Sedimentological Analyses, Internal Stratigraphy and Sediment-hosted Detrital Iron and Radioactive Ore Mineral Potential of the Mesoarchean Siliciclastic Succession around Keonjhar, Singhbhum Craton, Odisha, India

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Chapter 9

Discussion and Conclusions

The Keonjhar siliciclastics studied here is one among the rarest well preserved examples of Mesoarchean sedimentation. The succession is dominated by mature quartz arenite *albiet* modified to quartzite with low greenschist grade metamorphism, provided important information on the Mesoarchean arenite depositional system and nature of Mesoarchean upper crust from a collective study of internal stratigraphic development, interpretation of depositional settings and provenance.

9.1. Development of Keonjhar stratigraphy

The Keonjhar Quartzite is mapped here in 1: 50,000 scale. The mappability and the distinct lithological characters warrant a formal status of formation and the succession is named here as Keonjhar Quartzite Formation. Detailed mapping revealed that the formation is affected by at least three major thrust slices. The thrust slices repeated the stratigraphy. Based on distinct lithology, the mass-flow conglomerate dominated lower part of the formation has been assigned here the status of member. A lentil of iron ore bearing conglomerate near the upper part of the succession has also been recognized here as a member because of its distinct lithology. The thrust slices enabled to study the stratigraphic development and sedimentary facies variation in down dip transects thus facilitating the reconstruction of the depositional setting and paleoslope.

9.2. Depositional environment

Sedimentary facies analysis was attempted. Nine facies described on the basis of lithological characters reveal the deposition from mass flow as well as fluid-gravity flow mechanisms. The deposits further bear imprints of wave-reworking and deposition from wave/tide currents. Based on the ratio between mass flow deposits and fluid-gravity flow deposits number of environmental settings have been identified. The lower parts include mass-flow dominated subaerial proximal- to mid-fan depositional system. This grades upwards to mature arenites of wave-/tide-dominated shelf setting. The transition zone is characterized by grain-supported as well as matrix-supported finer conglomerates and pebbly sandstones that show strong wave reworking suggesting a fan-delta / braid delta setting. The iron ore clast-bearing conglomerates near the upper part of the succession are encased within the shelf succession. These deposits are likely to indicate an abrupt base level fall induced by local tectonics.

Paleocurrent pattern is dominantly unimodal WSW-ly with locally preserved bipolar distribution. Internal organization of sandstone beds into sets and cosets of trough/planar cross-strata and wave-reworked upper bounding surfaces of the sandstone beds together with the paleocurrent pattern testify to tidal influence in the sand accumulation and dispersal. The facies sequence can be described in terms of a depositional sequence. The sequence initiating over unconformity on the Singhbhum Granite and IOG greenstones includes a lowermost LST with Incised Valley Fills from FSST. This is followed by a TST and aggradational phase of TST-HST with locally developed *forced regressive incised valley fills* of iron ore clast-bearing conglomerates.

9.3. Nature of source terrain and the Mesoarchean upper continental crust

Provenance analyses carried out from petrographic and geochemical studies reveal the nature of the source terrain and nature of Mesoarchean upper crust. Standard QtFL, QmFL and QmPK ternary plots reveal that the arenites are sourced from craton interior to recycled orogen provinces, a typical signature of stable cratonic crust with enclaves of low-grade Archean greenstone belts. SEM-CL fabric analysis of the quartz framework grains reveal variation in internal CL-characters that can be further linked to the genetic types of quartz framework such as plutonic quartz, medium-grade metamorphic quartz and low-grade metamorphic quartz. The quartz CL characters reveal the predominance of plutonic quartz suggesting that the sediments are primarily sourced from plutonic terrain. On the other hand the rarity of metamorphic quartz signifies that high-grade metamorphic components from collisional geodynamics were not significant in the Paleo-Mesoarchean upper continental crust in the Singhbhum craton.

