Volume 65, Issue 1, 2021
Journal of Scientific Research
Institute of Science,
Banaras Hindu University, Varanasi, India.

Study of Lineaments Control on Drainage Development in Between Chandigarh and Kashipur using Geospatial Techniques

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Abstract: **The Himalayas form the Northern frontiers of the Indian subcontinent. Many streams originate in these mountain ranges and descend to the adjoining plains known as the Indo-Gangetic plains. The Himalayas presently experience immense stresses as a result of which multiple faults and shear zones traverse it. The signature of these large-scale structural elements on the surface can be identified in the form of lineaments. The Himalayas can be longitudinally divided into the Siwaliks, Lesser Himalayas, Middle Himalayas, and the Higher Himalayas, with each of these units being separated by active fault systems. Four significant trends of lineaments are observed in the area viz. NW-SE, NNW-SSE, NE-SW, and E-W. These trends also resemble with the pre-existing subsurface deformational pattern of the study area.**

Index Terms: **Lineament, Himalayan tectonics, Chandigarh area, North India**

I. Introduction

The drainage pattern is the spatial arrangement of streams and is, in general, characteristic of the terrain. Different drainage networks possess geometric regularity of various types, which reveal the character of the geological terrain and help to understand the fluvial system. The drainages are controlled by the topography of the area, which is, in turn, affected by the lineaments, faults and other structural discontinuities present in the area. The study of linear deformational features or lineaments is useful in the investigation of natural resources like water and minerals, and also useful for hazard mapping of landslides and earthquakes (Gansser, 1964; Philip, 1996; Pati et al., 2006). The lineaments may stand for faults which exhibit the regional or subsurface tectonics. The regional lineaments are frequently construed as the surface appearance of weak geologic zones at tectonic boundaries as well as faults and rock fractures (Thakur et al., 2007; Malik et al., 2010; Prakash et al., 2017). A spatial relation between rivers and geologic structures is that rivers passively following structural faults, lows, or zones of weakness is common along Himalayan rivers (Sahoo et al., 2000).

The Himalayas are an active tectonic belt formed as a result of a collision between the Indian and Eurasian plates. The Himalayas being tectonically active terrain, experience considerable stress throughout its extent. Thus, they are traversed by many lineaments and faults formed as a result of these stresses. These lineaments are present throughout the Himalayas and are even extended to the Piedmont Zone and the Indo-Gangetic Plains. The lineaments act as a surface expression to the deep-running faults in the Himalayas. They exert significant control on the topography and drainage in the region. The presence of faults and other structural discontinuities plays a major role in controlling any drainage development. The drainage pattern thus has the potential to record evidence of the kinematics of folds and faults. (Malik and Mohanty, 2007; Prakash et al., 2011, 2012, 2013; Singh et al., 2019; Prakash et al., 2019). This study aims to understand the lineament's control over the drainage development between Chandigarh and Kashipur, which covers parts of the Himalayas and the Indo-Gangetic plains.

II. Study Area

The Himalayas, a product of continent-continent collision, represent an active tectonic unit where continuous northward drift and under thrusting of the Indian Plate beneath the Tibetan Plate have made the entire adjacent terrain geo-dynamically active (Molnar and Tapponnier, 1975; Kumar et al., 20007; Kohan, 2014; Prakash et al., 2017). The zone between the Main Boundary Thrust and the Himalayan Frontal thrust forms the Himalayan foothill known as Siwaliks. Beyond the Main Boundary Thrust lies the Lesser Himalayas. The study area covers a part of the North-Western Himalayan foothill region along with the Piedmont zone and the Indo-Gangetic plains. The

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study area (Fig.1) lies between latitudes 28°N to 31°N and longitude 76°E to 80°E covering a significant part of Uttarakhand and parts of Uttar Pradesh, Punjab and Haryana.

