

Uranium mineralization in Camarines Norte, Philippines I. In-situ gamma spectrometry, geochemistry, and mineralogy

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Several localities with elevated radioactivity have been reported in the Camarines Norte mineral district, including the only verified uranium mineralization in the Philippines. To date, studies in this area are limited to reflected microscopy, exploration geochemistry, and preliminary resource estimates reported during the 1960/1970s. With renewed interest in nuclear energy and recognizing the importance of assessing the Philippines' natural uranium resources, we present the result of regional and local ground radiometrics surveys in the Camarines Norte mineral district designed to vector towards nuclear material-bearing localities. There is a prominent lithologic control on the measured K, eU, and eTh abundances with boxplot-defined high background and anomalous values located within the Eocene Tumbaga Formation and in the margins of Miocene intrusives. Background equivalent uranium (eU) values defined by the current dataset (n=161) range from 1 to 3 ppm. Dose rate of up to 5000 nSv/hr was measured at Nakalaya, with an eU value up to ~700 ppm. In Bessemer, the measured dose rate reaches up to 360 nSv/hr, with corresponding eU of 31.5 ppm. Dose rates measured in survey mode show an order of magnitude increase towards known uranium mineralized localities (e.g., Bessemer). Uranium mineralized zones delineated in Bessemer and Nakalaya have widths of less than 1 meter and are characterized negative Th/U anomaly in gamma transects. Bulk uranium concentrations determined by He mode ICP-MS/MS (n=27) indicate 10-100 times uranium enrichment in the Camarines Norte localities relative to Philippine crustal abundances. Likewise, we report the mineralogical characterization of uraninite from its principal Philippine locale with scanning electron microscopy, X-ray diffraction, and electron microprobe techniques. Larap uraninite is octahedral in form and measures ~80-250 microns along the c-axis. Powdered uraninite separates yield 2 θ peaks at 28.15° (1 1 1), 32.73° (2 0 0), and 46.90° (2 2 0). Larap uraninite polyhedra consists of U⁴⁺ cations coordinated with eight O atoms in cubic arrangement with each O atom bonded to four U⁴⁺ cations, with a lattice constant value of 5.4905 Å. EPMA-WDS spectra confirm the presence of Th, Y, Ca, P, and Pb suggesting potential cation substitution. Assuming that the total Pb present is radiogenic, the timing of uranium mineralization in Larap can be constrained at 18-16 Ma.