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The Mineralogical Composition of Fine Sand for Selected Soils in Suq Al-Shuyoukh City / Southern Iraq

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Abstract

Suq Al-Shuyoukh is one of the Iraqi alluvial plain areas. Five farms were selected and a total of three samples were taken from each farm at depths of 50, 100, and 150 cm. All samples were subjected to a polarized light microscope to determine the mineral type in fine sand grains and determine the origin and the mechanism of their formation. The results showed two main mineral categories in the fine sand, light, and heavy minerals. The light minerals were Calcite, Quartz, Chert, Gypsum, Anhydrite, and Feldspar, in addition to rock pieces and some fossils. Calcite was dominant. The heavy minerals included the dark minerals (Opaque), Chlorite, Amphibole, Pyroxene,Apidot, Zircon, Muscovite, Garnet, Biotite, Rutile, Tourmaline, in addition to pieces of rocks or fossils, and the dominant mineral was Opaque. Weathering index values for heavy and light minerals ranged between (0.2 - 0.5%) and (4.5 - 9.6%), respectively. The weathering unit index values for light minerals showed an increase in the surface weathering decreased with depth, which indicates the climatic influences mainly. According to the heavy minerals'types and concentration, the proposed source for these minerals is the Arabian Shield due to the volcanic provenance of the parent rocks.

Keywords: *Heavy minerals, Light minerals;,Weathering index, Polarized light microscope, Suq Al-Shuyoukh City.*

1. Introduction

The mineralogical part of the soil consists of particles of different sizes and proportions according to the factors and conditions of soil formation. Because the formation of the grains takes place through the natural fracture and chemical decomposition of large grains as a result of the formation process for the raw materials, it is expected that we will find a difference in the mineralogical and chemical composition of these grains as a result of the difference in their sizes. This will reflect the chemical and physical characteristics of the original substance from which it was formed.

General geological surveys and other investigations of these areas and surrounding lands have been studied by many authors (Al-Shakeri et al., 2017; Al-Janabi et al., 1988; Buday and Jassim, 1987; Shaker, 1986). Most of these studies focused on geological overviews of the study areas, and/or provided descriptions of its provenance, sedimentology, and mineralogy.

Soil consists of three main grain sizes which are sand, silt, and clay. This study focused on the separated sandy part of the studied soil samples, which consists of grains ranging in diameter from 1-0.05 mm. Sand fractions were chosen because their particle properties can be reorganized obviously under polarized microscope more than clay fractions, including shape, size, cleavage, twinning, and color. Sand grains are small pieces of rock (rock fragments) or minerals, which reflect the origin of the parent rock from which these minerals are formed. Sand grains are small pieces of rock (rock fragments) or minerals, which reflect the origin of the parent rock from which these minerals are formed. It is found naturally in different places in the Earth's crust (Dahnoun and Djadouni, 2020). Therefore, from a mineralogical point of view, sand contains primary minerals such as silica, feldspar, and mica , in addition to secondary compounds and minerals that result from chemical weathering processes such as free oxides, especially iron and aluminum oxides. The common minerals in the mineral composition of sand are quartz, feldspar, mica, amphiboles, pyroxene, and other (non-silicate) minerals (Awwad, 1986).

It is also possible to rely on some minerals that are resistant to weathering to study the process of soil development. These minerals are called index minerals. Quartz, zircon, tourmaline, and rutile, which can be found in the clay part of the soil, are the most important of these minerals. The identifying factors of soil components mainly depend on the study of the mineral composition of these soils, which are greatly affected by the processes of weathering and geological erosion, as well as their use as an indicator of soil formation and development through studying the environmental reality of the current and past period (Al-Jubouri, 2014). The separated fine sand has occupied the main importance in this research. It deals with the fine grains of the soil that are enough to determine its optical characteristics.

The aims of this study are

1. studying and determining the physical and optical properties of light and heavy minerals, and
2. determining the probable provenance of the rocks.

