

The Watershed scheelite skarn deposit, Far North Queensland, Australia

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The Watershed W deposit (49.2 Mt averaging 0.14% WO₃) lies within the Mossman Orogen in Far North Queensland. Regionally Ordovician-Devonian Hodgkinson Formation sedimentary rocks are metamorphosed and intruded by Carboniferous-Permian granites of the Kennedy Igneous Association. At Watershed, mineralization is hosted in a sequence of folded slates and, locally calcareous, psammites of the Hodgkinson Formation. In addition, multiple felsic dykes of the Permian S-type Whypalla Supersuite cut across the metasedimentary rocks. Two pre-mineral dykes have been dated at 354 ± 5 Ma and 300 ± 4 Ma (LA-ICP-MS zircon U-Pb) in this study.

Alteration and mineralization has strong lithological control and is mostly hosted in psammitic units. Based on field observations, petrography and subsequent EPMA analysis, alteration and mineralization have been divided into seven stages: starting with a pre-skarn event forming garnet porphyroblasts (Gr_{S40-75}Alm₉₋₃₅Spe₇₋₂₅And₀₋₉) and quartz veins (now deformed), followed by a prograde skarn event characterized by garnet (Gr_{S66-87} Alm₀₋₁₈Spe₁₋₁₃And₃₋₁₆), clinopyroxene (Di₃₆₋₅₉Hd₃₉₋₆₁Jo₁₋₅), and minor titanite. Subsequently four retrograde skarn stages occurred in veins and host-rock: Retrograde 1 is characterized by microcline (Or₉₃₋₉₄) + plagioclase (An₁₅₋₅₅) + quartz in veins and quartz + clinozoisite + and plagioclase (An₂₉) in vein halos and skarns. During Retrograde 2, quartz, more Na-rich plagioclase (An₃₋₃₃) and biotite was introduced in veins meanwhile phlogopite, amphibole (such as actinolite and Na-rich amphiboles) and plagioclase (An₂₅) developed in skarn. Scheelite is widespread in Retrograde 2 stage in both veins and vein halos. Retrograde 3 stage comprises muscovite, chlorite and calcite in veins and chlorite, muscovite, calcite and minor fluorite in wallrocks. The last Retrograde 4 event comprises laumontite and prehnite stringers in veins and aerinite in host-rock. After the retrograde stages a sulphide fracture-filling event occurred characterized by widespread pyrrhotite and arsenopyrite plus minor sphalerite and chalcopyrite in veins and pyrrhotite + arsenopyrite in wallrocks.

Scheelite occurs in veins and is disseminated in vein halos, granitic dykes, and to a lesser extent in skarns replacing psammite in the second retrograde stage. Illite crystallinity based on short wavelength infra-red spectral method shows a correlation of 0.9 with tungsten grades in granitic dykes. REE patterns of scheelite (LA-ICP-MS) are consistently flat with slightly negative Eu anomaly and enriched with respect to chondrite in veins and in a granitic dyke. In contrast, scheelite from another granitic dyke is bell-shaped enriched in HREE and depleted in LREE, with consistent positive Eu anomaly. The mineralization age is constrained by a retrograde 3 stage muscovite age of 253 ± 3 Ma (⁴⁰Ar/³⁹Ar and 2σ error). The isotopic values for hydrothermal calcite from Watershed (-7 to -19 δ¹³C‰ VPDB and 14 to 22 δ¹⁸O ‰ VSMOW) are similar to that of calcite from other W skarns. The δ³⁴S isotopic values for pyrrhotite, arsenopyrite, pyrite and sphalerite at Watershed are between -2.5 and 2.8‰ CDT which may be showing a magmatic origin for the sulphides.