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Research Article

Identification of Neotectonics using DEM-based Local Base-level Approach in Pothowar Plateau

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Abstract: The isobase map (local base-level map) represents the erosional stages and it gives a strong relationship between different Strahler order streams and the local erosion al conditions in a changingtopography. This approach is quick, efficient and reliable to delineate neotectonic influence within the same rock types. In this research, we evaluate the geomorphic landforms of Pothowar Plateau and Kalabagh fault zone using local base level approach. The purpose is to demarcate boundaries and to see whether they are influenced by the active tectonics or lithologic difference. For this purpose, we extracted the drainage network in the form of second and third order Srahler streams and automatic lineaments (by Houghman transformation)from SRTM 90m DEM. The isobase map was constructed based on the points of intersection of automated contours from the DEM and with the selected stream orders. We observed different base-level anomalies that relate to the prominent neotectonic features and lithological boundaries as presented in the published geological maps. The orientation, deflection and disconnection of the isobase lines correspond well with the local structures in the study area.

Keywords: SRTM DEM, Strahler orders, isobase, neotectonics, Potowar Plateau, Kalabagh fault zone, Uyt

1. INTRODUCTION

The dynamics of stream Strahler orders and topographic variations can be investigated by using an isobase map [1–3]. The isobase is a term which is used for a line that demarcates an erosional surface or a line of equal uplift (e.g., just in case of isobars and isotherms). The isobase surface is a hypothetical plane formed by connecting stream profiles of a similar stream order [4]. Therefore, this parameter is a handy tool to decode neotectonic signals preserved in the concerned landscape. The isobase level map is taken as a vital tool to identify neotectonic processes. The isobase lines show possible and different erosional/tectonic stages within a given study area. These erosional stages maybe related to erosional cycles as suggested by Davisian scheme. These erosional cycles can be attributed to the most current ones and maybe due to the lithologic contrast/tectonics scarps.

According to Golts and Rosenthal [1] the isobase map of the Arava (segment of the Jordon Dead Sea Rift Valley) revealed that a young sedimentary basin is explained by a plain and weak incised relief, and is valuable for the seismic studies. Zuchiewicz, and Oaks [5] used a topographic sheet at a scale of 1:100,000 scale and prepared isobase maps by using first, second and third stream Strahler order. He observed actual landscape whereas the third order isobase map was quite capable to show pronounced lineaments/faults/folds. According to Sant'Anna et al [6] the morphotectonic map of Fonseca Basin in SE-Brazil endorsed the presence of main structural breaks with north-south and less frequent towards east-west, north-east and north-west orientations.

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Grohmann et al [7] prepared an isobase level map using second and third order streams. This map generated the best possible results and its interpretation was found good and consistent with the elucidation of regional scale morphotectonics of Parnaiba Sedimentary province in north eastern Brazil. According to Mahmood et al [8] the isobase map of Hindukush, constructed from second and third order streams, was also consistent with the regional scale morphotectonics in Hindukush and surrounding regions.

The aim of this research was to generate an isobase map for the Pothowar plateau in order to constrain neotectonics; related surface deformation, erosional scarps and their relationship with the local faults/lineaments or lithologic variations.

2. TECTONIC SETTING OF THE STUDY AREA

The Indo-Pakistan Plate belongs to the east Gondwanaland [9]. The Gondwana's name was kept after the name of a district in India where the fossil plant named Glossopteris was found [10, 11]. The Pothowar plateau emerged as a result of collision between Indian and Eurasian plates that created large scale regional structures (Fig.1). This plateau is roughly defined by the rivers Indus and Jhelum to the west and east, respectively, the Kalachitta-Margalla Hill Ranges to the north, and the Salt Range to the south (Fig.2). It is mostly covered by the Siwalik sequence. Although at places upper Eocene shales and limestones crop out locally in folded inliers. Its northern region, termed as the North Pothowar Deformed Zone (NPDZ) is more deeply deformed. Is it characterized by east-west, tight and complex folds, reversed to the south and clipped by steep-angle faults.

The NPDZ is followed to the south by asymmetrical, wide and broad Soan syncline, with a gently northward dipping southern flank along the Salt Range and a steeply dipping northern limb along NPDZ (Fig.2). In the western part this basin consists of many east-west, broad and gentle folds (wavelength 26-40 km). In its eastern part the strike sharply changes to the northeast and the structures comprise tightly folded anticlines and broad synclines (fold wavelength 10-12 km). Axial zones of most anticlines dip steeply or are overturned. Faulting of the anticlines is rare [12]. This east to west difference in the structural style has been attributed to the reduced thickness of evaporates and lesser basement slope in the eastern part of the Pothowar and Salt Range. Increased drag at the base of the section has formed relatively complicated structures due to greater internal deformation [13].

