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Lineament Patterns and Mineralization Related to Alteration Zone by Using ASAR-ASTER Imagery in Hize Jan-Sharaf Abad Au-Ag Epithermal Mineralized Zone (East Azarbaijan—NW Iran)

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Abstract

East Azarbaijan belongs to the Iranian plateau and is part of lesser Caucasus province. Studied area is located in west-central Alborz. The intrusion of oligocene bodies in various units causes the alteration and mineralization in northwest of Iran. The Hizejan-Sharafabad is one of this named mineralized zone. Granitoidicrocks with component of Granodiorite to alkali have been influenced by hydrothermal fluids. Fractures and faults are as weak zone in earth surface and hydrothermal fluids rise to surface by these geological structures. These solutions cause to alteration in host rocks. Alteration zones are important features for the exploration of deposits. The altered rocks have specific absorption in some spectral portion and ASTER sensor is able to identify the type of alteration. Remote sensing method is useful tool for discovering altered area. The purpose of this study is to appraise ASTER data for surveying altered minerals in Hizejan-Sharafabad area in the event of detecting the potential mineralized areas. In this research, False Color Composite (FCC), Band ratio, and color composite ratio techniques are applied on ASTER data and Silica, Argilic, and Propylitic alteration zones are detected. These alteration types and mineralized area are related to Hizejan–Sharafabad fault which is absent in the fault maps. ASAR image processing has been used for lineaments and faults identified by the aid of Directional and Canny Algorithm filters. The structural study focuses on fracture zones and their characteristics including strike, length, and relationship with alteration zones.

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Keywords

Hizejan-Sharafabad Lineament, ASTER Image, ASAR image, NW Iran, Directional and Canny Algorithm

1. Introduction

This research is done with the aim of identification of altered zones associated with lineament patterns. The term “Lineament” is a commonly used term in geological remote sensing. The classification of lineaments, its direction and length can be easily specified by using satellite images. The automatic lineaments extraction in this research is performed by the directional filter of ENVI and Canny Algorithm in MATLAB software.

The area is within zone 38S of Universal Transverse Mercator coordinate system. The upper left and lower right coordinates of the study area are 4292744N, 610192E and 4260783N, 634422E, respectively. The total area covered is about 350 km^2.

The study area is situated in north-west part of Alborz, Iran (**Figure 1**). From tectonics view, it contains deformed zone of Cimmerianminiplate [1]-[3]. Based on previous work on the salt and mud diapirism [4]-[15] and

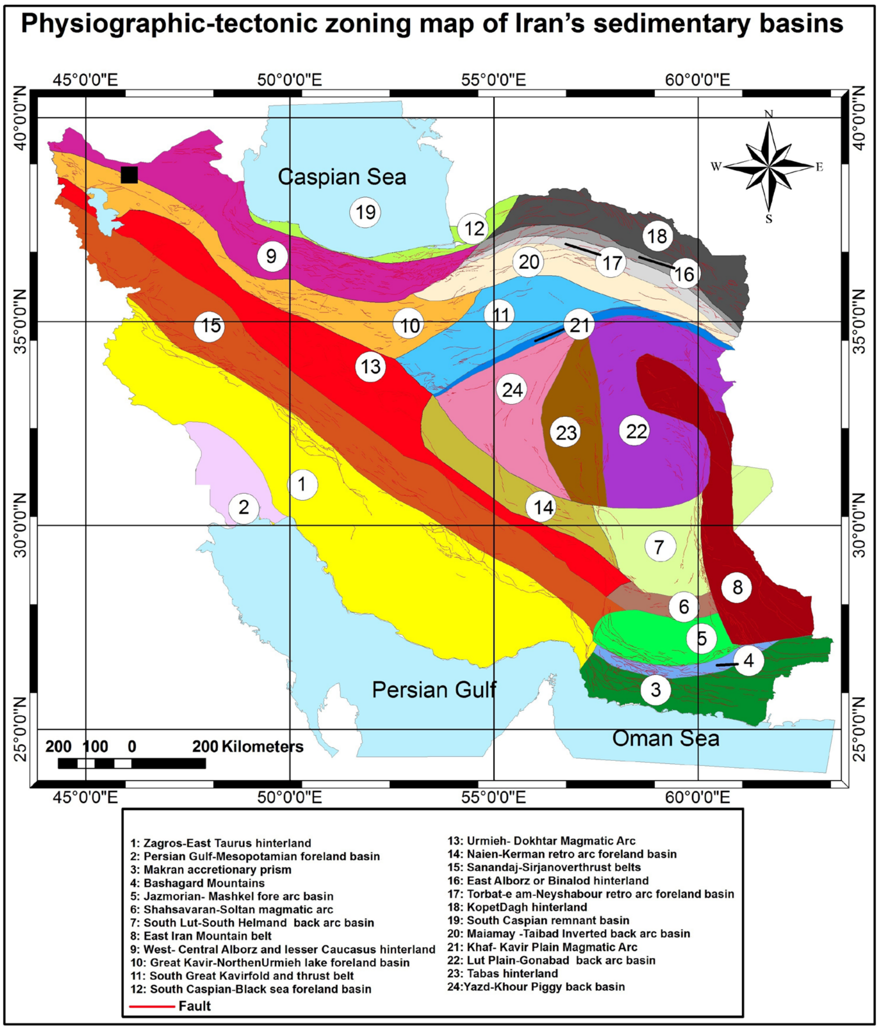

Figure 1. Physiographic-tectonic zoning map of Iran’s sedimentary basins, modified from [1] The study area isshown in the black rectangle.

neotectonic regime in Iran [16]-[21], Zagros in south Iran is the most activezone [22]-[43]. Then, Alborz [44]-[83] and Central Iran [84]-[99] have been situated in the next orders. General geology of study area has published by [100] [101]. Lithostratigraphically, the oldest rocks are of upper cretaceous age and consist of flysch type rocks and mafic to intermediate submarine volcanic rocks. They are composed of micritic limestone, sandstone, shale and mudstone. These sedimentary rocks have been folded and the calcareous layers decrease in abundance from west to east. Submarine volcanic activity is characterized by rocks of mafic to intermediate composition (andesite, basaltic andesite and pyroxene andesite) interlayered with the sedimentary sequence.

