Research Paper E-ISSN No : 2455-295X | Volume : 2 | Issue : 5 | May 2016

NEOTECTONIC ACTIVITY IN KACHCHH RIFT BASIN, WESTERN INDIA: EVIDENCED BY GEOMORPHIC MARKER AND PALEOSEISMIC FEATURES

*Gaurav Chauhan [1] | M. G. Thakkar [1] | Girish Ch. Kothyari [2] | Siddharth Prizomwala [2] | Subhash Bhandari [1] | S. K. Biswas [3]

[1] Department of Earth and Environmental Science, KSKV Kachchh University, Bhuj, Gujarat. (*Corresponding Author)

[2] Institute of Seismological Research, Raisan, Gandhinagar, 382007.

[3] Flat No. 201/ C-wing, ISM House, Thakur Village, Kandivali (East), Mumbai-400101.

ABSTRACT

Kachchh, a pericratonic rift basin, in Western India displays fault-controlled first-order topography. The five denudational cyclic surfaces identified indicate major episodes of tectonic movements responsible for evolution of the present landscape. The rift basin is defined by E-W trending master faults which bound the tilted upthrown blocks. A transverse fault system cuts across the E-W structural fabric. Geomorphic highs related to domes, anticlines, intrusive bodies and fault scarps associated with these faults suggest their active nature. The most striking feature of the basin is a NE-SW trending first order basement high or ridge across the master faults. This central high defined as Median High (MH) is active since Mid-Jurassic and plays a major role in the geomorphic evolution of the area. Present research highlights development of geomorphic signatures associated with neotectonic activity along master faults. The various tectono-geomorphic features confirms the basin is tectonically active in Quaternary period

KEY WORDS: Geomorphic Marker, Rift, Median High, Master fault, half-graben.

Introduction

The Kachchh pericratonic rift basin of Western India is featured by impressive rugged and rocky hilly terrains scattered over vast plains. The basin evolved during Late Triassic-Early Jurassic period. It is bound by two major basin-bounding faults, the Nagar Parkar Fault (NPF) to the north and Kathiyawar Fault (KF) to the south. The Basin has been under compressional stress regime since Late Cretaceous leading to uplifts along E-W trending intra-rift master faults (Biswas, 2005): Island Belt Fault (IBF), Kachchh Mainland Fault (KMF), and South Wagad Fault (SWF) from north to south. The uplifts are Nagar Parkar uplift, Island belt uplift, Kachchh Mainland Uplift, Wagad Uplift, and Kathiyawar Uplift (Fig. 2) (Biswas, 1987, 2005). Movements along these faults since the inversion stage have been the major cause of seismicity in the Kachchh region. Many secondary faults were also generated during inversion time viz. Gora Dongar Fault (GDF), Katrol Hill fault (KHF) and Vigodi Fault (VF). These gave rise to hill ranges within the uplifts (Fig.1). The master faults and secondary faults are affected by several NE–SW, N-S and NW–SE striking transverse faults (Maurya, et al 2003a). It is further assumed that most of the transverse faults were reactivated during neotectonic cycle associated with the major and minor earthquakes. The most striking feature of the basin is the occurrence of a meridional high, termed as Median High across the middle of the basin which evolved since Late Jurassic (Fig.2) (Biswas, 1987). The present study is a site specific documentation of geomorphic markers, Neotectonic and paleoseismic features along the structural elements of Kachchh Basin.

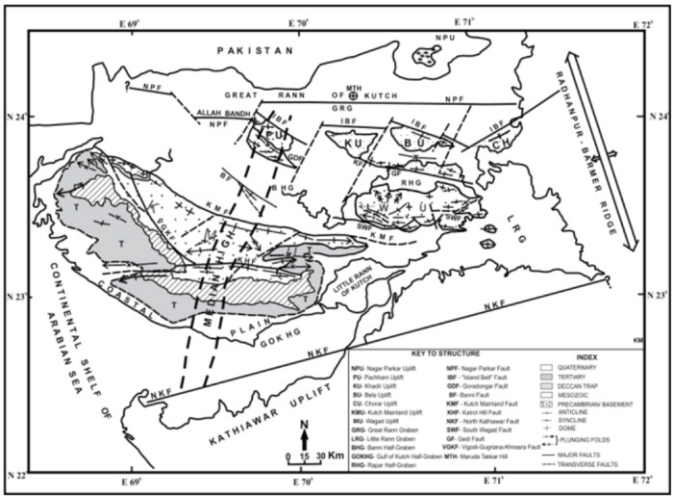

Fig. 1 Tectonic map of Kachchh Basin (after Biswas 2005) showing Master, Secondary and Transverse Faults.