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2. Materials and Methods

2.1. Study area

The study area is located in Suq Al-Shuyukh District, 30 km southeast of Nasiriyah City, southern Iraq within Iraqi Mesopotamia (Figure 1).The lands are agricultural and mostly covered by sedimentary plains. These lands are part of the flood plain unit branching from the Great Plain unit of the Iraqi sedimentary plain, which is characterized by its low and flat nature. There are no large slopes and their elevations range from (12-16 m) above sea level (Rahel, 2008).

Five sites were selected within the studied area, depending on agricultural practices and the nature of irrigation. Sites (1) and (3) represent soil that have been exploited for 10 years, irrigated from the Euphrates River, while sites (2), (4), and (5) have not been exploited for a period of 15 years for the purpose of comparison.

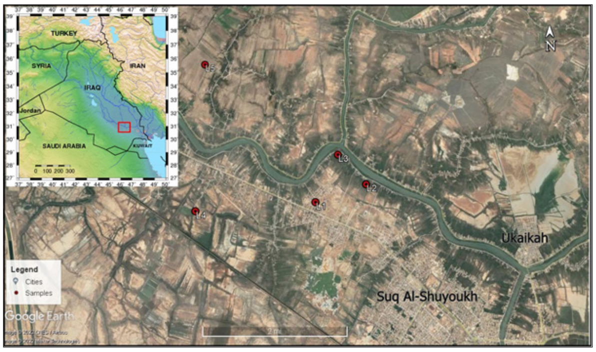

Figure 1. Google maps show the study area, modified from Google Earth

2.2. Soil Sampling

Each site included drill holes by an auger with a depth of 150 cm. Soil samples were obtained for each 50 cm depth for the purpose of conducting mineral analyses. Table 1 shows the coordinates of the five sites with their depths.

Table 1. The locations of the studied soil samples, showing the depth and dry color Munsell code

Sample No.	Depth / cm	Color/ Dry	Coordinates	
			Latitude	Longitude
L1-1	50	10YR6/1	30˚55.519 N	46˚25.568 E
L1-2	100	10YR7/2		
L1-3	150	10YR4/2		
L2-1	50	10YR6/1	30 ˚55.133 N	46˚26.333 E
L2-2	100	10YR7/3		
L2-3	150	10YR5/3		
L3-1	50	10YR5/3	30˚56.138 N	46˚25.931 E
L3-2	100	10YR5/3		
L3-3	150	10YR6/3		
L4-1	50	10YR5/1	30˚55.437 N	46˚23.792 E
L4-2	100	5YR5/3		
L4-3	150	10YR6/3		
L5-1	50	10YR5/3	30˚57.447 N	46˚23.887 E
L5-2	100	10YR6/3		
L5-3	150	10YR7/4		

2.3. Sample Preparation

After the samples were collected from the field, they were dried in the laboratory. It is passed through a sieve with a diameter of 2,000 microns (2 mm), to remove plant residues and unwanted materials. The samples were crushed well—without grinding—by a ceramic mortar in order to preserve the morphological shape of the mineral grains. It was treated with acid, distilled water, and peroxide to remove salts, organic matter, and adhesive materials.

For the purpose of studying the mineral composition through polarizing electron microscopy of fine sand grains separated by sieves, 15 grams were taken from each sample after good mixing (Awwad et al., 2009). Sand, clay, and silt were separated by the dry sifting method through a sieve with a diameter of 62 microns. The fine sand, remaining on the surface of the sieve, was separated and dried by air. Then, they were repeatedly exposed to a current of water for ensuring separating the mineral grains and removing the remaining mud or suspended materials on the surface of the grains, according to the method described by Jackson, (1975).

The remaining sand particles were taken from the previous separation process. The sand particles were divided according to their density into two parts using Bromoform ($CHBr_3$) liquid with a specific weight of 2.80 g. cm^{-3} to separate them into the respective cones. Then, the two parts were dried and placed on glass slides using Arabic glue (Canada balsam) as a preparation medium. After that, the dried parts are covered with thin glass slides. The prepared slides were examined by polarized optical microscope BS-5095TRF model. Based on what was mentioned by Carver (1971), the optical properties of each metal were observed, which were later used in the diagnostic process.