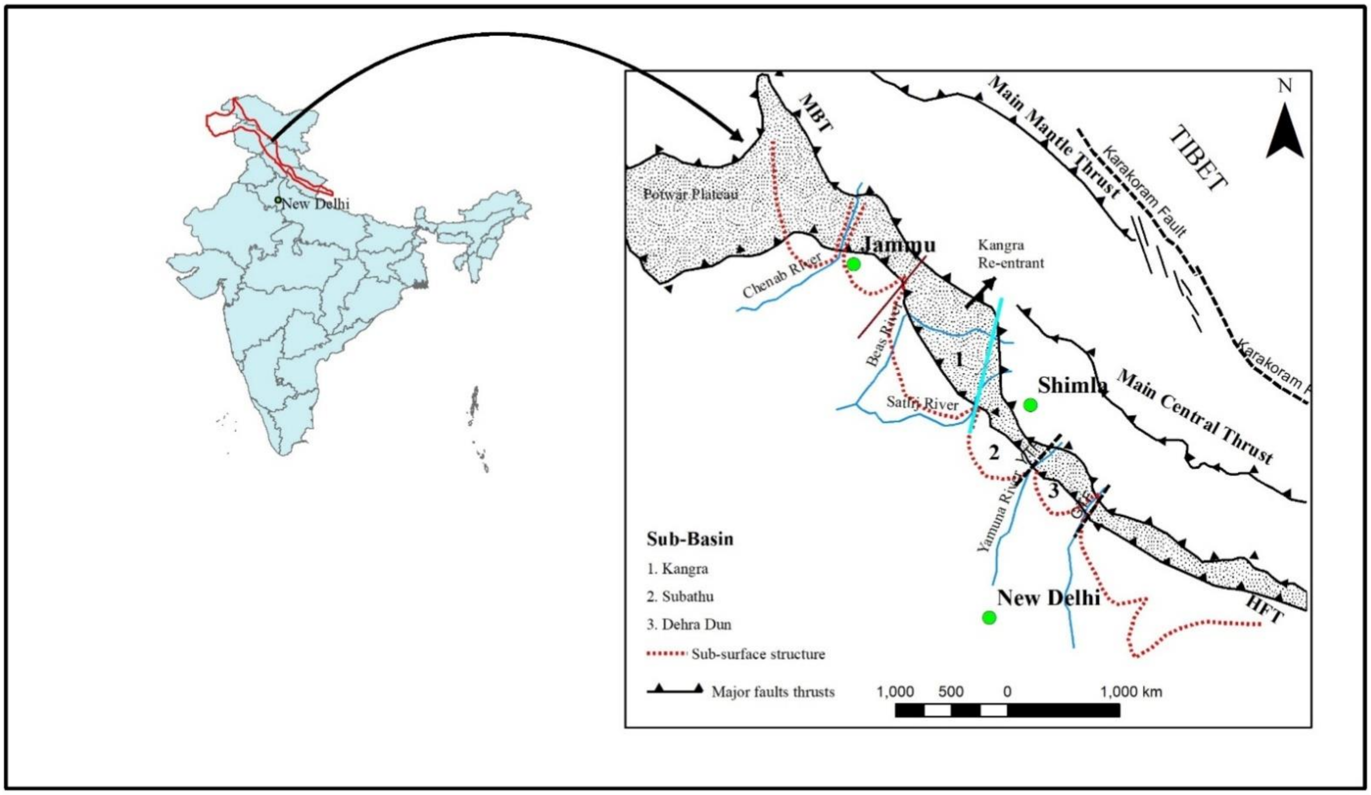

Fig.1. Location map of the study area (modified after Raiverman et al., 1983)

Himalayan Frontal Thrust (HFT) demarcates a tectonic and physiographic boundary between the Siwalik and the Indo-Gangetic plains (Jade et al., 2014). South of the HFT, the 10 to 25 km wide piedmont zone made by coalescing alluvial fans. The Piedmont zone is characterized by gentle undulating topography and 10–20 m incision by streams (Karunakaran& Rao 1979; Thakur, 2013).

The Siwalik sediments, which are part of the Himalayan foreland basin, were deposited in the foredeep created during the Himalayan orogeny. These Siwalik sediments are bounded by the Main Boundary Thrust in the north and the Himalayan Frontal Thrust in the south. The Siwalik basin is divided into several sub-basins separated by lineaments (Virdi 1979; Dubey 1997; Prakash et al., 2000). The study area also covers a part of Pinjor dun. The Pinjor Dun basin is mostly covered by the post-Siwalik Dun formation consisting of coalescing alluvial fans deposited by Southwest flowing streams (Rao, 1997; Thakur et al., 2009; De Sarkar et al., 2013). The study area also covers a part of the Lesser Himalayan sequence. The Lesser Himalaya sequence (LHS) in the Kumaun Himalaya is divided into the inner and outer Lesser Himalaya by North Almora thrust (NAT) (Valdiya, 1980; Pant et al., 2012; Srivastava and Mitra, 1994; Ahmad et al., 2000).

