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MINERALOGY AND GENESIS OF HEAVY MINERALS IN COASTAL DUNE SANDS, SOUTH EASTERN QATAR

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المعادن الثقيلة واصل تكونها في الكثبان الرملية الساحلية . جنوب شرقي قطر

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تتراكم كميات كبيرة من الرمال المسافية في جنوب شرقي النطاق الساحلي لقطر وذلك في حقل رملي يسمى محلياً باسم نقيان قطر ، لقد دلت الدراسة الحالية علي حزام من هذه الكثبان الرملية في منطقة مسعيد الصناعية أن توزيع المعادن الثقيلة متغير إقليمياً بتأثيرات محلية وخارجية تعود إلى فروقات أصلية . تتكون رمال الكثبان من أصداف المحاريات مختلطة بمعادن خفيفة من الكوارتز ، الفلسبار ، الكالسيت ، الجبس والهاليت ، بينما تتضمن المعادن الثقيلة مجموعتين من المعادن : معادن ثابتة وتشمل الزركون ، التورمالين والروتيل ومعادن غير ثابتة وتشمل البيروكسين ، الامفيبول ، الابيدوت ، الجارنت ، الاباتيت ، الاندالوسيت والكيانيت. بعض هذه المعادن تتواجد في الصخور النارية والبعض الأخر في الصخور المتحولة وبعضها قد يتواجد في كلا النوعين من الصخور ، لقد تم نقل الرمال المكونة للكثبان في منطقة الدراسة بواسطة الرياح ذات الاتجاه الشمال الغربي والمعروفة باسم رياح الشمال وذلك خلال فترة إنخفاض مستوى البحر مقارنة بالوقت الحالي، وذلك في فترة انغلاق خليج سلوى . بعض الرمال تكونت أيضاً نتيجة عمليات التجوية والتعرية لصخور العصر الثلاث المحلية بواسطة الرياح الشمالية السائدة في دولة قطر.

Key words : *Mesaieed, Qatar, Sand dune, Heavy Minerals, Winds, Al-Shamal*

ABSTRACT

Large amounts of aeolian sand occur in the southeastern coastal zone of Qatar Peninsula as sand dunes accumulated in a vast sand field locally called " Niqyan Qatar ". The present work, carried out on a sand dune belt of this field near Mesaied Industrial City, revealed the distribution of heavy minerals shows a regional variability induced by provenance and local variability reflecting genetic differences. The studied dune sands are rich in shells of pelecypods, with the light mineral assemblage including quartz, feldspar, calcite, gypsum and halite. On the other hand, the heavy minerals are found to consist of two mineral assemblages : (a) stable mineral assemblage, which includes zircon. tourmaline and rutile and (b) unstable heavy mineral assemblage, which includes garnet, epidote, pyroxene, amphibole and A12SiO5-polymorphs. Some of these minerals originate in igneous rocks, others originate in metamorphic rocks, while some minerals can be formed in both types of rocks. The aeolian sands forming the studied dunes have transported by the prevailing norhtwesterly Al-Shamal wind crossing the Arabian landmass, During periods of low sea level relative to the present, when the Gulf of Salwa was dry land. Further sands result from erosion and abrasion of the Tertiary rocks exposed on the Surface of Qatar by the still prevailing northwesterly wind toward the southeastern part of the country. These are believed to represent the most important sources of the heavy minerals in these dune sands.

INTRODUCTION

Heavy minerals in dune sands include various deterital minerals having specific gravities greater than about 2.9. The relative amount of heavy minerals in a sand dune depends on the abundance of each mineral in the source rock, its survival potential during weatheing, transportation, and diagenesis, as well as on its specific gravity. Due to the wide range in specific gravities of the common heavy minerals (2.9-5.2), there is a significant segregation among them during transportation. A high percentage of heavy minerals in the dune sands originate in metamorphic rocks, which are formed in a much wider range of temperature and pressure than do igneous rocks with some characteristic heavy minerals. However, several heavy minerals, such as zircon, tourmaline and magnetite, are formed in both igneous and metamorphic rocks. Some minerals, such as tourmaline, occurs in a variety of colors which may be diagnositc of metamorphic rocks (1). Furthermore, some heavy minerals are known to grow in sediments, they include zircon, tourmaline, rutile and anatase, However, in the dune sands, detrital augite, hypersthene and olivine can be abundant and domiante the heavy mineral suite. Based on their optical properties, heavy minerals are normally classified into two groups; non-opaques and opaques, according to their degree of transparency in thin sections. In the dune sands about one-half of the heavy minerals are opaque to the transmitted light. Heavy minerals are amongst the most sensitive indcators of the nature of sediment source areas. They have frequently been used in studies of mineralogical provinces and correlation of detrital sediments (2-13).

In a study of sand dunes in Qatar Peninsula, Embabi and Ashour (14) grouped the heavy minerals found in some samples into two quite distinct groups. A group of apatite, collophane, anhydrite and kyanite, which are considered to be of local origins, while the garnet, diopside, rutile, zircon, sillimanited and epidote form an exogenous group. In the present work, detailed mineralgoical studies are carried out on the heavy minerals in a sand dune belt near Mesaieed Industrial City, Sotheastern Qatar. Pattern of distribution of the detected heavy minerals is studied to determine the local and regional factors affecting their variation. The obtained results are interpreted in the light of geological history of Qatar Peninsula to elucidate the genesis of heavy minerals in the studied dune sands.

