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Magnetotelluric study to characterize Kachchh Mainland Fault (KMF) and Katrol Hill Fault (KHF) in the western part of Kachchh region of Gujarat, India

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ABSTRACT

The Kachchh Mainland Fault (KMF) is a major E-W trending fault in the Kachchh region of Gujarat extending > 150 km from Lakhpat village in the west to the Bhachau town in the east. The Katrol Hill Fault (KHF) is an E-W trending intrabasinal fault located in the central region of Kachchh Basin and the south of KMF. The western parts of both of the faults are characterized, and the sediment thickness has been estimated in the region using a Magnetotelluric (MT) survey at 17 sites along a 55 km long north-south profile with a site spacing of 2–3 km. The analysis reveals that the maximum sediment thickness is 2.3 km (Quaternary, Tertiary, and Mesozoic) in the region, out of which, the Mesozoic sediments feature a maximum thickness of 2 km. The estimated sediment thickness is found consistent with the thickness suggested by a deep borehole (depth approx. 2.5 km) drilled by Oil and Natural Gas Corporation (ONGC) at Nirona (Northern part of the study area). From 2-D inversion of the MT data, three conductive zones are identified from north to south. The first conductive zone is dipping nearly vertical down to 7–8 km depth. It becomes north-dipping below 8 km depth and is inferred as KMF. The second conductive zone is found steeply dipping into the southern limbs near Manjal village (28 km south of Nirona), which is inferred as the KHF. A vertical-dipping (down to 20 km depth) conductive zone has also been observed near Ulat village, located 16 km north of Manjal village and 12 km south of Nirona village. This conductive zone becomes listric north-dipping beyond 20 km depth. It is reported first time by a Geophysical survey in the region.

1. Introduction

The Kachchh basin in the western India host several major E-W trending faults like Kachchh Mainland Fault (KMF) on the northern fringe and the Katrol Hill fault (KHF) in the central part of the Kachchh Mainland uplift (Biswas, 1987) (Fig. 1a). The KMF is a discontinuous fault, which is laterally displaced by several NNE–SSW to NNW–SSE trending transverse faults (Biswas, 1993). Based on the satellite image interpretation, Malik et al. (2001) inferred several active fault traces along KMF and KHF.

The KMF is an active fault (Malik et al., 2008; Morino et al., 2008) and is a major source of seismic hazard for Western India (Rastogi et al., 2012; Chopra et al., 2012; Mohan, 2014). The tectonic behavior of the KMF in the Quaternary period has been studied in the central segment (Thakkar et al., 1999; Morino et al., 2008; Chowksey et al., 2011; Chauhan et al., 2015) and the eastern segment (Mathew et al., 2006; Malik et al., 2008; Malik et al., 2009; Chowksey et al., 2011; Chauhan et al., 2015). The easternmost part of the KMF has been studied by Magnetotellurics survey (Mohan et al. (2010); Naganjaneyulu et al. (2010a); Chandrasekhar et al. (2012); Mohan et al. (2015)) and through a seismic survey (Sarkar et al., 2007). On the other hand, the western segment of KMF has not been addressed by geophysical surveys. The E-W trending KHF is a hill range bounding intrabasinal fault that divides the Kachchh Mainland into northern and southern parts (Biswas and Deshpande, 1970). The KHF marks a sharp lithotectonic contact between Cretaceous and Jurassic formations particularly at the fault zone (Thakkar et al., 1999; Patidar et al., 2007). After studying stratigraphic offsets of the sediments, Kundu et al. (2010) suggested three episodes of reactivation of the KHF during the late Quaternary. Mathew et al. (2004) have used Electron Spin Resonance (ESR) to date interfault gypsum, suggested Quaternary deformation over Katrol Hill. Morino et al. (2008) dug a trench near Wandhay village across the low scarp and inferred the occurrence of at least three large magnitude earthquakes along KHF based on the displacement of the older terrace

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deposits. Sastry et al. (2008) conducted the MT survey and located the KHF, though site spacing was large. Naganjaneyulu et al. (2010a) through MT studies located the KMF in the eastern part of Kachchh, but site spacing was large and could not characterize the fault. The National Geophysical Research Institute (NGRI) in 1978 prepared a Bouguer anomaly map of the Kachchh region. Chandrasekhar and Mishra (2002) refined this map by adding 275 newly acquired stations. From the new map, they suggested that the KMF is almost vertical-dipping, while the KHF dips 50°–60° with a throw of 2–3 km. Seshu et al. (2015) conducted the 3D gravity modeling and suggested that the thickness of the Deccan Trap is almost negligible in the north of the KHF. Mandal (2016) suggested KMF is north-dipping on the basis of earthquakes recorded around the epicentral region of 2001 Bhuj earthquake near the eastern segment of KMF. On the basis of past geological and geophysical studies, we may infer that (i) KMF and KHF are active faults, (ii) the western parts of both faults are not studied well and (iii) their dip directions are not confirmed so far by any deep geophysical survey. The past studies have suggested that in case of large faults, the seismic potential of different segments are different (Azor et al., 2002; Silva et al., 2003; Joshi et al., 2013), hence, for evaluating seismic hazard potential of each fault segment, they should be assessed separately.