III. METHODOLOGY

The ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) G-DEM data and Landsat data for latitude 28°N to 31°N and longitude 76°E to 80°E are downloaded from USGS archive and used to carry out the present work. The missing data in ASTER-GDEM are filled by sink fill algorithm applied as pre-processing of DEM for minimizing errors. The ASTER-GDEM (with spatial resolution of 30 m) data is processed in Arc-GIS software. This DEM is utilized to compute the 3D surface visualization, generating contours, slope maps, and extracting drainage of the study area (Fig.2). The lineaments were identified from the drainage map and also verified from the Landsat data. The lineaments are recognized based on a sudden change in drainage course, straight channel, tonal contrast, trellis drainage pattern, etc. The rose diagram **(**Fig.3) of identified lineaments is plotted at 10° intervals in Geosoft software.

IV. RESULT AND DISCUSSION

A total of 503 lineaments were identified with the Landsat data and drainages present in the study area. Morphological analysis especially of topographical features and land surfaces has long been applied in the structure and tectonic studies (Hobbs 1912; Jordan et al. 2005). In accordance with Keller and Printers, 1996; and Singh and Srivastava 2011; the demonstration of the subsurface geology and structures is well documented in the landform features of a region. Drainage patterns are also affected by the sub surface structures and infiltration capacity which is directly related to the underlying lithology. Since the lineaments can act as a surface manifestation of faults and shear zones, the identified lineaments were compared with the major faults running in the study area. It is observed that a significant number of lineaments are found to concur with the pre-existing deformational trends of the area. The lineament map (Fig. 3) reveals that most lineaments are oriented in the NW-SE direction near the Chandigarh area. The mean resultant direction of the lineaments was found at 120°-300° from azimuth. The lineaments align with the Northwest-Southeast trend of the Himalayan Main Boundary Thrust (MBT). The majority of the faults in the North-Western Himalayas show a similar pattern. The N45°W-S45°E trending fault has been named as the Jainti Devi Fault (8). This fault orientation is nearly parallel to the trend exhibited by the MBT, Nalagarh Thrust, Nahan Thrust, and other regional tectonic elements in the region. Lineaments are trending parallel to the Trilokpur Fault, an NW-SE striking left-lateral strike-slip fault with significant oblique-slip (Chaudhri, 2012). The Himalayan Frontal Thrust (HFT) demarcates a tectonic and physiographic boundary between the Upper Siwalik sandstone and conglomerate of the Frontal Siwalik Range and the late Quaternary - Holocene fluvial sediments of the Ingo Gangetic Plains (4). The trace of the HFT resembles parallelism with NW-SE trending lineaments. It is also observed from the Rose Diagram (Fig. 3) that NNW-SSE is the next prominent lineament direction followed by NE-SW and E-W trend. The Yamuna Tear Fault (YTF), and the Ganga Tear Fault (GTF) are parallel to NNE-SSW lineaments. Sag ponds have been identified along the fault traces trending NW-SE as well as E-W. Stream offset has also been reported from the area along the fault trace. The Nahalgarh Thrust trends NNW-SSE (Singh et al., 2010) concurring with the second most lineament trend in the study area. In the northern part of the Doon valley, the older Doon gravel abates against the E-W-trending lineaments. These lineaments (faults) are parallel to the MBT (Joshi et al., 1997). The NE-SW trending lineaments are similar to the Delhi Haridwar Ridge, an important tectonic block between 28° and 30°N and 76°–79°E. The N-S oriented lineaments are a signature of faults that traverse the Himalayan Frontal Thrust. These lineaments were identified with the help of the streams located at the foothills of the Himalayas. The streams flowing along these faults traversing the Himalayas follow a relatively straight path. These transverse faults are responsible for the presence of significant N-S trend in the Rose diagram (Fig. 3). The majority of the lineaments concurred with the Himalaya's pre-existing faults, and the drainages also bear a resemblance to these pre-existing subsurface deformations in the study area.

