Journal of Asian Earth Sciences 91 (2014) 316–328

Contents lists available at ScienceDirect

Journal of Asian Earth Sciences

journal homepage: www.elsevier.com/locate/jseaes

Anomalous crustal and lithospheric mantle structure of southern part of the Vindhyan Basin and its geodynamic implications

O.P. Pandey *, R.P. Srivastava, N. Vedanti, S. Dutta, V.P. Dimri

CSIR-National Geophysical Research Institute, Uppal Road, Hyderabad 500007, India

A R T I C L E I N F O

Article history:
Received 1 March 2013
Received in revised form 5 October 2013
Accepted 27 November 2013
Available online 12 December 2013

Keywords:
Vindhyan Basin
Crustal evolution
Geodynamics
Heat flow
Lithospheric thickness
Gravity data inversion
Seismic velocities

A B S T R A C T

Tectonically active Vindhyan intracratonic basin situated in central India, forms one of the largest Proterozoic sedimentary basins of the world. Possibility of hydrocarbon occurrences in thick sediments of the southern part of this basin, has led to surge in geological and geophysical investigations by various agencies. An attempt to synthesize such multiparametric data in an integrated manner, has provided a new understanding to the prevailing crustal configuration, thermal regime and nature of its geodynamic evolution. Apparently, this region has been subjected to sustained uplift, erosion and magmatism followed by crustal extension, rifting and subsidence due to episodic thermal interaction of the crust with the hot underlying mantle. Almost 5–6 km thick sedimentation took place in the deep faulted Jabera Basin, either directly over the Bijawar/Mahakoshal group of mafic rocks or high velocity-high density exhumed middle part of the crust. Detailed gravity observations indicate further extension of the basin probably beyond NSL rift in the south. A high heat flow of about 78 mW/m^2 has also been estimated for this basin, which is characterized by extremely high Moho temperatures (exceeding 1000 °C) and mantle heat flow (56 mW/m^2) besides a very thin lithospheric lid of only about 50 km. Many areas of this terrain are thickly underplated by infused magmas and from some segments, granitic–gneissic upper crust has either been completely eroded or now only a thin veneer of such rocks exists due to sustained exhumation of deep seated rocks. A 5–8 km thick retrogressed metasomatized zone, with significantly reduced velocities, has also been identified around mid to lower crustal transition.

1. Introduction

Mid to late Proterozoic period is characterized by the development of several intracratonic basins all over the continental shields and platforms (Windley, 1977; Condie, 1989). It includes four major sedimentary basins on the Indian subcontinent, which are Vindhyan Basin, Cuddapah Basin, Pranhita–Godavari Basin, and Chhattisgarh Basin. All of these basins came into existence due to continued rifting and subsidence of the central part of the Indian peninsular shield. Out of these four basins, the sickle shaped Vindhyan Basin, situated in the central India, is considered the largest (Chakraborty, 2006; Ramakrishnan and Vaidyanadhan, 2008). It spreads in east–west direction along Rajasthan, Bundelkhand and Son valley sectors, encircling the Bundelkhand granitic–gneissic massif, which sits in the middle of Bundelkhand craton (Fig. 1). This basin covers an exposed area of only about 60,000 sq. km while a much larger portion (about 162,000 sq. km) is concealed below the Indo-Gangetic alluvium plain in north and thick 65 Ma Deccan volcanic lavas in south.

