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Mineralogical and geochemical aspects of sand dunes in Missan Governorate, Southeastern Iraq

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Abstract

Twenty sand samples were collected from the sand dunes of Missan fields, Southeastern Iraq. Grain size distribution, mineralogical and chemical composition were studied for the total, medium, and fine-size sand fractions. The grain size analysis shows that the sand is the main component, followed by silt and trace of clay. The predominant grain size of sand is 0.250 to 0.500 mm, which forms more than 57.28 %, which indicates that these dunes were formed under the influence of relatively strong winds and the sedimentary material is close to the source. The light components are quartz, feldspar, and different rock fragments, while the heavy mineral assemblages are composed of opaque minerals, chlorite, mica, and amphiboles. Pyroxene and epidote are the common minerals, while zircon, garnet, tourmaline, rutile, kyanite, and staurolite are in minor amounts. X-ray diffraction (XRD) data reveals that the predominant non-clay minerals are quartz, calcite, feldspar, and gypsum. While the dominant clay minerals are palygorskite and illite, followed by kaolinite and the mixed layer of montmorillonite – chlorite. There is a negative relationship between the percentage of heavy minerals and the grain size of sand. Dunes are distinguished by a relatively high percentage of minerals derived from intermediate and basic igneous rocks located in the Zagros belt, northern Iraq. They also may be derived from local source formations**,** Injana and Mukdadiya in the surrounding areas. The average geochemical components of sand as indicated by X-ray fluorescence (XRF) are**;** SiO_2 (61.36%), which is mainly represented by quartz, CaO (14.08%) related to the presence of carbonate, SO_3 (0.05%) is represented by gypsum, Al_2O_3 (6.76 %) and alkalis (2.30%) reflect the presence of the K-feldspar and clay minerals, Fe_2O_3 (3.2%) is attributed to the presence of hematite, magnetite and limonite minerals. SiO_2 is concentrated in a medium sand size fraction, while the other oxides are concentrated in a fine sand size fraction.

Keywords: Mineralogy, Missan field, Heavy minerals, Sand dunes, Iraq.

الملامح المعدنية و الجيوكيميائية لرمال الكثبان في ميسان ، جنوب شرق العراق

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جمعت عشرين عينة رملية من كثبان البرخان في حقول ميسان جنوب شرق العراق ودرس التوزيع الحجمي الحبيبي والتركيب المعدني والكيميائي لأحجام الرمال المختلفة (الكلي والمتوسط والناعم), اوضح التحليل الحجمي أن الرمل هو المكون الرئيسي يليه االغرين ثم قليل جدا من الطين. حجم الحبيبات السائد للرمل هو المتوسط (0.250−0.500 mm) والذي شكل اكثر من 57.28% مما يشير إلى أن هذه الكثبان قد تشكلت تحت تأثير الرياح القوية نسبيًا والمواد الرسوبية القريبة من المصدر. المكونات الخفيفة كانت عبارة عن الكوارتز والفلسبار وأنواع مختلفة من القطع الصخرية , بينما تتكون المعادن الثقيلة من معادن معتمة و كلوريت ومايكا و أمفيبول. و كان كل من البيروكسين والابيدوت هي المعادن الاكثر شيوعا , بينما وجد كل من الزركون و الكارنت و التورمالين و الروتيل و الكيانيت و الشتورولايت بكميات قليلة . كشفت بيانات الاشعة السينية الحائدة (XRD) أن المعادن غير الطينية الأكثر شيوعًا هي الكوارتز والكالسيت والفلدسبار والجبس. بينما كان الباليجورسكيت والإيلايت هما المعادن الطينية السائدة يليهما الكاؤولينايت والطبقات المختلطة (مونتموريلونايت – كلورايت) . هناك علاقة سالبة بين النسبة المئوية للمعادن الثقيلة وحجم حبيبات الرمل. تتميز الكثبان الرملية بوجود نسبة عالية من المعادن المشتقة من الصخور النارية القاعدية والمتوسطة الموجودة في حزام زاكروس شمال العراق بالإضافة إلى أنها قد تكون قد اشتقت من رواسب تكاوين كل من انجانه والمقدادية المنكشفة في المناطق المحيطة . بينت نتائج الاشعة السينية الوميضية (XRF) أن المكونات الرئيسية للرمل هي SiO_2 و بمعدل 61.36% والتي تمثل الكوارتز وCaO بمتوسط 14.08% االذي يعكس وجود الكربونات , بينما يمثل SO_3 (0.05%) وجود الجبس مرافقا للرمال. يعكس كل من Al_2O_3 (6.76%) والقلويات (2.30%) وجود معادن الفلسبار البوتاسي . اشار Fe_2O_3 (3.2%) إلى وجود معادن الهيماتيت والمغنتيت والليمونيت. تركز SiO_2 في حجم الرمل المتوسط بينما تركزت الأكاسيد الأخرى في حجم الرمل الناعم.

1-Introduction

Sand dunes result from complex physical interactions between wind flow and sand beds in the desert area [1]. Aeolian sand deposits are distributed in different parts of Iraq, such as the northeast belt of sand dunes that extend from Baiji to Badra and Alteeb. The sand dunes of Missan represent one of significant Iraq's dune fields and are located in the southeastern part of this belt [2]. These dunes extended in a prevailing wind NW-SE orientation. The commonplace characteristics of all dunes, in all international climates, their formation suggest considerable delivery of sand-sized sediment, strong sand shifting winds, and conditions favoring sedimentation of the sand [3]. Grain size is an important abiotic component of the dune ecosystem, indicating the shear stress that the media must apply to initiate and sustain particle movement [4]. The mineralogical characteristics of sand dunes indicate their sources, properties, stability of dunes, movement, and economic importance [5, 6]. Heavy minerals refer to those minerals that have a specific gravity greater than 2.89. However, it is very important to investigate the parent rocks and the sources even of occurrence in small amounts in the sand dunes [7]. Light minerals can potentially limit quartz as the most important [8]. The separation of heavy minerals from the volumetrically more abundant light minerals rarely comprises more than 1 % of sandstones, making it necessary to concentrate them before conducting a chemical and mineralogical analysis [9]. Previous results demonstrated that the grain size and geochemical parameters could be used to determine the sedimentary environment and possibly the provenance of different deposits [10-14]. There are no detailed studies on the geochemistry and mineralogy of sand dunes in the study area under investigation except the study of [1, 8], which concluded that quartz (66.05%), feldspar (18.72%), and rock fragments (15.23%) which composed the major components of light minerals, The heavy mineral assemblages consist mainly of opaque minerals, chlorite, pyroxene, and zircon. This study aims to evaluate the mineralogical and geochemical properties of sand dunes in the Missan Governorate to determine their sources.

2. Materials and methods

The studied sand dunes represent a part of the major dune field belt in Iraq, which is the northeast belt of sand dunes that extend from Baiji to Badra and Alteeb that are located northeast of Missan Governorate, between latitude (32° 21′0″ -32° 36′ 00 *″) N*, and longitude (46°53′ 00″- 47°21′ 00*″)* E. Five sites were selected near the Iraqi- Iran border, Manziliyah, Khazina, Zubadiate, Abu Ghrab, and Chailat (Figure 1).

The field trips indicated that the barchans dunes are an important form and widely distributed in the study area. The sand dunes' shapes range from asymmetrical to symmetrical shape. The fieldwork observed and diagnosed five types of dunes, including Barchan dunes, Barchanoid ridges, Nabkha, Irregular dunes, and sand sheets (Figur 2).

