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PROVENANCE OF SEDIMENTS OF SAND DUNES IN THE WESTERN PARTS OF THE EUPHRATES RIVER, IRAQ

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ABSTRACT

This study is concerned with the heavy minerals (HM) of the + 63 micron fraction of the sand dune sediments, which cover 608.686 Km^2 of an area from Najaf to Samawa, and the southern borders of Al-Qadissiya Governorate. Moreover, grain size analysis, chemical and XRD analysis are carried out. HM analysis indicates that the proportion of the unstable minerals makes about 12.7% for Najaf dunes and 44.83% for Samawa – Qadissiya dunes, whereas the metastable minerals make about 15.81% and 21.03% and the ultra stable minerals make about 16.83% and 3.01% for Najaf and Samawa – Qadissiya dunes, respectively. Opaques are present in high proportions reaching about 34.04% for Najaf dunes and 28.54% for Samawa – Qadissiya dunes.

Grain size analysis indicates that the sediments of Najaf dunes are coarser than the sediments of Samawa – Qadissiya dunes and the sorting of sediments of Najaf dunes are medium, while sediments of Samawa – Qadissiya dunes are fine. Moreover, the sediment of Najaf dunes are more mature than the sediment of Samawa – Qadissiya dunes due to the ZTR index.

Chemical and XRD analysis revealed that the sediments of the studied dune fields are composed essentially of quartz, feldspar; as the dominant minerals with a paucity of carbonate and sulphate minerals, in addition to heavy minerals. Clay minerals occur in Najaf dune fields represented by montmorillonite, palygorskite and kaolinite and the same clay minerals except montmorillonite occur in Samawa – Qadissiya dune fields.

All results indicate that Najaf sand dunes are derived from felsic igneous rocks (granitoid rock), metamorphic rocks (schist and gneiss) and older sedimentary rocks, while Samawa – Qadissiya dunes are essentially derived from metamorphic rocks (schist and gneiss), basic igneous rocks (Basalt and Gabbro) and older sedimentary rocks.

The Dibdibba Formation (Pliocene – Pleistocene) in Tar Al-Najaf, where the sediments are transported from the Arabian Shield, is the most important source for supplying sand forming the dune fields of Najaf, while the source area that supplies the sediments of Samawa dunes is mixed, the essential one is the surrounding formations, where the sediments are transported from Arabian Shield and the second source is the Euphrates River, where sediments are transported from the north (Syria and south of Turkey).

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أصل ومصدر رواسب الكثبان الرملية في الجزء الغربي من نهر الفرات، العراق

لمى عز الدين المختار

المستخلص

تتناول الدراسة الحالية دراسة المعادن الثقيلة للحجوم الرملية الأكبر من 63 مايكرون، إضافة الى التدرج الحجمي والتحليل الكيميائي لرواسب الكثبان الرملية العائدة لمحافظات النجف، القادسية والسماوة. وضحت نتائج دراسة المعادن الثقيلة بأن معدلات نسب المعادن غير المستقرة بلغت 12.7% و 44.83% لرواسب كثبان النجف، القادسية – السماوة على التوالي، وشبه المستقرة بلغت 15.81% و 21.03%، وفوق المستقرة بلغت 16.83% و 3.01% لرواسب كثبان النجف، القادسية – السماوة على التوالي، أما المعادن المعتمة فمعدل نسبها في كثبان النجف بلغت 34.04% وفي كثبان القادسية – السماوة بلغت 28.54%.

إن تطابق هذه المعادن واختلاف نسبها إضافة إلى مقارنتها مع الدراسات السابقة توضح لنا معرفة أصل ومصدر هذه الرواسب، حيث أن أصل الصخور المجهزة لرواسب كثبان النجف هي صخور نارية گرانيتيدية وصخور الشيست والنيس المتحولة، إضافة إلى الصخور الرسوبية المعاد ترسيبها. مصدر هذه الرواسب هو تكوين الدبدبة (پلايوسين – پلايستوسين) المتواجد في طار النجف ورواسب هذا التكوين منقولة من الدرع العربي. رواسب كثبان القادسية – السماوة هو صخور متحولة (شيست ونيس) وصخور نارية قاعدية (بازلت وگابرو) وتعود مصادرها بالدرجة الأساس الى التكوينات المتواجدة في منطقة الدراسة ورواسب هذه التكوينات منقولة من الدرع العربي. بالإضافة إلى رواسب الهولوسين المنقولة بواسطة نهر الفرات من سوريا وجنوب تركيا.

وضح التدرج الحجمي بأن الرواسب الريحية لكثبان النجف أخشن وأكثر نضوجا من رواسب كثبان القادسية – السماوة، كما أن رواسب كثبان النجف ذات فرز متوسط في حين رواسب كثبان القادسية – السماوة ذات فرز ناعم.

أوضحت نتائج التحليل الكيميائي وفحوصات الأشعة السينية بأن رواسب الكثبان الرملية للمنطقة المدروسة تتكون بالدرجة الأساس من معدن الكوارتز ثم معادن الفلدسبار وقلة من معادن الكربونات والجبس إضافة الى كميات أقل من المعادن الثقيلة. تتكون المعادن الطينية في رواسب كثبان النجف من معادن المونتموريلونايت والپاليكورسكايت والكاؤلينايت، أما رواسب كثبان القادسية – السماوة فتتكون من معادن الپاليكورسكايت والكاؤلينايت.