Geomorphological Features

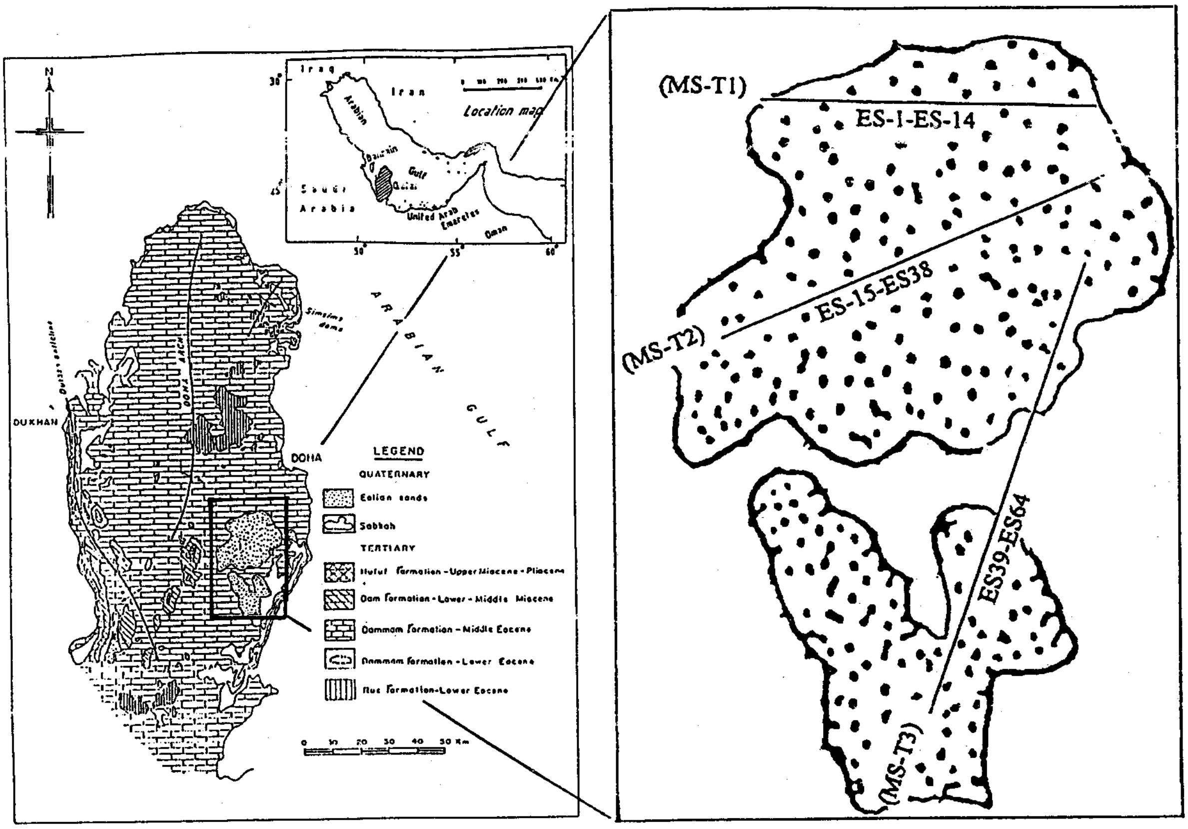
The land surface of Qatar is formed by a broad arch which has a Tertiary limestone carapace. The state of Qatar is bordered by the Arabian Gulf to the north, east and west and by Saudi Arabia and United Arab Emirates to the south. The surface is mostly desert. Eocene carbonates are exposed in the central part of the arch and in the Dukhan anticline in the western part of teh state (Fig. 1) Miocene sediments. occur in low mesas. Quaternary beach rocks form the coastal areas. Extensive areas of sabkha deposits cover the southernmost part of the state and the area east of Dukhan anticline. Sand dunes represent one of the most important geomorphological features of southern Qatar. Dunes of different types were developed by wind activity, The northern part of Qatar is almost dune free. Analyses of landsat images indicate the patterns are oriented in a N-to NW direction in most of the dunes. Barchan and dome dunes predominate, whereas, traversal and dead dunes are common near Khor El-Adied in the southwestern part of Qatar and seif longitudinal dunes are common in the region of Mesaieed (14-19). The Arabian Gulf region including Qatar, is characterized by dust and sand storm. Dust fallout is described as calcareous silt and quartzitic fine to very fine sand (20-21). The sand dune is strongly affected by the Shamal winds crossing from Iraq and the Rub Al Kahli to Qatar (14,18). Wind and mineralogical data indicated that the sands are of local and external sources.

Wind Regime

The distribution of various atmospheric pressure areas over the Arabic Gulf, reflects different types of wind that blown on Qatar Peninsula. The prevailing wind, locally known as «Al-Shamal», is blowing from NNW and NW directions, while about 20% of the winds blow from other directions mainly SE, S and SW (16, 17, 22-25). «Al-Shamal» wind blows from the high pressure areas over the middle of Asia from the end of October to February, where it is dry and cold during the winter months. The NNW wind prevails clearly in summer more than in other seasons, wheareas the NW, N and SE winds prevail in spring and winter, while the SE wind becomes more dominating, During the winter months, the wind speed is generally low, ranging between 10-20 km/h in the day time period, but from March to the end of July there is a steady NNW wind with an average speed of 25-30 km/h. This wind, combined with the rapidly rising temperature and decreasing relative humidities in day time, has a marked effect on evaporation owing to its dessicating properties (26). In fact, the aeolian sand deposits in Qatar start as isolated barchancs near the center of the peninsula, some 25 km southwest of Doha. Under the action of the prevailing northwesterly ("Al-Shamal" winds, these barchanse move to the southeast, where they combine into different barchanoid forms represented by compound, complex longitudinal and transverse dunes. These dunes types are found in the coastal area south of Mesaieed, where they are accumulated in a low-lying areas of sabkhas which creates an internal moisture in the dunes and reduces their rate of migration (19). Meanwhile, strong SE wind modifies the upper part of the slip faces of the barchans and sometimes it causes a reversal in the portion of this slip faces. The moving dunes end at the coastline of the Arabian Gulf, where they gradually lose heir hornes under the effects of wave and tidal movements.

Material and Methodology

In this work 66 sand samples were collected from three traverses (MS-Ti, MS-T2,MS-T3) around Mesaieed area (Fig. 2). The samples were collected from the crests and troughs of sand dunes in an area 50 x 50 cm and 10 to 20 cm down. Care was taken to obtain reliable representation of the entire explored profiles, with consideration of the geomorphology of the sand dunes. The samples were collected at intervales of 1 to 2 km. Each sample weighed about 1 kg. The samples were quartered and 100 gm was sieved and the sand size fraction between 2 and 4 phi (63-250um) was utilized for heavy mineral separations. Bromoform was used for the heavy mineral separation. A thin spray of heavy mineral grains was mounted in Canada balsam. Mineralogical identification was performed by a polarizing microscope. Quantitative analyses were accomplished by grain counting under the microscope. However, grains counting yields data on the relative distribution of mineral grains in any assemblage, without considering size and specific gravity (27). About 300 non opaque heavy mineral grains as well as opaque and non-opaque grains were counted and their relative frequencies were determined. For the purpose of this study analysis is restricted to the non-opaque detrital suite because this group is most diagnostic of provenance. Micas (Muscovite and biotite) were omitted from the count, because their density range straddles that of bromoform and their platy habit tends to cause them to float in the liquid and they are hydraulically equivalent to quartz of a finer grain size, so that their behaviour during transportation and deposition is quite different to that of other heavy minerals (7). Diagenetic grains are also omitted, as they give no indication of provenance.



