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Research paper

Crustal structure of the western Indian shield: Model based on regional gravity and magnetic data

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ABSTRACT

Regional surface gravity data and global satellite magnetic data have been utilized to generate a preliminary model of the crustal structure along a southwest–northeast profile (Gadra–Fatehpur) through western Rajasthan. The study area represents the western part of the Indian continental landmass which has undergone several major episodes of repeated subduction/collision, plume traces and rifting from Archaean to recent times. The temporal and spatial relationship between the various geotectonic provinces is quite complex, thereby limiting the emergence of a suitable crustal structure model for this region. Exposures of the Malani Igneous Suite (MIS), a product of bimodal volcanism (~780 Ma), and considered to be the third largest felsic magmatic province of the world, is evident along the profile and also to the southwest of the study area. The easternmost part of the profile is close to the DAFB (Delhi Aravalli Fold Belt), a Proterozoic orogenic belt.

This study probes the geometry of the different crustal units in terms of density and susceptibility variations in order to decipher the imprints of the major tectonic processes the region has undergone. In order to decipher the crustal geometry of the Gadra–Fatehpur profile, two NW–SE gravity and magnetic profile vertical sections (A–A′ in the south and B–B′ in the north) are modelled on the basis of the constraints provided from previous seismic models. The crustal model of the Gadra–Fatehpur profile is composed of alluvium, Tertiary sediments, MIS, Marwar Supergroup, low-density layers (LDLs) and the middle–lower crustal layers, with a distinct change in configuration from the southwest to northeast. The Moho dips from SW to NE, the MIS in the SW gives way to the thick pile of the Marwar Supergroup to the NE. The evolution of MIS has been suggested to have occurred as a consequence of delamination of the upper mantle. LDLs are incorporated in Gadra–Fatehpur model. In the SW, LDL (2550 kg/m^3) lies below the MIS in the NE, another LDL (2604 kg/m^3) is depicted below the mid-crustal layer.

1. Introduction

The western part of the Indian shield comprises the Marwar craton in the west and the Bundelkhand craton in the east, welded along the Delhi Aravalli Fold Belt (DAFB) during the Paleoproterozoic (Sinha-Roy et al., 1998). This seems to be a plate collision boundary as supported by the geophysical data (Vijaya Rao et al., 2000) which is used to explain the tectonic evolution of the DAFB. Naganjaneyulu and Santosh (2011), based on 3D gravity models have shown the existence of continental amalgamation in NW India. The Malani Igneous Suite (MIS) spreads over a large area (~50,000 km^2) of the northwestern part of the Marwar craton, and outcrops to the south of the craton (Fig. 1). It is dominantly made up of felsic (rhyolitic) lava flows and granitic plutons, with subordinate mafic lavas, and felsic and mafic dykes (~780 Ma; Rathore, 1995). Dharma Rao et al. (2012) found Cryogenian ages (765–768 Ma) from the SHRIMP U-Pb of analysis zircons in the basalts and associated rhyolites of the Sindreth Group. This suggests the presence of an arc setting associated with Neoproterozoic subduction prior to the final amalgamation of the Gondwana supercontinent.

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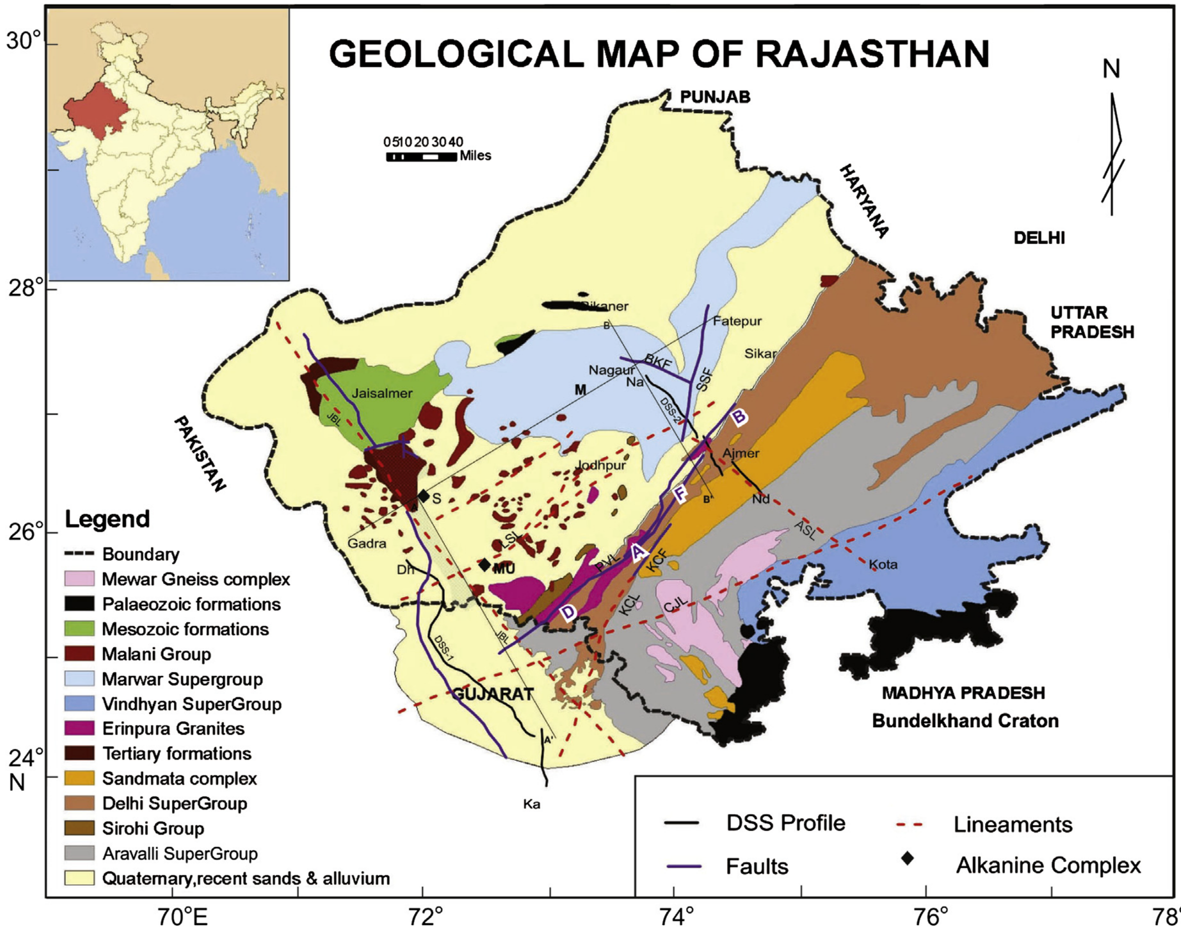

