IDENTIFICATION AND MAPPING OF TECTONICALLY ACTIVE POTENTIAL ZONES IN NORTHEASTERN PART OF ARAVALLI MOUNTAIN RANGE

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ABSTRACT:

The Great Boundary Fault (GBF) forms the eastern margin of the Aravalli Mountain Range (AMR) and, is exposed as boundary between highly deformed rocks of the AMR and relatively undeformed Vindhyan rocks. The GBF acts as important active dislocation zone between Himalayan regime in the north and, Son-Narmada regime in the south. Nevertheless, the intensity of active tectonics along GBF is relatively mild and hence, it requires special technique to identify and map active tectonics zone along this thrust.

The thematic maps of geology, geomorphology, slope, and vegetation index of study area have been prepared using Landsat 7 ETM$^+$ digital data. These themes are integrated in GIS environment to assess the active tectonic potential in the area. The observed four high potential zones in the area are located at the intersection of NE-SW lineaments. The study brings out methodology for assessing active tectonic potential of the area.

1. INTRODUCTION

The state of Rajasthan is regarded as geologist's paradise. The tectonic features ranging from magnificent regional scale folds and thrusts to local scale crenulations and faults are beautifully portrayed in the outcrops of the Aravalli Mountain Range (AMR)_(Heron, 1953, Sinha Roy et al., 1998). The Great Boundary Fault (GBF) forms the eastern margin of the AMR and, is exposed as boundary between highly deformed rocks of the AMR and relatively unreformed Vindhyans rocks (Verma and Greiling, 1995, Verma, 1996). The GBF acts as important active dislocation zone between compressional Himalayan regime in the north and, extensional Son-Narmada regime in the south. Nevertheless, the intensity of active tectonics along GBF is relatively mild and hence, it requires special technique to identify and map active tectonics zone along this thrust. The present work attempt to evolve effective GIS for identification and mapping of mild active tectonics zones with focused example from part of the GBF terrain.

2. LOCATION AND APPROACH

The present study area (Figure 1) is a part of eastern Rajasthan, which is situated under Three district of Rajasthan, these districts are Sawai Madhopur, Karauli and Dausa .The study area covers 5406.63 sq. Km. area and it is located between longitude 76^{0}15'-77^{0}5'E and latitude 26^{0}50'-26^{0}15'N on map. The area falls on Survey of India Toposheets no.54B/5,6,7,9,10,11,13,14,15 and 54F/1,2,3 Gangapur city, Karauli, Hindaun and Lalsot are the major cities of this area. Delhi-Mumbai train route passes through the Gangapur city. Area is well connected by roads and the conveniences are easily available.

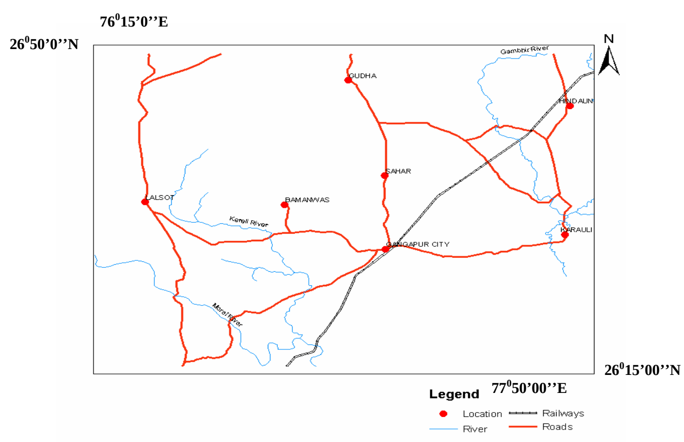

Figure 1 Location map of Karauli-Lalsot area of NE Rajasthan

3. METHODOLOGY

The basic data used in present study includes digital products of Landsat-7 ETM , IRS ID (LISS–III & WiFS) , IRS-P4 (OCM), Digital Elevation Model (DEM) 30 m data of Shuttle Radar Topographic Mission (SRTM) and, SOI topographical sheets at 1:1M, 1:250,000 and 1:50,000 scales. The general image interpretation elements (tone, texture, pattern etc.) are used in rock type and geomorphic features discrimination. The visual image interpretation techniques (tone, texture, pattern etc.) were followed in delineating geology, geomorphology and lineaments features. The digital image analysis and visual interpretation were carried out on IBM platform using ERDAS Imagine software. The UTM coordinate system was used for data input in the present study.