2. Materials and Methods

2.1. Software

The several types of software used for this research include: ENVI v5.1, Rockwork v16, ILWIS3.31 academic, MATLAB, and ARCGIS v10.3 were mainly used for processing and analysis of multi-spectral and single band images. ArcGIS v10.3 was used to georeference, digitize and capture various maps in a database.

2.2. Data Acquisition and Preprocessing RADAR (ASAR) Data

Radar is an active form of remote sensing that provides its own source of electromagnetic energy to illuminate the terrain. Radar energy is measured in wavelengths of centimeters that penetrate rain and clouds which is an advantage in tropical regions. Another advantage is that radar images may be acquired at a low depression angle that causes pronounced highlights and shadows that enhance subtle topographic features. These features are commonly the expression of faults, fractures, and lithology. Radar images of vegetated regions record the vegetation surface, rather than the underlying terrain. Satellite image of the area is the main data used in this study.

Considering spatial resolution of the available satellite images and the size of the study area, ASAR (Advanced Synthetic Aperture Radar), C-Band imagery (ASAR-IMP-IPN UPA), the data acquired on 06 07 2006 is select for this study. Lineament mapping is considered as a very important issue in different disciplines to solve certain problems in the area. For example, in sites election for construction a dams, bridges, roads, etc., for mineral exploration [102], for hot spring detection and hydrogeological research [103] the nature and the pattern of the lineaments should be known. The classification of lineaments and its direction and length can be easily demarcated using satellite image. RADAR (ASAR') imagery was used to classify the various geological, discriminate the lithology and structure of area, and delineate the associated zones of hydrothermal alteration a wide variety of digitalimages processing technique were applied.

2.3. Directional Filters

The automatic lineament extraction in this study is performed by the directional filter and Canny Algorithm of ENVI v5.1, Rockwork v16, ILWIS3.31 academic, MATLAB, and ARCGIS v10.3 software respectively. The image enhancement is one of the useful tools to improve the interpretability. One of those enhancements is edgesharpening enhancement technique for enhancing the edges in an image. Directional filters (edge detection filters) are designed to enhanced linear features such as roads, streams, faults, etc. the filters can be designed to enhance features which are oriented in specific directions. Directional filter is applied to the ASAR image in N-S, E-W, NE-SW, and NW-SE directions to increase frequency and contrast in the image. The filtering operation will sharpen the boundary that exists between neighbor units [104].

The best results were obtained for single band using the following matrix (**Figures 2-6**).

A remotely sensed lineaments map (**Figure 7**) was produced depending on directional filters and edge enhancement. This map presented the lineaments detected and ascribed to potential faulting in the present work. There is a general compromise between the macro-scale and the faults previously mapped by geological survey of Iran (Siyahrood 1:100,000 sheet) in **Figure 8**. The geological map georeferenced to the UTM zones 38S projection using WGS84 datum. The orientations of lineaments were created by using rose diagrams (**Figure 9**) and trends observed in the structural map field features and the lineament map could be recognized in these diagrams, showing strongly major trend in NW-SE in this area fractures and faults acts as an apertures to flow of fertile Fluids that are rich in metals (**Figure 10**).

The precision of lineament map is calculated by using ArcGIS overlay technique that determines where the lineaments and faults are matched. The output of these operation product two types of lines.

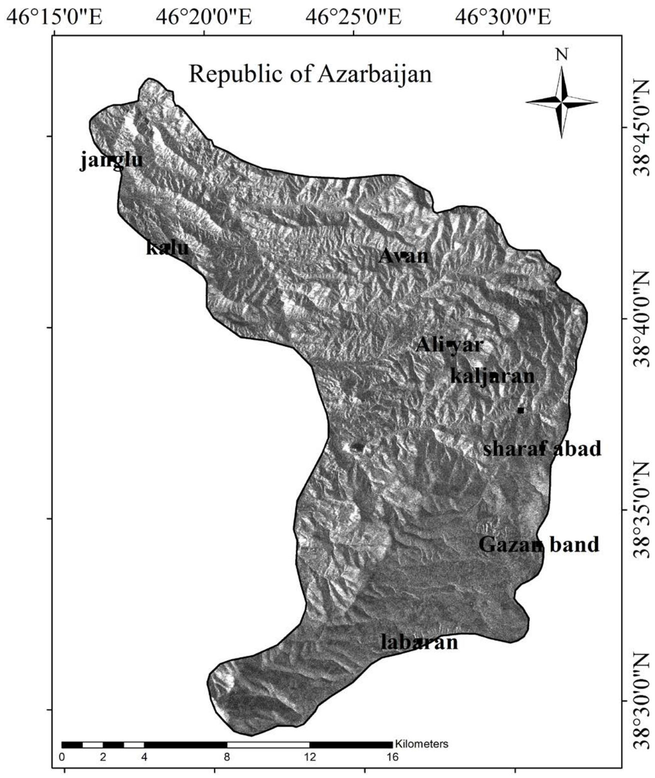

Figure 2. RADAR (ASAR) imagery of Hizejan-Sharafabad area.

