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Remote Sensing Application for Structural Analysis of Alwar district, Rajasthan

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Abstract

The application of remote sensing technology, over more than three decades, has shown a great promise for large-scale geological mapping. This work presents an investigation for enhancing lineaments with possible relevance to faults in Alwar district of Rajasthan using a landsat TM data. The rocks of the study area belong to Delhi super group. The photographic and geotechnical elements and convergence of evidence technique were used for extraction of the micro lineaments. These micro lineaments were studied and used to describe cardinal stress trajectories. Visual interpretation technique has been carried out for micro lineaments pattern in the area using Landsat TM FCC of band 2 3 4 on scale of 1: 250000 corresponding to path-row: 147-041 to generate the micro lineament pattern of the area in conjunction with SOI toposheets no 54A and 54B. The present study was carried out to develop time and cost effective approach for mapping the arid lands using remotely sensed data. Micro lineament analysis was attempted to interpret the stress distribution system for proper understanding of the structural evolution of the study area.

Index Terms: Structure, Photo-fabric, Landsat, Micro lineaments, Stress deformation,

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1 INTRODUCTION

Fault detection is an essential element in the field of structural, economic and environmental geology and remote sensing has been used effectively for geological application. For example, mapping of lineaments or structural features of any region may provide useful information for mineral or oil exploration studies [10]. Faults are often revealed as linear or curvilinear traces on satellite images. These image lines of different contrast are commonly referred to as lineaments [9] and may extend from a few meters to tens of kilometers in length. Certainly not all lineaments relate to faulting. They could also be attributed to lithological boundaries, boundaries between different land uses, drainage lines or even to man-made constructions such as roads. Therefore, it is not easy to interpret the potential structural origin of lineaments based on satellite images only.

The Landsat TM FCC of band 2 3 4 of study area falls in part of latitude 27^0 to 28^0 and longitude of 76^0 and 77^0 east having path-row 147:041 and includes the topographic sheet no 54A and 54B on scale 1:250000. In regions where joints are distinctly expressed in the weathered landscape, the mapping of joints is best achieved by image interpretation.

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The advent of remote sensing and availability of space satellite images in different electromagnetic radiation bands have made synoptic viewing feasible for regional and global fracture patterns, which are expressed as micro linements. Structural analysis using micro lineaments has given good results in different parts of the world [8].

2 STRUCTURAL ANALYSES

The part of Delhi fold belts has been interpreted using LANDSAT data. The formational contact and structural trends were plotted as trend line. Photo strike and photo dips were used to delineate the axial traces of anti formal and syn formal structures [3]. The dislocation planes were mapped as faults and thrust using the interpretational keys using the remotely sensed data in the study area. The rock units are reflecting hue and intensity saturation is low, and these exhibits dull color. In Alwar, group of rocks bedding is prominent.

2.1 Geological set up of the area:

The rocks of the study area belong to Delhi super group. The succession is fully developed in Alwar, the rocks of the area are highly deformed. Stratigraphically the Delhi super group is divisible into Alwar and Ajabgarh group having the thickness of about 5000 meters. The Alwar group is areneceous and the Ajabgarh group is predominantly argillaceous in character [6]. The deep erosion has exhumed the resistance quartzite of sequence of Alwar and Ajabgarh groups, which have determined the major architecture of the Aravalli mountain ranges in Rajasthan. This sequence exhibits structural discordance with the underlying rocks of Railo groups.

