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Active Sub-surface Structures in the Ghezel Ozan River Basin, NW Iran

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Abstract: The Ghezel Ozan River, the longest river system in Iran, has responded to tectonic deformation thoroughly. In this study, the most expressive geomorphic anomalies were identified on the satellite images and then verified through DEM and field observations. These anomalies were correlated with structural and magnetic lineaments extracted from geological and aeromagnetic maps. In this way the fluvial anomalies associated to magnetic lineaments were specified and so the active sub-surface folds and faults were recognized. Most of the magnetic lineaments in the Ghezel Ozan River basin are related to the geomorphic anomalies in the length of the river and are considered as active sub-surface structures. Observed fluvial response to the active sub-surficial deformation includes channel pattern variations, straightening and deflection of the river course and knick points in longitudinal profile of the river and indicates neo-tectonic deformation in the study area.

Key words: Ghezel Ozan River · Geomorphic anomalies · Magnetic lineaments · Active sub-surface structures

INTRODUCTION

River response to active tectonics depends upon the nature and amount of vertical movement in a river basin and the trend of the faults and folds with respect to river flow. Conventional methods such as seismic data analysis and fault plane solutions of earthquake data are often insufficient to relate active tectonic movements to any specific fault [1]. An integrated approach using remote sensing data and digital elevation models coupled with repeated field observations provide information on the nature of vertical movements of active sub-surface faults and folds.

This paper presents the results of investigations from the Ghezel Ozan River basin, northwest of Iran. Due to the Arabian-Eurasian collision the Iran plateau is one of the most tectonically active regions of the world. Numerous studies in the Iran plateau have shown ongoing convergence and active tectonics in this area [2- 4].

Numerous conceptual models and field investigations suggest that in tectonically active regions fault growth and associated deformation have a direct control in shaping the landscape and drainage evolution [5-11]. Traditional methods have failed to understand the style of surface deformation caused by the known seismogenic active faults because of thick alluvial cover, overprinting of frequent flooding effects. In this paper, we have attempted to understand the surface deformation pattern along the sub-surface faults and folds with the aid of proxy data such as geomorphological anomalies and fluvial processes.

Regional Setting: The study area is located in Sanandaj - Sirjan, Centeral Iran and Western Alborz zones [12] (Figure 1). These sedimentary-structural zones were separated on the basis of factories such as variety of crust, magmatic and metamorphic activities, difference in rock facieses and tectonic evolution [12]. In the regional tectonic, Sanandaj-Sirjan and Centeral Iran zones are located in the Turkish-Iranian plateau [4]. It extends from eastern Anatolia to eastern Iran and typically has elevations of 1.5-2 km. There are prominent strike-slip faults, especially in eastern Anatolia and northwest Iran [13].

Alborz Mountains, situated in central portion of Alpine-Himalayan System, form a composite orogenic belt that suffered shortening and uplift since Tertiary [14]. The Alborz range deforms by strain partitioning of oblique shortening onto range-parallel left-lateral strike-slip and thrust faults. Deformation is due to the north-south Arabia-Eurasia convergence and westward motion of the adjacent South Caspian relative to Iran.

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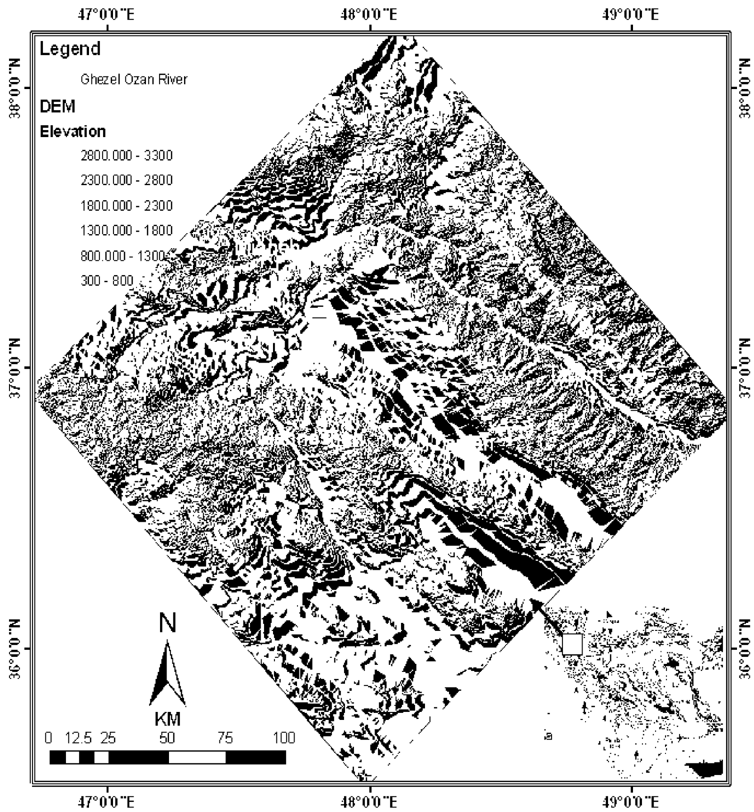