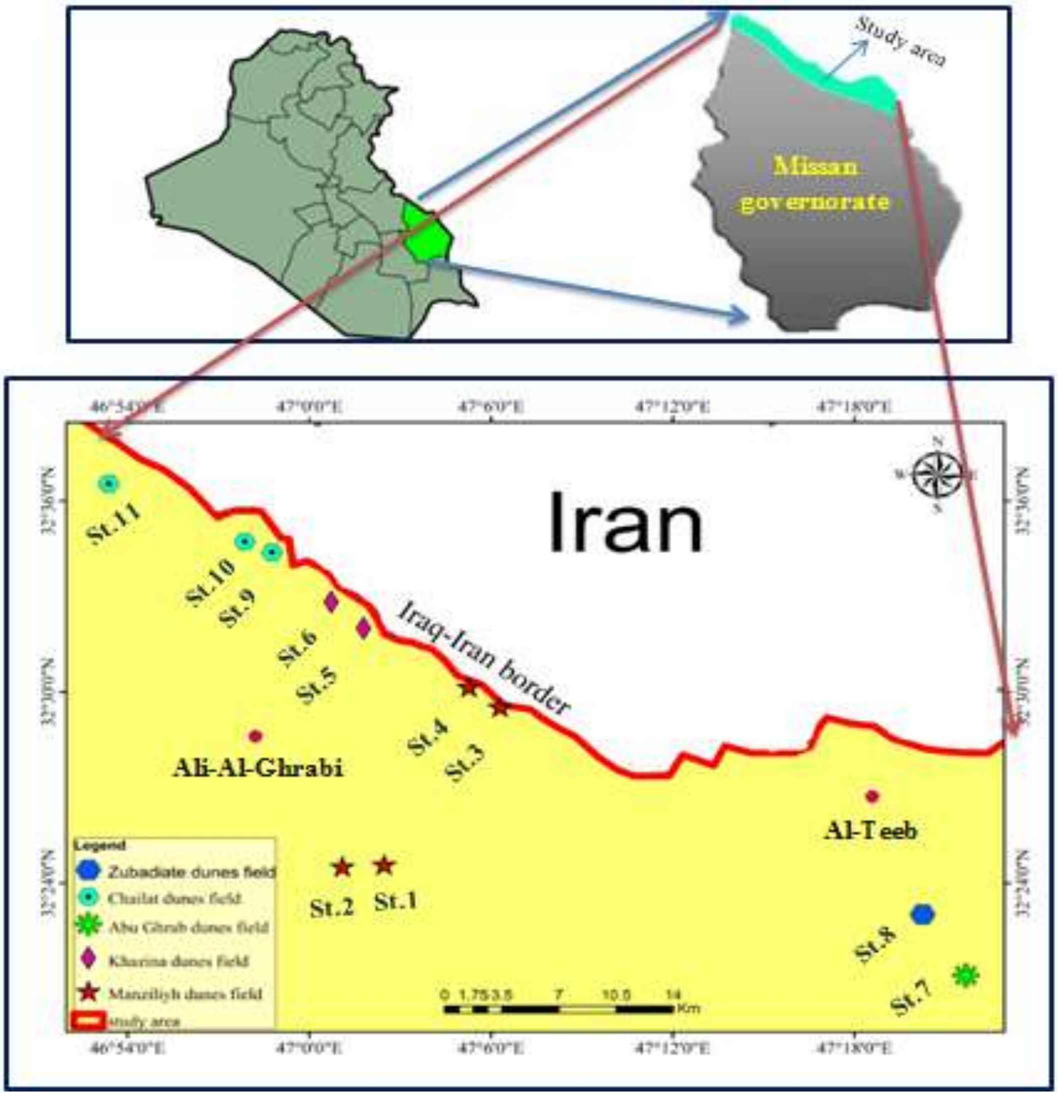


Figure 1- Location map of the sampling locations at the study area.

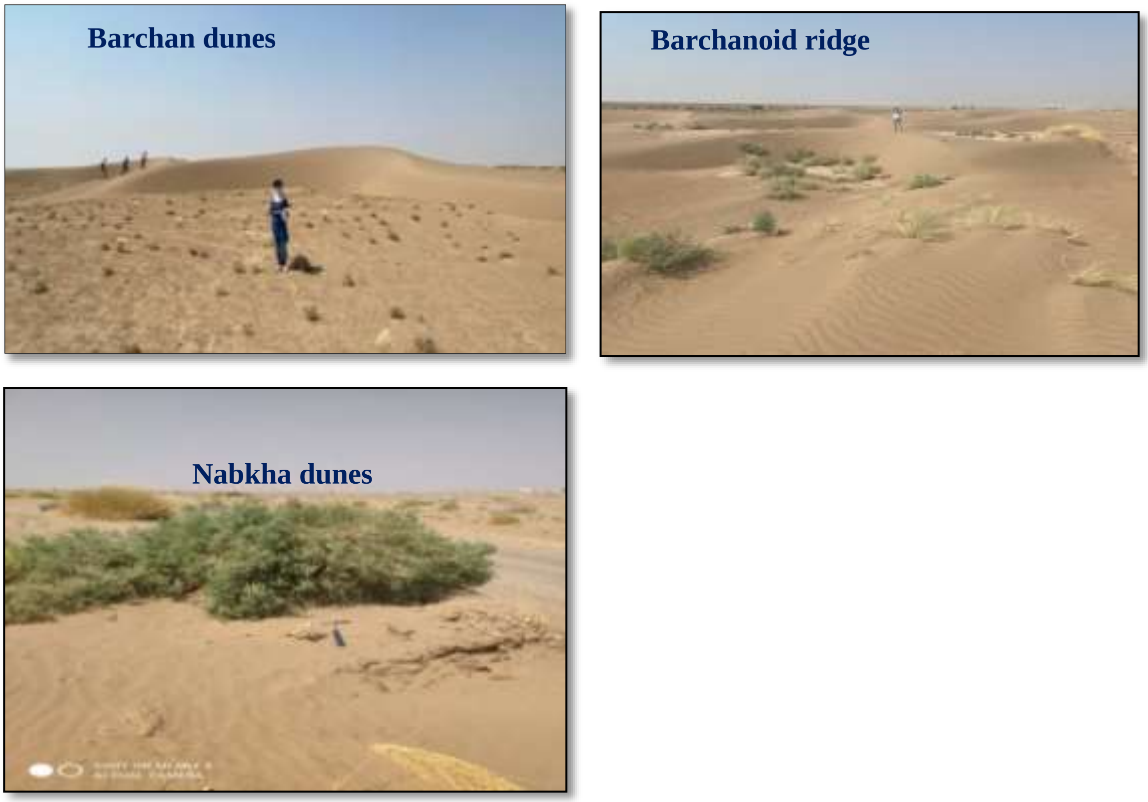


Figure 2- Barchan dunes, Barchanoid ridges, and Nabkha types of sand dunes in the study area.

Thirteen sediment samples were collected from the sand dunes fields during October 2020. The dunes' dimensions and the wind's direction were indicated (Figure 3). Samples were stored in plastic bags, and the field information (name of the site and sample number) was written on the bags. Mechanical and Mineralogical analyses of these dunes were determined in the department of geology, college of science, university of Baghdad, and Basrah by applying the well-known international methods. Mechanical dry sieving analyses of the selected samples were performed using a shaker machine; 300 gm of each sample was passed through six standard sieve intervals that are 2, 1, 0.5, 0. 250, 0.125, and 0.063 mm, respectively [7 and 15]. The percentage of each retained weight on each sieve was calculated as very coarse, coarse, medium, fine, and very fine. The pipette method separated the mud fraction into silt and clay [7]. The texture of the samples was classified according to the Folk, 1974 method [8]. Three oriented slides (untreated, heated, and ethel-glycolate) were prepared for the identification of clay minerals by using the XRD technique at the Ministry of Science and Technology, X-ray Laboratory, Baghdad.

