

Tectono-Geomorphic Features around Jaisalmer (Rajasthan)

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Abstract: The Jurassic to Quaternary succession of Jaisalmer region has formed horst and graben structures as a result of Neogene tectonic movements. The topography and long stretches of streams indicates influence of faults and regional lineaments. Deflections in the streams are due to faults present on either sides of the tilted blocks and the formations of flood plains adjoining the highlands can be attributed to horsts and grabens. Abrupt changes in the ground water levels in wells of the same hydrological formation are also inferred due to tilted blocks in the region.

Keywords: Neogene tectonic movements Tectono-geomorphology, Drainage, Topographic, Anomalies.

1. Introduction

Major part of the Jaisalmer area in NW Rajasthan is covered by blown sand; with rock exposures of Jurassic, Cretaceous and Lower Tertiary. The Quaternary sequences are contained on the erosional surfaces of the basement rocks and in tectonic troughs. The basement configuration and the inferred disposition of the Quaternary sub-basins in the region suggest a gradual westward increase in thickness of the sediments in the basins (Dhir et al., 1992).

The Neogene tectonic movements in the western Rajasthan have formed a series of NE-SW trending horst and graben structures which controlled the origin, configuration and development of the Quaternary basins and their sedimentation. The vertical movement rejuvenated the pre-existing faults and facilitated Quaternary sedimentation in marginal fault troughs and grabens forming linear alluvial valleys, and lakes formed by disorganised river courses (Dassarma, 1988). Striking relationship has been established between many of the NNE-SSW lineaments and drainage features (Kar, 2011).

The study of Tectono geomorphology in the Jaisalmer region has not been done previously and can be helpful in identifying features associated with active faults, though being a desert region some of the associated features may be covered by sand.

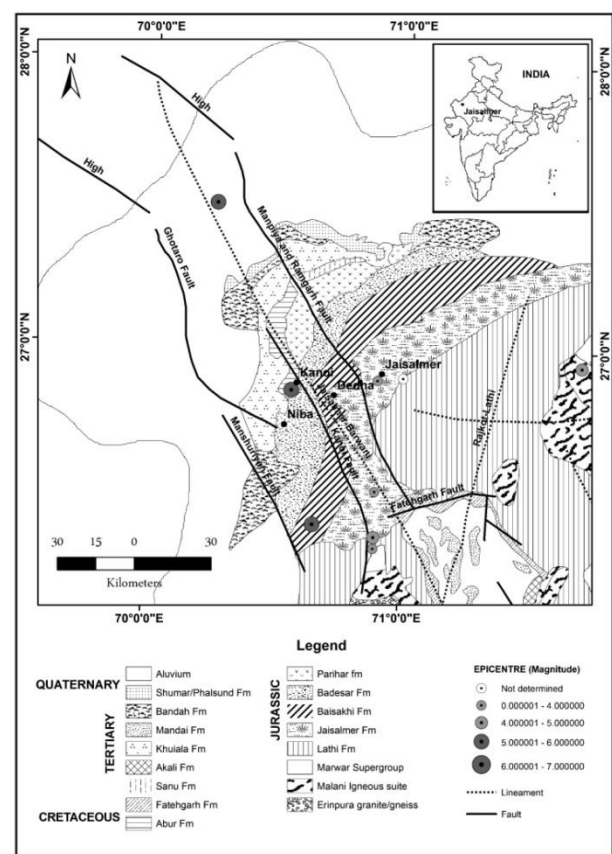
1.1 Tectonics of Jaisalmer basin:

