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Comparative Evaluation of Active Tectonics in the Piedmont Zone of Haryana, India: A Remote-Sensing and GPR based Approach

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Introduction:

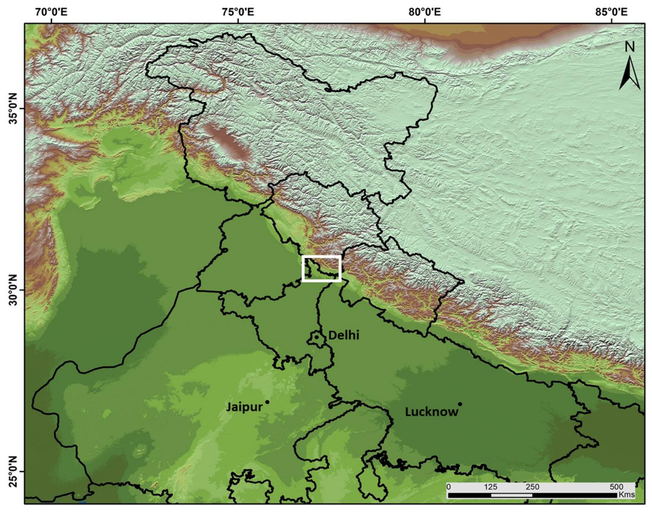
The India-Asia collision and continuing convergence of both continents is controlled by a strong northward drift of the Indian plate and by anti-clockwise rotation of India pinned in the western syntaxes. The constant continent – continent convergence between the Indian plate and Eurasian plate has resulted into the extensive shortening of lithosphere accompanied by southward movement of thrusts viz the Main Central Thrust (MCT), Main Boundary Thrust (MBT) and Himalayan Frontal Thrust (HFT) mainly.

The HFT marks the present day physiographic and tectonic boundary between the Himalayan mountain belt and the Indo-Gangetic plains, and is a plain of active tectonic displacement. Now, It is postulated that the active deformation is propagating further south of the Himalayan front to the Indo-Gangetic alluvial plains analogous to the formation of proto thrusts in the subduction zones. The Piedmont zone still needs to be studied in detail to understand the morphological evolution of the present day topographic and physiographic features of the area. In this study, a detailed morphometric analysis of drainage basins and topography by satellite images and transverse profiles (cross - section) generated from the Digital Elevation Models (DEM) are used to locate probable faults in the Himalayan Piedmont Zone. Further geophysical investigations by GPR at Sandhay and Sadaqpur villages confirm the presence of blind fault along with other fractures and wraps in the piedmont zone.

Objectives:

- Morphotectonic study for assessing tectonic activity in the region.
- Identification of blind fault by means of geophysical GPR surveys.

Study Area:

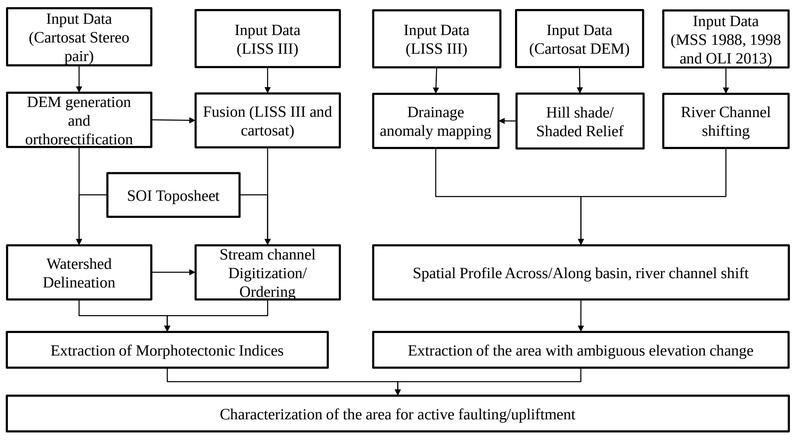


Study Area:- Geomorphology

- The study area is located in the Piedmont alluvial plains and covers parts of Panchkula, Ambala and Yamunanagar districts of Haryana and Mohali district of Punjab state.
- The study area is bounded by the Ghaggar river in the West and Yamuna river in the East.
- Geologically, the area is covered by recent Quaternary alluvial sediments brought down by the rivers. The alluvial deposits are composed of sand, silt and clay intermixed with calcareous concretions (kankar) and pebbles in varying proportions.
- Geomorphologically, the area comprises five major geomorphic units viz. hills, alluvial fans, alluvial plain, the flood plains and river terraces.

