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# Remote Sensing Study of Neotectonics of Katwaz Region in Balochistan-Pakistan

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**Abstract:** This investigation deals with the delineation of neotectonics and its connection to the regional surface deformation in the Katwaz region (KR) located in the north of Quetta along the Pakistan-Afghan border. It consists of rocks dominated by silicates and carbonates, were uplifted due to regional tectonics. In this study, SRTM DEM (90m spatial resolution) based Surface Dynamics (SDMs) of KR is analyzed to investigate the Isobase level (IBL), Relative relief (RR), Topographic surface roughness (TSR) and topographic Slope (TS) map to constrain the active surface deformation due to regional neotectonics. It gives complete information regarding the lithology based erosional margins and demarcation of neotectonic scarps and established the relationship between Strahler order streams and neotectonic settings in an actively deformed KR. This study aims to delineate margins for geomorphological variations and to find the effects of neotectonics. Another purpose is to examine the geomorphic parameters and to map active tectonics development due to transform sinistral movement of the Chaman Fault system (CFS) in the context of the ongoing collision of India-Eurasia. The resultant and generated surface dynamic maps (SDMs) were due to neotectonic developments, progressions and orientations along with CFS and Suleman fold, and thrust belts (SFTBs). The results obtained revealed that IBL values are higher in the NNE, SSW, and central parts along with the CFS, and partially in the NW corner of the KR due to uplifted SFTBs. The active tectonic nature of SFTBs and TSR values are lower in the central and northern parts of KR. The TSR values are higher along SFTBs and CFS due to greater vertical dissection between these two active faults system. The DEM based SDMs are time-efficient and cost-effective for easy identification and delineation of neo-tectonically active zones using remote sensing and GIS techniques.

**Keywords:** SRTM DEM, Isobase Level, surface roughness, relative relief, neotectonics.

## Introduction

The neotectonic deformation in Suleman fold and thrust belts (SFTBs) is associated with the left-lateral strike-slip movement of the Chaman fault system. It is a borderline between the western periphery of the Indian and Eurasian continental plates which results sinistral progression of the Ziarat-Harnai ranges, Chagai hills, SFTBs, Quetta syntaxis and Katawaz block are being formed (Sarwar et al., 1979). The chaman fault system and its associated splays (Awaran Faults, SFTBs and Ghazarband fault) are tectonically active as 4-5 deadly earthquakes have been experienced in the last 80–90 years. The slip rates along the CFS is quite analogous with the San Andreas Fault (SAF) in California of USA and the length of CFS is almost equivalent to SAF (Dubey et al., 1989; Ahmad et al., 2018). The slip rate along the CFS is 18 ± 1 mm/year (Sushma et al ., 2018; Schumm,1956; Keller et al., 1996; Keller et al .,2002; Chen et al ., 2003; Mahmood et al., 2012; O Callaghan et al., 1984; Fattahi et al., 2016; Luo et al., 2018; Sushma et al., 2018). The Indian plate is directing northwards at a rate of~40 mm/year, while its western edge is colliding with the Eurasia Pakistan-Afghan border. It appears that the relative transform plate motion is somewhat contained by the ~900km long CFS that is supposed to separate the margins between both the plates (Keller et al., 1984; Barnhart et al., 2017). The characteristics of morphometric indices (Keller et al., 1984; Duroy et al., 1989; Mahmood et al., 2012; Qureshi et al., 2019) may not be caused by relatively weaker neotectonic activities. In such transform regions, landforms subject to subsequent and relatively flatter topography along with lower uplifting and developing landscapes (Cloetingh et al., 2006; Mahmood et al., 2012; O Callaghan et al., 1984; Qureshi et al., 2019)) which cannot cause noticeable fault scarps and significant changes in topographic gradients known as knick points. Previously, Himalayas had immense importance given because of the topographic deformation that has caused the evolution and development of KR. The IBL, RR and TSR have become important geomorphometric markers that play a great role in the evolution of the topography. The use of the Digital Elevation Model (DEM) in a variety of research fields has injected a new spark in the researchers to envision rugged topography in a 3D form to compute variations in elevations (Amine et al ., 2017). Earth surveillance data along with geospatial datasets is extensively used to investigate the geomorphometric indices (Grohmann et al., 2004). Such investigations facilitate the model of the terrain both hydrologically and geologically. Geomorphometry is useful to examine the topography based on arithmetic computations of natural landforms (Duroy et al., 1989). The evaluation of topographic relief needs complete information of aspect and slope. The KR region represents a topography with variable elevations, magnitudes, scales and dimensions. Therefore, the major objective of this investigation is to evaluate the active deformation through SDMs including, TSR, Iso Base Level (IBL) and Relative Relief (RR). These geomorphometric indices are proficient in investigating the neotectonic characteristics of KR (Grohmann et al., 2011). GIS and remote sensing-based techniques are helpful in evaluating the SDMs using DEM based techniques. Accordingly, the basic input data were the acquisition of geometrically accurate, depressionless and seamless digital elecation model. Geologically Katwaz region is evolved due to North-westward transform movement of the Indian plate against Eurasia, specifically along the Afghan block located on the Eurasian platform moving southwards. Due to deformation of the Indian plate, Kirthar and Suleiman fold and thrust belts (SFTB and KFTB) evolved along the border between Katwaz region and the Eurasian plate.