INTRODUCTION

Sand dunes of Najaf, Qadissiya and Samawa constitute 13.98% from the whole studied area, which equals 4352.06 Km^2. This area is located between longitudes 44° 00' – 45° 28' and latitudes 32° 07' – 31° 00' (Fig.1). The present study includes 21 spot samples collected as follows: 14 samples from south of Najaf, 4 samples from NW Samawa and 3 samples from the southern border of the Qadissiya Governorate. These spot samples are selected from top, eastern side, western side and southern side of Najaf dunes and selected from top, bottom and slip of Qadissiya – Samawa dunes. The dominated forms of dunes are Barchan, Dom and Longitudinal. Heavy mineral analysis, grain size analysis and chemical analysis were carried out on the sample to estimate the origin and source of the dune sediments.

Many authors studied the source of sand dunes distributed in different areas, among them are:

- Al-Saadi (1971), studied morphology, distribution and origin of sand dunes covering a small area situated in the vicinities of Baiji, central Iraq. Grain size, heavy minerals and chemical analysis were carried out. He obtained that the source areas, which supply the Baiji dunes may be the old sediments of the Tigris River and the formations surrounding the area.

- Skocek and Saadalah (1972), their primary study of the sand dunes in Najaf – Samawa – Nasiriyah areas included mineral composition and grain size analysis for these sediments; they restricted the source area that supplied the sediments of these dunes are the surrounding formations which their sediments are transported from Arabian Shield.

- Al-Ani (1979), studied sedimentary and morphology of sand dunes in Najaf – Samawa and Nasiriyah. He mentioned that the sediments are transported from the rock formations present in these areas and from the recent sediments of the Euphrates Rivers.

- Jackowski and Hassan (1984), studied the sand dunes of Baiji – Tikrit – Shari area. They mentioned that the formation of these dunes was under strong influence of northwestern winds and the Injana, Jabal Makhul and Jabal Hamrin are the most important supply sources for sands forming dune fields of these areas.

- Shaker (1985), studied the geomorphology of sand dunes in Kut – Diwaniya – Nasiriyah area and mentioned the relation of sand dunes with the surrounding agricultural area and human settlement. It is found that the area is characterized by arid to semi arid climate.

- Mahmoud and Al-Ani (1985), studied the heavy minerals of sand dunes in the Western Desert. They indicated that the origin of sand dunes of Najaf, Samawa and Nasiriyah are the recent sediments of the Euphrates River and the older nearby exposed geological formations.

- Al-Khateeb and Capigian (2007), studied the climatic changes and their effects on geodynamic processes in Iraq during (1970 – 2000). They concluded that the studied area had an arid climate (with cold winter and hot dry summer).

GEOLOGICAL SETTING

Sand dunes of Najaf – Samawa areas are situated in the Stable Platform in the southern part of the Western Desert between latitudes 31º – 32º and longitudes 44º – 45º. Terrigenous and carbonate sediments of the Miocene Period cover most parts of the Western Desert with appearance of Paleocene to Holocene sediments. Dibdibba Formation sediments of the Pliocene – Pleistocene age are exposed in the southern part of the desert, while residual and terrace sediments are restricted to the western side of the Euphrates River alluvial plain (Al-Ani, 1979). The stratigraphic units according to Buday (1980) and Jassim and Goff (2006) are divided into Pre-Quaternary units and Quaternary sediments.

▪ Pre-Quaternary Units

Include the following formations:

- Dammam Formation (Eocene)
- Euphrates Formation (Early Miocene)
- Ghar Formation (Early Miocene)
- Nfayil Formation (Middle Miocene)
- Injana Formation (Late Miocene)
- Zahra Formation (Pliocene – Pleistocene)
- Dibdibba Formation (Pliocene – Pleistocene)

