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Heavy minerals study on the Tigris River's quarries deposits in Nineveh Governorate, northern Iraq

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Abstract

The increasing demand for building materials such as gravel and sand led to the chaotic and random spread of many quarries in Nineveh governorate, which led to the distortion of the main course of the Tigris River and the surrounding areas, and this appears clear and obvious by observing aerial and satellite images of the Tigris River course and comparing them with similar old pictures of the riverbed. The random extraction caused substantial changes in the river's morphology, distorting the main riverbed by making it impossible to discern between the main river and the surrounding areas, and the depletion of river sediments became essentially uncontrolled. The main objective of this study is to determine the origin of these extracted sediments and ascertain whether they came from inside Iraq or from southern Turkey. Nine different quarries located on both sides of the Tigris River in Nineveh Governorate were studied. Samples were collected, volumetric analysis tests were conducted, and heavy metals were studied. Furthermore, it has been demonstrated that the origin of these deposits is due to igneous, metamorphic, and sedimentary rocks originating in southern Turkey rather than Iraqi territory, and that the process of replacing these deposits has become impossible, particularly since the construction of the Mosul Dam. As a result, strong legislation defining the extraction technique and optimum extraction locations must be enacted in order to protect the remainder of these resources for future generations.

Keywords: Heavy minerals, Quarries, Tigris River, Nineveh Governorate, northern Iraq.

1. Introduction

From its headwaters to its confluence with the Euphrates in the Qurna area, the Tigris River travels 1718 kilometers. The Tigris River starts at the summits of mountains in southeastern Turkey, and its basin is next to the eastern basin of the Euphrates River. Turkey's Tigris River receives water from two major sources (Fig. 1) (El-Khouly, 1950).

The first source is named after the river and begins near the town of Diyarbakir, Turkey, flowing south, then deviates to the east after a short distance and links to the second source. This source's basin is modest in height, ranging from 1000 to 1500 meters above sea level, with a few spots exceeding 2000 meters.

The second source is named ButmanSou, and it runs for 100 kilometers from the center of the Hakkari Heights, located south of Lake Van in Turkey, to the first branch north of the Iraqi borders. The basin of this source is higher and runs from 2000 to 4000 meters above sea level, with some peaks reaching 5000 meters.

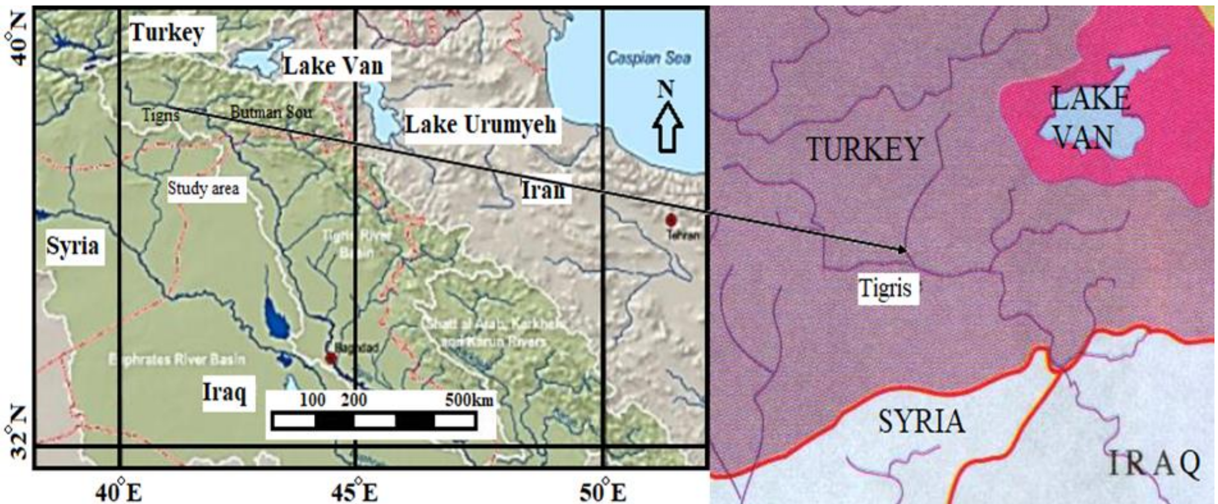

Figure1. Tigris River sources and the study area.

