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Geometric Analysis of Faults and Fractures of Vizenhaar Oil-rich Anticline using Remote Sensing Techniques

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ABSTRACT

Geometric interpretation and identification of surface faults and fractures that exist in an area based on remote sensing techniques help detect these terrains, and the maps of these areas can be used as a database for regional identification and planning. The aim of this study was to identify and extract fractures and faults of Vizenhaar Anticline in the southwest of Lorestan Province located in western Iran. For this purpose, the lineaments in this area were identified using 2013 images of Landsat 8 Operational Land Imager (OLI) sensor (rows 37 and pass 166) and application of directional filters in ENVI software and Lineament Extraction algorithm in Geomatica software. Afterward, by comparing the lineaments with the constructed band combinations, the digital elevation model (DEM) as well as a geological map of the study region, the faults and fractures were distinguished and their map prepared in Geographic Information System (ArcGIS) software environment. According to the results, the direction of most fractures and faults in the region is northeast-southwest. Also, ISODENSITY mapping of faults and fractures in the region shows that the highest density of faults and fractures is in the west, center, and east of the anticline. Therefore, these areas can be important considering the significant and undeniable role of fractures and faults in hydrocarbon properties and migration.

1. Introduction

The use of remote sensing technology and satellite data is an effective tool in the field of environmental studies and geosciences. Remote sensing is the science providing valuable information through observation and measurement of an object or terrestrial phenomenon from a distance without physical contact with it, and in the next stage, useful information can be obtained through analysis of these data (Mir Hosseini Mousavi and Almasyan, 2012). Remote sensing technology and satellite data often reduce costs, save time, increase accuracy and speed, and the importance of this technology for sustainable development is increasing day by day. Remote sensing is a new tool enabling basic information acquisition and extraction for the management of land resources. Using remote sensing technology, a wide range of projects can be completed globally, regionally, nationally, provincially and locally with lower budget over a shorter period.

Typically, lineaments are identified and interpreted using ground surveys and aerial photographs. Because aerial photographs are not able to provide a unified view of vast areas and also have a spectral limit, the desired

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terrains are not precisely identified in spite of spending a lot of time and money to map lines and faults. Today, one of the most important methods for examining tectonic structures is the use of satellite image processing, especially OLI sensor data. Several investigations have been conducted in Iran and other parts of the world to study fractures and lines using remote sensing data, which have also obtained favorable results, including the following.

Suzen and Toparak (1998) analyzed geological lineaments using satellite images, and their results showed that a higher number of lineaments can be identified by applying a filter. Eirini et al. (2001) identified the lineaments of western Crete in Greece and used Esther satellite imagery and GIS for this purpose. To better identify the lineaments, basic component analysis techniques, NDVI index, generation of false band combinations, as well as the digital elevation model have been used. Yahyaei Haghighi et al. (2010) analyzed the lineaments in Rectangle of Tehran using ETM^+ sensor images by applying different filters (soble and solar angle filter). Using band 7 of ETM^+ sensors; Aziz Zadeh and Mulla Mehr Alizadeh (2011) studied the deformation mechanisms of Izeh Fault system in central part of Zagros. Their research was done using remote sensing techniques from ASTER and IRS-Pan satellite images as well as digital elevation model (DEM) of the area; Rashidi et al. (2012) studied the tectonic lineaments of Nay Band Fault Zone (from Shahdad to Naybandan) using remote sensing methods. For this purpose, considering the expected morphologies related to faults, they took advantage of several different techniques such as band combination and filtering to highlight faults and fractures in the study area and prepared a map of faults and fractures. Abdullah et al. (2013) automatically identified the southwestern lineaments of part of Taiz region of Yemen and measured their accuracy by field studies. Gannouni and Gabtni (2015) geometrically interpreted the lineaments in Zahret Medien region of northern Tunisia using TM images; Ranjbar et al. (2020) identified and extracted faults in Ghoshadagh Fault Zone. For this purpose, using Landsat 8 satellite images of OLI sensors and applying Lineament Extraction algorithm in Geometica software, the area lineaments were detected.