(Fig. 1), Location of sampling traverses

Results and Discussion

In the study area the sands are generally white in color. The heavy minerals were found to range between 0.2 and 1.9% of the original sample weight (Table 1, Fig. 3). The highest percentage is found in travers 1 (0.8-1.9, samples ES!-ES14), whereas travers 3 have the lowest percentage (0.2-0.8, samples ES35-ES66) and moderate values in traverse 2 (0.3-1.2, samples ES15-ES34).

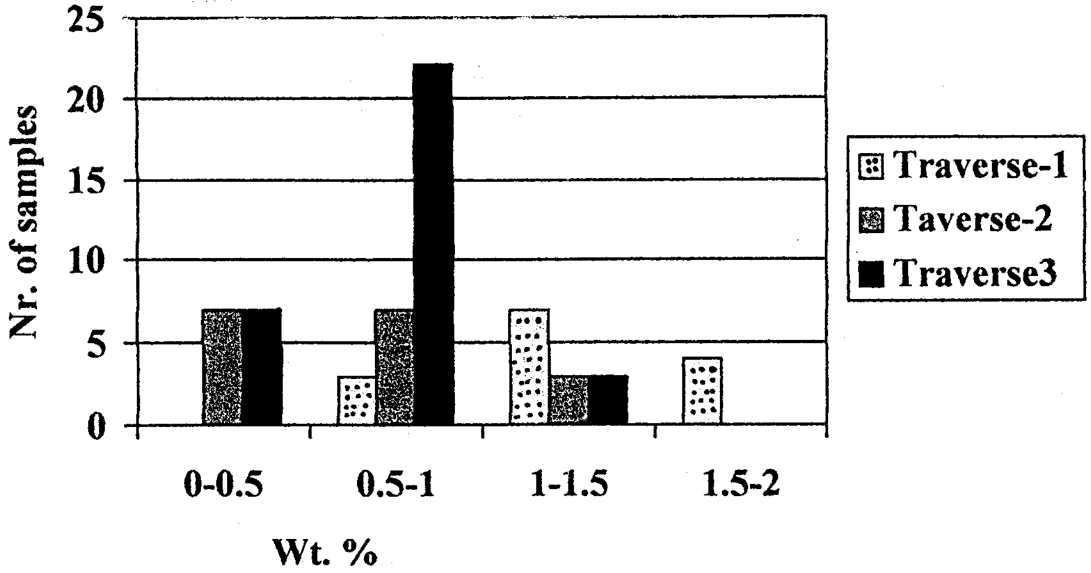
Heavy Minerals :

1 - Opaque heavy minerals :

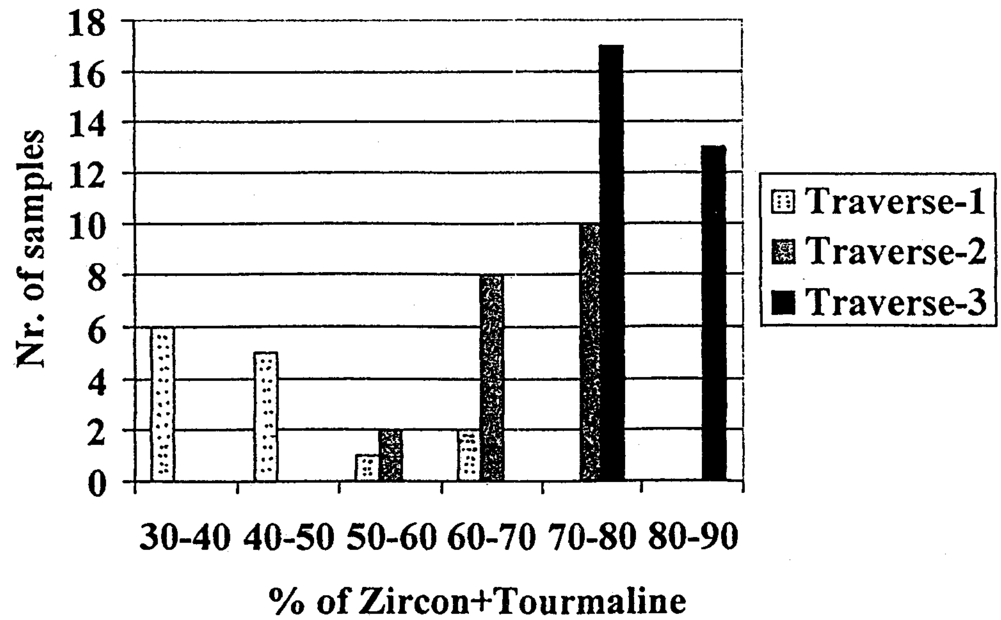
The majority of opaque grains were identified as magnetite, ilmenite with lesser amount of hematite and limonite. Opaques occur as subangular to subrounded grains with irregular outlines. Some iron oxides also occur as grain coatings to quartz and chert. The frequency percentage of opaques relative to all heavy minerals vary between 20 and 28 in travers 1, 20-30 in travers 2 and 15-3- in traverse 3.