The Tigris River flows through Tertiary igneous and metamorphic rocks, Plio-Quaternary basalts and Plio-Quaternary alluvial basins, Eocene limestone, Mesozoic metamorphic, and Tertiary volcano-sedimentary rocks (Fig. 2). After passing through Iraqi land, the Tigris River flows through the Mukdadiya Formation (Upper Miocene-Pliocene), Injana Formation (Upper Miocene), and Fatha Formation (Middle Miocene) (Fig. 3) (Sissakian et al., 2018).

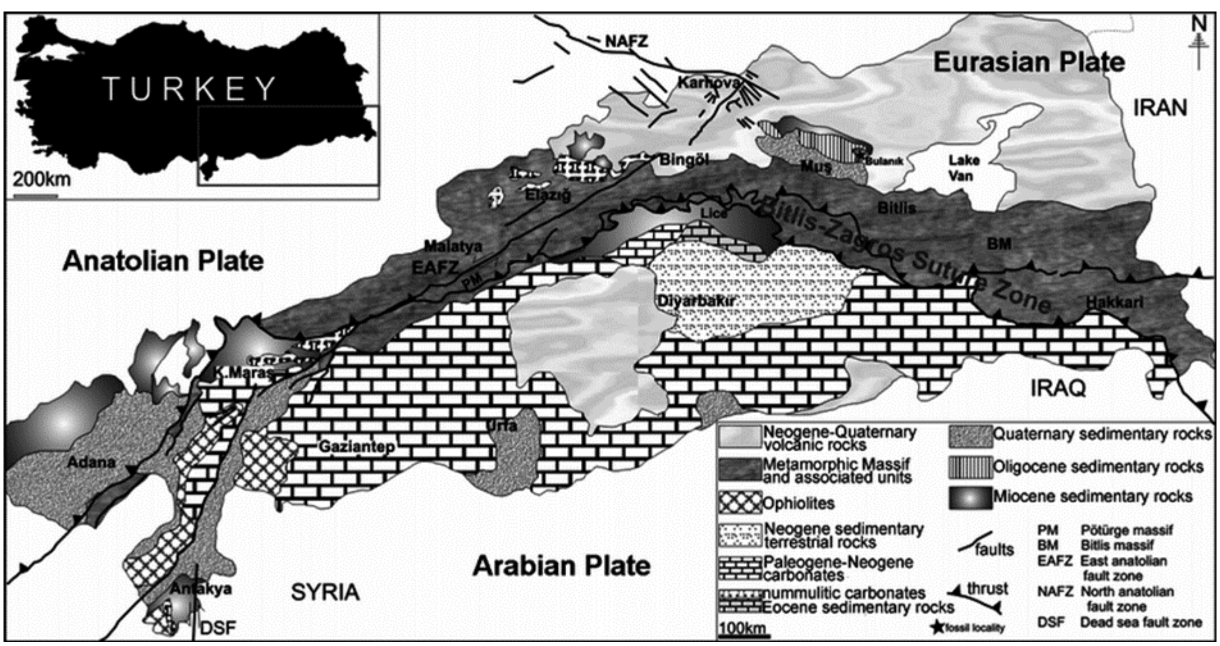

Figure2. Southeastern Turkey geological map with major tectonic structures (Hüsing et al., 2009)

The Tigris River deposits are rich in rock components produced from sedimentary, igneous, and metamorphic rocks, with the bulk being igneous and metamorphic in origin. The mineral investigation on the Tigris and Euphrates rivers revealed that the two rivers have extremely comparable proportions, therefore the Shatt al-Arab sediments are similar to those obtained from igneous and metamorphic rock disintegration (Philip, 1968). These deposits include seven light minerals out of thirty-two distinct mineral types and forty-one heavy mineral types represented by iron ores, epidotes, amphiboles, and pyroxenes (Philip, 1968). River sand deposits are rock relics of a feldspatho-quartzo-lithic, clastic of carbonate sediment, serpentinite, slate, shale, volcanic, metavolcanic, and chert (Garzanti et al., 2016). The sediments that flowed into the Tigris River and were deposited in the study area were the result of the river's large discharge in the past, which was at a rate of 1,207 m3/s from 1931 to 1960 and decreased to 522 m3/s after the year 2000 (Al-Ansari et al., 2018). Climate change and dam development have limited the Tigris River's capacity to carry silt and its efficiency (Al-Ansari et al., 2015).

