MINERALS AND SEDIMENTARY CHARACTERISTICS OF QUATERNARY SEDIMENTS OF DIFFERENT REGIONS IN SOUTHERN IRAQ

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ABSTRACT

This study tries to evaluate the sediments of Quaternary deposits with a depth from 8 to 24 meters, and determine the lights and heavy minerals with their origin. Three boreholes; Basrah, Thi-Qar and Missan, were selected, based on the grain size analysis of samples, three types of sediment were identified: silt, sandy silt, and silty sand. The statistical size parameters were applied to determine the energy and sedimentation environment, showed that the sediments of the study area were deposited in low-energy conditions. The sorting values ranged from poorly to very poorly, while the skewness ranged from strongly fine to near symmetrical skewed and kurtosis values ranged from platy to leptokurtic. The results of heavy minerals analysis proved the very low values comparative with light ones; Opaque was predominant in all study sites, accounting for about 50% of the heavy minerals and divided to mica minerals and Chlorite, Pyroxene, Amphibole, Zircon, Epidote, and Garnet, while Kyanite, Tourmaline and Staurolite. The light minerals are dominated by carbonate and quartz with few amounts of chert, evaporates, Feldspar, rock fragments and light muscovite. The difference in the values and diversity of heavy minerals in the study area indicates the multiple sources contributing to the deposits of the Mesopotamia Plain. The sources are limited between the rivers of Tigris, Euphrates and Shatt Al-Arab and the dust-fallouts, as well as the nearest formations and the Arabian shield.

Keywords: Quaternary; Mineral; Mesopotamia; Formation; Arabian Shield

INTRODUCTION

The Middle East comprises one of the most important geological sites, whereas this status gained from historical importance, especially in the Quaternary Period (1.65 M. Y). When many civilizations habitat this area over the years as Sumerian, Assyrian, Babylonian and Islamic

civilizations to the present day, as well as the marshes which are considered to be one of the largest and most important wetlands in the Middle East even dried during 1991–2003. Quaternary deposits are the main constituent of the Mesopotamian sediment. The origin and formation of these sediments witnessed many scenarios due to the overlap between the sediments of the Tigris, Euphrates Rivers, and marine. The Mesopotamia Plain has undergone many studies, like a Abdullah (1982), Al-Sakini (1993), Al-Jumaily (1994), Al-Azzawi (1996), Al-Jibouri (1997), Al-Baidhany *et al.* (2002), Al-Hamad *et al.* (2015), Al-Hawi *et al.* (2017), Al-Malkei *et al.* (2017), and Pournelle *et al.* (2019). The study area is a part of the Mesopotamia Basin, which represents a major subsidence basin that began from the middle ages to the recent (Buday, 1980). This Basin is a mobile structural zone with many folds, faults and salt structures (Fouad, 2010; Fouad and Sissakian, 2011), it lies within the Unstable Shelf of the Arabian Plate (Buday and Jassim, 1987). For Jassim and Goff (2006), the Mesopotamian Zone is a stable shelf within the Arabian Plate. The Mesopotamia Plain is a sedimentary unit and wide lowland with clear physiographic boundaries; it is bordered by the Low Folded Zone from the northern and eastern sides, the Western Desert and Al-Jazira Area from the western side, and from the south to the Arabian Gulf (Yacoub, 2011a). Although the Mesopotamia plain has a gentle slope and low-level terrain, it did not prevent the presence of different geomorphological features (Yacoub *et al.*, 1981). The Mesopotamian basin contains Quaternary sediments and is surrounded by the Tertiary sediments (Yacoub, 2011b), the thickness of these sediments is about 120 m (Bsho, 2004), that is revealed in the eastern and SE parts of Amara City, It belongs to Mukdadiya and Bai Hassan formations (Barwary, 1993). The sediments of Holocene are characterized by different environments, such as the fluvial, lacustrine, estuaries, and Aeolian environments, and others resulting from human activity and distributed in the Mesopotamia Plain (Yacoub, 2011b). Aqrawi (1995) explained that the deposition of this period was influenced by several factors, namely sedimentation rate, sea-level fluctuation, and neotectonic activities, and the thickness of these sediments range between 15–20 m. The source of these sediments is coming from the mountains of Taurus and Zagros and the drainage of the Tigris, Euphrates and Shatt Al-Arab rivers. This study is an attempt to predict the origin and provenance of these sediments through studying the heavy and light minerals.