2 - Non-opaque heavy minerals :

Transparent heavy minerals are more abundant than opaques (Table 1). Major transparent minerals are zircon (20-40 in traverse 1, 37-58 in traverse 2 and 40-65 in traverse 3), tourmaline (9-20 in traverse 1,13-25 in travers 2 and 15-35 in traverse 3), hornblende (5-15 in traverse 1, trace to 6 in traverse 2 and zero to 5 in traverse 3), pyroxene (30-55 in traverse 1,25-35 in traverse 2 and 14-24 in traverse 3), epidote (1-5 in traverse 1 and zero to 2 in traverse 2 and 3). Minor minerals include and rutile (0-3) and apatite (0-2 vol.%). The minerals garnet, kyanite, andalusite, sphene and staurolite are trace. Along the studied profiles a progressive compositional change is evident in southeastern direction, form travers 1 to 3 (Fig 4). It is marked by a relative increase of zircon and tourmaline and a relative decrease in pyroxenes, epidote and amphiboles. Pyroxenes (ortho and clino) are the dominant non-stable heavy minerals. They are represented by irregular to subrounded prismatic augite, diopside and enstratite in equal amounts. The grains are colorless, light green and subhedral (Fig. 5). Amphibole occurs in two varieties; green hornblende and brown basaltic hornblende. Green hornblende is the most frequent. Amphiboles occur as prismatic and subhedral grains. They show corroded edges (Fig. 6). Epidote is represented by rounded to subrounded greenish yellow grains (Fig. 7). Zircon is found in all samples. It occurs as euhedral, prismatic and oval and rounded grains (Fig. 8). The grains are mostly colorless. Few are light yellow colored. Tourmaline is found as brown, well rounded pleochroic grains (Fig. 9). Garnet occur as angular to subangular pink grains (Fig 10). Apatite occur in a trace amount (<2%). It is found as colorless, elongate prism or angualr to sub-angular grains. Rutile occur as reddish brown oval grains.



(**Fig. 2**) , Histogram showing wt % of the heavy minerals in the investigated traverses



(**Fig. 3**) , Histogram showing frequency % of zircon + tourmaline in the investigated traverses

Table 1. Continued.

Sample No.	H.M. wt.%	Opaques	Non-opaques								
			Amph	Pyrx	Epid	Gr	Zr	Tour	Rut	Apat	others
ES-47	0.5	15	-	15	-	-	65	20	-	-	-
ES-48	0.7	15	-	15	t	-	60	23	2	-	-
ES-49	0.6	20	-	15	t	-	55	30	t	-	t
ES-50	0.6	20	t	18	1	-	50	28	2	1	t
ES-51	0.4	26	1	14	1	-	60	20	2	2	-
ES-52	0.7	25	1	12	1	-	65	18	3	t	-
ES-53	0.5	23	1	24	-	t	45	28	1	1	-
ES-54	0.5	20	1	20	1	-	50	28	-	-	t
ES-55	0.2	25	1	22	-	-	47	28	1	1	t
ES-56	0.5	28	-	18	-	-	55	26	1	-	t
ES-57	0.7	30	-	15	-	-	50	33	2	-	-
ES-58	0.6	25	-	15	-	-	50	33	1	1	t
ES-59	0.8	23	-	17	-	t	50	33	t	-	t
ES-60	0.2	26	2	23	-	-	55	20	-	-	-
ES-61	0.8	25	1	20	1	-	55	23	-	-	t
ES-62	0.8	23	1	20	-	-	55	23	-	1	t
ES-63	0.3	26	2	18	-	-	55	24	-	1	-
ES-64	0.3	25	1	15	1	-	60	21	1	1	-
ES-65	0.5	25	5	18	2	t	50	22	2	1	t
ES-66	0.6	15	5	28	2	-	40	20	2	2	1

H.M: Heavy minerals, Amph: amphiboles, Pyrx: pyroxenes, Epid: epidotes, Gr:garnet Zr: zircon, Tour:tourmaline, Rut: rutile, Apat: apatite, others: silliminite, kyanite, topaz, monazite.

Table 11. Continued

Sample No.	H.M. wt.%	Opaques	Non-opaques Amph	Pyrx	Epid	Gr	Zr	Tour	Rut	Apat	others
ES-21	0.3	26	5	30	1	-	44	20	-	-	-
ES-22	0.4	25	4	35	1	-	37	21	1	1	-
ES-23	0.8	25	1	30	1	-	45	23	-	-	-
ES-24	0.7	25	4	30	1	-	45	19	1	-	t
ES-25	0.5	23	1	25	1	-	48	22	2	1	-
ES-26	1.1	25	2	26	1	-	50	20	1	-	t
ES-27	1.1	25	2	25	1	-	55	16	1	-	t
ES-28	0.5	20	t	30	1	-	50	18	-	1	t
ES-29	0.3	25	1	30	1	-	50	17	1	-	t
ES-30	0.5	28	1	25	1	-	58	13	2	-	t
ES-31	0.7	30	1	25	1	-	50	22	-	1	-
ES-32	0.8	25	1	25	1	-	50	22	-	1	t
ES-33	0.8	23	1	27	-	-	55	16	-	1	t
ES-34	0.3	25	1	25	1	-	57	14	1	1	-
Traverse 3 MS-T3											
ES-35	0.5	25	5	20	1	-	52	20	1	1	-
ES-36	0.4	23	4	17	t	-	40	35	3	1	t
ES-37	0.7	15	1	21	t	-	50	25	1	1	t
ES-38	0.8	20	1	23	t	-	50	25	1	-	t
ES-39	0.7	30	1	20	t	-	55	23	1	t	-
ES-40	0.6	28	t	20	t	-	60	18	1	1	-
ES-41	0.4	25	t	20	t	-	62	18	1	t	t
ES-42	0.6	28	1	20	t	-	50	28	t	1	t
ES-43	0.4	18	t	20	t	-	60	19	1	t	-
ES-44	0.5	15	t	20	t	-	65	15	-	1	t
ES-45	0.6	18	t	18	t	-	60	20	1	1	t
ES-46	0.5	20	-	14	-	-	60	25	1	-	-

Table 111. Distribution of heavy minerals in the studied sand dunes around Mesaieed, SE-Qatar