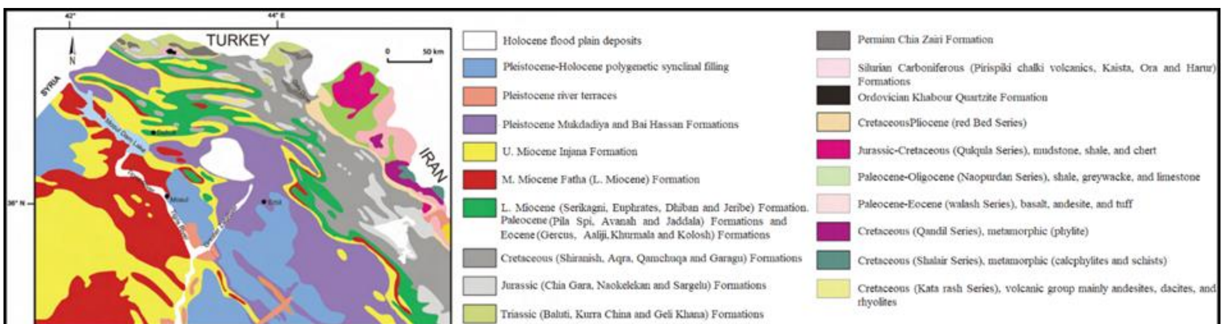

Figure3. Geological map of northern Iraq modified after (Al-Juboury, and Al-Miamary, 2009).

The preceding shows the lack or presence of sediments reaching the research region, which was distinguished by its diversity and varied origin as a result of dam building and climatic change. The aim of this study is to determine the origin of the Tigris River sediments extracted from quarries and to determine their main source, whether they are from inside Iraq or from Turkey, as they represent an economic wealth that must be taken care of.

2. Study Area

The city of Mosul is situated on both banks of the Tigris River, which is specified by coordinates Latitudes 36° 19' 21.25" N, and 36° 23' 54.22" N, and Longitudes 43° 10' 07.54" E and 43° 01' 40.38" E. Geological structures control the course of the Tigris River, and the most important of these structures are the faults that control its course (Adeeb et al., 2022). The Fatha Formation (Middle Miocene) is widespread on the western bank of the Tigris River. This formation is a stratigraphic succession of lagoon deposits of limestone, marl, and gypsum. As for the eastern bank of the river, the Injana Formation (Upper Miocene) spreads, consisting of a stratified succession of sandstone and mudstone. Because of Geomorphology, the city of Mosul is an undulating area located within the Low Folded Zone (Fig. 4) (Fouad, 2015). The Tigris River is of braided type within the city of Mosul, and this can be seen from the spread of islands along the river and its braiding in many locations (Fig. 5).

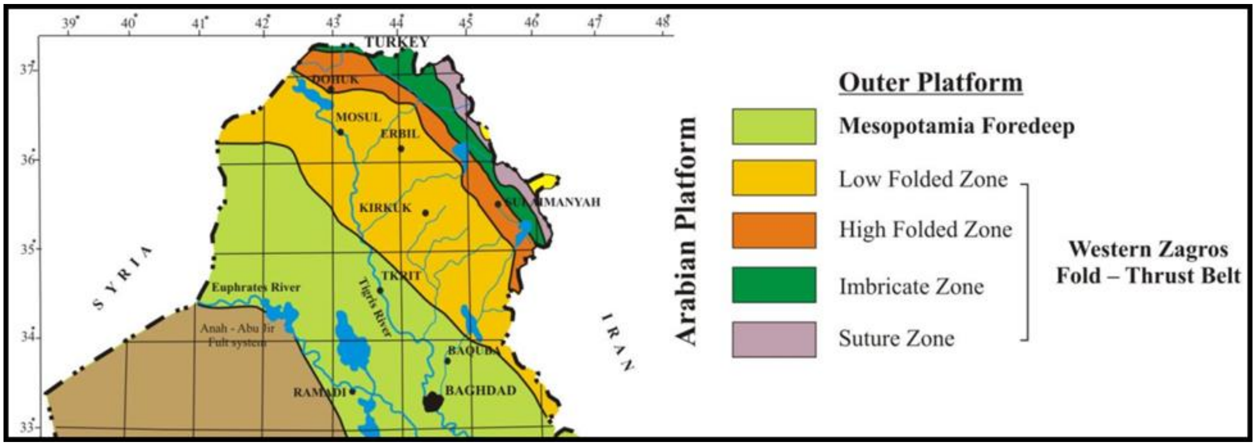

Figure4. Tectonic map of northern part of Iraq modified after (Fouad, 2015).