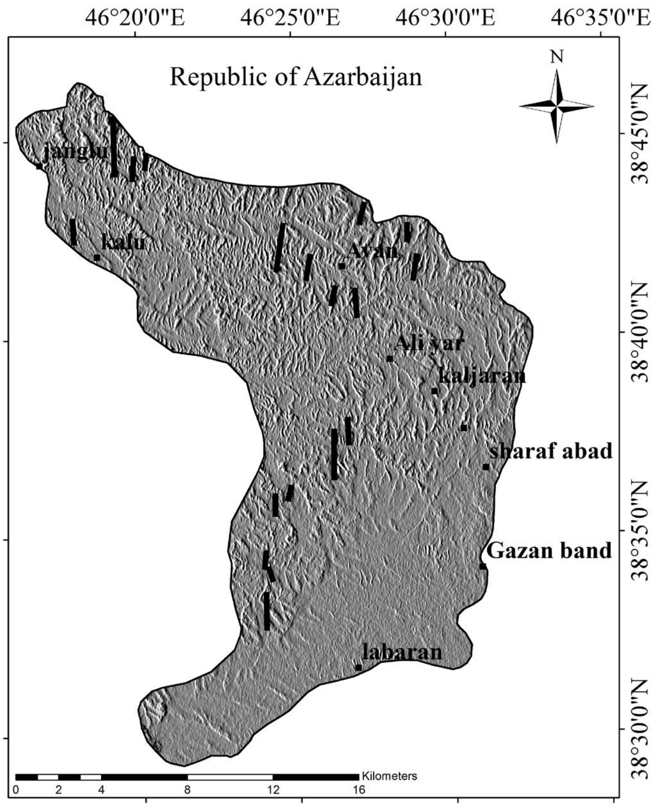

Figure 3. N-S directional filter and extracted lineaments.

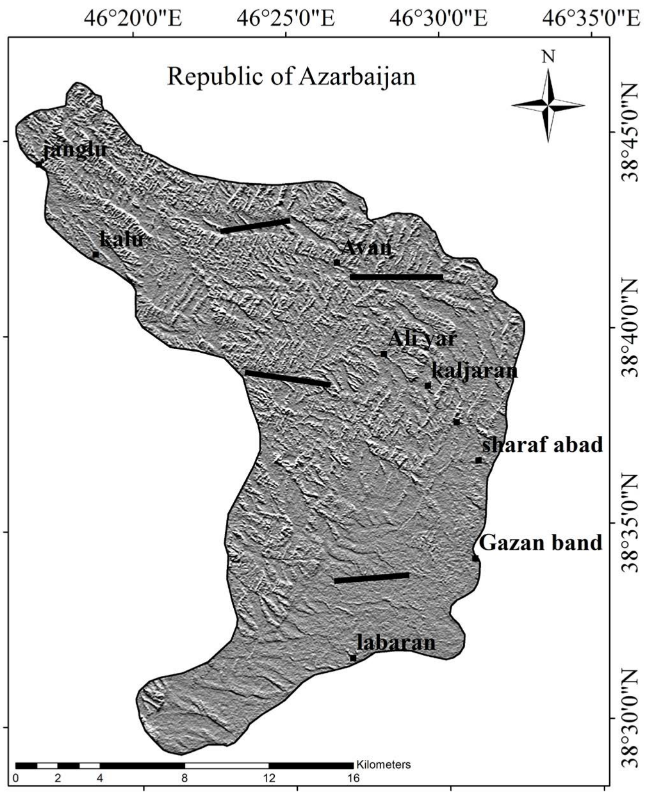

Figure 4. E-W directional filter and extracted lineaments.

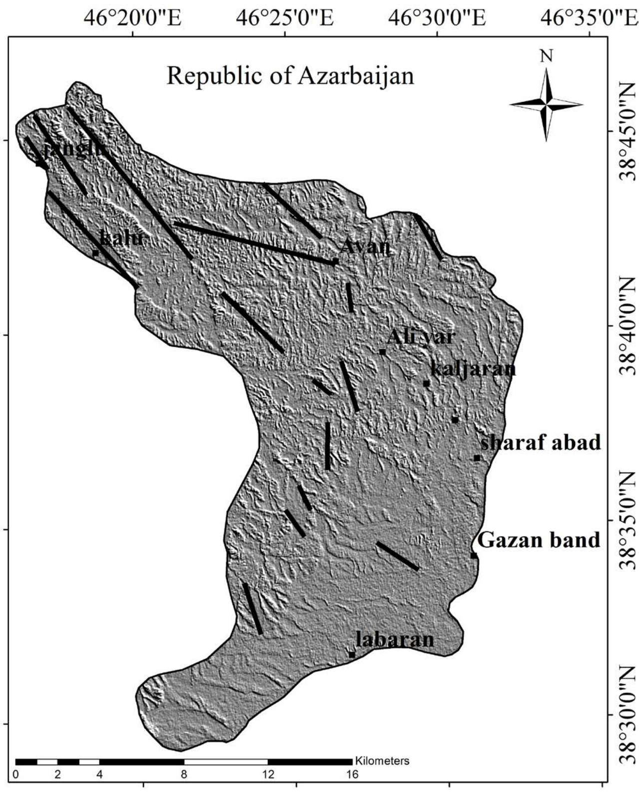

Figure 5. NW-SE directional filter and extracted lineaments.

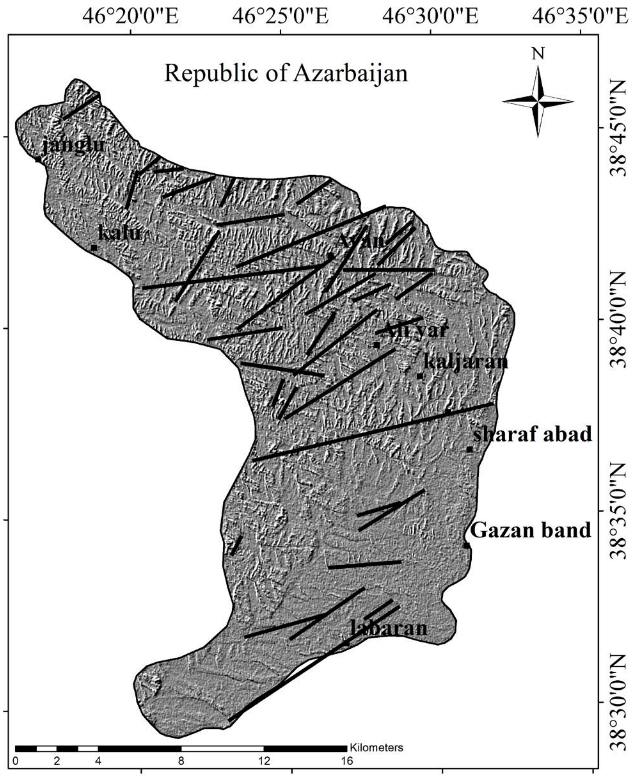

Figure 6. NE-SW directional filter and extracted.