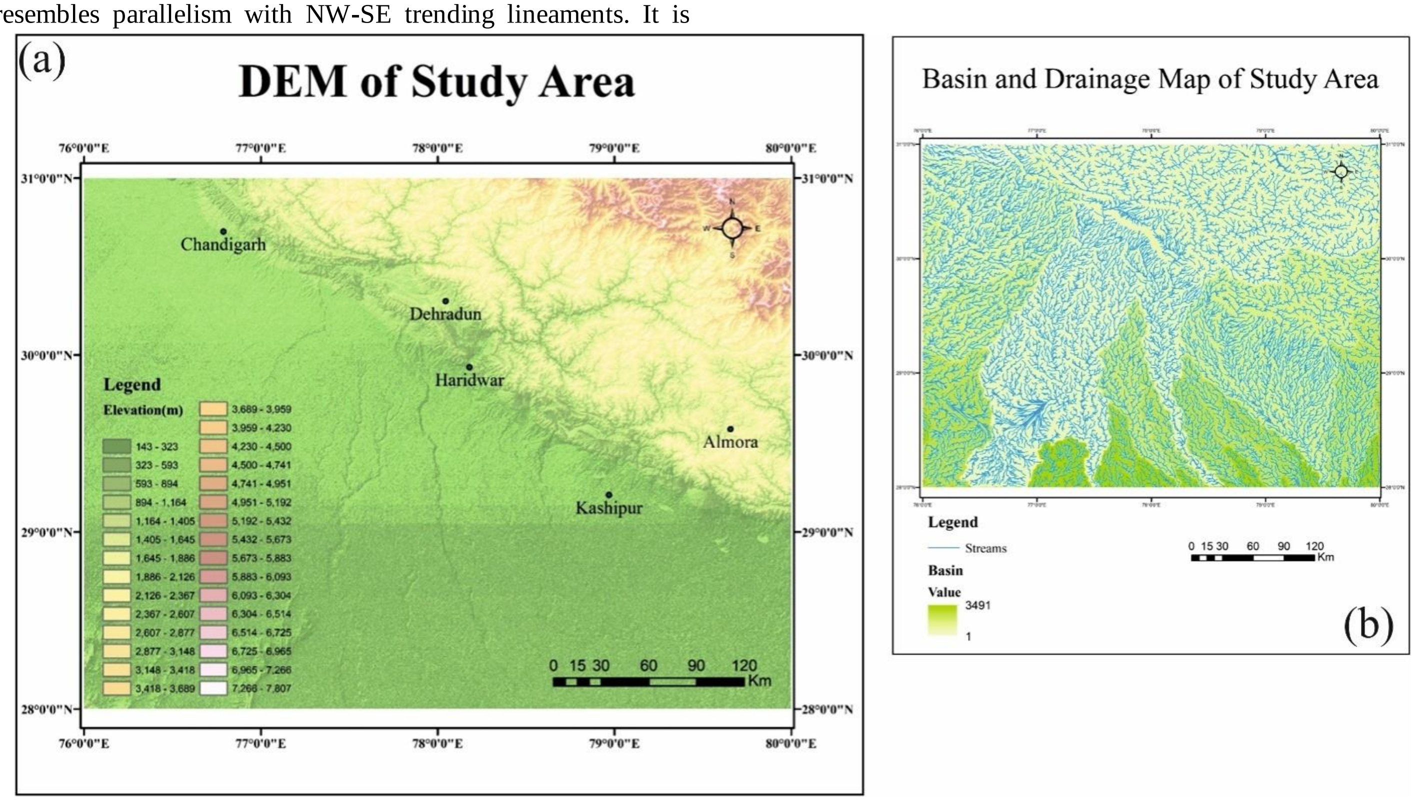

Fig.2. (a) DEM from ASTER data. (b) Drainage map extracted from G-DEM in Arc-GIS platform

