

Clay Alteration Associated with Proterozoic Unconformity-Type Uranium Deposits in the East Alligator Rivers Uranium Field, Northern Territory, Australia

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Abstract

Clay minerals associated with the unconformity-type uranium deposits of the East Alligator Rivers uranium field have been used to determine the spatial distribution of hydrothermal alteration and the conditions of uranium deposition within the altered basement underlying the Kombolgie unconformity. Alteration develops a similar pattern at regional and smaller scales, with a close relationship between the degree of alteration and the amount of structural discontinuities observed on both sides of the unconformity (e.g., faults, fractures, breccias). These discontinuities were mechanically active during the hydrothermal activity. The hydrothermal clay minerals partly to totally replace diagenetic dickite and illite in the Kombolgie sandstones and metamorphic phengite and chlorite in the basement rocks.

The time-space alteration sequence established in this study can be summarized as follows: (1) early crystallization of illite ± illite-smectite (I-S) mixed layer minerals + LREE-Sr-bearing aluminum phosphate-sulfates (APS) in sandstones above the unconformity, illite ± I-S mixed layer minerals + sudoite + APS on both sides of the unconformity and in fault gouges, and illite ± I-S mixed layer minerals + chlorite ± apatite deeper in the basement; and (2) late precipitation of chlorite in the open fracture network mainly centered below the unconformity. The main stage of uranium deposition was associated with chloritization in the basement rocks.

Smaller particle size, lath-shaped or flaky morphology, common interstratification with expandable layers, lower crystallinity, and Mg-rich chemical compositions can be used to distinguish the hydrothermal clays from the other diagenetic and metamorphic illite and/or chlorite. Hydrothermal illite can be distinguished from diagenetic and metamorphic illite-phengite by its poor crystallinity along the c-axis, interstratification with minor amounts of smectite layers, and a 1M polytype in which trans-vacant octahedral sites predominate (1 Mt). Chemically, the hydrothermal illite differs from diagenetic illite by a lower interlayer charge and a higher Mg content. The hydrothermal chlorite is distinguished from the metamorphic chlorite by its smaller particle size, spherulitic habit, poor crystallinity along the c-axis, and common association with corrensite and/or chlorite-corrensite mixed layers. Most of the hydrothermal chlorite is Mg rich and has a structural formula close to that of clinocllore ($X_{\text{Fe}} < 0.20$). Near the uranium deposits, the spherules of hydrothermal chlorite are chemically zoned (from $X_{\text{Fe}} < 0.10$ to $X_{\text{Fe}} < 0.40$), which is interpreted as the result of a change in the oxidation state of the hydrothermal solution during the chlorite crystallization.

The space-time alteration sequence established for clay minerals and the observed transition of APS to apatite are interpreted as the result of an increasing degree of interaction of the basement rocks with infiltrating acidic and oxidizing sub-basinal brines. In turn, these fluids tend to be neutralized and reduced by their ongoing interaction with ferrous iron-bearing phyllosilicates (Fe chlorite and biotite) and iron sulfides of metamorphic origin. The ore deposits are surrounded by zones in which the degree of fluid-rock interaction was very high and chloritization is most abundant. The octahedral Mg content of the associated hydrothermal illite from the sandstone can be used as a guide to indicate the possible presence of uranium orebodies in the basement rocks, tens to hundreds of meters below.

The crystal structures of the hydrothermal illite and chlorite suggest that these minerals crystallized at temperatures approximately 30° to 50°C lower than those expected at the peak diagenesis of the Kombolgie sandstones near the unconformity.

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