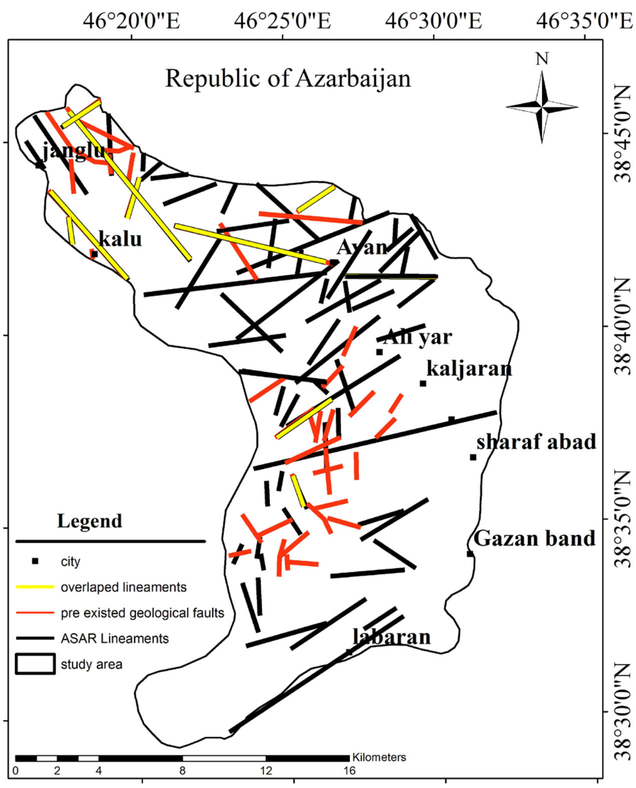

Figure 7. Lineaments map generated after directional filtering operation.

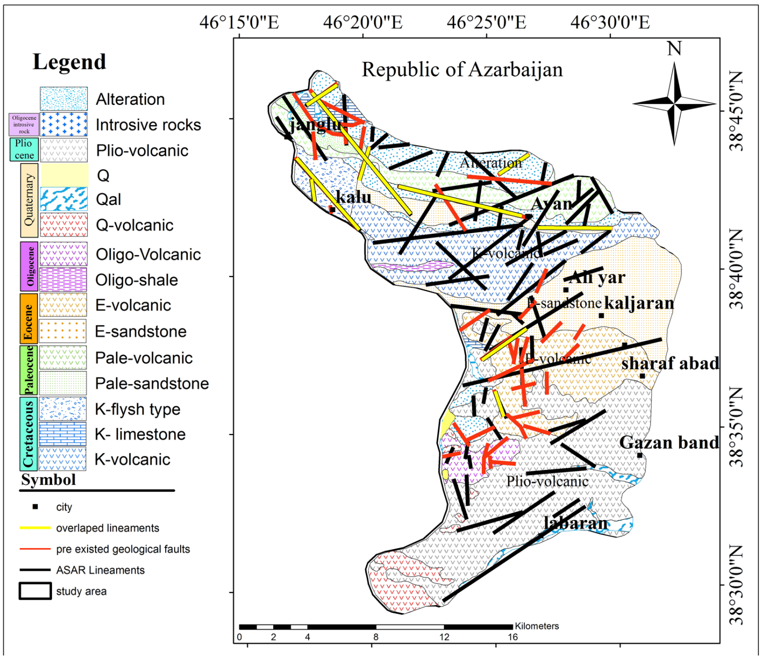

Figure 8. Map of previously verified faults by geological surveyof Iran.

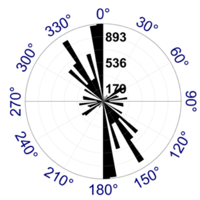

Figure 9. Dominant directions of lineaments.

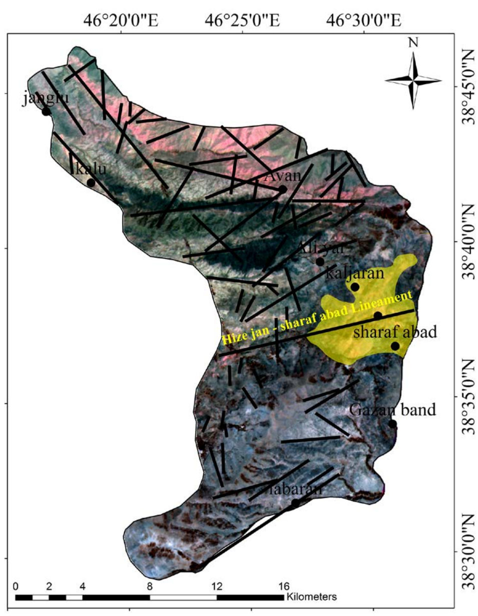

Figure 10. integration of ASAR-ASTER imagery and extracted lineaments (Hizejan-sharafabad Lineament) and relation with Alteration zone map (Yellow polygons).

1) Non-matching lineaments: these are the lineaments that do not match to any fault line (shown as black lines in the figure and these lineaments are newest lineaments that identified by ASAR imagery).

2) Matching lineaments and fault lines: these are the segments in yellow both lineaments and faults exist.

2.4. Canny Algorithm

Lineaments have important role in initial exploration of geologic structure, mineral exploration. This work, canny algorithm with different kernel windows size is a main component and new geomatical tool for lineament extraction. In this section, automatic detection algorithm such as Canny is performed to acquire excellent accuracy of lineament extraction. Prior to implementations of automatic edge detection processing, ASAR data is enhanced and then geometrically corrected and in second step, manual digitizing of lineaments are visualized after performing appropriate image enhancement tool.