Methodology

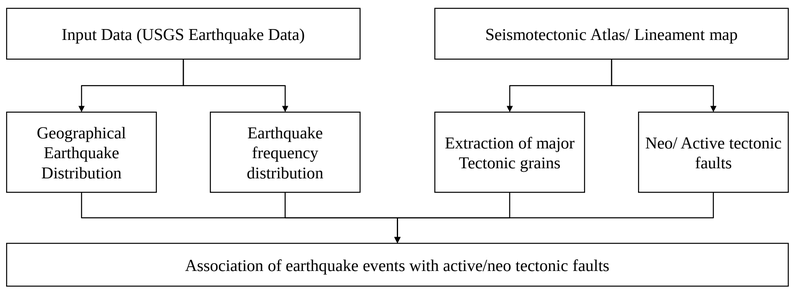
1. Morphotectonic, drainage anomaly and terrain study for evaluation of active tectonics



Ground Penetrating Radar (GPR) Analysis

- GPR surveys were done at Sandhay and Sadaqpur villages based upon spatial co-occurrence of geomorphic anomalies such as drainage anomalies and topographic breaks present in the region.
- Low pass space domain along with time domain filters were applied to the profiles in order to obtain the probable penetration depth and orientation of the probable fault in the area.

Historical Earthquake Analysis



Results:-

Basin at different locations

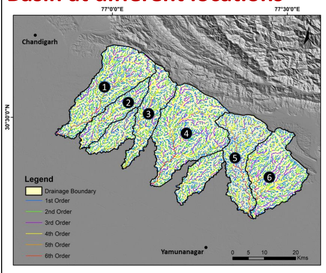


Fig. Hill shade image depicting the study area in the Piedmont zone basins starting from the left (1) Tangri, (2) Balaiali, (3) Begna, (4) Markanda, (5) Somb, and (6) Pathrala.

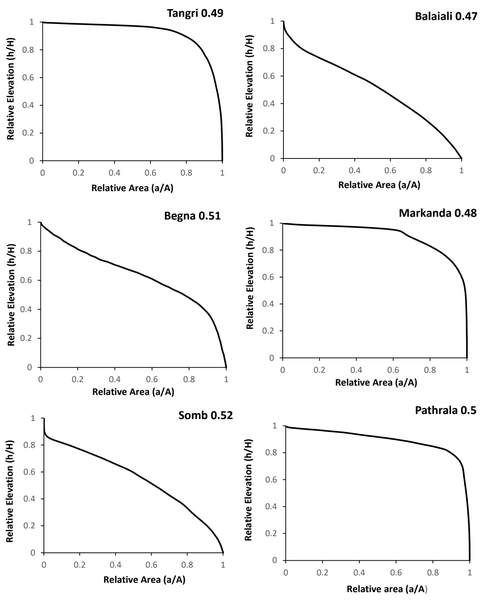
Drainage Basin Asymmetry

Basin	Basin Total Area (sq. km)	Right side basin area (Sq Km)	AF	Inferences
Tangri	309.13	183.22	59.26	Tilted Eastwards
Balaiali	128.41	73.57	57.29	Tilted Eastwards
Begna	169.55	55.40	32.67	Tilted Westwards
Markanda	415.85	192.41	46.27	Tilted Westwards
Somb	237.02	98.83	41.71	Tilted Westwards
Pathrala	287.32	131.05	45.61	Tilted Westwards