## Study Area

Katwaz Basin is also connected with Muslimbagh in Balochistan in the context of tertiary classification of KR-Muslimbagh-Ophiolites that are superimposed over each other (Fig. 1). In Paleocene-early Eocene period, Muslimbagh-ophiolites were placed throughout and comprised of volcanic and ultramafic rocks (Ahmad et al., 2018).

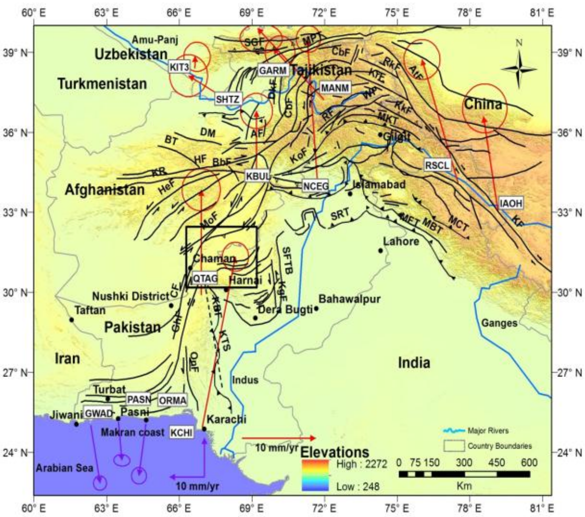


Fig 1: Location of Study Area

## Materials and Methods

SRTM DEM (Jarvis et al., 2008) is free of cost and available to download from Global Land Cover Facility (GLCF) in Tagged Information File Format (TIFF) with a spatial resolution of 90m. The KR was investigated for a variety of geomorphometric indices including TSR, IBL and RR, and thoroughly examined for different sizes of geometric moving windows/grids in square kilometres, Evans et al., (1972) introduced Steepest Adjacent Neighborhood Algorithm (SANA), though four nearest neighbourhood algorithm (FNNA) is most valid and is a commonly used flow algorithms (Evans et al., 1972; Fattahi et al., 2016). The eight-neighbourhood D8 algorithm was used to process the digital elevation model which has been used in this study for the computations of flow angles, sink fillings and flow directions (Garrote et al., 2008). A variation between SANA and FNNA explores the impact of SANA on geomorphometric factors, but the preciseness of the D8 algorithm remains authentic. The topographic slope was calculated using D8 neighbourhood algorithm. SANA was used to calculate particular solitary values for slope at the mid-locations (Golts et al., 1993). The IBL, RR and TSR mechanisms for their computations are based on methodology by (Grohmann et al., 2011). Isobase leve (IBL) map was generated by computing the contours from the DEM. The drainage network was extracted and classified as second and third Strahler order Streams. the intersection points of contours with second and third order were demarcatedand interpolated to generate IBL map. For the RR, mechanism a moving window was selected in such a way that one ride and one valley should be covered in this window, otherwise it will calculate simply the slope of the Katwaz region. The TSR map was generated by taking the ratio between the plane surface area and the real surface area (Grohmann et al., 2011; Mahmood and Gloaguen, 2012).

