Study of Tectonic Elements of Punjab Plains from Satellite Imagery, Drainage Network and Gravity Anomalies

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Summary

The study is aimed to provide an insight to the tectonic elements of a morphologically subdued less deformed area like the Punjab plains. A lineament study is performed to uncover the dominant trend in the region and later it is exemplified how this trend plays an important role in the modification of the course of a river. Several drainage anomalies were marked over the region and a morpho-tectonic study was undertaken to show how the tectonic element helps in the formation of one of the anomaly. The study overall elaborates how the drainage anomalies extracted from the image and from the elevation data act as a structural indicator and document different tectonic events.

Introduction

The Punjab Plains was once considered as to be one of the promising oil bearing regions in India owing to the presence of natural gas in Jawalamukhi, Bahl, Nurpur etc. Though the areas have not yielded commercial hydrocarbons, exploration work is still on. Here the area is once again revisited and restudied with the available sets of new data to bring forward fresh leads to the exploration of the area.

The main objective of the study was to delineate the structural elements of the Punjab Plains through the Remote Sensing data and to see how the different trends affects the course of the river and consequently develops to a drainage anomaly. With significant improvement in the resolution of the available digital data combined with the availability of the elevation data the evaluation of morphotectonic units through Geographical Information System (GIS) tends to be more informative and more quantitative.

Area of Study & Data used

The study area covers the states of Jammu & Kashmir, Himachal Pradesh and Punjab and SOI toposheets number 43, 44, 52, 53 series in the scale of 1:250,000. Seven Landsat TM scenes and seven Landsat ETM data were used for the study. The scenes were mosaiced and processed and geo-referenced with the base map. Different image processing techniques like contrast stretching and spatial enhancement techniques were applied for better visualization of the data.

In the present study, analyses of the terrain were made using a Digital Elevation Model (DEM). Shuttle Radar Topographic Mission (SRTM) provided the elevation data needed to create a seamless DEM of 80% of the world's landmass at different spatial resolution through the use of synthetic aperture radar (SAR) technology (Mohanty, 2004). The SRTM data used for the present study area was having resolution of 90 m.

General geology & tectonics

The Punjab Plains is a Proterozoic pericratonic pre-foredeep shelf superimposed by rapid subsidence and sedimentation by Tertiary foredeep molasse. A monoclinal northerly dipping strata is suggested by the Airborne magnetic and ground gravity-magnetic data.

The basin is bounded by the Main boundary thrust (MBT) in the north while the Delhi-Sargodha ridge marks the southern margin, the western part is demarcated by the Aravalli ridge.

The basinal area of about 30,000 sq km is covered by recent alluvium. The stratigraphy of the Tertiary and Quaternary sediments as given by Lithostratigraphy of Indian petroliferous basins document- I, KDMIPE-ONGC 1993 is as follows:

Identification of the Tectonic Elements

To delineate the tectonic elements of the area a Lineament analysis was performed followed by mapping of several drainage anomalies which indicates the presence

Table I :

Recent Alluvium	Silt occasional clay and pebble, lighter in colour than older alluvium
Up. Siwalik	Predominately conglomerate with minor sst and claystone
Mid. Siwalik	Sandstone with pebbly clay & minor conglomerate band at the top
Lr. Siwalik	Fine to medium grained Sst. and reddish brown claystone & siltstone
Up. Dharmasala	Sandstone & purple claystone
Lr. Dharmasala	Claystone and siltstone
Subathu Fm.	Splintery Sh with fossiliferous Lst
Mohand Formation	Dolomitic lst. With pyritiferous slaty shale
Januari Group	Marble
Basement	Granite

of a subsurface structure.

Finally, a morpho-tectonic study is attempted for the most prominent anomaly of the drainage network to show the implications of faults on drainages and the subsequent modifications of the drainage anomaly.

Lineament analysis

Lineaments were identified on the basis of the major trends of morphological features, alignments of stream, textural alignments, tonal differences. Lineaments were mapped by manually interpreting the false colour composite as well as the individual bands of Landsat TM and ETM data.

The trends of the lineaments were plotted on a Rose diagram, which shows the dominant trend of the lineament **(Fig 1)** as NE-SW with minor cross trends. To get a better idea of the lineament pattern the area was divided into two parts Sector I in the Northern part which basically covered hilly parts and Sector II which covers the plains of Punjab. Comparing the Rose diagram of two sectors we can see that the NW-SE trend of the Sector I is completely missing in Sector II while the NE-SW trend is the dominant trend.