The Jaisalmer basin represents the eastern flank of the Indus basin and is divided into four N-S trending geotectonic blocks which have different tectonic features. The Kishangarh Sub basin forms the Northwesterly dipping shelf. The Jaisalmer-Mari High is gravity high features located along shoulder zone of Kanoi Fault and is attributed to upthrusting and wrench faulting and is a zone of lifted blocks. The Shahgarh Sub Basin is the deepest depression and is less disturbed. The Miajhar Sub Basin in the south of the Jaisalmer Basin is structurally simple. The structural style of Jaisalmer basin has been controlled by faults and the maximum effect of faulting is limited between Ramgarh and Kanoi Faults which can be traced on outcrops and in subsurface (Mishra and Sharma, 1986). The NW-SE

trending faults in the region are the Mansurian Fault and Ghotaro Fault in the west, Kanoi Fault and Manpiya Ramgarh Fault near Jaisalmer. The Fatehgarh Fault is E-W fault separating the Jaisalmer basin from the southern Barmer Basin (Fig 1). Two regional lineaments traversing the area are the Rajkot-Lathi and Jaisalmer- Barwania Lineament.

The Jurassic rocks of the Jaisalmer region lie over the basement of Lathi Sandstone followed by the Cretaceous and Tertiary rocks. The Quaternary sediments are mostly wind- blown and form sand dunes.

Figure 1: Geology and Seismotectonic Map around Jaisalmer (Rajasthan)



1.2 Seismic activities

The Jaisalmer area has witnessed earthquakes in the recent past and the epicenters are located near the existing faults in the region (Fig 1). Brahman (1993) reported them to be located on the proximity of gravity high. The earthquake that shook the western Rajasthan on 8th November, 1991, was felt over an area of about 130 km. radius around Jaisalmer town. The intensity of earthquake with epicenter at Kanoi village ($70^{\circ} 34'$; $26^{\circ} 51' 30''$; 40 J/9) was 5.4 on Richter scale. A fault (N289⁰ striking and 61⁰ dipping) parallel to the gravity anomaly of the area was supposed to be reactivated for this event (Brahman, 1993).

2. Methodology

The geoinformatic methods were used by creating layers of all the relevant data on Arc GIS platform. The interpretations were subsequently field checked. The published geological map (Gupta et al, 2002) was the base and the faults and lineaments were digitized from Seismotectonic Atlas (Dasgupta et al., 2000), the epicenters were marked from catalogue of Seismotectonic Atlas, (Dasgupta et al., 2000) and Rao, (2014). The drainage was digitized from Survey of India topo sheets. The SRTM data of 90m resolution downloaded from <http://srtm.csi.cgiar.org/> was used to generate the elevation model. Ground water data from PHED, Government of Rajasthan were used.

3. Observations

3.1 Drainage Anomalies

The pattern of stream development is an indicator of active faulting (Twidale, 2004). Various workers have characterized the associated tectonic landforms by systematically deflected stream channels, aligned drainages and valley linear, valley fault scraps (Okada, 1980; Deng et al., 1986; Zang et al., 1995; Keller 1986). In regions of active faulting long stretches of drainage indicates influence of faults and some straight sections are aligned parallel to the regional lineament pattern. The faults and lineaments control the straight course of the rivers. Deflection in the streams is explained due to shift of a part of the river courses in response to the tilt of the blocks on either sides of the faults and lineaments. Offsets of various landforms are caused by strike slip movement along the faults. Stream channels are disruption or deflection. Evidences of drainage disorientations have been reported by earlier workers (Kar, 1988), and have been widely studied for tracing the course of River Saraswati in Western Rajasthan.

The rose diagrams of the faults and lineaments in the Jaisalmer basin shows that the NW-SE direction is the most prominent direction followed by NE-SW direction (Fig 2A, and B). The drainage in the region has followed the latter direction (Fig 2C). At places the angularity in the trends of faults/lineaments and drainage in the basin has resulted in the drainage anomalies: being parallel to the Manpiya-Ramgarh Fault (Fig 2D), produces offsets and splay faults along the Kanoi Fault (Fig 2E and 2F) and truncation along Jaisalmer Barwania Lineament (Fig 2G).