The Canny edge detector is an edge detection operator that uses a multi-stage algorithm to detect lineaments features in images. It was developed by John F. Canny in 1986. Canny also produced a computational theory of edge detection explaining why the technique works. Indicative result of the application of the selected algorithm is illustrated in **Figure 11**.

2.5. ASTER Data

ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) is an advanced multi-spectral satellite imaging system, which was launched on February 11, 2013 by NASA. It measures reflected radiation in VNIR (0.52 and 0.86 μm), SWIR (11.6 to 2.43 μm), and emitted radiation in TIR wavelength region (8.125 to 11.65 μm) with 3, 6, 5 bands and 15 m, 30 m, 90 m resolution, respectively [105]. Since 2000, ASTER has been successfully used for hydrothermal alteration mineral mapping in well-exposed areas.

Based on the spectral properties of typical alteration mineral and geological background, four image processing techniques were selected to recognize different alteration minerals, including Band ratio, colorcomposite, and colorcomposite ratio. Hydrothermal ore deposits are created by the activity of fertile fluids that are rich in metals. Remote sensing used in mineral exploration of hydrothermal ore deposits often use the spectral

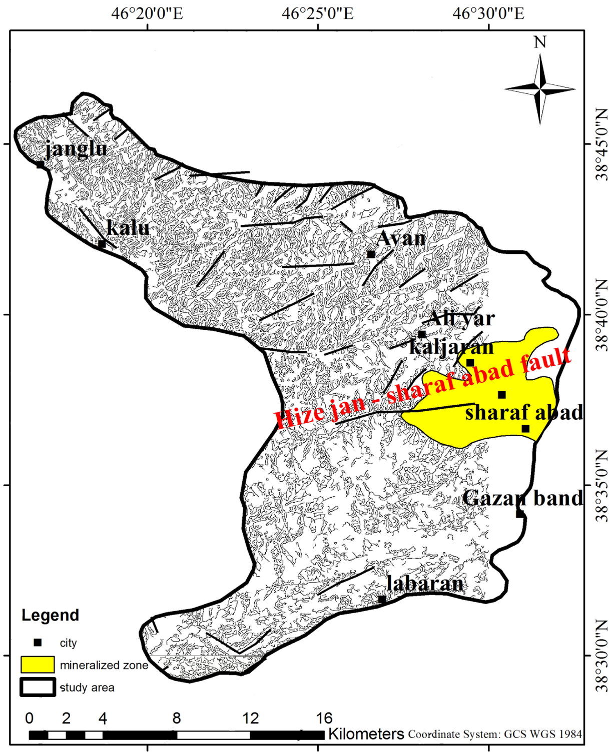

Figure 11. The canny algorithm applied on the ASAR image.

features of thealteration minerals at wavelength of 2.0 to 2.5 µm to find alteration zones and identify alteration minerals. Features of ASTER image is shown in **Table 1**.

3. Results and Discussion

The human eye is capable of discriminating about 30 grey levels in the black to white range [106] but muchmore sensitive color differences to recognize color patterns.

3.1. False Color Composite (FCC)

For any band of multispectral image, the interpreter can placement a display color and it be done in freewill ways. In the displayed image, the color of an object dose not has any similarity to its true color and is known as a FCC image. There are various methods to producing FCC image and some of these methods can be more appropriate for identifying sharp objects in the produced image. In the order to identify hydrothermal alteration zones and alteration minerals in different altered rocks, kind of FCC of multispectral image were used. Generally, granite units and mafic to ulteramafic intrusive bodies are important targets for exploration because they are caused to alteration. Because of high resolution of VNIR region, created false color of this region provide more structural features. To identification of alteration units, by applying bands 468 (in SWIR region of RGB Respectively) and created false color image alteration zones appear as specified colors. Advanced argillic alteration (alunite, kaolinite) and phyllic alteration (sericite, smectite) are indicated in red to pink, propylitic alteration (chlorite, epidote) is indicated in pale green and calcareous units are indicated in yellow. Advanced argillic and phyllic alteration appear as red to pink. Propylite alteration chlorite or epidote, appear as palegreen and Carbonate rocks appears as yellow as distinct features identifiable without error (**Figure 12**).

TIR region contain spectral emissivity and temperature information and are useful for identifying silicate rocks because of its spectral emissivity features due to the lattice vibration of Si-O. By assigning of TIR region (14, 12, and 10 = RGB respectively) helpful to identify mafic to ulteramafic rocks and silica rich felsic rocks (**Figure 13**) [107]-[110].

3.2. Band Ratio

Rocks and minerals have specific absorption and reflectance in some spectral portion. Band ratioing is the very useful technique in the Remote Sensing for detection of altered rocks and minerals. Different authors [111] [112] have been used band ratio techniques for geological mapping and surveying. Advanced argillic alteration contain alunite and kaolinite altered minerals and identifying these targets in the SWIR region we use bands 5 and 6 because alunite and kaolinite have more absorption in these bands and can be enhanced by band ratio of b4/b6 (**Figure 14**).

Propylitic alteration contains chlorite, epidote, and altered minerals. These minerals have absorption at band 8

Table 1. Varying spatial, temporal and spectral resolutions of satellite imagery.

