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Identification of Active Structures via Remote Sensing

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Abstract

Active structures have an important role in controlling fluvial systems through longitudinal and lateral tilting. The Ghezel Ozan River in northwest of Iran has responded to ongoing tectonic deformation in the basin. The study area is located in the Western Alborz zone and includes part of the Ghezel Ozan River. This paper presents the role of active structures in making active deformations via detection and characterization of fluvial anomalies and correlation with structures. The study area is characterized by association of fluvial anomalies viz. deflection, anomalous sinuosity variations and knick point in longitudinal profile. Such fluvial anomalies have been identified on repetitive satellite images and maps, and they have been interpreted through Digital Elevation Model and field observations to identify the active structures in the area. Some of the structures in the study area have caused the fluvial anomalies, and the most active structures are surface and sub-surface faults and folds with the trend of NE-SW.

Keywords: Active structures; Ghezel Ozan River; Fluvial anomalies

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1. Introduction

River responses to active tectonics produce geomorphological anomalies manifesting surface deformation in any area. These processes can be responsible for river incision and river diversions. River incision is related to tectonic uplift although other processes such as base-level lowering and climatic variations are also responsible for river incision (Pérez-Peña et al., 2010).

The interactions between tectonic uplift and river erosion are fundamental processes which have contributed to shape landscapes. The geomorphic analyses are useful to investigate the impact of tectonic activity on geomorphic processes and landscape development (Giaconia et al., 2012). Tectonic geomorphology aims to highlight the behavior of active faults and the successive earthquakes that they generate (Ritz et al., 2016). Geomorphic indices are useful indicators for evaluating the impact of active tectonics (Cheng et al., 2016). Geomorphic indices have been used as a tool to identify the region deformed by active faults (Pedrera et al., 2009; Perez-Peña et al., 2010). Mahmood and Gloaguen (2012) have used geomorphic indices to compute the IRAT using GIS at the Hindu Kush, Karakorum, and Himalayas ranges. Sarp and Duzgun (2012) have tested the significance of the morphometric indices in tectonically active Bolu pull-apart basin.

The indicative values of the IRAT are compatible with uplift rates. Gao et al. (2013) have used geomorphic indices such as the hypsometric integral index to evaluate the recent uplift of the northeastern margin of the Tibetan Plateau. Alipoor et al. (2011) recognized active tectonics using geomorphic indices in the High Zagros Belt (SW of Iran). The morphometric analyses for assessing the relative tectonic activity were applied for the Sarvestan area of central Zagros (Iran) (Dehbozorgi et al., 2010). Demoulin et al. (2015) have studied the patterns of Quaternary tectonic movements in the area of the Corinth rift (north Peloponnese, Greece) by fluvial landscape morphometry. Sarp (2014) has analyzed the tectonic and geomorphic history of the Bingol pull-apart basin based on morphometric features. Pirasteh (2018) applied The Light Detection and Ranging (LiDAR) techniques to investigate tectonic geomorphology analysis of the Karun River mobility with high resolution Digital Elevation Models (DEMs). The Karun River responses were investigated by using an integration of LiDAR, geomorphology, and field survey to determine the tectonic geomorphology signatures.

The studies in Iran terrene have shown ongoing convergence and active tectonic in this area (Jackson et al., 2002; Allen et al., 2003; Allen et al., 2004). This paper presents the results of studies from the part of the Ghezel Ozan River basin in northwest of Iran. One of the major unresolved questions is whether the drainage and topographic features of the Ghezel Ozan River are due to the recent Tectonism. The main objective of this paper is to evaluate the drainage basin of the Ghezel Ozan River according to fluvial anomalies from the entrenched section and discuss their implications.

There are some surface and subsurface faults and folds in the study area. In this paper, we have attempted to understand the surface deformation pattern along the surface and subsurface faults and folds with the help of geomorphological anomalies and fluvial processes.

The geomorphology provides the situation to identify active and potential hazardous faults. We apply this opportunity through the use of digital elevation models. Our observations demonstrate the potential for using drainage basins as tectonic markers in the quantification of uplift, which may have a wider applicability in other deforming parts of the world.

We propose a general model of fluvial anomalies in the study area in which the detection of these features can lead to the identification of the most active fault segments in the Ghezel Ozan River region. Such an approach can help better constrain faults activity in long-term deformation. Such configuration is likely to occur in many datasets worldwide where fluvial anomalies are controlled by fault zones.

2. Regional setting

The study area is located in the Western Alborz zone (Fig. 1) and includes the part of the Ghezel Ozan River with trend of NW-SE. Volcano-sedimentary rocks of Eocene Karaj tuff comprise most of the outcrops in the area. The Western Alborz zone deforms actively due to the north–south Arabia–Eurasia convergence, and westward motion of the adjacent South Caspian relative to Iran. This zone deforms by strain partitioning of oblique shortening onto range-parallel left-lateral strike-slip and thrust faults (Allen et al., 2003) and forms a composite orogenic belt, suffering shortening and uplift during Tertiary (Alavi, 1996). There are indications of recent uplift in the western Alborz in the form of incised river terraces and coastal marine terraces (Berberian, 1983).