Fig. 1: DEM of the study area (USGS/SRTM data) illustrating structural and sedimentary zones marked by dashed lines and some urban points in NW Iran. Inset shows DEM of Iran with location of the study area

Both field observations and seismicity data for the Alborz demonstrate the partitioning of strain into dip-slip and strike-slip components. The principal strike-slip faults produce prominent surface ruptures, but major thrusts are commonly blind. The overall oblique convergence is simply partitioned into strike-slip and compressional components, but the compressional deformation involves ramps and flats and locally complete detachments between basement and cover. Major strike-slip faults do not have this complication; hypocentres at depths of 12 km are coeval with surface ruptures [3].

Around the Ghezel Ozan River, marl, sandstone, siltstone, limestone, tuff, agglomerate and volcanic rocks are exposed. These rocks belong to Qom, Upper red, Lower red and karaj formations.

MATERIALS AND METHODS

In order to identify the active sub-surface structures in the Ghezel Ozan River basin the following works were accomplished:

- The geomorphic anomalies in 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.
- 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. This channel profiles provided data on river profile irregularities (knick points) that may be associated to active tectonics.
- The whole surface structures (faults and folds) were extracted from geologic maps at scale 1:100,000 provided by Geological Survey of Iran (GSI) (Figure 2 and Figure 3).
- The whole magnetic lineaments were extracted from aeromagnetic maps at scale 1:250,000 provided by the GSI (Figure 4).
- 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 are considered.

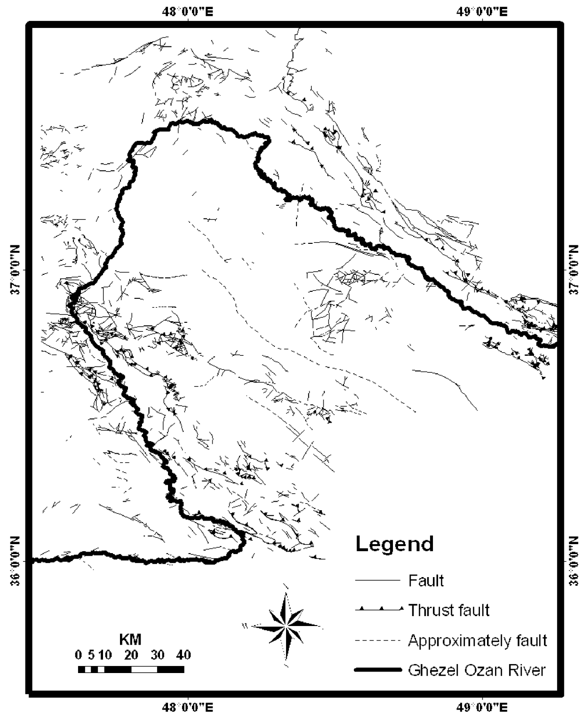

Fig. 2: This map shows all faults in the Ghezel Ozan River basin

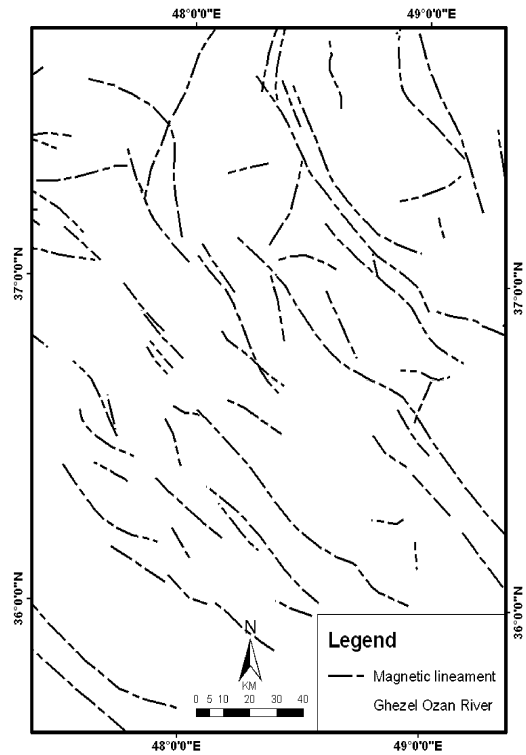

Fig. 4: This map shows all magnetic lineaments in the Ghezel Ozan River basin.