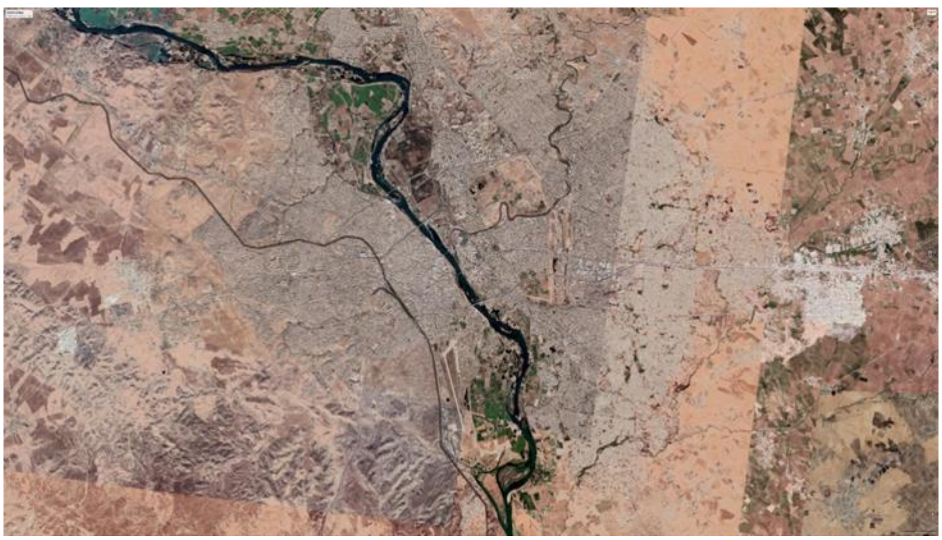

Figure5. ASTER Global digital map of Mosul city showing the meanders and braiding of the Tigris River

3. Methodology

Several field trips were taken to several quarries located on both banks of the Tigris River inside the Nineveh Governorate. The study's nine locations were located, and samples were collected. The sieve analysis method was then carried out in the laboratory using a set of sieves with varied volume periods to separate sediment sizes and preparing them for the separation of heavy minerals. The process of separating heavy minerals was carried out by means of bromoform solution and acetone alcohol to determine the origin and source of the Tigris River sediments. Furthermore, the process of cutting and polishing the stones was carried out by a rock-cutting equipment to show their texture, minerals, and geological composition.

Figure6. A Tigris River trip conducted and Laboratory separation of heavy minerals

4. Results and Discussions

- Sieve analyses

Nine samples of the sediment selected in the study area with different weights were taken, and a sieve analysis was conducted to find out the size distribution, and the percentage of particles remaining from the sieves (Table 1).

Size mm	Munaira	Zawia	4th Bridge	5th Bridge	3rd Bridge	River Police	Oberwi	Rashedya	Huleileh
76.2	0	0	0	0	0	0	0	0	0
50.8	10.6	3.1	0	0	4.4	0	9.9	0	28.1
25.4	31.9	25.8	11.5	16.6	17.6	10.8	27.6	23.8	45.7
19.05	39.2	33.5	25.2	29.0	32.8	21.6	41.9	37.1	54.0
9.525	55.0	47.6	50.8	56.9	53.8	46.6	62.6	54.4	62.6
4.75	67.0	61.2	66.3	76.1	66.1	65.4	74.8	67.0	71.5
2.36	73.4	68.8	73.7	85.0	80	75.5	81.4	77.9	79.4
0.297	85.6	88.2	84.0	94.3	90.1	86.1	91.6	89.5	89.2
0.075	100	100	100	100	100	100	100	100	100

The size distribution of the particles passing through the sieves shows a relatively organized distribution for all samples, except for a few differences that indicate the nature of sedimentation in each region (Fig. 1). The figure shows that the distribution of grains in the Huleileh area is characterized by an increase in large sizes relative to small sizes, and this is what was observed in one of the quarries located there, as the owner of the quarry breaks large gravel and produces gravel and sandy aggregates from it, due to the infeasibility of obtaining useful gravel for construction purposes.