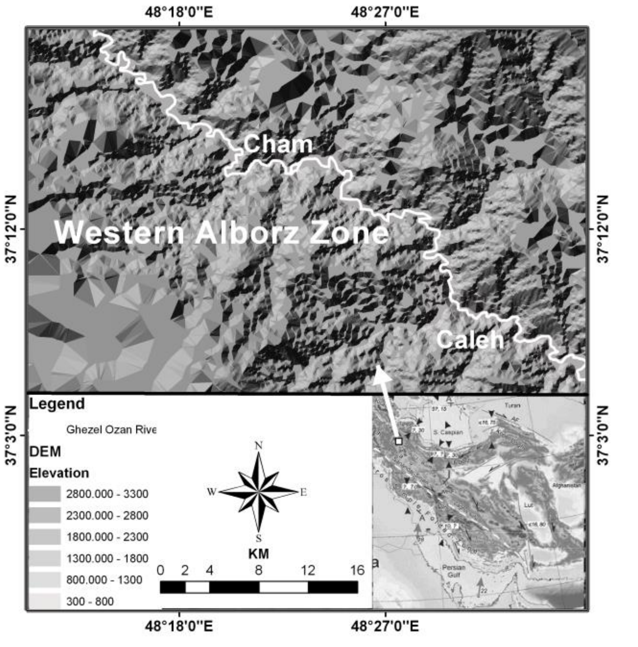

Fig 1. DEM of the study area (USGS/SRTM data) illustrating the Western Alborz structural zone in NW Iran.

3. Materials and methods

In this study, we used topographic maps at the scale of 1: 25,000, geological maps at scale of 1:100000, aeromagnetic maps at scale of 1:250000 and satellite images. Also, we have used 10-m grid cell DEM. Its projection was the UTM zone 39 N. The DEM was derived from the contour lines of the 1: 25,000 topographic maps provided by Iranian Survey Organization (ISO) with 10-m contour intervals. In order to evaluate the qualitative and quantitative data for such drainage anomalies, a geographic information system (GIS) was used to manage the digital elevation model (DEM).

In order to identify the role of structures in creating the fluvial anomalies, the following works were accomplished:

1- The geomorphic anomalies along the length of Ghezel Ozan River were recognized by use of Landsat ETM images with resolution of 28.5 m and by subsequent field verification.

2- The DEM were derived from the contour lines of the 1: 25,000 topographic maps provided by Iranian Survey Organization (ISO) with 10-m contour intervals. The DEM was employed for the preparation of longitudinal profiles of the Ghezel Ozan River.

3- This channel profiles provided data on river profile irregularities (knick points) that may be associated to active tectonics.

4- The whole surface structures (faults and folds) were extracted from geologic maps at scale 1:100,000 provided by the Geological Survey of Iran (GSI).

5-The whole magnetic lineaments were extracted from aeromagnetic maps at scale 1:250,000 provided by the GSI.

6- The fluvial anomalies created by surface structures, such as abnormal sinuosity and compressed meanders, were omitted and only the geomorphic anomalies related to magnetic lineaments were considered.

7- In this way, the surface and sub-surface active faults and folds in the Ghezel Ozan River basin have been recognized.

4. Results

The Ghezel Ozan River in the study area flows toward the southeast, and the length of the river in this section is 51 kilometer (Fig. 2). The geomorphic anomalies and tectonic structures in the area are shown in Fig. 3.

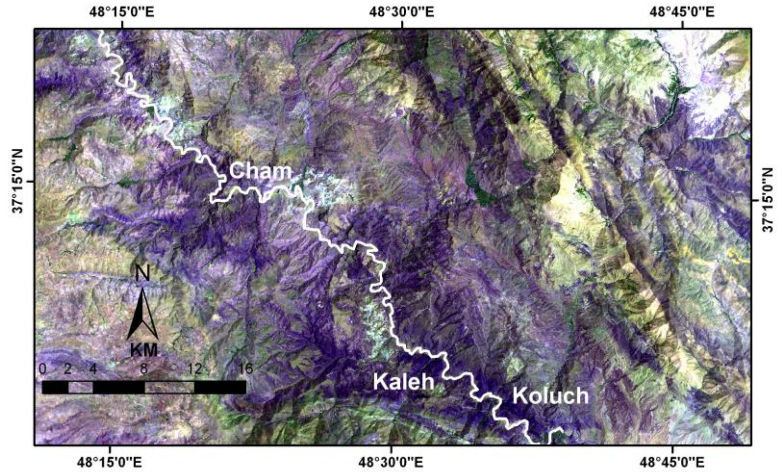

Fig 2. Annotated Landsat image depicting the situation of the Ghezel Ozan River and the key geographical regions of the study area.

