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STRUCTURE AND TECTONICS OF KUTCH BASIN, WESTERN INDIA, WITH SPECIAL REFERENCE TO EARTHQUAKES*

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EXTENDED ABSTRACT

The Kutch basin is a western margin pericratonic rift basin of India The rift is bound by Nagar Parkar uplift in the north and Kathiawar uplift (Saurashtra horst) in the south respectively along Nagar Parkar and North Kathiawar faults The rift is styled by three main uplifts along three master faults with intervening half-grabens (*see* Fig 2 in Biswas and Khattri, 2002) The uplifts are upthrust basement blocks tilted along sub-vertical faults with normal separation The North Kathiawar fault is the principal master that along which the rift subsided most The structure is thus styled by tilted footwall blocks and half-grabens Blanketing sediments over the basement drape over the tilted edges of the upthrusts as marginal flexures The flexures are narrow deformation zones along master faults enclosing complicated folds, locally much faulted and intruded by igneous rocks

A subsurface basement ridge – Median High, crosses the basin at right angles to its axis in the middle It divides the basin into a deeper western part and a shallower and more tectonised eastern part The rift is terminated in the east against a transverse subsurface basement ridge Radhanpur Arch, which is the western shoulder of the adjacent N-S oriented Cambay rift To the west the rift merges with offshore shelf, which is styled by NW-SE trending shelfal horst graben systems

The Kutch basin is the earliest pericratonic rift basin to form in the western margin of the Indian craton during the Late Triassic breakup of Gondwanaland (Biswas, 1982) The rift evolution and syn-rift sedimentation continued through Jurassic till Early Cretaceous as Indian plate drifted northward along an anticlockwise path During post-rift stage, the Tertiary sediments were deposited on the peripheral plains of the uplifts The rift expanded from north

**Lecture delivered at the monthly meeting of the Geological Society of India at Bangalore on 24 December 2002* to south by successive reactivation of primordial faults of Mid-Proterozoic Delhi fold belt. The faults strike E-W but eastward the strike swings to NE-SW merging with the Delhi-Aravalli strike (Biswas, 1987). The motion during the drift stage of the plate induced horizontal stress. At this stage the near vertical normal faults became wrench faults involving divergent strike-slip movements. The sense of movement was oblique-slip along reactivated faults. At the transitional stage vertical force predominated but horizontal component became dominant in the later stages (Biswas, 2002).

The rifting was aborted by the trailing edge uplift during Late Cretaceous pre-collision stage of the Indian plate. At this time most of the uplifts came into existence by upthrust of the footwall blocks. During post-collision compressive regime of the Indian plate the Kutch rift basin became a shear zone with convergent strike-slip movements along sub-parallel rift faults. The present structural style evolved by right lateral slip, which shifted the uplifts progressively eastward relative to each other from south to north. This resulted in the present *en echelon* positioning of the uplifts with respect to Kutch Mainland uplift. The strike-slip related structuring modified the linear flexures breaking them into individual folds. Narrow deformation zones formed along the master faults.

During the present compressive stage, the Radhanpur arch acts as a ramp for eastward movements along the principal deformation zones. This is creating additional strain in this part of the basin between the arch and the Median High. The strain build up in the eastern part of Kutch rift is relatively more than in the western part, west of the Median High, where the effect of earthquake is much less.

The Kutch Mainland Fault (KMF) along the rift axis is the active principal fault. This right lateral strike-slip fault side steps as the South Wagad Fault (SWF) in the eastern part of the basin with a overlap (Biswas, 2002). The over-step zone between the two wrench faults is a convergent transfer zone undergoing transpressional stress in the strained eastern part of the basin. Expectedly, this is the most favoured site for rupture nucleation. The locations of closely spaced epicenters of two major earthquakes viz., 1956 Anjar (Ms 6.1) and 2001 Bhuj (Ms 7.9), in this zone and concentration of aftershock hypocenters around it validate this conclusion. The mounting stress in the eastern part of the Kutch basin is discussed above, is responsible for repeated thrusting along SWF. Presumably, the SWF would tend to flatten towards a detachment surface close to the base of the seismogenic layer around 15-20 km depth where thrusting is expected. Thus, SWF (the side stepping eastern trace of KMF) becomes the active segment of the principal fault causing repeated thrust at depth in the mid-crustal region. The fading KMF is likely to converge with SWF or might be over stepped down dip by the latter at depth (*see* Fig.7 in Biswas and Khattri, 2002 and Fig.6 in Biswas, 2002). The distribution pattern of aftershock data and seismo-tectonic analysis (Kayal et al. 2002; Negishi et al. 2001) corroborate this interpretation. Kayal et al. (2002) presented a geological model based on then seismo-tectonic studies. They showed a south dipping "blind thrust" from the north, converging at depth with the Kutch Mainland fault (Fig.17 in Kayal et al. 2002). This "blind thrust" matches with the South Wagad fault mentioned above. It appears that this "blind thurst" of Kayal et al. is indeed the subsurface continuation of the South Wagad fault of Biswas (2002) and Biswas and Khattri (2002).

