Analysis of 33 Uranium Ore Concentrate Samples: A Case Study in Nuclear Forensics

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Nuclear forensics is a scientific discipline interfacing law enforcement, nuclear science and non-proliferation. Information on the history and on the potential origin of intercepted nuclear material can be obtained through nuclear forensic analysis. Using commonly available techniques of mass spectrometry, microscopy and x-ray diffraction, we have gained insight into the processing and origin of a suite of uranium ore concentrate (UOC) samples.

The 33 UOC samples are in the form of ammonum di-uranate (ADU). The sample suite is thought to represent a time series collected at the same location over a number of years. The rare earth element (REE) patterns match the REE patterns for phosphorites reported in [1], implying that the samples are derived from a phosphorite deposit (Figure 1). The REE patterns are fairly consistent throughout the series, although absolute concentrations of REEs decrease through the time sequence (Figure 1) suggesting improvments in metallurgy with time.
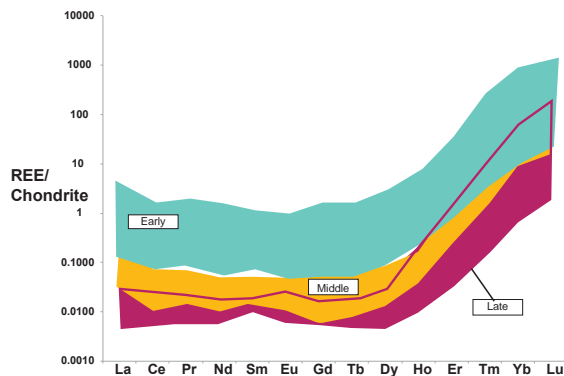

Figure 1: Chondrite normalized REE patterns for the suite of UOC samples.

The U purification process appears to be OPPA solvent extraction based on the form of the UOC (as ADU). The first few samples in the time series have higher concentrations of almost all impurity elements, and lower concentrations of U, than subsequent samples. Some of the later samples have on up to 40% higher concentrations of alkali earths and alkali metals, indicating slight variations in feedstock. The consistency in trace element patterns, however, suggests the samples are derived from geologically related ore bodies. This study illustrates one way in which nuclear forensic analysis can provide insight into the ore geology and production and purification methods used to produce UOC.

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The Terceira Rift, Azores: a melt inclusion study of submarine lavas

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The Azores plateau, a bathymetric high seated on an anomalous mantle domain is located in the Azores Triple Junction where the American, EUR and AFR lithospheric plates meet. The cause for these anomalies is controversial but many authors consider the presence of an anomalously hot/wet enriched mantle probably supplied by a plume [1]. The origin, size and present location of the plume is under debate but an area near Terceira is the favoured plume centre [2]. The Terceira Rift (TR) defines the EUR/AFR plate boundary of the Azores triple junction. The TR is a 550 km long, generally ESE trending line of volcanic massifs (e.g. São Miguel, D. João de Castro, Terceira and Graciosa) alternating with deep basins (e.g. Hirondelle basin). The latter are interpreted to be volcanically unfilled rift valley segments [3]. Vesicular, porphyritic basalts were sampled along the Terceira Rift during Portuguese scientific cruises (EMEPC 2007-2009). Initial studies focused on the adjacent areas Don João de Castro - DJC (submarine volcano) and Hirondelle - Hir (basin). Major and trace element data of phenocrysts (olivine, clinopyroxene, plagioclase), groundmass and exposed melt inclusions in these vesicular lavas depict only slight differences between the two sites although DJC samples have somewhat higher Fo and Mg# in olivine and clinopyroxene, respectively. Chondrite-normalized REE data indicate that groundmass material is LREE-enriched in both Hir and DJC lavas. Exposed melt inclusions (MI) show similar REE patterns compared to their hosts. Clinopyroxene in both sites displays L-MREE enriched, HREE depleted sinusoidal patterns. MI were found in olivine, clinopyroxene and plagioclase phenocrysts. MI are glassy to completely opaque and devitrified, with one or more bubbles, and sulfide globules (SG). SG are spherical, depict two-phase lamellar intergrowths of Fe-Ni and Cu-Fe phases, and are ubiquitous in DJC and Hir lava samples. Some lavas display SG within clinopyroxene-hosted MI and dispersed in the groundmass. Preliminary data suggest that lavas found in these areas of the Terceira Rift were sulfur-saturated in different stages of their evolution; during early fractionation and prior to eruption. The geochemistry of melt inclusion will contribute to the understanding of mantle source, melting and mixing processes in the Terceira Rift, Azores.

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