Heavy minerals were separated for the fine and very fine size sand intervals using bromoform heavy liquid, with a specific gravity of (2.89) [15, 16]. Fourteen thin sections were prepared by spreading about 400-500 grains of heavy minerals onto the glass slide for petrographic study by using a polarized microscope (Type Optika) based on their optical properties and calculating their percent by the point-counting method [17]. Bulk samples were crushed using clean agate mortar to approximately 75 µm to identify the minerals using the XRD and XRF techniques. The diffractograms of both bulk and oriented slide samples were identified [18 and 19]. The XRF instrument was used to determine the major oxides of the sand samples.

Figure 3- Collecting samples from the study area.

3. Results and Discussion

3-1 Grain Size Analysis

The results of grain size analysis showed that the sand is the main component of dunes in all collected samples with an average of 99.35%, followed by silt and clay with an average of 0.47% and 0.17%, respectively (Table 1). The predominant size fraction in the sand component is the medium size containing 57.28%, followed by fine, very fine, and coarse sand size fractions of 33.54%, 3.04%, and 5.49%, respectively. It is important to note that the very coarse size fraction was absent in all studied samples (Figures 4 and 5). According to the Al-Hajjawi, 2003 descriptive classification [20], the sand of the study area is predominantly medium sands, except sample No. 11, which is classified as fine sand. The predominant medium-size sands in all studied samples indicate that these sand dunes were formed under the influence of relatively strong winds, and the sedimentary material is close to the source, as well as, the similarity in the sediment sources that believe to belong to the Injana and Mukdadiya Formations, transportation modes and distances, weathering, and depositional processes [21].

Table 1- Grain size analysis of sand dunes samples.

Station	Sample No	Gravel %	Grain size (mm)					Sand %	Mud %		Textural Class
			Very coarse (1-2)	Coarse (0.5-1)	Medium 0.250-0.5)(	Fine (0.125-0.250)	Very fine (0.063-0.125)		Silt %	Clay %	
Manziliyah	1	0	0	0.11	53.17	40.4	5.64	99.31	0.49	0.2	Sand
	2	0	0	0	57.56	33.18	8.2	98.94	0.82	0.24	
	3	0	0	0	50.02	42	7.31	99.32	0.49	0.19	
	4	0	0	38.2	52.3	6.77	2.04	99.32	0.43	0.25	
	5	0	0	0	58	36.14	5.35	99.49	0.35	0.16	
	6	0	0	0.11	53.17	40.4	5.64	99.32	0.47	0.21	
Khazina	7	0	0	0.02	66.07	29.38	4.21	99.68	0.23	0.09	
	8	0	0	0.53	69.7	24.34	4.9	99.47	0.43	0.1	
Abu-Ghrab	9	0	0	0	60.09	35.15	4.17	99.41	0.45	0.14	
Zuabadite	10	0	0	0.52	74.82	23.47	0.74	99.55	0.36	0.09	
Chailat	11	0	0	0	22.73	59.67	16.68	99.08	0.7	0.22	
	12	0	0	0.05	66.87	30.07	2.29	99.28	0.5	0.22	
	13	0	0	0	60.09	35.15	4.17	99.41	0.43	0.16	
Range		**0**	**0**	**0 -38.2**	**22.73-74.82**	**6.77-59.67**	**0.74-16.68**	**98.94-99.68**	**0.23-0.82**	**0.09-0.25**	
Average		**0**	**0**	**3.04**	**57.28**	**33.54**	**5.49**	**99.35**	**0.47**	**0.17**	

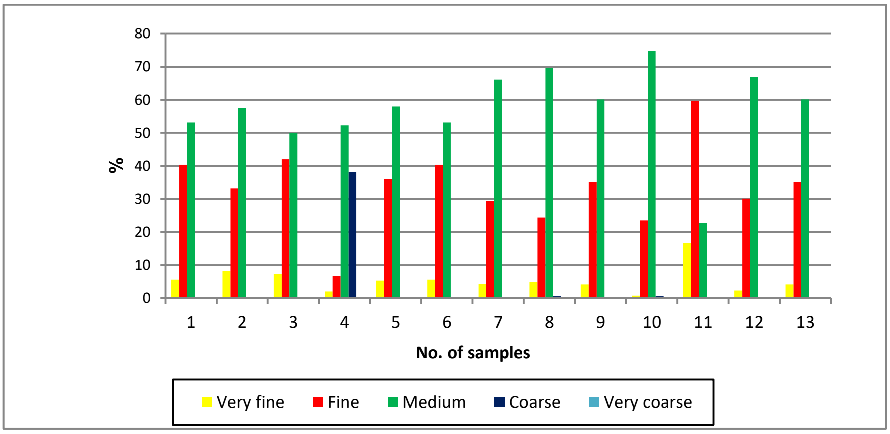


Figure 4 - Average of sand size fractions.

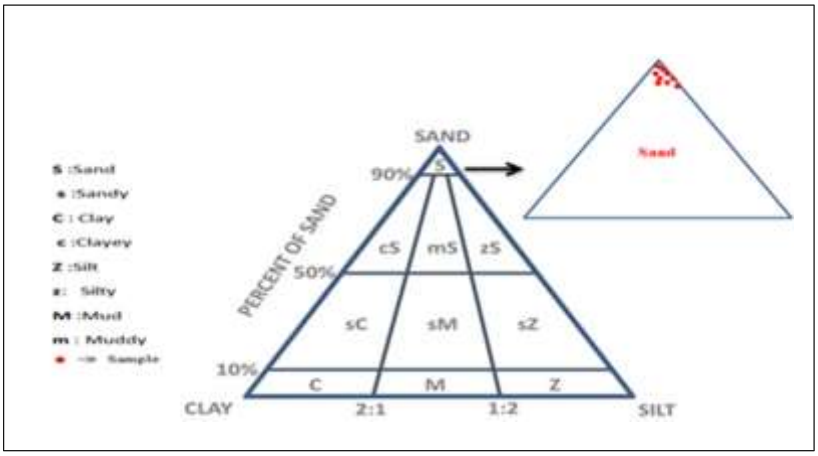


Figure 5- Grain size distribution according to [7].

3-2 Mineralogy

In this research, the fine and very fine sand size fractions were used for mineralogical identification. The light mineral fraction is about 95.7%, with about 4.3 % heavy mineral fraction (Table 2). Generally, the heavy minerals are more concentrated in the very fine sand fractions than in the fine sand fractions. The heavy mineral assemblages can indicate the source rocks.

3-2-1 Light minerals analysis

Identifying the light mineral fraction indicated that the most predominant light minerals in the fine sand fraction are monocrystalline and polycrystalline quartz, with an average of 52.42. Carbonate with an average of 18 %, feldspars (potash feldspar and plagioclase) with an average of 9 .43 %, and rock fragments (chert, evaporates, igneous and metamorphic) with an average of 17.5 %. On the other hand, their averages in the very fine sand size fraction are 53.77% quartz, 18.7% carbonate, 7.86% feldspars, and 18.18 % rock fragments (Table 3 and Plate 1).

The probable source of monocrystalline grains is reworked quartz of sedimentary rocks [7]. In contrast, the probable source of polycrystalline quartz is metamorphic rocks such as schist, gneiss, and plutonic igneous rocks [7, 22]. Orthoclase and plagioclase may be derived from plutonic igneous and metamorphic rocks [23]. Microcline is commonly derived from plutonic igneous and metamorphic rocks and is found to be rare in volcanic rocks. The identified carbonate rock fragments include several varieties, remnants of old formations, such as dolomitic limestone and mudstone rock fragments, or aragonite shell fragments.