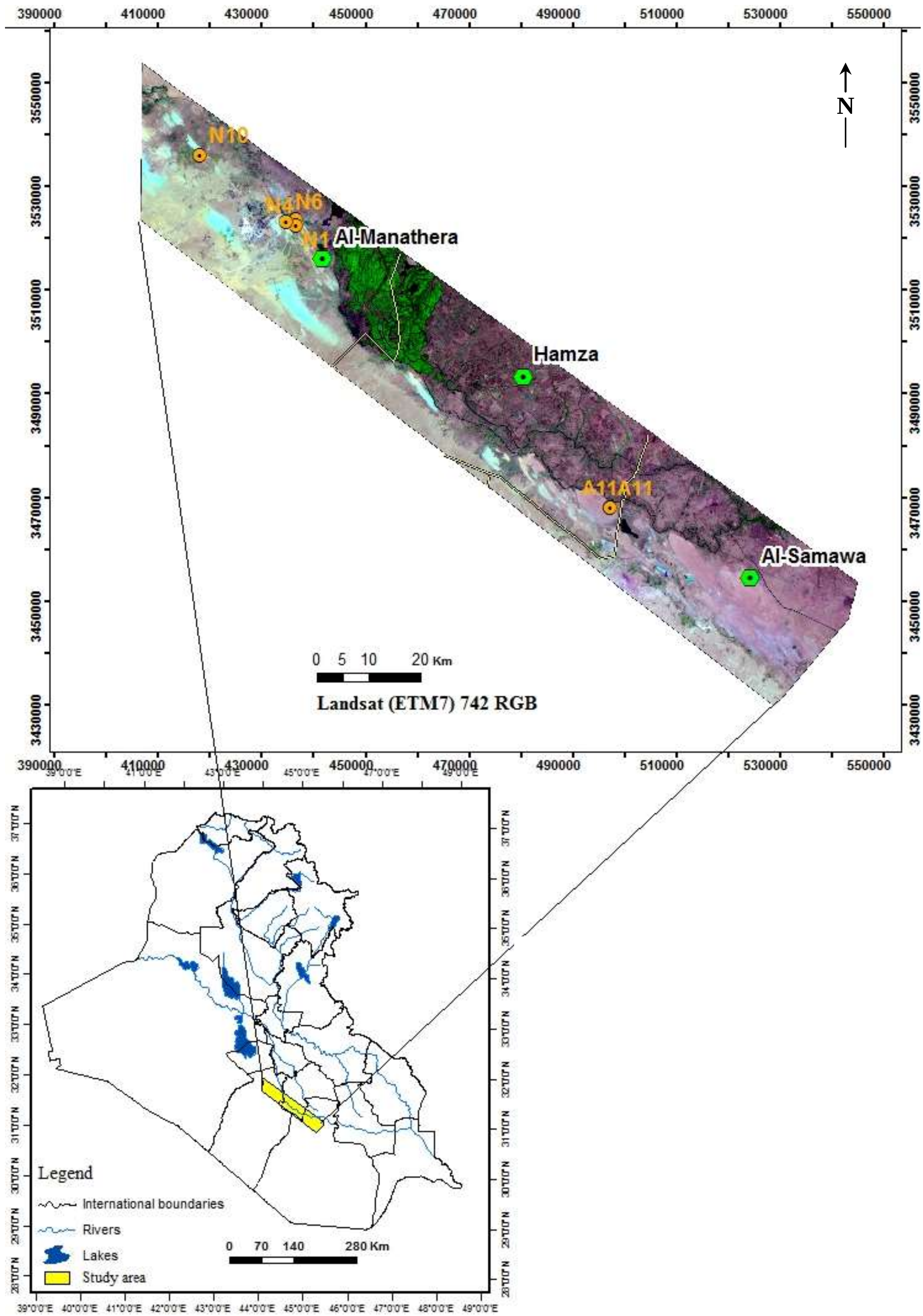

Fig.1: Location map of the studied area

- **Quaternary Sediments**

These sediments include marsh, sabkha, fluvial, evaporate and aeolian sediments (Fig.2). The aeolian sediments include sand sheets and sand dunes. They are spread over the whole of the studied area due to wind activities. Sand dunes generally trend NW – SE, especially on the surface of Karbala – Najaf Plateau. In many places, the simplest form of aeolian sediments are Nebkhas and drifting sand sheets. Aeolian sediments are composed of well sorted fine grained sand. The thickness of the aeolian sediments depends on the forms of accumulation. Sand dunes may reach up to 12 m in height and sand sheet is more than 1 m thick.

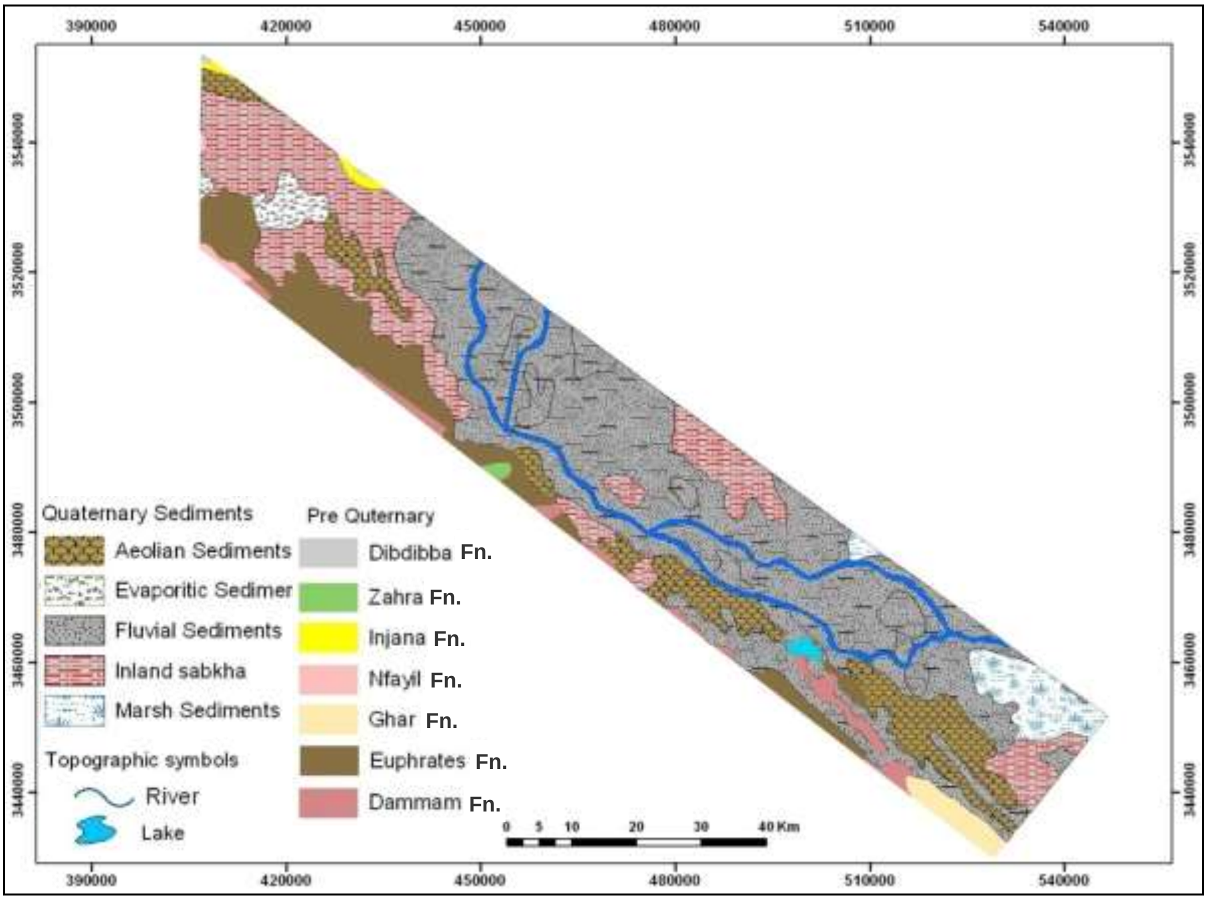

Fig.2: Geological map of the studied area (after Sissakian, 2000)

METHOD OF WORK

The work included sieving of the samples according to Wentworth (1922) and their treatment with separation according to Carver (1971) procedure.

