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NEWS AND NOTES

Warm and dry palaeoclimate during the Palaeoproterozoic: Evidences from the Papaghni sub-basin of the Cuddapah Basin, India

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The sedimentary rock records indicate widespread low-latitude glaciations both near the beginning and end of the Proterozoic eon. However, a major part of the Proterozoic was most likely warm and dry as attested by findings of an increasing number of aeolian deposits in different Proterozoic basins worldwide (Cosgrove et al., 2023). Context to this, evidences for the existence of a warm and dry palaeoclimate are presented here especially from the south-western part of the c.2.0–1.9 Ga Papaghni sub-basin of the Cuddapah Basin, located in the east-central part of the Eastern Dharwar Craton, India.

The sediments of the Papaghni and Chitravati groups were deposited in the Papaghni sub-basin. The Papaghni Group is composed of terrigenous sediment (sandstone, shale and conglomerate) dominated Gulcheru Formation, and carbonate (stromatolitic dolomite, minor limestone, calcareous shale) and basaltic volcanics dominated Vempalle Formation. The Papaghni Group non-conformably overlies the Neoarchaean to Palaeoproterozoic dominantly crystalline basement rocks. The basement-sediment contact is sharp and any development of palaeosol has not been observed. Though there are different views, but the sedimentological characteristics indicate deposition of the Gulcheru sediments initially in fluvio-aeolian and later in coastal to shallow marine regimes (Basu et al., 2007 and references therein). Discrimination plots using modal analysis data of the sandstones and geochemical data of both the sandstones and mudrocks indicate the derivation of the sediments from cratonic interior continental blocks (Basu et al., 2018) and deposition in passive margin setting. The Vempalle Formation is inferred to have been deposited in a low-gradient carbonate ramp (Banerjee et al., 2019 and references therein).

Fluvio-aeolian sediments have been identified in the lower part of the Gulcheru Formation (pink massive sandstone, after Basu et al., 2007). The aeolian sandstones are characterized by very large-scale planar-tabular cross-stratification, translatent strata, pin-stripe lamination, zibars, high-index granule ripples, grainflow cross-strata and grainfall laminae (Basu et al., 2014). The planar-tabular cross-stratification is often characterized by foresets that asymptotically sweep over the lower bounding surface, flatten near the toe and lap conformably over the pre-existing topography. The aeolian sandstones are made up of dominantly rounded to well-rounded, fine-to medium-grained monocrystalline (67.7–94.2 vol.%) and polycrystalline (1.2–17.2 vol.%) quartz with frequent unimodal to often bimodal textures. Interestingly, the coarser mode in bimodal sandstone is polycrystalline quartz (Basu et al., 2018). As polycrystalline quartz is susceptible to dissolution and disintegration in the presence of water, its presence indicates limited availability of water. Further, monocrystalline as well as polycrystalline quartz with rounded grain boundaries (Fig.1) indicates recycling in arid aeolian environments (Garzanti et al., 2013).

The sandstones of the Gulcheru Formation are found to contain sub-rounded to rounded fresh grains of K-feldspar and plagioclase. Well-rounded grains of fresh feldspars are a strong indicator of intense aeolian activity (Basu et al., 2018 and references therein). Recent studies on low-gradient granitic regoliths reveal that plagioclase weathering is more sensitive to variations in water availability (Mao et al., 2022). The coexistence of fresh K-feldspar and plagioclase therefore indicates dry climatic conditions. Additionally, high Th/K (>6) and low Th/U (<2) ratios suggest mechanical destruction of feldspars in aeolian environment.

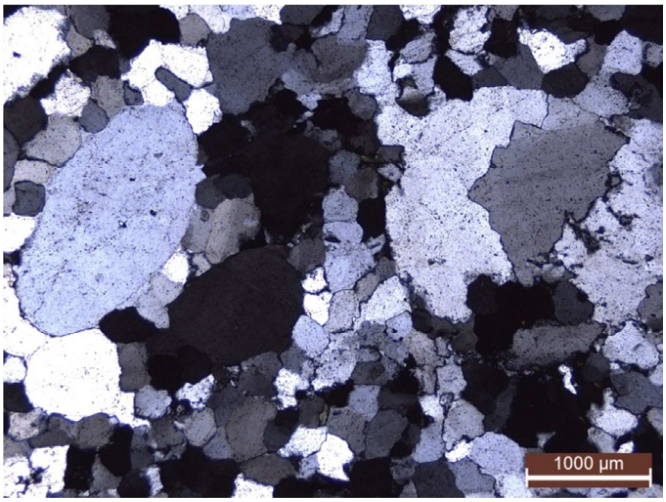

Fig. 1. Monocrystalline as well as polycrystalline quartz with rounded grain boundaries. Note the distinct bimodal grain-size distribution.