A drainage map of the area is prepared to illustrate the major characteristic of topography morphology and also to emphasis the impact of the faulting on the final geometry of the area. Morphometric analysis is carried out and different parameters are calculated viz. Bifurcation ratio, Drainage density, Length of over land flow, Stream Frequency, Form factor etc. (Strahler, 1964). A polygon map is prepared by assigning a code for each category. The important geomorphic parameters, which help in identification of active tectonics in the area (viz. sinuosity of river, mountain front sinuosity, valley floor width and height ratio, concavity index etc.) are quantified. The important morphotectonic parameters, which help in identification of active tectonics in the area (viz. sinuosity of river and mountain front sinuosity) and the indices of sinuosity (Muller, 1968) are calculated as follows.

Channel Index (CI)=CL/AL (CL is channel length and AL is air length)
Valley Index (VI)=VL/AL (VL is valley length)
Standard Sinuosity Index (SSI)=CI/VI
Hydraulic Sinuosity Index (HSI)=(CI-VI/CI-1)*100.
Topographic Sinuosity Index (TSI)= (VI-1/CI-1)*100.

Mountain front sinuosity (S) is defined as the ratio of observed length along the margin of the topographic mountain piedmont junction (Lmf) to the overall length of the mountain front (Ls).

Smf=Lmf/Ls

Sinousity Fractal dimension (SFD) values have been computed for each of the river considering the whole drainage basin as a spatial unit. The calculation has been done by using Box Flex method (Barton, 1995).

Following digitization, rastorisation of all maps are carried out in the ERDAS imagine. The UTM coordinate system is used for data input in the present study. The four characteristic indicators of active tectonics in this area are identified as geology geomorphology, slope, and vegetation index. Each of these characteristic indicators is assigned weight value of 0 and 25 at minimum and maximum, respectively to obtain a 100 point scale for active tectonics intensity. Accordingly, the integrated weight of prepared active tectonics intensity zone map ranges between 0 and 100. The area has been contoured based on integrated weight to demarcate zones of active tectonics intensity.

4. GEOLOGY AND GEOMORPHOLOGY

The area is occupied mainly by the rocks belonging to the Vindhyan, Delhi Supergroups and Aravalli rock covering part of the area (Sinha Roy, 1984; Sinha Roy et al., 1995; Banerjee and Singh, 1981; Gupta et al., 1997; Roy and Jhakar, 2002). The Great Boundary Fault separates the Vindhyan rocks from the older rocks of Aravalli Mountain Range (Hacket, 1881; Roy, 1988). The Vindhyan supergroup, in general, contains undeformed and unmetamorphosed conglomerate, sandstones, shales and limestones. These rocks are nearly horizontal to sub horizontal, however, near the GBF, this sequence is steeply dipping and intricately folded. The Delhi Supergroup contains metamorphic succession with limestones and quartzites of the Raialo Group (Figure 2). Geomorphologically, the area represents a fairly rugged topography with presence of structural hill ranges, linear and curvilinear ridges, and plateaus with intermontane valleys. The pediments as well as pediplains are frequently observed (Figure 3).