Neotectonic and seismicity of Kachchh Rift Basin

Kachchh is an active tectonic zone which possesses fault-controlled first-order topography and several geomorphic features indicative of neotectonic activities (Maurya et al 2003b). The basin developed through varying stages of movement of Indian plate. Initiated as a rift basin in Early Jurassic, it passed through several tectonic cycles ending up as an active shear zone in the present neotectonic cycle under transpressional stress regime caused by plate collision and anticlockwise plate rotation (Biswas, 2005). Neotectonic activities in Kachchh reflect through evidences of structural inversion viz. First order topography, local thrusts on the back limbs of uplifts, local occurrences of fault-propagated folds, overturned limbs of the flexures (Biswas, 2005). Neotectonic activities along E-W and transverse faults are reflected in morphotectonic features viz. horizontal offsetting streams and switching of streams, sharp angular turns in the courses and beheading of streams. Tectonic landforms along faults including deflection of rivers and ridges, knick points, alignment of fault scarp, unpaired terraces, alluvial fans, development of gorges and intense incision in bedrock and Quaternary deposits along faults (Thakkar et al, 2006) (Fig. 3).

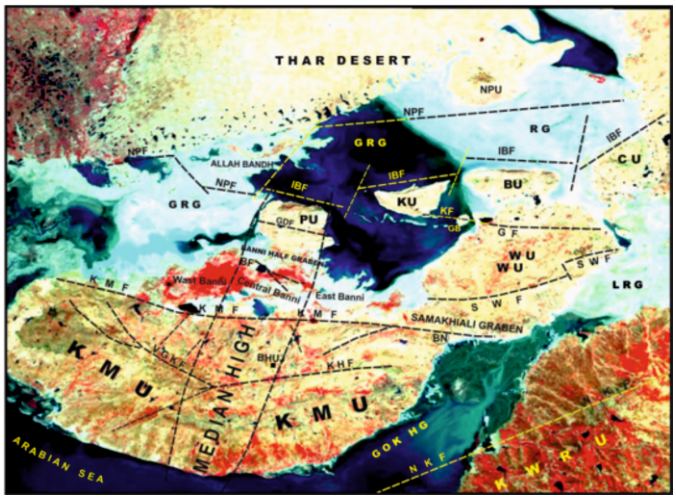

Fig. 2 Satellite image of Kachchh basin showing Morphotectonic features

Activity of median high in neotectonic cycle is evident in an elevated central part of the Banni plains which is a geomorphic high separating this depression into two subsidiary basins (Fig. 2). Four polycyclic denudational land surfaces identified in the present landscape are the evidences of repeated uplift and erosion (Biswas, 1974). The eastern segment of the KMF and the western segment of the SWF zone are laterally growing, whereas the anticlines on the western segment of the KMF, and eastern segment of the SWF have coalesced, thereby presently being inhibited for active lateral growth (Mathew et al., 2006).

Kachchh is seismically the most sensitive zone and experienced several moderate to large earthquakes such as the 2700 BC Dholavira earthquake (Mw 6.5), 1668 AD Indus Delta earthquake (Intensity X) (Bisht, 2011), 1819 Allah bund earthquake (Mw 7.8), 1956 Anjar earthquake (Mw 6.0) and 2001 Bhuj earthquake (Mw 7.7) (Oldham, 1926, Chung and Gao, 1995, Yagi and Kikuchi, 2001, Johnston, 1996 and Rajendran, et al. 2001 and 2008). Fault plane solution of 2001 Bhuj and 1956 Anjar earthquake suggest south dipping reverse fault (Chung and Gao, 1995; Negishi et al., 2001). Recent stochastic studies of earthquakes in Kachchh using Weibull, Gamma and Log-normal models have indicated recurrence interval of earthquakes with $M_w \geq 5$ to be 13 years (Yadav, et al., 2008).