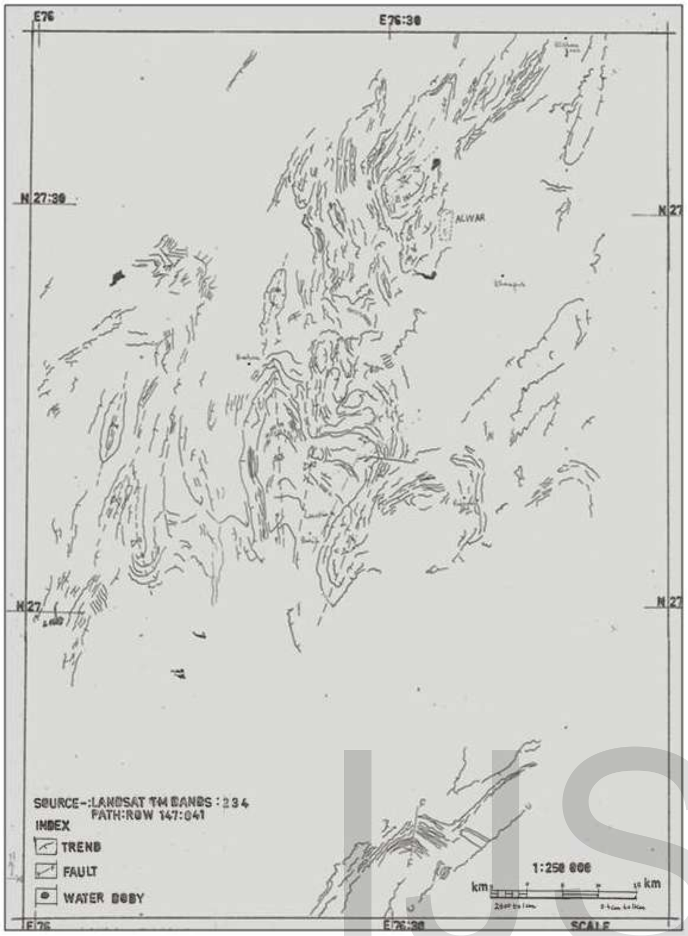

Fig: 1.Structural map of study area Alwar district, Rajasthan

2.2 Structural fabrics:

The structural fabric of the area around Alwar comprises fold, faults, micro lineaments, foliation etc. The image interpretation carried out from the remotely sensed data, which help significantly to map structural fabric, has been summarizing in a table 1.

3 MICROLINEMENTS

Micro lineaments are present as joint controlled photo fabric in the study area. The joints have been distinguished from faults in the image interpretation on the basis of their restricted axial extention, close spaced fracturing and presence of joint sets [3]. The detailed description of microlineaments and their statistical treatment has been presented here.

3.1 General Statement

Joints are the most common elements of rock geometry. The term joint is most commonly used in reference to relatively continuous and thorough going fractures that are reasonably planer and along which there has been imperceptible

Structural Fabric	Character/trend/ nature	Photo-interpretation
Bedding	Steep and moderate dip, locally inversion of the bedding has been seen, which is manifested by attitude of beds in the area.	Mapped as trend lines Tonal banding and slope lengths have been found as useful keys in the interpretation of dip direction.
Folds	The closure defined by the quartzite beds occurs as hogback and cuesta ridges defining the architectural pattern of the Delhi fold belts in the study area. Locally in study area folds are polyclinal and simulate box geometry was noticed, this box geometry is the result from fanning of the axial traces from NNW-SSE in west and NE-SW in the east.	Mapped as axial traces The major axial traces mapped as anticline and synclinal trends having general trend NNE-SSW. Folds are steeply dipping and moderately to steeply plunging, the steepening of the plunge has locally resulted in the over turning and isoclinal folding in the area.
Foliation	The foliation trend has been locally mapped in the argillaceous metasediments, characterized by penetrative and pervasive linear fabric. Foliation trend has been variable from NS to NNE and SSW following the regional deformational pattern.	Expressed as first order gullies in the image and short ridges forming water divides between these gullies.
Faults	Faults have been mapped as non penetrative linear fabric. The fault traces suggest vertical to sub vertical dip of the failure surface.	Characterized by offsetting of beds, rectilinearly the faults trace expressed as linear photo tones, short ridges, depression and linear segment of drain aged channel.
Micro lineaments	Joints have been distinguished from faults in the image interpretation on the basis of their restricted axial extension, close spaced fracturing and presence of joint sets.	Microlineament is present as joint controlled photo fabric.

Table 1: The structural fabric of the study area around Alwar.

Movement [7]. The infinitesimal movement that gives rise to a joint can be a shear parallel to the joint surface, a shortening

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perpendicular to the joint surface through actual loss of material, or some combinations of these factors [2].

Joints and joint related structure are developed to varying degrees in different regional geologic environments. Conventional geological mapping of joints for structural analyses has provided useful information on structure and stress distribution of the area [1].

Fig: 2. Micro lineament map of Alwar district, Rajasthan

However, there are shortcomings associated with using the image interpretation approach, exclusively in the mapping of joints. Furthermore, it is difficult to measure from photographs the dip and dip direction of joints and to gather information regarding the types of joints and joint related structures that exists in the area [2]. Hence the study is based on two-dimentional analysis of data. In the present study, the fractures controlled micro lineaments developed in the supra crystal of the area around Bhopal have been analysed to determine the cardinal stress trajectories which controlled the structural evolution in this part of the Vindhyan basin.

4 STATISTICAL TREATMENTS OF MICROLINEMENTS

4.1 Rolling Mean analysis

Micro lineaments are fracture controlled linear and their distribution pattern is sometimes erratic and random and thus are not amiable to contouring [4]. In order to smoothen the noise, two dimensional smoothing technique known as rolling mean analysis, has been adopted for study.