Mountain Front Sinuosity

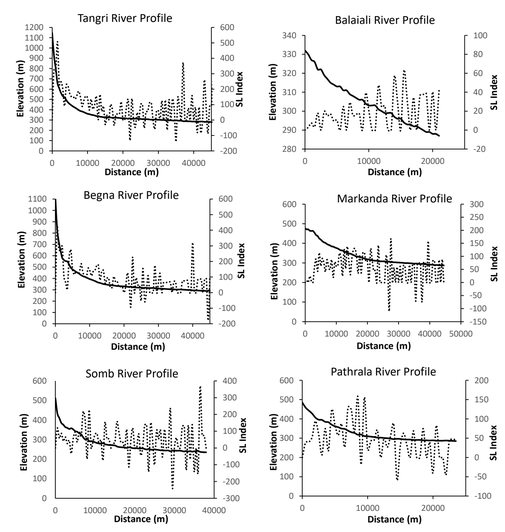
Segments	L_{mf} (in km)	L_s (in km)	S_{mf}
S1	10.57	6.39	1.67
S2	3.95	2.54	1.55
S3	6.21	4.19	1.48
S4	5.79	3.98	1.44
S5	4.47	3.54	1.26
S6	4.10	3.41	1.20
S7	14.32	12.35	1.15
S8	6.72	4.83	1.38
S9	3.65	2.47	1.47
S10	5.22	4.19	1.25

Hypsometric Curve



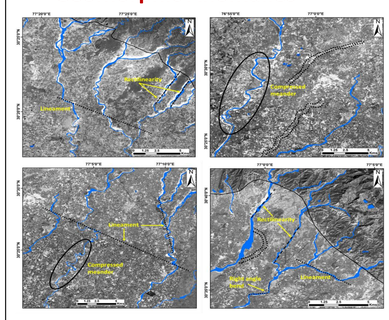
In the present study, H.I. varies from 0.47 to 0.52 and the hypsometric curves show a sigmoidal shape, which infers, all basins are in their mature or early mature stage.

Longitudinal river profile and Stream Length Gradient Index



- Somb basin shows the highest value of SL and thus suggests a highly active basin. Around five high SL index peaks are identified on the longitudinal profile of the Somb river.
- Tangri and Begna drainages also show a similar pattern in the SL index, where the SL value reaches more than 200, first in the HFT region and then again in the lower reaches in the piedmont zone.
- Balaiali, Markanda, and Pathrala show moderate SL index values (100 - 150) and represent moderately active basins in terms of tectonic activity.

Geomorphic Anomalies



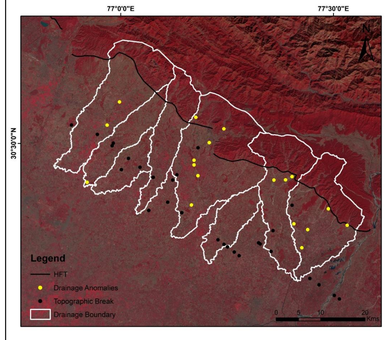
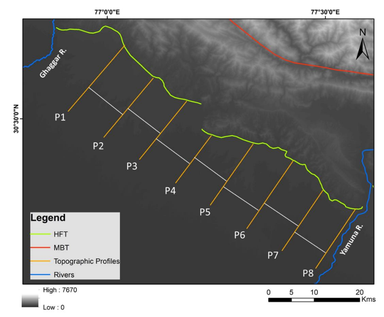


Fig. Anomaly map showing locations of drainage anomalies and topographic breaks in the study area. Drainage anomalies viz. rectilinearity, straight channel segment, compressed meanders, river offsets bends, and Paleo/abandoned channels are observed in the area.

Topographic profile anomaly



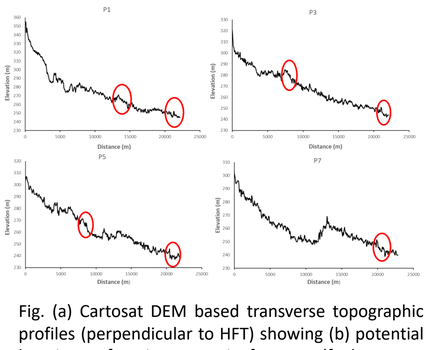


Fig. (a) Cartosat DEM based transverse topographic profiles (perpendicular to HFT) showing (b) potential locations of active tectonic features (fault scarps, lineaments) based on subtle topographic breaks unrelated to Piedmont slope.