Subsystem	Band No.	Spectral Range (µm)	Radiometric Resolution	Absolute Accuracy (σ)	Spatial Resolution	Signal Quantization Levels
VNIR	1 2 3N 3B	0.52 - 0.60 0.63 - 0.69 0.78 - 0.86 0.78 - 0.86	NEΔρ ≤ 0.5%	≤±4%	15 m	8 bits
SWIR	4 5 6 7 8 9	1.600 - 1.700 2.145 - 2.185 2.185 - 2.225 2.235 - 2.285 2.295 - 2.365 2.360 - 2.430	NEΔρ ≤ 0.5% NEΔρ ≤ 1.3% NEΔρ ≤ 1.3% NEΔρ ≤ 1.3% NEΔρ ≤ 1.0% NEΔρ ≤ 1.3%	≤±4%	30 m	8 bits
TIR	10 11 12 13 14	8.125 - 8.475 8.475 - 8.825 8.925 - 9.275 10.25 - 10.95 1.95 - 11.65	NEΔT ≤ 0.3 K	≤3K (200 - 240 K) ≤2K (240 - 270 K) ≤1K (270 - 340 K) ≤2K (340 - 370 K)	90 m	12 bits

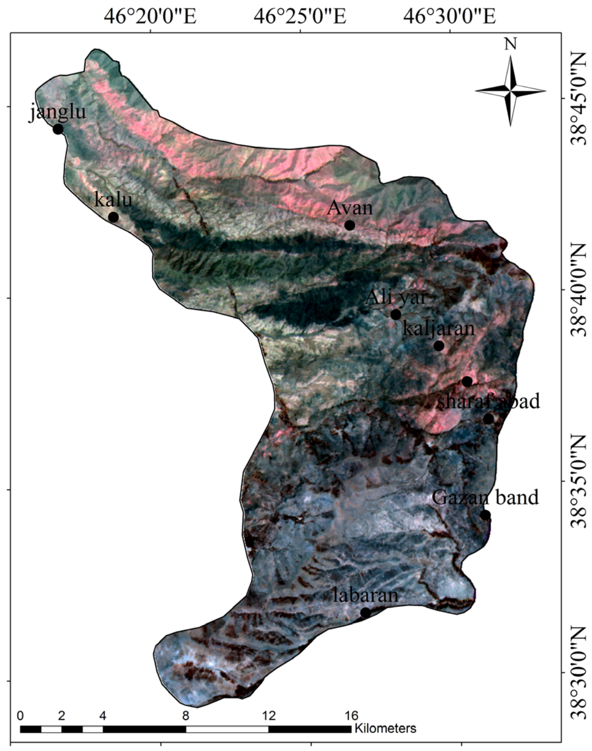

Figure 12. In the SWIR false color image, advanced argillic (alunite, kaolinite) alteration and phyllic alteration (sericite, smectite) appear as pink, propylitic alteration (chlorite, epidote) appears as green and calcareous units appear as yellow.

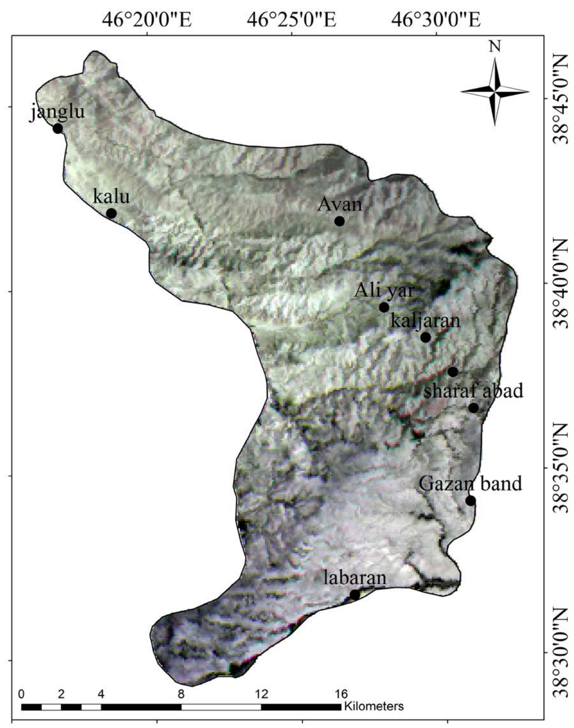

Figure 13. Color composite in TIR region (R: 14, G: 12, B: 10) to identify mafic-to-ulteramafic units and quartz rich felsicunits.

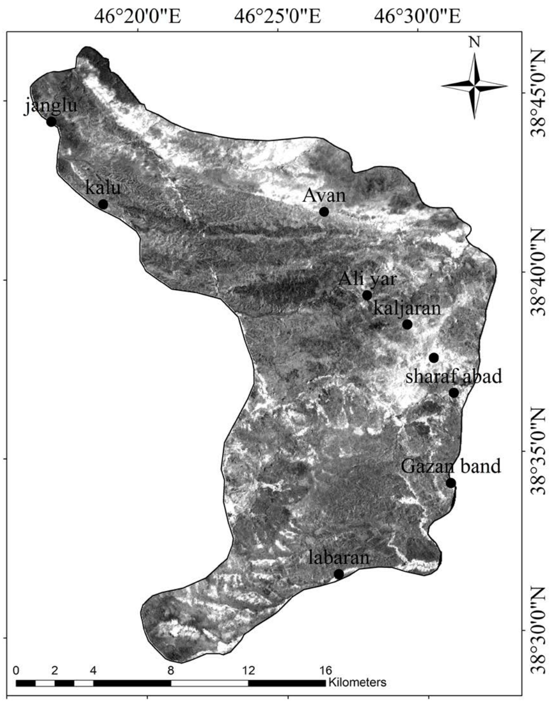

Figure 14. Alunite and kaolinite identification enhanced byband ratio of b4/b6.

and for identification can be enhanced by band ratio b5/b8 (**Figure 15**).

To identify quartz [113] used band ratio (b13/b12) and for ferric iron oxide minerals used band ratio (b2/b1) (**Figure 16**, **Figure 17**).

3.3. Color Composite Ratio

Color composite ratio images are produced by combining three ratio images in blue, green, and red. According to **Figure 18** band ratios 3/5, 3/1, and 5/7 in red, green, and blue, respectively. The brown and yellow-green hues represented Au-Ag mineralized zone (**Figure 18**).

For mapping alteration zones [114] has used band ratio composite of (B2/B1, B4/B9, and B3/B2) in RGB respectively and in resulted map the yellow color represents the hydrothermal alteration zones (**Figure 19**).

