**Occurrence of Uranium in Organic-Rich Black Mudstones of the Early Mesozoic Newark Basin in New Jersey and Evidence of Secondary Enrichment Processes**

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The nature of uranium (U) occurrence in black shales and the fate of the U when in contact with water are important issues when developing water or energy resources from black shales. Organic-rich black mudstones of the Mesozoic Basin in New Jersey are important aquifers locally, and on occasion waters from wells penetrating these formations have been noted to contain U and radium-226 (Ra-226) in concentrations above drinking water standards. Analysis of the most radioactive core samples from some of the affected wells for uranium (and progeny of its decay series, which includes Ra-226) using gamma-ray spectrometry indicated the maximum concentration of uranium in the mudstone was about 1700 ppm (parts per million), though more typical values were on the order of 100 ppm. Thorium (Th) and progeny are a possible source of alpha particles as well, but the concentration of Th were typically about 15 to 20 ppm, or about 20 percent that for U in the radioactive zones.

Alpha-autoradiographs were generated to investigate the sources of U (or other alpha-emitting radionuclides) in core samples of organic- and U-rich black mudstone. Scanning electron microscopy (SEM) and energy dispersive x-ray (EDX) allowed for mapping of the occurrence of U at specific points within thin sections. The bulk organic-rich fine-grained rocks contained abundant but dispersed U that likely is not readily mobilized to water resources where the rock is not fractured. The dispersed nature of the U, the presence of abundant dark organic matter, and the fine grain size made it difficult to pinpoint U sources using solely the alpha-autoradiograph and SEM/EDX images. Many modes of U enrichment relative to the general dispersed U already present in the organic-rich fine silts were noted and appear to be associated with diagenetic fluid mobility in zones of higher permeability (coarse silt and fine sand layers) or within fractures. U-bearing minerals were concentrated along pressure solution fronts, in silty or sandy zones of intense carbonate- and sulfide-mineral cementation and mineralization, and within mineralization zones in fractures. In some fractures, multiple zones of mineralization are likely resultant from the extensional tectonics experienced within the Mesozoic Basins. An association of alpharadioactivity (U, and presumably Ra-226) with secondary iron minerals, typically classified as chlorite, in minimally weathered silty and sandy samples was also noted. These minerals were, in places, weathered to iron-oxides, which coated partly intact grains with an orange weathering rind; the weathering of these minerals was likely also a source of iron oxide for grain and fracture coatings. The association of alpha-particle radioactivity with the iron in oxide form remained strong. These images show zones of secondary enrichment of U in the fine-grained rock, and also show changes in radionuclide distribution in the rock at successive stages of weathering, in particular, concentration of alpha-emitting radionuclides on fracture faces. While it may be generally presumed that U concentration are somewhat enriched in carbon-rich fine-grained sedimentary deposits relative

to typical sedimentary deposits, the modes of U occurrence and enrichment were variable even within this single setting. Thus, modes of U occurrence can be expected to vary within each unique depositional basin setting on the basis of local depositional, tectonic, diagenetic, and weathering history. Observations compiled from any one black shale deposit may serve as broad guidance (analogue) to the possible modes of U occurrence and preferential enrichment in black shales in other basins. Detailed studies of specific modes of U occurrence, enrichment, and potential pathways to mobility need to be conducted from sediment from the portions of the specific basins where water and (or) energy resources are extracted.