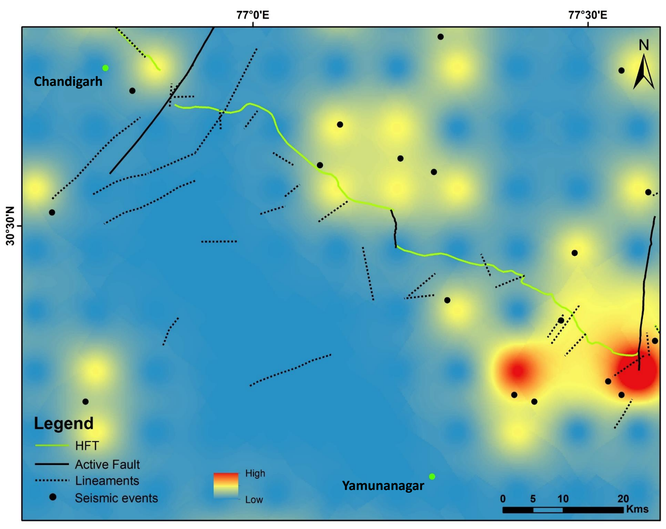


Fig. Spatial frequency distribution of historical seismicity and abundance of active tectonic features in Himalayan foothills and piedmont region in and around HFT.

Upliftment in the Piedmont Zone

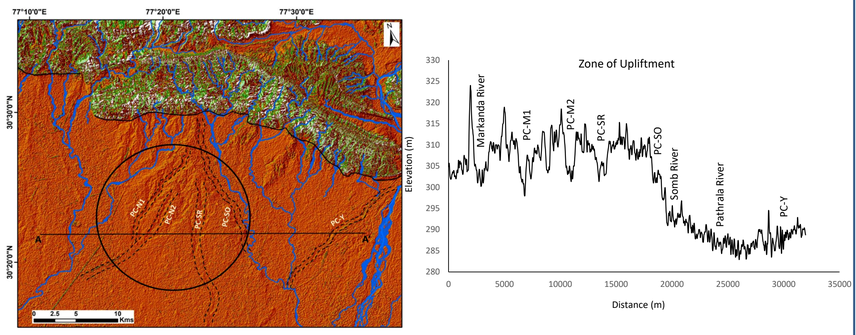
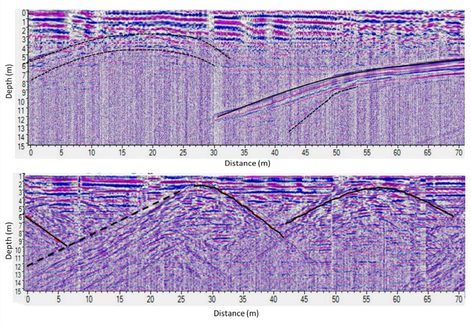


Fig. Shaded relief map of the uplifted zone of study area, PC-N1, and PC-N2: Nakti river paleochannels, PC-SR: Saraswati river paleochannel, PC-Y: Yamuna river paleochannel. The Nakti river has migrated towards the West, the Somb and Yamuna rivers have migrated towards the east with the uplifted zone (marked in solid black circle) as the central axis. The rivers have shifted their courses in response to the upliftment in the piedmont zone and have been exhibiting a migration pattern.



The presence of north dipping layers is revealed by GPR measurements obtained near the drainage anomalies and topographic breaks at Sadaqpur and Sandhay villages.

Conclusion:-

- Morphology of the Piedmont region, has been significantly altered by tectonic processes and Morphotectonic indices analysed, confirm the tectonic activity within the region.
- Drainage anomaly study, especially the changes or development in stream channel through satellite images of different dates provides significant information on tectonic activity.
- Combined study of Morphotectonic indices, terrain analysis and drainage anomaly provide a robust way to identify the neotectonic or active tectonic faults.
- Earthquake distribution shows a very few events along HFT and surrounding plains in the area.
- A prominent bluff of 5 to 7 m separates the Piedmont alluvial zone from the central alluvial plains. The bluff could be the remnant of a blind fault in the sub-surface south of the HFT. This could evolve into a new frontal thrust in the future.
- GPR investigations can provide information for detailed study of subsurface structures by trench and palaeoseismic survey.

References:-

Yeats, R.S. and Thakur, V.C. (2008) 'Active faulting south of the Himalayan Front: establishing a new plate boundary', Tectonophysics, 453(1–4), pp. 63–73.