Sample No.	H.M. wt.%	Opaques	Non-opaques								
			Amph	Pyrx	Epid	Gr	Zr	Tour	Rut	Apat	others
Traverse 1 MS-T1											
ES-1	1.3	23	10	43	1	-	30	15	-	t	t
ES-2	1.5	25	10	40	5	-	30	15	-	-	t
ES-3	1.4	23	6	54	5	-	23	9	2	1	-
ES-4	1.3	35	8	45	5	-	25	13	2	2	-
ES-5	1.2	20	10	50	4	-	25	9	1	1	-
ES-6	1.3	25	5	40	5	-	40	10	-	-	-
ES-7	1.2	20	8	48	2	-	28	12	2	-	t
ES-8	0.9	25	10	50	5	-	20	13	1	1	t
ES-9	1.7	25	5	55	3	-	20	12	2	3	-
ES-10	1.9	28	7	52	3	-	25	11	1	1	-
ES-11	0.9	20	5	30	2	-	40	20	1	2	-
ES-12	1.8	25	15	35	3	-	30	15	-	1	t
ES-13	1.1	25	12	38	3	-	30	12	3	2	t
ES-14	0.8	20	6	25	1	t	45	20	2	1	t
Traverse 2 MS-T2											
ES-15	0.3	25	3	27	t	-	45	25	-	t	t
ES-16	0.3	26	2	33	t	-	42	22	-	1	-
ES-17	0.6	25	2	35	2	-	40	19	1	1	-
ES-18	0.5	25	5	30	1	-	40	20	3	1	-
ES-19	0.4	25	2	28	1	t	50	18	1	-	t
ES-20	0.5	25	1	25	1	t	47	24	1	1	t

Table 2. Distribution of light mineral in selected representative samples from the different sand dune around Emsaid.

Sample	quartz	silicate (feldspar, mica)	carbonate	others (chert, halite, gypsum)
Traverse 1				
ES-1	37	20	41	2
ES-2	41	15	41	3
ES-3	36	15	47	2
ES-4	37	20	41	2
ES-5	42	15	40	3
ES-6	37	20	40	3
ES-7	45	20	32	3
ES-8	40	20	38	2
ES-9	35	25	38	2
ES-10	40	20	38	2
Traverse 2				
ES-14	40	13	45	2
ES-15	35	15	48	2
ES-16	3	18	47	2
ES-17	34	15	49	2
ES-18	46	10	42	2
Traverse 3				
ES-36	38	10	50	2
ES-37	30	12	56	2
ES-41	27	15	55	3
ES-43	35	12	50	3
ES-45	30	10	57	3
ES-53	30	15	52	3
ES-63	38	10	50	2

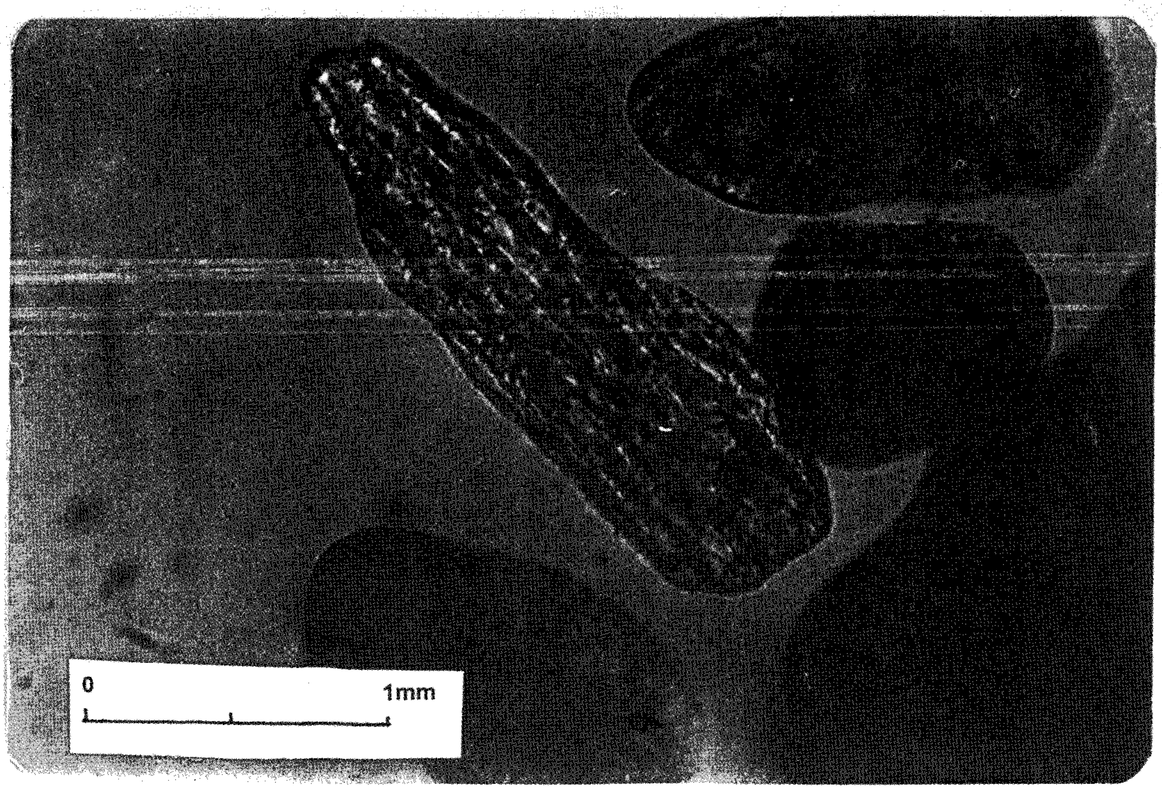


Fig. 5. Photomicrograph showing prismatic grain of pyroxene. (plain-polarized light)