3-2-2 Heavy minerals analysis

The heavy minerals were identified to determine the stability of these minerals and the nature of the source rocks area. Identifying the heavy minerals fraction indicated that their average percentages in the fine sand fraction are composed of opaque minerals as the main component with an average of 41.3% and other heavy minerals with an average of 58.7 %. The heavy minerals assemblages is mainly composed of chlorite 7.93 %, mica (muscovite and biotite) 8.8%, amphiboles 8.2%, pyroxene 7.5%, epidote 5.3 %, garnet 5.43%, zircon 3.8%, rutile 3.56%, tourmaline 3.04%, kyanite 2.04% and staurolite 1.77%, (Table 4 and Plate 2).
The presence of chlorite, epidote, garnet, kyanite, glaucophane, and staurolite minerals indicate metamorphic sources, in addition to rutile, biotite, and muscovite [24, 25 and 26]. The effect of acidic igneous sources is indicated by the presence of euhedral to subhedral, subangular to angular zircon, and green hornblende [24, 25, 27]. Opaque minerals (iron oxides) indicate the effect of the basic igneous rocks [23]. Pyroxenes, amphiboles, rutile, biotite, muscovite, and tourmaline give an indication to the effect of both igneous and metamorphic rocks' sources [26]. The study area is located in an active continental margin [1], which is characterized by a relatively high percentage of minerals derived from basic and intermediate igneous rocks. This is indicated by an increase in the unstable heavy minerals (pyroxene and tourmaline) and a decrease in the stable heavy minerals (zircon, tourmaline, and rutile). These source rocks are represented by the Zagros belt in the high folded zone and derived from exposed formations such as the Injana and Mukdadiya in the surrounding area.

Table 2- Percentage of heavy to light minerals in the study area.

.Dune Name	Sand fractions	Weight of Sample (gm)	Weight of Light Minerals (gm)	Percentage of Light Minerals (%)	Weight of Heavy Minerals (gm)	Percentage of Heavy Minerals %
Manziliyah 1	Fine	5	4.77	95.4	0.23	4.6
	Very fine	5	4.79	95.8	0.21	4.2
Manziliyah 2	Fine	5	4.81	96.2	0.19	3.8
	Very fine	5	4.76	95.2	0.24	4.8
Khazina	Fine	5	4.82	96.4	0.18	4.6
	Very fine	5	4.75	95.0	0.25	5.0
Abu-Ghrab	Fine	5	4.79	95.8	0.21	4.2
	Very fine	5	4.78	95.6	0.22	4.4
Zubadiate	Fine	5	4.80	96.0	0.20	4.0
	Very fine	5	4.80	96.0	0.20	4.0
Chailat 1	Fine	5	4.79	95.8	0.21	4.2
	Very fine	5	4.79	95.8	0.21	4.2
Chailat 2	Fine	5	4.82	96.4	0.18	4.6
	Very fine	5	4.76	95.2	0.24	4.8
Range	**Fine**		**4.72-4.88**	**95.4-96.4**	**0.18-0.23**	**3.8-4.6**
	Very fine		**4.75-4.80**	**95-96**	**0.2-0.25**	**4-5**
Average	**Fine**		**4.8**	**95.71**	**0.2**	**4.29**
	Very fine		**4.77**	**95.5**	**0.23**	**4.5**

Table 3- Light components of sand dunes in the study area

Name of sample	Size of sand	Light Component												
		Quartz %		Feldspar %			Rock fragments %						Coated grains by clays	Others
				Potash feldspar										
		Monocrystalline	Polycrystalline	Orthoclase	Microcline	Plagioclase	Carbonate R.F	Chert R.F	Igneous R.F	Metamorphic R.F	Mudstone R.F	Evaporate (Gypsum)		
Manziliyah 1	Fine	49.7	2.1	3.4	2.6	18.1	10.5	1.8	2.2	2.0	2.2	3.3	1.2	0.6
	Very fine	52.2	2.2	1.4	3.3	2.3	20.4	10.2	1.4	1.6	2.3	1.5	0.3	0.9
Manziliyah 2	Fine	50.4	2.2	1.3	4	3.2	17.4	11.0	2.7	2.2	2.3	1.4	0.6	0.3
	Very fine	53.4	1.5	2.6	2.1	3.2	18.4	9.3	2.9	1.4	1.4	2.6	0.9	0.3
Khazina	Fine	48.1	1.8	1.2	3.6	3.5	19.8	9.1	1.6	1.4	3.9	4.2	1.2	0.6
	Very fine	50.4	2.4	2.1	4.9	2.2	19	8.5	2.6	2.5	2.7	1.2	0.6	0.9
Abu-Ghrab	Fine	53.0	2.2	1.2	3.3	2.4	18.7	10.6	2	2.1	2.4	1.2	0.3	0.6
	Very fine	49.3	3.3	2.2	3.2	3.1	17.3	11.2	2.3	1.8	1.1	2.4	1.2	1.6
Zubadiate	Fine	47.2	2.4	2.2	2.3	2.1	20	13.2	2.2	1.7	2.5	2.1	1.8	0.3
	Very fine	50.1	2.4	1.9	3	3.4	18.3	12.7	2.3	1.6	2.0	1.7	0.3	0.3
Chailat 1	Fine	50.6	2.9	2.6	2.2	1.3	19.7	10.3	1.6	1.4	3.3	2	1.5	0.6
	Very fine	51.4	2.2	1.5	2.2	3.7	19.4	9.1	2.4	2.3	2.6	2.3	0.6	0.3
Chailat 2	Fine	52.3	2.0	2.7	1.4	1.5	20.2	9.5	2.1	2.6	2.2	1.3	1.3	0.9
	Very fine	54.4	1.2	2.9	2.4	1.5	18.3	10.0	2.2	2.1	2.3	1.1	1	0.6
Range	Fine	47.2-53	1.8-2.9	1.2-3.4	1.4-4	1.3-18.1	10.6-20.2	1.8-13.2	1.6-2.7	1.4-2.6	2.2-3.9	1.2-4.2	0.3-1.8	0.3-0.9
	Very fine	49.3-54.4	1.2-3.3	1.4-2.9	2.1-4.9	1.5-3.7	17.3-20.4	8.5-12.7	1.4-2.9	1.4-2.5	1.1-2.7	1.1-2.6	0.3-1.2	0.3-1.6
Average	Fine	50.2	2.23	2.08	2.8	4.58	18.0	8.77	2.1	1.9	2.7	2.21	1.13	0.6
	Very fine	51.6	2.17	2.08	3.0	2.77	18.7	10.1	2.3	1.9	2.0	1.83	0.7	0.7