The cell value of the central cell is calculated as a mathematical mean of the adjacent cell value of the central cell, which is provided a Weightage factor of 2. The sum of the value is divided by the number of the cells involved (usually 9) [5]. The mathematical mean is plotted as the calculated cell value for the central cell. The process is repeated for all the cells involved in the area. For calculating the cell value of the cells located at the periphery of the area, rational values are provided by assuming the cells around the periphery.

$$Md = \frac{M\,(n-1) + 2M\,(c.c)}{n}$$

Where, n is number of cells involved
M (n-1) is the cell value of the adjacent cells.
M (c.c) is the cell value of the central cell
2 is the weightage factor
Md is the mean cell value circulated for the central cell.

The new computed values obtained by rolling mean analysis are subjected to contouring. Then the anomaly axis is drawn from the contour map, which is interpreted in terms of stress regime.

In the present study this technique of giving 88% overlap for smoothening the data was applied for all the three maps prepared i.e. isofracture, micro lineaments incidence and intersection density maps.

4.2 Analysis of Micro lineaments

4.2.1 Orientation analysis of Micro lineaments

For orientation analysis, the quadrant orientations of micro lineaments in the area were measured from the micro lineament map prepared. For a matter of simplicity the area was plotted as a single sector. The data thus arranged can be plotted in a rose diagram.

4.2.2 Circular (Rose) diagram:

For this diagram computer aided software Stereonet was used. The orientation of every micro lineament in the sector was entered into the computer and the resulting rose diagram was oriented. The classes with less number of micro lineaments are ignored as noise. The mathematical mean of the dominant classes is computed. These values were used as the orientation of the cardinal joint trends. The obtuse bisector of the two dominant factor sets was drawn to indicate the $_{-1}$ trajectory (fig: 3), the computed $_{-1}$ orientation was correlated with the axial traces of the fold. From these results, the conceptual kinematics model for stress distribution system was computed. The two dominant anomaly axes are N45^{0} E and N32^{0}W. The obtuse bisector lies ($_{-1}$) almost North-south.

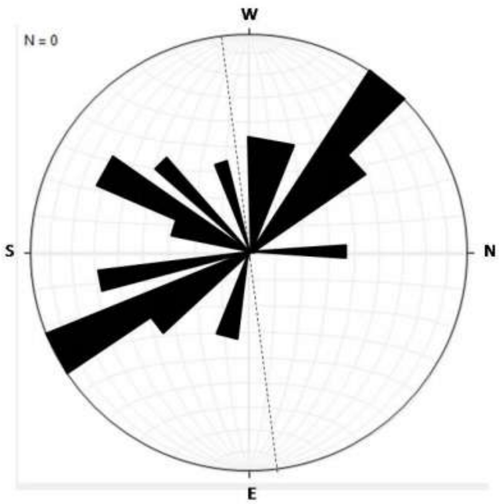


Fig: 3. Rose diagram depicting the orientation of the lineaments.

4.2.3 Isofracture Density analysis

To do such analysis an isofracture density map is a prerequisite. The micro lineaments of the area were mapped from the Landsat TM FCC image, using photographic and geotechnical elements as recognition tools. The area was divided into cells of equal dimension (5km x 5km). The cell boundaries were drawn parallel to the latitude & longitudes. The number of micro lineaments falling in each cell was counted and plotted in the center of the cell as cell value. The cell values were subjected to rolling mean analysis and the new computed cell values were used as controls for contouring the area.

The anomaly axes were drawn following the general trend of elongation. The anomaly axes is oriented, North-South. The isofrature density anomaly axis has a trend, which roughly coincides with the trend of dominant fractures.

It shows a good correlation with the results of orientation and intersection density analysis. There is no scientific justification for determining the trajectory from isofracture and incidence density anomaly axes, though they often show good correlation. The isofracture analysis is useful tool for exploration of ground water, and often in petroleum exploration, where higher density values indicate prospective areas.

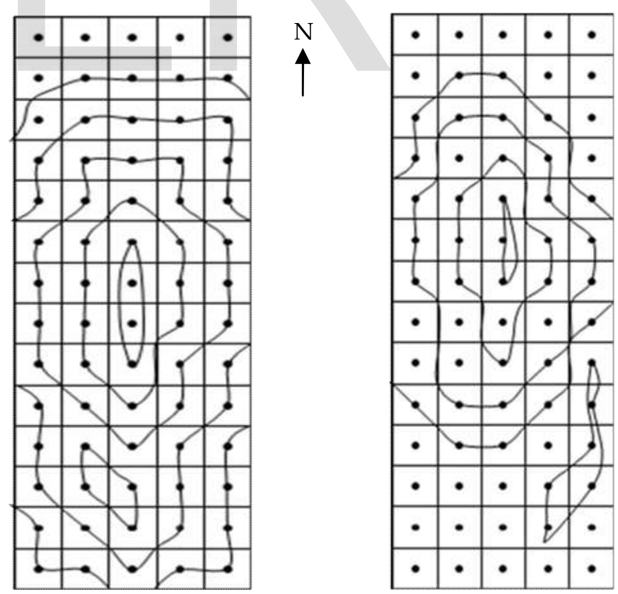
4.2.4 Microlineament Incidence Density Analysis

