Available online at https://sanad.iau.ir/journal/jrors
Publisher: Ya.C., Islamic Azad University
Journal of Radar and Optical Remote Sensing and GIS
Print ISSN:2645-484X Online ISSN:2645-5161

Investigating the Relationship Between Fault Activity and the Occurrence of Travertine Deposits in the Southwest of Yazd Province by RS & GIS Technique

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Article Info

Article type:
Research Article
(Article, Review, Short Communication, etc.)

Article history:
Received February 20, 2023
Received in revised form May 16, 2023
Accepted July 25, 2023
Published online September 26, 2023

Keywords:
RS,
GIS,
Fault,
Building stone,
Travertine,
Geothermal source

ABSTRACT

The western and southwestern part of Yazd province, which has a good mineral potential due to its special geological location and proximity to the Dehshir-Baft major fault and other micro-faults in the region, can be mentioned as a result of the activity of this fault, such as marble travertine quarries. Among the rapid and emerging methods for exploration the aforementioned building stone quarries is the use of GIS and RS techniques. In this study, the two aforementioned techniques were used to determine promising areas for exploring building stone quarries. Remote sensing studies were carried out in the ILWISE software environment. After analyzing the Landsat satellite images of the desired area, a false color image 347 was used for further studies. In the Arcview environment, information layers were created including the location of travertine masses and the distribution of faults in the region to explore building stone quarries. The false color image showed a close and tight relationship between the faults in the area and the distribution of travertine masses. Therefore, this model can be used to limit the exploration and exploration of travertine masses to areas where faults are concentrated. In the northwestern part of the Dehshir fault, numerous travertine masses were identified after studies on the 1:100,000 Dehshir map and the relevant satellite image, which have mining potential.

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Cite this article: Hemmati, A. (2025). Investigating the Relationship Between Fault Activity and the Occurrence of Travertine Deposits in the Southwest of Yazd Province by RS & GIS Techniques. ***Journal of Radar and Optical Remote Sensing and GIS***, *7*(3), pages.7-19

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Introduction

The Dehshir fault is located on the southern slope of the Shirkuh range and it's extend is almost similar to the extent of the main Zagros fault. This fault is considered an important area in terms of the appearance of mixed colored rocks. To the west and southwest of this fault, the Gavkhuni, Abarkuh and Sirjan pits have been formed (Nabavi, 1976). The Dehshir fault is about 350 km long with a northwest-southeast direction starting from Naein and continuing to around Sirjan. One of the most important features of this fault is related to its neotectonic activity. Around the main fault and even along its subsidiary faults, the displacement of dry watercourses has occurred in connection with the mainly right-slip movement of the faults. This phenomenon is fully determined through the study of aerial photographs and satellite data and aerial magnetic maps of the region. Along the fault zone, young alluvial fans have formed on top of older fans, which is a sign of the uplift of the watershed in the fault zone. Such morphological phenomena together indicate the new function of the Dehshir fault. Travertine-producing springs and related domes are seen along the fault, which mostly occurred along the tectonic seams associated with it. In this study, Remote sensing and GIS was used to investigate the relationship between the fault and micro-faults in the region and the travertine masses.

The first satellite dedicated to natural resources and geological studies was launched and put into operation by NASA in 1972. This satellite was named Landsat. This satellite had devices called Multi Spectral-Scanner, which is why it was called MSS. The information was in four bands and with a spatial resolution of 80 meters. The next generations of Landsat had more and more accurate information bands and were referred to as TM. In 1999, the United States placed the Landsat satellite with the ETM0+7 sensor in Earth orbit, which was capable of collecting information in near-infrared and short-infrared wavelengths. The resolution of this satellite is within 30 meters for the visible and infrared bands, 60 meters for the thermal infrared band, and 15 meters for the PAN band. Today, satellite information is used for various purposes such as: mineral exploration, geological mapping, environmental studies, water resource studies, natural resources and natural disasters (Karimpour, 2005).

Each satellite image consists of a series of elements or pixels arranged in rows and columns, called a raster array. Each pixel has a numerical value, called a digital number or DN, which represents the intensity of the measured electromagnetic energy. generally, digital image processing involves the following steps (Gupta, 1991).