In the Fig. 1, the GPS velocity vectors (Red) with respect to Eurasia fixed reference frame from the purple vector is transformed from velocities with respect to India fixed. Note the direction and decreasing GPS velocities towards north showing convergence and anticlockwise rotation of India. Abbreviations of fault names: AM, Alburz Marmul, CbF, Central Badakhshan Fault, HF, Herat Fault, CF, Chaman Fault; MoF, Mokar fault, GzF, Gardez Fault, KoF, Konar Fault, MBT, Main Boundary Thrust; MFT, Main frontal thrust, MMT, Main Mantle Thrust, and MKT, Main Karakoram Thrust, Reshun Fault, SF, Sarobi Fault, ST, Spinghar Thrust [14].

3. MATERIALS AND METHODS

We used Shuttle Radar Topographic Mission SRTM DEM (http://srtm.csi.cgiar.org) [15] with spatial resolution of 90 m to extract drainage network of different Strahler orders [16] automatically, e.g., 1, 2, 3 and so on. The local base level map is prepared on the basis of intersection of different stream Strahler orders, for example a third order tributary is s fragment along the downstream, the meeting of any two second order tributary and a third order segment is formed by the confluence of any two third order tributaries and so on as shown in the (Fig. 3). To generate a second order isobase level map, we use all Strahler order tributaries instead those of first order tributaries. Isobase map represents a simplified shape of actual 3D Landscape, where we actually neglect the relief above the isobase surface. Previously, physical generation of isobase maps werea time taking procedure.

Drainage network classification based on different Strahler orders and the explanation of isobase lines needs highly qualitative topo-sheets at appropriate scale. For the DEM based automatic extraction and classification of drainage network permits the required data for a larger area in a quick

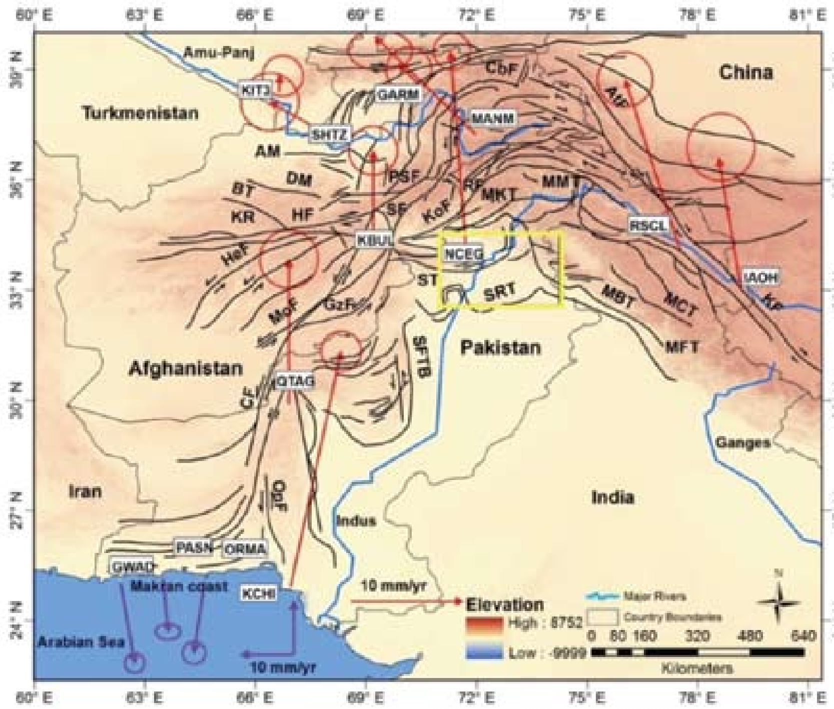

Fig. 1. Tectonic map of the Hindu Kush-Himalaya-Pamirs-Karakoram showing reported and newly confirmed faults with inset showing the study area [11].