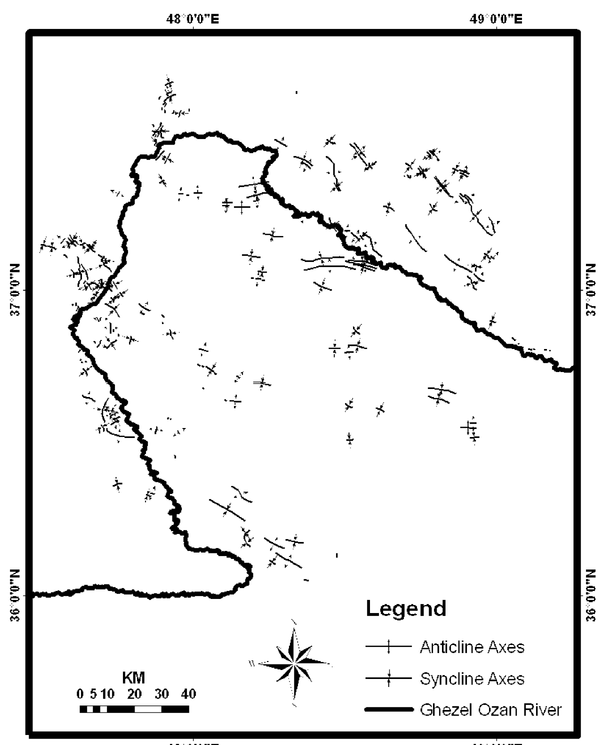

Fig. 3: This map shows all folds in the Ghezel Ozan River basin.

RESULTS

The geomorphic anomalies related to magnetic lineaments in the Ghezel Ozan River basin (Figure 5) are as follow:

Channel Pattern Variations: Channel pattern may be altered directly or indirectly by increase or decrease in slope imposed by an impeding zone of uplift or subsidence. Sufficiently decreased slopes may cause rivers to transform along the path of braided to meandering to straight or anastomosing patterns and vice versa. More typically, rivers undergo minor variations within pattern without undergoing complete shifts in pattern type. The most commonly observed of these intrapattern adjustments is for a meandering channel to increase its sinuosity in response to increased slope, or decrease its sinuosity as an adjustment to decreased slope [15].

Transform channel pattern of braided to meandering (Figure 6) showing zone of uplift in course of the Ghezel Ozan River was associated to a magnetic lineament with trend NW-SE. Magnetic basement of this lineament is located beneath a sedimentary cover of marl, sandstone, shale and conglomerate rocks. Thus, this magnetic lineament is an active sub-surface structure in the area.

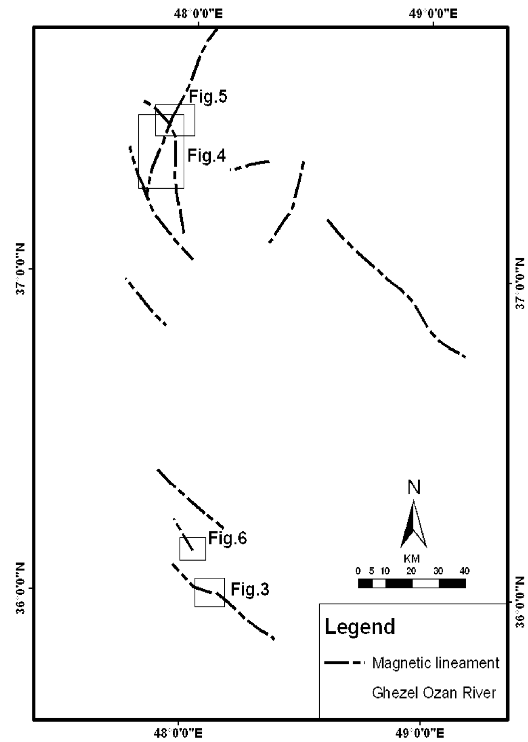

Fig. 5: This map shows the situation of the Ghezel Ozan River and place of Figures 6, 7, 8 and 9 in the study area

Straightening of River Course: In two regions the natural and meandering pattern of the Ghezel Ozan River is modified and the course of the river is completely straightened (Figure 7). Straightening is related to a magnetic lineament with trend NE-SW. Magnetic basement of this lineament is composed of acidic tuffs and igneous rocks with Eocene age. This lineament has had the most influence in straightening of the river course and is accounted to an active sub-surface structure in the area.