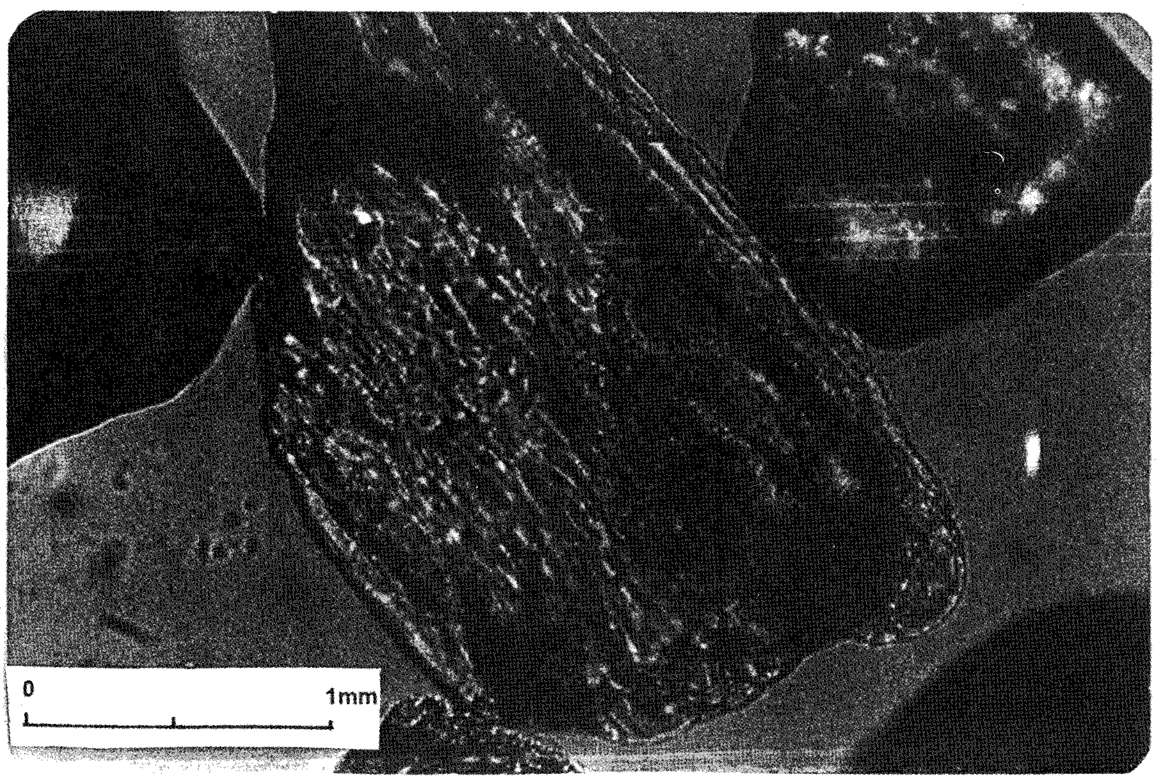


Fig. 6. Photomicrograph showing corroded grain of amphibole. (plain-polarized light).

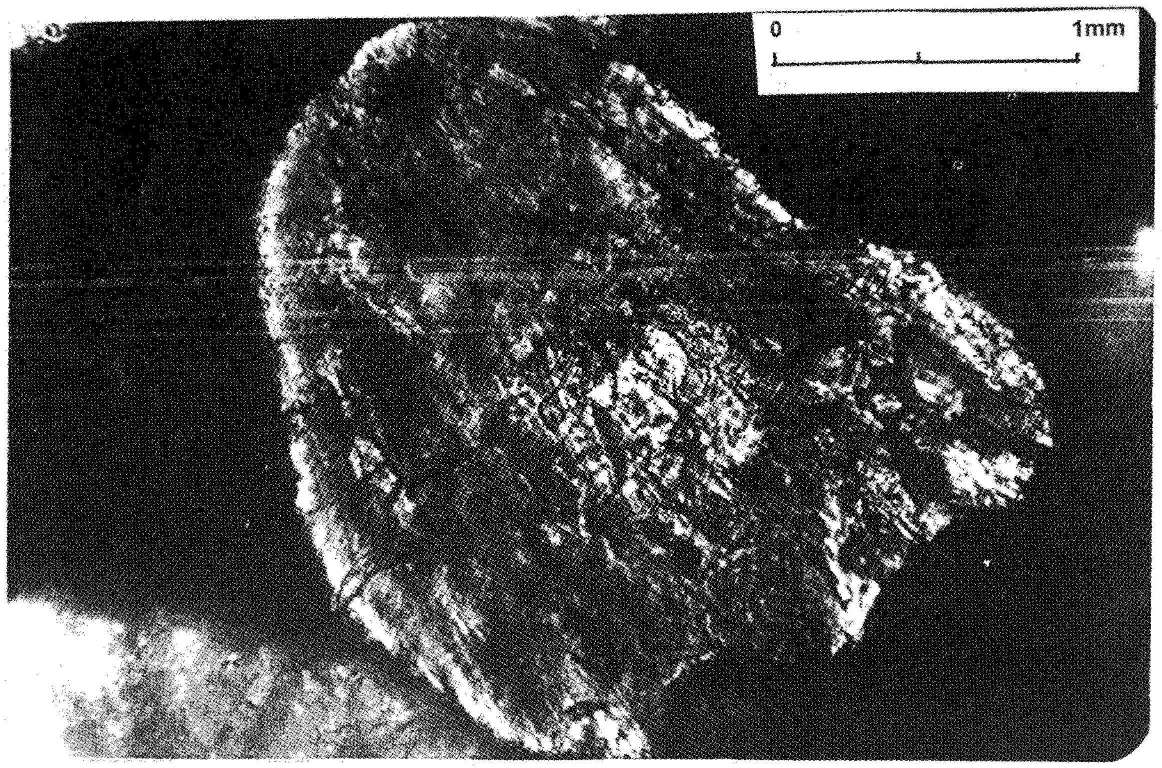


Fig. 7. Photomicrograph showing rounded grain of epidote. (cross-polarized light)