Advanced argillic alteration, phyllic alteration, propylitic alteration and calcite can be identified by the color composite image of band ratios by applying advanced argillic alteration to red, phyllic alteration to green and propylitic alteration to blue (B4/B6: B5/B6: B5/B8) (**Figure 20**).

4. Conclusions

This research presented an investigation into integration satellite Remote Sensing and ArcGIS techniques for detecting lineaments that might be related to faults and mineralization zones. To achieve these goals we used ASTER and RADAR (ASAR) imagery as following.

At the first step, an RADAR (ASAR) single-band image has been processed for lineaments identification; at the second step, ASTER multi-spectral images have been applications mainly related to mapping rock types and identified alteration zones; and at the end step, relationship between lineaments and alteration zones has been investigated.

The results show that directional filter provides highly precisely lineaments information compared to canny algorithm. Also, integration between Canny algorithm and directional filter can be used as an excellent tool to understand variation of lineament density. The spectral attributes of hydrothermally altered rocks provide a basis for mapping the alteration minerals using ASTER VNIR + SWIR + TIR data, and also ASAR data improves the accuracy of analyzing geological structures specially lineament identification. Band ratio, color composite, and

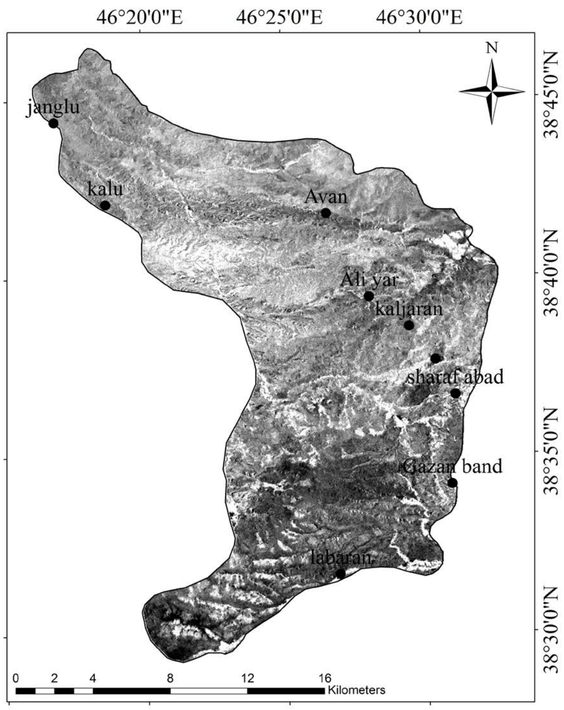

Figure 15. Chlorite, epidote and calcite enhanced by band ratio b5/b8.

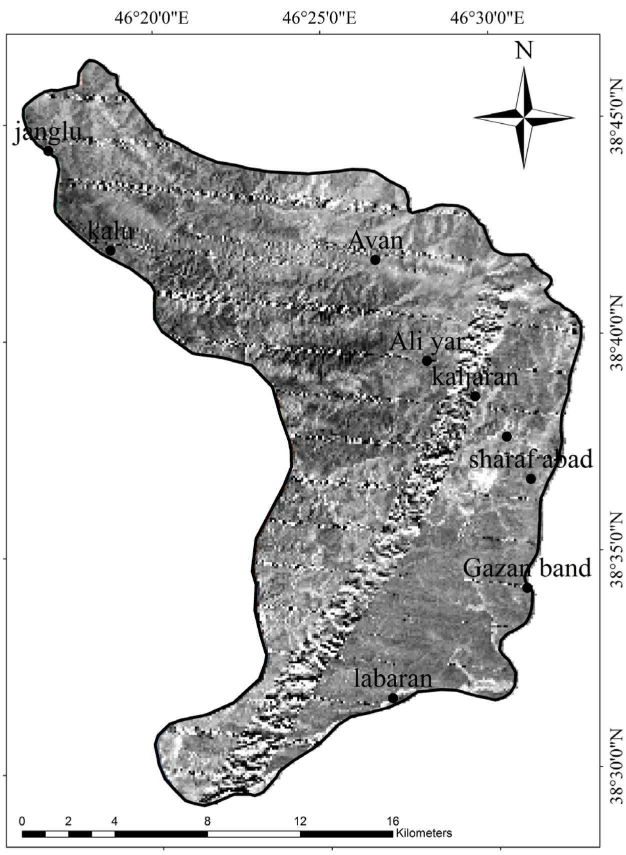

Figure 16. Band ratio (B13/B12) for mapping quartz.

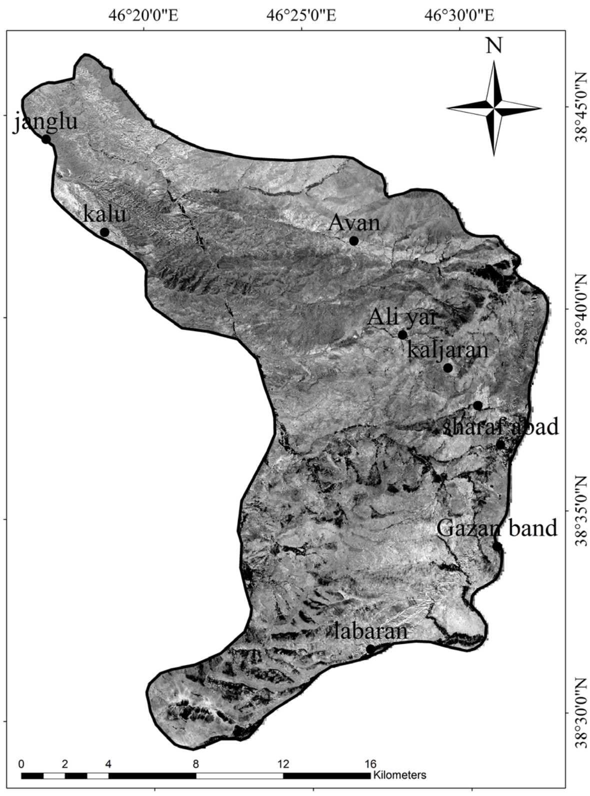

Figure 17. Band ratio of B2/B1 for ferric-iron oxide minerals.