Geomorphic Marker and Paleoseismic features

A wide variety of geomorphic features, such as fault scarps, valley shapes and drainage patterns indicate past or ongoing tectonic movements (Burbank and Anderson, 2001; Keller and Pinter, 2002). Effects of vertical deformation is reflected by aggradation or degradation, knick points, surface faulting of terraces, changing river patterns, deflected river courses. Effects of strike-slip deformation are reflected by faulting in terraces, offset river courses. Effects of regional tilting are represented by tilted terraces and lateral channel movements. The complex drainage pattern in Kachchh is due to streams switching or abandoning outlets as they cross the E-W trending Master faults. It indicates that there is strike slip movement along transverse faults. Tectonic landforms along fault trend including systematic deflection of stream channels and ridges, alignment of fault scarp, knick points, unpaired terraces, and displacement in the basement rocks along incised Quaternary deposits reflects that the area is undergoing active deformation driven by E-W and transverse faults system. Tectonic activeness in the Kachchh basin is also revealed by marine terraces, alluvial fans and erosional surfaces, ridge crest, knick points, bedrock gorges and tectono-erosional terraces near structural elements (Fig.3).

Fig. 3 A). ~35m E-W trending knick point on southern strand of KHF. B). North facing active fault scarp along the KHF. C). Displaced Holocene fluvial sediments in the vicinity of KHF. D). N-S trending gorge in Khari River showing activeness of Median High.

Paleoseismology is the study of prehistoric earthquakes, especially their location, timing, and size. Various paleoseismic features like soft sediment deformations, liquefactions, seismites, displaced Quaternary Sediments, terrain flexuring and subsidence of Rann of Kachchh have been documented in the basin (Fig. 3) (Thakkar and Goyal, 2004; Thakkar et al 2012a, 2012b).

Conclusions

The basin has been tectonically active since its formation in Late Triassic-Early Jurassic till date in response to the plate movement through various tectonic cycles – break up from Seychelles plate fragment, trailing edge uplift, thermodynamic subsidence, plate drifting, collision with Eurasian plate, and post collision transpressional stress due to continuing subduction, ridge push and anticlockwise plate rotation. The geomorphic signatures associated with neotectonic activity along master faults and median high like channel deflections, ridge offsets, fault scarps, knick points, gorges, displaced Quaternary deposits, unpaired strath terraces, sag ponds, truncated alluvial fans, triangular fault facets, back tilting of alluvial surfaces, incision of Quaternary cover and gorges formed on the youngest erosion surface along with several paleoseismic features like soft sediment deformations, liquefactions, seismites and large scale terrain changes have been documented in Kachchh. The Neotectonic and paleoseismic features indicate that faults have been active since rifting and inversion stages in Mesozoic time and continues to be active in the responsible for highly active basin in the neotectonic cycle. It can be concluded that repeated activation of primordial faults is present stage of neotectonic cycle.

Acknowledgements:

Author acknowledges the INSPIRE program (IF-120594), DST New Delhi for financial support.