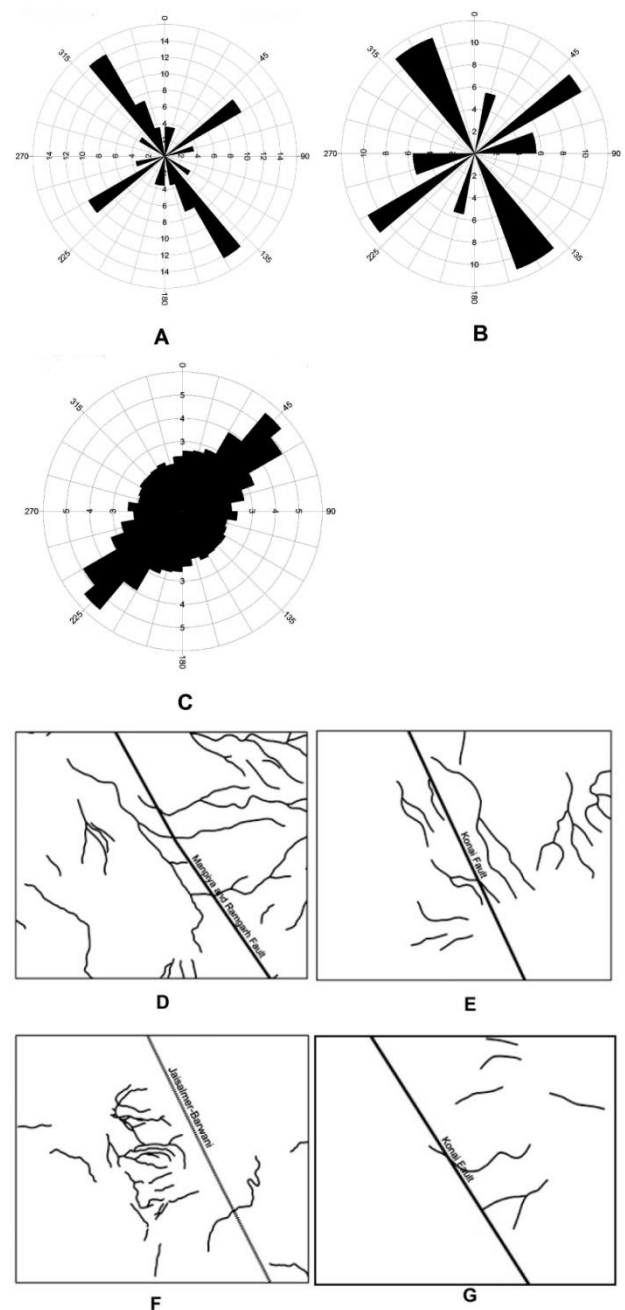


Figure 2: Rose Diagram and Drainage Anomaly

3.2 Topographical Anomalies

The Digital Elevation Model (DEM) is the representation of terrain elevation as a function of geographic locations (Burrough and Mc Donnell, 2004). The DEM was incorporated in the Arc GIS software and was used to produce slope and shaded maps of the topography. Discontinuities and significant changes in slope in the DEM's and changes in behaviour of drainage pattern when the slope discontinuity was encountered, provided evidence of fault identification. The geomorphic anomalies were observed between Kanoi Fault and Manpiya-Ramgarh Fault in the (DEM) using the SRTM image (Fig 3). Abrupt changes in the elevations are noted in the region and especially between Kanoi and Manpiya-Ramgarh Faults.

The drainage has also been subsequently affected by these faults and offsets are formed.

In the DEM's fault were inferred at the junction of abrupt topographical changes associated with drainage anomalies. The NE-SW trending inferred faults which are not visible on the surface due to sand cover controlled the topography of the region (Fig 3).