The percentage of the presence of each metal was calculated using the counting method for about 300-350 grains in each slide along straight and parallel lines covering the whole sample. Minerals were diagnosed by the physical properties by polarizing microscope according to Milner (1962) represented by color, form, cleavage, relief and extinction.

3. Results and Discussion

3.1. Light minerals

The results of the process of separating light and heavy minerals from sand particles in the depths of the soils in the study areas showed that light minerals with a specific weight of less than 2.89 form the bulk of the sand particles. These minerals included Quartz, Feldspar, Calcite, Chert, Gypsum, Anhydrite, and rock fragments.

Table 2 shows the percentages of light minerals of the separated sand. Calcite was the dominant mineral in all study sites with a percentage ranging between 42.0 and 45.7%. The results also showed that the vertical distribution of this mineral within the soil depths was not consistent, due to the differences in the geological processes, such as weathering and erosion, as well as the pedogenic processes with increasing depth. The dominance of calcite mineral in the study soil is due to the presence of carbonate-rich formations, such as Dammam, Euphrates, and Nfayil formations, which spread widely in the study area representing the sedimentary rocks (limestone). These sedimentary rocks were subjected to exposure, weathering, and erosion processes that led to its fragmentation, transfer, and deposition within the soils of the study area (Al-Ankaz, 2012). Figure 2 shows the calcite mineralو representing carbonate rocks fragments under a polarizing microscope.

Quartz is considered to be the most resistant mineral to chemical and mechanical weathering factors. Quartz (SiO_2) is ranked in the second place in terms of dominance. Its percentage ranged between (18.2 - 21.2%). The results also showed that the vertical distribution of quartz through the depth horizons of the studied soil locations was not consistent. The dominance of quartz in the study soils is due to the effect of the nature of the soil origin material, which is originally rich in quartz, the main component of the sand. Also, the quartz is characterized by its high resistance to weathering due to the nature of its ionic chemical bonds and the degree of its hardness (Al-Azami, 2006). Figure 2-b shows the Quartz under the microscope. The source of Quartz comes from the deposits of the Debdiba formation in Nasiriyah, which are formed under semi-humid conditions with relatively short dry periods. These climatic conditions played an important role in the dominance of Quartz and reduced the proportion of Feldspar (Al-Khafaji and Al-Najar, 2010).

In third place came the sedimentary mineral Chert (flint stone) (Figure 2-c). This mineral, consisting mainly of Silica, is considered one of the highly weathering resistant minerals. Its percentage ranged between 13.2and17.5%. It has taken a somewhat vertical distribution in the depths of the studied soil locations.

The reason for the presence of this mineral in high proportions in the soil is the result of its presence in the sandstone layers in the formation of Al-Dibbah, which is exposed in areas close to the study area. Likewise, according to Pettijohn (1957), the presence of limestone pieces is attributed to the mineral maturation of sandstone deposited in the Dibdiba formation, which was subjected to the processes of weathering and erosion.

Table 2. The percentages of light minerals in the fine sand particles for the locations of the study area

Location	Depth/ cm	Quartz	Feldspar	Gypsum and Anhydrite	Calcite	Chert	Rock Fragments	Others	Index Weathering*
	%								
Location 1	50	19.9	2.7	10.7	42.0	17.1	6.6	1.0	7.3
	100	20.1	2.4	9.2	43.9	16.5	6.7	1.2	8.3
	150	19.3	3.0	8.9	43.0	17.5	7.2	1.1	6.4
Location 2	50	18.2	3.7	10.6	42.3	17.4	6.3	1.5	4.9
	100	18.2	3.0	10.8	43.2	16.9	6.9	1.0	6.0
	150	20.9	2.4	9.5	42.7	15.9	7.7	1.4	8.7
Location 3	50	19.3	2.0	8.0	45.7	15.7	7.9	1.4	9.6
	100	18.5	3.0	9.9	42.7	16.2	7.9	1.7	6.1
	150	20.2	3.9	10.7	42.6	13.2	5.9	1.5	5.1
Location 4	50	20.1	4.1	8.4	45.7	14.7	6.4	1.6	4.9
	100	21.2	3.4	6.7	44.5	15.4	7.4	1.4	6.2
	150	20.5	3.9	6.4	43.8	16.8	7.2	1.4	5.2
Location 5	50	20.9	3.3	5.8	44.2	16.9	7.4	1.5	6.3
	100	19.6	4.3	6.8	42.5	17.3	7.8	1.7	4.5
	150	19.5	4.1	6.8	43.4	17.5	7.1	1.6	4.7

