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Potentials of Evaporite Deposits West of Hormuzgan Province

[1]R. Afshinfar, [2]M. R. Jafari, [3]M. Almasian

[1]*Department of Geology, North Tehran Branch, Islamic Azad University, Tehran, Iran, Email: r.afshinfar@hotmail.com*
[2]*Assistant Professor, Department of Geology, North Tehran Branch, Islamic Azad University, Tehran, Iran, Email: mr.jafari_1348@yahoo.com*
[3]*Assistant Professor, Department of Geology, North Tehran Branch, Islamic Azad University, Tehran, Iran, Email: ma.almasian@gmail.com*

Abstract

This study aimed to conduct a potential mapping of evaporite deposits in the west of Hormuzgan province. This article used remote sensing techniques and various ratioing methods to map the potentials of areas. In remote sensing, different types of sensors, alteration readings, satellite images of geological surveys and exploration, satellite data used, and spectral studies, geometric correction, atmospheric correction, vegetation removal, and mineralization evidence using various methods were taken into account. In the end, remote sensing findings revealed that the best band ratios had been used in the area under study. Theoretically speaking, iron oxide was also recognized as a moderate alteration in copper exploration. In the area under exploration, false band ratios and various band ratioing were used. Interpreting and reviewing the images of the studied area reveals that the area has great potential of such minerals as copper, gold, magnesium, gold, and iron, with the mineral value of the northeastern, southeastern, and central parts of the area overshadowing other parts.

Keywords: Evaporite deposits, Remote sensing, False band ratio, Hormozgan province.

INTRODUCTION

During the geological epoch, concomitant with tectonic processes and reduced depths of existing basins, various evaporite deposits were formed in different parts of Iran. These evaporite deposits can be divided into three Precambrian (Hormuz series/complex), Jurassic (Kangan Formation), and Tertiary (Qom, Upper Red, and Gachsaran Formations) categories (Rahimpour Bonab and Kalantarzadeh, 2005). Many evaporite deposits are seen to have formed in the stratigraphic column of Phanerozoic sediments of Zagros Basin, with the Hormuz salt located at the beginning of this column and Gachsaran Formation (previous Miocene) in the upper part of it, forming a wide range of evaporite units (Bahroudi and Koyi, 2004). The petrological composition of Gachsaran Formation as an evaporite deposit west of Bandar Abbas (Section of Khamir salt mountain) reveals the number of such evaporite minerals as gypsum-anhydrite (85.5%), lime (8%), and marl (6.5%) (Salari Sargo et al., 2015). The findings demonstrated that marly, calcareous and gypsum-anhydrite facies had been left in lagoon environment, intra-and supra-tidal states, respectively (Salari, 2013).

Many types of research have also been carried out in this regard. Mir Hosseini et al. (2014) have performed a preliminary analysis of whether or not salt can be extracted from the brine (salt) springs south of the Bam salt dome (West of Hormuzgan, Bastak). They maintained that the brine springs bordering the salt domes south of the country are examples of natural brine springs with a high potential of evaporite salts, helping extract edible and industrial salt of acceptable purity using evaporation ponds.

Alsharhan and Kendall (2003) provided the most inclusive article on evaporite and carbonate deposits of the southern coast of the Persian Gulf as well as some similar ancient examples. Also, Hay et al. (2006) performed major analyses on evaporites, investigating the salinity of the oceans during the Phanerozoic epoch, yielding conclusions on the climate, and motion of the ocean water within geological epochs. Dentskoy et al. (2015) used the textural properties of iron specimens under the microscope to identify hematite, goethite, and their porous types. Cracknell (2015) used the textural-spatial properties of rock images to determine sedimentary sequences, support vector machine, and random forest classification algorithms.

