Palaeoseismicity in relation to basin tectonics as revealed from soft-sediment deformation structures of the Lower Triassic Panchet formation, Raniganj basin (Damodar valley), eastern India

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The Raniganj basin in the Damodar valley of eastern India is located within the riftogenic Gondwana Master-Basin. The fluvio-lacustrine deposits of the Lower Triassic Panchet formation of the Damodar valley in the study area preserve various soft-sediment deformation structures such as slump folds, convolute laminae, flame structures, dish-and-pillar structures, sandstone dykes, pseudonodules and syn-sedimentary faults. Although such soft-sediment deformation structures maybe formed by various processes, in the present area the association of these structures, their relation to the adjacent sedimentary rocks and the tectonic and depositional setting of the formation suggest that these structures are seismogenic. Movements along the basin margin and the intra-basinal faults and resultant seismicity with moderate magnitude (2–5 on Richter scale) are thought to have been responsible for the soft-sediment deformations.

1. Introduction

The varieties of sedimentary structures that form in semi-liquefied sediments when they lose their strength are designated as the soft-sediment deformation structures (e.g., Lowe 1975). Soft-sediment deformation structures in clastic sediments reflect deformation that occurs in still un lithified sediments or in sedimentary rocks that had not yet undergone complete lithification before the deformation started (Van Loon 2009). The origin of soft-sediment deformation structures remains an often contentious question. Owen (1995) found that either sedimentary or tectonic processes may control the formation of most of these deformation structures. It remains difficult to decipher whether the soft-sediment deformation structures in seismically-induced mass-flow deposits are formed by the direct or indirect effect of a seismic event (Seilacher 1984). The different degree of compaction of sediments is one of the most important controls on soft-sediment deformation (Mazumder et al 2009). Rapid deposition, differential loading in adjacent parts of the sediment, and slope and gravity controlled density currents are other main

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causes for soft-sediment deformation (Bowman et al. 2004).

Seismic activity may result in the deformation of unconsolidated sediments leading to liquefaction and fluidization (Obermeier 1996; Sukhija et al. 2003; Guccione 2005). These ‘seismites’ (Seilacher 1969) or ‘seismically induced soft-sediment deformation structures’ (sensu Ricci Lucchi 1995) are important indicators of syn-sedimentary earthquake activity and can throw light on the tectonic setting of the depositional basin (Seth et al. 1990). To help understand whether soft-sediment deformation structures are sedimentation-controlled or seismically-induced, a combination of various field criteria is prescribed by different authors (e.g., Sims 1973, 1975; Obermeier 1996; Jones and Omoto 2000; Bose et al. 2001; Wheeler 2002).

In this paper, we document the suite of soft-sediment deformation structures from an extensive 1.5 to 2.0 m thick sand–mud heterolithic horizon, extending over a 9 km² area within the Lower Triassic Panchet formation, in the immediate vicinity and surrounds of Banspetali village, within the Raniganj basin of the Damodar valley (figure 1). Additionally, the spatial relationships of these structures are carefully examined and interpreted to understand the genesis of these structures better, and to correlate their inferred genesis with basin configuration and its inferred tectonic setting.

2. Geological setting

2.1 Tectonic framework of Gondwana basins

The Indian plate is thought to be an assembly of microcontinents, sutured along Proterozoic mobile belts (Biswas 1999 and references therein). These belts acted as zones of rift propagation, and reactivation of palaeo-sutures and graben formation along these sutures is inferred to have generated the intra-cratonic Gondwana basins (Mitra 1994; Tewari and Casshyap 1996). In the Permo-Triassic, before separation of the east and the west Gondwana terrains, intra-continental extensional tectonics was active and this was responsible for the formation of the sag basins of the Gondwana period; most of the continental Gondwana sediments in India were deposited during this extensional regime (Biswas 1999). These Gondwana sedimentary successions overlie Late Archaean or Middle-to-Late Proterozoic basement rocks and are flanked by regional dislocation zones (Narula et al. 2000). Sediment accumulations of great thickness reflect repeated syn-sedimentary subsidence events and dislocation along the intra-basinal faults and asymmetric basin-fills with greater thickness towards one of the basin margin fault systems indicate faulting-induced subsidence to provide the necessary accommodation (Ramanamurthy and Parthasarathy 1988; Chakraborty and Ghosh 2005 and references therein; Veevers and Tewari 1995; Mishra et al. 1999).

The continental Gondwana sedimentary successions of India are exposed in eastern, central and south-central parts of the country, and the basins are mainly aligned along three river valleys: the Narmada–Son–Damodar, the Pranhita–Godavari and the Mahanadi (figure 1). These three Permain-Jurassic-aged riftogenic continental basins filled with Gondwana sediments converge to meet at the Satpura area in central India (Narain 1994; Chakraborty and Ghosh 2005).

The Raniganj basin (figure 1), the easternmost part of the Damodar valley is a semi-elliptical, elongated basin, situated between Damodar and Ajoy rivers (Ghosh 2002). The sedimentary fill of the Raniganj basin comprises a Gondwana succession from the Lower Gondwana Group (Permian) to the Upper Gondwana Group (Triassic to Lower Cretaceous) (Gee 1932; Ghosh 2002). The southern boundary of the basin is E–W trending, steep down-displacement dip-slip fault zone, indicative of an extensional tectonic setting (Gibbs 1984), which led to a half-graben geometry with accumulation of greater thickness of sediment towards the south (Ghosh 2002). Transverse normal faults, regarded as transfer faults (Gibbs 1984), are distributed along the basin margin and have affected the contact of the Gondwana sedimentary successions with the basement rocks. These faults have dislocated the basin boundary fault and are thus younger and were probably initiated after the beginning of sedimentation. Conjugate sets of intrabasinal normal faults transverse to the basinal trend are common, and have truncated the entire Gondwana sediment package as well as the basement rocks. Other intrabasinal normal faults parallel to the basin margin are thought to have been active during the sedimentation (Ghosh 2002).

2.2 Damodar valley basin-fill succession

In Damodar valley, the Gondwana sediments overlie the Chhotanagpur Granite Gneiss Complex (CGC) showing broad concordance with the regional structure of the surrounding basement (Mazumdar 1988). Gondwana basins of the Damodar valley are presumed to extend also beneath the Cenozoic sediments of the Bengal basin (Uddin 1996) to the east. In Damodar valley basins, Phanerozoic sedimentation on Neoproterozoic basement was initiated with the deposition of Late Carboniferous Gondwana sediments.