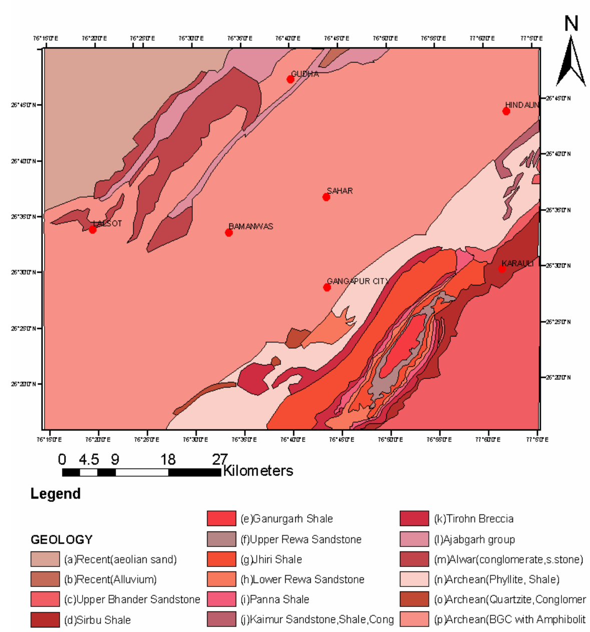

Figure 2 Geological map of the study area

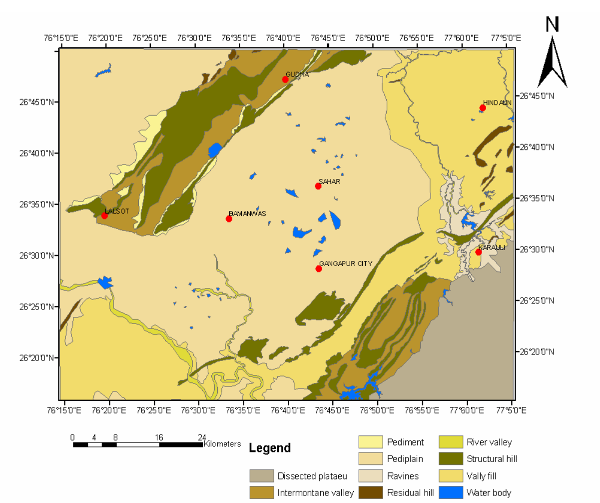

Figure 3 Geomorphological map of the study area

5. MORPHOMETRIC AND MORPHOTECTONIC CHARACTERISTICS

The river systems often adjust themselves against changes in ground slope conditions arising due to tectonic processes. These changes are often reflected in river lateral and longitudinal profiles (Hack, 1957; Bull & Knuepfer, 1987; Sinha Roy, 2001a).

The area is mainly drained by Kareli River, which is left branch of the Morel River. The general flow direction of the river is NW- SE. The total catchment of the river covers an area of 720 sq km and basin perimeter of about 153 km. Morphometric study of the area reveals the predominance of dendritic, sub-parallel and trellis drainage patterns. A systematic drainage analysis indicates the presence of the 5th order stream. Most of these streams are rain fed and dry up during the summer. The computed values of Bifurcation ratio is 3.9, Infiltration number (If) is 1.47, Stream Frequency (Sf) is 1.3, Ruggedness (Hd) is 0.29 and Texture Ratio (Tu) is 6.17. Low drainage density of the area suggests that the area has higher density of joints and fractures. Further, high infiltration and low runoff suggests highly fractured underlying rocks.

Table 1 Values of sinuosity parameters calculated for the different sections of Kareli River

S.No.	CL (Km)	VL (Km)	AL (Km)	HSI	TSI	SSI
1	5.75	5.625	5	16.67	83.33	1.02
2	6.75	6.5	5	14.29	85.71	1.04
3	5.75	5.5	5	33.33	66.67	1.05
4	6.75	6	5	42.86	57.14	1.13
5	5.75	5.375	5	50.00	50.00	1.07
6	5.25	5.15	5	40.00	60.00	1.02
7	5.6	5.15	5	75.00	25.00	1.09
8	7.25	6.25	5	44.44	55.56	1.16
9	6	5.5	5	50.00	50.00	1.09
10	8.5	7	5	42.86	57.14	1.21
11	6.5	5.35	5	76.67	23.33	1.21
12	8	6	5	66.67	33.33	1.33

Table 2 Fractal value of Kareli River

S. No.	Slope value	Fractal value
1	-0.04444	1.044
2	-0.0394	1.039
3	-0.03265	1.033
4	-0.03265	1.033
5	-0.02637	1.026
6	-0.0266	1.027
7	-0.03427	1.034
8	-0.04568	1.046
9	-0.0346	1.035
10	-0.08507	1.085
11	-0.06751	1.068
12	-0.09122	1.091