A. Image preprocessing and preparation; B. Image enhancement; C. Information classification and final processing. In the preprocessing stage, a series of operations on raw data, atmospheric radiometric errors, geometric, etc. are considered. The purpose of image enhancement is to improve the visual interpretation and interpretation of an image by increasing the apparent discrimination between phenomena in a landscape. Effective enhancement methods include: image expansion, filtering, false color image, spectral attribution and vegetation indices. In the classification and final processing stage, information extraction is performed by separating similar spectral sets and dividing them into classes that have the same spectral behavior (Alavipanah, 2006).

Image enhancement

The purpose of image enhancement is to increase the visual recognition of these small differences in order to make them visible in a simple and easy way. The unenhanced image is called the raw image, which is dark and lacks stretch. The mean value is approximately 30 and the data occupies the range between 0 and 60, which is 25% of the range 0 to 255, which causes low contrast and consequently darkening of the image. Therefore, each initial Landsat image needs to be enhanced to become a useful and usable image. One type of contrast enhancement method is linear stretching. In a simple linear stretching, the lowest DN is assigned a new value of zero and the highest DN is assigned a new value of 255, and the numerical values are linearly transformed to new values from 1 to 255 (Lillesand and Kiefer, 1994). Another type of image enhancement method is histogram enhancement.

Filtering

Filters are divided into three main groups: low-pass filters, high-pass filters, and edge-enhancing filters. A filter usually contains an array of 33 (kernel) coefficients. However, arrays of 5x5 or 7x7 and even higher are also available. A filter is like a window that moves across the width of the image and includes all DN values within the window. Each pixel value is multiplied by the corresponding filter coefficient, and the 9 results are summed, and the final value replaces the initial value in the center pixel (Alavipanah, 2006).

False Color Image

Digital images are usually displayed as color composites using the three colors red, green, and blue. This representation is widely used in digital processing to display normal color composites, colored infrared, and various other color composites. ETM+ bands are also commonly used to create color images for geological imaging. All three of the six visible and infrared bands can be combined into the three colors blue, green, and red to create a false color image, but the choice of which three bands to select for the composite is important. Using the six ETM+ bands, it is possible to create about 120 color composites. However, only a few of these composites are theoretically and experimentally suitable for various applications, including geology (Lillesand and Kiefer, 1994).

Band Ratio

This operation is obtained by dividing the DN values in one spectral band by the DN values corresponding to the other band for each pixel. The main advantage of these images is that they convey the color or spectral characteristics of the image phenomena regardless of the changes in the lighting conditions of the scene caused by topographic changes, emphasizing the given color content. The usefulness of any desired spectral ratio depends on the specific reflectance characteristics of the phenomena involved and the intended application. For the 6 non-thermal ETM+ bands, 30 ratio combinations are possible.

Geographic Information System (GIS)

One of the most important advantages of processed digital satellite data is the ability to store it as an information layer in a GIS system and integrate it with other information layers for modeling and mapping mineral potential (Karimpour, 2005).

A GIS system consists of hardware and software with an interface (user) that provides access to specific operations and goals. For a GIS to be useful, it must be able to receive and produce information effectively. The creation and implementation of a GIS includes data entry, data management, data analysis and processing, and finally data output. Input data includes spatial data that shows the geographical location of features and non-spatial descriptive data that describes the characteristics of features. Data entry into a GIS can take the form of keyboard entry, manual digitization, scanning, and importing digital files (Motei, 2005).

Data is stored in two formats: vector and raster. Vector data usually takes up less space and better represents the real world, while raster data shows a closer image to the real world. Geological maps are usually shown in vector form, showing lithological boundaries as polygons, faults as lines, and elevation points as dots. Of course, vector data can be rasterized or vice versa. The information that is entered into the GIS system at different stages of exploration and exploitation can vary in terms of scale, accuracy, quality, and other things. As exploration progresses, the quality of the information and, as a result, decision-making will be more accurate. Because in mineral exploration, geological, geophysical, geochemical, etc. information is compared with each other, it is necessary for all this information to have common coordinates and a map image so that they match each other when entered into the GIS (Karimpour, 2005).

Data processing is carried out by several software programs, the most famous of which are: Arcview; ARC/INFO, ARC/GIS. Data extraction is the process by which information obtained from GIS is presented in a form suitable for user.