MATERIALS AND METHODS

The study area includes the lower part of Mesopotamian basin, which represents the triangle between Basrah, Thi-Qar and Missan, specifically located between Latitude 32°30'0"–30°0'0" N and Longitude 45°30'0"–48°0'0" E (Fig. 1). Fieldwork and samples were executed in cooperation with many private and public laboratories to provide samples for the study area, due to the high

cost of drilling. Three boreholes (Bh) were secured in the study area from these labs, one borehole in Emam Reidha quarter, Basrah (BR), and one in Ebtera, Missan (MI), while the samples of Thi-Qar were collected from the irrigation channels in Awadiyat (TN) (Table 1). The descriptions of these boreholes were mentioned in figures (2, 3, and 4). Samples were analyzed to determine the percentage of sand, silt and clay by the Master Sizer (Model UM 2000) in the Geology Department, University of Basrah. The heavy and light minerals were separated and identified in the Department of Geology, College of Science, University of Baghdad. The fine sand of size 3 and 4 phi was separated by a heavy liquid (bromoform) with a specific weight of 2.89. The procedure of separating heavy and light minerals is done according to Müller (1967), Griffiths (1967), Carver (1971) and Tucker (1985). These minerals were identified using binocular and a polarized microscope.

Table 1: Source and location of boreholes in the study area

Bh. Symbol	Depth (m)	Graphical location	Latitude N	Longitude E	Source
BR	24	Basrah/Emam Reidha quarter	30° 31' 42.7"	47° 48' 1.1"	Engineering College lab/ University of Basrah
TN	8	Thi Qar/Awadiyat	31° 24' 18.29"	46° 33' 43.65"	Field work
MI	19	Missan/ Ebtera	31° 51' 4.6"	46° 22' 35.3"	General commission of ground water/Missan

RESULTS

According to the classification of Folk (1974), the results of the grain size analysis in Basrah showed two types of sediments: silt, and sandy silt, while in Thi-Qar, three types were recorded, sandy silt, silty sand, and silt. In Missan there were two types, sandy silt, and silty sand, and the statistical size parameters are present in Table (2). The heavy and light minerals with their average are presented in tables (3, 4, and 5). Plates (1–4) show the heavy and light minerals present in the study area.

Fig. 1: Locations of the Boreholes (Rounded green circles are the boreholes)