* The Quartz/Feldspar ratio was adopted as an indication of the light minerals weathering intensity in the study area (Carver, 1971).

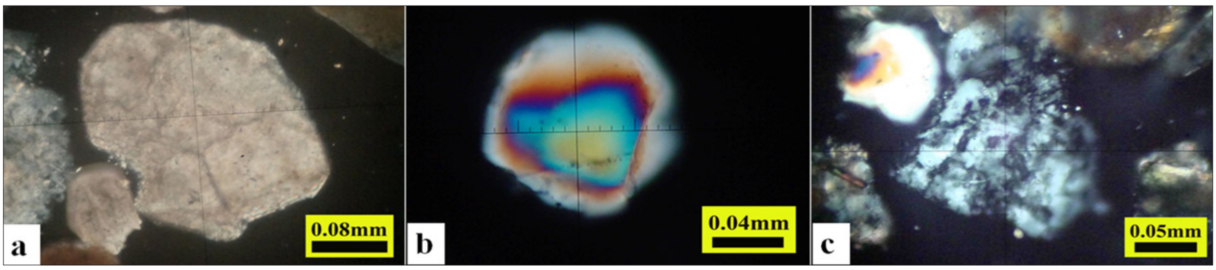

Figure 2. Shows three types of light minerals: a) Calcite (carbonate rock fragment (Limestone), Sample Number L5-2 , b) Quartz, Sample Number L5-2, and c) Chert rock fragment, Sample Number L3-2

Gypsum and Anhydrite came in fourth place. They showed a difference in their distribution pattern with the depth of each location as well as in their percentage which ranged from (5.8 - 10.8%). This vast difference in their percentage is due to the influence of the pedogenic process on these two minerals at different levels, depending on the nature of agricultural practices and the nature of the solubility of both minerals as well as soil materials inherited from the original substance and its mineral composition (Figure 3-a). These two minerals may represent a rearrangement within the soil body, representing a structural and evolutionary stage for the formation of Gypsum horizons, as stated in the study of Al-Azami, 2006.

As for Feldspar minerals, which came in the fifth rank with few percentages compared to other minerals, the percentages of their presence in the study horizons ranged between (2.0 - 4.3%), and their percentage was close in most of the horizons (Figure 3-b). It is one of the minerals that is greatly affected by different weathering processes, as it is affected by the nature of the soil components, the nature of the origin (parent) material, and the severity of weathering. So, we note that its percentages are greatly reduced in some horizons. The reason of this reduction is due to the ease of chemical weathering and transformation into clay minerals such as Kaolinite and Illite (Tucker, 1985) according to its low presence in the studied samples. This result indicates the mineral's transmission over short distances and the speed of its chemical weathering, and this is due to the presence of Feldspar minerals in the sandy sediments of the formation of Al-Dibbeh in the Nasiriyah region (Al-Khafaji and Al-Najar, 2010). Feldspar is more abundant in metamorphic and igneous rocks than in sedimentary rocks, and its presence in sandstones is generally very beneficial (Pettijohn et al., 1987).

Table 2 also shows the rock fragments' percentages that ranged between (5.9 - 7.9%). They are limestone sedimentary, clay, and silica rock pieces. As for their shapes under the microscope, they were in different shapes from round to angular shape. Most of them were covered with clay materials or iron oxides, and their distribution pattern was heterogeneousone within the horizons of the studied locations (Figure 3-c).