Redbeds are known to form both in warm-moist and warm-dry climatic conditions. However, redbeds associated with evaporite-bearing succession are typical indicators of sedimentation in warm and dry climatic conditions. The redbeds (conglomerates, sandstone and shale) have been identified in the Gulcheru Formation (Fig. 2). The quartz grains in it (sandstones) are found to be coated and cemented with hematite. The presence of redbeds, especially in association with aeolian sandstone, indicates the prevalence of warm and dry palaeoclimate. The presence of evaporite in the overlying Vempalle Formation further substantiates it.

The chemical index of alteration (CIA) is an important geochemical tool for quantitative evaluation of the intensity of chemical weathering in the provenance and therefore palaeoclimate. The sandstones (58–

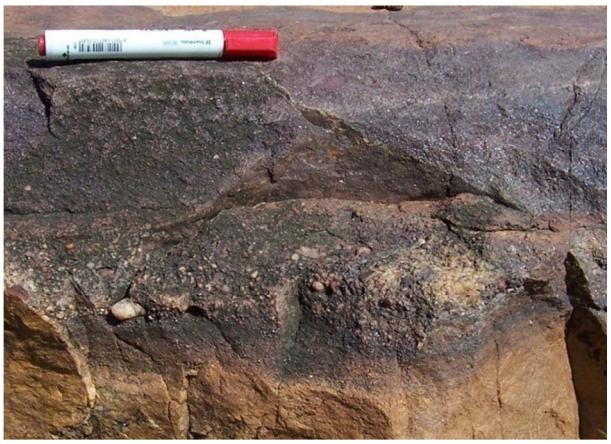

Fig. 2. Redbed in the Gulcheru Formation. Note the gradual in-situ reddening towards the bottom of the bedding (marker pen 14 cm long).

95, 74±9, n=64) and mudrocks (60–82, 70±5, n=27) of the Gulcheru Formation are characterized by moderate average-CIA values. Comparable CIA values of the finer siliciclastic sediments have been reported from several contemporary Palaeoproterozoic basins worldwide. The corrected (pre-metasomatized) CIA values (74–86) of the mudrocks indicate overall moderate to marginally intense chemical weathering of the provenance and therefore semiarid palaeoclimate. The mean annual temperature (MAT) has been estimated from the pre-metasomatized CIA values of the mudrocks using the empirical relationship between MAT and CIA (CIA=1.02*MAT+59.23; Deng et al., 2022). The MAT during the deposition of the Gulcheru sediments is estimated to have ranged between 14.5–26°C.

Evaporites (viz. gypsum, anhydrite) have been reported from the overlying Vempalle Formation (Bhattacharjee et al., 2018 and references therein). Evaporites are unambiguous indicators of arid to hyperarid climates. At modern times, gypsum precipitates from penesaline (salinity: ~130–160‰) seawater (Warren, 2016). A combination of (i) development of an enclosed basin margin environment, (ii) restricted groundwater and/or riverine influx (e.g., Bhattacharjee et al., 2018), and (iii) prevalence of warm and dry palaeoclimatic conditions are inferred to have favoured deposition of evaporites in the Vempalle Formation.

The $\delta^{18}O$ values of carbonate rocks are helpful proxies for reconstructing the isotopic composition of water and/or the temperature conditions during precipitation. The $\delta^{18}O$ values of the carbonate rocks of the Vempalle Formation are found to vary between -22.42‰ to -0.49‰ (n=218; data compiled from published literature). Statistical processing of data helped in identifying three distinct peaks at -7.23‰, -8.57‰ and -17.53‰, which are inferred to indicate (i) precipitation of carbonates from ^{18}O-enriched seawater (during seepage-reflux-type dolomitization by evaporative pore fluids), (ii) modification of isotopic signature during higher temperature burial diagenesis and/or exposure to meteoric water, and (iii) modification of isotopic signature by fluids related to uranium mineralization, respectively. Temperature estimates reveal that the minimum surface temperature of the Palaeoproterozoic Vempalle seawater was ~29°C.

Thus, the lithological, mineralogical, geochemical and isotope geochemical data indicate the prevalence of warm and dry palaeoclimatic conditions during the deposition of the Papaghni Group. The gross absence of palaeosol at the base of the Gulcheru Formation is also an indirect evidence for the prevalence of warm and dry palaeoclimate. These along with the aeolian deposits recognized in several parts of the world, viz. Karutola Formation (Palaeo-proterozoic?), India; Bandeirinha Formation (1.70 Ga), Brazil; Kazan Formation (1.82 Ga), Canada; Makgabeng Formation (1.9–1.7 Ga), South Africa; Nora Formation (2.1 Ga), Zimbabwe; and Kinga Formation (2.45–2.1 Ga), Canada (Cosgrove et al., 2023 and references therein), indicate prevalence of warm and dry palaeoclimate during the Palaeoproterozoic.

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