Mapping of Anomalies

A detail study was carried out to identify anomalous area over the region, which may reflect possible subsurface structural features. Image characters like tone, texture and drainage pattern were considered to identify the anomalous area. For the study the plain areas were considered while the hilly parts were avoided as anomalies in the plains indicate subsurface structures. A total number of thirteen anomalies were detected **(Fig 2)** broadly grouped as drainage anomaly and tonal anomaly.

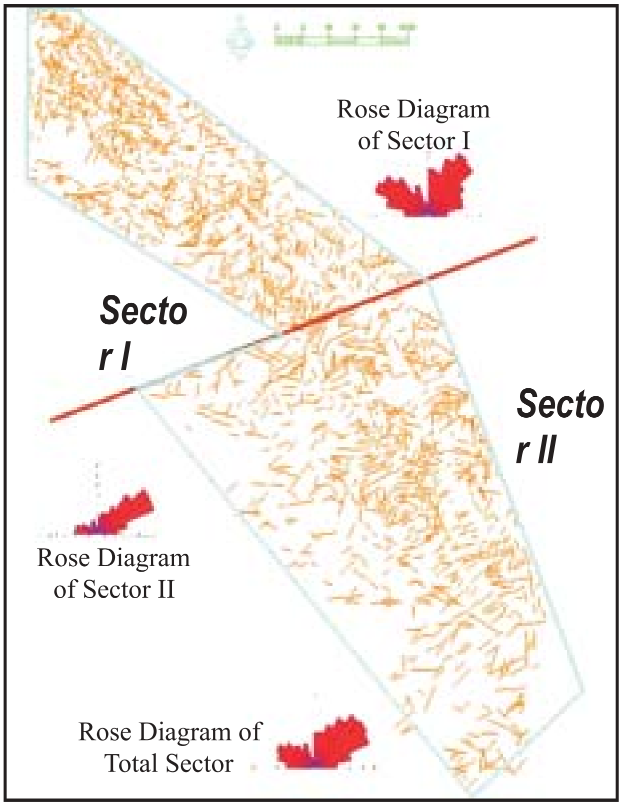

Fig. 1: Lineament Analysis of the whole area along with the rose diagrams

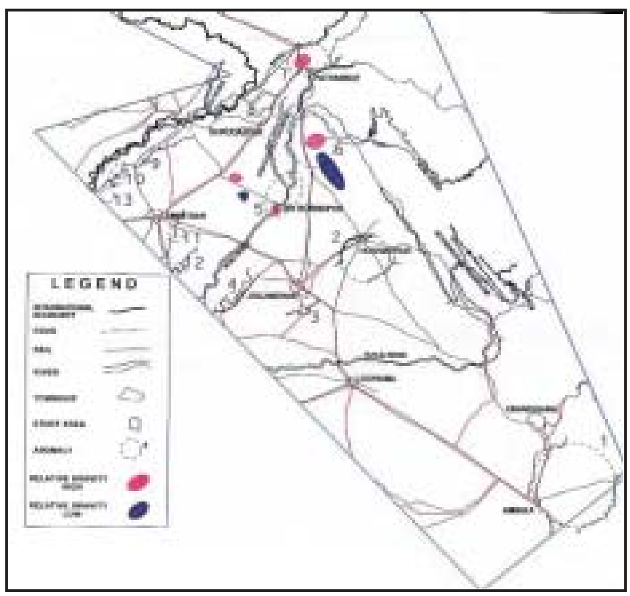

Fig. 2: Showing different types of anomalies marked along with the cultural features

- **Drainage anomaly**
  It is seen that there are two types of drainage abnormalities.

I. Drainages showing anomalous pattern

The channel pattern can be observed in detail by studying the extracted drainages created from the SRTM data using the automated drainage extraction process of PCI Geomatica software (Fig 3). The figure describes this type of anomalies where several subsequent drainages and marginal drainages develops due to the presence of the subsurface high.

- Anomaly 1, 2, 6, 7 and 8 are all drainage anomalies with drainages having peripheral/ marginal drainages and in some cases a median drainage is also found like in 1 and 8.
- In all the anomalies it can be seen that the drainages are trying to avoid the straight path due to some obstruction and this is well illustrated in anomalies 1, 2 and 6.