Table 2: Grain size analysis and statistical size parameters in the study area

Region	No. of Samples	Depth (m)	Sand %	Silt %	Clay %	Mean	Median	Sorting	Skewness	Kurtosis	Texture
Basrah	BR7	6	6	79	15	6.4	6.4	1.5	0.04	0.86	Silt
	BR7	6	6	79	15	6.4	6.4	1.5	0.04	0.86	Silt
	BR6	11	5	79	16	6.4	6.4	1.5	0.04	0.86	Silt
	BR5	14	5	80	15	6.5	6.4	1.53	0.04	0.88	Silt
	BR4	17	33	56	11	4.9	5.7	2.85	-0.3	0.77	Sand
	BR3	20	22	57	21	5.5	6.4	3	-0.4	1.15	Sand
	BR2	22	19	74	7	5.5	5.5	1.83	-	1.36	Sand
	BR1	24	23	67	10	5.6	5.5	2.02	0.80	0.81	Sand
Thi-Qar	TN1	0.5	50	47	3	4.4	3.9	1.80	0.39	0.80	Silty
	TN2	1	70	28	2	3.5	3.2	1.6	0.20	1.0	Silty
	TN3	2	40	58	2	3.8	3.4	1.72	0.36	1.04	Sand
	TN4	3	76	23	1	3.4	3.3	1.55	0.56	1.31	Silty
	TN5	4	44	53	3	4.5	4.4	1.91	0.07	0.8	Sand
	TN6	5	10	79	11	5.8	5.8	1.46	0.04	1.13	Sand
	TN7	6	42	52	6	4.8	4.7	2.0	0.08	0.86	Sand
	TN8	7	9	83	8	5.8	5.6	1.42	0.17	1.25	Silt
	TN9	8	83	16	1	3.4	2.8	1.38	0.60	1.75	Silty
Missan	MI19	1	32	62	6	5	5.1	2.16	-	1.0	Sand
	MI18	2	34	60	6	5.3	5.3	1.07	-	1.5	Sand
	MI17	3	58	38	4	4.1	4.1	2.02	0.1	0.7	Silty
	MI16	4	47	47	6	6.7	4.5	2.08	0.02	0.81	Sand
	MI15	5	53	43	4	4.03	3.7	2.1	0.24	0.76	Silty
	MI14	6	60	38	2	3.9	3.5	2.1	0.26	0.84	Silty
	MI13	7	62	35	3	3.8	3.3	2.2	0.28	0.93	Silty
	MI12	8	30	64	6	5.3	5.3	2	-	1.12	Sand
	MI11	9	55	41	4	4.3	4.2	2.03	0.11	1.15	Silty
	MI10	10	35	60	5	4.9	4.9	2.01	0.01	1.10	Sand
	MI9	11	57	40	3	4.2	4.2	2.05	0.05	0.80	Silty
	MI8	12	50	46	4	4.3	4.0	2.02	0.12	0.80	Silty
	MI7	13	49	46	5	4.6	4.2	2.2	0.23	0.81	Sand
	MI6	14	51	46	3	4.6	4.3	2.1	0.16	0.80	Silty
	MI5	15	43	52	5	4.6	4.5	2	0.1	0.80	Sand
	MI4	16	40	53	7	4.7	4.5	2.04	0.13	0.86	Sand
	MI3	17	50	45	5	4.4	4.1	1.9	0.22	0.80	Silty
	MI2	18	43	52	5	4.7	4.5	1.9	0.16	0.77	Sand
	MI1	19	60	36	4	4.1	3.5	1.9	0.43	0.83	Silty

Table 3: Percentage of heavy and light minerals of the study area

Region	Sample Number	Depth	Percentage of Light Minerals	Percentage of Heavy Minerals
		(m)	(%)	(%)
Basrah	BR1	6	96.4	3.6
	BR2	11	96.0	4.0
	BR3	14	96.2	3.8
	BR4	17	93.8	6.2
	BR5	20	95.2	4.8
	BR6	22	95.4	4.6
	BR7	24	95.4	4.6
Thi-Qar	TN1	0.5	92.4	7.6
	TN3	2	96.4	3.6
	TN5	4	92.2	7.8
	TN7	6	90.2	9.8
	TN9	8	97.2	3.8
Missan	MI1	1	95.8	4.2
	MI2	2	95.6	4.4
	MI4	4	90.6	9.4
	MI6	6	92.0	8.0
	MI8	8	91.4	8.6
	MI10	10	96.0	4.0
	MI12	12	92.2	7.8
	MI14	14	91.6	8.4
	MI16	16	94.6	5.4
	MI18	18	93.4	6.6