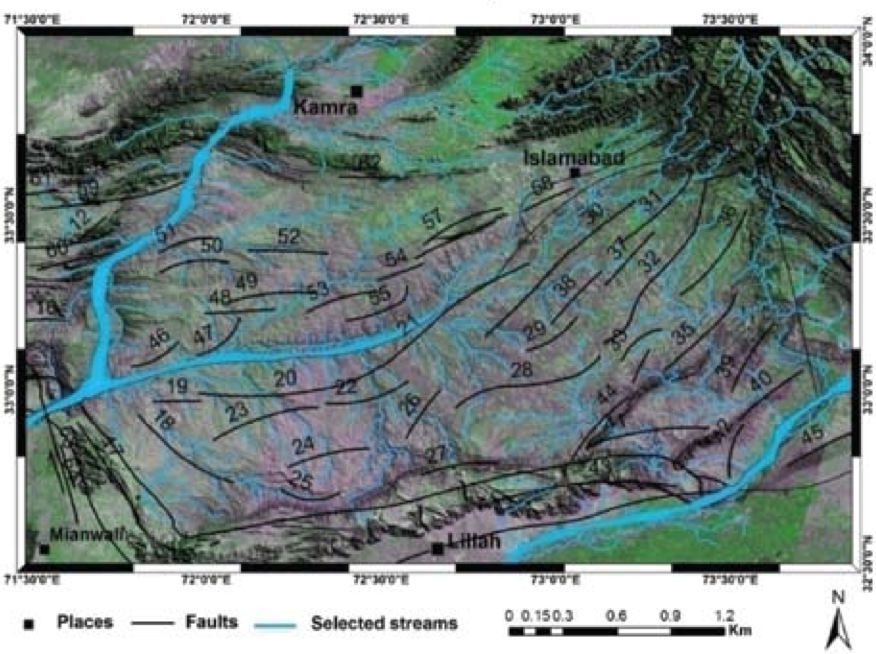

Fig. 2. Location of study area of Pothowar Plateau and Kalabagh fault zone (northern Pakistan) with Landsat bands 742-RGB combination drapped over shaded relief map along with major rivers (Indus, Soan and Jhelum) and drainage network.

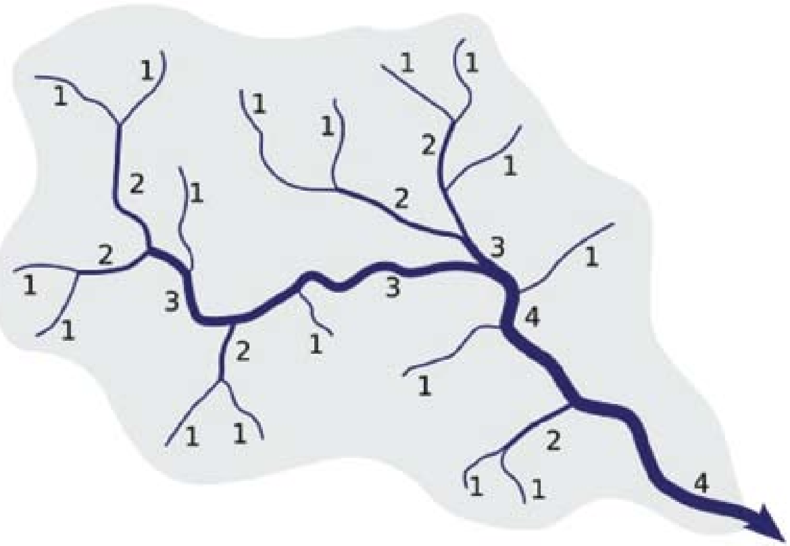

Fig. 3. Illustration showing Stream Strahler ordering.

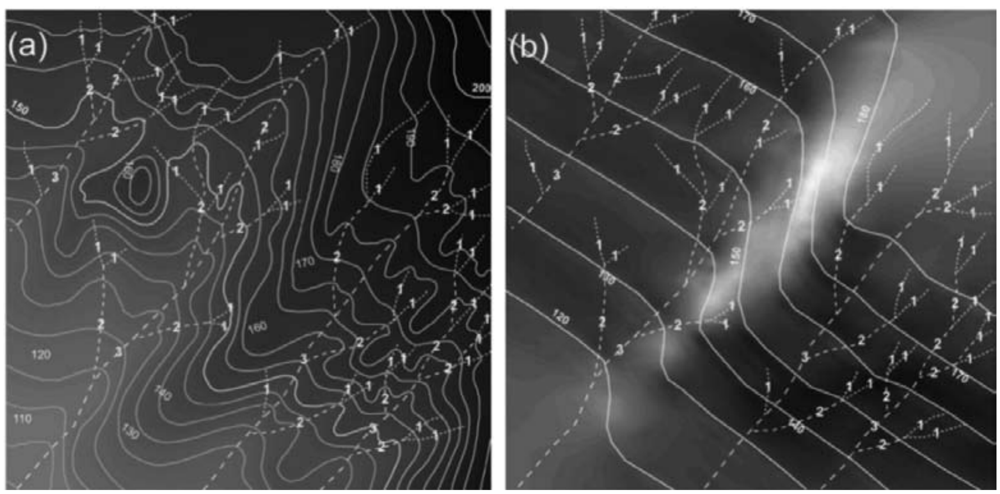

Fig. 4(a,b). Illustration showing mechanism of isobase map construction [1].

and efficientmanner with no cost [7]. It is observed that the stream Strahler ordering highly rely on spatial resolution of the DEM, which means that high resolution DEM will generate denser stream network and vice versa. It simply means that the main rivers will be representing a higher Strahler order. The DEM based stream network classification along with the elevation points used to interpolate the isobase surfaces can be derived by draping the required stream Strahler orders with the DEM based contours [17] (Fig. 4 a, b).