When the width of the river decreases, as in the 5th Bridge area, the large sizes increase in proportion to the soft sizes, and the quarry located there produces gravel only and throws out very few soft materials and returns them to the river. These differences in the results of volume gradients indicate that the sediments differ in their quantities from one region to another according to their influence by the processes of erosion and sedimentation. Due to the different quantities of sediments carried by the river in each period, three characteristics of different levels were formed, known as river terraces (Al-Ani and Al-Barazi, 1991).

Sand is produced in good quantities in the quarries of southern Mosul, especially in the village of Al- Zawia, as it was the highest proportion of sand in the size distribution in this region (Fig. 7). A table was prepared showing the volume gradient rate for each sample and the size of the upper and lower limits in each quarry to match that with the production of each quarry (Table 2). It is clear from the table that the highest amount of sediment was of size 9.525 mm in the quarries of Huleileh and opposite the River Police site, the 3rd bridge, the 5th bridge, and the 4th bridge, and this indicates the homogeneity of sedimentation in these areas. The highest percentage of size was 25.4 mm in the quarries of Oberwi, Munaira and Zawia, while the highest percentage of size was 50.8 was in the Huleileh quarry, and this confirms what was previously mentioned by the spread of large sizes of gravel in this quarry, which breaks it and produces coarse and fine aggregates the size of gravel and sand.

Table (2) shows the average volume gradient for all models, the lower limit and the upper limit.

Size mm	Maximum	Size mm	Minimum	Average	Site
50.8	3311	2.36	930	1309	Huleileh
25.4	1855	0.075	817	867	Rashedya
9.525	3636	2.36	1146	1947	Oberwi
9.525	3981	2.36	1610	1774	River Police
9.525	2651	50.8	551	1403	3rd Bridge
9.525	3218	0.075	657	1283	5th Bridge
9.525	4218	2.36	1218	1830	4th Bridge
25.4	2589	2.36	776	1353	Munaira
25.4	2751	50.8	373	1345	Zawia

- **Rock Types Analysis**

Fieldwork revealed that the majority of the Tigris River sediments in Mosul are pebble deposits of various sizes with volcanic, metamorphic, and sedimentary origin, indicating that their source is from Turkish territories rather than within Iraq (Fig. 8). Which makes the opportunity to replace these sediments very difficult due to the construction of the Mosul Dam and the interruption of sediments reaching within the borders of Nineveh Governorate, (Al-Jawadi et al., 2023).