Currently, this basin is in lime light, due to its hydrocarbon potential which is considered as moderate to good, specially the southern part, where sediment thickness is maximum and there have been reports of surface gas shows. In order to assess its subsurface information, Oil and Natural Gas Corporation has drilled three exploratory wells, Jabera-1, Damoh-1 and Kharkhari-1, in the southern part of the basin (W1, W2, W3 in Fig. 2), which has also been studied in great detail by 1500 new gravity observations in and around Jabera–Damoh–Katangi regions utilizing a novel fractal based gridding approach (Srivastava, 2006; Srivastava et al., 2007, 2009). Besides, the Vindhyan Basin has been mapped in detail by seismic investigations along three deep seismic sounding profiles which cover its southern parts (Fig. 1). The updated seismic sections along these profiles (Tewari et al., 2002; Murty et al., 2004) indicate an anomalous crustal structure underneath, which is also supported by subsequent magnetotelluric (MT) studies (Gokarn et al., 2001). Besides, crustal S-wave velocity distribution, derived by the receiver function technique, has also now become available for five broadband seismic stations, out of which two stations are located over the thick Vindhyan strata (Julia et al., 2009; Vijay Kumar et al., 2012). Geothermally, this basin has not been studied well. A sole heat flow reported for Shivpuri, located in upper Vindhyans of central India ranges from 45 to 61 mW/m^2 (Nagaraju et al., 2012). Being covered by thick sequences of Deccan volcanics and Indo-Gangetic alluvium, as mentioned earlier, very little is understood about the evolutionary and paleo-geodynamic

* Corresponding author. Tel.: +91 40 27012818; fax: +91 40 23434651.
E-mail address: om_pandey@rediffmail.com (O.P. Pandey).

1367-9120/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jseaes.2013.11.015

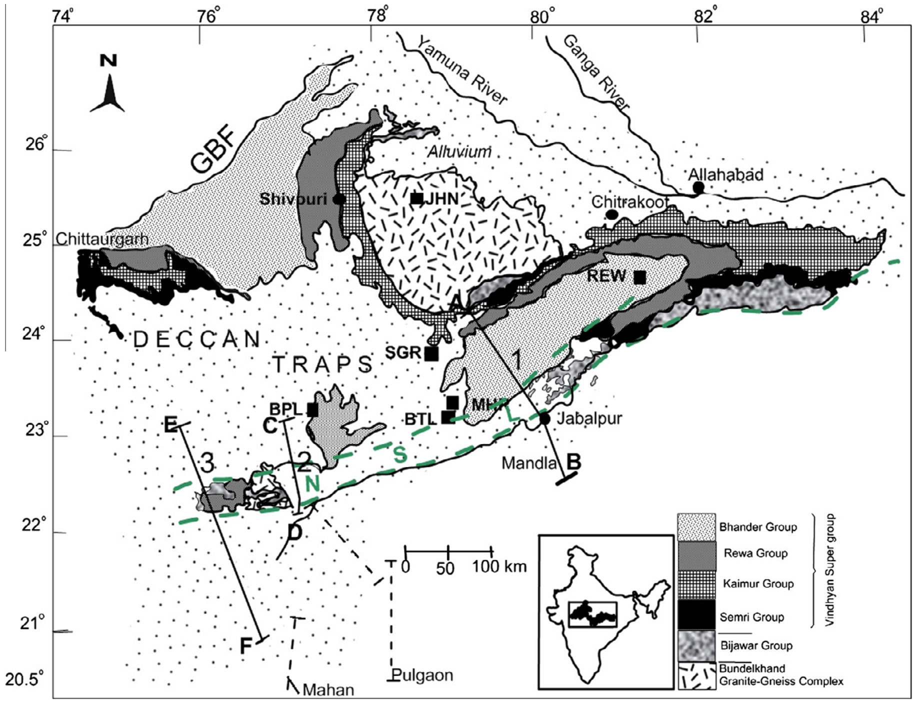

Fig. 1. Simplified geological map of the Vindhyan Basin, central India (Azmi et al., 2007; Bengtson et al., 2009). Solid rectangles refer to location of broadband seismic stations. GBF is great boundary fault. AB, CD, EF are the respective locations of three DSS profiles, Hirapur–Mandla, Khajuriakalan–Rahatgaon and Ujjain–Mahan.