Zagros Mountains in southwestern Iran are one of the richest folds and thrust belts in the world. This belt contains world-proven oil and gas reserves. Given that most oil reserves in Zagros Basin are located in fractured carbonate rocks and because these fractures play a major role in the production of hydrocarbons, it is necessary to map them to study the fracture pattern and its relationship with folding as well as its effect on fluid movement (Beck, 2009). Therefore, this research was conducted with the aim of investigating and preparing the map of fractures and lineaments of Vizenhaar oil-rich anticline located in Lorestan province in order to prevent further excavations by identifying the areas with the greatest potential for digging oil wells.

2. Material and Methods

2.1. Geographical Setting

Vizenhaar Structure is located as an anticline with an 18-km long northwest-southeast direction west to Rumeshkan County in Lorestan Province (Fig. 1). This anticline is composed of Asmari and Shahbazan formations (Fig. 2), and the former is the highest carbonate sequence as well as the most important reservoir rock of Zagros sedimentary sequence.

2.2. Research Method

Mapping the lineaments and analyzing them through remote sensing data is a useful tool for regional tectonic and structural studies. Geological structures such as fractures, faults, joints, shear zones and foliation show themselves in the form of lineaments in remote sensing studies (Kamali et al., 2013). There are manual, automatic and semi-automatic methods for extracting lineaments and faults. In this study, a semi-automatic approach has been used, namely a combination of automatic and manual methods that is more reliable than other techniques with acceptable speed. For this purpose, 2013 Landsat 8 images taken by OLI sensor (row 37 and pass 166) have been analyzed. The reason for preferring these images to those of Landsat 7 is that Landsat 8 provides images with a higher resolution.

Satellite images often have geometric and radiometric distortions and require spatial and spectral corrections. When capturing an image, a satellite sensor generates errors in geometric position of pixels (geometric error) as well as in the measured brightness of pixels (radiometric error). In the preprocessing stage, radiometric and geometric errors are removed from satellite images (Abbasi and Yasaki, 2011).

In this research, by applying the Lineament Extraction filter in Geometica Software, first the lineaments in the region were extracted automatically. Then, faults and fractures in the area were manually identified by spatial highlighting and applying directional filters on Band 8 image of Landsat 8 OLI sensors, as well as creating band combinations.

In spatial enhancement, also known as local enhancement, the numerical value of a pixel is improved according to the values of the surrounding pixels. Spatial enhancement is done by applying different filters on images. Filter operators are usually 3*3, 5*5 or 7*7 windows, and by applying to the image, they obtain a new value for each pixel according to the surrounding pixels and save it. In this study, to identify fractures and faults, the directional filter has been used in north-south, northeast-southwest, east - west and southeast-northwest directions.