The exclusion of first order Strahler streams decreases the noise in the digital elevation model that can help improve the detectionof a fault scarp/ erosional scarp or any other morphotectonic feature that could be significant in the contest of topographic development. For instance, the geomorphic development of a thrust fault scarp, the preliminary boundary condition is perturbed by the thrust fault and the knick zones along the river longitudinal profile explain the convex up/ concave down profiles, because of the thrust evolution different boundaries of erosional surface and accordingly the profile geometry development, such that the erosional processes start appearing significant in different stages. According to Zuchiewicz and Oaks [5], 10^5-10^6 years are adequate to fade out a recently developed tectonic scarp to a stage some where, all the off cuts have been removed.

For the automatic extraction of lineaments/ faults we used Houghman transformation (an alogorithm in the Geomatica software v.9.1) which is quite capable of isolating features of a particular shape (e.g., lineaments, ridges and sharp edges, etc.) within an image (e.g., Digital Elevation Model).

The Hough transform can be used to identify the parameter(s) of a curve which best fits a set of given edge points. This edge description is commonly obtained from a feature detecting operator such as the Sobel or Canny edge detector and may be noisy, i.e. it may contain multiple edge fragments corresponding to a single whole feature. In addition, as the output of an edge detector defines only where features are in an image, the work of the Hough transform is to determine both what the features are (i.e. to detect the feature(s) for which it has a parametric (or other) description) and how many of them exist in the image. The lineaments obtained using above mentioned method have been analyzed in the context of anomalies found in drainage network analysis.

4. RESULTS AND DISCUSSION

Keeping in view the past studies regarding the understanding of regional scale morphotectonics, the isobase map for the Pothowar Plateau and Kalabagh fault zone was prepared using second and third stream Strahler orders (Fig. 4). This map found good to reveal the excellent results. We generated isobase contours with different spatial intervals (50 m, 100 m, 200 m, 300 m, 400 m, 500 m) using ArcGIS 10 and prepared isobase maps as shown in (Fig.5–9). Both small and large structures can be identified from the generated isobase maps in the visual context. Some of these structures are associated with neotectonic activity.

The ellipse # 1 (Fig. 5) shows the Attock-Cherat-Range (ACR). We can clearly observe

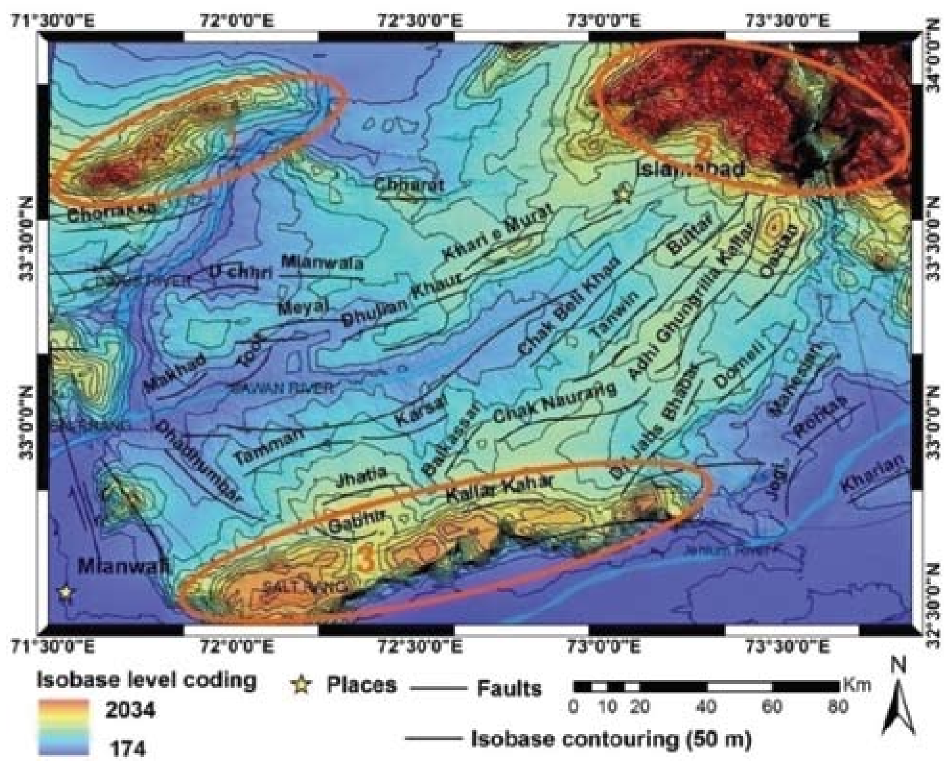

Fig. 5. Isobase map with isobase contour lines with spatial interval of 50 m, orange circles, 1,2 and 3 showsAttock-CheratRange,MBT and Jhelum faults and Salt Range Thrust (SRT).