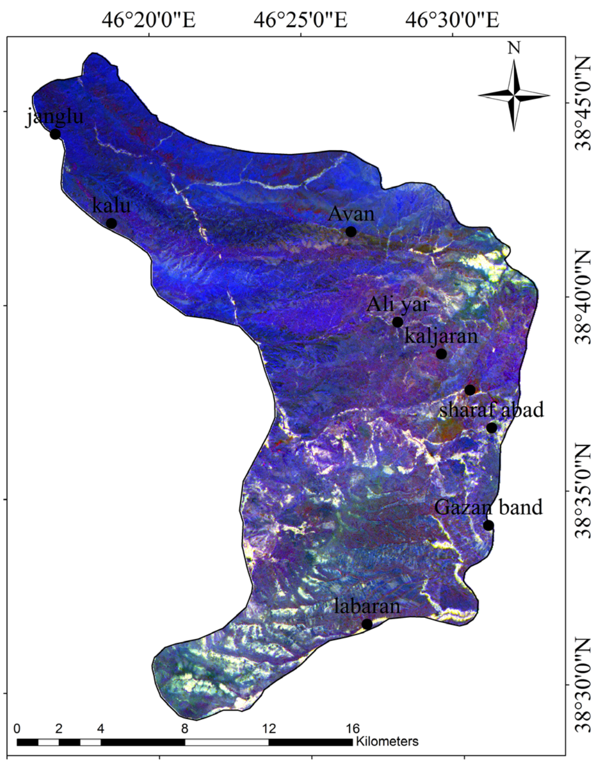

Figure 18. Color composite ratio of band ratios B3/B5, B3/B1, and B5/B7 in RGB respectively.

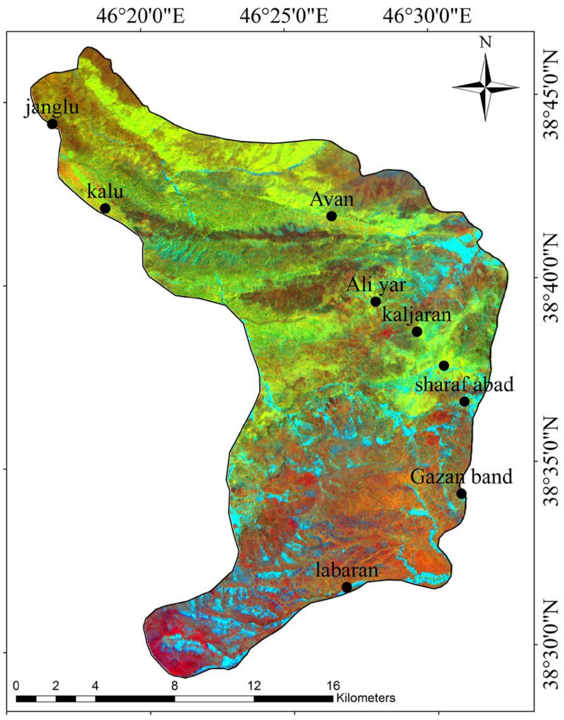

Figure 19. VNIR and SWIR color composite ratio images created by applying band ratio B2/B1, B4/B9, B3/B2 to red (R), green (G), and blue (B) (R:G:B) that yellow color represents the presence of hydrothermal alteration.

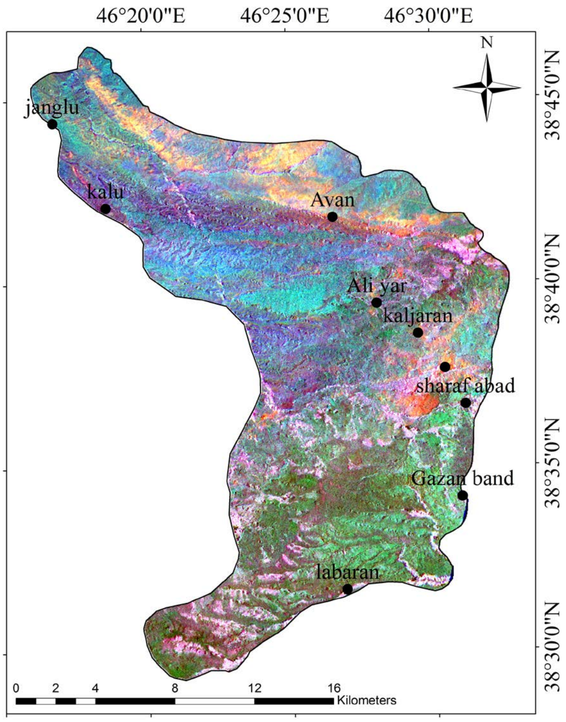

Figure 20. Color composite image of band ratios by applying advanced argillic alteration to red, phyllic alteration to greenand propylitic alteration to blue (R:G:B = 4/6:5/6:5/8).

color composite ratio are selected for detailed alteration minerals mapping and Silica, Argilic, and Propylitic alteration zones are detected. The four methods have high-level of similarity in the mapping results presented by recent authors. Evaluation of the density and orientation of the lineaments (NW-SE) indicates that several fault segments are identified in the region which are absent in the fault map due the difficulty in mapping during the field studies. In Hizejan-Sharafabad area, fractures and crushed zone act as a weak zone to up heave of hydrothermal solution into the rocks and cause to alteration and mineralization in host rocks. It is concluded that the proposed methods can be used as a powerful tool for ore deposit exploration; ASTER images can be employed for mineral characterization; and ASAR data can be employed for lineaments identification. In conclusion, we have shown that identification of hydrothermal alteration zones over wide area is possible and detailed information on alteration for the purposes of exploration of mineralized zones can be obtained using the proposed ASTER image creation methods.

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