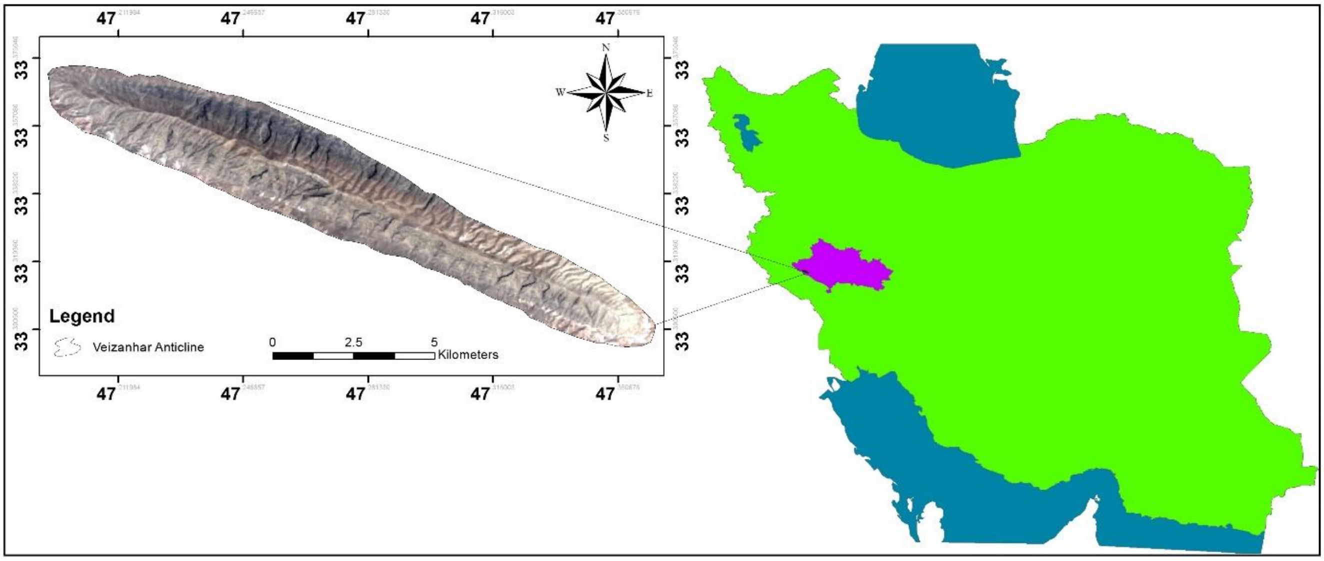

Figure 1. Geographical location of Vizenhaar Anticline

Figure 2. A view of Vizenhaar Anticline

In band combinations, the most common image enhancement technique is to assign digital values in the pixels of an image to specific colors in order to increase the overall sharpness of that image. In this way, a black and white image is visible in color. Satellite images can be displayed as a single band or as color combination. In a multi-band combination, the recorded energy for each pixel is measured in three bands and displayed in three colors: red, green, and blue. Several combinations can be obtained from OLI bands that are different from band combinations in Landsat 7. Depending on type of information to be extracted from each combination, that combination is used in a specific application. RGB=432 combination in Landsat 8 is called a true color combination because it represents colors that look like natural colors, and the rest of combinations are called a false color combination. In this study, 432 (Fig. 3), 543 (plants seen in red, Fig. 4), 642 (separation of rock units, Fig. 5) and 752 (geological studies) combinations have been used to investigate the faults (Fig. 6).

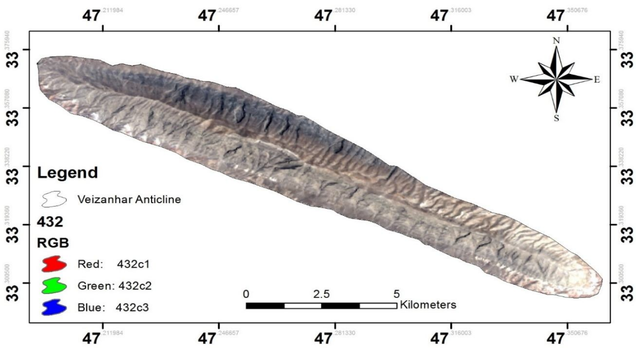

Figure 3. Band combination 432 for studying the lineaments of Vizenhaar Anticline (real image of the anticline surface)

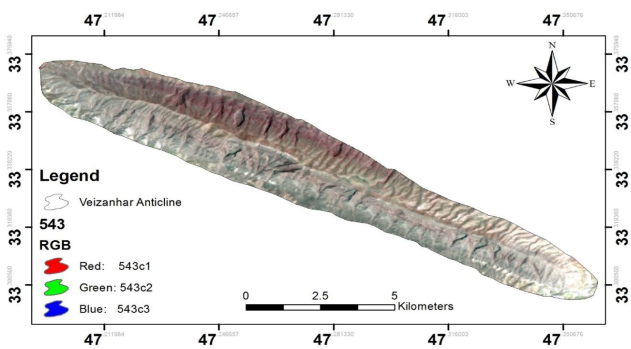

Figure 4. Band 543 combination for studying the lineaments of Vizenhaar Anticline (plants seen in red)