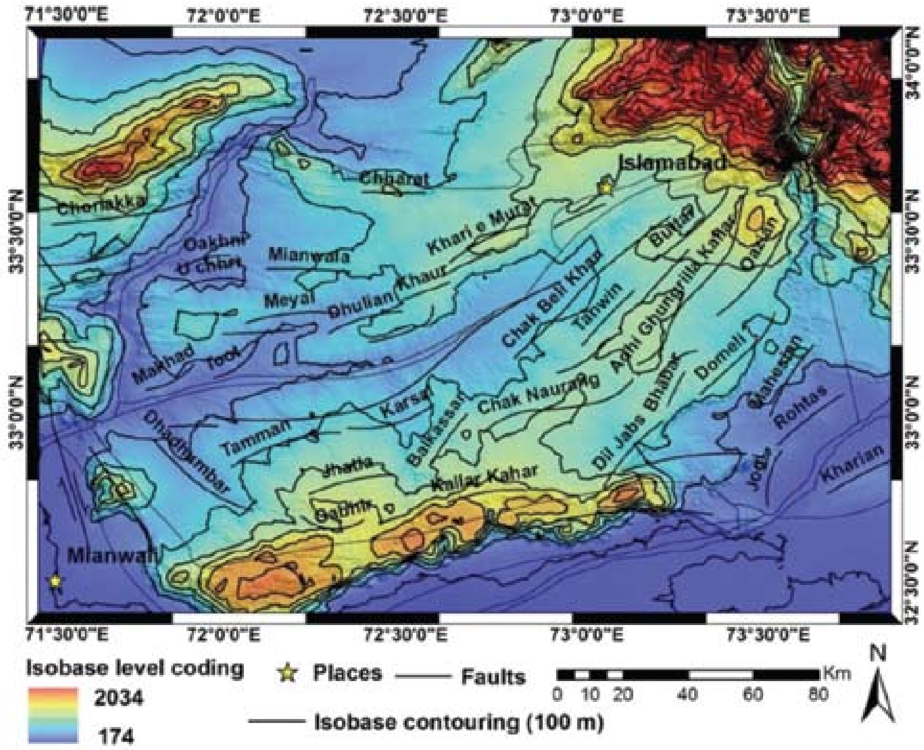

Fig. 6. Isobase map with 100 m interval isobase contour lines.

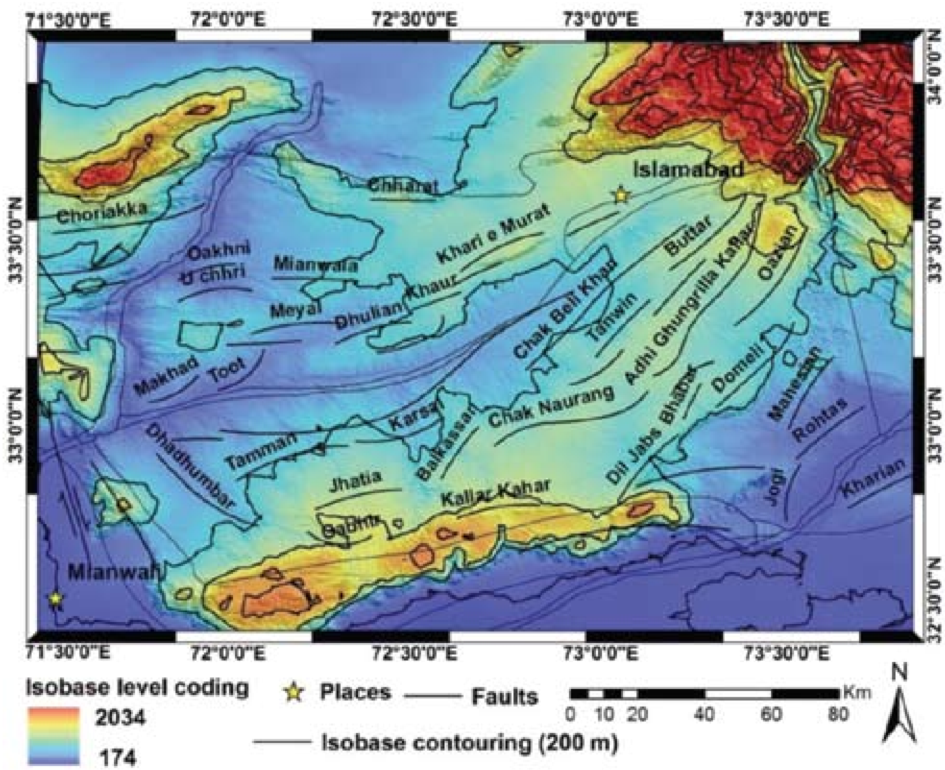

Fig. 7. Isobase map with 200 m interval isobase contour lines.

