

Rare earth element minerals in the Olympic Dam deposit, South Australia: Petrography and compositional variation

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Olympic Dam is a world-class iron-oxide copper-gold-uranium ore system located in the Gawler Craton of South Australia. It contains elevated concentrations of rare earth elements (REE), almost exclusively LREE (0.18 wt% La_2O_3 , 0.27 wt% Ce_2O_3 , 0.06 wt.% Nd_2O_3), although not sufficiently high enough to be economically exploited at present. Discrete REE-minerals at Olympic Dam are typically fine-grained ($<50 \mu\text{m}$), and occur as disseminations in sulphide and gangue minerals throughout all ore zones in the deposit, although they can be locally concentrated to macroscopic REE-mineral rich pockets. REE abundance broadly correlates with whole-rock Fe concentration and the presence of sulphide mineralization; REEs are, however, depleted in the barren, Fe-dominant core of the deposit. Aside from REE-minerals, trace to minor REE occur in uraninite and apatite, among other minerals. While REE-minerals are documented in previous studies of Olympic Dam, there has been no prior, focused investigation on their mineralogy, or variation, either compositionally or spatially. Documenting the speciation, occurrence, and compositional variation of REE-minerals has potential value for constraining variation in fluid parameters by thermodynamic studies.

The most widespread REE-mineral within the sample suite is the REE-fluorocarbonate bastnäsité [$\text{REE}(\text{CO}_3)\text{F}$], followed in abundance by the REE-phosphate florencite [$(\text{REE})\text{Al}_3(\text{PO}_4)_2(\text{OH})_6$] and crandallite group minerals [$(\text{REE}, \text{Ca}, \text{Sr})(\text{Al}, \text{Fe})_3(\text{SO}_4, \text{PO}_4)(\text{PO}_3\text{OH})(\text{OH})_6$]. Also present are subordinate synchysite [$\text{CaREE}(\text{CO}_3)_2\text{F}$] and monazite [$(\text{REE}, \text{Th})\text{PO}_4$], only observed in some samples, and most commonly around the deposit margins. Xenotime [$(\text{Y}, \text{REE})\text{PO}_4$], frequently as overgrowths on zircon, and phases of intermediate xenotime-coffinite-thorite solid solution are also present. Bastnäsité is observed to replace, and as twinned grains with, synchysite. Florencite appears paragenetically late, occasionally replacing apatite and overprinting bastnäsité, synchysite, and Cu-(Fe)- sulphides. Bastnäsité can also be replaced by copper-(iron)-sulphides.

Electron probe microanalysis of REE-minerals within drillcore samples and flotation tailings reveals significant compositional variation among all REE-mineral groups. Ce-dominant species are most prevalent; synchysite is always Ce-dominant, ($\sim 1:2$ La to Ce), whereas the La/Ce ratio in bastnäsité can range significantly from 0.3 to >1 , with the majority around 0.6. Florencite and crandallite group minerals display the highest overall La/Ce ratios, with many analyzed grains being La-dominant. $\sum\text{REE}+\text{Y}$ (hereafter REY) does, however, vary significantly (from 4.9 to 30.1 wt.%) in the alumino-phosphates. The same minerals also display significant variation with respect to SrO (0.6-12.9 wt.%) and SO_3 (0.5-12.1 wt.%), suggestive of significant solid solution. The HREE (Tb-Lu) +Y are generally slightly more enriched in synchysite (up to 6% of the $\sum\text{REY}$) while more depleted in the florencite (typically $<1\%$ of $\sum\text{REY}$ but can be up to 2%); bastnäsité shows a range from 0.3 to 4% HREE+Y of $\sum\text{REY}$. Xenotime is the most significant host for Y and HREE in the deposit.

The aforementioned complex textural and compositional variation across the sample suite suggests diverse, highly localised conditions of formation, and cycles of replacement, remobilisation, and recrystallization, suggesting perhaps there is not a clear deposit zonation as with other minerals. Ongoing microanalysis will establish trace element distributions in REE-minerals and further study is aimed at numerical modelling of REE-minerals to understand whether factors, such as pH, correlate with observed variation.