RESULTS

- **Grain Size Analysis**

Grain size analyses of nine size fractions from collected twenty one samples was carried out. The results of the average weight percentage of size components of the studied dunes are shown in Table (1), which indicate that the higher weight percent is in size (0.5 – 0.250) mm for Najaf dunes. This means that the main size of these sediments is medium; referring to medium sorted sediments (Folk 1974), while sediments of Samawa – Qadissiya dunes have higher weight percent in sizes (0.250 – 0.180) mm, indicating that the main size of these sediments is fine, which refers to fine sorting of sediments (Folk, 1974).

Table 1: Average weight percentage of size components of Najaf and Samawa – Qadissiya sand dunes

Diameter (mm)	Najaf sand dunes	Samawa – Qadissiya sand dunes
	Weight%	Weight%
> 2	–	–
2 – 1	1.18	0.44
1 – 0.71	12.42	17.83
0.71 – 0.5	15.51	6.01
0.5 – 0.250	36.63	13.90
0.250 – 0.180	17.02	25.87
0.180 – 0.125	10.01	22.55
0.125 – 0.063	6.92	13.05
< 0.063	0.31	0.35

▪ Heavy Mineral Analysis

Twenty one samples of fraction (0.250 – 0.063) mm, which contain high proportion of heavy minerals were studied. They belong to sand dunes of Najaf, Samawa – Qadissiya areas. Binocular and polarizing microscopes were used. The heavy mineral suites recognized in the studied samples are opaque and non-opaque minerals.

▪ Opaque Minerals

This group includes opaque black minerals represented by magnetite, which is separated from the heavy fraction using hand magnet. Their average weight percentage reaches (0.23% and 0.16%) for Najaf, Samawa – Qadissiya dunes, respectively (Table 2). Ilmenite is seen as trace, and opaque brown mineral is represented by hematite, few goethite and limonite. The shapes of two types of opaque minerals are subrounded, subangular and few subhedral. The average percentage of opaque minerals reaches 34.04% and 28.54% for Najaf and Samawa – Qadissiya dunes, respectively (Table 2). Accordingly, their origin is likely to be igneous, metamorphic and sedimentary rocks (Hamilton *et al*., 1976).

▪ Non-opaque Minerals

The non-opaque minerals are classified according to their resistance to chemical weathering into:

- Ultra stable minerals include zircon, rutile, and tourmaline.
- Unstable minerals include amphibole group and pyroxene group
- Meta-Stable minerals include epidote group, garnet, staurolite, kyanite, andalusite, sillimanite, muscovite, biotite and chlorite.
- Alterite

The non-opaque minerals represent 65.96% of the heavy minerals, in Najaf dunes and 71.46% in Samawa – Qadissiya dunes.

▪ Zircon ($ZrSiO_4$)

The zircon is colorless, most of the grains are rounded to subrounded in shape and few are subhedral. Some grains are with inclusions of opaque minerals or minute zircon. The average percent of zircon is 9.04% and 1.18%, in Najaf, Samawa – Qadissiya dunes, respectively (Tables 2, 3, and Fig.3). Zircon is particularly ubiquitous in silicic and intermediate igneous rocks; it may reach high concentration in some beach sands and placers (Mange and Maurer, 1992). Consequently, detrital zircon may be recycled many times and represent multi cycles sand, which may contain zircons from variety of source rocks. Carbonates and mafic igneous rocks have little or no zircon (Bernet *et al*., 2004).

Table 2: Average percentage of heavy minerals in Najaf, Samawa – Qadissiya sand dunes

Area	Weight%			Count%													
	H.F.	Magnetite	L.F.	Opaque	Alterite	Zoisite-Epidote	Hornblende	Ortho-Pyroxene	Mono-Pyroxene	Zircon	Rutile	Tourmaline	Garnet	Staurolite	Chlorite	Celestite	Others
Najaf	3.12	0.23	96.65	34.04	1.21	5.42	3.78	1.01	5.96	9.04	2.18	5.61	8.29	0.6	0.83	19.45	Kyanite 0.04, Tremolite-Actinolite 1.49, Brown Pyroxene 0.26, Biotite 0.63, Glaucophane 0.12, Basaltic Hornblende 0.08,Anatase 0.04, Muscovite 0.05,Andalusite 0.02,Titanite 0.21.
Samawa and Qadissiya	5.71	0.16	94.13	28.54	1.36	8.07	12.98	3.73	25.23	1.18	0.24	1.59	7.41	2.45	1.07	1.31	Kyanite 0.61, Tremolite-Actinolite 2.09, Brown Pyroxene 0.42, Biotite 1.42, Glaucophane 0.09, Basaltic Hornblende 0.29, Anatase T., Titanite 0.08, Sillimanite T.

