ABSTRACT

Chemical and isotopic studies on the accessory minerals such as tourmaline, magnetite, fluorapatite, and monazite from the Mohuldih and Bagjata mines were performed to understand the uranium mineralizing history in the Singhbhum Shear Zone.

Three textural types of tourmalines with different chemical and B-isotope composition indicate three events of mineralization. The earliest tourmaline, coeval with the primary uraninite recorded $\delta^{11}B$ of 8.8 ± 0.3 ‰, which suggests an externally-sourced high saline fluid for mineralization. The high saline fluids reacted with the phyllosilicates (chlorite/biotite) of the schistose rocks of the Mohuldih and Bagjata and produced Mg-rich tourmaline as Fe and U remain complexed with Cl. Salinity of the fluids decreased with continued phyllosilicate dissolution, which destabilized the Cl-complexation, leading to the precipitation of Fe as Fe-tourmaline and magnetite, and U as uraninite. The second and third generation of tourmalines range from 2.5 to 6.3 ‰ in their $\delta^{11}B$ values. They formed from mixing of at least two fluids, wherein one was externally derived saline, isotopically heavier, and the other was internally generated during the metamorphic dehydration of pelites. The boron isotopic values of the tourmalines from the schists of the Singhbhum Shear Zone are comparable with the range of values (–10.4 ‰ to +6.0 ‰) reported earlier for the IOCG-type deposits associated with metamorphic slab-derived fluid sources.

Two textural types of hydrothermal fluorapatite, magnetite, monazite, and allanite were identified and these phases coexist with primary uraninite, while the secondary phases formed as a result of coupled dissolution-reprecipitation. Uranium-lead dating on the hydrothermal monazite grains from Mohuldih provided four concordant age clusters ca.1.85 Ga, 1.65 Ga, 1.43 Ga, and 0.96 Ga. The oldest age of 1.85 Ga recorded from the texturally early monazite date the primary hydrothermal event and associated U mineralization. This event was synchronous with the emplacement of the Arkasani Granophyre and linked to rifting/extensional tectonics in the North Singhbhum Mobile Belt. The 1.6–1.4 Ga ages obtained from the homogeneous rims of the monazite grains represent the hydrothermal activities that were synchronous with the Andean type arc-continent collision. This event resulted in the amalgamation of the North Singhbhum Mobile Belt with the Singhbhum Craton. The youngest 0.96 Ga ages measured from fine-grained later-stage monazite date the hydrothermal alteration events coeval with the Grenville-age Alpine type continent–continent collision. This event led to the amalgamation of the Chhotanagpur Gneissic Complex with the Singhbhum Craton-North Singhbhum Mobile Belt composite. The Bagjata uranium mine, on the other hand, only records the 0.9 Ga alteration event, as revealed from the U-Pb dating of uraninite and monazite. However, the textural relation of the minerals and their chemical composition point to the possibility of multiple events. Two major alteration types can be interpreted based on the mineral assemblage at Mohuldih and the known metamorphic events in the Singhbhum Shear Zone. The M_1 metamorphic event was accompanied by a combination of high-temperature calcic-iron±sodic and high-temperature potassic-iron alteration, followed by a low-temperature silicification/K-Al alteration during the M_2 metamorphic event, which led to coupled dissolution-reprecipitation in the deposit. A comparative study between the magnetite and fluorapatite trace element data of this study and those from global magnetite type iron oxide-copper-gold (IOCG) and iron oxide-apatite (IOA) deposits indicates Mohuldih as an IOCG type deposit.

Keywords: tourmaline, fluorapatite, magnetite, monazite, B-isotope, U-Pb dating