Relative relief needs no specific definition but simply related to altitude with the reference of defined base levels and just indicates relative elevation (Amine et al., 2017). There are multiple ways to calculate RR comparison of the distance between two relevant points, i) with the difference in elevation, ii) with the change in elevation between a base of stream elevation and a highest ridgeline iii) By the lowest and highest point, the user defines square grids or moving windows (Duroy et al.,1989; Amine et al., 2017). In this investigation, RR is calculated by moving a square grid of fixed size to cover a minimum of one valley and one ridge top in a basin otherwise results will not be considered as RR but just the slope of the valley (Amine et al., 2017)..

## Results and Discussion

The TSR, IBL and RR have been investigated to examine fluvial drainage networks in relationship to neotectonic activities in KR. Several DEM processing methods were performed on SRTM data (Mahmood et al., 2011; Wiang et al.,2018). Geographic Information System (GIS) and Matlab were employed in this investigation to evaluate the DEM data. To speed up and simplify the IBL thematic map in Katwaz region, a semi-automated method was chosen as a preliminary footstep to examine morphotectonics. DEM based demarcation of drainage network was done in Matlab using D8 algorithm (Callaghan et al., 1984) along with the sink fillings, flow angles, link files and stream Strahler orders. D8 algorithm track "flows" from every pixel to one of its neighbouring eight pixels. This technique is well-suited to identify individual channels, stream networks, and watershed boundaries. Stream strahler order in a basin is a section of a channel within a stream network and is treated as a knob in a tree, with the next section downstream as its parent. Two first-order streams after confluence make a second-order stream. Lower order Strahler streams joining a higher Strahler order stream do not change the actual order of the higher stream. According to Strahler et al., (1952), it is a fact that a first-order stream, where precisely the water starts to flow must be removed, as it causes "noise" and may prevent the recognition of a fault line or erosional escarpment or other landscape features (Grohmann et al., 2011;Mahmood et al., 2012; Walker et al., 2013). DEM derived contours gave a source of anecdotal elevations which were integrated at different locations of second and third Strahler orders (Golts et al., 1993; Grohmann et al., 2004; Grohmann et al., 2011;Amine et al., 2017). Isobase Level (IBL) IBL maps exhibit a relation between distance and elevation. The location of water channels and drainage systems is strongly associated with valleys. Drainage patterns direct towards the valley, while the stream order reveals the information about geological events and also their age (Golts et al., 1993). With the help of IBL, the topographic variations and evolutions at different geological times can be studied and decoded. IBL surface is connected with stages of erosion and can be taken as a reference in the monitoring of tectonic and erosional events ( Garrote et al., 2008; Golts et al., 1993). In the study of any neotectonic region, the morphological characteristics of the surface are very useful (Grohmannet al., 2004). Tone and texture are a direct measure of roughness or smoothness of the surface. The size of constituents of any surface can be measured by the coarseness or ruggedness of a surface. In the remotely sensed data, the abnormalities on the surface are significant, the surface is coarser, if they are minute in magnitude and the surface is smoother or flat otherwise. To examine the topography, the assessment of inconsistency in a surface is a useful tool as it reflects great information about landform appearance and degree of erosion.

The IBL map fits well with the localized lineaments situation and regional relative uplifts specially observed in the Katwaz block in the NE part of the study region. This result is in agreement with the regional surface deformation. The impression of the slope and isobase codings constructed from 2nd and 3rd order valleys (Fig. 2a,b) are also systematically linked to the local morphostructures, the irregularities at the baseline of local uplifted structures can easily be identified) along automatic local lineaments derived from the SRTM DEM. The Indo-Pak plate is subducting underneath Eurasia and as a result, Katwaz block and SFTB evolved. The yellow, orange and red shadings show higher IBL values that mean higher and equal lines of uplift (CFS, Katwaz, SFTB) which show active surface deformation (Fig. 2b). The fault systems that are oriented NW-SE and E-W are linked to actively deformed valleys (Fig. 2b). The NE-SW Chaman fault indicates a major drainage capture in the first instance by a powerful East-oriented isobase line turning south, along with west and south by the inflection of the drainage network near the Chaman fault.