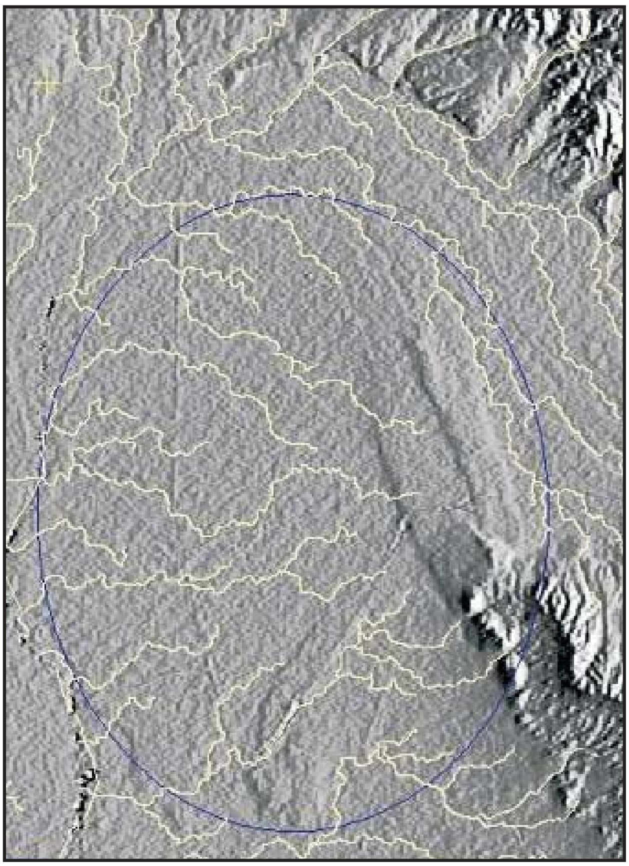

Fig. 3: Extracted drainages over the shaded relief.

II Drainages showing anomalous path

Here drainages show irregular behavior as they show more sinuosity over the area than the surrounding area.

- Anomaly 3, 4, 5, 9, 10, 11 and 12 are all seen to have drainages deviating from the straight/ normal course of the path.

The digital elevation data from the SRTM data was used to visualize the variation in the terrain over the anomalies. For this the satellite data of Landsat TM was draped over the terrain model (**Fig 4)** and a fly-through model was generated. The slight undulations of the topography over the two types of drainage anomalies were observed.

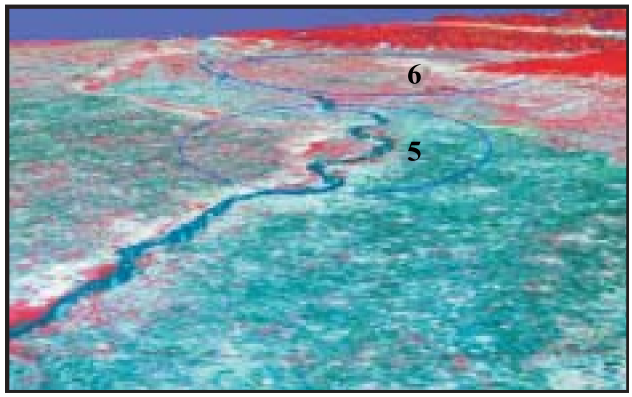

Fig. 4: DEM from the SRTM data draped over the Satellite image showing the two types of anomalies (Anomaly 5 & 6)

- **Tonal anomaly**
  Compaction of unconsolidated or even consolidated material over a buried high feature could result in a tonal change directly over the feature. These areas being well drained render a lighter tone over the buried features and thus a tonal anomaly develops.
  - Anomaly 13 is marked entirely on the basis of tone. A darker tone is seen to exist in the inner part of the circle compared to the outer part.
  - Anomaly 1, 2, 7, 10 and 12 shows a lighter tone compared to the surrounding area.
  - Anomaly 3, 6 and 9 shows a darker tone compared to the surrounding area.
  - While Anomaly 4, 5 and 8 do not show any tonal variations.

The gravity highs and lows which are studied by ONGC over the area are superimposed over the anomalies **(Fig 2)** and it is seen that three of the anomalies falls over the gravity high areas.

As an example it can be shown how the oval shape of the anomaly 6 is also reflected by the bending trends of the gravity lows from the residual gravity map (**Fig 5**) (Singh et. al., 2005) over the area.