Magnetotellurics (MT) is a proven technique for the identification/location of the subsurface structures, including tectonics. A number of studies related to tectonics were conducted in India using MT survey (Fig. 1b). Gokarn et al. (2002a), Arora et al. (2007), Israil et al. (2008) and Rawat et al. (2014) have conducted the MT surveys in the Northwest Himalaya. The MT surveys in the Siwalik Himalaya were conducted by Gokarn et al. (2002b, 2008). Patro and Harinarayana (2009) and Pavan Kumar et al. (2014) have conducted MT surveys in the Northeast region of Himalaya to delineate major faults. Rao et al. (2004), Naganjaneyulu et al. (2010b, Naganjaneyulu and Santosh, 2011), Abdul Azeez et al. (2013, 2017) and Patro and Sarma (2016) have conducted MT surveys in central India. Sarma et al. (2004), Sastry et al. (2008), Mohan et al. (2010), Naganjaneyulu et al. (2010a), Chandrasekhar et al. (2012) and Mohan et al. (2017) have conducted the studies in western India. Gokarn et al. (2003) and Harinarayana et al. (2007) have conducted the MT surveys in the Deccan Volcanic Province. Gokarn et al. (2004), Naidu et al. (2011) and Patro et al. (2014) have conducted the MT surveys in Southern India.

In the present study, MT survey is being carried out in the western part of KHF and KMF to characterize these faults and to estimate the sediment thickness in the western central part of Kachchh.

2. Geology and tectonics of Kachchh

The Kachchh region is located in the western most part of India. It is bounded by the Thar Desert and Indus alluvium in the north, Saurashtra in the south, the vast Gujarat alluvium in the east and the Arabian Sea in the west. The basin extends across the continental shelf (Biswas, 2005). Six major uplifts have been recognized in the Kachchh, which have given rise to the highlands namely, Kachchh Mainland, Wagad, and the four blocks of the Island Belt, i.e., Pachham, Khadir, Bela and Chorar (Karanth and Gadhavi, 2007) (Fig. 1a).

The Kachchh region is a rift basin, and the rift was initiated during the Late Triassic breakup of the Gondwana land due to the reactivation of primary faults in the Precambrian Delhi fold belt (Biswas, 2005). It is bounded between the two extensional faults namely the south-dipping Nagar Parkar Fault in the north and the north-dipping Kathiawar Fault in the south. The major tectonic features of the Kachchh region of E-W are Allah Bund Fault (ABF), Island Belt Fault (IBF), KMF and KHF (Fig. 1a). The KMF is the active principal fault of the Kachchh basin. A reversal from extensional tectonics to compressional tectonics started at 40 Ma that caused strike-slip/transverse and reverse motion along the normal faults.

The stratigraphy of the Kachchh consists of three packages – Mesozoic, Tertiary, and Quaternary. The Mesozoic package consists of

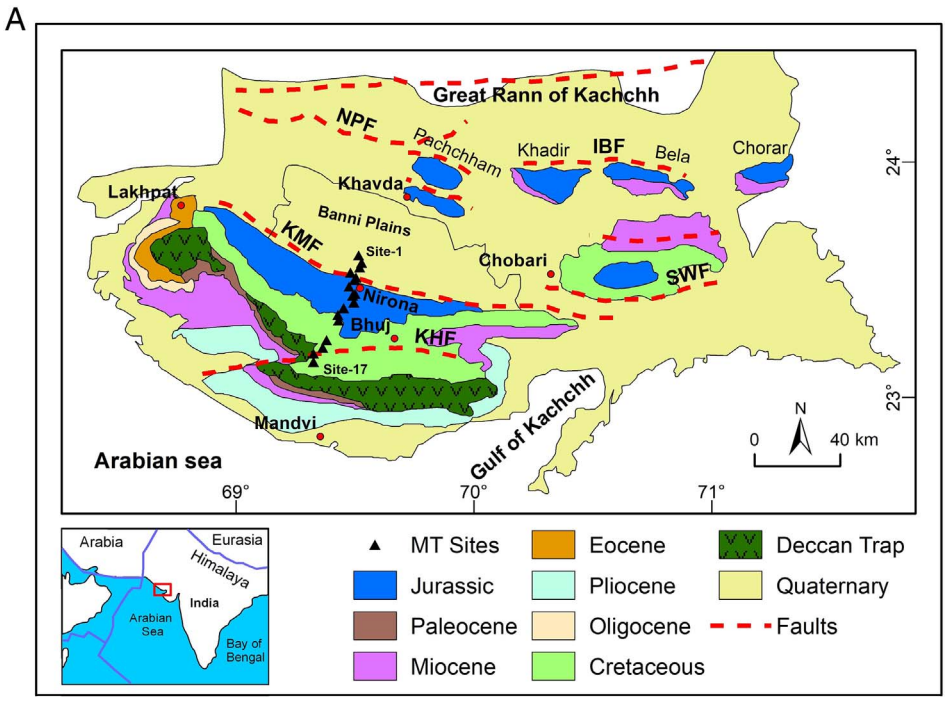

Fig. 1. A: Location of the MT profiles (marked as triangles) overlapped on the geology and tectonic map of the area (after Biswas, 2005). The KMF stands for Kachchh Mainland fault, KHF for Katrol Hill fault, SWF for South Wagad fault, NPF for Nagar Parkar fault and IBF for Island Belt Fault.
B: (a) The locations of MT survey conducted in India for the tectonic study overlapped on a geological map of India (after Geological Survey of India (GSI), 1998) and (b) the region wise MT profiles.