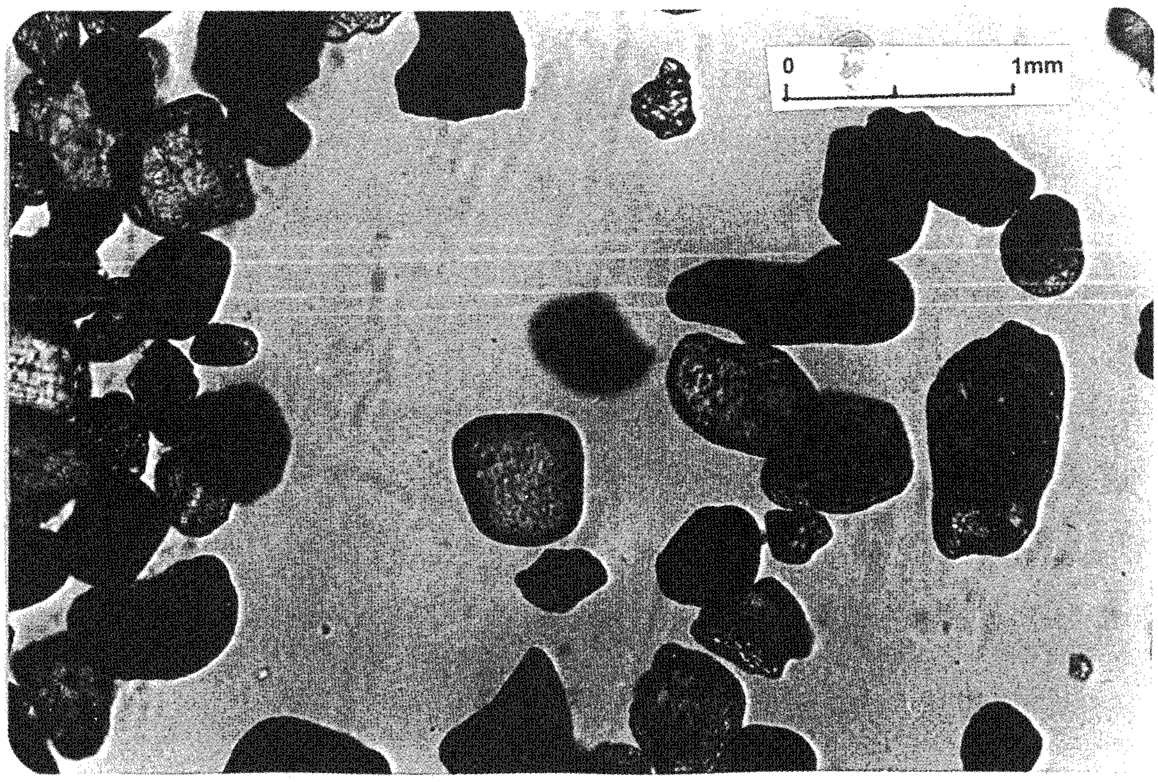


Fig. 8. Photomicrograph showing rounded grains of zircon. (plain-polarized light)

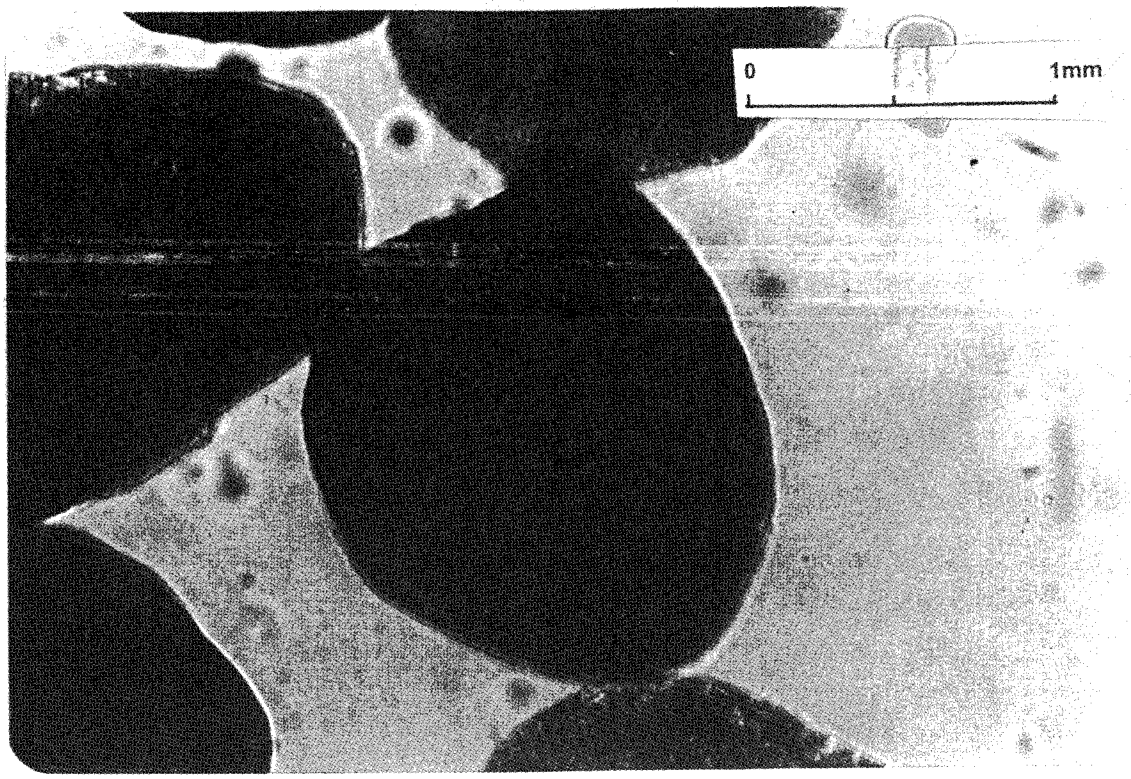


Fig. 9. Photomicrograph showing rounded grain of tourmaline. (plain-polarized light)