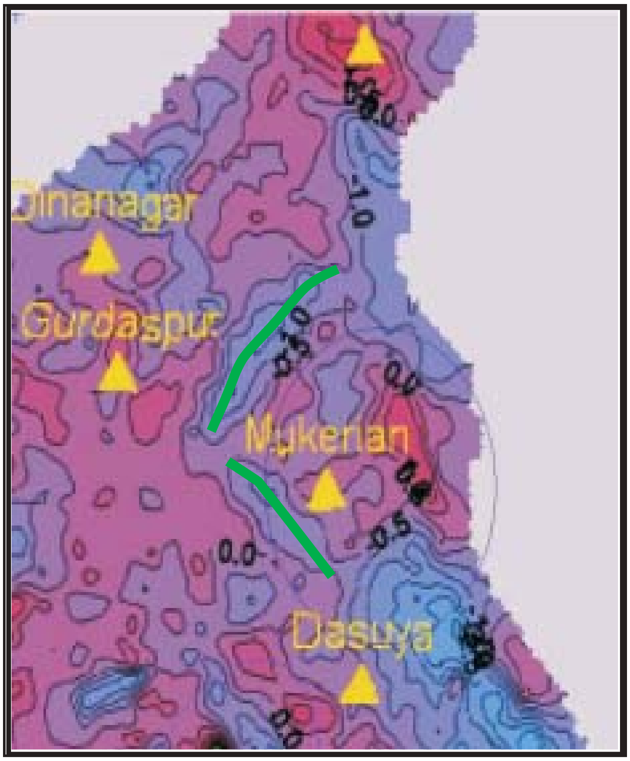

Fig. 5: Drainage anomaly 6 superimposed over residual Gravity (After Singh et. al, 2005)

Morpho-Tectonic Study of the most prominent Anomaly

The study was undertaken to see how the tectonic elements influences in the development of an anomaly and consequently in shaping the drainage network of the area. The most prominent of the anomaly –Anomaly 6 was considered for the study and a detail drainage study was done to deduce the influence of tectonic events on the drainage.

One of the interesting feature which is observed in this region near Gurdaspur area is that of a presence of an abandoned channel marked A in **Fig 6 a**. The geometry of the abandoned channel matches exactly with that of the present day channel, which indicates the extent of anomaly upto the abandoned channel. In the toposheets even, evidences of the abandoned channel can be found in the form of marshy land and swamp.

Towards the eastern bank of the channel a continuous band of vegetation (red tone of the image-**Fig 6a**) is also observed to follow the course of the abandoned channel marked as B in **Fig 6 a, b**. This portion is interpreted as the levee of the channel, which is again well illustrated by the elevated area in the shaded relief, generated from the SRTM data with 90° illumination angle. From the above two figures it may further be deduced that the abandoned channel was connected to the main channel at points C and D of the **Fig 6 a, b**.

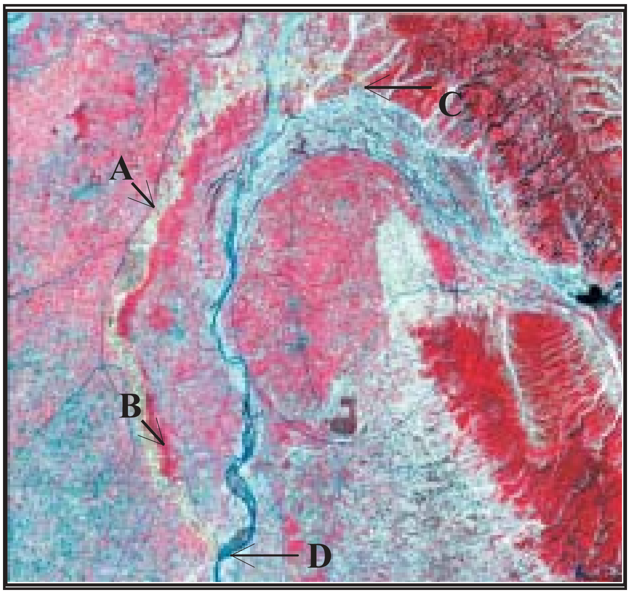

Fig. 6a: Image showing the abandoned channel (A), levee (B), (C) & (D) are the point's of connection.

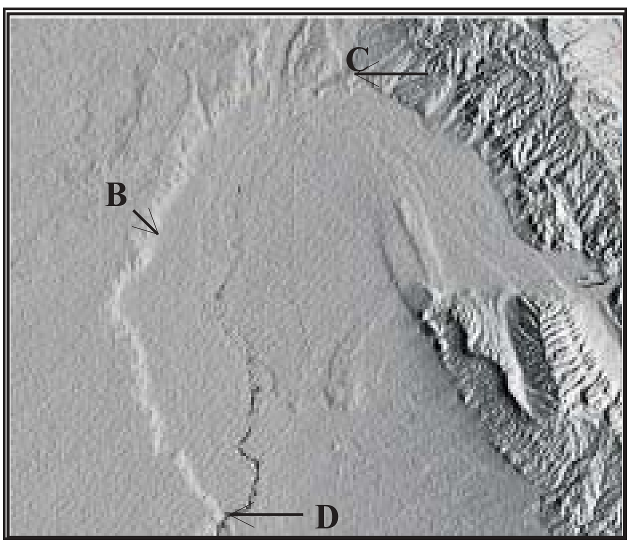

Fig. 6b: Shaded relief showing the levee (B), (C) & (D) are the point's of connection

As observed from the satellite image (**Fig 7a**) the rock unit A is abruptly truncated in the northern part indicating the probable presence of a fault along the line *X-X'*.