Table 4- Heavy minerals average in fine and very fine sand size

Dune Name (Station)	Sand fractions	Op	Ch	Pyroxene		Amphibole			Mica		Gar	Zir	Epi	Sta	Rut	Tou	Ky	Other
				Orth	Clyn	Hor	Glau	Tre	Bio	Mus								
Manziliyah 1	**F**	39.3	7.2	2.7	5.7	4.7	1.6	1.8	6.3	4.5	6	3.1	6.3	1.5	3.2	2.1	2.4	1.6
	V.F	43.2	9.6	2.8	3.1	4.8	2.3	0.9	4.9	3.6	5.9	3.2	4.5	2.5	2.9	2.7	2.6	0.5
Manziliyah 2	**F**	41.5	8.1	2.4	3.8	5.5	1.8	0.9	5.4	4.3	5.3	4.2	6.2	1.2	4.2	1.8	2.2	1.2
	V.F	42.6	7.2	1.8	3.2	5.1	1.8	0	4.3	5.9	6.3	4.5	6.6	1.3	3.9	2.6	2.4	0.5
Khazina	**F**	42.8	6.4	3.2	4.6	4.6	1.8	2.4	4	3.2	4.2	3.9	4.6	2.1	3.2	3.7	2.5	2.8
	V.F	42.8	7.9	2.8	4.9	4.8	2.1	2	3.2	4.9	5	3.5	4.8	1.3	3.2	3.4	2.6	0.8
Abu-Ghrab	**F**	38.3	8.2	3.5	5.6	6.1	0.9	1.5	3.9	5.3	6	4.2	5.6	2	2.4	4.1	1.8	0.6
	V.F	40.9	9.4	2.6	2.4	6.5	1.2	0.9	3.7	3.3	6	4.3	6.3	2.2	3.6	2.4	2.8	1.5
Zubadiate	**F**	38.4	8.1	3.5	5.6	6.1	0.9	1.5	3.3	5.3	6	4.2	5.6	2	2.4	4.1	1.8	1.2
	V.F	45.9	8.2	3.2	3.5	4.5	0.9	1.8	3.3	3.3	5.3	4.3	4.5	2.4	3.7	3.2	1.6	0.4
Chailat 1	**F**	44.1	8.3	2.8	3.2	4.9	1.8	1.5	3.4	4.2	4.5	3.2	4.7	2.1	5.6	3.7	1.5	0.5
	V.F	44.2	8.2	2.5	3.8	3.6	2.4	0.9	5.4	4.2	4.9	3.5	3.3	1.5	5.8	2.8	1.8	1.2
Chailat 2	**F**	44.8	9.2	2.3	3.6	4.9	1.2	0.9	4.9	3.7	6	3.8	4.2	1.5	3.9	1.8	2.1	1.2
	V.F	41.4	9.8	3.7	2.8	5	1.2	1.2	3.9	4.6	6.2	4.8	4.3	1.6	3.2	3.7	1.8	0.8
Range	**F**	**38.3-44.8**	**6.4-9.2**	**2.3-3.5**	**3.2-5.7**	**4.6-6.1**	**0.9-1.8**	**0.9-2.4**	**3.3-5.4**	**3.2-5.3**	**4.2-6**	**3.1-4.2**	**4.2-6.3**	**1.2-2.1**	**2.4-5.6**	**1.8-4.1**	**1.5-2.5**	**0.5-2.8**
	V.F	**40.9-45.9**	**7.2-9.8**	**1.8-3.7**	**2.4-4.9**	**3.6-6.5**	**0.9-2.4**	**0-2**	**3.2-6.3**	**3.1-5.9**	**4.9-6.3**	**3.2-4.8**	**3.3-6.6**	**1.3-2.5**	**2.9-5.8**	**2.4-3.7**	**1.6-2.8**	**0.5-1.7**
Average	**F**	**41.3**	**7.93**	**2.91**	**4.58**	**5.26**	**1.43**	**1.5**	**4.46**	**4.36**	**5.43**	**3.8**	**5.3**	**1.77**	**3.56**	**3.04**	**2.04**	**1.3**
	V.F	**43**	**8.6**	**2.77**	**3.38**	**4.9**	**1.7**	**1.1**	**4.1**	**4.21**	**5.66**	**4.0**	**4.9**	**1.83**	**3.76**	**2.97**	**2.28**	**0.85**

Op: Opaque minerals**, Ch**: Chlorite **,Orth** :Orthopyroxene ,**Glyn**: Clynopyroxene ,**Hor**: Hornblende , **Glau**: Glaucophane, **Tre**: Tremolite ,**Bio** :Biotite**, Mus** :Muscovite **, Gar** :Garnet ,**Zir** :Zircon **,Epi**: Epidotes**, Sta**: Staurolite ,**Ru** :Rutile ,**Tou**: Tourmaline ,**Ka**:Kainite , **F**:fine,**V.F**: Very fine

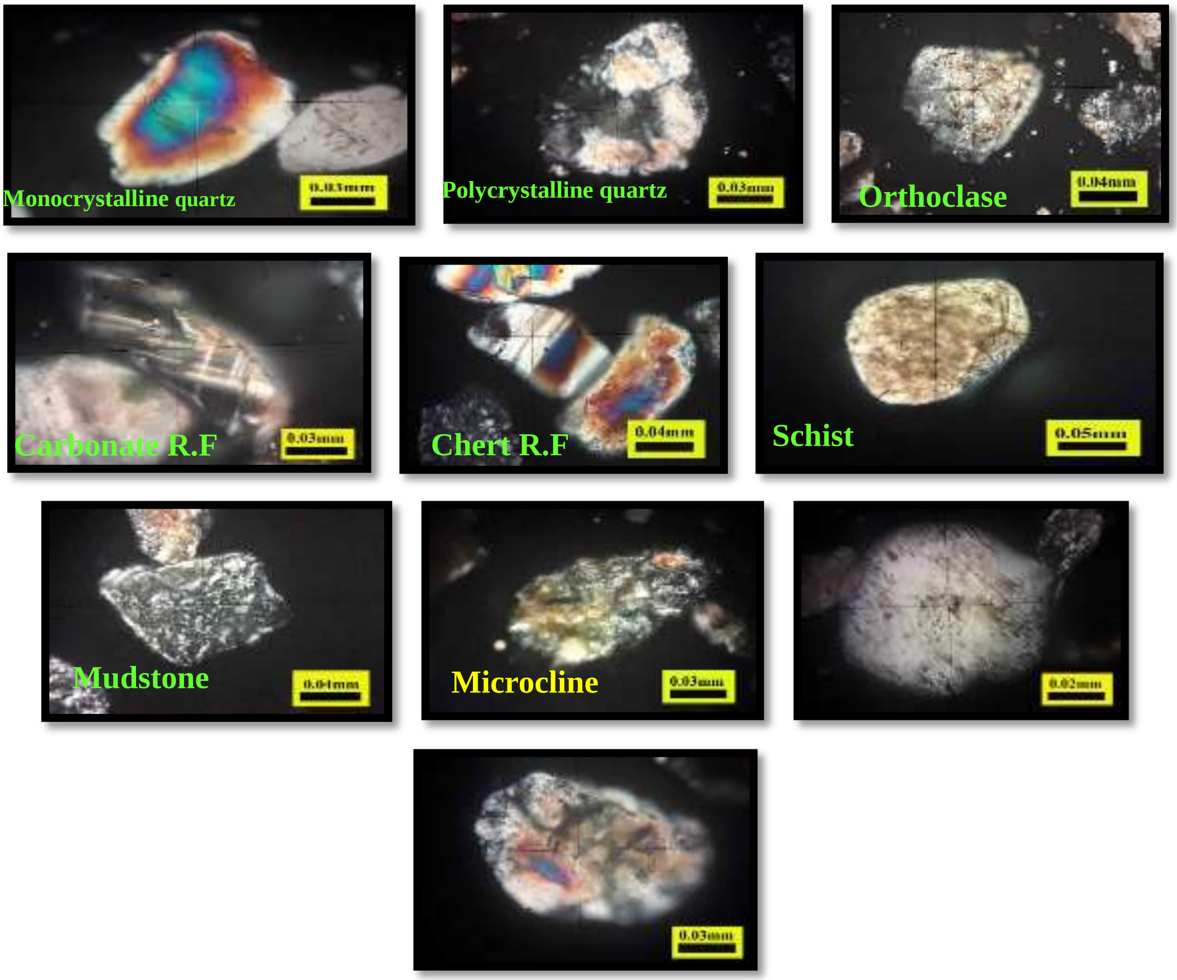
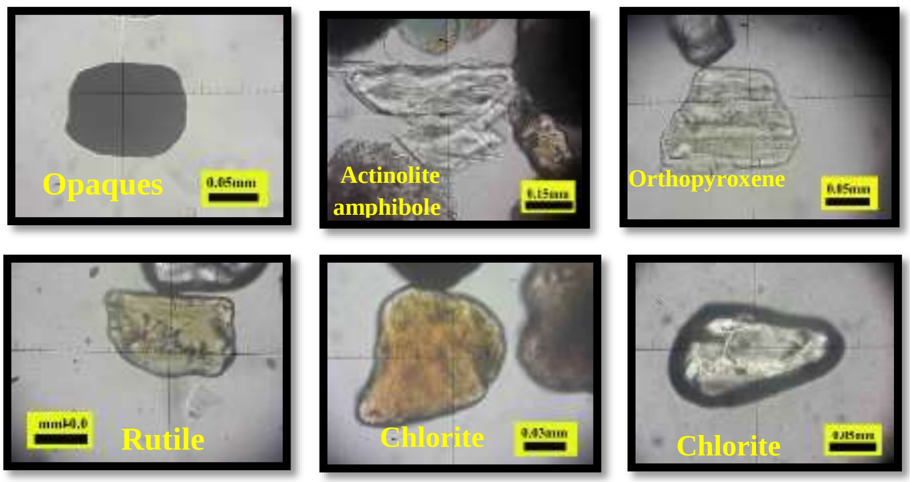


