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Landform development in a zone of active Gedi Fault, Eastern Kachchh rift basin, India

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ABSTRACT

An earthquake of 2006 Mw 5.7 occurred along east–west trending Gedi Fault (GF) to the north of the Kachchh rift basin in western India which had the epicenter in the Wagad upland, which is approximately 60 km northeast of the 2001 Mw 7.7 earthquake site (or epicenter). Development of an active fault scarp, shifting of a river channel, offsetting of streams and uplift of the ground indicate that the terrain is undergoing active deformation. Based on detailed field investigations, three major faults that control uplifts have been identified in the GF zone. These uplifts were developed in a step-over zone of the GF, and formed due to compressive force generated by left-lateral motion within the segmented blocks. In the present research, a terrace sequence along the north flowing Karaswali river in a tectonically active GF zone has been investigated. Reconstructions based on geomorphology and terrace stratigraphy supported by optical chronology suggest that the fluvial aggradation in the Wagad area was initiated during the strengthening (at ~8 ka) and declining (~4 ka) of the Indian Summer Monsoon (ISM). The presence of younger valley fill sediments which are dated ~1 ka is ascribed to a short lived phase of renewed strengthening of ISM before present day aridity. Based on terrace morphology two major phases of enhanced uplift have been estimated. The older uplift event dated to 8 ka is represented by the Tertiary bedrock surfaces which accommodated the onset of valley-fill aggradation. The younger event of enhanced uplift dated to 4 ka was responsible for the incision of the older valley fill sediments and the Tertiary bedrock. These ages suggest that the average rate of uplift ranges from 0.3 to 1.1 mm/yr during the last 9 ka implying active nature of the area.

1. Introduction

The Kachchh pericratonic rift basin that evolved during the last 135 Ma is bound by two major basin-forming faults, the south-dipping Nagar Parkar Fault (NPF) to the north and north-dipping Kathiawar Fault (KF) to the south (Fig. 1a). During the last stage of evolution, Kachchh was under a compressional regime when the hanging-wall blocks uplifted along the E–W master faults and formed the highlands, and intervening half-graben formed the plains (Biswas, 1987). The rifting was aborted by the trailing edge uplift during the Late Cretaceous pre-collision stage of the Indian plate when the leading edge of the plate was slab-pulled towards the Tethyan trench (Biswas, 2005; Rastogi et al., 2014). The uplift caused structural inversion during the rift–drift transition stage. Most of the uplifts with drape folding over the edges came into existence by up-thrusting of the basement domino blocks along the master faults (Rastogi et al., 2014). This created first-order marginal flexures over the foothill uplifts. Lateral motion during the drift stage of the plate induced horizontal stress and near vertical normal faults, which were reactivated as reverse faults during initiation of the inversion cycle, and became strike-slip faults involving divergent oblique-slip movement (Biswas, 2005 and Rastogi et al., 2014). During this stage the blocks tilted towards south and the nature of the master faults changed from normal to reverse and strike-slip in nature (Rastogi, 2001, 2004).

Major structural features of the Kachchh region include east–west trending faults such as Island Belt Fault (IBF), Kachchh Mainland Fault (KMF) and Katrol Hill Fault (KHF) (Fig. 1a) (e.g. Biswas, 1987; Mandal et al., 2004). The Wagad region of Kachchh, bound by the South Wagad Fault (SWF) in the south, comprises Mesozoic (135–65 Ma) and younger Cenozoic sediments overlying a granitic basement (Biswas, 1987; Maurya et al., 2000, 2003; Rastogi, 2004).

It is considered that, in tectonically active regions, the rivers are dominantly involved in incising the underlying resistant bedrock (Whipple, 2004; Bhattacharya et al., 2014). Hence, rivers flowing in such dynamic regions lack laterally continuous alluvial deposits; instead, discrete sedimentary patches can be found along their courses (Howard et al., 1994). Previous studies in seismically active and monsoon dominated regions, suggest that the rivers oscillate between incision and valley aggradation on millennial time scales due to the changes in monsoon intensity and sediment flux (Pratt-Sitaula et al., 2004). In this connection the morphology of river terraces and