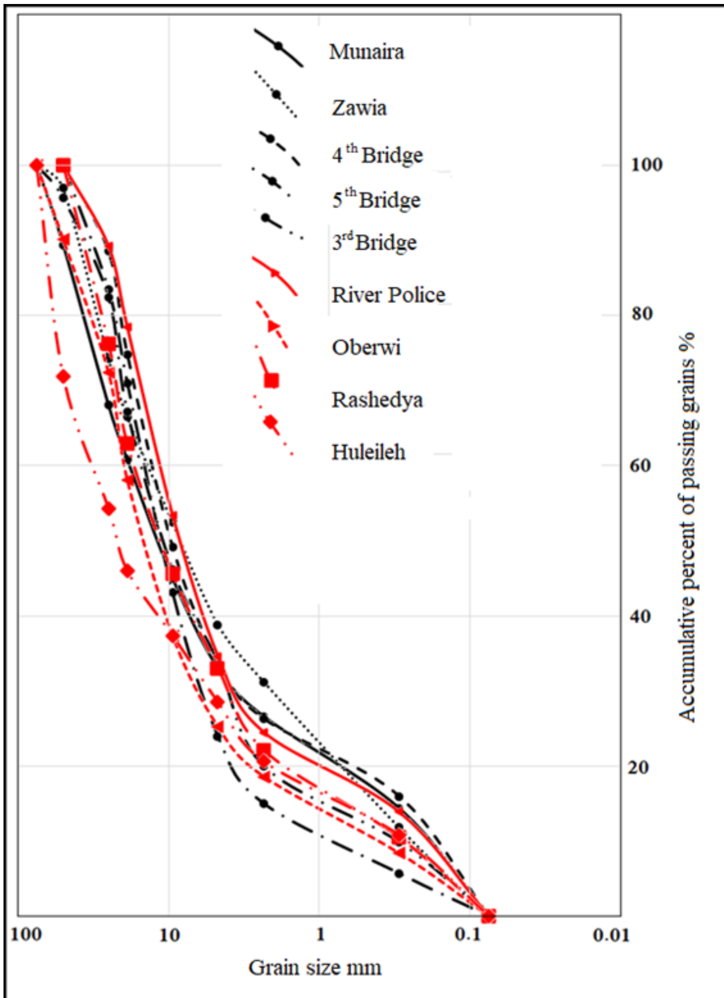

Fig. 7. The size distribution of the particles passing through the sieves.

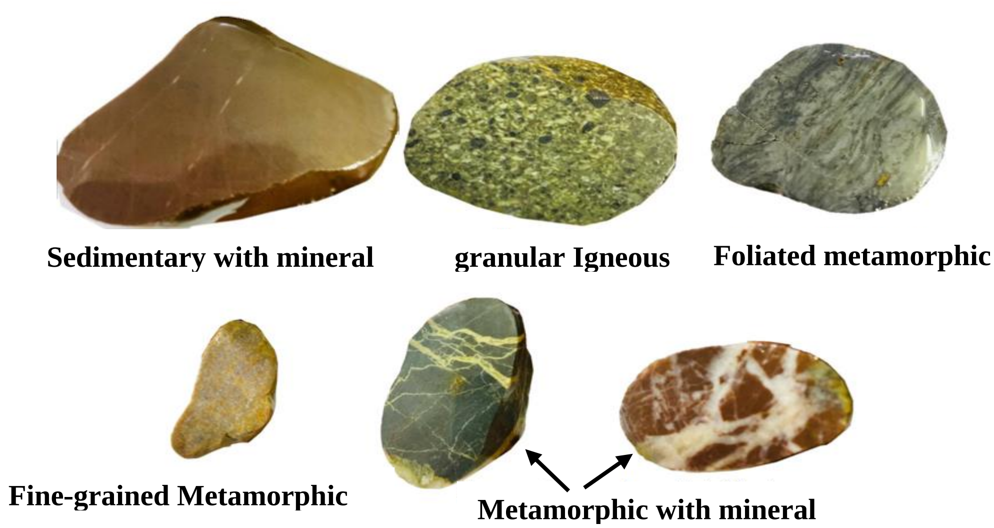

Figure 8: The rock pieces in the study area show the types of rocks and their internal texture

- **Heavy Minerals**

Opaque minerals represent an important component of the types of heavy minerals that were diagnosed in the current study and usually constitute more than one third of the heavy part that is examined, and the studied sandy sediments of the Tigris River in northern Iraq are characterized by a higher proportion of unstable minerals such as muscovite, biotite and chlorite (Fig. 9), which constitutes about 30% of the heavy fraction in medium-grained sand, while the rest of the heavy minerals are more abundant in fine-grained size.