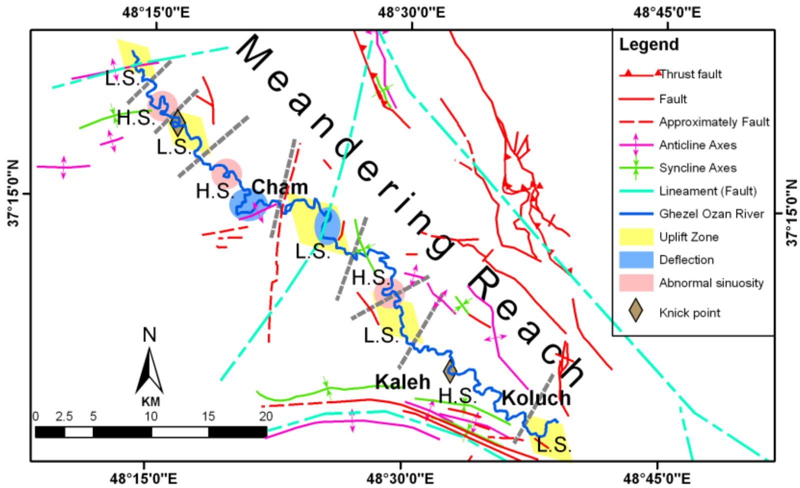

Fig 3. Structural map illustrating the role of structures in creation of fluvial anomalies in the study area. Abbreviations in this map are as follows: H.S., High Sinuosity; L.S., Low Sinuosity.

The intense and sudden deflection in the river course, the abnormal changes in the river sinuosity and knick points on the longitudinal profile of the river are recognized in the area. Deflection of the river course and abnormal changes in the river sinuosity are identified on the satellite images and approved through field observations. The knick points are specified on the longitudinal profile of the river that has been obtained from digital elevation model (DEM).

Some of the magnetic lineaments in the Ghezel Ozan River basin have caused the geomorphic anomalies along the river length. The lineaments with trend of NE - SW have created fluvial anomalies such as variations of channel pattern of the river and deflection of the river course (Fig. 3) and could be identified as active subsurface structures.

Several of the faults and folds with trend of NE - SW have created fluvial anomalies such as deflection of the river course and changes in the river sinuosity (Fig. 3) and could be identified as active surface structures. None of the knick points coincide to the lineaments or faults and folds. Therefore, it is concluded that the knick points are created by other factors such as variations of lithology.

The alluvial Rivers in Himalayan basin shows similar morphological features in the uplift zone. Active tectonics in Hindu Kush has greatly influenced the drainage system and geomorphic expressions. The average of the seven measured geomorphic indices was used to evaluate the distribution of relative tectonic activity in the study area. Landsat imagery and field observations evidence the presence of active tectonics, based on the deflected streams, deformed landforms and active mountain fronts (Mahmood and Gloaguen, 2012).

5. Conclusion

This study aims to understand the different effects of tectonism on fluvial network and to interpret the tectonic deformations using described and analysed systematic anomalies in the drainage basin of the Ghezel Ozan River. The survey of the impacts of the structures on the rivers can detect a deformation pattern of the area in the surface and sub-surface faults and folds. River response to active tectonics depends upon the trend of the faults, folds and lineaments with respect to river flow. In the study area, some of the structures cut across the river channel and affect the fluvial process. The differential movements along the structures have produced longitudinal tilting in the area.

One of the most important tectonic problems in fluvial basins is the recognition of surficial deformation patterns, which are mostly produced by the performance of active faults and folds in the sub-surface. In many cases, these structures are located beneath a thick sedimentary cover and a direct study of them is not possible. Therefore, using fluvial anomalies, one can recognize regional surface deformation patterns related to sub-surface faults and folds.

The Arabia-Eurasia collision deforms the study area, making it as one of the regions of convergent deformation on the earth. The ongoing convergence was caused both by uplift and reactivation of basement faults in the area. Active incise of river channel occurred due to the created uplift and incised river terraces. The reactivation of basement faults initiates the development of fault lineaments on the sedimentary cover that were recognized on the aeromagnetic maps. These concealed structures have caused the above-mentioned geomorphic anomalies in the Ghezel Ozan River basin.

Regarding the effective structures in the creation of fluvial anomalies, it is specified that structures with the trend of NE-SW are the most active structures in the study area. The dominance of structures with the trend of NE-SW in this area (Western Alborz zone) is due to the westward movement of the Caspian Basin, which causes the oblique left lateral compression of the Western Alborz as a result of the reactivation of deep-seated transverse basement faults. The high tectonic activity in the study area is in agreement with the seismicity of region, for example the Rudbar earthquake of June 20, 1990 (MS = 7.7, MW= 7.3, mb = 6.4) that occurred in the vicinity of this area.

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