Sherkati et al. (2004) studied the role of salt domes on folded Zagros faults, arguing the movement of these domes affects the activity of basement rock faults. Sam Boggs (2009) demonstrated that evaporite deposits were common in the history of petrology and are abundant in the stratigraphic sequences of the late Cambrian, Permian, and late Miocene Jurassic. Dehghani et al. (2009) studied the micro-facies of the Asmari Formation northwest and south of Shiraz with the major facies of this area including Madstone, Wexton, Paxton-Greenstone, as there were some elements of bioclast, ploid, extraclast, and intraclast in the facies. In their research, Soltaninejad et al. (2016) investigated the evaporite minerals of Kerman province, specifically focusing on spectral properties and mineralogy using remote sensing. The findings suggested that the CEM method highlights the areas with halite, gypsum, and to some extent thenardite well; however, concerning calcite, no distinction was made and it was because of its intermixture with other minerals.

Research has suggested that the presence of the folded Zagros belt and prevailing specific geological conditions in the west of Hormuzgan province (Zagros area) have led to the significant accumulation of hydrocarbon reserves. Moreover, the area under study has a great potential of non-metallic mineral reserves. Data suggests that Hormuzgan province has a good potential of evaporite deposit reserves. This study aimed to map the potential of evaporative deposits in the west of Hormuzgan province using modern geological techniques.

EXPERIMENTAL

In this research, ASTER satellite sensing images were applied. Spectral and spatial resolution and sensing landscape dimensions to study the argillic, phyllic, and propylitic alterations in the context of the area under study and to survey the potentiality of it, constitute the reasons for choosing sensing images in connection with the remote sensing studies. The remote sensing data recorded by the ASTER satellite involves 14 bands, the specifications of which are summarized in Figure 1.

Band	Label	Wavelength (μm)	Resolution (m)
B1	VNIR_Band1	0.520–0.600	15
B2	VNIR_Band2	0.630–0.690	15
B3	VNIR_Band3N	0.760–0.860	15
B4	VNIR_Band3B	0.760–0.860	15
B5	SWIR_Band4	1.600–1.700	30
B6	SWIR_Band5	2.145–2.185	30
B7	SWIR_Band6	2.185–2.225	30
B8	SWIR_Band7	2.235–2.285	30
B9	SWIR_Band8	2.295–2.365	30
B10	SWIR_Band9	2.360–2.430	30
B11	TIR_Band10	8.125–8.475	90
B12	TIR_Band11	8.475–8.825	90
B13	TIR_Band12	8.925–9.275	90
B14	TIR_Band13	10.250–10.950	90
B15	TIR_Band14	10.950–11.650	90

Figure 1. Spectral characteristics of ASTER satellite image bands.

For enhancement, metal mineralization alteration, such as argillic and chlorite, is focused attention, while in the next step, their spectral behavior is examined. These studies used spectral libraries with the required wavelength range examined in micrometer (μm) units.

Characteristics of the area under study

From a geological point of view, the Hormuzgan province is situated within three important sedimentary-structural units in Iran. Its northern part (part of Hajiabad city) pertains to the Sanandaj Sirjan zone and is rich in metal mineral reserves. The eastern part of the province pertains to the Mukran zone with a great potentiality of metal resources. The middle and western part of the province is a part of the Zagros zone, rich in oil, gas, gypsum, marl, lime, ochre, and salt resources (Aghanbati, 2006). With a length of 1800 km situated in the middle of the Alpine-Himalayan belt, the Zagros mountain ranges, begin from the Taurus Mountains in northeastern Turkey and end in the Strait of Hormuz, Iran (Stocklin, 1968; Haynes and Mcquilan, 1974; Falcon, 1991; Alavi 1994, 2004; Smit et al., 2010). This belt, extending from northeast to the southwest, includes three structural zones: high Zagros, folded Zagros, and crushed Zagros (Stocklin, 1968; Falcon, 1967, 1991). Characterized by tectonic and sedimentological properties, the folded Zagros has six parts: Lorestan, Dezful, Abadan, Izeh, Fars, and Hinterland in BandarAbbas (Agha-nabati, 2006).

The Zagros Basin consists of deposits of 7 to 12 km in thickness, considered as the northern and northeastern boundaries of the Arabian plate (Bahroudi and Koyi, 2004).

