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Inversion of calcite twin data, paleostress reconstruction and multiphase weak deformation in cratonic interior — Evidence from the Proterozoic Cuddapah basin, India

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A B S T R A C T

Paleostress orientations from mechanically twinned calcite in carbonate rocks and veins in the neighborhood of large faults were investigated to comment on the nature of weak upper crustal stresses affecting sedimentary successions within the Proterozoic Cuddapah basin, India. Application of Turner's P—B—T method and Spang's Numerical dynamic analysis on Cuddapah samples provided paleostress orientations comparable to those derived from fault-slip inversion. Results from the neighborhood of E—W faults cutting through the Paleoproterozoic Papaghni and Chitravati groups and the Neoproterozoic Kurnool Group in the western Cuddapah basin, reveal existence of multiple deformation events — (1) NE—SW σ_3 in strike-slip to extensional regime along with an additional event having NW—SE σ_3, for lower Cuddapah samples; (2) compressional/transpressional event with ESE—WNW or NNE—SSW σ_1 mainly from younger Kurnool samples.

Integrating results from calcite twin data inversion, fault-slip analysis and regional geology we propose that late Mesoproterozoic crustal extension led to initial opening of the Kurnool sub-basin, subsequently influenced by weak compressional deformation. The dynamic analysis of calcite twins thus constrains the stress regimes influencing basin initiation in the southern Indian cratonic interior and subsequent basin inversion in relation to craton margin mobile belts and plausible global tectonic events in the Proterozoic.

1. Introduction

The theory of plate tectonics envisages that crustal deformation is usually concentrated at the plate margins while the cratonic interior remains stable, rigid and generally undeformed (Condie, 1997). Major seismic activities are more common at plate margins compared to the plate interior, lending credence to postulation that crustal deformation is localized along plate margins. However, the sensitivity of the continental interior towards tectonic activities at the plate boundary has generated considerable research interest (e.g. van der Pluijm et al., 1997; Craddock and van der Pluijm, 1999). The continental interior is considered an ideal location to estimate paleostress tensors, as the stress heterogeneities are less as compared to the any plate margin (Hindle, 2008). However, reactivation of older structures and influence of pre-existing structural grains during later deformation event(s) call for a cautious approach in interpreting results of paleostress inversion. For example, multiple sets of calcite *e*-twins may provide different sets of stress orientations from the same sample, which may be related to various deformational events. Ambient stress states of the geologic past may be estimated from fault-slip analysis and dynamic analysis of mechanical *e*-twins in calcite. The latter method is commonly employed where the cover successions in cratonic interior contain calcite bearing rocks, either as stratified limestone/marble or as veins and segregation within other rock types. Dynamic analysis of calcite twins is a useful tool in areas where fault-slip data are sparse or altogether absent, and for an independent check on the results obtained from fault-slip analysis. The study of calcite *e*-twins for estimation of stress and strain has been used in many areas across the world, such as from the Sevier Laramide continental interior (van der Pluijm et al., 1997; Craddock and van der Pluijm, 1999); Southern Pyrenean foreland (González-Casado and García-Cuevas,

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1999); Paris basin (Rocher et al., 2004); Sheep Mountain, Wyoming (Amrouch et al., 2010); Ogcheon Belt, South Korea (Kang et al., 2005); Iberian Chain, Spain (González-Casado and García-Cuevas, 2002); various fold-and-thrust belts including western foreland of Taiwan, Zagros fold belt and Northern Pyrenean foreland (Lacombe, 2010). These studies on mechanical twins in calcite are instrumental in deciphering the regional patterns of tectonic stress, and estimation of strain and differential stress.

The Eastern Dharwar craton (EDC) hosts the second largest intracratonic basin in India namely the Cuddapah basin with several unconformity bound successions formed in the Paleoproterozoic to Neoproterozic times indicating recurrent crustal mobility (e.g. Saha and Tripathy, 2012; Patranabis-Deb et al., 2012; Saha and Patranabis-Deb, 2014). Flat lying to gently dipping sedimentary strata in the western part of the basin are devoid of any regional penetrative deformation, but are affected by large brittle-ductile faults indicating localized shallow crustal deformation. In this paper we focus on the estimation of paleostress from mechanical twins in calcite with samples from the western Cuddapah basin and examine how the estimated paleostresses and their variation relate to regional tectonics.

2. Geological background

The Cuddapah basin is a composite of a number of sub-basins with distinct evolutionary history, as evident from the disposition of the stratigraphic successions and records of various Proterozoic tectonic events in the region (King, 1872; Nagaraja Rao et al., 1987; Saha and Tripathy, 2012; Patranabis-Deb et al., 2012, Fig. 1). The crustal thinning and sagging due to thermal perturbations in the mantle initiated the Cuddapah basin opening (Bhattacharji and Singh, 1984). The alkaline rocks present outside the Cuddapah basin, e.g., Paleoproterozoic Dancherla syenite (Rb–Sr WR, 2211 Ma; Suresh et al., 2010) post-orogenic and anorogenic granitoids in central part of Eastern Dharwar craton – 2.2 Ga Dorigallu A-type granite (Zakaulla et al., 1998), and mafic dyke swarms (~1.9 Ga, French et al., 2008; Heaman, 2008) are indicative of such shallow to deep crustal thermal perturbations. These secular variations in thermal regime in the Eastern Dharwar craton possibly led to changes in lithospheric stress fields that helped in pulsed opening of the intracratonic Cuddapah basin.