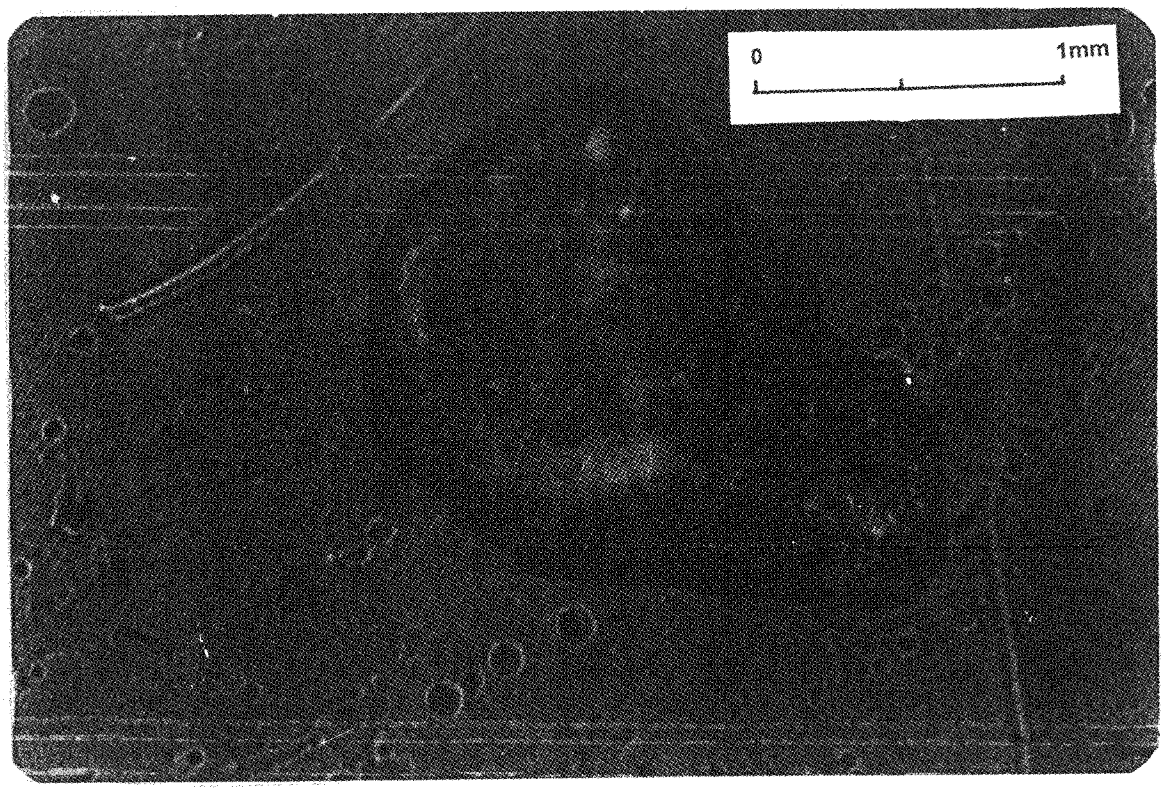


Fig. 10. Photomicrograph showing subrounded grain of garnet. (plain-polarized light)

Light Minerals :

The light mineral grains are composed mainly of quartz, carbonate grains (mainly calcite) and Pelecypod shells, feldspar, chert, gypsum halite and mica (Table 2). Quartz grains are found to be subangualr to subrounded. However, they are more angular in the fine sand fraction (<150 micron) relative to the coarse fraction (250 micron). Some grains are stained by iron hydroxides, giving the reddish color of the sand in travers 1. Feldspars occur as rounded to subrounded grains of albite, orthoclase and microcline. They are more concentrated in the coarse sand fraction mainly in travers 1. Gypsum and halite are more concentrated in traverse 2 and 3. Chert is mostly angular, reddish and occurs mostly traverse 1. Calcite is more frequent in the very fine and fine sand fractions. It occurs as rounded micritic grains. Mica, mainly muscovite, occurs in minor amount.

The raw data obtained from the microscopic investigations could be used to differentiate between the different sand dunes in both a regional and mineralogical sense and enable mapping of sedimentary provenance (7). The criteria used in this study is the presence/absence or the proportion of individual minerals or mineral groups. The hydraulic controls at the time of deposition and subsequent intrastratal solution can cause major modifications. Intrastratal solutions effects are diagnosed by grain-surface etching. Provenance, nature and degree of weathering in the source and abrasion during transportation and diagenesis are the major factors which must be taken in account before the interpretation of a sediment source areas can begin. The following points play important roles in the distribution of the heavy mineral suites:

a. Provenance :

Petrographic examination of the light and heavy minerals of sand dunes aroud Mesaieed City revealed that the sand dunes consist of one main mineralogical suite which is dominted by shelly carbonate, quartz, gypsum, halit, feldspar as major light minerals and zicron, tourmaline, pyroxenes. amphiboles, epidote, and garnet as major heavy minerals. The parent rocks provide the initial control on the development of the heavy mineral suite in sandstones. If the heavy minerals in the source area are sufficiently distinctive, the influence of the source can be traced directly into the adjacent sediments. The mineralogical assemblage is characteristic of mixed sediments form two types of source rocks; recycled sandstone and granite supply zicron and tourmaline while basic igneous and metamorphic rocks supply amphiboles, pyroxenes, epidotes and opaques. Zircon and tourmaline seem to have been derived from recycled Neogene sediments originated primarily from a plutonic source such as the Hofuf Formation (28,29). Aeolian materials are transported as bed load form local source and as suspend load form regional sources, particularly the Mesopotamian plain to the northwest. Reworking of ancient sediments and igneous rocks is probably a more important contributor to the heavy minerals. However, the differences in the heavy mineral percentages suggest that other sources are also contributing to the sand dunes. Qatar is characterized by the frequent occurrence of dust storms. Dust its transported from southern Iraq, Kuwait, and Al-Rub Al-Khali by the northwesterly Al Shamal wind (30). The dust is mainly quartzitic, calcareous sandy silt with amphiboles, pyroxene, epidote, garnet, zircon and tourmaline as distinctive heavy minerals (20, 21).

b. Degree of sediment recycling

The degree of sediment recycling is usually addressed by the concept of the zircon-tourmalin-rutile (ZTR) index 13,12,7). Theses minerals have high chemical and mechanical stability and tend to become concentrated during recycling, so that a height ZTR index may be regarded as a measure of maturity. The sand dunes in traverse 3 have higher ZTR index relative to traverses 1 and 2 and thus they are more mature.

c. Intensity of weathering

Erosion and abrasion of older sediment is believed to represent the most important source of heavy minerals. Weathering depends on the climate and the rate of erosion. The presence of high percentages of unstable minerals such as epidote, garnet, pyroxene and amphibole in the sand dunes of Mesaieed suggest low degree of weathering. Therefore, the low percentage of unstable minerals in sand of traverse 3 is expected to be the result of intense source area weathering.

d. Effects of intrastratal solution

Intrastratal solution could play an important role other than provenance, affecting heavy mineral distribution in sands. The potential for intrastratal solutions is present in any sandstone subject to pore fluid movement. The increasing degree of grain corrosion indicates the high effect of pore fluid. However, the minerals epidote, amphibole and pyroxene are considered to be moderately unstable under ana-and epi-diagenesis, whereas zircon and tourmaline and rutile are extremely stable (7). The presence of an etched-grain surface is indicative of this process especially in the source region of the sands.

Conclusions

The association of unstable heavy minerals, with much hornblende, pyroxene and epidote characterize the sand dunes of Mesaieed. These minerals were derived from elevated metamorphic and magmatic terrains which underwent rapid stripping by erosion. Transport was short without intensive weathering, thus preserving much of the composition of the source rocks. The sand dunes are calcareous-siliceous in composition and contain lower silicate heavy minerals and higher zircon and tourmaline heavy mineral assemblages especially in traverse 3. Eolian sediments, transported form the Mesopotamian plain and from Al-Rub AL-Khali by Al Shamal wind are believed to be the source for most of the sand dunes in Qatar.

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