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Sedimentation and magmatism in the Paleoproterozoic Cuddapah Basin, India: Consequences of lithospheric extension

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A B S T R A C T

The Cuddapah Basin is one of many Proterozoic, intracontinental sedimentary basins across Peninsular India. The basin comprises several unconformity-bounded successions, the lowermost of which (the Papaghni Group and overlying Chitravati Group) are intruded by dolerite sills that contact metamorphosed their host rocks. A mafic-ultramafic sill from the base of the Tadpatri Formation in the Chitravati Group was previously dated at c. 1885 Ma, and interpreted to be part of a large igneous province (LIP). We have dated two samples of a felsic tuff from the upper part of the Tadpatri Formation at 1864 ± 13 Ma and 1858 ± 16 Ma; combining data from the two samples yields a weighted mean date of 1862 ± 9 Ma. Mafic sills intrude rocks stratigraphically above the tuffaceous beds, indicating that mafic magmatism continued until after c. 1860 Ma. Given that the sills intruded lithified rocks, some of the sills may be considerably younger than 1860 Ma. Mafic volcanic rocks are also known from below the unconformity at the base of the Chitravati Group, within the basal Papaghni Group (>c. 1890 Ma). Collectively, these data indicate that mafic sill emplacement spanned more than 30 myr so that it is likely to have been a protracted event or a series of events, and, therefore unlikely to represent a LIP. The time span for mafic magmatism is more compatible with episodic, lithospheric extension (passive rifting) during basin evolution than it is with a mantle plume (active rifting).

1. Introduction

A series of Proterozoic sedimentary basins dominated by siliciclastic fill across Peninsular India historically was referred to collectively as the 'Purana' (Holland, 1909), but more recent work has highlighted disparities in ages and tectonic settings (Basu and Bickford, 2015; Meert and Pandit, 2015) indicating that there is not a coherent and related group of basins. However, there are few reliable depositional ages for the basins, and correlations between them are still largely based on lithostratigraphy (Basu and Bickford, 2014; Collins et al., 2015; Meert and Pandit, 2015). For example, in many of the Proterozoic basins, the only published ages are imprecise Rb-Sr or Sm-Nd isochrons or Pb-Pb model ages, commonly with uncertainties of up to 200 myr (Chakraborty et al., 2015; McKenzie et al., 2013). Detrital zircon age dating has recently been applied to several basins. Although the basins are primarily composed of siliciclastic sedimentary rocks, with variable amounts of carbonate and mafic volcanic rocks, importantly felsic volcanic rocks or tuffs are present in some basins (Rasmussen et al., 2002; Ray et al., 2002; Patranabis-Deb et al., 2007; Bickford et al., 2011; Basu and Bickford, 2014).

The second-largest of the Proterozoic basins in India, and one of the best studied, is the Cuddapah Basin (Fig. 1). French et al. (2008) proposed, on the basis of U–Pb ID-TIMS baddeleyite geochronology, that mafic magmatism in the lower part of the Cuddapah succession was part of an 1891–1883 Ma large igneous province (LIP). They suggested that mafic volcanic rocks in some other Purana basins may be contemporaneous, although this suggestion largely relied on lithological correlations. They noted that the ages obtained were similar to 1890–1870 Ma ages for LIPs in the Superior and Kalahari cratons, and proposed that magmatism was related to "enhanced mantle plume activity and/or a period of focussed mantle upwelling into regions of previously thinned lithosphere" (French et al., 2008; p. 320). Large igneous provinces (Coffin and Eldholm, 1994; Bryan and Ernst, 2008) are widely,

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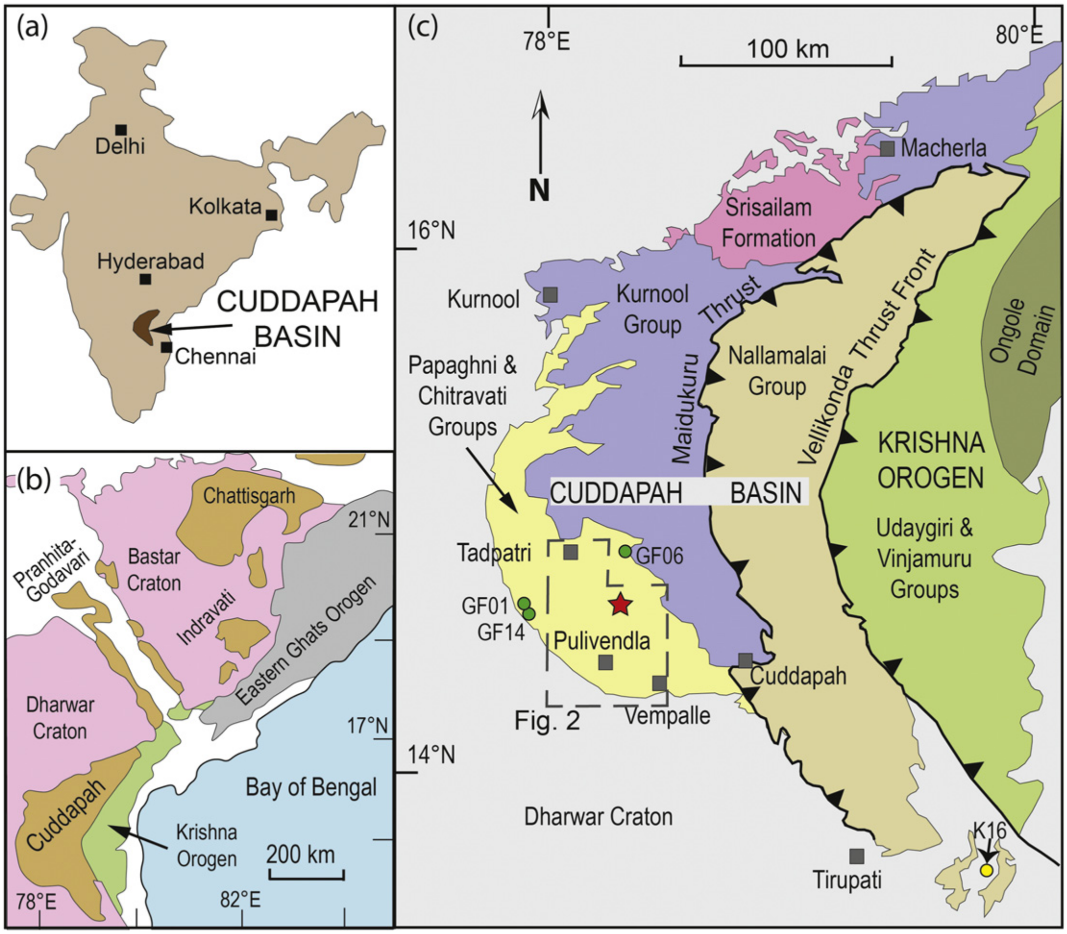