Sudden Change in the Flow of the River (Deflection): Deflection of the river around an uplift or into a zone of subsidence is manifested as an abrupt shift in the river course coincident with the deformed zone. Streams naturally tend to gravitate toward the subsided zone, if the zone is proximal to the river and there are no topographic barriers between the river and zone [15]. Deflection of the Ghezel Ozan River course (Figure 8) is associated to a magnetic lineament with trend of NW-SE. Magnetic basement of this lineament is located beneath a thin sedimentary cover of marl, sandstone and conglomerate rocks. This deflection which is nearly 90 degrees shows the activity of sub-surface structure.

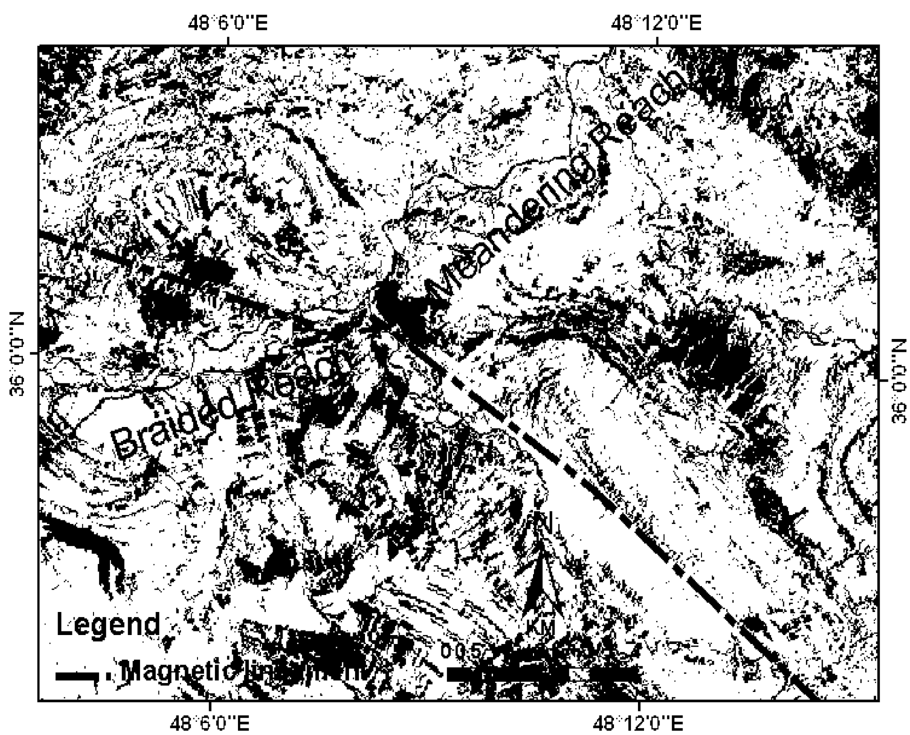

Fig. 6: Annotated Landsat image depicting the situation of magnetic lineament and resulting channel pattern variation in the Ghezel Ozan River.

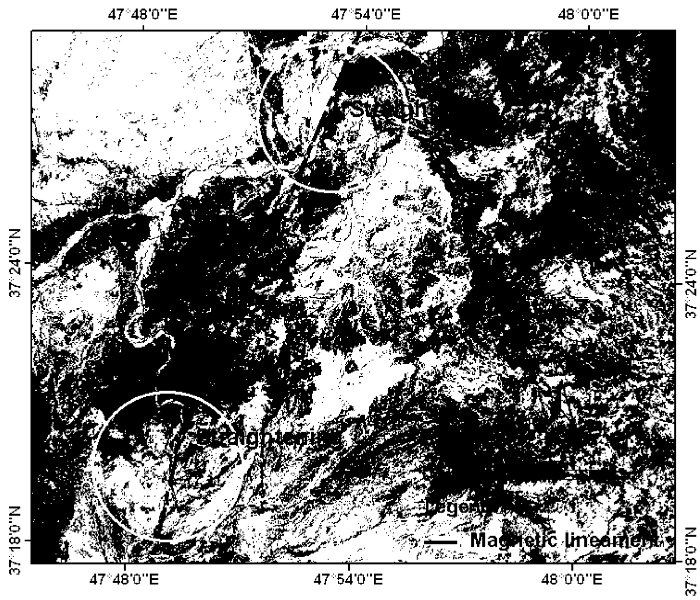

Fig. 7: Annotated Landsat image depicting the situation of magnetic lineament and resulting straightenings of the river course in the area