REFERENCES

1. Bisht R. S (2011) How Harappans Honoured Death at Dholavira, proceedings of conference held at L.M.U, L.A, USA 2011
2. Biswas, S. K. (1974) Landscape of Kutch- A morphotectonic analysis. *Ind. Jour. Earth Sc*. v.1, pp.177-190
3. Biswas, S. K. (1987) Regional tectonic framework, structure and evolution of the Western margin basins of India. *Tectonophysics,* v.135, pp.307-327
4. Biswas, S. K. (2002) Structure and tectonics of Kutch Basin, western India with special reference to earthquake, 8th IGC Foundation Lecture, *Ind. Geol. Cong.,* pp. 1-21
5. Biswas, S. K. (2005) A review of structure and tectonics of Kutch basin, western India with special reference to earthquakes, *Curr. Sci.* v. 88 (10), pp.1592-1600
6. Burbank, D. W. and Anderson, R.S. (2011) Tectonic Geomorphology 2nd edition. New York, Wiley-Blackwell, pp 472
7. Chung, W. P. and Gao, H. (1995) Source parameters of the Anjar earthquake of July 21, 1956, India, and its seismotectonic implications for the Kutch rift basin. *Tectonophysics, v.* 242, 281–292
8. Johnston, A. C. (1996) Seismic moment assessment of earthquakes in stable continental regions – II, Historical seismicity. *Geophy. Jour. Inter'l,* v. 125, 639–678
9. Keller, E. A., Pinter, N. (2002) Active Tectonics, Earthquakes, Uplift and Landscapes, 2nd ed. Prentice Hall 362 pp
10. Mathew, G., Singhvi, A.K., Karanth, R.V., (2006) Luminescence chronometry and geomorphic evidence of active fold growth along the Kachchh mainland fault (KMF), Kachchh, India, Seismotectonic implications. *Tectonophysics*, 422, 71–87
11. Maurya, D. M., Thakkar, M.G., Chamyal, L.S. (2003a): Implications of transverse fault system on tectonic evolution of Mainland Kachchh, Western India *Curr. Sci.* Vol.85, No. 5, pp.661-667
12. Maurya, D. M., Thakkar, M. G., Chamyal, L. S. (2003b): Quaternary geology of the arid zone of Kachchh: Terra incognita. *Proc. Ind. Nat. Sci. Acad.* 69, A, No.2, *March 03.* pp.123-135
13. Oldham, R. D. (1926) The Cutch (Kachh) earthquake of the 16th June, 1819 with a revision of the great earthquake of the 12th June, 1897. *Indian Geological Survey Memoir*, v. 46, 71– 147
14. Prantik Mandal., B.K. Rastogi, H.V.S. Satyanarayana, M. Kousalya et.al (2004) Characterization of the causative fault system for the 2001 Bhuj earthquake of Mw 7.7, *Tectonophysics,* 378, 2004, pp 105-121
15. Rajendran, K., C. P. Rajendran, M. Thakkar, and M. P. Tuttle (2001), The 2001 Kachchh (Bhuj) earthquake: Coseismic surface features and significance, *Curr. Sci.*, 80, 1397–1405
16. Rajendran, C. P., K. Rajendran, M. Thakkar, and B. Goyal (2008), Assessing the previous activity at the source zone of the 2001 Bhuj earthquake based on the near-source and distant paleoseismological indicators, *J. Geophys. Res., 113, B05311, doi: 10.1029/2006JB004845*
17. Thakkar, M. G., Bhanu Goyal, Patidar, A., Maurya, D. M. and Chamyal, L.S. (2006): Bedrock gorges in the central mainland Kachchh: Implications for landscape evolution *Jour. Earth Sys. Sci. 115 No.2 pp.1-8*
18. Thakkar, M. G. and Bhanu Goyal (2004): On Relation between Magnitude and Liquefaction Dimension at the Epicentral zone of 2001 Bhuj Earthquake. *Curr. Sci.*, Vol. 87, No.6
19. Thakkar, M. G., Mamata Ngangom, P. S. Thakkar and N. Juyal (2012a) Terrain response to the 1819 Allah Bund earthquake in western Great Rann of Kachchh, Gujarat, India *Curr. Sci., Vol. 103, No. 2*, pp 209-212
20. Thakkar, M. G., Bhanu Goyal, D. M. Maurya and L. S. Chamyal (2012b) Internal geometry of reactivated and non-reactivated sandblow craters related to 2001 Bhuj earthquake, India: A modern analogue for interpreting paleosandblow craters *J Geol. Soc. India, vol. 79,* pp. 367-375
21. Yadav, RBS, Tripathi J.N., Rastogi, B.K., Das M.C., Chopra S. (2008) Probabilistic assessment of earthquake hazard in Gujarat and adjoining region of India. *Pure Appl. Geophys* 165:1813–1833