It is quite evident that there has been a substantial increase in the uplift, of upper reaches of these valleys represented by the steeper stream gradients and thereby suggesting higher levels of drainage and lineament densities. The incision or relative relief map also shows that NNE Katwaz block is uplifted (compressional regime) in contrast with the southern portion of the Katwaz basin. In the lower part of the investigation site, moderate to low incision levels (RR Values) from north to south indicate a decline in drainage density and increased erosion which slead to relatively low relief (Figs. 2c,d,e). The bands of high values of the TSR are thus interpreted in particular in the central and NNE portion of the Katwaz basin as elevated blocks along the Sulaiman fold and thrust belt. The high TSR values also indicate the existence of abundant lineaments, an indicator of new landscape/topographic growth in the investigation site as a consequence of neotectonic activity.

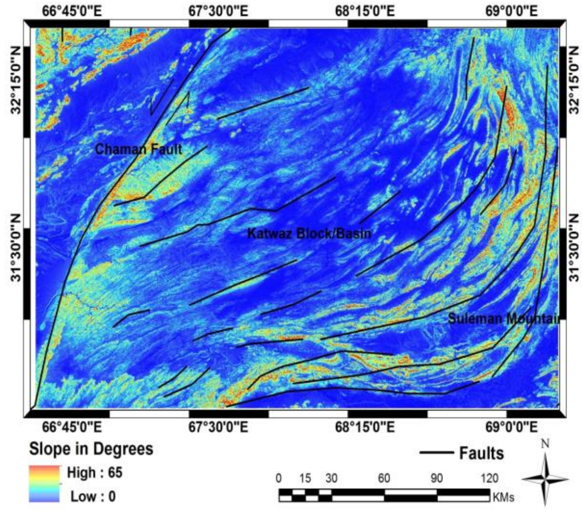


Fig. 2a. Map showing slope in degrees.

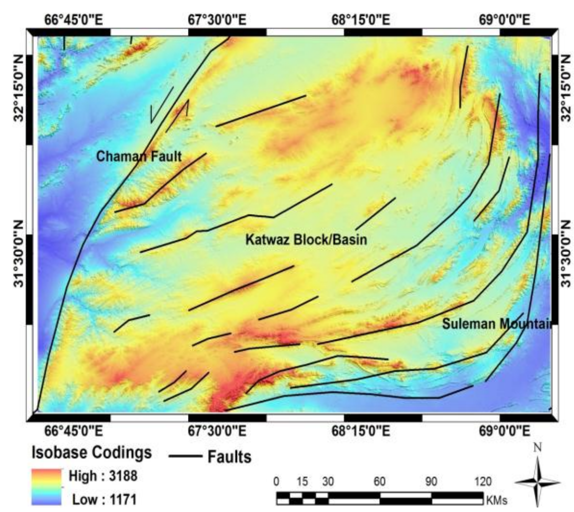


Fig. 2b. Map isobase coding.

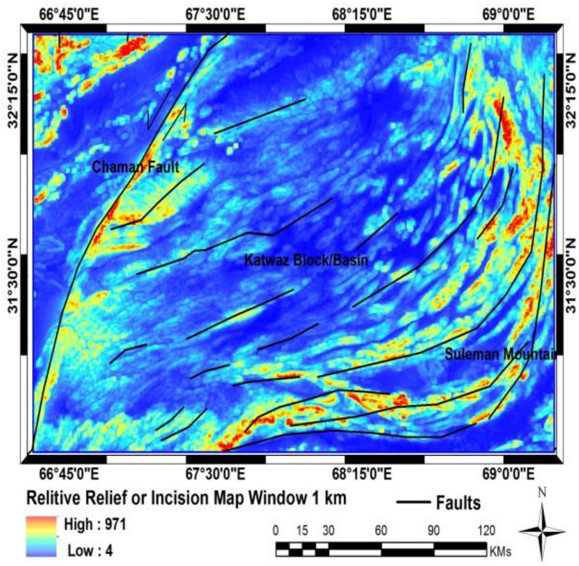


Fig. 2.c Map showing RR codings 1 km.