H.F. (Heavy Fraction) L.F. (Light Fraction) T. (Trace)

Table 3: Average weight percentage of chemical analysis of sand dunes in Najaf, Samawa and Qadissiya areas

Area	SiO_2	Fe_2O_3	AL_2O_3	TiO_2	CaO	MgO	SO_3	L.O.I.	Na_2O	K_2O
	(%)									
Najaf	62.53	0.45	1.16	0.09	13.54	3.17	9.29	9.77	0.33	0.55
Samawa and Qadissiya	78.56	0.99	3.09	0.18	7.55	0.70	0.75	6.33	0.99	0.78

- **Rutile (TiO_2)**

Rutile is the most frequent of the three polymorphs of Titania (TiO_2). The two other polymorphs are brookite and anatase. The color is red, reddish brown, rarely yellow, the shape of the grains is mostly subrounded oblong forms. The average percent of rutile is 2.18% and 0.24%, in Najaf, Samawa – Qadissiya dunes, respectively (Table 2). Rutile is a widespread accessory mineral in metamorphic rocks, particularly in schist, gneiss and amphibolites; it is less significant in igneous rocks, where it occurs in hornblende-rich plutonic types and in pegmatite (Mange and Maurer, 1992).

- **Tourmaline Na (Mg, Fe, Mn, Li, Al)$_3$Al$_6$ (Si$_6$O$_{18}$) (BO$_3$)$_3$ (OH, F)$_4$**

Tourmaline displays a wide range of colors and these are indications of composition, Iron Tourmaline (Shorl) is blue to greenish- blue in color, rarely occurs in this study. Magnesium Tourmaline (Dravite) is yellowish brown to brown and colorless, present as dominant tourmaline in the studied area. The shape of grains is mostly subrounded and few are subhedral. It is characterized by strong pleochroism. The average percent in Najaf, Samawa – Qadissiya dunes is 5.61% and 1.59% respectively (Table 2 and Fig.3). Iron Tourmaline is found in granitoid rocks, while magnesium tourmaline occurs in some metamorphic schist, in metasomatic rocks and in certain basic igneous rocks (Mange and Maurer, 1992).

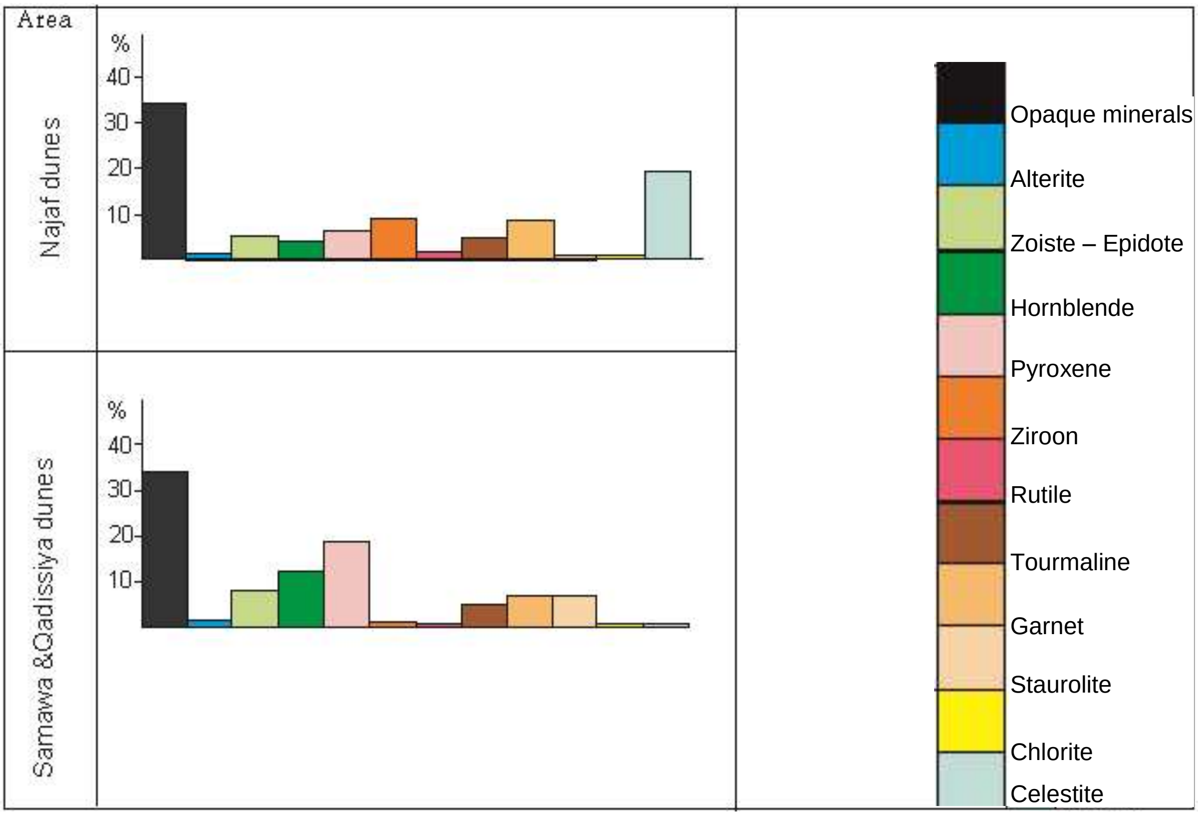

Fig.3: Heavy minerals of sand dunes of Najaf, Samawa – Qadissiya areas

▪ **Amphibole Group**

The amphiboles are an important group of rock forming silicates that are widely distributed in igneous and metamorphic rocks (Hamilton *et al*., 1976). Four types of amphibole were recognized in this study, the essential one is the hornblende and others include tremolite – actinolite, basaltic hornblende and rare glaucophane.

Hornblende is usually found in metamorphic rocks, because it alters from pyroxene both during early magmatic stages of crystallization of igneous rocks and during metamorphism. In the studied samples it was found as elongated grains with prismatic cleavage and corroded edges; some grains are thick and massive, bladed, others are partially fibrous. The color of hornblende is green and brown-green. The average percent of hornblende is 3.78% and 12.98%, in Najaf, Samawa – Qadissiya dunes, respectively (Table 2 and Fig.3).