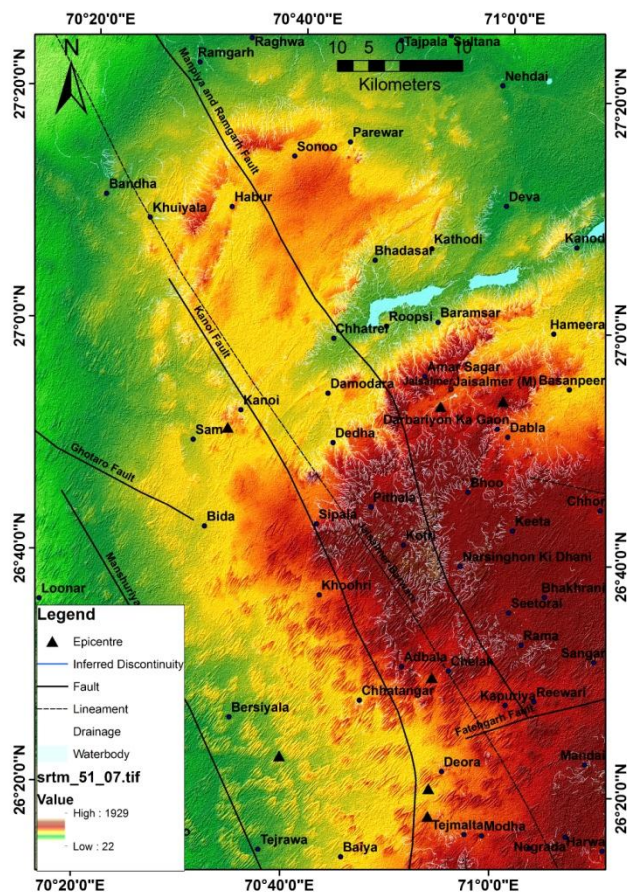


Figure 3: SRTM Image around Jaisalmer (Rajasthan)

To further visualize the changes in the topography between the between Kanoi Fault and Manpiya – Ramgarh Fault, cross sections across various lithological boundaries were made at regular intervals from north to south (Fig 4).

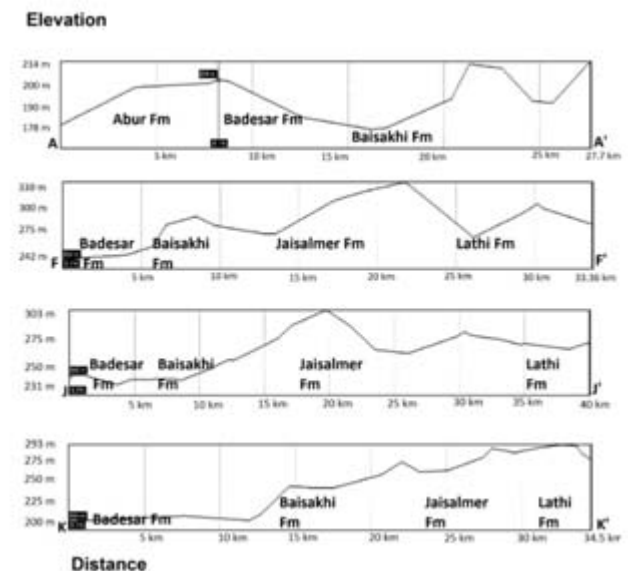


Figure 4: Topographical profiles between Kanoi and Ramgarh Manpiya Fault, Jaisalmer (Rajasthan)

In the northern most profile (A-A') the highest elevation is 210m above msl in the Baisakhi Formation composed of sandstone, which drops abruptly on either sides. The rocks of Baisakhi and Badesar Formations are forming valley and the lowest elevation is 178 m. In the southern profile (F-F'), a sudden drop in elevation is observed on the west of Baisakhi Formation. The Jaisalmer Formation has attained a height of 330m above msl. and the lowest elevation is 242 m above msl. In the profile (J-J') a gently sloping profile is present between the Jaisalmer and Baisakhi Formations. In profile (K-K') a sudden drop in the elevation from 250 m to 200 m in a stepped manner is present between Baisakhi and Badesdar Formations. Near village Dedha the abrupt truncation of the Baisakhi Formation has resulted in formation of alluvial fan at the contact of Baisakhi sand stone and Jaisalmer limestone and a wide flood plane has developed in between these formations. The flood plains of this type are known as `Khadins` in the local language and are irrigated after the rains.

Figure 5 Alluvial plane between Baisakhi sandstone and Jaisalmer limestone).



These profiles represent discontinuous terrace, flat flood plains and abrupt changes in the profiles.