Plate 1- The light minerals in Missan sand dunes.



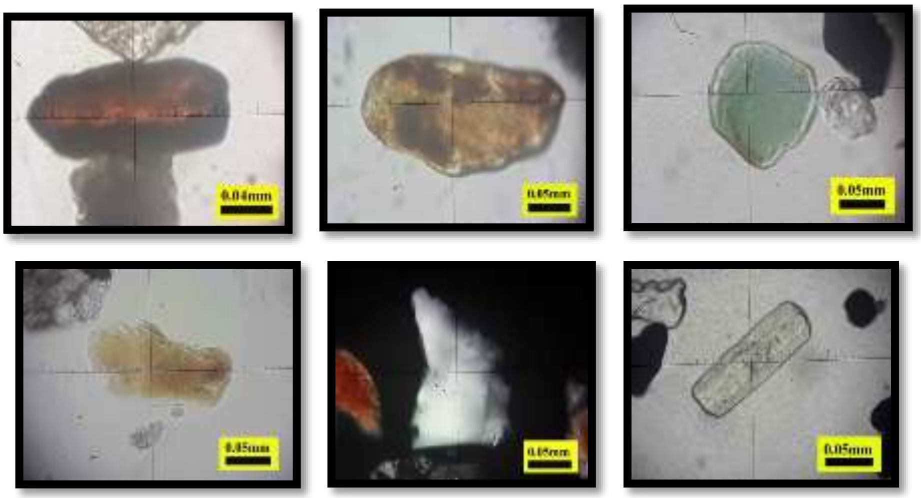


Plate 2- The heavy minerals in Missan sand dunes

3-2-3 The XRD analysis

The XRD analysis of bulk sand samples revealed that quartz, calcite, feldspar, and gypsum are the main constituents in all sand samples. Quartz is the most abundant minerals component with an average of 51.5% (Table 5), which is identified at the reflections of 3.34 A$^{\circ}$, 4.26 A$^{\circ}$, 2.45 A$^{\circ}$, and 1.81A$^{\circ}$ respectively (Figure 6). Feldspar has an average of 7.63% and is identified at the reflection of 3.20A$^{\circ}$. This mineral is associated with quartz in most clastic sedimentary rocks. Calcite was recorded with an average of 18.33%, which was identified at the reflections of 3.04 A$^{\circ}$, 2.29 A$^{\circ}$, 2.10 A$^{\circ}$, 1.95 A$^{\circ}$, and 1.91 A$^{\circ}$, respectively. Gypsum is the least abundant mineral, with an average of 2.7% at the reflection of 7.56A$^{\circ}$.

Table 5- Average of the main minerals of sand dunes (0.063-2 mm)

Dune Name	Minerals %			
	Quartz	Feldspar	Calcite	Gypsum
Manziliyah	49.8	8.5	17.1	2.3
Khazina	53.2	7.5	18.5	2.2
Chailat	51.5	6.9	19.4	3.5
Average	51.5	7.63	18.3	2.67

Regarding granular size, quartz and gypsum have high percentages in a medium sand fraction of sand, while feldspar and calcite have high percentages in fine sand fractions (Table 6).

Table 6- Average of the main minerals of (0.125-0.250mm), (0.250-0.500 mm) in sand samples

Sand fractions	Minerals %			
	Quartz	**Feldspar**	**Calcite**	**Gypsum**
Medium (0.250-0.500mm)	53.12	7.17	18.9	2.3
Fine (0.125-0.250mm)	52.4	7.21	19.13	2.2

Each value represents an average of three percentage

3-2-4 The clay minerals analysis

The most common clay minerals in sand dunes are palygorskite and illite, with an average of 36.96 % (identified at 10.5A$^{\circ}$) and 29.94% (identified at 10.5A$^{\circ}$), respectively (Table 7 and Figure 7). The other identified clay minerals are kaolinite with an average of 18.7%

(identified at 7.1 A°), mixed layers of montmorillonite-chlorite (identified at 14. 9A°, and 4.97 A°) with an average of 14.4% (Figure 8). Clay minerals are used as a tool to expect the source rocks. Illite minerals formed by direct weathering and erosion or alteration of alumino-silicate minerals, e.g. alkali-feldspar minerals and muscovite, which existed in acidic igneous and metamorphic rocks. Palygorskite is formed by weathering and erosion of basaltic igneous rocks [28]. Kaolinite is derived from weathering of K-feldspar in acidic igneous rocks [29 and 30].

Table 7- Clay minerals percentage of studied samples **(semiquantitative)**

Clay minerals percentage (%)			
Kaolinite	**Palygorskite**	**Illite**	**Montmorillointe –Chlorite**
18.7	36.96	29.94	14.4

