ABSTRACT

The A-type granites situated on the boundary of the Singhbhum Craton with the Rengali Province in the Jharsuguda district of Odisha in eastern India are significant due to their role in the tectonic evolution of the region. This study presents new zircon ages for these granites and the associated Nb-Ta bearing pegmatites. It also, for the first time, reports potential LREE mineralization in the granites and associated granitic gneiss.

There are four populations of zircon ages. The oscillatory-zoned magmatic zircon zones yield an age of 2.95 Ga, which is distinctly older than the earlier reported Rb-Sr age of 2.7–2.8 Ga for the Jharsuguda granites. The ~2.8 Ga age is obtained from altered zircon zones and represents the time of the first metamorphic event in the Jharsuguda granites following their emplacement at 2.95 Ga. The so far unknown source of the 2.95 Ga detrital zircons in the western Iron Ore Group rocks that lie to the east of the present study area must have been the Jharsuguda granites. The altered zircon appears darker in CL images and contains non-formula elements like Al, P, Ca, Fe, Y, and REEs. Inclusions of U- and Th-bearing minerals, including those of monazite, xenotime and rare Nb-rich phases, are typical of the altered zircon. There are also imprints of thermal events at ~2.45 and ~2.1 Ga, the ~2.45 Ga age population having been the second most prominent one next to the 2.95 Ga population. All the three metamorphic events have been reported from the Rengali Province suggesting that the Jharsuguda granites may be the extension of the Rengali Province. The presence of all but the 2.95 Ga zircon in the pegmatites suggest that the pegmatites were formed during the 2.8 Ga metamorphism. Fergusonite (the product of Nb-Ta mineralization through the replacement of zircon) yielded an EPMA age of ~2.1 Ga, which matches with the youngest and smallest population of zircon ages. This shows that fergusonite, similar to monazite, can be used for age dating by EPMA method.

The main Nb-Ta mineral in the granite and pegmatite is the fergusonite-(Y), which has formed by the replacement of zircon and probably allanite. In the pegmatite, they range in size from a few μm to 500 μm. Within the granite, the replacement of zircon by fergusonite appears to have taken place along cracks which fluids from the pegmatite were conducted through. In one of the granite and associated granite gneiss, the LREE carbonates bastnäsite-(La), bastnäsite-(Ce), bastnäsite-(Nd), parisite-(Ce), synchysite-(Ce), and LREE silicate cerite-(Ce) are observed, revealing the possibility of LREE mineralization potential of these rocks. Similar to fergusonite-(Y), these minerals replace earlier zircon and allanite crystals forming pseudomorphs of sizes ranging from 40 μm to 500 μm. The hydrothermal fluid was evidently enriched in F^-, CO_3^{2-} and PO_4^- ions.

LREEs are enriched in both primary and altered zircons, influenced by magmatic inheritance, hydrothermal fluid interactions and radiation damage. Unaltered zircons show positive Ce-anomalies, while altered and pegmatitic zircons show both positive and negative anomalies. This suggests varying oxidation conditions during zircon formation and alteration. Unaltered zircons have ≥0.5 Th/U ratios typical of igneous zircons and crystallized at relatively low magma temperatures (average 724°C). The presence of M-type lanthanide tetrad effects in zircons and W-type tetrad effects in whole rocks indicates interactions with evolved granitic

melts and magmatic fluids. Lower zircon saturation temperatures compared to crystallization temperatures suggest significant influence from hydrous melts or fluids.

The LREE mineralized granite gneiss has a flat chondrite-normalized REE pattern and about thirty times REE enrichment compared to the chondritic meteorites. While the Jharsuguda granites have higher LREE abundance with negative Eu-anomaly, the granites to the west of the present study area have a REE pattern complementary to the Jharsuguda granites with overall depleted REE abundance and positive Eu-anomaly. The partial melting of the granite gneiss gave rise to the Jharsuguda granites and the western granites are the residues, left after the segregation of them out of the granite gneiss.