Inhomogeneous distribution of REE and initial Nd isotopic compositions in scheelite crystals from an Archaean gold deposit (Mt Charlotte, Western Australia)

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Scheelite (CaWO₄) is a widespread accessory mineral in mesothermal Au deposits of various ages. Scheelite can host relatively large amounts of Sr and REE (up to >1 wt.% REE), and has been used to date mineralisation, and to constrain the nature and origin of the ore-forming fluids (Anglin et al., 1996; Eichhorn et al., 1997; Kent et al., 1996; Müller et al., 1991).

The Archaean Yilgarn Craton (Western Australia) consists of large volumes of felsic basement supporting relatively thin (<8 km) greenstone belts. Many large Au deposits were formed in the greenstone belts of the Eastern Goldfields Province during a major crustal scale mineralising event at around 2.63 Ga. The Mt Charlotte deposit is a large quartz stockwork embedded in a differentiated gabbroic sill (locally known as ‘Golden Mile Dolerite’) within the Norseman-Wiluna greenstone belt, and is spatially associated with the giant shear-hosted Golden Mile deposit (Clout et al., 1990).

Previous Sm-Nd isotopic studies on scheelite from Mt Charlotte (Kent et al., 1996) have revealed large variations in REE concentrations and in ¹⁴⁷Sm/¹⁴⁴Nd ratios (~0.2 to 0.4). The Sm-Nd data define an errorchron at 2772 ± 86 Ma, older than the mineralising event (2.63 Ga).

We present in situ trace element data obtained by UV laser ablation high-resolution inductively-coupled plasma mass-spectrometry (LA-HR-ICP-MS, using a Merchantek LUV266 laser microprobe and a Finnigan MAT ELEMENT) on scheelite from Mt Charlotte, with the aim to decipher the nature of the inhomogeneous distribution of REE in scheelite. The morphology of the REE zoning in scheelite was studied by optical luminescence (cathodoluminescence and proton induced luminescence). We have also analysed the Sm-Nd isotope geochemistry of the same zones studied by LA-HR-ICP-MS and luminescence using a micro-drilling/sampling technique.

Results
The scheelite from Mt Charlotte is Mo-free (=5 ppm Mo), has generally high Sr contents (up to 4300 ppm), and is characterised by very inhomogeneous REE contents within single grains. Two types of REE patterns coexist in most scheelites (Fig. 1b): MREE enriched (hump-shape) patterns with no or a slightly positive Eu anomaly (type I), and flat or middle REE (MREE) depleted patterns with a large positive Eu anomaly (type II).

Two types of zonation have been recognised in the scheelite from Mt Charlotte:
(1) In some crystals, luminescence reveals a first order oscillatory zoning involving type I (yellow luminescence; dark grey in Fig. 1a) and type II REE patterns (blue luminescence; light grey in Fig. 1a). The zones of contrasting REE composition are parallel to the crystal faces, and measure from <10 μm to 500 μm in width. Closer inspection of the zones, however, often reveals complicated fine
structures, which reflect dynamic growth conditions. This growth zonation is dislocated by cracks, which formed at an unknown time after scheelite crystallisation (Fig. 1a).

(2) LA-HR-ICP-MS depth profiles (vertical resolution of 200 to 700 nm, depending on the number of analysed elements) show oscillatory zoning with zone widths = 10 μm. This second order zoning involves the LREE, and is thus different from the first order zoning which involves primarily the MREE.

Small but significant differences in the initial isotopic compositions of Nd exist between zones of predominantly yellow (εNd2,63 = 2.5–3.5) and blue (εNd2,63 = 1.1–2.6) luminescence (first order zoning). patterns may not reflect a change in the oxidation state of Eu in the fluid, but may result from a smaller partition coefficient for Eu2+ relative to Eu3+. Thus, Eu will be less rapidly depleted in the fluid than the other REE, resulting in a growing positive Eu-anomaly in the fluid, which is recorded in scheelite as well. Under the conditions prevailing during scheelite formation (325–375°C, CO2/CH4 1–50), Eu2+ was predominant in the scheelite-forming fluid. The inhomogeneity of the initial Nd isotopic composition reflects the complex interaction between the mineralising fluid and the heterogeneous greenstone belt, and explains the erroneous (too old) age of the Sm-Nd scheelite errorchron.

**Discussion**

The oscillatory zoning involving REE in the Mt Charlotte scheelite is a primary feature. Where luminescence was able to map the distribution of REE, no evidence for post-crystallisation REE mobility (e.g. recrystallisation along the rim of the crystals or along cracks) has been detected. The transition from a MREE enriched pattern (type I) to a flat or MREE depleted pattern (type II) can be explained if a fluid with an originally flat REE pattern crystallises a mineral which preferentially incorporates MREE, like scheelite, for example. In this case, the increase of the Eu anomaly from type I to type II patterns may not reflect a change in the oxidation state of Eu in the fluid, but may result from a smaller partition coefficient for Eu2+ relative to Eu3+. Thus, Eu will be less rapidly depleted in the fluid than the other REE, resulting in a growing positive Eu-anomaly in the fluid, which is recorded in scheelite as well. Under the conditions prevailing during scheelite formation (325–375°C, CO2/CH4 1–50), Eu2+ was predominant in the scheelite-forming fluid. The inhomogeneity of the initial Nd isotopic composition reflects the complex interaction between the mineralising fluid and the heterogeneous greenstone belt, and explains the erroneous (too old) age of the Sm-Nd scheelite errorchron.

**References**