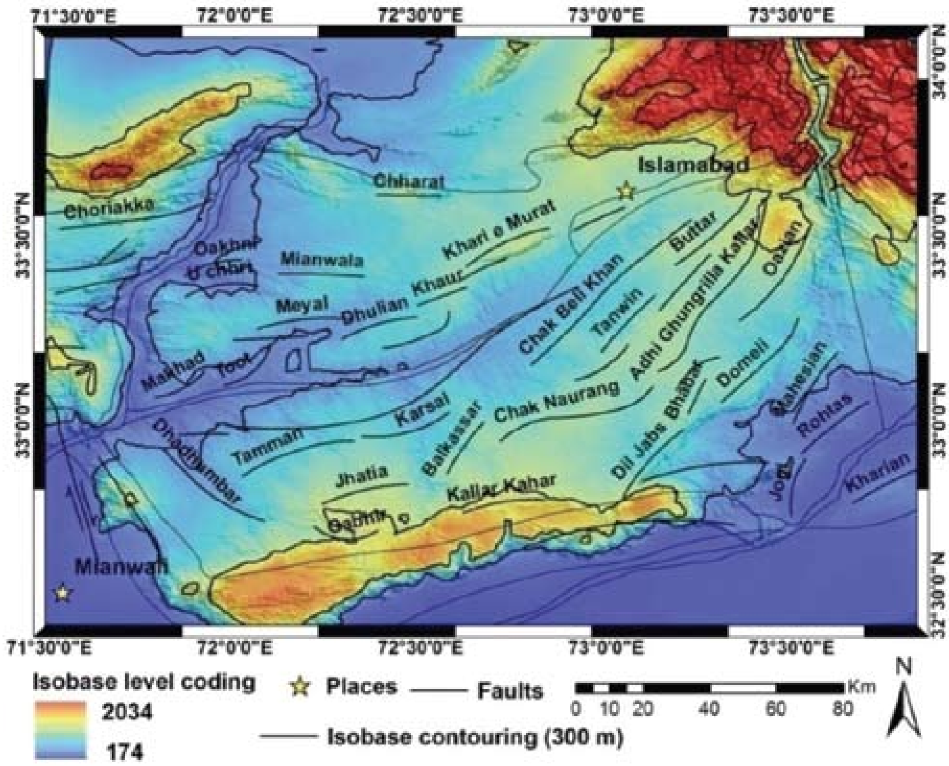

Fig. 8. Isobase map with 300 m interval isobase contour lines.

