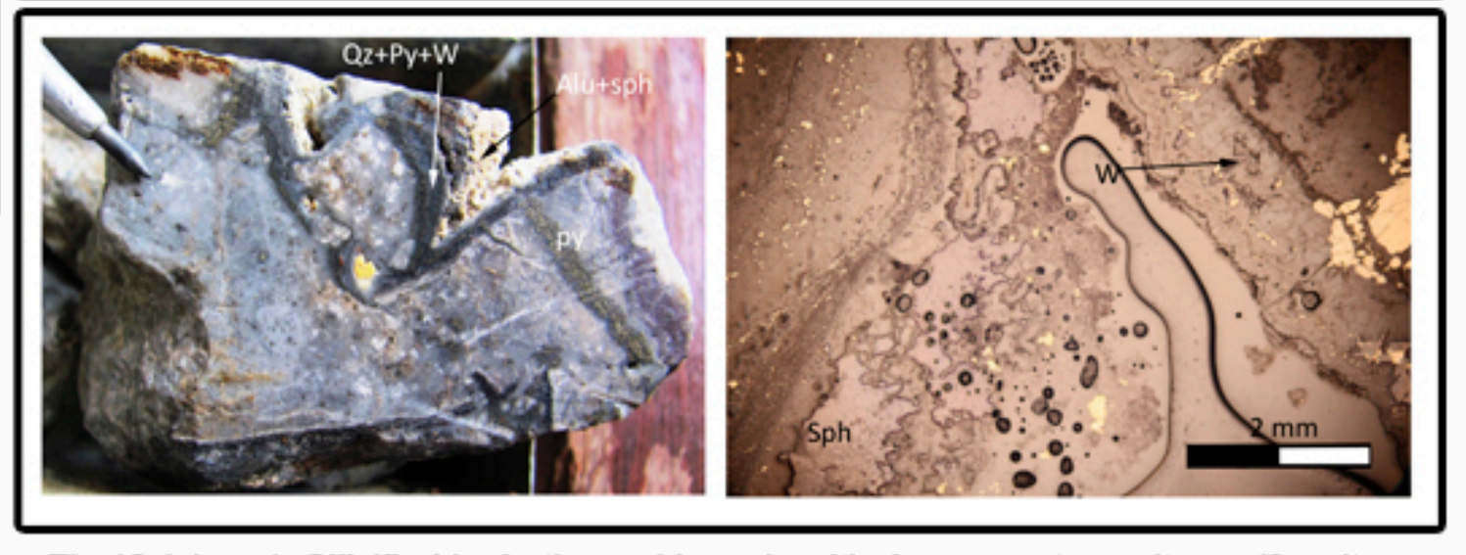


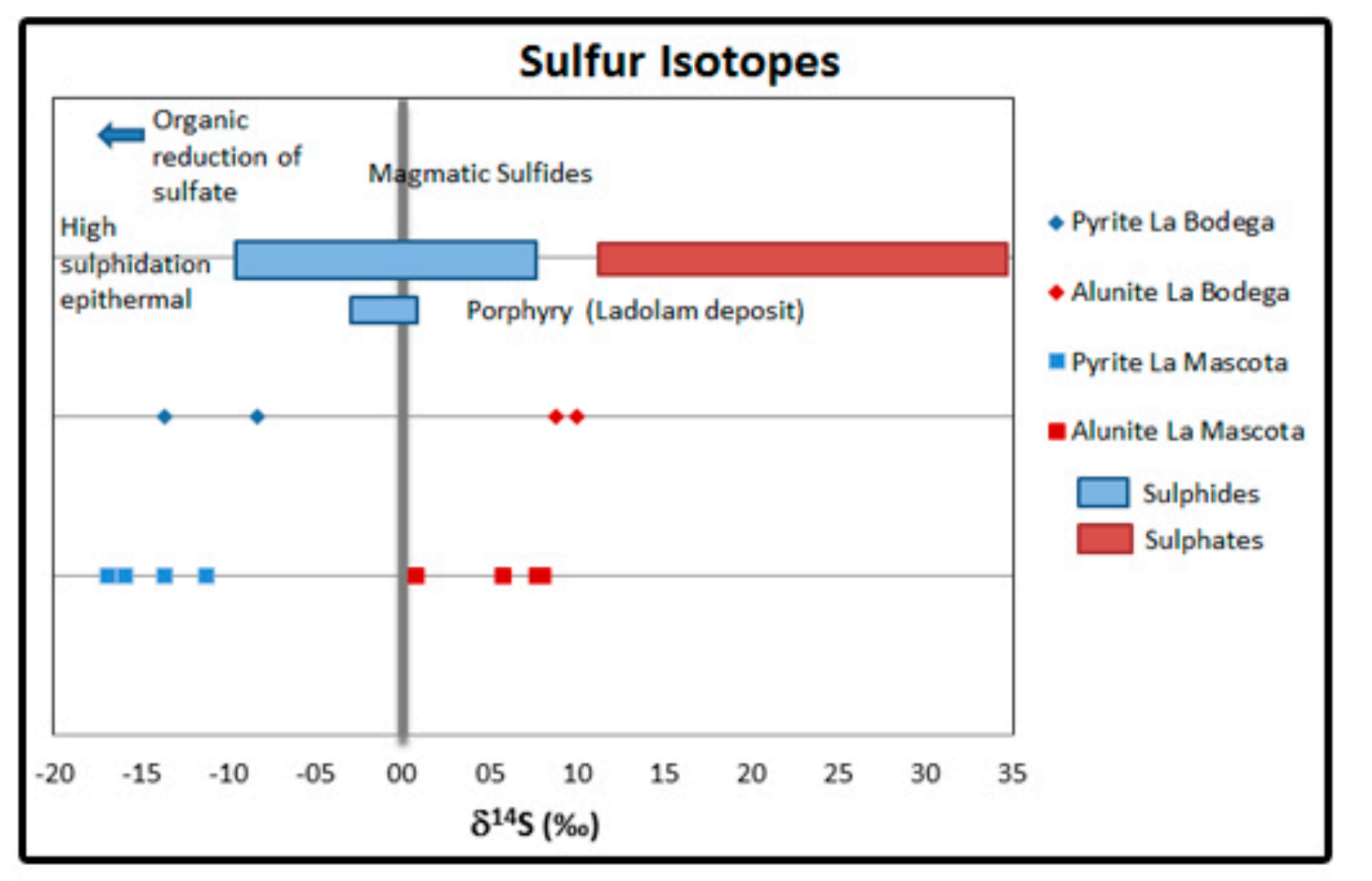
Fig 13 (above). Silicified hydrothermal breccia with drusy quartz+pyrite+wolframite (w) (stage 5) cavity filled with sphalerite+pyrite+alunite (stage 7).

Stable Isotope Gelogy

Pyrite Sulfur isotopes

$\delta^{34}S$ values ranging from -16.9‰ to –11.3‰ at La Mascota, -8.3‰ and –6.1 at La Bodega .

