

Significance of Alteration Assemblages for the Origin and Evolution of the Proterozoic Nabarlek Unconformity-Related Uranium Deposit, Northern Territory, Australia

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Abstract

The Proterozoic Nabarlek unconformity-related uranium deposit in the Alligator Rivers uranium field is hosted by Paleoproterozoic amphibolite-grade, metamorphosed semipelitic sedimentary rocks and amphibolite schist. High-grade ore is confined to the Nabarlek fault, a reverse fault/shear zone that crosscuts a series of interbedded muscovite-quartz-biotite schists and amphibolite. Petrographic studies on polished thin sections combined with electron microprobe analyses, X-ray diffraction, fluid inclusion data, O-H and U-Pb isotope values, as well as ⁴⁰Ar/³⁹Ar dating have identified up to eight significant fluid events beginning with the precipitation of early quartz veins during uplift of the Myra Falls Metamorphics at 1830 Ma and ending with limited uraninite recrystallization during reactivation of the Nabarlek fault between 1380 and 750 Ma.

Quartz veins that likely formed toward the end of the Top End orogeny represent the earliest recorded fluid event. Fluid inclusion data and $\delta^{18}\text{O}$ and δD values indicate that these veins formed from basement-derived fluids that may have been heated by a cooling Nabarlek Granite during circulation through reverse faults/shear zones. The next fluid event, represented by fine-grained sericite and chlorite occurred when fluids passed into these faults and altered the metamorphic minerals following the exhumation of the basement and deposition of the Kombolgie Subgroup at ca. 1760 Ma. The intrusion of the Oenpelli Dolerite at ca. 1720 Ma resulted in the local remobilization of silica and the precipitation of quartz associated with minor pyrite and dolomite around the reverse faults.

Uranium mineralization is associated with an inner and outer alteration halo that extends as far as 1 km from the Nabarlek fault. Alteration in the outer halo began as early as 1700 Ma and is dominated by chlorite and sericite, which formed when a 200°C fluid flowed into the Nabarlek fault from the overlying Kombolgie Subgroup. U-Pb and ²⁰⁷Pb/²⁰⁶Pb dating reveals that massive uraninite precipitated at ca. 1640 Ma and formed together with illite and hematite at ca. 200°C. Chlorite was not coeval with uraninite precipitation. Stable isotope values indicate that the pre- and synore alteration assemblage formed from basinal brines with $\delta^{18}\text{O}_{\text{fluid}}$ and $\delta\text{D}_{\text{fluid}}$ values of 2 ± 2 and -25 ± 10 per mil, respectively.

Reactivation of the Nabarlek fault at ca. 1360, 1100, and 900 Ma is indicated by U-Pb and ²⁰⁷Pb/²⁰⁶Pb dating of uraninite. These ages correlate with the intrusion of the Maningkorriir phonolitic dikes and the Derim Derim Dolerite at ca. 1316 ± 40 and 1324 ± 4 Ma, respectively, the amalgamation of Australia and Laurentia during the Grenville orogen at ca. 1140 Ma, and the breakup of Rodinia between 1000 and 750 Ma. Fluid incursions associated with these events precipitated much of the chlorite that has previously been related to uraninite precipitation. Drusy quartz veins that host high-salinity fluid inclusions and sulfides, particularly galena, also formed after the initial uraninite-forming event. Finally, erosion of the Kombolgie Subgroup and subsequent weathering of the deposit resulted in the recent formation of kaolinite and numerous secondary uranium minerals. These data constrain individual events more precisely than previous studies and thus advance the current genetic model to a level that takes into account the multiple stages of fluid overprinting that occurred over a period of at least 800 m.y.

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