The micro lineament map and the cell grid pattern prepared for the iso-fracture density analysis was maintained for this micro lineament incidence density analysis. The length of the micro lineamnet falling within each cell was measured and their summation was plotted as cell value in the center of each cell. The cell values were subjected to rolling mean analysis and the new computed cell values were used as controls for contouring the area. Hence the micro lineament incidence density map resulted. The anomaly axes were drawn following the general trend of elongation.

The micro lineament incidence density map thus prepared show similarity in contour pattern with the isofracture density map (fig:4(b)). The dominant anomaly axis trends North-south. The east-west direction roughly indicates the $_{-1}$ trajectory and the East-west direction corresponds with the axial trace of the fold.

4.2.5 Microlineament Intersection Density Analysis

The micro lineament map and the cell grid adopted for isofracture density and micro lineament incidence density analysis were used for the micro lineament intersection density analysis as well. The points of intersection of the micro lineaments falling within each cell were identified, counted and their sum total was plotted as cell value in the center of each cell. The cell values were subjected to rolling mean analysis and the new computed cell values were used as controls for contouring the area. Thus the micro lineament intersection density trend surface map was prepared (fig:4(a)). The anomaly axis was drawn along the general trend of elongation. The anomaly axis of the micro lineament intersection density map shows parallelism with the trend of the axial trace of the fold. The $_{-1}$ trajectory lies perpendicular to the axial trace of the fold and thus is oriented in East-west direction.



(a) (b)

Fig:4. (a). Intersection density contour map, (b). Incidence analysis contour map of Alwar belt.

5 STRESS DISTRIBUTION ANALYSIS

From the study of micro lineament intersection density analysis the orientation of anomaly axis drawn from the girdle trend has emerged as North-South which will suggest the principal compression was from East-West. The sub vertical to vertical trend of the fracture indicated by rectilinear trend of the micro lineaments suggest that -2 was vertically disposed during the structural evolution of the Delhi fold belts in the study area. The sub-vertical disposition of -2 is also correlated from the fault pattern mapped in the area. The stress distribution indicates -1 and -2 were horizontal disposed and -2 were vertical as shown in stress model.

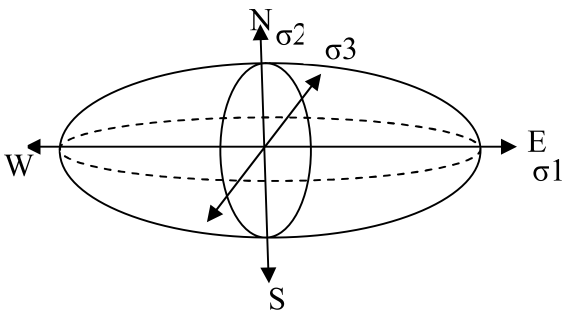


Fig: 5. Stress ellipsoid, sigma2 is vertical axis.

The mean stress was small and stress deviation was large which was possibly responsible for the directional control in the structure architecture of Delhi fold belt. Though the fracture pattern suggest the east-west direction of -1 trajectory, orientation of the axial traces of the folds and structural trend lines indicates ESE-WNW trend of the principle stress in the area. The disparity between the stress distribution derived from the axial orientation and the micro lineament analysis is possibly due to the effect of the superimposed strain in the micro lineament data of the area. The micro lineaments developed during F1 folding have been filtered from the bulk data which have possibly affected the outcome of the stress distribution system as NS for -1 trajectory.

Comparison of results of the different micro lineament analyses methods was studied to find out the trends. A table is shown below:

Method	**Trend**
Trend analysis	$N45^0E$, $S\ 32^0E$
Isofracture analysis	North-south
Incidence analysis	North-south
Intersection density analysis	North-south
Fold axis	North-south
-1	East-west

6 CONCLUSION

The structural analysis in parts of Alwar belts was studied using remotely sensed satellite derived data. The structural fabris of Alwar belt has been evolved by tectonic activities. The fracture controlled micro lineaments in the Alwar belts were analysed to determine the cardinal stress trajectories. The satellite derived data revealed that the fracture pattern can be used for trend analysis, micro lineaments incidence analysis and intersection density analysis, quite effective. The present study has indicated that micro lineaments intersection density can also be used as guide to assess the intensity of deformation and tightness of structures.

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