Today, GIS technology is used in the exploration of oil and gas mineral reserves, zoning of landslide and flood-prone areas, finding connections between earthquake centers and tectonic lines, preparing erosion maps and annual sediment production in watersheds using various methods, studying surface and groundwater resources, etc. (Karimpour, 2005).

Raymond and Macrae (1997) and Duffett and Leaman (1997) showed how to explore mineral reserves in the Australian trust and Macarthur areas with the help of GIS capabilities using geophysical, geochemical, surface geology and current deposit locations.

Bonham-Carter, Agterberg, and Wright, (1998) succeeded in determining new gold anomalies by GIS capabilities using lithological layers, geochemistry, satellite data of faults and current gold occurrences in Nova Scotia, Canada.

Atef et al. (2023) used GIS & RS technique to identify and discover copper and gold deposits. Using petrographic maps, alteration zones and buffer analysis of old trenches, copper and gold deposits were identified.

Gajere et al. (2024) combined RS & GIS and used multi-criteria decision-making techniques including TOPSIS

MOORA and ARAS to identify barite deposits in Nigeria. Pekham Ganguly (2023) in a study using RS&GIS and using ENVIS software and measuring changes in sound wave speed, changes in power and changes in electromagnetic wave distribution identified various minerals.

Tagwai et al., (2023) conducted a study to investigate the current and future status of the combined RS&GIS technique in mineral resource identification.

Houran et al., (2023) showed that Geographic Information Systems (GIS) can effectively map features such as elevation and lithological units in mineral exploration. Machine learning methods, such as random forest and artificial neural networks, enhance automatic mineral mapping and achieve classification accuracy of approximately 98%.

Remote sensing (RS) technology facilitates mineral exploration by identifying minerals and rocks through their absorption characteristics at different wavelengths. Techniques such as image classification and principal component analysis enhance the determination of mineral zones and structural elements in diverse environments.

Cheng et al., (2023) in a study using GIS-based machine learning methods, integrating mineral system models and spatial proxies to improve mineral prospecting mapping, demonstrate effective exploration for copper-gold deposits in Tibet, demonstrate high prediction accuracy, and identify potential targets for further exploration.

Limited exploration of the specific mechanisms by which fault activity influences travertine formation remains under-researched, indicating a need for more detailed geological studies that connect these phenomena directly. The existing literature often focuses on broader geological features without delving into localized studies that assess the impact of micro-faults on mineral deposits, suggesting a gap in understanding the significance of smaller geological structures. In this research, relation between micro-faults on mineral deposits was studied.

Materials and Methods

In this study, Landsat satellite images were used to investigate the relationship between travertine formation and faults in the region using GIS and RS techniques. The study areas include part of the area around Dehshir and Abarkooh. The studied areas were located in a satellite image frame, so there was no need to connect the satellite images. Geometric correction and radiometric correction and noise removal are operations that are performed by the station receiving the image from the satellite and are made available to users after the aforementioned corrections are made. However, for greater accuracy, the researcher performed a ground reference operation on it. By identifying control points on the ground using GPS and transferring them to the satellite image and running the ILWIS software, the image was adapted to the new geometric position. It should be noted that the characteristics of the control points included the locations of some travertine masses, the intersections of waterways and some faults in the region, which were extracted by GPS and using 1:100000 geological maps and converted to the UTM system, and then used in the ILWIS environment. After performing the above correction, the highlighting and information extraction operations from the aforementioned image were performed as follows.

Since the raw image is dark and lacks stretch, the enhancement operation was performed using linear expansion and histogram on all Landsat bands to distribute the data in a wider range and increase its resolution. In order to exaggerate some phenomena, a number of false color images were created, the purpose of which was to display the travertine masses as well as possible. Among them, the false color combination of 347 and 247 was identified as suitable for final processing, and in GIS studies, image 347 was used as an information layer.

During the field visit, the location of some travertine masses was taken. It should be noted that the information about the location of the travertine masses, which was collected using GPS, was converted to the UTM system, and after entering the information into Map Source, it was transferred to the Arcview environment, and after creating a table, file in .dbf format, it was converted into an information layer. The geological maps of 1:100000 Dehshir, Abarkooh, and part of the Khezrabad region were connected with appropriate accuracy after cutting in Photoshop, and after connecting and digitizing in ERDAS software, it was used as an information layer in the Arcview environment for further study.