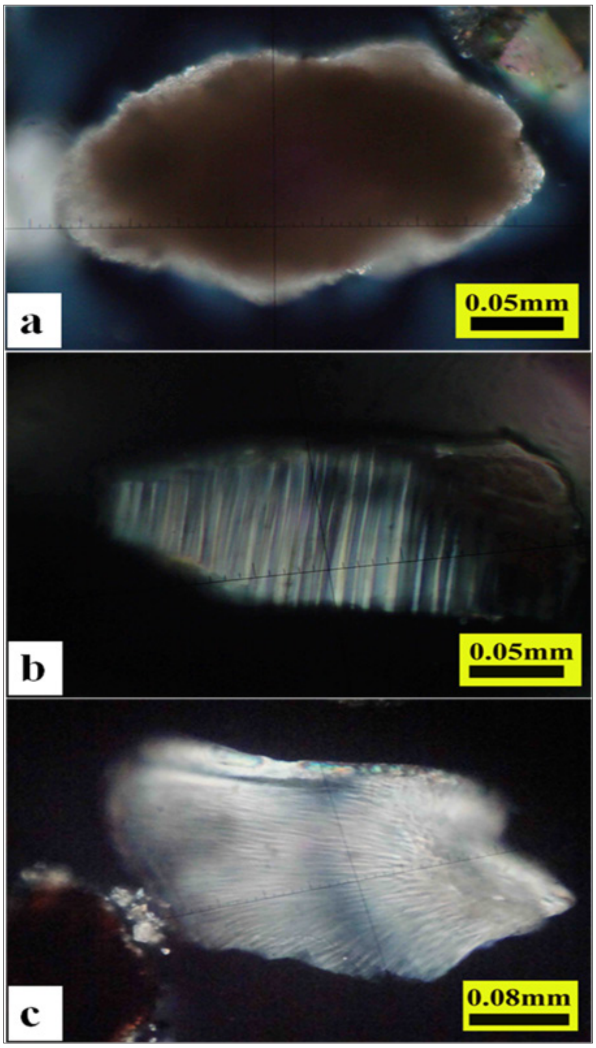

Figure 3. Shows three types of light minerals: a) Secondary Gypsum, Sample Number L3-3, b) Plagioclase Feldspar, Sample Number L2-1, and c) Carbonate Rock Fragment (Shell Fragment) (Aragonite), Sample Number L1-1

Other materials were found in considerable ratios, most of which consist of fossils that spread widely in the sedimentary plain area, in addition to their large spread in the study area, representing marshes and swamps. The proportions of these fossils ranged from (1.0-1.7%) as shown in Figure 4.

To clarify the weathering condition of light minerals, the Quartz / Feldspar mineral ratio was adopted as an indication of the intensity of weathering of light minerals in the study soils (AlKhalil and Essa, 2020). As shown in Table 2, the weathering index values for light metals ranged between 4.5 and 9.6%. The lowest weathering index appeared within the fifth location at the depth of 100-150 cm. While the highest weathering index appeared within the third location of the surface horizon (depth of 0-50 cm). These values indicate the increase in surface weathering and its decrease with depth.

3.2. Heavy Minerals

Heavy minerals generally include Opaque minerals with a high specific weight because of their iron content. They are sometimes black, such as Magnetite, which spreads in igneous rocks (Kerr, 1959), or brown, as in Hematite, which spreads in metamorphic and sedimentary rocks (Bishop and Hamilton, 1974) or yellowish as in Limonite that is produced from the oxidation of ferrous minerals (Kerr, 1959).