▪ **Pyroxene Group**

Within the pyroxene group, two principle subdivisions exist: clinopyroxene with monoclinic and orthopyroxene with orthorhombic symmetry. Pyroxenes are colorless, green and brown in colors. The grains are dominantly long or short stumpy prisms, irregularly terminated prismatic fragments, some grains have rounded edges and corners, and others are with cleavage and parting.

Orthopyroxenes are common constitutes of igneous rocks such as gabbro and pyroxenite, while some monopyroxene occur in igneous rocks such as basalt, gabbro and pyroxenite and others occur in metamorphic rocks (Hamilton *et al*., 1976). The average percent of orthopyroxene is 1.01% and 3.73% and for monopyroxene is 5.96% and 25.23% in Najaf, Samawa – Qadissiya dunes, respectively (Table 2).

▪ **Epidote Group**

Two types of Epidote Group were recognized in this study, the first type is epidote and the other is clinozoisite. They are colorless, usually in shades of green, usually yellowish green. They occur mostly in irregular, angular, equant forms; moreover, clinozoisite occurs as short or long prisms and rounded grains. The occurrence of epidote mineral is the green-schist of regional metamorphism origin, and the contact metamorphic rocks and hornfelses, epidote together with clinozoisite common product of low to medium grade metamorphism (Mange and Maurer, 1992). The average percentages of epidote group are 5.42% and 8.07% for Najaf, Samawa – Qadissiya dunes, respectively (Table 2).

Other minerals occur such as celestite, titanite and anatase, their average percentages are indicated in Table (2). Occurrences of these minerals are in igneous, metamorphic and sedimentary rocks (Hamilton *et al*., 1976).

▪ **Alterite**

It is difficult to differentiate the alerite by polarizing microscope, because it does not have any character to be recognized. The average percentage is indicated in Table (2).

▪ **Chemical Analysis**

Analysis of eight samples from Najaf and Samawa dunes were analyzed for the major elements that includes SiO_2, which is represented essentially by quartz and entered the structure of other silicate minerals. The average percent age is 62.53% and 78.56% for Najaf, Samawa – Qadissiya dunes, respectively (Table 3). CaO occurs with percentages of 13.54% and 7.55% in Najaf and Samawa – Qadissiya dunes, respectively. This is related to the presence of calcite mineral that inters the structure of other silicate minerals. SO_3 is represented by gypsum and some inter the structure of celestite. The concentration of SO_3 in Najaf dunes is 9.29% and in Samawa – Qadissiya dunes is 0.75. The increase in concentration of SO_3 is related to the occurrence of celestite and gypsum in Najaf dunes, where it is more than that of Samawa – Qadissiya dunes and this coincides with the results of the heavy mineral analysis.

The average percentage of L.O.I. is 9.77% and 6.33% in Najaf, Samawa – Qadissiya dunes**,** respectively. Their occurrences are related to the presence of carbonate minerals. Al_2O_3 occurs with percentage of 1.16% and 3.09% in Najaf, Samawa – Qadissiya dunes, respectively (Table 4). It represents the clay minerals; including montmorillonite, palygorskite and kaolinite. Iron oxide (Fe_2O_3) is represented by the minerals hematite, magnetite and limonite. The average percentage is 0.45% and 0.99% in Najaf, Samawa – Qadissiya dunes, respectively. The average percent age of TiO_2 is 0.09% and 0.18% Najaf, Samawa – Qadissiya dunes, respectively; it is represented by rutile, ilmenite and anatase minerals. MgO occurs with percentage of 3.17% and 0.70% in Najaf, Samawa – Qadissiya dunes, respectively, it is represented by tourmaline. The average concentration of Na_2O in Najaf, Samawa – Qadissiya dunes is 0.33% and 0.99% respectively. Sodium oxide reflects the occurrence of Na-plagioclase minerals and the average concentration of K_2O in Najaf, Samawa – Qadissiya dunes is 0.55% and 0.78%, respectively. Their presence refers to the occurrence of K-feldspar minerals.

▪ **XRD Analysis**

Six samples were analyzed by XRD to know the type of non clay and clay minerals, and four heavy fraction samples were analyzed to emphasize the type of opaque minerals in Najaf and Samawa – Qadissiya dunes. The results are illustrated hereinafter.

─ **In Najaf Dunes:** Clay analysis showed the occurrence of montmorillonite, palygorskite and kaolinite, while heavy fraction analysis indicates the presence of hematite, ferrihydrite, lepidocrocite (or goethite), ilmenite, zircon, rutile and celestite.

─ **In Samawa – Qadissiya Dunes:** Clay analysis showed the occurrence of palygorskite and kaolinite, and heavy fraction analysis demonstrated the occurrence of goethite, mackinawite (FeS), edenite, chlorite-serpentinite, aegirine, augite and epidote.

The light minerals include quartz, calcite, dolomite, gypsum, halite and feldspar, which are present in Najaf dunes. The same diversity of light minerals, except gypsum were found in Samawa – Qadissiya dunes.

DISCUSSION

The study of heavy minerals of 215 samples indicated that the sediments of Najaf dunes contain ultra stable minerals represented by zircon, rutile and tourmaline; more than the unstable minerals represented by amphibole and pyroxene, whereas the sediments of Samawa – Qadissiya dunes on the other hand, showed the following results:

- Source area supplying the sediments of the two localities is different.
- Source rocks are affected by chemical weathering more than by mechanical weathering in Najaf area, while the mechanical weathering affected the source rock in Samawa – Qadissiya area more than the chemical weathering.
- Source area of Najaf dune sediments is characterized by semi-humid climate, while source area of Samawa – Qadissiya dune sediments is characterized by arid to semi-arid climate.