U-Pb and Lu-Hf compositions from detrital zircon in Meso-Neoarchean siliciclastic successions provide a robust database for distinguishing the relative proportion of juvenile and recycled plutons in the upper crust that constitute the provenance for such sediments. Lu-Hf compositions from detrital zircons of ~ 3.0 Ga Keonjhar Quartzite reveal the proportion of juvenile/recycled crust in the Paleo-Mesoarchean Singhbhum craton and explores the implications for early Archean geodynamics. To summarize the $€_{Hf}$ isotopic compositions vary between -1.8 to +4.45 (2-sigma error). Most of the zircons yielded a superchondritic $€_{Hf}$ with high positive range from +0.5 to +4.5. The superchondritic Hf isotopic compositions expressed as $€_{Hf}$ values against their stratigraphic ages suggest depleted mantle source and juvenile crustal components which in turn indicates possible onset of accretionary plate tectonics during Mesoarchean.

9.4. QPC-hosted uranium paleoplacers

The radioactive Quartz Pebble Conglomerates (QPC) in the Keonjhar Quartzite occur in the basal part of the succession. The geochemical and petrographic (including SEM) studies reveal that the radioactive mineralization of Mesoarchean Keonjhar QPC is composed of rutile/ uraniferous leucoxene aggregate associated with coffinite, thorite, uranothorite, zircon, pyrite and monazite. Detailed study of the QPC further reveals that rutile/leucoxene and uranium enriched brannerites are predominant mineral over all other uraniferous phases. U-Ti phases are restricted within QPC just above the unconformity. From external morphology, geochemical composition and core-rim structure, brannerite and all U-Ti phases speak in favour of diagenetic alternations process similar to Pronto Reaction. Correlations of U and Th wrt other elements reveal positive correlation with TiO_2, Zr and Hf. Correlations with Ti, Zr and Hf in turn suggest that uranium concentration is related to the concentration of detrital rutile and hence detrital zircon. U also reveals positive correlation with LREEs indicating preferential U-concentration in supergene phosphate phases. Such signature may be important in understanding hidden redox U-paleoplacers below the supergene weathering profile. Geochemical proxies further analysed based on major trace and REE compositions of the arenites. La-Th-Sc and Th–Sc–Zr/10 proxies reveal both granitic components and components from source close to the active continental margin. Trace and REE compositions from the sandstones are points towards a mixed source of felsic as well as mafic terrain. This mixed source origin supports the presence of both cratonic and recycled orogen provenance types. The presence of negative Eu-anomalies observed in REE distribution patterns of Keonjhar samples suggests major component of the provenance possibly was derived by intracrustal differentiation processes. The evidence of differentiated upper crust during Paleo-Mesoarchean has important bearing for the Paleo-Mesoarchean continental crust as source for U-Th QPC placer deposits.

9.5. Detrital iron ore deposit and implications on age of iron ore formation

The iron ore conglomerate in the upper part of the succession is interpreted as product of a forced regression in this profile. The conglomerates are very unique in a sense that they are encased in a shelf sandstone host succession and the ore clasts are remarkably similar with the hard laminated or hard massive ores of the neighbouring BIF-hosted high-grade deposits of the Noamundi- Joda iron ore district. Minimum age of ore formation here is interpreted from the detrital zircon U-Pb ages from the sandstone clasts in the conglomerates. The U-Pb data detrital zircons are mainly magmatic in nature with oscillatory zoning. The minimum age population of these zircons which represents the maximum depositional age of conglomerate clasts ranges from 3.1 Ga to 3.2 Ga. The hard ore clasts in the conglomerate suggest that the ore formation in the source terrain predated the deposition of the conglomerate and hence should be a >3.0 Ga event. The detrital zircon U-Pb ages of the iron ore bearing conglomerates therefore indicate that the BIF-hosted high-grade iron ores from the Singhbhum craton must have been formed during Mesoarchean or earlier time.