After examining tectonic units and understanding evaporite formations (formations containing evaporite minerals such as salt, gypsum, anhydrite, etc.) and recording the abbreviations of each formation from a digitalized geological map, a map of evaporite formations was provided using the ILWIS software (Figure 2).

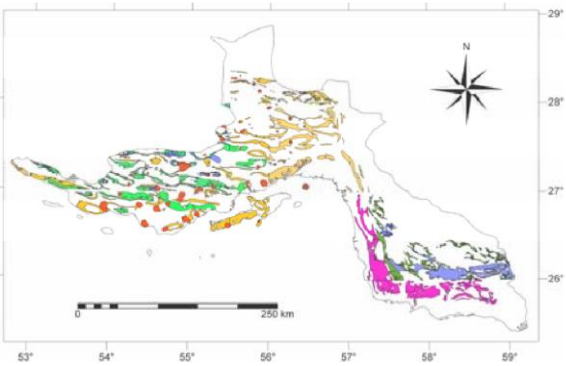

Figure 2. Map showing the scattering of evaporite formations in Hormozgan province.

Considering the importance of evaporite formations and tectonic analyses in this study, the Hormuzgan province is divided into two regions with different properties: one region has evaporite formations in the west of the Minab fault (Zagros) and the other in the east of the Minab fault (Mukran) (Table 1).

Table 1. Spatial position of evaporite formations in Hormuzgan province.

Name of the region	**Period**	**Evaporite formations**	**Characteristic sign in geological map**	**Location of enhancement**
Zagros	Paleozoic	Salt domes (Hormuz complex)	Sph	Over 70 salt domes are extending in northern, northwestern, and western parts of the province, some of which have been referred to in the context.
	Cenozoic	Fars group (unseparated)	F	They extend in northern, northwestern, and western parts of the province
			Mg	They extend in northern, northwestern, and western

		Gachsaran		parts of the province
		Aghajari	Ma	They extend in northern, northwestern, and western parts of the province
Mukran	Cenozoic	Sabz unit	Ms2	In the east of the province within the quadrangle map of Minab and Tahrouei
		Darpehen Unit	Mdp	In the east of the province within the quadrangle map of Minab and Tahrouei
		Maron Gooshi	Mm1	In the east of the province between the Gaz river and Sadij river leading to the eastern part of Jask city in line with coastal plains

RESULTS AND DISCUSSION

This study aimed to conduct a potential mapping of evaporite deposits in the west of Hormuzgan province. Figure 3 illustrates the spectral properties of the minerals using argillic alteration (kaolinite) and propylitic alteration (chlorite) indices. Because this study does not involve calculations of earth surface temperature, only bands 1 to 9 of the ASTER sensor are used and the ideal spectral behavior of the minerals in this range is examined.

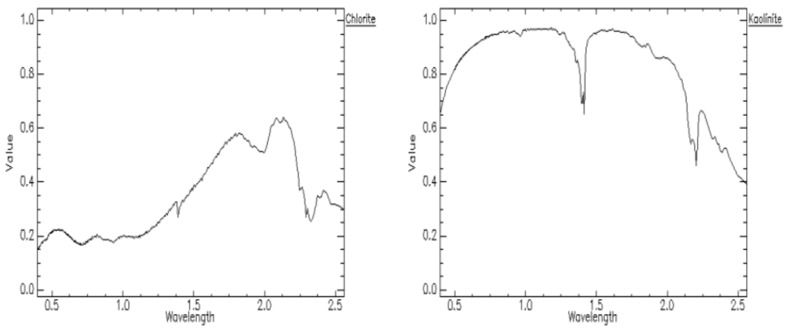

Figure 3. Spectral behavior of alteration index of minerals: i.e., kaolinite and chlorite.

This study used internal average relative reflectance (IARR) methods. This is a technique that removes sunlight radiation, atmospheric reflection, and topographic effects, greatly affecting geological analyses on minerals. The effect of this method on one pixel in the spectral enhancement of ASTER satellite bands is shown in Figure 4.

