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Tungsten mineralisation, a mineral system approach

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Tungsten is considered a critical metal because of its high economic importance and restricted supply. The high melting point and hardness make tungsten an essential metal used in many commercial and industrial applications. However, its supply risk is high with >80% produced by one country. Through literature reviews, thermodynamic models and geochemical datasets, we gather further insights on tungsten behaviour in magmatic-hydrothermal processes from source-control to magma fractionation, source mobilisation and metal deposition. From this, we explore the application of mineral system in tungsten exploration.

In this review, we revisit the mineral system approach, which consists of understanding: 1) the drivers for mineralisation from tectonic settings, source rock formation and alteration; 2) the input of sources of metals and ore-forming fluids, as well as the energy that drives circulation; 3) the migration, i.e., the transportation process of metals; and 4) the deposition processes including fluid-vapour phase separation and fluid-rock interaction that form a deposit. We summarised that tungsten is hosted predominantly in peraluminous I-S-type granite. Economic tungsten minerals are commonly found as wolframite ($(Fe, Mn)WO_4$), a tungsten oxide present in stockwork veins and greisen deposits, and scheelite (CaWO4), a calcium tungstate found in skarn deposits. In magmatic systems, tungsten behaves as an incompatible element and is enriched through fractional crystallisation. In hydrothermal conditions, tungsten is transported as anionic tungstate species which speciation depends on pH and redox conditions. Tungsten is then precipitated upon lowered temperature and raised pH.

Alongside the mineral system approach, the whole-rock geochemical data of granitic rocks linked to tungsten mineralisation are compared to a worldwide compiled dataset. The latter is filtered for tungsten contents and excludes data that may result from sample contamination. This allows an understanding on geochemical behaviour of tungsten-fertile granitic rock, as well as their spatial distribution. Results show that samples enriched in tungsten (>300 ppm) might form from a range of magmatic processes, including magma mixing, partial melting of metasomatized lithospheric mantle, partial melting of crustal sources and crustal assimilation. Elevated tungsten is detected exclusively on continental crust supporting the importance of a continental crust component in producing a fertile source rock.