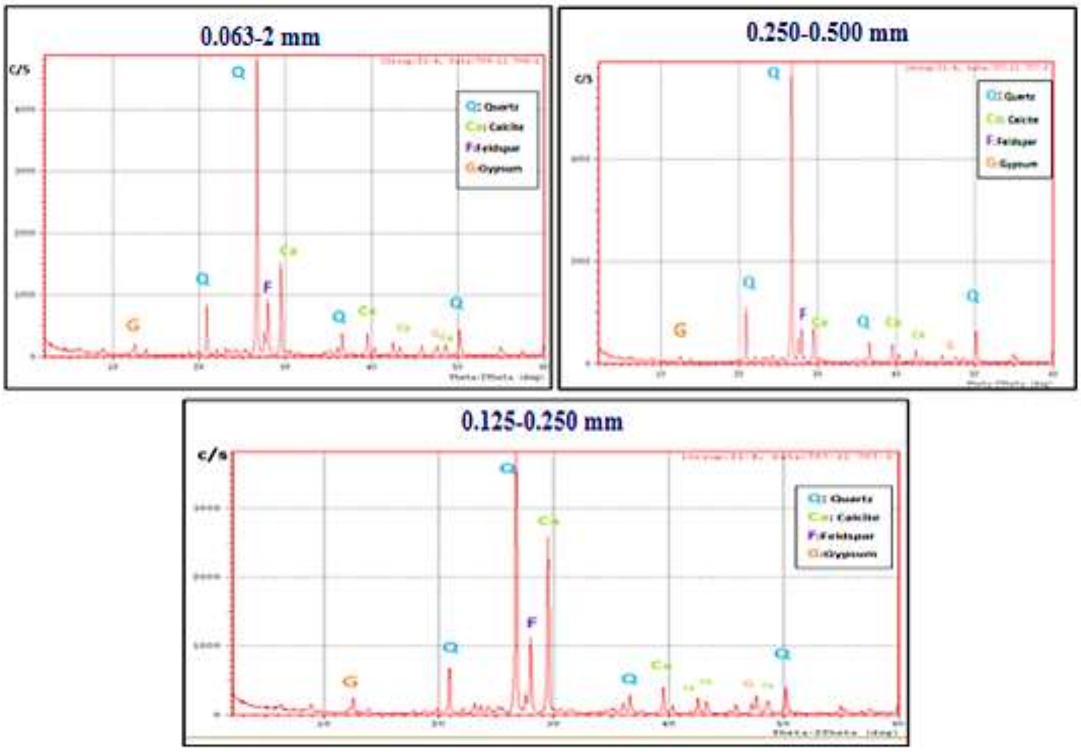


Figure 6- XRD charts show the mineralogical composition of sand dunes in different size fractions.

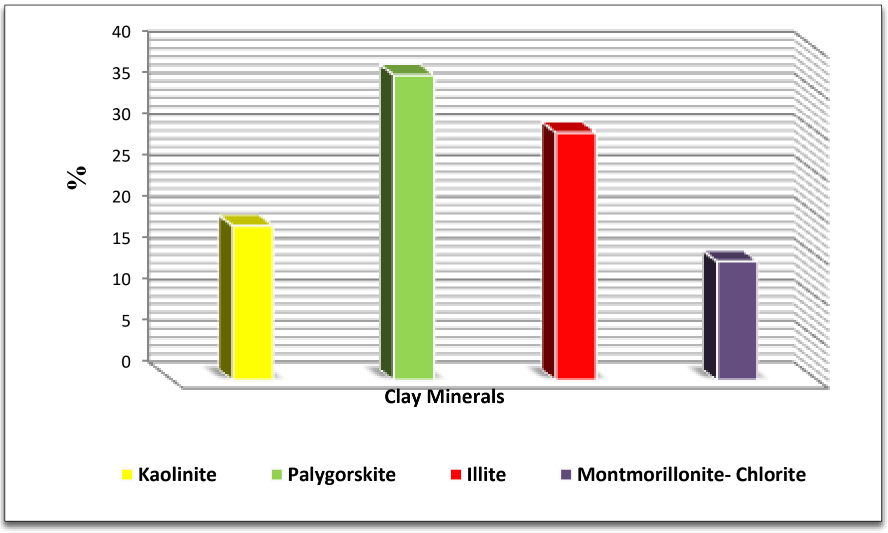


Figure 7- Average percentages of clay minerals identification using the XRD technique.

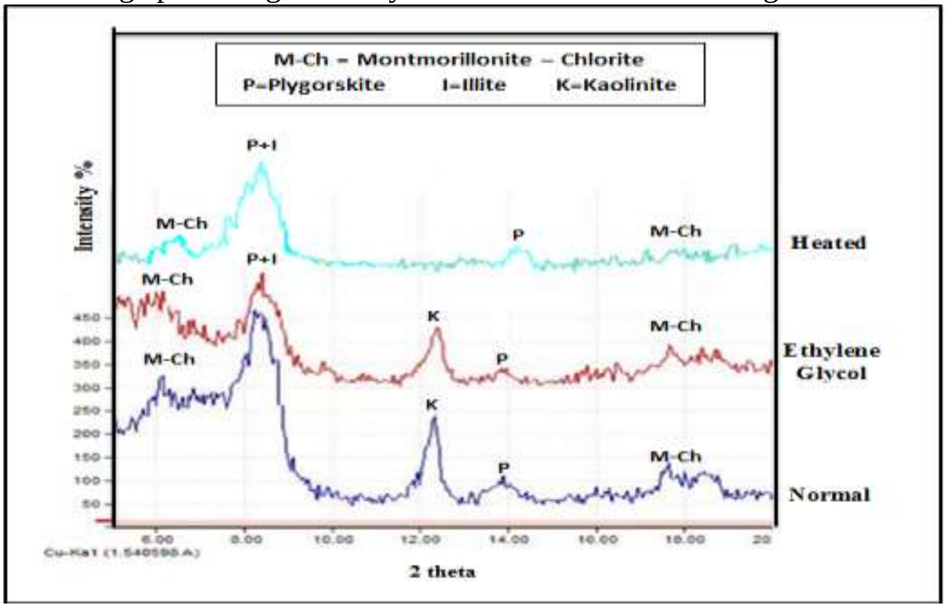


Figure 8- The XRD patterns identification of clay fraction of sand dunes using the XRD technique.

3-3 Geochemistry

The XRF analysis of bulk sand samples revealed that the average major oxides are 61.36% SiO_2, 14.08 % CaO, 6.76% Al_2O_3, 3.2% Fe_2O_3, 2.30 % Alkalies (Na_2O+K_2O), and 1.09% MgO. The others SO_3, TiO_2, P_2O_5, and MnO are all less than1% (Table 8 and Fig. 9).

The highest percentage of SiO_2 was recorded in Khazina sand, whereas TiO_2, Fe_2O_3, MgO, MnO, CaO, and Alkalis have the highest percentage in Chailat sand. The highest percentage of Al_2O_3 and SO_3 was recorded in Manziliyah, and Zubadiate sand, respectively. The lowest percentage of SiO_2, P_2O_5, TiO_2, Fe_2O_3, MgO, Alkalis, and Al_2O_3 were recorded in Zubadiate sand, whereas the lowest percentage of MnO, SO_3, and CaO were recorded in Khazina sand. The presence of SiO_2 can be attributed to silicate minerals like quartz, feldspars, chert, igneous, and metamorphic rock fragments.

The high percentage of alumina is due to the main component of clay and feldspar minerals associated with sand. Fe_2O_3 is associated with opaque minerals and amphibole and pyroxene groups [31]. The high content of CaO is related to calcite, which was observed as carbonate rock fragments in sand dunes. Additionally, the other calcium oxide source is probably from weathering of pyroxene and amphibole. Titanium is the most mineral composition of rutile. Gypsum is the most source of SO_3 in the sand sample.

Magnesium is included in the crystalline structure of some clay minerals in the sand samples, such as palygorskite, chlorite, and montmorillonite minerals [32]

MnO is always associated with Fe_2O_3 in clay and some heavy minerals, Na_2O is the main oxide in the feldspar or adsorbed on the surface of clay particles, and potassium is abundant in feldspar (microcline and orthoclase) as well as in mica (biotite and muscovite) also in clay minerals like illite and montmorillonite [33].

K_2O is higher than that of Na_2O in all the studied samples, this indicates the dominance of the potash feldspar mineral (orthoclase and microcline) with small percentages of sodic plagioclase (albite) [34].

In terms of grain size SiO_2 have the highest values at the sand fractions of 0.250 mm and 0.500 mm in all studied areas, especially in Khazina sand, while they have the lowest values in size fractions of 0.125 mm and 0.250 mm, especially in Zubadiate sand. These results encourage using medium sizes of sand for industrial applications which need a high concentration of silica. Other oxides such as CaO, Al_2O_3, Fe_2O_3 MgO, SO_3, TiO_2, and MnO, are reached their highest values at the sand sizes of 0.125 mm and 0.250 mm in all studied areas, while they have the lowest values at the sand fraction of 0.250 mm and 0.500 mm in all studied areas (Table 9 and Fig. 10). The distribution of oxides in sand fractions in the study area is consistent with the study of Al-Khafaji et al. 2010 [34].