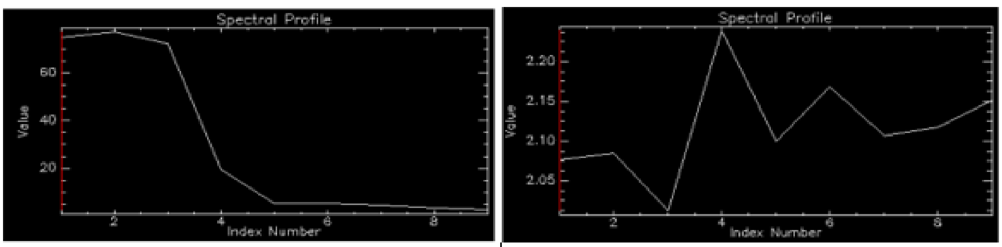

Figure 4. Identical pixel spectral behavior before atmospheric correction (image on the left) and after it (image on the right).

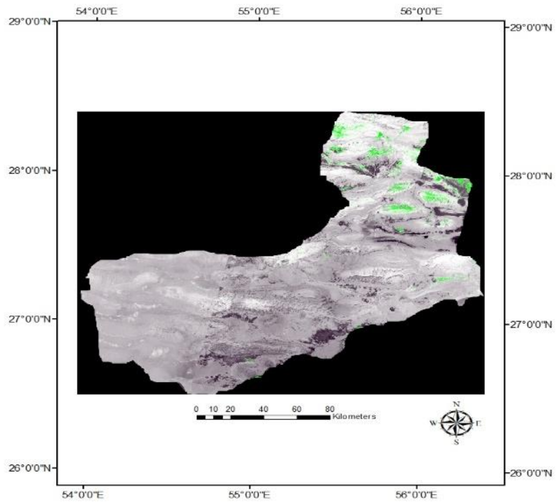

Figure 5. NDVI processing outcome for recognition of vegetation units.

Figure 5 shows vegetation units in green. The wide-ranging and regional alterations indicate the presence of a mineralization system which is quite clear in the northern parts of the area under exploration. These alterations can be well tracked when processing satellite images. The color composition used is RGB = 468, which, due to the greater reflection of OH-based minerals (kaolinite, muscovite, alunite, etc.), pixels containing phyllic and argillic alterations in band 4 are marked by pink compared to bands 6 and 1, and due to the greater reflection of most chlorite and epidote minerals within the range of band 6, propylitic alteration is seen in green. The outcome of this processing is summarized in Figure 6, which confirms the existence of highly severe alterations in the area under study.

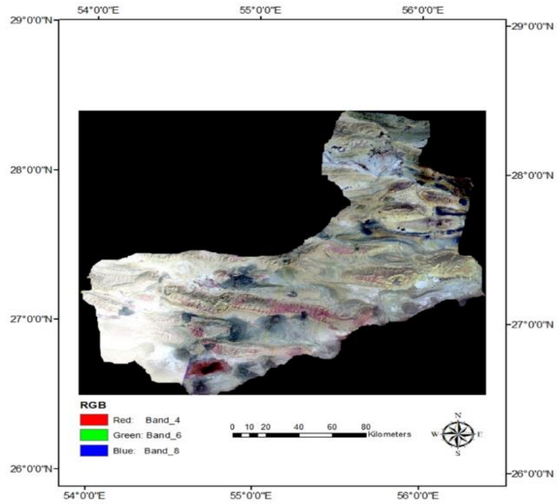

Figure 6. False color image of RGB468; the area with wide-ranging argillic (pink), propylitic (blue), and less phyllic (green) alteration indices.

The best band ratios were used in the area under study. Theoretically, iron oxide is also recognized as a moderate alteration in copper exploration (Figures 7-13).

