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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 in Balochistan along the Pakistan-Afghan border. It consists of rock deposits having silicates and carbonates that are 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 deforming KR. This study aims to delineate margins for geomorphological variations and to demonstrate whether these are affected by neotectonics or not. Another purpose is to examine the geomorphic parameters and to map active tectonics development due to the nearby 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 by 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, central parts along with the CFS and partially in the NW corner of the KR due to uplifted SFTBs. Due to the active tectonic nature of SFTBs, 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 the rapid identification and delineation of neo-tectonically active zones using remote sensing and GIS techniques.

Keywords: SRTM DEM, Isobase Level, Topographic surface roughness, relative relief, neotectonics and Katwaz region.

Introduction

The neotectonic deformation in SFTBs is associated with the left-lateral strike-slip movement of the Chaman Fault System (CFS), which is a borderline between the western periphery of the Indian and Eurasian continental plates because of which sinistral progression of the Ziarat-Harnai ranges, Chagai hills, SFTBs, Quetta syntaxis and Katawaz block are being formed [32]. The CFS 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 [8,2]. The slip rate along the CFS is 18 ± 1 mm/year [35,33,17,18,6,25, 26,11,23,35]. 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 [19,5]. The characteristics of morphometric indices [19,9,25,30] may not be persuaded by comparatively weaker neotectonic activities. In such transform regions, landforms subject to subsequent and relatively flatter topography along with lower uplifting and developing landscapes [7,2526,30] which cannot persuade 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 [3]. Earth surveillance data along with geospatial datasets is extensively used to investigate the geomorphometric indices [15]. 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 [9]. 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 [15]. GIS and remote sensing-based techniques are capable of evaluating the above mentioned SDMs using DEM based techniques. Accordingly, the basic input data was the acquisition of geometrically accurate, depressionless and seamless DEM.

Study Area

Geologically Katwaz region (KR) is evolved as a result North-westward transform movement of the Indian plate against Eurasia specifically along the Afghan Block located on the Eurasian platform moving towards southwards.

Due to the deformation of the Indian plate, Kirthar and Suleiman fold and thrust belts (SFTB and KFTB) evolved along the border between KR and the Eurasian plate. Katwaz Basin is also connected with Muslimbagh in Balochistan as shown in Fig. 1 in the context of tertiary classification of KR-Muslimbagh-Ophiolites that are superimposed over each other and are unconformable. In Paleocene-early Eocene time, Muslimbagh-ophiolites were placed throughout and comprised of volcanic and ultramafic rocks [2].

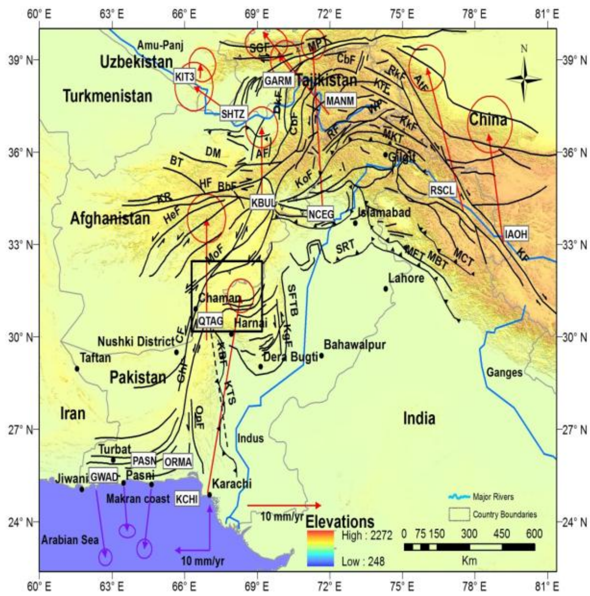

Fig 1: Study Area

Materials and Methods

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 [24, 37]. 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 KRR, 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 [27] 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 and so on. Lower order Strahler Streams joining a higher Strahler order stream do not change the actual order of the higher stream. According to [34], 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 [15,26,36]. DEM derived contours gave a source of anecdotal elevations which were integrated at the different locations of second and third Strahler orders [13-15,3]. SRTM DEM [16] 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 the different sizes of geometric moving windows/grids in square kilometres. [10] introduced Steepest Adjacent Neighborhood Algorithm (SANA), though the four nearest neighbourhood algorithm (FNNA) is most valid and is a commonly used flow algorithms according to [10-11]. The eight-neighbourhood D8 algorithm was established by EVANS [12] that has been used in this research for the computations of flow angles and flow directions. 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 [13]. The IBL, RR and TSR mechanisms for their computations are following the methodology presented by [15].