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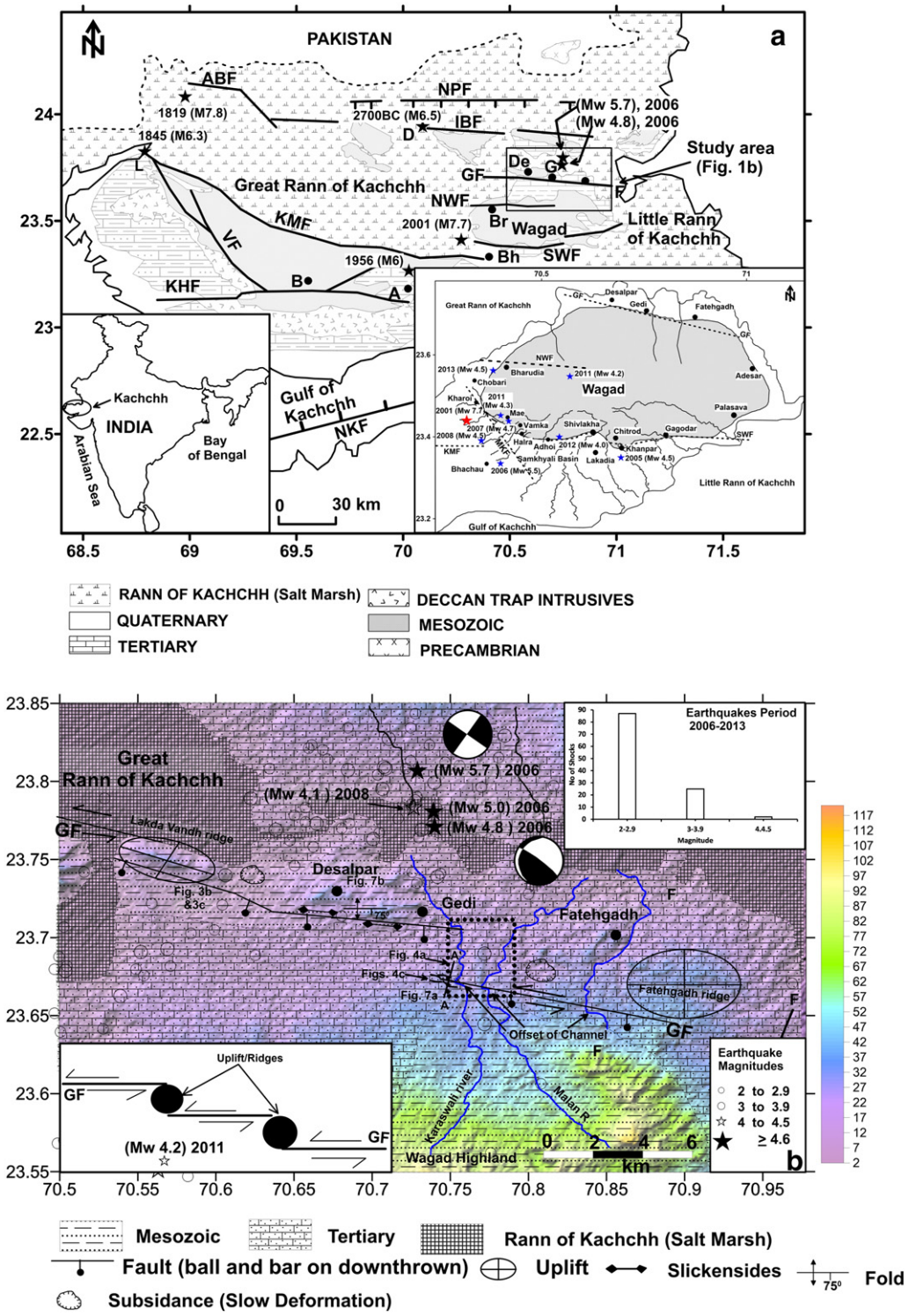

Fig. 1. (a) Seismotectonic map integrated with geological Map of Kachchh, Western India showing epicenters of significant earthquakes (modified after Biswas (2005)). Wagad area is in between SWF and GF (Note: Locations — A (Anjar), B (Bhuj), Ba (Bhachau), Br (Bharudia), D (Dholavira), De (Desalpar), L (Lakhpat), F (Fatehgarh) and G (Gedi); Faults: NKF (North Kathiyawad Fault, KHF (Katrol Hill Fault), VF, Vigodi Fault, KMF (Kachchh Mainland Fault), SWF (South Wagad Fault), NWF (North Wagad Fault), GF (Gedi Fault), IBF (Island Belt Fault), ABF (Allah Bund Fault) and NPF (Nagar Parkar Fault) (note: inset geomorphic map of the Wagad and surrounding area and distribution of post 2001 Bhuj earthquake epicenters with magnitude (Mw > 4.0) that occurred during 2006–2013; earthquake data source Institute of Seismological Research (ISR) catalogue). (b) Geological map of the study area shows locations of ground deformation observed along the trace of GF. Along the southern strands of Gedi Fault offset of channel has been observed. Some 50 earthquakes of magnitude >3 since 2006 are associated with GF (note: inset shows possible mechanism for the formation of uplifts along GF; histogram shows earthquake magnitude distribution along GF since 2006).

sedimentary successions of the rivers can be used to reconstruct the history of enhanced uplift and climate variability. The Kachchh region of western peninsular India lies in the southwest monsoon trajectory and provides information of temporal changes in tectonics/climatic in the fluvial developments (Bhattacharya et al., 2014). The rivers in Kachchh region are actively incising the Mesozoic and Tertiary bedrocks (Thakkar et al., 1999; Maurya et al., 2003; Patidar et al., 2007, 2008). However, the valley-fill deposits preserved in river valleys suggests