3.3 Ground water level anomalies:

The ground water in sedimentary formations is expected to have the same depth in a hydrological formation, but in the Jaisalmer region the depth to water table is not similar (Table 1).

S. No	Hydrological Formation	Range Water table bgl (m)
1	Alluvium	37-170
2	Parihar Formation	180-250
3	Bhadesar Formation	95-243
4	Baisakhi Formation	39-204
5	Jaisalmer Formation	35-180
6	Lathi Formation	44-242
7	Granites and Gneisses	39-105

In the Lathi Formation the average depth to water table is between 44-242 m. The deeper depths are near the southern side of the Lathi Formation near the Fatehgarh Fault and between Kanoi and Fahegarh Faults subsequently becoming shallower just in the south of Fatehgarh Fault in granite and gneisses. Across the Kanoi Fault the depth has abruptly changed in the Jaisalmer and Baisakhi Formations. In Bhadesar Formation exception changes in depth to ground is observed, the well which lies on the Mansurian Fault has shallower depth. Exceptional deep wells are also present in the Parihar Formation; these wells are located between Kanoi and Manphia Ramgarh Fault. No abnormal changes are found in the Alluvium.

Abrupt changes in the ground water levels are observed in the wells in the same hydrological formation across the identified and inferred faults and areas not marked by faults.

4. Results and Discussion

The Stable Cratonic Regions (SCR) of the intraplate cratonic environments also referred as stable cratonic cores (Fenton et al, 2006) are the areas where no large earthquake or abundant paleoearthquakes are evidenced similar to the area of the present study. In the SCR paleoearthquakes may cause minor tilting of fault bounded blocks, giving rise to geomorphic anomalies for which there are not likely depositional and erosional explanation (Schumm et al., 2000). In western Rajasthan the formation of NW-SE and NE-SW faults during the Mesozoics has initiated block tectonics in (Roy and Jakhar, 2002), and have formed a series of NE-SW trending horst and graben structures which controlled the origin, configuration and development of the Quaternary basins and their sedimentation. The major faults that pass through the Jaisalmer area have NNW-SSE trend and other cross faults trends in the ENE-WSW direction. One such is the Fatehgarh Fault that runs south of Jaisalmer. The geomorphology of the terrain is broadly controlled by the two major NNW-SSE trending faults: Kanoi Fault in the west and Manpiya Ramgarh Fault in the east. A depression between the two faults forms a graben, which itself is segmented by a number of subparallel fault systems bounding horsts and grabens. Because of the development of such fault systems the broad graben is dissected into a series of narrow (between 250-300 meter wide) valleys (graben)

separated by a narrow a little elevated upland (horsts) (Fig 5).

The block tilting can also start the channel of alluvial rivers in predictable ways so as the changes in the sinuosity or gradient or deflection; Schumm et al., 2000. Crustal tilt can also be creating anomalies in smaller streams and their depositional and erosional patterns (Guccione et al., 2002; Guccione, 2005). The drainage network itself may display an asymmetry unexplainable by local stratigraphy of structure created by tilt. The ENE-WSW faults though not so prominent like major faults appear very effective in causing drainage disorganization especially of the NE-SW trending ephemeral drainage systems in the Jaisalmer area tuning them into saline lakes (or Ranns) (Roy, 1999).

5. Conclusion

The sets of lineaments developed in the Indian lithospheric crust fragmented it into large number of blocks (Roy, 1999). The lineaments also developed a structural heterogeneity in the crust and gave rise to blocks bounded by narrow zones. The relative movement between the rigid blocks tilted them and brought geomorphic changes. As such a steepened graben structure can be deciphered on the west and northwest of Jaisalmer basin. The effect of faulting has been more pronounced between Kanoi and Ramgarh-Manpia Faults. Bedrock incision, sudden branching, widening of the stream beds, and stream courses flowing over faults and lineaments are indicative of neotectonism in the region. The abrupt changes in the depth to water table in the same hydrological formation across the faults and in some cases across unidentified regions are due to the uneven tilting of the crustal blocks between the major faults of the region.

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