Table 4: Range and average of heavy minerals in the study area

Heavy Minerals	Basrah (BR)		Thi-Qar (TN)		Missan (MI)	
	Range	Average	Range	Average	Range	Average
Opagues	40.8-46.7	44.34	43.2-49.2	46.16	42.3- 50.7	46.84
Chlorite	6.5-9.2	7.81	9.1-10.4	9.72	8- 11.2	9.03
Garnet	2.2-4.2	3.62	4.4-6.4	5.2	3.2- 6.4	5.06
Zircon	4.8-6.1	5.54	4.5-5.4	5.04	3.8- 6.5	5.16
OrthoPyroxene	2.3-4.9	3.11	2.3-3.9	2.98	1.6-3.4	2.81
ClinoPyroxene	3.5-5.2	4.21	3-4.6	3.74	2.8-5.7	4.2
Amphibole	4.1-5.3	4.71	3.1-6.1	5.14	5-7.2	5.98
Epidote	4.2-6.3	5.27	4.7-6.4	5.96	5.1- 7.1	5.86
Biotite	4.7-6.4	5.37	4.3-4.7	4.48	2.2- 6.5	3.36
Muscovite	5.7-6.8	6.1	4.3-7.2	5.64	2.5-7.6	4.53
Tourmaline	3.1-4.1	3.53	1.9-4.1	2.6	1.3-4.3	2.58
Staurolite	0.7-2.7	2.04	0.6-0.6	0.6	0.3-2.6	1.83
Kyanite	2.1-2.6	2.36	1.3-2.7	2.12	1-2.3	1.59
Others	1.4-2.5	1.96	0.5-1.7	1.1	0.5-1.8	1.35

Table 5: Range and average of light minerals in the study area

Light components	Basrah		Thi-Qar (TN)		Missan (MI)	
	Range	Average	Range	Average	Range	Average
Monocrystalline Quartz	18.3-23	21.7	17.6-20.6	18.92	14.1-22.5	19.18
Polycrystalline Quartz	2.8-5.7	3.93	2.5-4.7	3.46	2.1-6.6	3.78
Alkali Feldspar Orthoclase	2.3-3.5	2.64	2.6-3.9	3.06	2-3.7	2.86
Alkali Feldspar Microcline	1.8-2.9	2.46	1.6-3.3	2.24	0.7-2.8	1.76
Plagioclase Feldspar	2.2-3.8	3.07	2.2-4.7	3.72	2.3-4.7	3.76
Carbonate Minerals	21.7-32.5	27.3	29.8-33.8	32.12	24.8-34.5	31.61
Chert Rock Fragments	8.2-12.5	10.8	6.5-11.2	9.14	5.3-10	8.25
Igneous Rock Fragments	2.8-4.3	3.71	2-3.9	3.1	2.1-5.6	3.17
Metamorphic Rock Fragments	1.6-4.5	3.47	2.3-3.4	2.9	1.6-3.8	3.07
Mudstone Rock Fragments	3.4-5.7	4.31	2.6-3.9	3.42	3-5.8	4.06
Evaporates	6.8-10.3	8.08	6.6-9.1	7.62	6.9-10.8	8.59
Coated Clay	2.0-3.1	2.43	1.7-3.8	2.62	2.5-3.3	3
Light Muscovite	3.3-4.5	4.16	4.5-7.4	5.52	2.7-6.9	5
Others	1.5-2.5	1.93	1.6-2.8	2.16	1.4-2.7	1.91

Fig. 2: Lithology of Emam Reidha quarter (BR), Basrah region

Fig. 3: Lithology of Thi-Qar region

Fig. 4: Lithology of Ebtera (MI), Missan region

DISCUSSION

Sedimentological Study

Grain size analysis shows that the sediments of the Basrah region are silty sand and sandy silt (Fig. 2) which are generally characterized by finning upward. While Thi-Qar region included three types of sediments, silty sand, sandy silt and silt (Fig. 3). The Missan regions, two types of sediments were recorded, silty sand and sandy silt (Fig.4). The texture of the two regions Missan and Thi-Qar are similar, possibly due to the distance between them and or that they could belong to the same sedimentary environment.

In general, the results recorded in the present study of granular size consisting of silts and very fine sand could relate to weak energy, where the coarse sediments of the Tigris and Euphrates Rivers are deposited when entering the marshes, and the finest sediments (fine silt and clay) reach to the Shatt Al-Arab River. The addition also comes from the erosion of the river bank (Albadran, 1987). This thought is also explained by an increase in sand and silt ratios in the northern part of the study area. The increase of silt sediment type in the study area could refer to the fluvial environments. The values of the statistical size parameters show that the sorting ranges from very poor to poor sorting in the three regions this can be attributed to the low sedimentation energy and the sedimentary environments in the three regions with a similar condition which could belong to the lakes and low depressions of the area. This makes certain from the mean size values wherein Basrah sediments ranged between 4.9 and 6.5 which show the fine of the granular size, in Missan, the average values ranged from 3.8- to 6.7, and in Thi Qar, there is a rapprochement of Missan, as well as an intermediate situation between Missan and Basrah. The diversity in the values of Skewness and Kurtosis values in the study area were close (Table 2), their values indicate that the size of the sediment is fine to very fine and this could reflect the low energy of the sedimentary conditions.