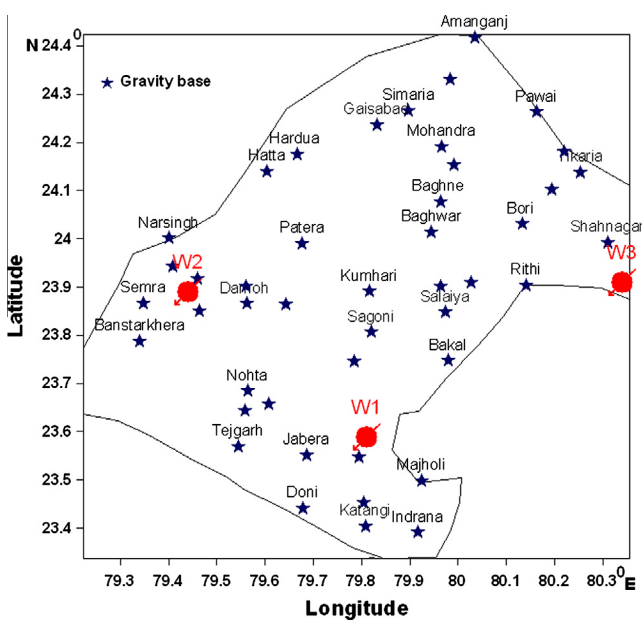

Fig. 2. Gravity bases distribution map of Jabera–Damoh area in Vindhyan Basin. Locations of bore holes W1, W2 and W3 drilled by ONGC are also shown.

nature of this basin. Present study makes an attempt to provide a new insight into the nature and evolution of the crust and uppermost mantle beneath the southern part of the Vindhyan Basin, using recently acquired deep geological and geophysical data.

2. Geotectonic and geologic features

Geotectonically, the Vindhyan Basin evolved on a rifted crust apparently as a foreland basin. It is bounded by a prominent NE–SW trending great boundary fault on its west, which virtually separates it from the Aravalli-Delhi Mobile Belt (ADMB). Similarly, the Son-Narmada-Tapti rift (SONATA), which has been associated with complex thermo-tectonic history, demarcates its southern boundary. This rift structure divides the Indian subcontinent into two major geotectonic segments exhibiting distinct geological and geophysical signatures on either side (Pandey and Agrawal, 1999). The depositional history of this basin is said to be intimately related to the evolution of this rift valley. Reportedly, the Vindhyan rocks are totally absent south of this rift valley. The Bundelkhand Archean granitic–gneissic massif (Fig. 1) divides this basin into two parts; Chambal valley Vindhyans to the west and Son valley Vindhyans to the east.

Sedimentation in this basin seems to have begun somewhere around 1.7 Ga (Ray, 2006) and continued till the end of Proterozoic era. Lithostratgraphically, Vindhyan Supergroup, comprises mainly un-metamorphosed and mildly deformed sandstone, shale and limestones with a few volcanoclastic and conglomerate beds (Chakraborty and Bhattacharya, 1996). They are usually considered as deposits of shallow marine environment with maximum sedimentary thicknesses in its southern part near Jabera region (Kaila et al., 1989; Srivastava et al., 2007, 2009). These sediments have been classified into four individual groups, Semri, Kaimur, Rewa and Bhander (Chakraborty, 2006). The Semri Group, which comprises lower Vindhyan rocks, is the oldest as well as thickest and forms bottom of the Vindhyan sediments, which in turn rests unconformably on a variety of rocks like Archean Bundelkhand granite-gneisses and Bijawar Group of metamorphics and Mahakoshal group of rocks belonging to the Paleoproterozoic age. Southern part of the basin hosts a prominent domal structure (Jabera dome) which is located about 40 km NW of Jabalpur and extends in ENE–WSW direction. Detailed geological and geotectonic information of this region can be found in Srivastava (2006), Srivastava et al. (2007, 2009) and references therein.

3. Gravity investigations

Southern part of the Vindhyan Basin is very well studied by mounting a close spaced gravity survey network designed with