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C, O, Sr and Nd isotope systematics of carbonates of Papaghni sub-basin, Andhra Pradesh, India: Implications for genesis of carbonate-hosted stratiform uranium mineralisation and geodynamic evolution of the Cuddapah basin

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ABSTRACT

The Cuddapah basin (CB) is one of a series of Proterozoic basins that overlie the Archaean cratons of India, and contains a unique stratiform carbonate-hosted uranium mineralisation. In the present work, we discuss stable (C, O) and radiogenic (Nd, Sr) isotope systematics of carbonates of the Papaghni sub-basin in order to understand uranium ore forming processes and geodynamic evolution of the CB. Uranium mineralised dolomites (UMDs) of the basal Vempalle Formation show a significantly lighter (~1.5‰) C-isotope signature compared to that of open-marine stromatolitic sub-tidal facies, suggesting input of isotopically lighter carbon through in situ remineralisation of organic matter (OM). This implies deposition in a hydrologically-restricted, redox-stratified lagoonal basin wherein exchange with open oceanic dissolved inorganic carbon (DIC) was limited. Persistent bottom water anoxia was created and maintained through consumption of dissolved oxygen (DO) by decaying OM produced in oxidised surface water zone. Significantly more radiogenic $\varepsilon Nd_{(t)}$ of UMD (-6.31 ± 0.54) compared to that of Dharwar upper crust (-8.64 ± 3.11) indicates that dissolved constituents did not originate from the Dharwar craton, rather were derived from more juvenile exotic sources — possibly from a continental arc. Dissolved uranyl ions (U^{+6}) were introduced to the basin through fluvial run-off and were reduced to immobile uranous ions (U^{+4}) at the redox interface resulting in precipitation of pitchblende and coffinite. Carbonate horizons of upper Vempalle Formation and Tadpatri Formation show progressively more radiogenic Nd isotope compositions signifying increased juvenile arc contribution to the Papaghni sub-basin through time, which is also corroborated by the presence of younger zircons (1923 ± 22 Ma) in Pulivendla quartzites. We propose that the Papaghni sub-basin opened as a back-arc extensional basin at ~2 Ga as a result of westerly-directed subduction of oceanic crust beneath the eastern Indian continental margin. The 'Papaghni' back-arc basin eventually evolved to 'upper Cuddapah' foreland basin with collision of the Dharwar craton and Napier block of Antarctica at ~1.6 Ga, possibly, during the final stage of amalgamation of the Columbia supercontinent.

1. Introduction

A prominent feature of the Precambrian shield of Peninsular India is the presence of several intracratonic basins of Paleo- to Neoproterozoic age. These include the Vindhyan, Chhattisgarh, Indravati, Khariar, Pranhita–Godavari, Cuddapah, Bhima, and Kaladgi basins (Fig. 1) and are collectively known as 'Purana' basin (Holland, 1906). Except near the basin margins they preserve nearly undeformed, thick sedimentary successions which are important for the study and understanding of past surface conditions and lithosphere–hydrosphere–atmosphere interactions (e.g. Holland, 2006). On the basis of U–Pb age data of detrital zircons, considerable differences in depositional ages for these basins are now recognised and their source-sink relationships with adjoining orogenic belts have been proposed (Amarasinghe et al., 2015; Bickford et al., 2011a, 2011b; Collins et al., 2015; Malone et al., 2008; Mukherjee et al., 2012). However, precise mechanisms and timings of opening and closing of these basins are still not known, limiting the possibility of paleo-supercontinent reconstruction in the context of global geodynamics (cf. Rogers and Santosh, 2009).

The 'Purana' basins of Eastern Dharwar Craton (EDC) viz. Cuddapah and Bhima basins are known for the occurrence of uranium mineralisation and the Cuddapah basin has been established as a major uranium province of India (Parihar and Rao, 2012 and references therein). Two types of uranium deposits have been found in environs of