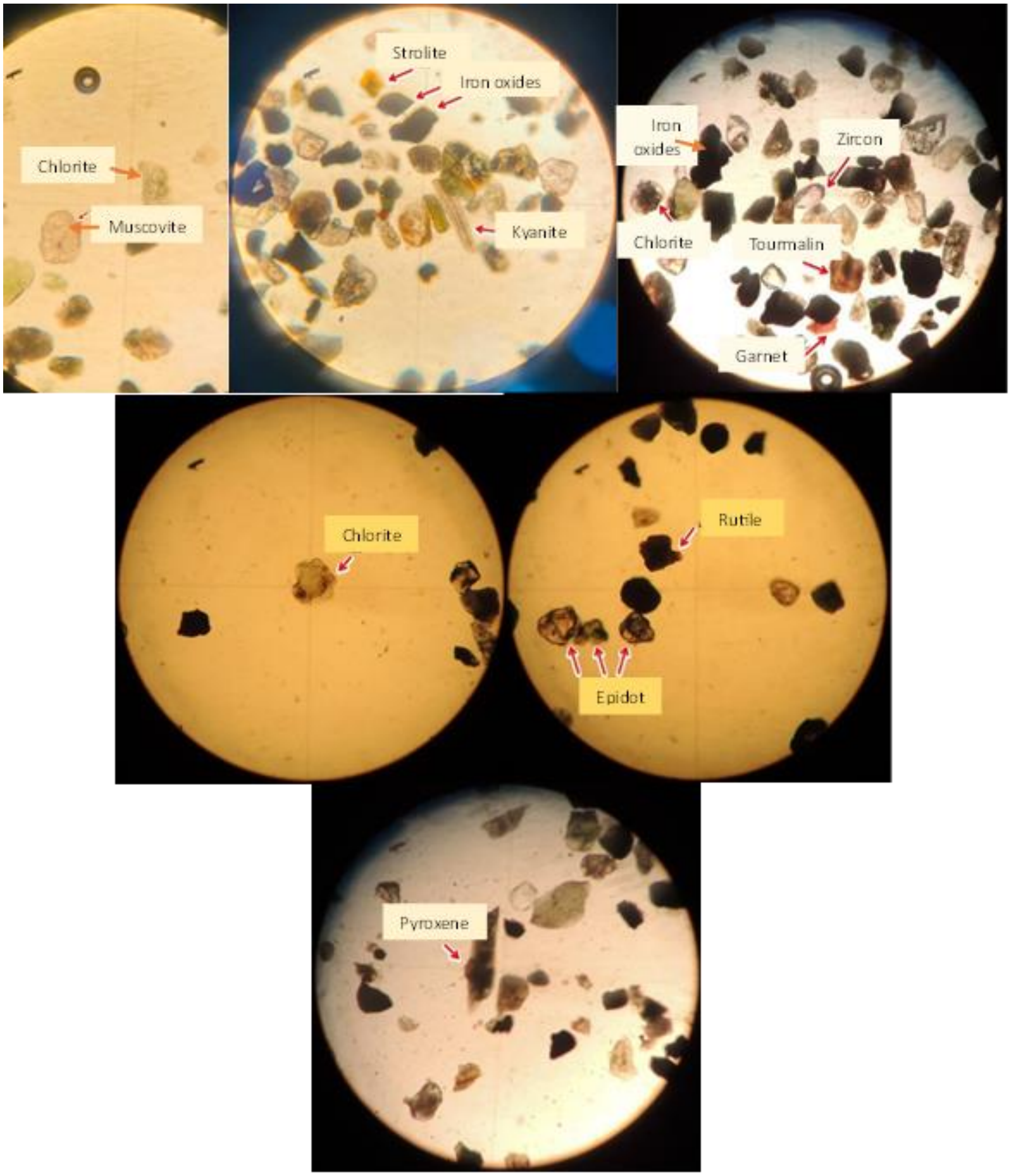

Figure 9: Heavy Minerals in the study area

This enrichment of mica may be due to the sampling method from the meandering part of the river, as unstable minerals may accumulate in pockets or lenses, moreover, the presence of the Mosul Dam reservoir leads to the stabilization of heavy minerals in the lake and this allows the transport of unstable light minerals beyond the lake along the course of the river (Al-Jubury, 2002; Al-Juboury and Ghazal, 2008) (Günre, 1994).Through the mineral aggregates identified in the current study, it is clear that the source of these minerals is from sedimentary, igneous and metamorphic rocks located in the regions of southern Turkey.

5. Conclusions

The current study showed through Sieve analysis and heavy minerals study of nine quarries scattered on both sides of the Tigris River within the borders of Nineveh Governorate that the origin of these deposits is due to different types of igneous, metamorphic and sedimentary rocks located in southern Turkey and not from Iraqi territory, and that the process of replacing these deposits has become impossible After the construction of the Mosul Dam, then, according to the study (Al-Jawadi et al. 2023), the compensation of these sediments takes 80 years, and this is in the absence of the Mosul Dam. Now, with the presence of the dam, the compensation of these sediments has become impossible, and therefore strict laws must be put in place to limit the unjust depletion of these sediments, as they represent a national wealth of high value for the next generations

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