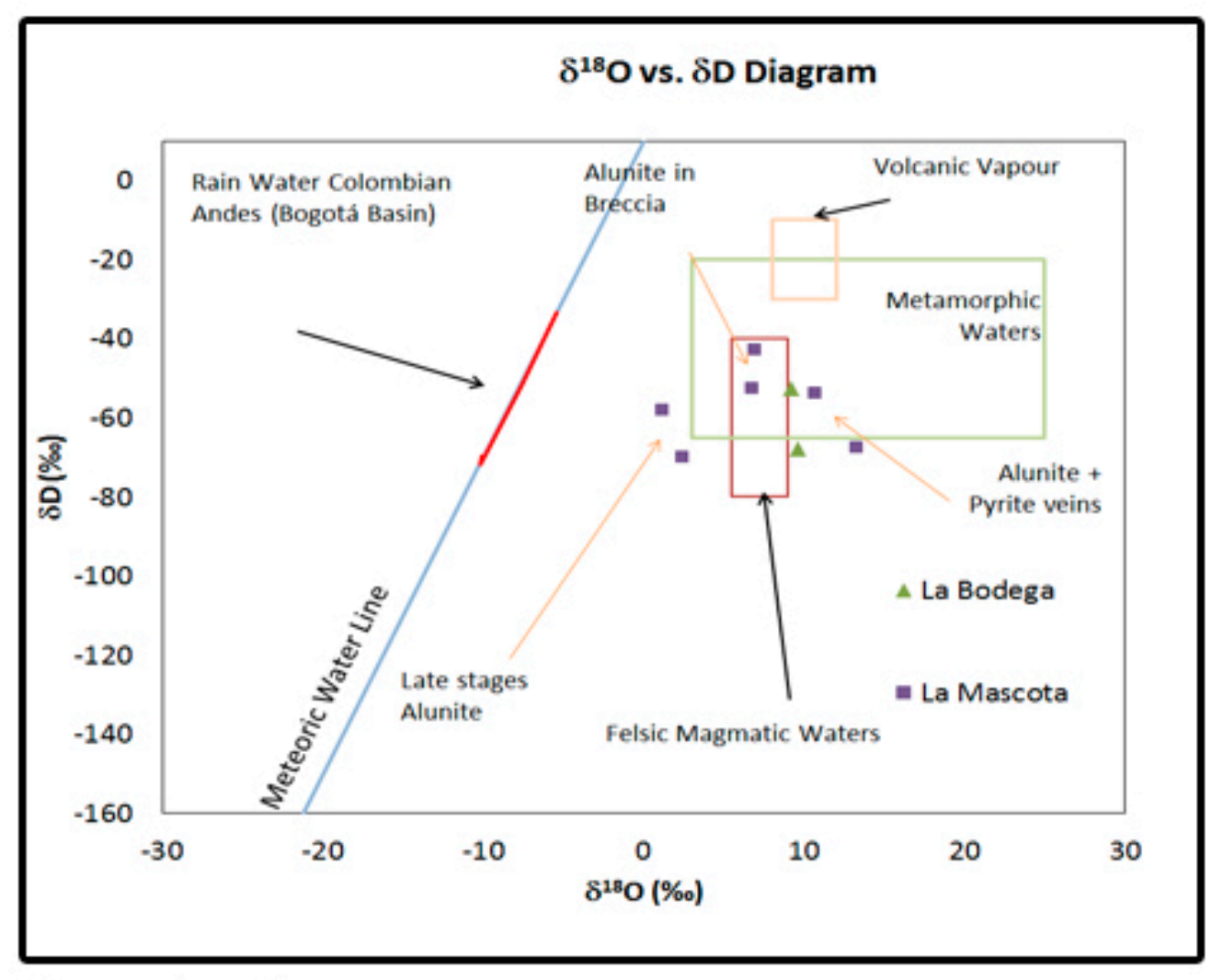
Fig 14 (left). Pyrite and Alunite Sulfur Isotopes. $\delta^{34}S$ for pyrite are below porphyry (Ladolam Porphyry field after Gemmel et al., 2004) and high sulphidation deposits fields (Arribas ,1995).



Temperature of the Paleofluids Related to Mineralization

A paleo fluid temperature of 250°C was calculated using the $\Delta^{34}S$ alunite-pyrite thermometer (Rye et al.; 1992) on one alunite-pyrite pair in textural equilibrium for which mineral separation was possible.

$\delta^{34}S$ Sulfate Alunite	$\delta^{34}S$ sulfide Pyrite	ΔS Alunite-Pyrite	Temperature (celcius) (Rye et al. 1992)
7.7	-16	23.7	250



Origin of the Mineralizing Fluids

Oxygen and deuterium stable isotope show that the fluids related to mineralization are mainly magmatic and minor to no interaction with meteoric water took place.

Fig 15 (left). Plot $\delta^{18}O$ vs. δD (report relative to VSMOW). Isotopic compositions are calculated in equilibrium with hydrothermal fluids at 250°C. Reference fields are from Taylor (1974) for magmatic waters, Taylor (1974) for metamorphic waters, Giggenback (1992) for Volcanic Vapour, Craig (1961) for meteoric water line and Mora & Pratt (2001) meteoric water in the Colombian Andes.

Conclusion

Based on the characteristics observed, LB is considered the shallow part of a porphyry system overprinted by gold rich advanced argillic alteration and high-sulfidation epithermal mineralization. At LM most ore textures are typical of low to intermediate sulfidation epithermal environments but the presence of enargite, alunite and copper sulfides as well as the magmatic origin of the fluids indicates that gold was precipitated from fluids typical of high sulfidation epithermal deposits.

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