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Using pattern classification and nuclear forensic signatures to link UOC to source rocks and purification processes

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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 unknown 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. We have applied chemometric techniques to investigate the relationships between uranium ore deposits and UOC samples in order to identify chemical and isotopic signatures of nuclear forensic importance. We developed multivariate signatures based on elemental concentrations and isotope ratios using a database of characteristics of UOC originating throughout the world. By introducing detailed and specific information about the source rock geology for each sample, we improved our understanding of the preservation of forensic signatures in UOC. Improved characterization of sample processing and provenance allows us to begin to assess the statistical significance of different groupings of samples and identify underlying patterns. Initial results indicate the concentration of uranium in the ore body, the geochemical conditions associated with uranium emplacement, and host rock petrogenesis exert controlling influences on the impurities preserved in UOC. Specific ore processing techniques, particularly those related to In-Situ Recovery, are also reflected in UOC impurity signatures. Stable and radiogenic isotope geochemistry can be used in conjunction with rare earth element patterns and other characteristics to link UOCs to specific geologic deposits of origin. We will present a number of case studies illustrating the ways in which nuclear forensic analysis can provide insight into the ore geology and production and purification processes used to produce UOC.

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