Figure 1. Geologic and tectonic map of Rajasthan. LSL: Luni–Sukri Lineament; JBL: Jaisalmer–Barwani Lineament; KCL: Kishangarh–Chipri Lineament; CJL: Chambal–Jamnagar Lineament; ASL: Ajmer–Sadia Lineament; SSF: Sardhar Shahar Fault; BKF: Bhagu–Kathu Fault; PVL: Pisangan–Vadnagar Lineament; DSS: Deepseismic sounding profiles; S: Sarnu dandali; MU: Mundawara; DAFB: Delhi Aravalli Fold Belt; M: Marwar Basin; Dh: Dharimanna; Ka: Khatana; Na: Nagaur; Nd: Nandsi.

The Malani province represents a large, intraplate, anorogenic felsic event, which is why some workers have ascribed it to an early mantle plume (Sharma, 2003). In the southern part of the craton, at Sarnu Dandali and Mundwara, evidences of intrusions predating the Deccan event around 68.5 Ma have been found (Ray and Pandey, 1999). Signatures of pericontinental rifting that lead to the formation of the Barmer basin between early Jurassic and Tertiary are also evident (Biswas, 1982). Sinha-Roy et al. (1995) suggested the evolution of MIS as a result of low-angle subduction of the Delhi crust (oceanic?) from DAFB beneath the western Rajasthan craton. It is pertinent that the collision which was responsible for DAFB must have been driven by slab-pull or by ridge-push over the entire plate in question and hence it may be expected that the alterations in the crustal structure due to emplacement of the MIS would show different signatures in the vicinity of the DAFB.

Geophysical evidences are sparse in the western part of Rajasthan (Marwar craton) in the trans-Aravalli area because the crustal structure due to the MIS must have been altered in the vicinity of DAFB. This points to the evidence of the presence of MIS as the low Bouguer anomaly of this region in an engulfed high. Seismic imaging of the crust along the 400 km Nagaur–Jhalawar deep seismic reflection profile has provided information on the broad crustal structure of the orogenic region (DAFB) and part of the Marwar Supergroup, which covers a part of the present study region (Tewari et al., 1997). Satyavani et al. (2004) showed the presence of a Low Velocity Layer (LVL) in the Marwar basin and underplating all along the Naguar–Nandsi sub profile of Naguar–Jhalawar profile. Another seismic profile (Dharimanna–Kathana) in the south of the study area provides vital seismic velocity information for constraining density values (Kaila et al., 1990). The thickness of the magnetic crust in this area estimated from the MAGSAT data for the DAFB is around 36–40 km (Mishra, 1987).

In the present study, an attempt is made to examine the prominent anomalies in the regional gravity and magnetic data (Figs. 2 and 4) for deciphering the subsurface geology, which dominates the southwestern part of the craton and fades out to the north and northeast, apparently getting obliterated over the expanse of the Marwar basin. Two NW–SE gravity and magnetic profile vertical sections (A–A′ in the south and B–B′ in the north) are modelled on the basis of constraints provided from the previous seismic models (Figs. 5 and 6). These seismic data were obtained from deep seismic sounding profiles in western Rajasthan (Kaila et al., 1990; Tewari et al., 1997; Satyavani et al., 2004). These sections subsequently serve to constrain a crustal model along an SW–NE profile (Gadra–Fatehpur), running across the western part of the Marwar craton, sub-parallel to the DAFB. It is constructed on the basis of existing geological knowledge as well as the Bouguer gravity anomalies (GSI-NGRI, 2006) and the global magnetic model (Maus et al., 2009). The model reveals the nature of interaction between the different crustal units associated with the various tectonic episodes of the past, and further sheds light on the probable dynamics of collision, origin of felsic magmatism, formation of