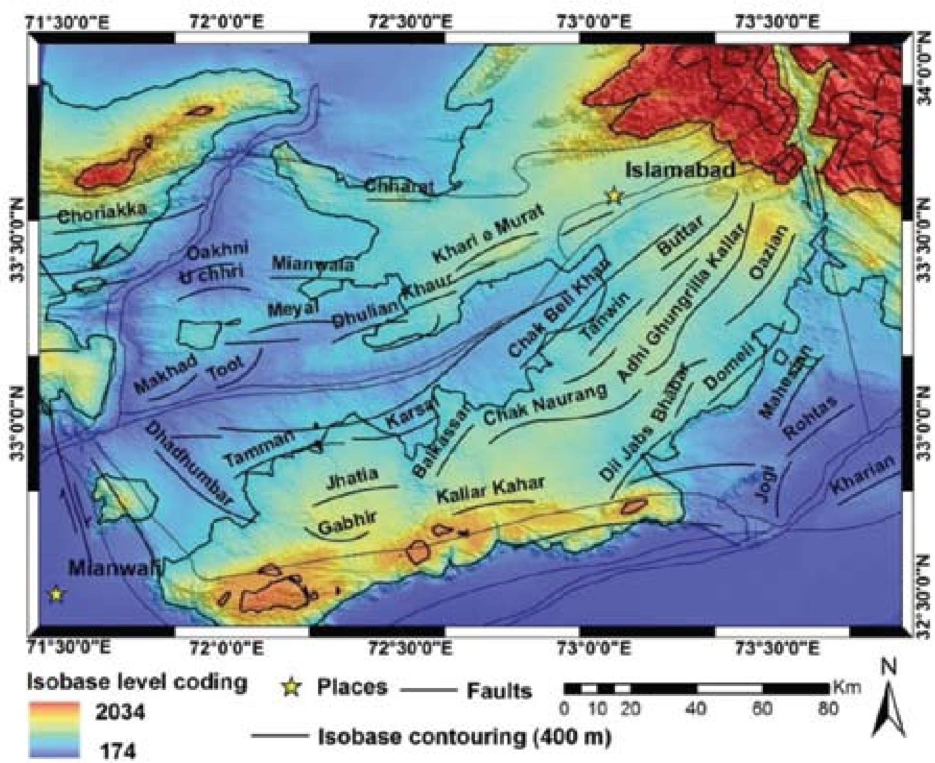

Fig. 9. Isobase map with 400 m interval isobase contour lines.

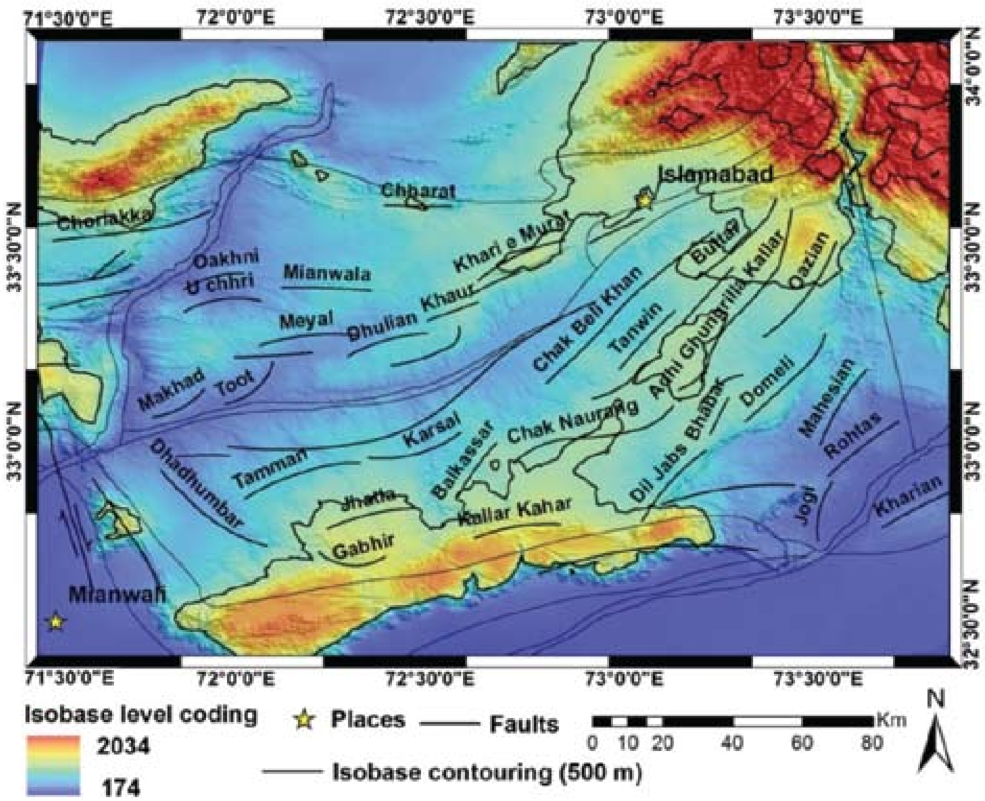

Fig. 10. Isobase map with 500 m interval isobase contour lines.