Table 8- Chemical analysis of (0.063-2 mm) of raw sand samples.

Dune Name	Oxides (Wt.%)									
	SiO2	Al2O3	Fe2O3	CaO	SO3	P2O5	TiO2	MnO	MgO	Na_2O+ K_2O
Manziliyah	63.87	7.16	3.16	12.7	0.04	0.09	0.57	0.05	1.47	2.36
Khazina	65.69	6.55	2.9	10.75	0.03	0.12	0.49	0.04	1.19	2.29
Zubadiate	57.73	5.5	2. 6	13.99	0.07	0.07	0.31	0.045	0.03	1.91
Chailat	58.15	7.79	3.55	18.9	0.05	0.11	0.66	0.07	1.68	2.63
Max	**65.69**	**7.79**	**3.55**	**18.9**	**0.07**	**0.12**	**0.66**	**0.07**	**1.68**	**2.63**
Min	**57.73**	**5.5**	**2.9**	**10.75**	**0.03**	**0.07**	**0.31**	**0.04**	**0.03**	**1.91**
Average	**61.36**	**6.76**	**3.2**	**14.08**	**0.05**	**0.097**	**0.50**	**0.05**	**1.09**	**2.3**

Table 9- Chemical analysis of (0.250-0.500mm), (0.125-0.250mm) size of sand.

Dune Name	sand fractions	Oxides Wt.%									
		SiO_2	Al_2O_3	Fe_2O_3	CaO	SO_3	P_2O_5	TiO_2	MnO	MgO	Na_2O + K_2O
Manziliyah	Medium	67.40	6.7	2.7	9.4	0.03	0.09	0.43	0.04	1.27	2.37
	Fine	49.33	7.2	3.84	19.3	0.06	0.09	0.65	0.07	1.69	2.34
Khazina	Medium	68.23	6.22	2.78	6.77	0.02	0.12	0.53	0.02	0.77	1.83
	Fine	46.03	6.88	3. 93	19.8	0.03	0.10	0.65	0.07	1.56	2.30
Zubadiate	Medium	60.77	5.74	2.51	16.2	0.04	0.15	0.35	1.19	0.04	2.04
	Fine	46.02	6.49	3.4	22.5	0.043	0.08	0.53	1.57	0.07	2.25
Chailat	Medium	67.55	7.28	2.74	8.97	0.03	0.09	0.42	0.03	1.38	2.74
	Fine	52.30	7.38	3.47	17.5	0.03	0.09	0.57	0.06	1.62	2.41

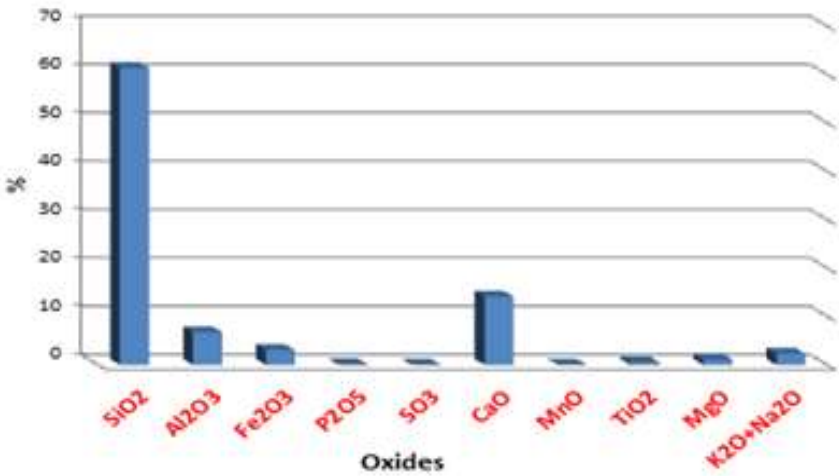


Figure 9- Average of major oxides in (0.063-2 mm) size of sand.

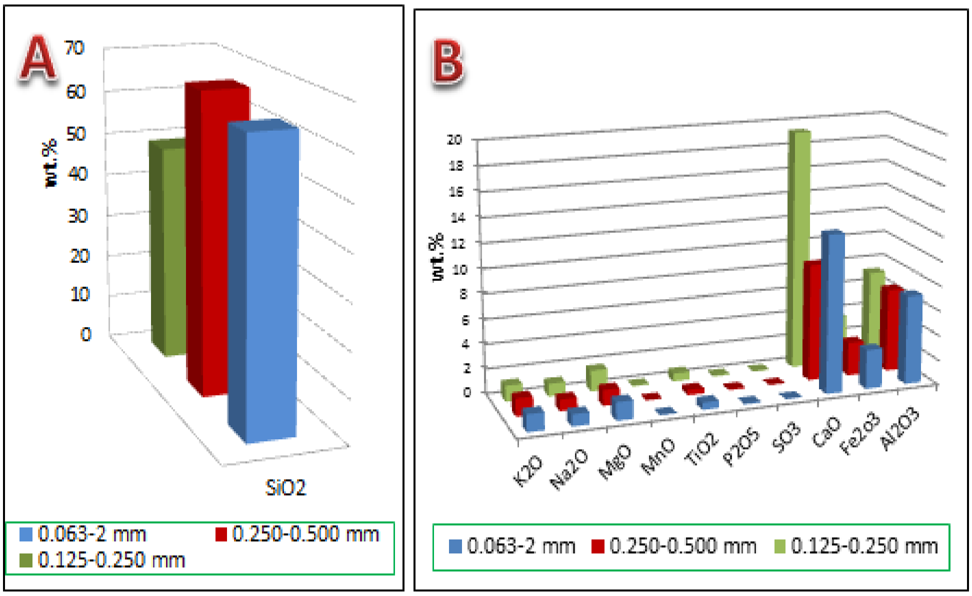


Figure 10- Relationship of percentages and distribution of A: silica and B: other major oxides with granular size.

4-Conclusions

1-Medium sand size (0.250-0.500mm) represents the predominant sand size fractions of all studied sand dunes, averaging 57.28 % except the Chailat sand dune.

2-Quartz represents the predominant light mineral in all studied sand dunes, followed by carbonate rock fragments, feldspar, and igneous and metamorphic rock fragments.

3- The heavy mineral assemblages consist mainly of opaque minerals, chlorite, mica, and amphiboles. Pyroxene and epidote are common minerals; zircon, garnet, tourmaline, rutile, kyanite, and staurolite are in a minor amount. The abundance of these heavy minerals indicates different source rocks, such as igneous, metamorphic, and sedimentary rocks.

4- Playgorskite and illite are the most common clay minerals in the study area, followed by Kaolinite and mixed layer montmorillonite –chlorite, which indicates that the source of sand is acidic and basic igneous rocks, and to a less extent of metamorphic rocks

5-Silica has the highest percentages among other oxides, followed by CaO, Al_2O_3, Fe_2O_3, alkalis (Na_2O+K_2O), MgO, SO_3, TiO_2, P_2O_5, and MnO.

6-SiO_2 is concentrated in medium sand, whereas the other oxides are concentrated in fine sand.

7- The source of sand dunes in the Missan Governorate is the Zagros belt, and the local sources area represents by Injana and Mukdadiya formations.

8- There is a clear relationship between the carbonate percentages and the grain size, as they increase with finer sizes. The high percentage of carbonate may indicate closeness to the source area and the relatively high carbonate content in the parent rocks.

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