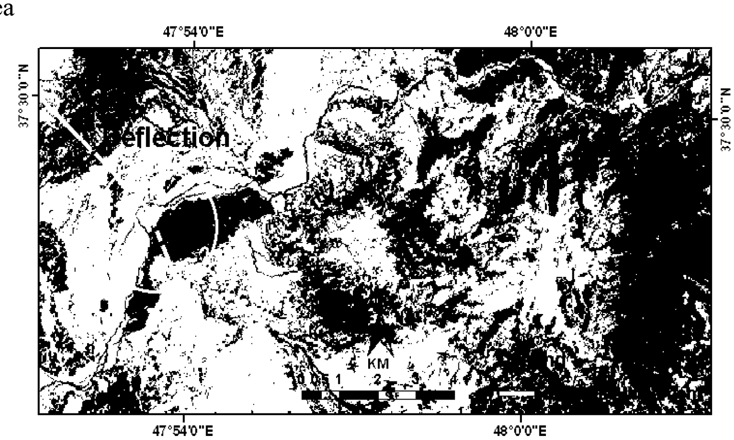

Fig. 8: Annotated Landsat image depicting the situation of magnetic lineament and resulting deflection of the Ghezel Ozan River

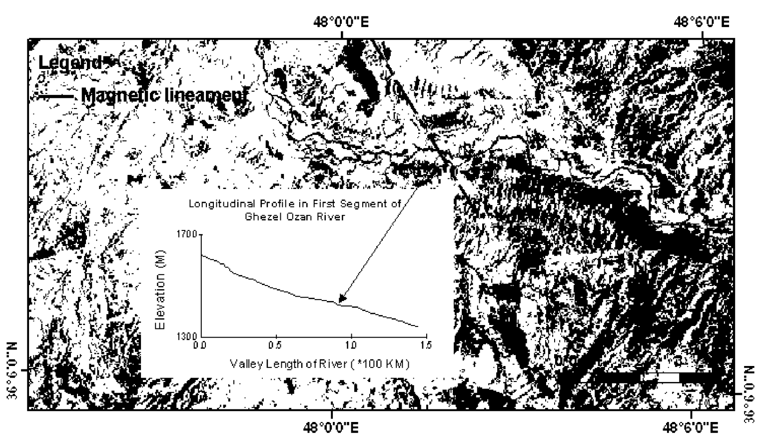

Fig. 9: Landsat image depicting the situation of magnetic lineament and resulting knick point in longitudinal profile of the Ghezel Ozan River

Knick Points in the Longitudinal Profile of River: A segment of a river long-profile that is steeper than adjacent segments is commonly referred to as a knick zone or a knick point if it is visibly steeper than the trend of the longitudinal profile. Knick zones are often observed along bedrock rivers [16-19] and the most visible form is a waterfall [20, 21]. A knick point in the longitudinal profile of the Ghezel Ozan River is observed which this anomaly is located in place of intersection of the river with a magnetic lineament trending NW-SE (Figure 9). The magnetic basement of this lineament is located beneath a sedimentary cover of marl, siltstone and conglomerate rocks. Regarding the invariability of lithology in ground it is inferred that the knick point is created by a magnetic lineament and, therefore it is considered as a active sub-surface structure.

DISCUSSION

One of the most important tectonic problems in fluvial basins is the recognition of surficial deformation patterns which are mostly produced by the action of active faults and folds in the sub-surface. In many cases, these structures are located beneath a thick sedimentary cover and their direct survey is not possible. Therefore through the use of fluvial anomalies we can recognize regional surface deformation patterns related to sub-surface faults and folds. In the Ghezel Ozan River basin, most of the magnetic lineaments are cutting across the river channel and have affected the fluvial processes. The differential movements along the lineaments have produced longitudinal tilting in the area. In general, channel pattern variations, straightening of the river course, deflection of the river course and knick point in longitudinal profile of the river are some of the geomorphic expressions of active sub-surface structures in the Ghezel Ozan River basin. Regarding the trend of this lineaments in the area it is specified that the active sub-surface structures have trends of NW-SE and NE-SW which are concordant with the trend of basement fractures in basement of Iran.

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

CONCLUSIONS

- Most of the sub-surface structures in the Ghezel Ozan River basin are presently active and have produced distinctive response manifested as fluvial anomalies.
- The active sub-surface structures in the Ghezel Ozan River basin have trends of NW-SE and NE-SW.
- The sub-surface structures with trend of NW-SE have caused channel pattern variations, deflection of the river course and knick point in longitudinal profile of the river while, the sub-surface structures with trend of NE-SW have only caused straightening of the river course.
- Morphology of the Ghezel Ozan River was influenced from neo-tectonic movements caused by active structures especially the magnetic lineaments.

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