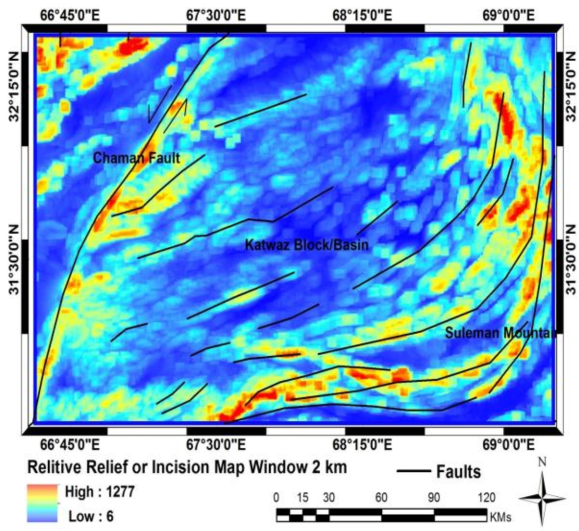


Fig. 2d. Map showing RR codings in 2 km.

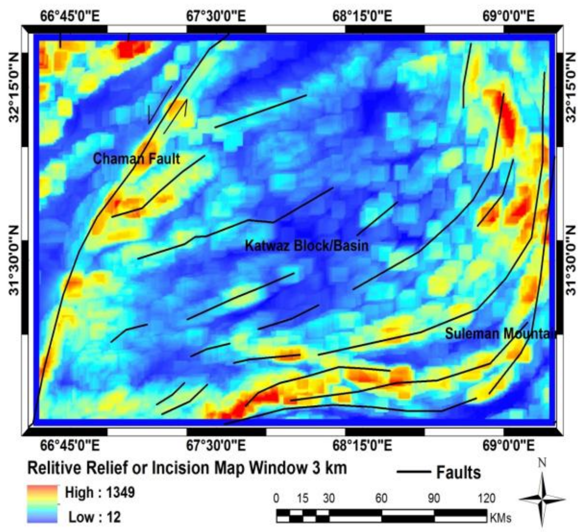


Fig. 2.e Map showing RR codings in 3km window.

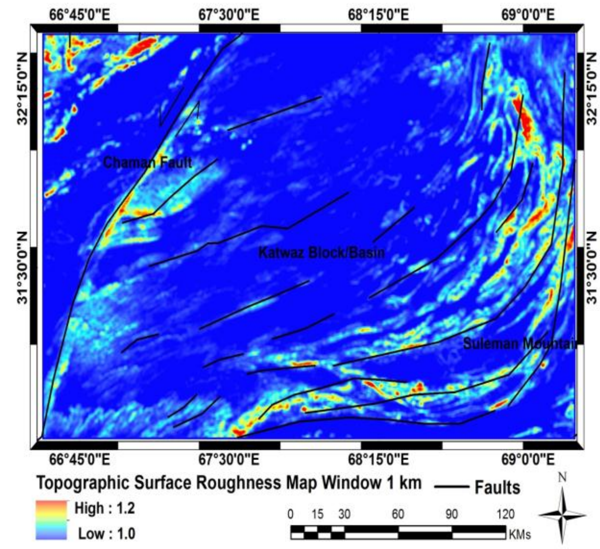


Fig. 2.f Topographic surface roughness map.

Due to the comparatively flat, less incised region with recent active deposits, low TSR is confined to small (lower parts) areas of the study area in the intermountain basins. Increased relief is caused by high TSR in the central and NNE segments of Katwaz blocks (Fig. 2f) and provides topographic imprints to the neotectonically deformed elevations due to active nature of the Chaman fault system and SFTB.

## Conclusion

Surface dynamics maps (SDM) represent the implications and rates of geomorphometric variations of erosional processes and regional differential uplifts. The SDMs findings reveal a decline in erosion in the central and northern portion of the study region relative to the southwest of the study area. Owing to the tectonic control over erosion in the context of sinistral transform movement of Chaman fault, this area has uplifted due to recent neotectonic activity and also due to sufficient precipitation, both in summer and in winter monsoon periods and results in differential active erosion in this region. The mapped active structures and automatically demarcated lineaments epitomize comparatively young neotectonics. The KR is presently experiencing increased neotectonic activity because of the presence of highly active sinistral CFS along the Indo-Pak western margin plate with a transformed motion in NS trending movement as well as E-W subduction beneath Eurasia, which is evident from the higher values of TSR and IBL.

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