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Plate margin paleostress variations and intracontinental deformations in the evolution of the Cuddapah basin through Proterozoic

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ABSTRACT

The sedimentary basins are often influenced by adjoining mobile belts as is the case of the Proterozoic Cuddapah basin in southern India, lying in proximity of the Eastern Ghats granulite belt (EGB) and the Southern granulite terrain (SGT). Two major faults – Gani–Kalva and Kona faults – in the western part of the Cuddapah basin have been examined in this work to comment on the changes in paleostress conditions affecting the basin evolution punctuated by several stages of extensional and compressional regimes in the time interval 1.9–0.5 Ga. The tensor solutions were obtained for the mesoscale faults and fault striae using the improved Right Dihedron method followed by the Rotational Optimization method (TENSOR, Delvaux and Sperner, 2003). Combining the paleostress field reconstruction and other structural/stratigraphic attributes we propose a possible scenario of punctuated evolution of the Cuddapah basin and its inversion. The stress regimes are tentatively correlated with multiple stages of basin opening and deformation of basin in-fill, representing the pre-Grenvillian through the Pan-African orogeny. The paleostress conditions derived from various stratigraphic horizons provide an opportunity to comment on the changes in tectonic stresses including several stages of extensional and compressive regimes in the Cuddapah basin.

The tensor solutions were obtained for the mesoscale faults and fault striae in the neighborhood of above two fault lines using the improved Right Dihedron method followed by the Rotational Optimization method (TENSOR, Delvaux and Sperner, 2003). The most prominent stress states recorded around the two fault lines can be classified into those affecting (1) the Paleoproterozoic lower Cuddapah successions, (2) the younger Kurnool Group and (3) both the groups. Integrating the stress states of the fault-slip analysis obtained from different unconformity bounded rock groups of lower Cuddapah and other geologic data, we suggest extensional to transtensive/pure strike-slip regime to be active during the first phase of basin opening and c. 1.89 Ga mafic igneous activity. Late compressional to transpressive/pure strike-slip regimes are well recorded from the younger Kurnool Group, representing late Neoproterozoic deformations. The tensor solutions from different unconformity bound stratigraphic horizons constrain different states of deformation. We relate the extensional to transtensive/pure strike-slip regimes from lower Cuddapah successions to the ongoing basin opening events and the associated Palaeoproterozoic igneous activities. The late Neoproterozoic to early Paleozoic compressional to transpressive/strike-slip regime present the possible effects of compressional activities happening around the cratonic margin. The present analysis lends further support to the idea that estimation of paleostress states from fault-slip data even in regions of relatively weak deformation in continental interior are important while assessing influence of plate margin stresses on the continental interior.

1. Introduction

The origin and evolution of sedimentary basin has long been considered to be controlled by the changes in the lithospheric stress fields (Bally and Snelson, 1980; Bally, 1982; Bickle and Eriksson, 1982; Delvaux et al., 1995, 1997). The temporal variation in the applied stress also plays an important role in the deformation of sedimentary in-fill and basin inversion. Pre-existing faults, suture zones and other tectonic discontinuities in the crust are additional factors that influence the development of sedimentary basins, as these faults are prone to reactivation (Nemčock et al., 2005; Viola et al., 2012). An examination of the regional stress fields and tectonic regimes provide important clues for understanding the developmental history of a basin (e.g. Angelier, 1989; Bergerat et al., 1992; Delvaux et al., 1995, 1997). Such attempts for deriving the

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paleostress from different sources around the world provide an insight to the stress conditions present in the earth's crust at different periods of geological history (World Stress Map, WSM, Sperner et al., 2003).

Geologic history and regional tectonic analysis often lead to clues on the ambient crustal stresses which help in validating models of amalgamation of cratonic blocks and their separation. Precambrian India is built around four Archean nucleus mantled by one or other mobile belt and overprinted by development of the Proterozoic intracratonic basins (Saha and Mazumder, 2012). In this contribution one such large basin at the eastern margin of the Dharwar craton in southern India is examined in the context of regional paleostress field and wider implications. Global tectonic processes, such as those associated with plate tectonics or major changes in mantle flow leading to enhanced plume activity, are likely to leave their mark at Precambrian craton margins. While enhanced mantle plume activity may lead to large igneous provinces, supercontinent breakup and episodic production of passive margins of cratonic blocks, plate tectonics driven crustal convergences are associated with orogenic activities influencing closure of oceans including deformation of passive margins, crustal accretion and culminating in episodic supercontinent assembly (e.g. Condie and Aster, 2010; Bradley, 2011; Nance and Murphy, 2013). The tectonic development along the margins of Dharwar craton in India is important in the context of finding correlatives in other contemporaneous cratonic blocks across the globe in order to validate models of supercontinent reconstruction in the Precambrian. For example, the correlation of Eastern Ghats belt in India with the Rayner–Napier complex in East Antarctica underpins the assembly of so called East Gondwana fragments and formation of Rodinia c. 1.1–1.0 Ga ago (e.g. Dobmeier and Raith, 2003). Similarly, the developments in the North China craton during the Paleoproterozoic may have bearing on the contemporaneous development in Eastern Dharwar, particularly when one considers the 1.8–1.9 Ga dyke swarms and extensive passive margin sequences (e.g. Chaudhuri et al., 2002; Zhao et al., 2002, 2004; Ravikant, 2010)