Fig. 1. (a) Location of the Cuddapah Basin in India (after Chakraborty et al., 2016), (b) tectonic units adjacent to the Cuddapah Basin (after Collins et al., 2015), and (c) main sedimentary successions in the Cuddapah Basin and tectonic units of the Krishna Orogen (modified from Collins et al., 2015 and Patranabis-Deb et al., 2012). Green circles are detrital zircon samples of Collins et al. (2015) and yellow circle marks the location of the granite dated by Vadlamani et al. (2014). Red star marks the location of the rhyolitic tuff samples dated in this study.

although not universally (e.g., Sheth, 1999; Anderson, 2013), attributed to mantle plumes, which are considered to be responsible for anomalously high rates of predominantly mafic melt production over very short intervals (Ernst et al., 2005).

Sills intruded at 1885 ± 3 Ma in the lower part of the Cuddapah Basin succession (French et al., 2008) were preceded by small volumes of basalt lower in the succession sometime before c. 1900 Ma (Anand et al., 2003). Here we present the results of in situ U-Pb dating of zircon in a felsic tuff higher in the stratigraphic succession, and which is present at the same stratigraphic level as, or below, some mafic sills. We show that mafic magmatism did not comprise a single, brief event, but was far more protracted, spanning >30 myr.

2. Regional geology

The Cuddapah Basin in southern India is nearly 450 km long and about 200 km wide, and is sited on Archean granite-greenstones and gneisses of the Dharwar Craton (Fig. 1b; Nagaraja Rao et al., 1987; Chakrabarti et al., 2015). The preserved western margin of the basin is arcuate (Fig. 1c) and commonly strongly discordant to the tectonic grain in the basement. The basin is described as an arcuate, low-amplitude, asymmetrical synclinorium (King, 1872; Nagaraja Rao et al., 1987). The successions in the western part of the basin dip gently (~10–15°, Sesha Sai, 2014), and are characterised by open folding. The thickness of the Cuddapah Basin succession has long been estimated at about 12,000 m (e.g., see Mohanty, 2011; Chandrakala et al., 2013), but these estimates were derived from adding up the thicknesses of various groups and formations assuming a layer-cake succession (Basu and Bickford, 2015). It is also unclear as to how the effect of open folding in the basin fill was accounted for in these estimates. More recent estimates from remapping and geophysics suggest that the basin fill is about 4000 m or less (Chandrakala et al., 2013; Basu and Bickford, 2015). These newer estimates are important because they imply much less subsidence (and extension) than previously thought (Chandrakala et al., 2013). Deposition may have been related to episodic rifting controlled by a series of steeply east-dipping faults imaged in seismic studies (Patranabis-Deb et al., 2012), although Chakrabarti et al. (2015) noted that the distribution of basal units shows no relation to the tectonic grain in the basement. The latter authors proposed that basin initiation was related to thermal relaxation following the impact of a mantle plume, but that later evolution of the basin may be related to active faults.

The Cuddapah Basin comprises the following successions, in ascending order: the Papaghni Group, Chitravati Group, Nallamalai Group, Srisailam Formation, and Kurnool Group (Fig. 1c; Nagaraja Rao et al., 1987; Matin, 2015). The oldest two units, the Papaghni and Chitravati groups, crop out in the western part of the basin, and are separated by an unconformity (Fig. 2). The Nallamalai Group is strongly deformed and confined to the eastern part of the basin, and was long considered to be unconformable on the Chitravati Group (e.g., Chaudhuri et al., 2002). However, the Nallamalai Group is thrust bound and, therefore, possibly allochthonous (Narayana Swami, 1966; Saha et al., 2010; Saha and Tripathy, 2012). The Srisailam Formation may be unconformable (Patranabis-Deb et al., 2012, table 2) or disconformable (Collins et