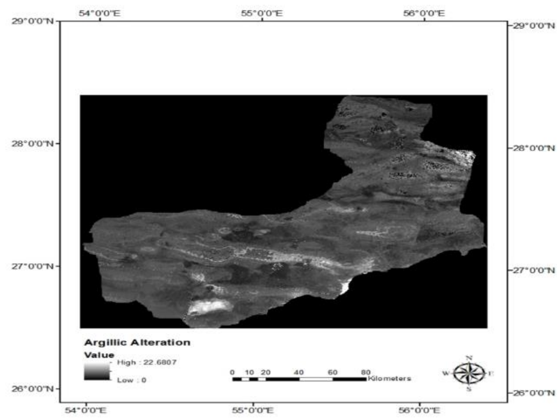

Figure 7. Band ratio analysis for argillic alteration (kaolinite mineral by 4.5 ratios).

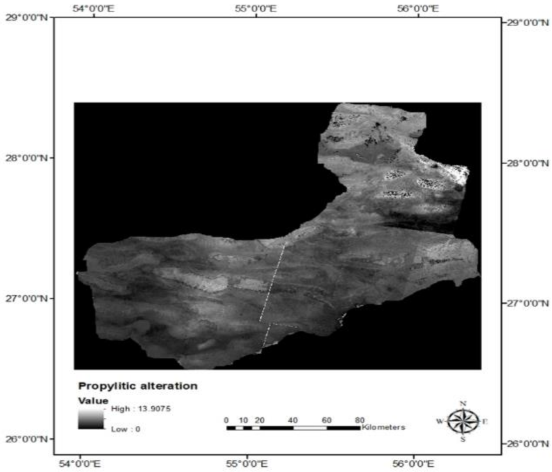

Figure 8. Band ratio analysis for propylitic alteration (chlorite mineral by a 9.8 ratio).

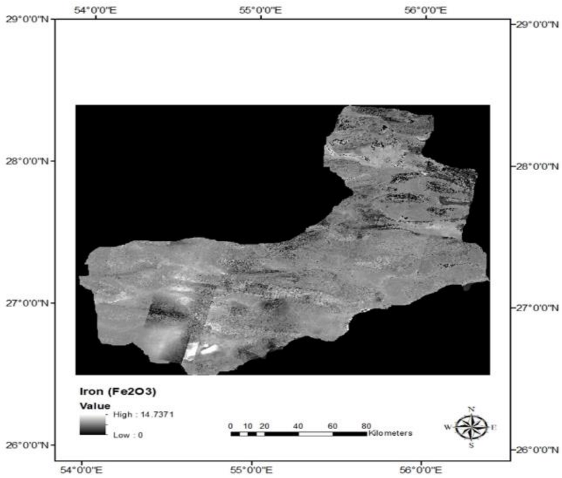

Figure 9. Band ratio analysis for trivalent iron alteration (from 3.4 ratio).

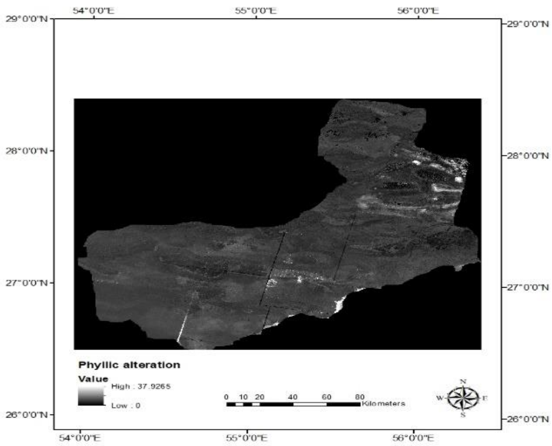

Figure 10. Band ratio analysis for phyllic alteration (muscovite, sericite, and illite minerals by a (5 + 7)/6 ratio.

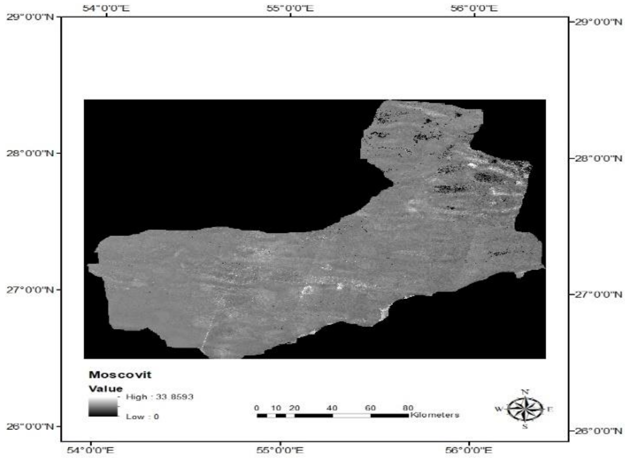

Figure 11. Band ratio analysis for phyllic alteration (muscovite mineral by a 5.6 ratio).