The Proterozoic Cuddapah basin in southern India with an outcrop area of ~60,000 square km and >12 km of cumulative sedimentary thickness is the second largest Proterozoic basin in India. The polyhistory basin is traditionally subdivided in to a number of sub-basins (Nagaraja Rao et al., 1987). The Papaghni and Kurnool sub-basins with fluvial to shallow marine depositional environment in the western part of the Cuddapah basin host sedimentary sequences with major internal unconformities (Fig. 1; Nagaraja Rao et al., 1987; Saha and Tripathy, 2012a; Patranabis-Deb et al., 2012). These were deposited over a time span exceeding 1000 Ma beginning from ~1900 Ma (Bhaskar Rao et al., 1995; Ramam and Murty, 1997; Chaudhuri et al., 2002; Anand et al., 2003). The sedimentary successions of the Paleoproterozoic Papaghni Group in the western part unconformably overlie the c. 2.5 Ga old Peninsular Gneiss and greenschist belts. The Papaghni Group and the unconformably overlying Chitravati Group constitute the Papaghni subbasin which is overshadowed by a younger subbasin which hosts the unconformably overlying Neoproterozoic Kurnool Group (Table 1 and Fig. 1). In contrast, the deformed sedimentary succession in the eastern half of the Cuddapah basin constitute a N–S trending 400 km long arcuate fold-and-thrust belt, named as the Nallamalai fold belt (NFB) which has suffered the main deformation prior to 1.5 Ga. The Nellore Schist Belt (NSB) occurring further east is thrust over the NFB along the Vellikonda thrust front (Venkatakrishnan and Dotiwala, 1987; Saha, 2002, 2004; Saha et al., 2010). The NFB rocks are thrust over the generally flat lying Neoproterozoic Kurnool Group lying further west (Fig. 1a). The contact is referred as the Rudravaram line (Meijerink et al., 1984), later reinterpreted as the Maidukuru thrust (Chakraborti and Saha, 2009).

A number of E–W trending faults (e.g. Gani–Kalva fault, Kona fault, Atmakuru fault) occur in the western part of the Cuddapah basin (Fig. 1a). The ~60 km long steep ENE-WSW trending Gani–Kalva fault offsets the outcrop of Archean Peninsular gneiss and overlying Proterozoic sequences (Nagaraja Rao et al., 1987; refer to Tripathy, 2010). Similarly, the NW-SE trending ~50 km long Kona fault cuts through the western part of the basin. The sedimentary sequences in the western part of the basin usually show gentle dips except along these fault lines. This paper bears on the structural details along the Gani–Kalva and Kona faults particularly the fault-slip data collected from the neighborhood of the Gani–Kalva and Kona faults affecting lower Cuddapah sequences consisting of the Papaghni and the Chitravati groups, and the unconformably overlying Kurnool Group (Table 1). The paleostress analysis of the fault slip data is presented here to document any significant changes in stress regime as the older and younger subbasins developed and finally inverted. The analysis is important in the context of constraining the evolutionary history of the Cuddapah basin, regional correlation of the basin history with that of other intracratonic basins in India, continental stresses over large igneous provinces which seems to influence the Proterozoic basins in India (Drury, 1984; French et al., 2008) and assessing the influence of plate margin stresses on to the craton interior. We also discuss tectonic development along the margin of Eastern Dharwar craton as reflected in the episodic basin initiation and inversion, in the context of contemporaneous development elsewhere in the globe. These developments have wider implications in terms of Proterozoic supercontinent assembly and breakup.

2. Geological and tectonic setting of the Cuddapah basin

Lying over the Eastern Dharwar craton which was stabilized by c. 2.6–2.5 Ga, the Cuddapah basin at the eastern margin of the craton evolved over a prolonged period of time in the Proterozoic as evidenced by several unconformity bound sequences. The occurrence of extensive mafic dykes and sills in the lower Cuddapah sequences and the western basin margin has been posited as signatures of a large igneous province affecting India around 1.9 Ga (French et al., 2008). Recent recognition of the late Paleoproterozoic/early Mesoproterozoic NFB as an allochthonous unit thrusted over the Neoproterozoic Kurnool sub-basin add to the complexity of the regional tectonic build up involving multiple crustal convergences (Saha and Tripathy, 2012a; Fig. 1). The eastern margin of the crescent shaped Cuddpah basin is within 100 km of present day SE margin of India where the southern part of the Eastern Ghats granulite belt (EGB) is outcropped. The EGB is generally interpreted as a remnant of a Proterozoic collisional belt involving India and East Antarctica (e.g. Dobmeier and Raith, 2003; Vijaya Kumar and Leelanandam, 2008). The 50–60 km wide multiply deformed Nellore schist belt (NSB) is sandwiched between the Eastern Ghats and the Vellikonda thrust marking the eastern margin of the NFB.

Three cycles of siliciclastic to carbonate sedimentary rocks with alkaline to sub-alkaline basaltic flows, mafic to ultramafic sills/dykes and ash fall tuffs have been recognized within the Cuddapah basin (King, 1872; Nagaraja Rao et al., 1987; Ramam and Murty, 1997; Anand et al., 2003; Saha and Tripathy, 2012a). The lower Cuddapah rocks (the Papaghni and the Chitravati groups with a composite thickness of ~7 km) are restricted to the western and southwestern part of the basin while the deformed Nallamalai Group constitutes NFB in the eastern part of the basin. The presence of mafic sills, dykes and flows in the Papaghni and the Chitravati groups is in contrast to the younger and relatively thinner Kurnool Group (450 m) which is devoid of mafic igneous rocks suggesting a major shift in tectonothermal environment. However, recently rhyolitic to rhyodacitic tuff beds are reported from the Owk Shale,