Mineralogical Study

The presence of heavy minerals in the sedimentary rocks and detrital sediments is varied, not necessarily that these minerals are connected with each other, but the method of separation and isolating them is determined as a group, these minerals reflect the parent's rocks after being stripped and weathered (Jasim, 2009). Heavy minerals are used to identify the source rocks (Boggs, 2006), as well as the identification of sedimentary environments (Kasper-Zubillage *et al.*, 2008). Al-Bassam (1999) pointed out that the study of the heavy minerals in ancient and recent sediments is important to

determine the degree of maturation of the sediment and its relation to the climate as well as the transport distance and sedimentation cycles.

The percentage of heavy to light minerals indicates that the samples in the three regions have varying proportions in some beds and are converging in the others this could belong to the different conditions of the supplied source. The percentage of heavy minerals in the Basrah region is very close in most of the depth but varies from depth 17 to 22m (Fig.6) and the sedimentation environment in this bed could be different. This depth could be the top of the Dibdibba Formation. While in the Thi-Qar region the percentage of heavy minerals is high in depths (0.5; 4; 6 and 8m) and low in depth (2m) (Fig. 7). This is also observed in Missan (Fig. 8). The difference in the percentage of minerals in the depths is attributed to several factors; including climatic changes that affect the weathering processes in the source rock region (Folk, 1974 and Pettijohn, 1975), as well as the river meanders and grain size of sediments affect the concentrations of heavy minerals. The difference in heavy minerals with depth, some of them are increasing and others are decreasing (Figs. 6, 7, and 8), this could explain the interference between the sedimentary environments; from the river to marsh or under the influence of dust-fallouts as well as the formation of some minerals in the same environment as a result of the diagenesis and alterations.

Fig. 6: Vertical variations in the percentage of the heavy minerals of Basrah region

Fig. 7: Vertical variations in the percentage of the heavy minerals of Thi-Qar region

Fig. 8: Vertical variations in the percentage of the heavy minerals of Missan region

Dust-fallouts could be the main supplier of the heavy minerals were the opaque minerals recorded with a significant rate of about 46% in the three regions (Plate 1A and B); this ratio was similar to the minerals of the dunes near Thi-Qar and Missan regions (Jasim, 2017). Whereas for Tucker (1985) and Bassi *et al.*, (1989) opaque minerals were recorded with a significant rate of about

46% in the three regions, tried to connect them to the river origins. Albadran *et al.* (1996) and Sedkhan (2009) recorded the highest percentage of these minerals which are concentrated by washing the Shatt al-Arab River sediments because the presence of these minerals in the old sediments is less than the recent one (Philip, 1968). The pyroxene and hornblende (Plate 2D, E, and F) recorded different rates but are considered to be closed across the three regions, with the average in Basrah 12.03%, 12% in Dhi Qar and 13% in Missan. It is possible to have opaque, pyroxene, hornblende and chlorite that refers to the source rocks of alkali igneous rocks in the area (Folk, 1974). Whereas, the presence of Epidote, Garnet and iron oxides minerals refer to metamorphism origin (James, 1984), as well as the sedimentary origin which is observed through the rounded shape of ultra-stable minerals grains. The pyroxene and hornblende recorded different rates, but are considered to be closed across the three regions, with the average in Basrah 12.03%, 12% in Dhi Qar and 13% in Missan. Epidote was recorded in Basrah at average 5.27%, 6% in Thi-Qar and 6 in Missan. According to Philip (1968), the percentage of this mineral is high in the old sediments compared to recent. This mineral also appears in the current rivers like the Tigris, Euphrates, and Shatt Al-Arab (Al-Ali, 1976; Albadran *et al.*, 1996 and Sedkhan, 2009), which means that the origin of this mineral could be a river. The sources of heavy minerals in the sediments of the Euphrates River are numerous (AL-Bassam, 2000), igneous and sedimentary complexes in the areas where the river crosses in Turkey and Syria, as well as the desert valleys that rainwater contributes to the river like the Horan Valley, As well as from Dibdibba and Injana formations, which are important sources of heavy minerals in the sediments of the Euphrates River.