Isobase Level (Ibl)

In the fields of Geology and Geographic Information System (GIS) the term "ISOBASE" means line joining the points of equal elevation [21]. Such base levels below which a dry land does not erode are called a base level. IBL maps consist of equally uplifted lines. Usually, mean sea level is considered to be the absolute base level, but not in all scales. In the fields of Geology, geography, climatology and tectonics the temporal conditions and local parameters are more important at a regional scale [38,15]. So, IBL remains more significant in these research fields. 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 [13]. 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 [12,13].

Relative Relief (Rr)

Relative relief needs no specific definition but simply related to altitude with the reference of defined base levels and just indicates relative elevation [3]. 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 [9,3]. 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 [3].

Topographic Surface Roughness (Tsr)

In the study of any neotectonic region, the morphological characteristics of the surface are very useful [14]. 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 (for example, landform appearance and degree of erosion). In this research, surface roughness was calculated in ArcGIS using Digital Elevation Model (DEM). The result of this analysis appears in raster form and each cell of this raster layer contains a surface area/ planimetric area ratio for topography that is within the cell boundary. Then both surface and surface area ratio is used to calculate the indices indicating the more realistic surface roughness and complexities in topographic deformation.

Results and Discussion

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 isobase codings constructed from 2nd and 3rd order valleys (Figure 2.1) are also systematically linked to the local morphostructures, (for example, irregularities at the baseline of local uplifted structures can easily be identified) along automatic local lineaments derived from the SRTM DEM. The IndoPak 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) that shows active surface deformation (Figure 2.2). The fault systems that are oriented from NW-SE and E-W are linked to actively deformed valleys (Figure 2.2). The NE-SW Chaman fault indicates a major drainage capture in the first instance by a powerful East-oriented isobase line turning South (Figure 2.2), 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. For example, 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 and thus lead to relatively low relief (Figure 23,2.4,2.5). 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.

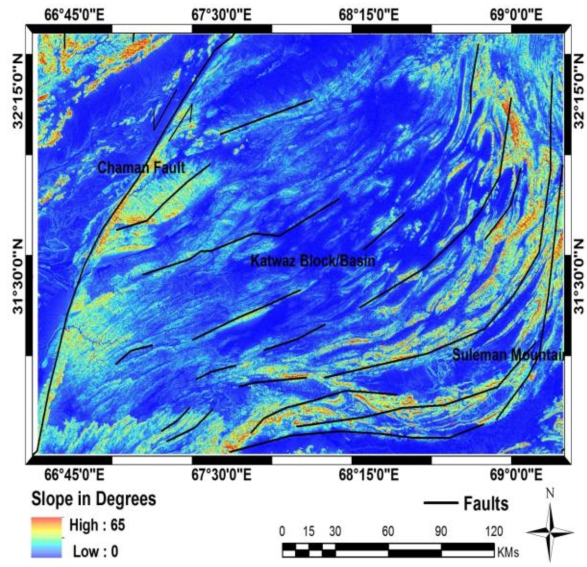

Fig. 2.1. Map showing slope in degrees.

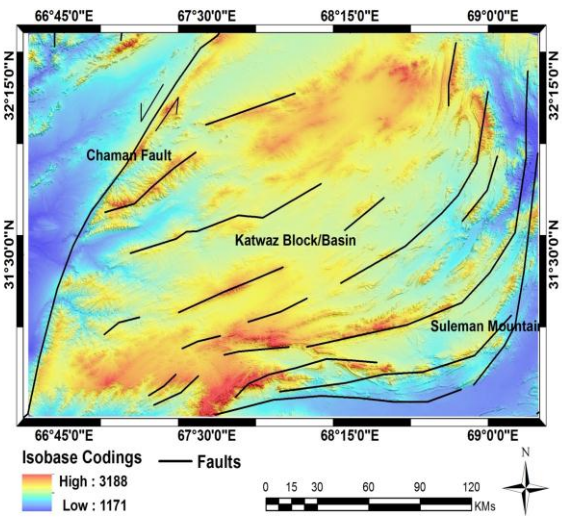

Fig. 2.2. Map isobase coding.

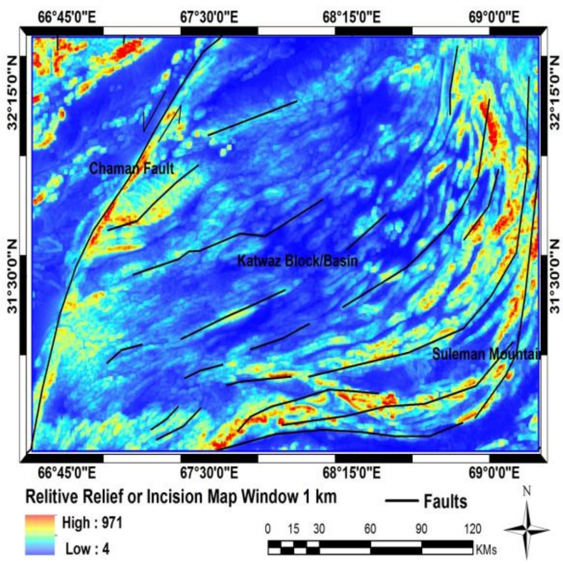

Fig. 2.3. Map showing RR codings 1 km.