The river sinuosity is important parameter that undergoes rapid modification during episodic and/or continuous tectonic processes and, thus, the sinuosity parameter of rivers becomes an important indicator of tectonic history of drainage basins (Schumm, 1963; Muller, 1968; Burnett and Schumm, 1983). The present work is an attempt to assess various sinuosity indices as indicator of active tectonics in the area. These parameters are computed for different segment of Karli river basin. Sinuosity value of fractal dimension of Kareli River basin ranges from 1.091 to 1.026 (Table 1). The SSI values of all 12 sections range between 1.02 and 1.33 indicating non-sinuous course for all the sections (Table 2). The study area indicates higher topographic factor with the values of TSI Kareli River 53.9%. The difference between TSI and HSI in the study area, however, is not very contrasting indicating very slow rate of tectonic activity with TSI being at slightly higher side due to ongoing tectonics and corresponding topographic modifications.

The values for all sections are indicative of late youth to early maturity stage of basin development. The low value of HSI and correspondingly higher values of TSI Index in section suggest that the streams do not belong to the initial denudation cycle but the area has been rejuvenated.

Mountain front sinuosity assesses the influence of tectonic uplift, assuming that tectonically inactive mountain fronts will be more embayed than those of similar lithology undergoing recent tectonic uplift. Mountain front sinuosity (Smf) is defined as the ratio of observed length along the margin of the topographic mountain piedmont junction (Lmf) to the overall length of the mountain front (Ls) front (Smf = Lmf/Ls; Bull & McFadden 1977, Keller& Pinter 2001). The Smf values lower than 1.4 indicate tectonically active fronts (Rockwell et al. 1984, Keller, 1986) while higher Smf values (>3) are normally associated with inactive fronts in which the initial range–front fault may be more than 1 Km away from the present erosional front.

6. LINEAMENT FABRIC

Lineament is defined as mappable, simple or composite linear features of a surface, whose parts are aligned in a rectilinear or slightly curvilinear relationship and which differs distinctly from the patterns of adjacent features and presumably reflects a subsurface phenomenon (O'Leary *et al.*, 1976).

The lineament analysis reveals a distinct variation in the frequency and distribution of lineaments in the area (Figure 4). The rose diagrams plotted with respect to Frequency azimuth and Length azimuth indicate three significant trends that are well correlated with the observed tectonic trends in the field. Lineament Intersection map, number of lineament map and lineament total length map have been prepared using unit grid size of 25 sq km. The lineament intersection contour map shows that the northwestern part of area has higher values of intersections. The lineament length contour map illustrates that the northwestern and some part of southeast of the area have larger length of lineaments. Lineament number contour map depicts that the greater number of lineaments are concentrated in the NW part of the study area.

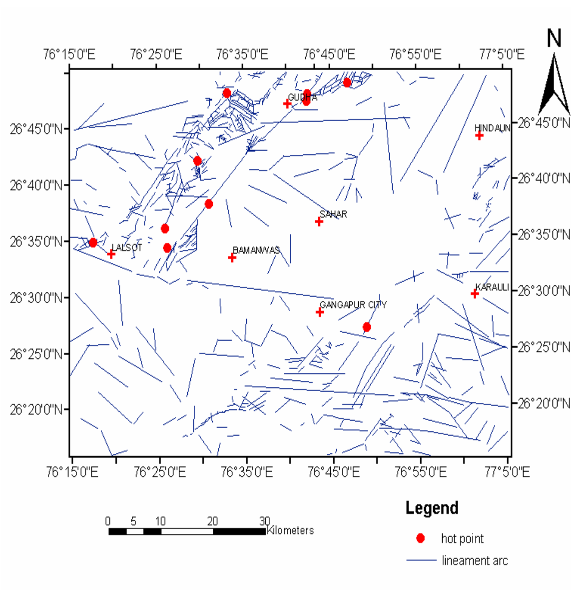

Figure 4 Lineament map of the study area

7. ACTIVE TECTONICS ZONES

Based on the result obtained during the present investigation, an active tectonics potential map has been generated. This map show different zones with the estimated potential for present day tectonic activity. The four important parameters identified for assessing degree and potential of active tectonics in the area are Geomorphology, Geology, Slope and Vegetation index for which thematic maps have been generated. The four thematic maps are classified with value ranging between 0 and 10. The weight value that have been assigned to the individual classes are mainly on the basis of literature, result obtained during the present investigation and knowledge about the present terrain. This exercise consists of following four steps for identification and grading of active zones.