Thus, the overlapping transfer zone, Samakhali graben, between the Mainland and Wagad uplifts where the epicenters of both 1956 Anjar and the recent 2001 Bhuj earthquakes are located close to each other, is the crucial area for the occurrence of earthquakes. The focal depths (15-20 km) occur in the expected zone of flattening of SWF, which appears to be the critical site for rupture nucleation. Accordingly, this segment is interpreted as the most vulnerable site for repeated ruptures causing earthquakes.

Finally, I would like to draw your attention to the geomorphic map of India (Fig.1). In this map five major lineaments across the continent are noted whose offshore extensions across the western continental shelf were mapped as major strike slip faults, viz., (from N to S) North Kathiawar Fault, Narmada Fault, Alibagh Fault, Vengurla Fault, and Palghat (Tellichery) fault (Biswas, 1992). Of these the Narmada and Palghat faults are interpreted as ocean to continent transform faults (Biswas, 1987). The former extends across the continent becoming Dauki fault in the NE India and merges with the northeastern transform boundary along the Disang thrust. The Palghat fault follows through the aborted Palghat rift along the intraplate boundary between the Dharwar greenschist and granulite (charnockite) terrain and across the southern part of the shield. It extends northeastward along east coast following the Eastern Ghat trend and passes through the "Swatch-of-no-Grounds" canyon in the Bay of Bengal and finally merges with the Disang thrust through the Hail-Hakalula lineament in the NE (Ganju and Khar, 1985). All these faults traversing the Indian shield including those of Gujarat and the west coast fault are interconnected forming a network of active faults. Such a network is a fractal system which is basically unstable. Any displacement in one of the faults may set off concurrent reciprocal movement in other parts of the system.