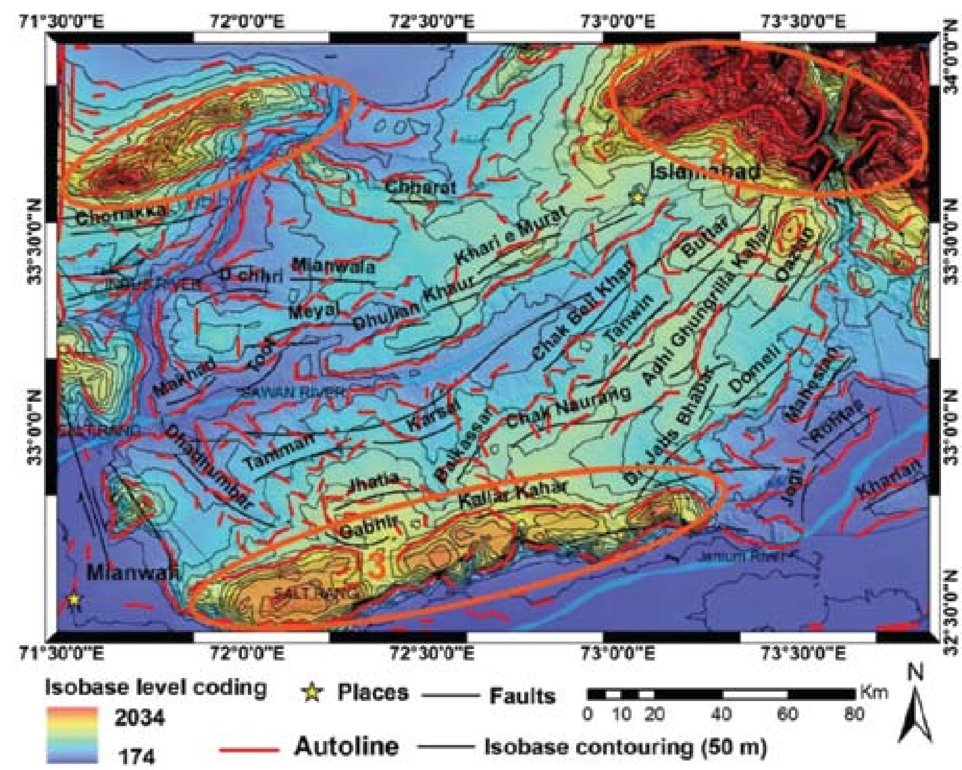

Fig. 11. Isobase map with isobase contour lines automatically extracted red lineaments from SRTM DEM (using Houghman transformations) with spatial interval of 50 m.

the deflection of isobase contour lines which are NE-SW oriented along the NE-SW propagation of the ACR indicating various differential stages of erosion. This deflection indicates that ACR is tectonically active range, and isobase maps reveal a possible of five to sixepisodes of quick relative neotectonic/erosional /uplift stages. The existing deep narrow canyons/gorges and valleys in ACR could have been developed due to the episodic neotectonic uplift resulting from the subsequent erosion and shaping. The eroded sediments weredumped in the foothills of the ACR as alluvial fans at the piedmont-mountain junction and plains in the southern Peshawar basin. The isobase maps prepared at isobase contour intervals are shown in the (Fig. 6–9).

The neotectonic activity along ACR is evidenced by the capture of Indus River in a NE-SW direction as initially it was flowing in N-S direction just after the confluence of Kabul and Indus rivers. The river capture is under the neotectonic influence of ACR rather than lithologic one. The ellipse#2 illustrates the region of Main boundary thrust (MBT) and the closely packed isobase lines in this region again reflect the severe nature of E-W oriented thrust faulting. A strong E-W orientation of the isobase lines evidences the orientation of the MBT. This zonetips-off a major drainage capture as the Jhelum River flows in a SSE, SSW and then SSE direction again while making sudden inflexions in a very short span of distance. The quick inflexion of the rivers dictates the strong neotectonic influence over the Jhelum River.

The ellipse #3 in the isobase map represents the region of Salt Range in Potowar Plateau, which shows relatively more erosion as compared to MBT and ACR. It means that the Salt range is may be less active seismically in comparison to MBT and ACR which are more active tectonically as they show higher local bas level values. Higher isobase values are indicators of more uplifted conditions/ less eroded areas. Some 60 km north of Mianwali, at Kalabagh site, the Indus River is captured by the dextral Kalabagh fault. A prominent NE-SW inflextion of the river can be observed clearly while Indus River makes an exit from Potowar Plateau. The higher isobase values in the north-eastern section of the Salt Range Thrust (SRT) are higher as compared to the south-western and central parts of the SRT, Which means that all these three different parts of the SRT shows differential erosion rates which is another indication of the non-steady state environment or zones of differential relative uplift rates. In (Fig. 10),the alignment of automated lineaments reveal that they are very much in accordance with the already published local and regional structures (e.g., in MBT in the NE, ACR in the NW and in entire salt range in southern Pothowar Plateau.

5. CONCLUSIONS

SRTM DEM-based isobase technique has been quite useful, quick and efficient technique for the morphotectonic investigation. In this research, an example from the Pothowar Plateau and its outskirtshas has been examined for the differential erosional/neotectonic events. The isobase map prepared from the automated DEM based drainage networkusingsecond and third stream Strahler orders has generated excellent results which are consistent with the neotectonics of the Pothowar Plateau. The east-west orientation of the MBT, NE-SW orientation of the ACR and NE-SW orientation of the SRT and the resulting major drainage capture of Indus River at ACR and at dextral Kalabagh Fault Zone (KBFZ) correspond to recent tectonic activity. The morpho structures revealed from the isobase map also provides a close visual relationship with the in situ scenario. Isobase maps permit the quick, delineation, recognition and orientation of neotectonics that present either poor or very less exposedexpressionson the thematic maps. Free usage of remote sensing data (SRTM DEM) and MATLAB software facilitates state of the art research in the field of tectonic geomorphology.

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