Step-1: Assigning weight value to the classes of the parameter maps. The weight values are assigned in tables connected to the raster map. First a table is created for each map and then a column weight is created, in which weight values for different classes are added. In present case weight value ranging 0 – 10 is given to different components. Four important parameters characterizing the tectonic zones are identified. Each of these parameters (Geomorphology, Geology, Slope and Vegetation index) is assigned weight value of 0 and 10 at minimum and maximum respectively. Thus the integrated weight of final map ranges between 0 and 100.

Step-2: Renumbering the parameter map to weight maps. The combination of each parameter map with the weight values derived from the table created in the previous step is called renumbering.

Step-3: Combining the weight maps in to one single active tectonics map. The weight map is combined in this exercise by simply summing them up. In the present case, the sum of all four components comes to be maximum 100 and minimum 0.

Step-4: Classifying the combined weight map into active tectonics zone map. The combined weight map, which has many classes, is simplified by classifying the values into three classes, namely, high active zone, moderate active zone and low active zone.

The following four thematic layers have been used in generation of active tectonic potential map.

7.1 Geomorphological Map

Geomorphological units are reclassified by giving more importance to structural hills (weight value 9). This unit covers major part of the study area and is characterized mostly by hard and compact sandstone with steep slope. The valley fills are less important from tectonic point of view (Table 3, Figure 3)

7.2 Geological map

Geological units are reclassified on the basis of their relative hardness, higher the hardness higher the value and vice-versa. In this study Ajabgarh Group has higher weight value (9) and recent alluviums having lesser weight value (0). The groups having higher value are most important from tectonic point of view then others. The weight values are represent in following table (Table 3) and the weighted geological map is shown (Figure 2).

7.3 Slope map

The interpolated raster image of contour lines is used for preparing the slope. The gradient filters DF DX and DF DY are used respectively in X and Y direction. The application of gradient filters yields pixel values as attribute difference per unit cell in X or Y direction. The maps are created by applying the equation:

Slope map = {[HYP (DX, DY)/12]*100}

The slope map is classified into five classes based on slope percentage (Table 3 Figure 5). The very low slopes (<10%) are mainly associated with valley fills. The low slopes (10-15%) observed in undulating pediplain areas. The moderately sloping areas (20-25%) are in association with pediment, residual/ denudational hills and intermountain valley zone. Steep slopes (25-30%) and very steep slope (>30%) are associated with neck of dissected ridges, structural hills, ravenous land and escarpments. This map is reclassified by giving more importance to areas having steeper slope.

Table 3: Geomorphic, Slope and Vegetation index units with assigned weight values

Geological Unit	Geomorphic Unit	Slope Unit	Vegetation Unit	Assigned Weight
Sst, Qtz, Ajabgarh,	Structural hill	Very high	Very low Vegetation	9
Phyllite, Slate	Dissected Pateau	Moderate	Low Vegetation	8
Shale	Pediment	Moderate	Low Vegetation	7
Shale	Intermountain valley	High	Low to medium	4
Alluvium	Ravenous land	Moderate to high	Low vegetation	6
Sst, Qtz,	Residual/ denudational hill	Moderate	Moderate Vegetation	5
Shale, Alluvium	Pediplain	Low	High Vegetation	1
Recent Alluvium	Valley Fills/River valley	Very low	Water (moisture zone)	0

