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Characteristics and formation of the W>Mo>Sn quartz veins from Carris, northern Portugal

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The Carris mine is located in northern Portugal close to the Spanish border. It consists of two partially exploited quartz swarms in two shear corridors aligned N008ºW-N007ºE, which are 200 m away and a third smaller structure at 300 m from the latter. They are 1-2 m wide and consist of six to eight narrow mineralized quartz veins. The quartz veins cut a coarse- to medium-grained porphyritic light pink biotite I-type Gerês granite of 296±2 Ma. The Re/Os data of molybdenite from the mineralized quartz veins and adjacent granite yield ages of 279±1.2 Ma and 280.3±1.2 Ma, respectively, which are in good agreement with the ID-TIMS U-Pb zircon age of a fine-grained slightly porphyritic biotite I-type Carris granite of 280±5 Ma, which crops out hundred meters away from the mineralized quartz veins. A typical and gradual transition occurs from miarolitic pegmatites to the microcline selvages and feldspar borders of some mineralized quartz veins. Most pegmatites and mineralized quartz veins show a concordant orientation. The pegmatites belong to the rare element class and NYF family.

The paragenetic sequence for the Carris quartz veins shows three distinct hypogenic stages separated by Variscan faulting and fracturing. Quartz dominates in each stage and is mainly accompanied by silicates in the first stage, oxides and tungstates in the second stage and sulfides and sulfosalts in the third stage. Different generations of the same mineral occur. The earlier cassiterite belongs to the second stage and contains small amounts of Nb, Ta, Ti, W, Fe and Mn, whereas the later cassiterite belongs to the third stage and is pure. The earliest crystals of wolframite have 91 mol% WO_4Mn, but the most common wolframite contains 26-57 mol% WO_4Mn. This change in composition results from the change in the fluid composition. The Nb_2O_5 content of wolframite is up to 4.93 wt% and belongs to the second generation. The strong negative correlation between (W^{6+}+Fe^{2+}+Mn^{2+}) and (Nb^{5+}+Fe^{3+}) suggest the coupled substitution [(Fe, Mn)$^{2+}$+W^{6+}] ↔ (Fe^{3+}+Nb^{5+}). No chemical distinctions were found between the two generations of arsenopyrite and pyrite. Molybdenite is the most abundant sulfide and has a pure composition.

The Carris granite magma evolved by fractional crystallization to originate pegmatites and mineralized quartz veins. The circulation of mineralizing fluids took place up to 1-4 Ma after the emplacement of the Carris granite. Isotopic He-Ar data of pyrite from these quartz veins indicate that He data represent a mixture of a magmatic mantle fluid component with a radiogenic He-rich crustal fluid, which agrees with the origin of the Carris granite with $(^{87}Sr/^{86}Sr)_i$ values of 0.7048-0.7077. These veins have a low Mo/W ratio, indicating that it was low in magmatic hydrothermal fluids and related to low oxygen fugacities in the ore magma system, which is supported by the fact that the Carris granite contains more ilmenite than magnetite and consequently has a low oxygen fugacity.