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Constraining the Magmatic-Hydrothermal Evolution of a Gneiss Dome: Insights from U-Pb Dating and Trace Element Analysis of Sn-W Mineralization

Daniel Bermejo-López[1], Lorena Ortega[1], Pedro Castiñeiras[1], Lorenzo Tavazzani[2], Santos Barrios[3], Juan Gómez-Barreiro[3], Elena Crespo[1], Cyril Chelle-Michou[2]
1. Complutense University of Madrid, Madrid, Spain, 2. ETH Zürich, Zürich, Switzerland, 3. University of Salamanca, Salamanca, Spain

The Martinamor extensional gneiss dome (Salamanca, Spain) represents a late-Variscan geologic feature resulting from the gravitational collapse of the Variscan orogen. This dome formed during the E2 extensional stage (~315–300 Ma), and it is characterized by a wide extensional shear zone leading to tectonic denudation and thermal attenuation of the crust. The footwall exhumation also led to isothermal decompression and heat transfer through the detachment zone, inducing syn-kinematic low-pressure metamorphism and ultimately reaching melting conditions in the dome core. Partial melting ultimately gave rise to S-type magmatism locally associated with Sn and W mineralizations.

This study focuses on Sn-bearing pegmatites, and cassiterite and wolframite vein-type mineralizations, which occur in different structural levels, both in the shear zone hanging wall and footwall. Cassiterite and wolframite in situ U-Pb dating by laser ablation-inductively coupled-mass spectrometry (LA-ICP-MS) indicate a prolonged mineralizing period spanning nearly 25 m.y. (324–301 Ma). This interval initiated with the emplacement of Sn-bearing pegmatites at 324 Ma and W-veins at 323 Ma, followed by the development of Sn veins between 320 and 301 Ma. Partial melting and crystallization + hydrothermal activity took place within uncertainty of the obtained U-Pb dates, implying an earlier onset of the Martinamor gneiss dome exhumation, during the E1 deformation stage (330–315 Ma).

Trace element composition of cassiterites, when used as thermo indicator (i.e., Zr-Hf and Nb-Ta ratios), reveals a cooling pattern from older (324 Ma) to younger (305 Ma) cassiterite, followed by an inverse, reheating trend from 305 to 301 Ma. This suggests a protracted cooling of the magmatic-hydrothermal system during dome exhumation until a heating event, which nature is still to determine, occurred around ~305 Ma, elevating cassiterite temperatures in the Sn vein-type mineralization.