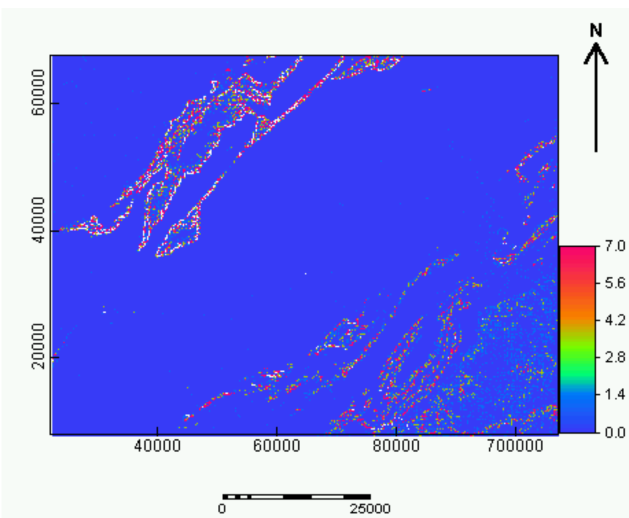

Figure 5 Slope Map of study area with Weightage value

7.4 Vegetation index maps (NDVI)

The following formula is used to calculate NDVI in map Calc function:

NDVI = (Infrared Band- Red Band)/ (Infrared Band + Red band)

This map is classified into five subclasses based on the vegetation index values. The vegetation index values are divided in very low or barren land (-0.165-0.06), low (0.06-0.15), Low to moderate (0.15-0.2), moderate (0.2-0.35) and high vegetation (>0.35) classes. The very low vegetation is found in very steep slopes and structural hills areas Higher vegetation index points to lower weathering potential (Table 3 Figure 6)

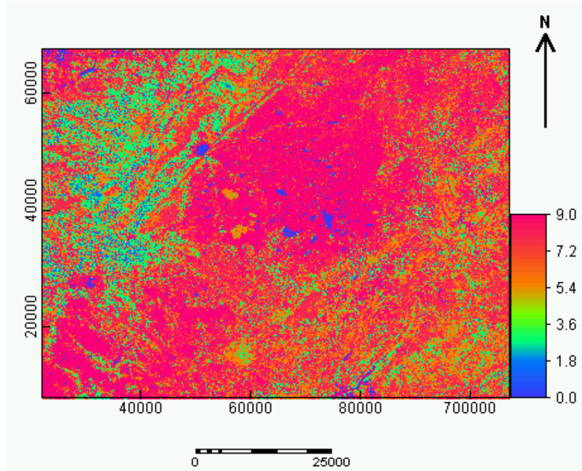

Figure 6 NDVI Map of study area with Weightage value

Final result is obtained in form of Neotectonic Potential Zone Map ((Figure 7). This map shows that the less part of the study area is affected with neotectonic activity and North-western part of the study area is showing prominently Neotectnic zone.

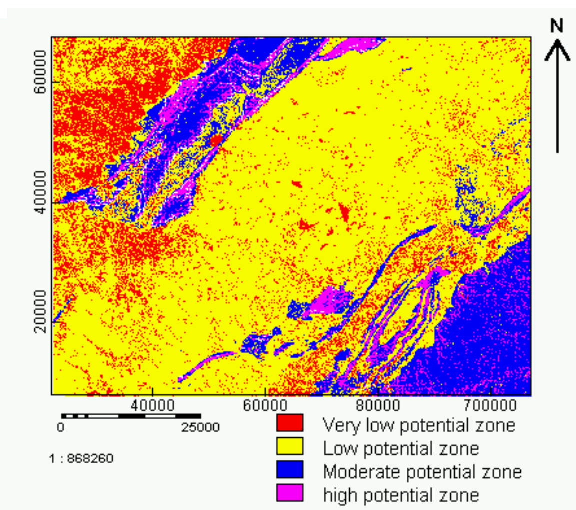

Figure 7 Neotectonic Potential Map

CONCLUSION

There are several direct and indirect evidences for active tectonics. The evidences are more pronounced where the rate of tectonism is higher. The quantification of these evidences to formulate a yard stick for measuring present and potential tectonic zone is possible using GIS technique.

The GIS developed in the present study distinctly assesses the active tectonics in Karauli-Bayana area and classifies the area into active tectonic zones based on present and potential tectonic activities. Interestingly, the high tectonic potential zones identified through this technique are also characterized by the presence of areas of high heat flow. The methodology may be well suited for studies pertaining to land stability, seismic zonation and related programs.

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