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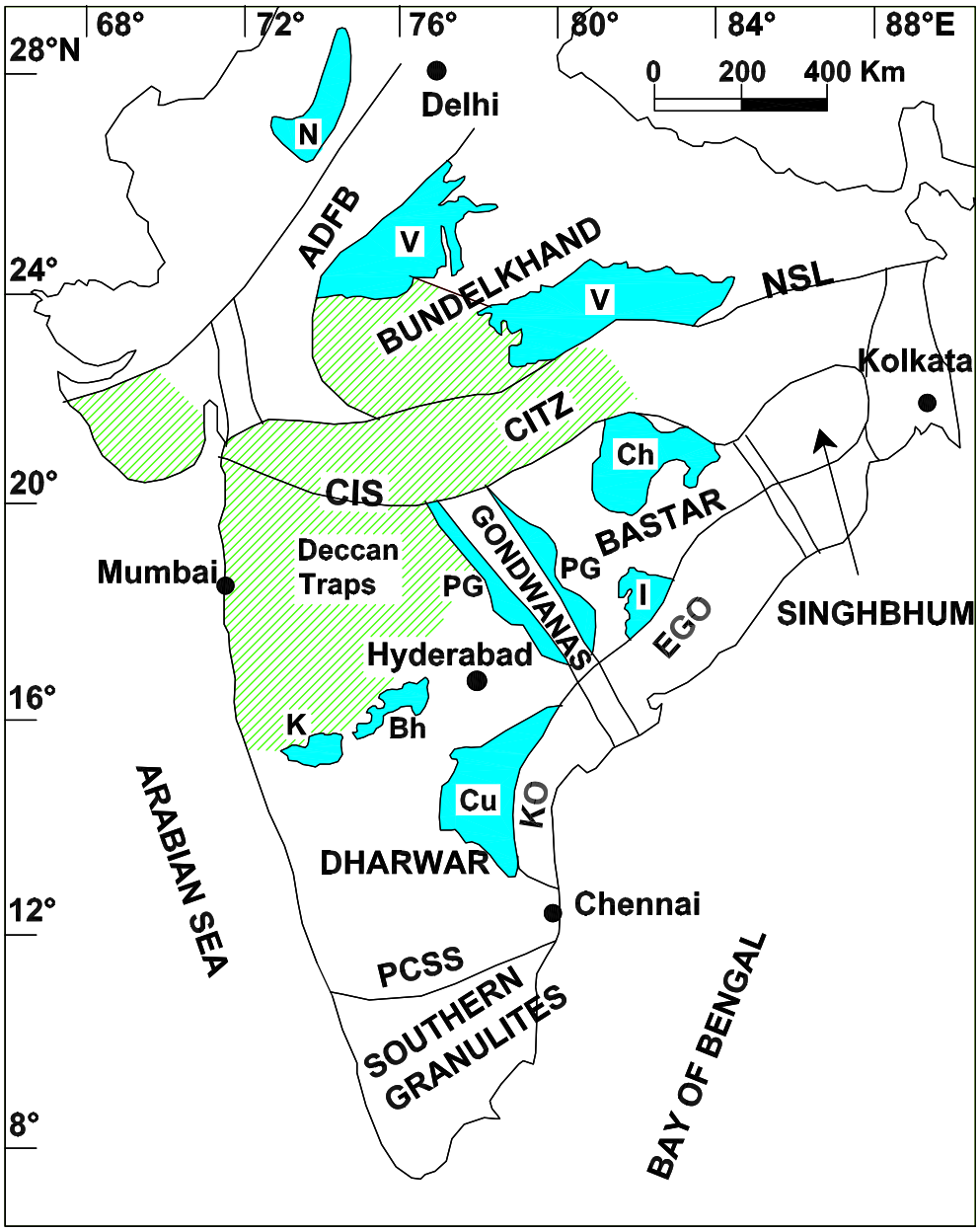

Fig. 1. Schematic geological map showing the main cratons, the Proterozoic orogens and the Proterozoic basins of India. Abbreviations for sedimentary basins: Cu — Cuddapah, Bh — Bhima, K — Kaladgi, I — Indravati, Ch — Chhattisgarh, V — Vindhyan, PG — Pranhita–Godavari, N — Nagaur–Ganganagar. Abbreviations for tectonic features: ADFB — Aravalli Delhi Fold Belt; NSL — Narmada Son Lineament: CIS — Central Indian Suture; CITZ — Central Indian Tectonic Zone; KO — Krishna Orogen; EGO — Eastern Ghats Orogen; PCSS — Palghat–Cauvery Shear System. (Modified from Vijaya Rao and Reddy, 2002.)

Cuddapah basin (Fig. 2). These are (1) unconformity related deposit hosted in the interface between basement granite (~2.5 Ga) and Srisailam quartzite, located in the northern Srisailam sub-basin (2) stratiform type deposit hosted in carbonate rocks of Vempalle Formation, located in Papaghni sub-basin in the southern part. However, comprehensive studies on ore forming processes of these important ore deposits are not available (e.g. Roy and Dhanaraju, 1997, 2012; Thomas et al., 2014) and their relationship with global geodynamic/supercontinent cycles is unclear. In this paper, we discuss C, O, Sr and Nd isotope systematics of the carbonate horizons of the Papaghni sub-basin in order to place constraints on metallogenic processes of formation of carbonate-hosted uranium deposit of Lower Cuddapahs, the evolution of provenance of the Papaghni sub-basin and implications for geodynamics.

2. Geological setting

The Cuddapah basin (CB) is situated in the eastern part of the Dharwar Craton (DC) and is one of the largest Proterozoic intracratonic sedimentary basins in India (Figs. 1, 2). The outcrops of the basin-fill successions cover an area of about 46,000 km^2 and attain a maximum thickness of ~4 km in the eastern part of the basin (Chandrakala et al., 2013; Kaila et al., 1987). Nagaraja Rao et al. (1987) suggested that deposition took place in four different sub-basins (viz. Papaghni, Kurnool, Srisailam and Palnad sub-basins) as a result of migration of basin depocentre with time and proposed four-fold stratigraphic classification for CB (Figs. 2, 3).

The Papaghni sub-basin has an arcuate western boundary, which is primarily depositional. It is bordered on the south and the west by