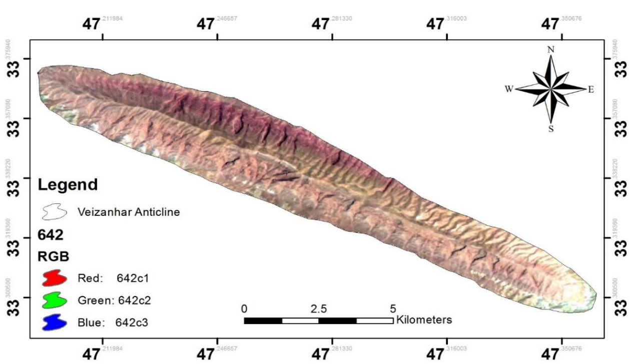

Figure 5. Band 642 combination for studying the lineaments of Vizenhaar Anticline (plants seen in red)

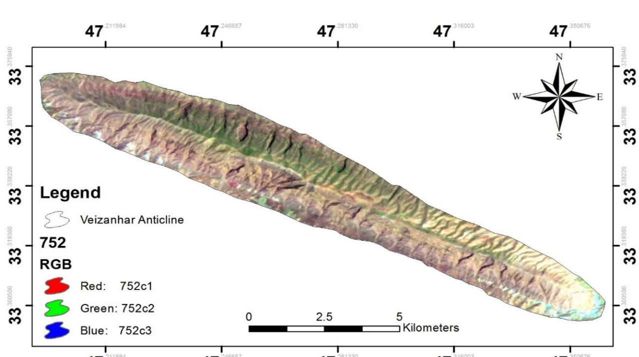

Figure 6. Band 752 combination for studying the lineaments of Vizenhaar Anticline (for geological studies)

In this study, after detecting fractures and faults using processed images, we transferred them to ArcGIS software. The fault and fracture trend was plotted using a rose diagram in ArcGIS software environment, and finally, ISODENSITY map of faults and fractures was prepared.

3. Results and Discussions

In this research, the goal of processing data such as satellite images and digital elevation model is to identify and extract fractures and faults of Vizenhaar Anticline. For this purpose, a combination of information layers from the mentioned processes can be used. At this stage, all information layers are fed into ArcGIS software so that fractures and faults can be mapped from their overlap. On each layer of processed information, a series of lineaments can be identified that are visually recognizable. After extracting the lineaments through comparing them with band combinations and maps obtained from the digital elevation model as well as geological map of the region, the lineaments and faults of Vizenhaar Anticline fractures and faults were separated from the other lineaments and their Shapefile map was prepared (Fig. 7).

Vizenhaar Anticline is located in southwestern part of Lorestan Province in folded Zagros sub-zones with a northwest-southeast direction. The rock lining of Vizenhaar anticline is Asmari-Shahbazan limestone. In this research, after mapping anticline fractures and faults using ArcGIS software, their density map was prepared (Fig. 8).