Mica and chlorite minerals were recorded at a good percentage of about 19% in Basrah 20 % in Thi-Qar, and 17% in Missan (Plate 2A, B, and C). Garnet was recorded in Basrah 3.62%, 5.2% in Thi-Qar and Missan about 5.06%, in the deeper layers of the sediments of Basrah; it decreases since these beds belong to Dibdibba Formation. The chlorite ratio is predominant (Plate 1C, D, E, and F), it could be related to the Shatt Al-Arab sediments (Philip, 1968) and Missan and Thi-Qar dunes (Jasim, 2017). Ultra-stable minerals recorded at the rate of 9% in Basrah, 8% in Thi-Qar and 8% in Missan. It was observed that the minerals are well-rounded grains which could relate to the origin of the reworked sediments. Salman and Saadallah (1986), AL-Jabbry (2005) and Al-Humaidan (2018), concluded that the ultra-stable minerals in the sediments that reach to the northwest of the Arabian Gulf are from Dibdibba Formation and Al-Batin fan. For Asiedu *et al.* (2000 in Al-Jabbry, 2005) these minerals were supplied from the Western desert and originated from the Arabian Shield. The minerals of Kyanite and

Staurolite (Plate 3B, C, and D) were low in the region, and the Staurolite was not recorded in the sediments of Thi-Qar, except at the 0.5 m depth, the source could be the Euphrates River where AL-Bassam and AL-Mukhtar (2008) showed that the values of Staurolite in the sediments of the Euphrates River decreases southwards, whereas its presence in 0.5 depths could be related to the aeolian sediments.

Light minerals come from multi-sources. This makes there difficult to determine the source of these sediments, as well as their high resistance for weathering processes, reflect the nature of these processes and the distances of transport, through the grain form. The results show that the carbonate and quartz minerals (Plate 3A, B, and F) are dominant in the deposits of Mesopotamia plain, due to the sedimentation environment and the multi-sources of sediments. Al-Bassam and Al-Mukhtar (2008) pointed out that most of the light minerals in the Euphrates River sediments are carbonate, quartz, and Feldspar (Plate 3C, D, and E). Figures (9, 10 and 11) show the contrast of light minerals with depths, Quartz records high ratio in the sediments and varies with depths. In the Basrah region, the quartz decreases toward the depth of 11 m, this could belong to Hammar Formation, and then returns to increases towards the depth of 24 m. This depth could belong to Dibdibba Formation. In the Thi-Qar, the quartz increases with depths. In Missan, it oscillates between the beds. The increase of quartz returns to its high stability and resistance to weathering. The ratio of feldspar minerals is low due to the non-stability of these minerals and transformation into clay minerals. Carbonate minerals recorded a high percentage in the sediments of the study area. In the Basrah region, carbonate increases toward the depth of 11 m and then returns to decreases towards the depth of 24 m. which could refer to the transition from Hammar to Dibdibba formations. In the Thi-Qar, it is also increased with depths, while in Missan, it decreases towards the depth. This could be related to the source supplied, as well as the content of the shells, Purser and Seibold (1973) clarified that carbonate minerals are increased with fine-grained deposits. Albadran (2006) noted that the carbonate minerals in the Shatt al-Arab deposits returned to fauna shells, as well as detrital Low-Mg calcite, and authigenic carbonate. Muscovite was recorded in this study within light minerals, and this muscovite has a specific weight of less than 2.89, a significant decrease in the specific weight in the muscovite between 2.77 – 2.88. Evaporites were recorded in the third-largest percentage in terms of carbonate and quartz. This can explain the hot climate of the area and the opportunity to precipitate the evaporate minerals. The study identified many types of rock fragments such as igneous, metamorphic and sedimentary rocks, and this may explain the diversity of source rocks of the study area sediments. In general, the sediments of the

Mesopotamia Plain are immature, as the sediments of the Tigris and Euphrates Rivers and Dibdibba Formation (Philip, 1968).