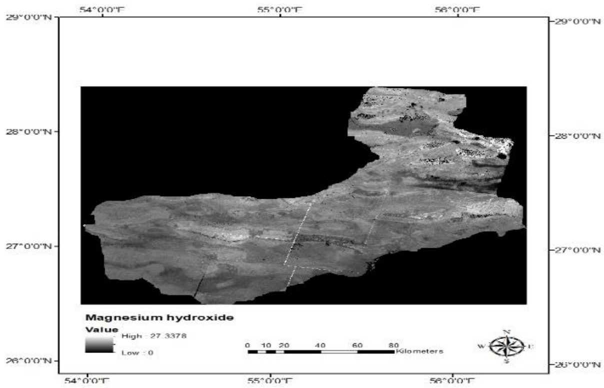

Figure 12. Band ratio analysis for the MgOH-based mineral alteration (by a (6 + 9)/8).

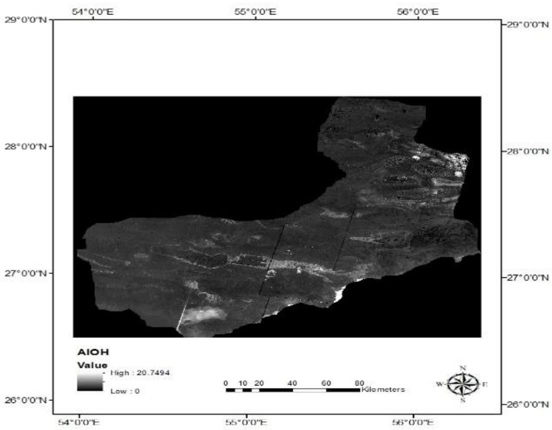

Figure 13. Band ratio analysis for the AlOH-based mineral alteration of (by the (6*2 bands)/(4 + 7).

CONCLUSION

This study aimed to conduct a potential mapping of evaporite deposits in the west of Hormuzgan province. This article used remote sensing techniques and various rationing methods to map the range potentials. In remote sensing, different types of sensors, alterations readings, satellite images of geological surveys and exploration, satellite data used, and spectral studies, geometric correction, atmospheric correction, vegetation removal, and mineralization evidence using various methods were taken into account. In the end, remote sensing findings revealed that the best band ratios had been used in the area under study. Theoretically speaking, iron oxide is also recognized as a moderate alteration in copper exploration.

In the area under exploration, false band ratio (468) and different band ratioing methods were used. As the images suggest, extensive propylitic alterations were observed in the northeastern to southeastern part, which could lead up to copper metal deposits, especially of porphyry type. In the middle and southern part of the area, predominant argillic alterations are noted, which can help explore copper and gold of epithermal type. Propylitic alteration in the 9.8 band composition is seen in white in the northeastern part of the area. The findings illustrate the band composition for the iron alterations scattered over most parts of the areas as it can help explore gold minerals and even iron ores. Like propylitic alteration, phyllic alteration is also seen in the northeast and southeastern parts. The best part of the area extends from northeast to southeast to explore deposits of minerals rich in MgOH such as magnesium. For AlOH-based deposits such as aluminum, the northeastern and central parts can yield better reserves than other parts.

In sum, interpreting and reviewing the images of the studied area reveals that the area has great potential of such minerals as copper, gold, magnesium, gold, and iron, with the mineral value of the northeastern, southeastern, and central parts of the area overshadowing other parts.

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Conflict of interest: The authors declare that they have no conflict of interest.

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