The extension of the faults in the region was also extracted in the Arcview environment using the geological maps of 1:100000 of the regions that have been digitized and converted into an information layer (Figure 2). After creating the above information layers in the Arcview environment, a buffer was created to better display the travertine masses around the mentioned points, and the aforementioned layers were used in the following processing to conduct the study. In Arcview software, by superimposing the aforementioned information layers, the relationship between travertine masses with the Dehshir fault and other micro-faults in the region was examined.

Results and Discussion

In the ILWISE environment, images were drawn and appropriately highlighted, and in the second method, namely histogram, more prominent information was extracted from the image. Figure 3 shows the band images that were highlighted in this way. Among the false color images formed, the color combination of 347 and 247 showed prominent information in the field of structural features such as faults and elevations of the region, as well as geological units such as travertines and vegetation. Figure 3 Image 347, which was formed from linear filtered bands, clearly showed the boundaries of the units and was very useful in identifying fault lines and was selected as an information layer. In this image, travertine masses were seen in light color, and the accumulation of these masses is usually located next to faults (Figure 3).

The study identified promising areas for travertine exploration using GIS and RS techniques. False color images revealed relationships between faults and travertine masses. Travertine masses were confirmed near fault lines, indicating tectonic origins. Active mines were located in the study area, particularly near the Dehshir fault.

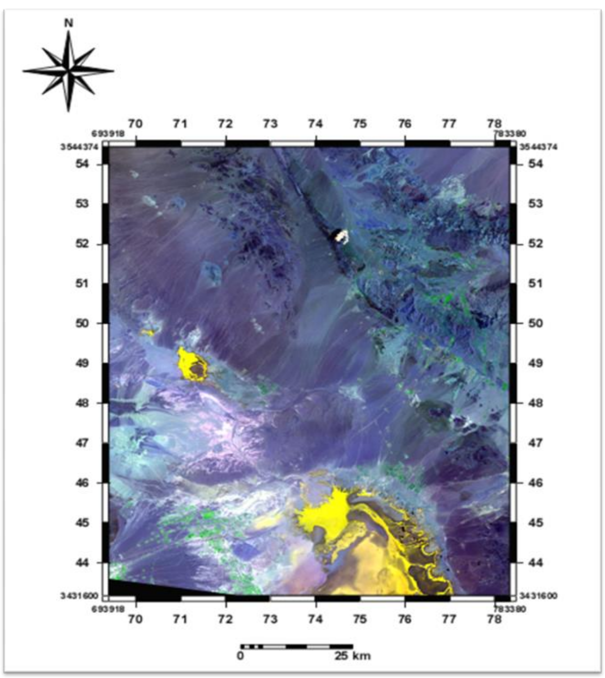

Figure 1. False color combination 247.

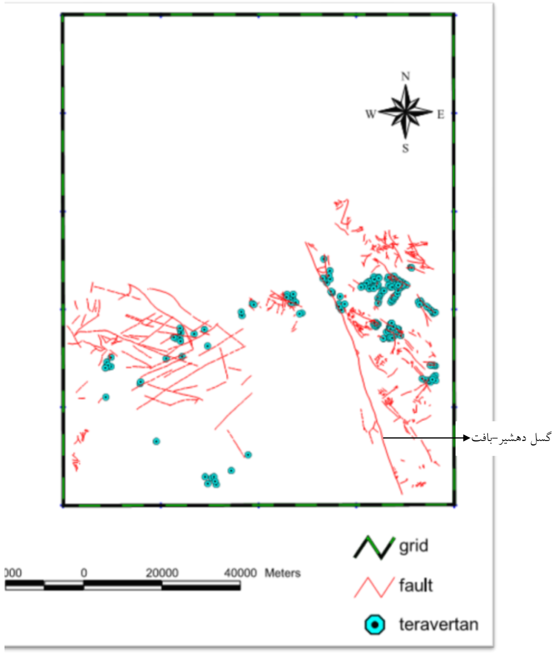

Figure 2. Correspondence of the position of travertine masses to the faults of the region.