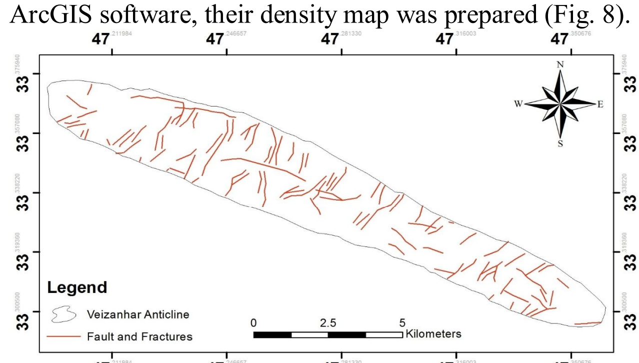

Figure 7. Fracture map and faults of Vizenhaar Anticline

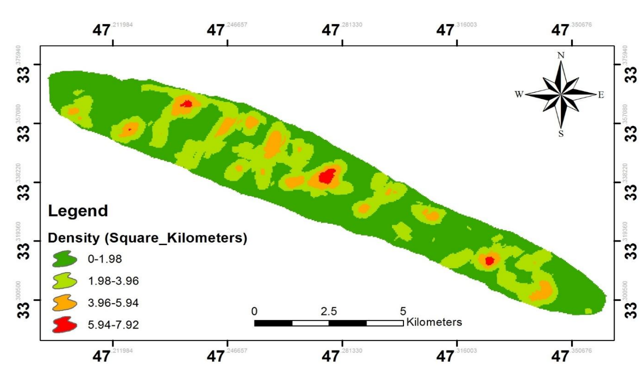

Figure 8. Density map of fractures and faults in Vizenhaar Anticline

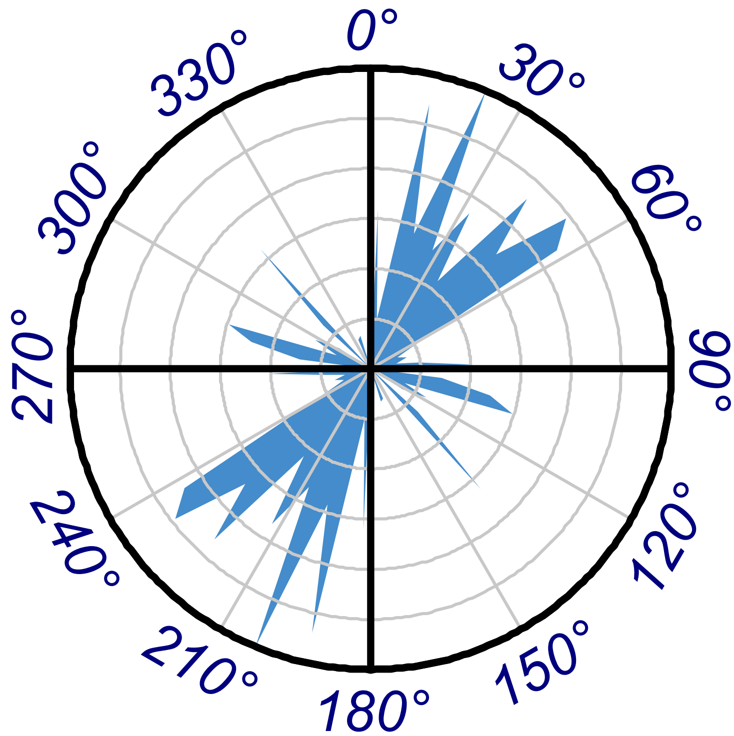

Figure 9. Rose diagram of fractures and faults of Vizenhaar Anticline fractures and faults

The results show that the highest density of faults and fractures is in three parts: west, center and east of the anticline. Polar-Plots extension in ArcGIS software environment was used to plot rose diagram of faults and faults (Fig. 9). The results obtained from this diagram showed that the predominant trend of fractures is northeast-southwest, which is perpendicular to the pressure trend prevailing in the region.

4. Conclusion

Most studies on fracture and fault modeling in each region depend on the analysis of lineaments. In this research, a remote sensing technique (OLI sensor satellite images) was used to prepare an integrated digital map of the lineaments in the region. Satellite imagery and digital elevation model along with geosciences are a suitable tool for the extraction of lineaments, and results of this extraction have high accuracy. The point to be considered in this method is the extraction of all existing lineaments, including edges, waterways and roads after applying directional filters on images, which should be identified by an expert decision and removed from fractures and faults through comparing band combinations from the region. Therefore, using remote sensing techniques, fracture maps and faults of Vizenhaar Anticline located in southwest of Lorestan province was prepared and the following results were obtained, which we hope will be used to explore oil wells in the anticline:

A) Using directional filters and applying them on satellite images is one of the fastest and most accurate methods for extracting faults and fractures.
B) Due to vastness of the area and unavailability of some parts of it, identifying faults and fractures is a difficult and time consuming task in normal conditions; therefore, the purposeful use of remote sensing techniques can play a significant role in detecting and plotting many fractures and faults in the area.
C) Surveys show that the fractures of the region are composed of two categories: longitudinal and transverse. Northeast-southwest transverse fractures are the predominant trend of Vizenhaar Anticline fractures.
D) The results obtained from ISODENSITY map of faults and fractures in the region show that the highest density of faults and fractures is in western, central and eastern parts of Vizenhaar Anticline.
E) Field studies show that remote sensing method has a high accuracy in identifying fractures and faults on the surface of Vizenhaar Anticline.

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