Fig. 9: Vertical variation in the light minerals percentage of Basrah region

Fig. 10: Vertical variation in the light minerals percentage of Thi-Qar region

Fig. 11: Vertical variation in the light minerals percentage of Missan region

CONCLUSIONS

The sediments of the study area were classified into three types: sandy silt, silty sand and silt, and the silt fraction is the dominant size of sand and clay fraction. The sedimentation environment of the study area is shown to be of quiet energy, and the grain size decreases relatively from northern to southern. Basrah was recorded finning upward and both of Thi Qar and Missan regions recorded close grain size but different between the beds. Opaque, chlorite, muscovite, zircon, epidote, biotite, amphibole, pyroxene, and garnet, are the main heavy minerals in the study area. The diversity of heavy minerals reflects the multiple sources of sediment, represented by the igneous, metamorphism and sedimentary rocks. The mineral content shows that the sedimentary environment of the region is overlapping of fluvial, marine and aeolian. The sources of the sediments are the Tigris, Euphrates, Shatt al-Arab Rivers and the Arabian Gulf in Basrah region but in Thi-Qar and Missan the sources of their sediments are the Tigris, and Euphrates Rivers and dust- fallouts. The dominant light minerals are light muscovite and rocks fragments which related to its sedimentary origin, and presence of different minerals which include Carbonate minerals, quartz, Evaporites, Feldspar and chert, and the presence of quartz, zircon, and tourmaline refer to reworked sediments.

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Plate 1: Heavy minerals under polarizing microscopic

(A) & (B) Opaque grain (Iron Oxide), sample number MI6, PPL

(C) Fresh green chlorite, sample number MI19, PPL

(D) Fresh green chlorite, sample number MI2, PPL

(E) Flaky form, brown chlorite with spots of iron oxides, sample number TN7, PPL

(F) Altered corroded chlorite, sample number TN7, PPL

Plate 2: Heavy minerals under polarizing microscopic

- (A) Flaky form, fresh muscovite mica, sample number MI6, XPL**
- (B) Flaky form, brown color, pleochroic biotite, sample number MI10, PPL**
- (C) Flaky form, light brown color, pleochroic biotite, sample number MI2, PPL**
- (D) Orthopyroxene (Enstatite), sample number BR1, PPL**
- (E) green color, subhedral prismatic clinopyroxene, sample number MI6, PPL**
- (F) green color, subhedral prismatic clinopyroxene, sample number TN9, PPL**

Plate 3: Heavy minerals under polarizing microscopic

A: High Relief, Light brown garnet, sample number MI2, PPL

B: High relief, prismatic, colorless kyanite, sample number TN7, PPL

C: Yellowish color, staurolite, sample number TN7, PPL

D: Yellowish color, staurolite, sample number BR3, PPL

E: High relief, euhedral, prismatic, colorless zircon with black shades, TN7, PPL

F: Euhedral, prismatic, colorless zircon with blue shades, sample number BR4, PPL

Plate (4): Light minerals under polarizing microscopic

- (A)Monocrystalline quartz, sample number TN5, XPL**
- (B) Polycrystalline quartz, sample number TN3, XPL**
- (C) Euhedral alkali feldspar (Orthoclase), sample number TN7, XPL**
- (D) Alkali feldspar (Microcline), sample number TN1L, XPL**
- (E)Subhedral, plagioclase feldspar, Sample number BR2, XPL**
- (F) Carbonate minerals (Limestone), sample number TN5, XPL**