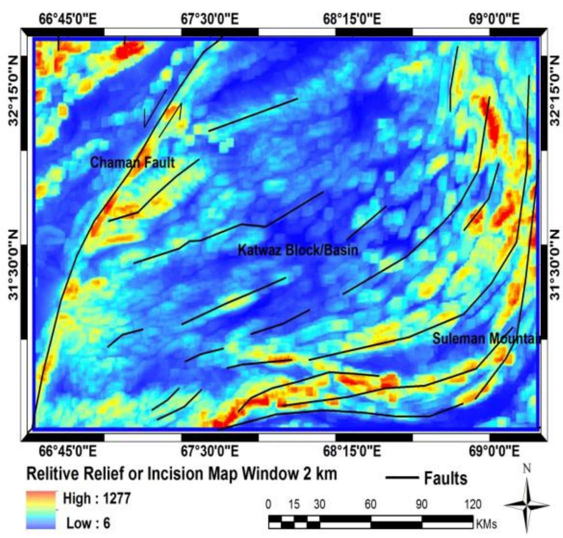

Fig. 2.4 Map showing RR codings in 2 km.

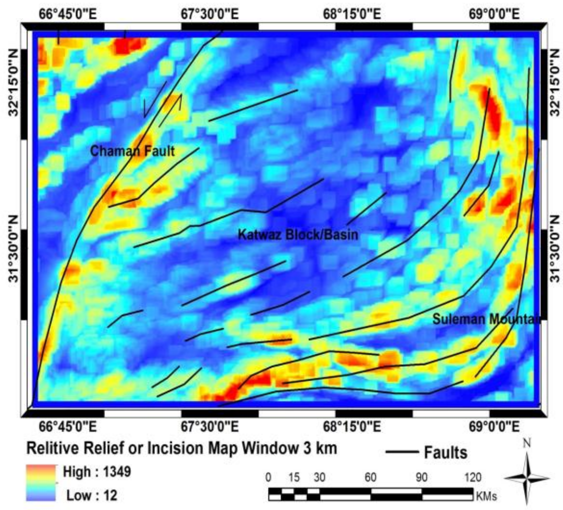

Fig. 2.5. Map showing RR codings in 3km window.

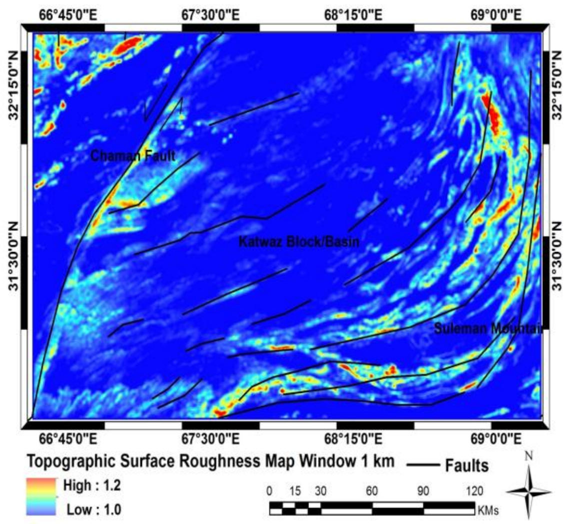

Fig. 2.6. Topographic surface roughness Map.

Due to the comparatively flat, less incised region with recent active deposits, Low TSR is confined to small (lower parts) areas of the investigation region in the intermountain basins. Increased relief is caused by high TSR in the central and NNE segments of Katwaz blocks (Figure 2.6) and provides topographic imprints to the neotectonically deformed elevations due to the 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. Therefore, these are valuable techniques for understanding the sustained and most recent Holocene erosional and neotectonic developments in sub-basins by adopting urgent, precise and efficient measures for soil and water conservations. In this appraisal, we present the applicability of the IBL method for a regional level investigation in KR. IBL analysis performed efficiently for comprehensive morphometric researchers in the last two decades. 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 durations 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 IndoPak western margin plate with a transformed motion in an NS trending movement as well as E-W subduction beneath Eurasia, which is quite evident from the higher values of TSR and IBL. This investigation was performed on SRTM DEM with a spatial resolution of 90 m. This study may be further improved through ASTER Global Digital Elevation Map Global (GDEM) with a 30m resolution. But we preferred SRTM DEM over GDEM due to its accuracy and precision. This research may further be enhanced using ALOS PALSAR 1 and 2 sensor datasets and CHRIS PROBA to make high-resolution DEMs that can cover the least possible faults, Lineaments, fractures and folds

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