The bouger gravity map (Singh et. al, 2005) also corroborates this inference (**Fig 7b**). Since the area marked as B is totally covered by alluvium it is inferred that the continuation of the rock unit A is probably downthrown and the presence of this rock unit in the subsurface results in an anomalous region of B- Anomaly 6 of **Fig 2**.

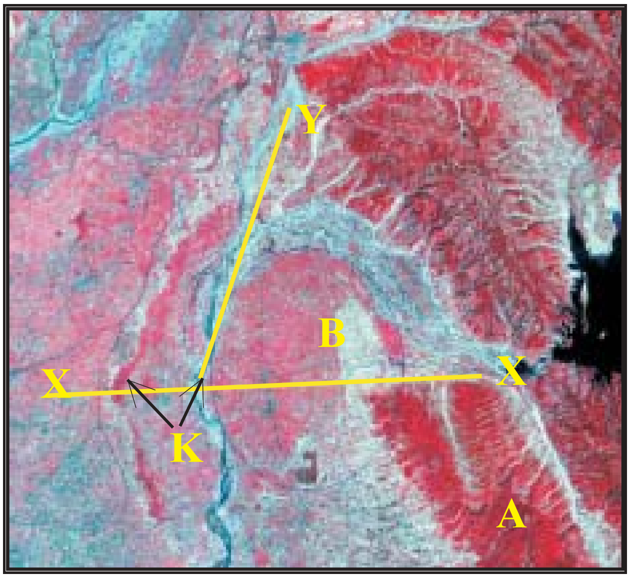

Fig. 7 a: The two faults interpreted from the imagery and at the kinks of the channel at K

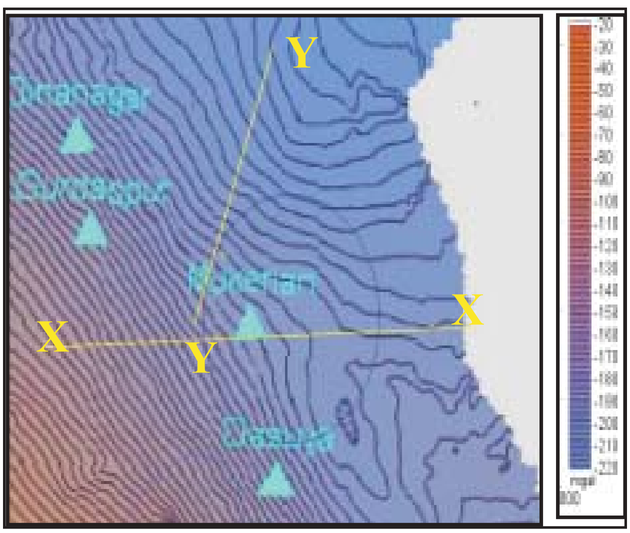

Fig. 7 b: Faults superimposed over the bouger gravity (After Singh et. al, 2005)

At a later stage, a fault *Y-Y'* gets initiated, which is deduced from the straight edges of the river which is again supported by the gravity map (**Fig 7b**). The trend of this fault matches with the dominant trend of NE-SW of the sector II (**Fig 1**).

At this instance the course of the river changes to follow the zone of weakness i.e along the fault trace *Y-Y'* and thus the abandoned channel of A in **Fig 6 a, b** develops.

Another noticeable thing is that of the occurrence of a kink in both the abandoned and the present channel at K of the **Fig 7a**. The possible reason for the kink in both the channels may be because of the reactivation of the series of faults along *X-X'*.

This study reveals that tectonic elements are very much prevalent in this less deformed and flat terrain area and they leave their signatures over the surface in the drainages which needs to be evaluated in detail to uncover the tectonic system of the area.

Conclusions

The study shows the utility of the remote sensing imagery to delineate the tectonic features of a less deformed region by identifying the lineaments and the probable subsurface structures, which have resulted in the formation of the anomalies.

Analyzing the drainage data in detail, in one of the most prominent anomalous area, has helped to illustrate how the NE-SW dominant trend played an important role in shaping the course of the river and the minor trend of E-W helps in the formation of the anomaly 6. Both of this structural trend corroborates well with the gravity data

Thus it can be concluded that for the study of tectonic elements of any region drainage analysis becomes an integral part of the study.

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