YREE, Th and U enrichment associated with biogenic material in phosphatic oil shale, Green River Formation, Utah, USA

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The Eocene Green River Fm. (GRF) at Gate Canyon, Uinta Basin, Utah, has been widely sampled and analyzed by whole rock XRD, FEG-SEM, solution ICP-MS, and LA-ICP-MS. Relative to variably fissile lake marlstone in the section, XRD indicates many beds of oil shale are anomalously rich in calcium fluorapatite (CFA). SEM shows associated algal mats, phosphatized vermiform (coprolitic?) and globular (coccoid microbe?) structures, and a diagenetic succession of rhombic dolomite, followed by microcrystalline CFA, and blocky low Mg-calcite. SEM-EDS has detected Na and S (as SO_4) at near expected values for balanced substitutions in the CFA lattice.

Solution ICP-MS shows CFA-rich intervals in the oil shale also contain Th, U, and YREE anomalies. LREEs may be slightly enriched with respect to background levels in the marlstone, but remain below PAAS values. There is a gradual increase in relative enrichment for the HREEs, and Lu values can reach x3 PAAS values. Thorium and U are enriched by up to an order of magnitude. LA-ICP-MS confirms these enrichments and shows maximum values of all these trace metals typically occur within 1 cm of the margin of the CFA interval, similar to fossil-bone alteration. Across the phosphatic boundary in two oil shales, REE ratios show complex variation from outside to in (Fig 1). Values for U and Lu are highly correlated and peak up to 1 cm in from the CFA margin. Closer to the margin, Th correlates most closely with Er to Tm peaks. Likely via diffusion, YREEs, Th and U are substituting into the CFA crystal lattice (e.g. $2Ca^{2+} = REE^{3+} + Na^{+}$) as CFA diagenesis progresses.

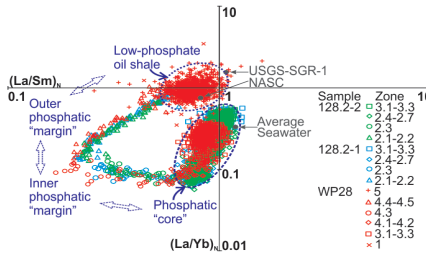

Fig. 1: PAAS normalized La/Sm v La/Yb plot for three ablations (128-1: n=1256, 128-2: n=1206, WP28: n=1613) across the same oil shale CFA interval at different sites.