Owing to the unstable nature of amphibole, pyroxene and epidote, their occurrence is usually limited to younger sediments (Morton, 1985). Moreover, the Pleistocene sediments are generally coarser than Holocene sediments (Yacoub and Persur, 1980 in Benni, 2009). In this study, it was found that the sediments of Najaf dunes are coarser than those of Samawa – Qadissiya dunes. From the analyses carried out in this study, it is concluded that the source sediments of Najaf dunes are older than source sediments of Samawa – Qadissiya dunes.

The correlation coefficient of heavy minerals in Najaf dunes (Table 4) indicates three groups of heavy minerals, where the positive symmetrical relation (significant value R = 0.514) reflects the source and origin rocks for transported clastics, these groups are:

- Heavy minerals, magnetite, epidote, hornblende, zircon, and garnet group: Reflect felsic igneous and metamorphic origin.
- Opaque, light minerals, alterite, tourmaline, and staurolite group: Reflect metamorphic and sedimentary origin.
- Rutile, hornblende, mono-pyroxene: Reflect metamorphic and igneous origin.

Table (5) shows correlation coefficient of heavy minerals in Samawa – Qadissiya dunes. It indicates four groups of heavy minerals, according to positive symmetrical relation (significant value R = 0.707) and these groups are:

- Heavy minerals, magnetite, hornblende, zircon, and chlorite group: Reflect igneous and metamorphic origin.
- Alterite, epidote group: Reflect metamorphic and sedimentary origin.
- Mono-pyroxene, ortho-pyroxene, and staurolite: Reflect metamorphic and basic igneous origin.
- Tourmaline, garnet and rutile group: Reflect metamorphic origin.

Most heavy minerals of the aforementioned groups belong to metamorphic rocks; this may refer to the source area to be in the north (Syria and Turkey), which is the source of metamorphic rocks (Al-Bassam and Al-Mukhtar, 2008).

The correlation coefficient for other heavy minerals is less than the significant value for the Najaf dunes and Samawa – Qadissiya so it cannot be commented upon; or interpreted.

The value of ZTR index (which is a combined percentage of zircon, tourmaline and rutile among the transparent heavy minerals; omitting micas and authegenic species) of Najaf dunes is 0.68 and of Samawa – Qadissiya dunes is 0.05. This reflects that sediments of Najaf dunes are more mature than those of Samawa – Qadissiya dunes, and also indicates a possible re-deposition from older sediments; the higher index is the more matured sedimentary material (Aubrecht, 2001).

There is a coincidence in the concentration of heavy minerals present in Najaf dunes, with the sediments of Dibdibba Formation (Table 6) and the concentration of heavy minerals present in Samawa – Qadissiya dunes, which coincide with the Euphrates River sediments (Table 10). This indicates that the source area supplying the sediments of Najaf dunes is Dibdibba Formation, exposed in Tar Al-Najaf, where the sediments are transported from the Arabian Shield. While the source area that supplies the sediments of Samawa – Qadissiya dunes is mixed, the essential one is the surrounding formations, where sediments are transported from Arabian Shield and the second source is the Euphrates River, the sediments are transported from the north (Syria and South of Turkey).

Table 4: Correlation coefficient of heavy minerals in Najaf dunes

	H.F.%	Magnetite	L.F.	Opaque	Alterite	Zoisite-Epidote	Horenblende	Ortho-pyroxene	Mono-pyroxene	Zircon	Rutile	Tourmaline	Garnet	Staurolite	Chlorite	Celestite
H.F.%	1.00															
Magnetite	0.98	1.00														
L.F.	– 1.00	– 0.98	1.00													
Opaque	– 0.59	– 0.54	– 0.59	1.00												
Alterite	– 0.54	– 0.49	0.53	0.76	1.00											
Zoisite-Epidote	0.14	0.11	– 0.14	– 0.44	– 0.17	1.00										
Hornblende	0.60	0.55	– 0.60	– 0.62	– 0.45	0.26	1.00									
Ortho-pyroxene	0.06	0.09	– 0.06	– 0.40	– 0.37	0.29	– 0.15	1.00								
Mono-pyroxene	0.28	0.18	– 0.27	– 0.33	– 0.33	0.27	0.53	– 0.43	1.00							
Zircon	0.74	0.70	– 0.74	– 0.53	– 0.52	0.50	0.49	0.21	0.38	1.00						
Rutile	0.48	0.39	– 0.47	– 0.47	– 0.28	0.32	0.68	– 0.21	0.46	0.27	1.00					
Tourmaline	– 0.72	– 0.67	0.72	0.83	0.72	– 0.35	– 0.72	– 0.09	– 0.31	– 0.55	– 0.51	1.00				
Garnet	0.69	0.60	– 0.69	– 0.66	– 0.53	0.45	0.60	0.05	0.35	0.47	0.70	– 0.77	1.00			
Staurolite	– 0.40	– 0.37	0.40	0.30	0.50	0.02	– 0.33	0.08	– 0.24	– 0.40	– 0.31	0.46	– 0.38	1.00		
Chlorite	0.27	0.35	– 0.27	– 0.12	– 0.04	0.39	0.48	– 0.37	0.36	0.38	0.21	– 0.30	0.12	– 0.27	1.00	
Celestite	0.06	0.08	– 0.06	– 0.46	– 0.46	– 0.34	– 0.06	0.36	– 0.30	– 0.24	– 0.18	– 0.37	0.02	– 0.14	– 0.35	1.00