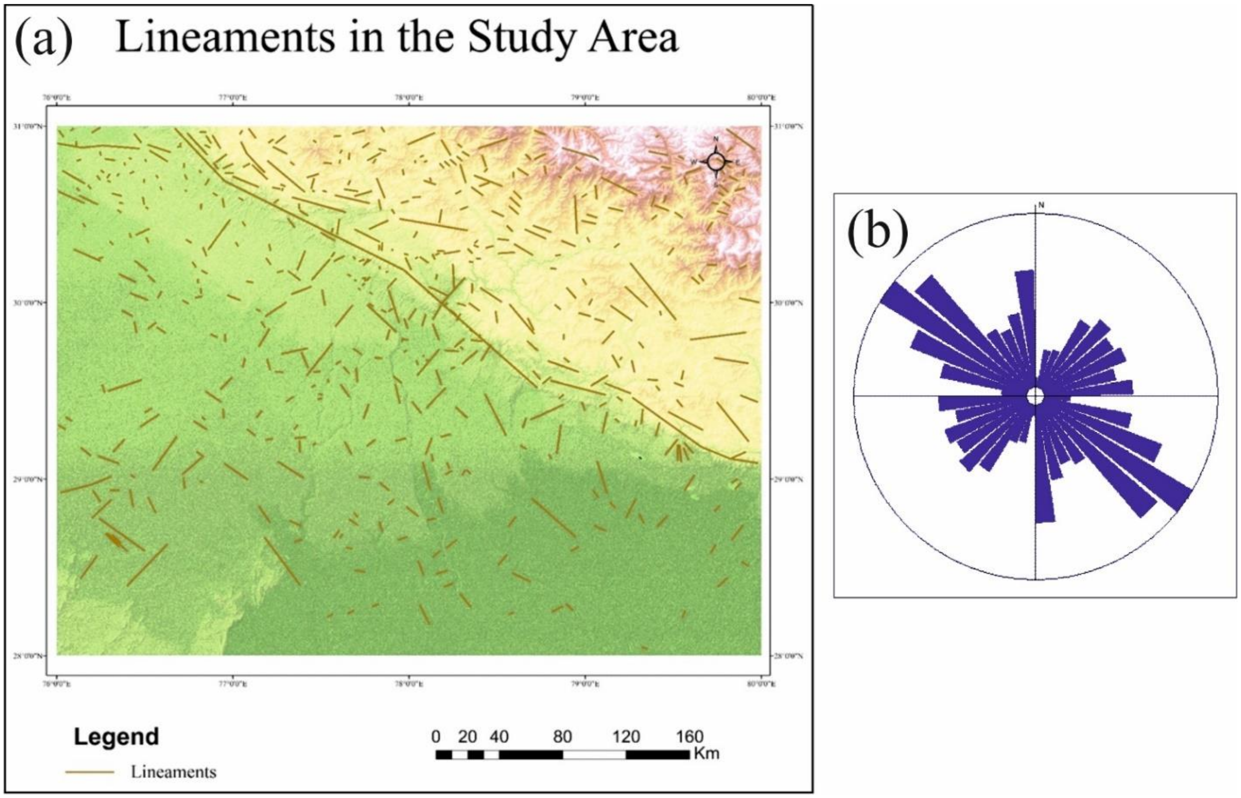

Fig. 3. (a) Lineament map traced out from drainage map and Landsat data. (b) Rose diagram of 503 lineaments at 10-degree interval

CONCLUSION

The geospatial techniques are useful tools for the extraction of subsurface deformation in terms of lineaments present in Himalaya's foothill. The lineaments are linear structural features and are considered as surface signatures of the faults present in the area. The Rose diagram was plotted using the lineament orientation data; shows three prominent directions viz. NW-SE, NNW-SSE, and E-W. The most significant numbers of lineaments orient towards NW-SE, which also corresponds to the Himalayas MBT trend. Comparing this with the existing data verified that these lineaments identified in the present work show parallelisms with the Himalayan tectonics. The lineaments were found to be parallel to the NW-SE trending faults in the Himalayas. The other prominent direction in which the lineaments are aligned is NNW-SSE. Most of these lineaments lie close to the Himalayan Frontal Thrust, further offset by several transverse faults. These transverse faults are present through the entire length of HFT. Even the lineaments in the map aligned with these faults. Some of the lineaments identified in the region aligned in the E-W direction. This orientation was found to concur with the orientations of the faults present in the Indo-Gangetic plains and some of the faults in the Himalayas. The drainage in an area is thus a manifestation of its geology, geomorphology, structural geology, and tectonics, with all the parameters described above playing a significant role in its development. The data extracted in the present work may be useful for the delineation of subsurface natural resources.

ACKNOWLEDGMENT

Authors are thankful to the Head of the CAS, Department of Geology, Banaras Hindu University, Varanasi, for making available the functioning conveniences. P. Singh is grateful to the CSIR-UGC, JRF fellowship. SS is thankful to the SERB (Project No. PDF/2018/004148), New Delhi, India, for financial support.

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