The Paleoproterozoic Papaghni and Chitravati groups, consisting of siliciclastic to carbonate sedimentary successions outcropping in the southwestern part in the Papaghni sub-basin, represent the early development of the basin (Nagaraja Rao et al., 1987; Ramam and Murty, 1997; Saha and Tripathy, 2012). These rock units include contemporaneous mafic to ultramafic dykes and sills of ~1900 Ma age (Bhaskar Rao et al., 1995; French et al., 2008), connected to thermal perturbations and basin opening in the Eastern Dharwar craton (Drury, 1984; Bhattacharji and Singh, 1984; Nagaraja Rao et al., 1987; Dasgupta et al., 2005; Ravikant, 2010). The unconformably overlying Kurnool Group, which are devoid of such mafic igneous intrusive is understood to have been deposited during the Neoproterozoic. The source of diamond and harzburgite garnets within the basal conglomerate of the Banganapalli Quartzite of the Kurnool Group, is suggested to be either the 1090 Ma kimberlite pipes (Anil Kumar et al., 1993; Joy et al., 2012), occurring just outside the western margin of the Cuddapah basin, or the 1.4 to 1.3 Ga lamproites within the Tadpatri Formation (Joy et al., 2012).

The Papaghni sub-basin is cut through by a number of faults such as the Gani-Kalva and Kona faults after the cessation of earlier sedimentation, probably during the late Mesoproterozoic to early

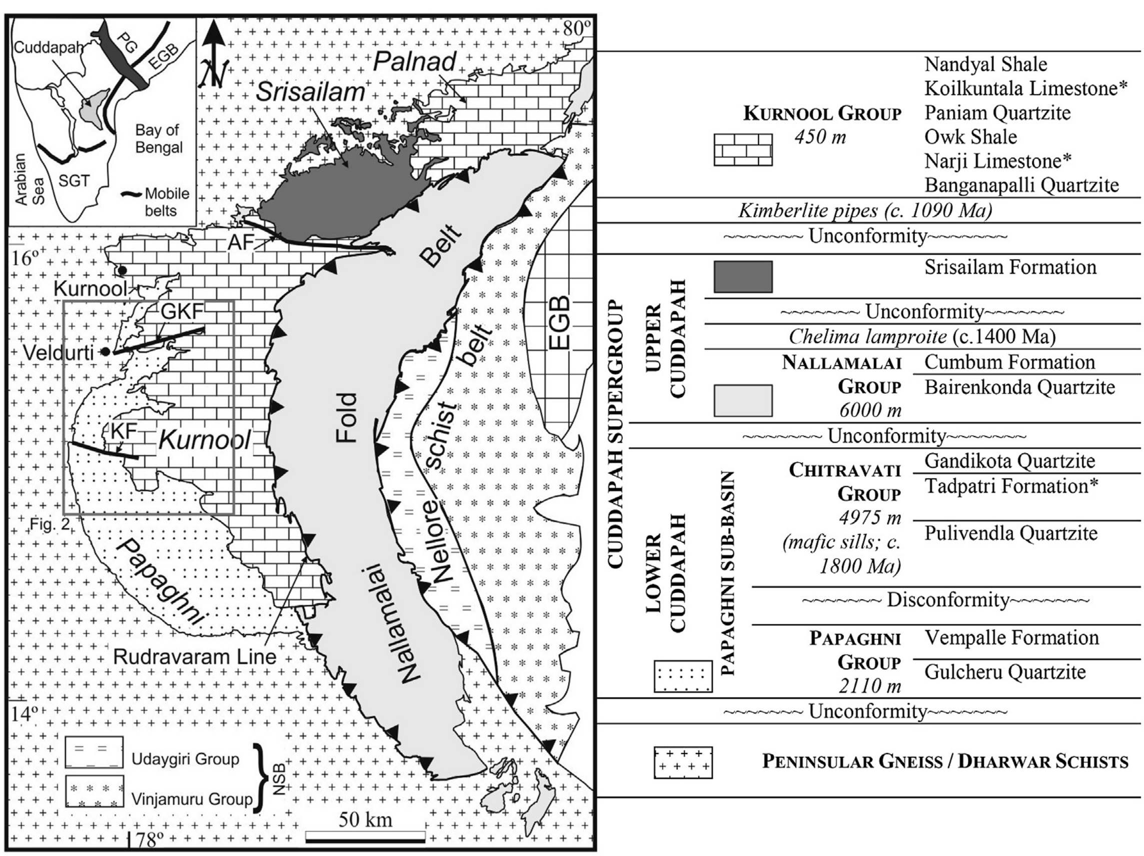

Fig. 1. Regional geology and abridged stratigraphic successions of the Cuddapah basin, modified after Nagaraja Rao et al. (1987) and Geological Survey of India (1990). Asterisk represents the stratigraphic horizons from where samples for calcite *e*-twin analysis were collected.