Structural Control of the World-Class Sn District of San Rafael, Peru

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The San Rafael mining district in southern Peru is located in the Eastern Cordillera at the northern tip of the Central Andean tin belt. San Rafael is owned by the Peruvian mining company Minsur S.A. and is the largest and richest underground tin mine in the world, with estimated resources of 10 million tons of ore at 2.05% Sn, and historic production to date of 1 million tons of tin metal, and an output that accounts for around 6% of the global tin supply.

The Sn-(Cu) quartz veins at San Rafael and the adjacent Quenamari prospect are spatially related to a composite shallow peraluminous granitic intrusion, U/Pb dated at 24.6±0.2 Ma (zircon) and 24.7±0.2 Ma (monazite), emplaced in Ordovician slates of the Sandia Formation, and overlain by Carboniferous silty-sandstones of the Ambo Group. The mineralization is hosted by a vein system within a sinistral array, which is mainly NNW-SSE striking and mostly dipping at high angle toward the NE. The vein system extends for more than 1,500 m vertically and more than 3 km along strike, developing laterally over 5 km in a SW-NE direction as a series of adjacent lodes. Our $^{40}Ar/^{39}Ar$ adularia ages (±2 s) of 22.43 ± 0.16 Ma and 22.72 ± 0.11 Ma from late stage veins from San Rafael and Quenamari, respectively, indicate that the mineralization process (which includes early tourmaline veins, main cassiterite stage, sulfide-dominated stage, and late quartz ± carbonates ± fluorite ± adularia veins) was completed ~2 million years after the emplacement of the peraluminous granitic intrusion. This is a slightly shorter time span than previously proposed. The data also indicate that the mineralizing events, both in the San Rafael deposit and in the previously undated Quenamari veins, took place roughly at the same time.

This work, carried out in the framework of a larger study at the University of Geneva in collaboration with Minsur S.A., presents new data both on the regional structural evolution of the San Rafael district and on the vein system formation. The ongoing detailed structural work yields (1) additional evidence for left-lateral motion controlling the emplacement of the main mineralized veins, and (2) shows that the left-lateral motion is associated with a normal component. This latter concept, which was not unanimously recognized in previous work focusing on San Rafael, can now be extended to the whole San Rafael-Quenamari district. The same sinistral-normal structural control has been identified in the field from outcropping granitic dikes along the western flank of the San Rafael intrusion. This indicates that similar tectonic conditions prevailed along the whole history of the magmatic-hydrothermal system, from the emplacement of magmatic dikes to the subsequent vein formation. Tentatively, this scenario can be accounted for by considering i) local extensional conditions in a large-scale Andean compressional environment, ii) gravity tectonics related to the rise of granitic magma, or iii) a combination of both factors.