Table 5: Correlation coefficient of heavy minerals in Samawa – Qadissya dunes

	H.F.%	Magnetite	L.F.	Opaque	Alterite	Zoisite-Epidote	Horenblende	Ortho-pyroxene	Mono-pyroxene	Zircon	Rutile	Tourmaline	Garnet	Staurolite	Chlorite	Celestite
H.F.%	1.00															
Magnetite	0.90	1.00														
L.F.	– 1.00	– 0.90	1.00													
Opaque	– 0.21	0.19	0.19	1.00												
Alterite	– 0.40	– 0.18	0.39	0.62	1.00											
Zoisite-Epidote	0.06	0.34	– 0.08	0.65	0.82	1.00										
Hornblende	0.76	0.59	– 0.76	– 0.42	– 0.69	– 0.24	1.00									
Ortho-pyroxene	– 0.09	– 0.47	0.11	– 0.82	– 0.18	– 0.48	– 0.09	1.00								
Mono-pyroxene	– 0.27	– 0.58	0.29	– 0.86	– 0.28	– 0.55	– 0.07	0.90	1.00							
Zircon	0.73	0.84	– 0.73	0.24	– 0.33	0.01	0.35	– 0.43	– 0.56	1.00						
Rutile	– 0.05	– 0.20	0.05	– 0.17	– 0.53	– 0.51	0.50	– 0.10	– 0.05	– 0.18	1.00					
Tourmaline	– 0.27	– 0.42	0.28	– 0.08	0.08	0.00	0.21	0.05	0.05	– 0.66	0.72	1.00				
Garnet	0.18	0.18	– 0.18	– 0.05	– 0.69	– 0.42	0.67	– 0.44	– 0.25	0.19	0.83	0.35	1.00			
Staurolite	– 0.13	– 0.36	0.14	– 0.34	0.08	– 0.34	– 0.47	0.75	0.49	– 0.07	– 0.35	– 0.30	– 0.66	1.00		
Chlorite	0.90	0.96	– 0.91	0.10	– 0.13	0.31	0.47	– 0.28	– 0.45	0.85	– 0.38	– 0.56	– 0.05	– 0.11	1.00	
Celestite	0.13	0.47	– 0.14	0.40	0.09	0.34	– 0.14	– 0.53	– 0.33	0.52	– 0.61	– 0.77	– 0.08	– 0.31	0.46	1.00

Table 6: Average concentration of heavy minerals in sediments of Najaf, Samawa – Qadissiya dunes and sediments of Euphrates River and Dibdibba Formation

Heavy minerals (%)	1	2	3	4
Opaques	49.45	31.77	34.04	28.54
Pyroxenes	0.52	31.81	6.97	28.96
Amphiboles	0.83	18.34	5.47	15.45
Chlorite	0.42	2.60	0.83	1.07
Garnet	1.12	3.73	8.29	7.41
Epidote	1.0	2.84	5.42	8.07
Biotite	0.01	1.18	0.63	1.42
Staurolite	0.64	0.94	0.60	2.45
Zircon	11.81	0.75	9.04	1.18
Kyanite	0.04	0.51	0.04	0.61
Tourmaline	3.96	0.37	5.61	1.59
Rutile	2.03	0.10	2.18	0.24
Celestite	27.55	0.52	19.45	1.31

1) Clastics of Dibdibba Formation, Tar Al-Najaf (Al-Mukhtar and Mankhi, 2009)
2) Sediments of Euphrates River (Al-Bassam and Al-Mukhtar, 2008)
3) Sediments of Najaf dunes (present study)
4) Sediments of Samawa – Qadissiya dunes (present study)

CONCLUSIONS

From this study, the followings can be concluded:

- The sediments of the studied dunes are composed of > 94% sand, < 6% silt and clay. The Sediments of Najaf dunes are coarser than that of Samawa – Qadissiya dunes; due to their size components.
- The main size of the sediments of Najaf dunes are medium, which indicates medium sorting, while the sediments of Samawa – Qadissiya dunes are essentially fine in size; referring to fine sorting.
- Sediments of Najaf dunes are more mature than sediments of Samawa – Qadissiya dunes; according to ZTR index.
- From the chemical and XRD analysis, the sediments of the studied dune fields are composed essentially of quartz and feldspar; as dominant with paucity of carbonate and sulphate minerals, in addition to the presence of heavy minerals. Clay minerals of Najaf dune fields are represented by montmorillonite, palygorskite, kaolinite, and the same clay minerals; except montmorillonite occur in Samawa – Qadissiya dune fields.
- Najaf sand dunes are derived from felsic igneous rocks (granitoid rocks), metamorphic rocks (schist and gneiss) and older sedimentary rocks, while Samawa – Qadissiya sand dunes are essentially derived from metamorphic rocks (schist and gneiss), basic igneous rocks (basalt, gabbro) and older sedimentary rocks; according to the diversity of the present heavy minerals.
- Climate affecting the source area of Najaf dunes is semi-humid type while in Samawa – Qadissiya dunes the type of climate is arid to semi-arid, according to occurrence of stable, unstable and clay minerals in these localities.
- The age of the source sediments of Najaf dunes is older than that of Samawa – Qadissiya dunes, because the unstable minerals are more than the stable minerals in Samawa – Qadissiya dunes, which are limited to younger sediments.

- The Dibdibba Formation (Pliocene – Pleistocene), in Tar Al-Najaf is the most important supply-source of sand-forming dune fields of Najaf. The sediments are transported from the Arabian Shield, while the source area, which supplies the sediments of Samawa – Qadissiya dunes is mixed, the essential one is the surrounding formations, where the sediments are transported from Arabian Shield, and the second source is the Euphrates River where the sediments are transported from the north (Syria and South of Turkey).

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