Further, it is noticed that the Great Boundary Fault along

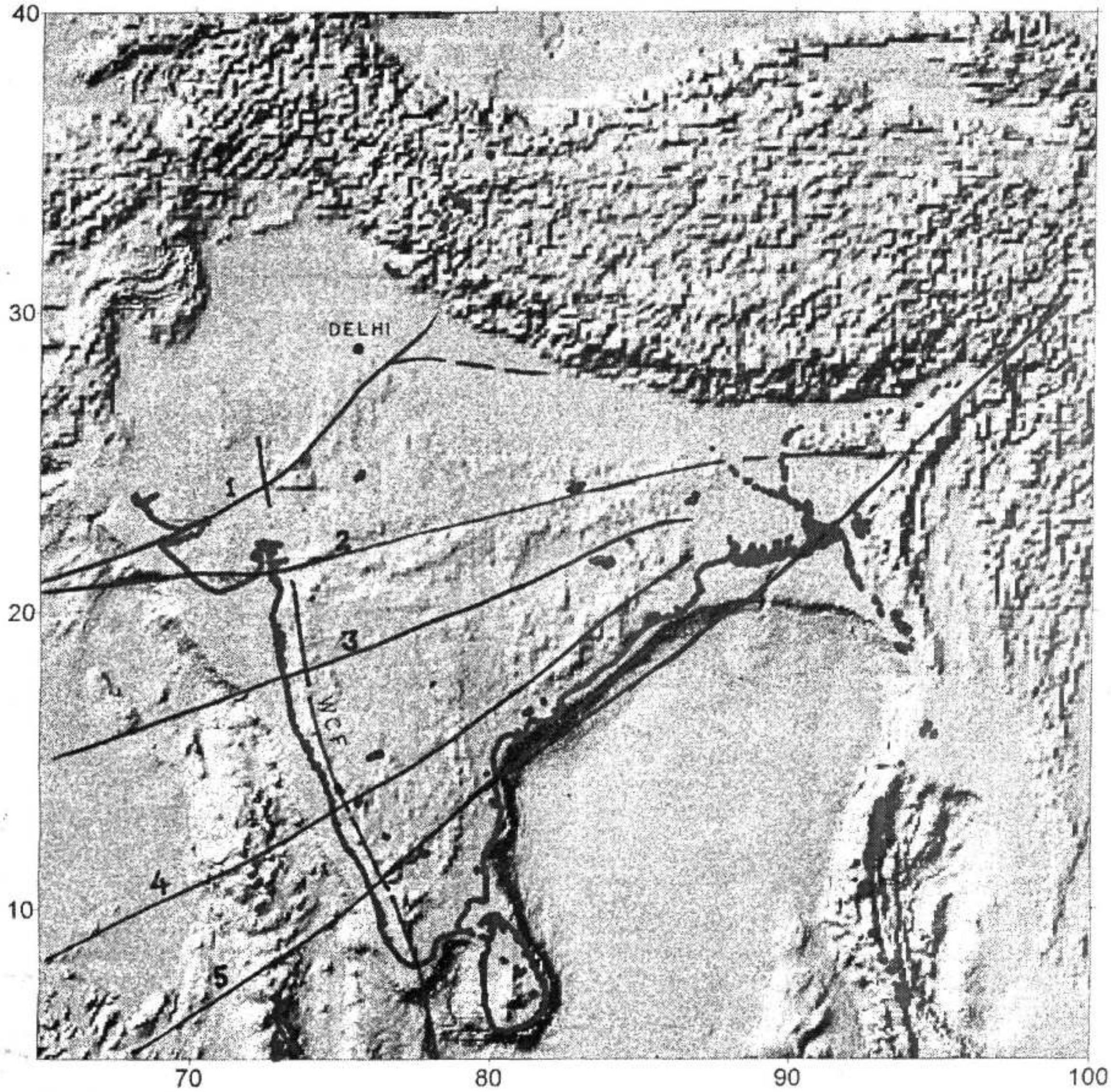

Fig.1. Satellite image of India showing physiographic features. Important transcontinental lineaments identified as transform faults from offshore seismic data are shown. **1** - North Kathiawar - Great Boundary fault; **2** - Narmada fault; **3** - Alibagh fault, **4** - Vengurla fault; **5** - Palghat fault; **WCF** - West Coast Fault.

the eastern flank of the Aravalli Belt is seemingly continuous with the North Kathiawar Fault, which played an active role in the 2001 Bhuj earthquake. The Great Boundary fault is a strike-slip fault and extends from Chittorgarh to Nepal border through the subsurface of Ganga valley across the northern part of the shield (Tiwari, 1995). Activation along this fault in the present compressive regime is a potential hazard that may cause damages in many important cities of North India including Delhi.

For illustrations and other details the reader may refer to the paper by Biswas and Khattri published in August 2002, v.60(2) of the Journal.

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REPORT ON THE NATIONAL SEMINAR ON NATURAL HAZARDS: ITS GEOLOGICAL IMPLICATION IN HILLY REGIONS

The Department of Geology, St Xavier's College, Ranchi (Jharkhand) organized a national seminar on the above theme during 21-23 November, 2002 The Seminar was inaugurated by His Excellency Rama Jois, Governor of Jharkhand, Sri Ravindra Kumar Rai, State Minister, Department of Mines and Geology, Government of Jharkhand was the guest of Honour Acting Vice-Chancellor and other officials of Ranchi University were also present on this occasion

The Seminar was sponsored by University Grants Commission, Eastern Regional Office, Kolkata, and was co-sponsored by the Geological Survey of India, Kolkata, Central Mine Planning and Design Institute, Ranchi and Jharkhand/Bihar State Mineral Development Cooperation, Ranchi

The National Seminar was a small effort from the Department of Geology to provide a common platform for scientific deliberation and group discussion among the delegates from the different parts of our country so that with improved knowledge base the adverse impact of environmental degradation and the hazard to life and property can be minimised to the benefit of the society

The Seminar included five keynote lectures and 35 technical papers dealing with a wide range of natural hazards The following keynote lectures were delivered at the Seminar (1) An overview of Natural Disaster, Disaster Management and Post-disaster Trauma with special reference to the Indian scenario by Prof O P Verma, Ex-Head, Dept of Applied Geology, ISM, Dhanbad, (2) Himalayan Mountain Building and Related Problems of Landslide Management by A K Sinha, Director, Birbal Sahni Institute of Palaeobotany, Lucknow, (3) Impact of Mineral Exploitation on the Ecosystem and the Environmental Hazard Management by S Das Gupta, Director (Geology), Dept of Mines and Geology, Govt of Jharkhand, Ranchi, (4) A General Approach to Landslides in Hilly Regions – Classification and Risk Assessment Technology by Arabinda Ghosh, Dept of Geological Sciences, Jadavpur University, Kolkata, (5) Landslips Management in the Himalayan Region by Akhouri Pramod Krishna, Acting Director, G B Pant Institute of Himalayan Environment and Development, Sikkim Unit, Tadong, Gangtok

All the technical papers were widely discussed They related to natural disasters, landslides, industrial effluent, hazards etc, in different regions such as Himalayan area, Chotanagpur Plateau, Coal mining areas etc More than 65 delegates inlcuding guest speakers attended the seminar On the last day of the Seminar, a field trip to Rajrappa coalfield was organized

In the concluding part of the Seminar, it was recommended that a Centre for Risk Management should be established in the Department of Geology of St Xavier's College, Ranchi to impart theoretical and practical knowledge to policy level personnel/planners, technocrats, academicians and NGOs

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