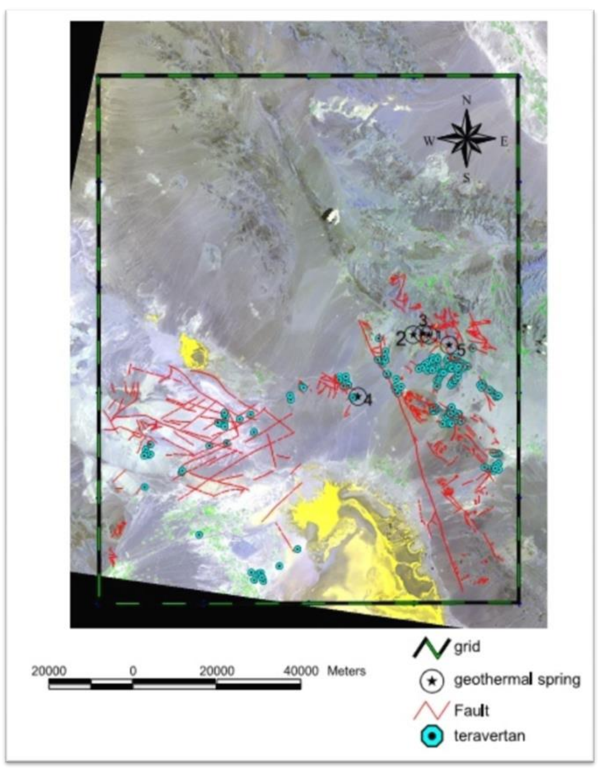

Figure 3. Final information layer including the location of travertine masses and geothermal resources with faults and satellite image of the area (false color composite 347).

Figure 4. Travertines of Dehshir region.

Conclusion

Since travertines are either of climatic origin or tectonic origin, the location of these masses in areas adjacent to fault lines visually proved that the travertines of the region have a tectonic origin. GIS technology was used to further confirm the matter. The location of a large number of these masses was recorded with GPS and turned into an information layer. Also, by extracting the location of the faults in the Arcview software and creating an information layer that included a false color image of 347 locations of travertine masses and hot springs and faults in the region (Figure 3), the relationship between the formation of travertine masses and the activity of the faults in the region was confirmed. Many of these masses are active mines and are being exploited, but in parts of the study area, such as the northwest of the Dehshir fault, there is a cluster of faults, which is likely to contain travertine masses, whose existence was also confirmed by studying aerial photographs. Therefore, travertine exploration can be limited to these points, which is considered a promising area.

It is suggested that an exploration study of evaporite deposits be conducted using RS and GIS techniques in the region and promising areas be determined. Considering the displacement in the alluvium, the Dehshir-Baft fault is currently active, so earthquake zoning can be conducted in the region and disaster-prone areas can be identified, and many disasters can be prevented by observing engineering principles and other measures.

While GIS and RS techniques have been widely applied in mineral exploration, there is a lack of comprehensive studies that integrate machine learning methods with these technologies to enhance the accuracy of mineral mapping in fault-affected areas. It is suggested that integrate machine learning methods with these technologies is done in this region.

The study effectively utilized Remote Sensing (RS) and Geographic Information System (GIS) techniques to identify the relationship between fault activity and travertine deposits, similar to other studies that have employed these technologies for geological exploration. The use of false color images, particularly image 347, was instrumental in highlighting structural features and geological units, which aligns with findings from other research that emphasizes the importance of image processing in geological mapping. The identification of travertine masses in proximity to faults corroborates previous studies that have noted a correlation between fault lines and mineral deposits, reinforcing the notion that geological structures influence resource distribution. The methodology of creating information layers in Arcview and analyzing geological maps is consistent with established practices in geological research, showcasing the effectiveness of integrating various data sources for comprehensive analysis. - There is a scarcity of studies that validate remote sensing findings with extensive field data, which could strengthen the reliability of the results and provide a more robust framework for future research.

- The application of false color imaging in geological studies is not fully explored, particularly in terms of optimizing band combinations for specific mineral identification, indicating a potential area for further investigation.
- Field validation through GPS data collection for travertine locations adds credibility to the findings, a practice that is often recommended in similar geological studies to ensure accuracy.

Author Contributions

All authors contributed equally to the conceptualization of the article and writing of the original and subsequent drafts.

Data Availability Statement

Data available on request from the authors.

Acknowledgements

The authors would like to thank all participants of the present study.

Ethical considerations

The study was approved by the Ethics Committee of the Islamic Azad University, Abar.C., The authors avoided data fabrication, falsification, plagiarism, and misconduct.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of interest

The authors declare no conflict of interest.

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