HYDROTHERMAL ACTIVITY AND ORE GENESIS AT THE BORRALHA TUNGSTEN LODE (WESTERN TRÁS-OS-MONTES)

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The Borralha tungsten deposit (85% wolframite, 15% scheelite) is composed of several sets of veins (vertical and subhorizontal) up to one metre thick and hundreds of metres long, and two well developed breccia pipes unique in the Portuguese tin-tungsten province. Vein and breccia formation was controlled by the evolution of the local stress field, related to emplacement of a prolate granitic cupola under the lode, and also to pre-existing lithological and structural anisotropies. Previous paragenetic and fluid inclusion studies (**F. Noronha**, 1984, Bull. Mineral., 107: 273-284, and references herein) coupled with detailed petrography, mineral chemistry and whole rock geochemistry of wall rocks indicate that ore genesis took place as follows: (1) Emplacement of a late-tectonic granitic pluton at shallow crustal levels was accompanied by hydraulic fracturing of host rocks and release of magmatic (?) fluids (relatively high $[K^+]/[H^+]$ and pH) at temperatures around 500-400 °C, produced early potassic alteration (early albite+orthoclase+muscovite+quartz), with concomitant increase of K and Si, and removal of Fe, Mg and Ca, under conditions of vertical σ max and horizontal radial ($=\sigma_2$) and tangential ($=\sigma$ min) stresses; (2) Heating of wall rock meteoric pore fluids (∿10 wt% eq. NaCl, 9-11 mole% CO_2) leads to large scale convection around the pluton, with cooling (∿ 350°C) and $[H^+]$ increase. During this stage, sharp decrease of pCO_2 lead to the main phase of tungstate precipitation and gradual evolution of wall rock alteration into propylitic assemblages (microcline+chlorite+quartz+sericite+albite). Slight variations in the pH value and in Fe, Mn and Ca concentrations in solution are responsible for variations in the composition of wolframites and scheelite precipitation. A first fracturing episode affects all minerals formed up to this stage, probably related with a change in the stress conditions whereby σmax is no longer vertical, but tangential, with opening of a funnel shaped set of normal tensional fractures that includes early subhorizontal veins (W-bearing), possibly emplaced with reopening of preexisting fractures. (3) Further cooling (300-200°C), low values of pH and fO_2 and progressive rise of pS^{2-} lead to precipitation of late tungstates and to the main stage of sulphide precipitation (including molybdenite). Alteration is propylitic (calcite+epidote+quartz+K-feldspar+ +albite), with gains in Fe, Mg, Ca, P and Na, and loss of K and Si. This stage probably corresponds to crystallization of the apex of the pluton, with consequent contraction and fracturing. σmin is now vertical (and σmax $\equiv \sigma_2$), leading to the formation of late subhorizontal tensional fractures, which complete the main episodes of vein formation (stages 1 to 3). The (collapse) breccia pipes seem to have formed at this stage. (4) High water/rock ratios and marked changes in the composition of mineralizing fluids lead to alteration of pyrrhotite, and precipitation of siderite+fluorite (213+25°C) followed by adularia (∿150°C) and vermicular chlorite. This contrast is probably related to reaction with previously formed alteration minerals, and to fluid access into the fractured pluton, with increase of pH, fO_2, aM^{2+} and K^+. (5) Late stage fracturing and further cooling to subhydrothermal temperatures leads to late argillization along fractures, reflecting slow percolation of large volumes of essentially unmodified meteoric water.

It is worth noting that many of the above observations and interpretations are similar to those reported in studies of porphyry-Cu and porphyry-Mo deposits.

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