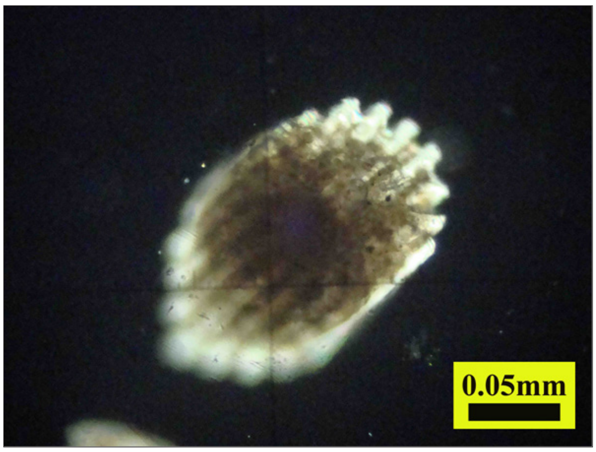

Figure 4. Shows a sample of the fossils (shells) that appear in the study area, Sample Number L4-3

Table 3 shows the values of heavy minerals as percentages of their distribution with depth for fine sand grains separated by sieve. It was noted that it contained large numbers of minerals in the following sequence: the dark minerals, Chlorite, Amphibole, Pyroxene, Apidot, Zircon, Muscovite, Garnet, Biotite, Rutile, and Tourmaline.

Through the values of Table 3, it appears that the dark minerals Opaque Grains represent the largest percentages of heavy minerals in all the depths of the study area, as their percentages ranged (from 46.7 to 50.9%). The reason for the dominance of the Opaque group of minerals over the rest of the minerals is due to the role of the oxide-rich parent material (Figure 5-a). It was shown (Kerr, 1959) that Opaque minerals are found in metamorphic rocks and re-depositioned sedimentary rocks (Al-Jubouri, 2010).

Chlorite is found in metamorphic rocks (Pettijohn, 1975). It comes in second place through its supremacy in the studied locations, where the percentage ranged from (8.9-10.7%). It showed a kind of vertical distribution within the depth of one location, specifically location No. (2), which is graded from 8.9 - 9.2 - 10.0 (Figures 5a-b).

Among the heavy minerals is the presence of Amphibole minerals group represented by Hornblende. It is considered a medium stable mineral and common in igneous and metamorphic rocks (Pettijohn et al., 1972). Its percentage ranged between (6.8 - 7.7%), and it took an irregular pattern and distribution with depth for all study locations, where it increases in the surface horizons and decreases with depth in a location and in the surface horizons. It also shows an increase with depth in other locations. The reason for the difference in its ratio may be attributed to the variation of the original material, the nature of its mineral composition, chronological age, and deposition conditions.

Table 3 also shows the presence of Pyroxene in rates ranging from (6.2-7.4%). In general, the value was linearly homogeneous and convergent for the surface horizons, and heterogeneous vertically. It is considered one of the important mineral groups that make up the Ferromagnetic rocks found in igneous and metamorphic rocks (Murray, 2007). It was shown by (Al-Fatlawi, 2002) that the source of these minerals in Iraqi soils is either intermediate-basic and ultra-basic igneous rocks or acidic rocks.

As shown in Table 3, the presence of Epidote in percentages ranging from (5.2-6.5%). This mineral, as is common among the minerals resistant to weathering, appears in metamorphic rocks. It may be found as an additional mineral in igneous rocks (Figure 5c).

Also, Zircon appeared with a percentage ranging between (3.1 - 5.9%) in all study locations. Its presence didn't indicate any homogeneous distribution. It was present in all locations in different proportions vertically and horizontally, and the source of this mineral is common igneous and metamorphic rocks (Figure 5d).

Muscovite is found in lower percentages ranging between (3.8 - 4.9%) than the previous minerals in all the study locations where it is considered less resistant to weathering. It was noted that Muscovite has a vertical increase with depth in locations (1), (3), and (4). This may be due to the lack of weathering processes with depth, represented by pedogenic processes and climatic conditions.

Garnet is one of the minerals resistant to weathering, but it was found in small percentages in the study locations, which ranged between (3.5 - 5.3%), and perhaps the reason of this scarcity is due to the nature of the origin materials, which contain little of this mineral. Garnet is a common mineral in metamorphic rocks and may be also found in igneous rocks as an additional mineral (Pettijohn, 1975).

Table 3 also shows the Biotite (Figure 6- a) with a value ranging between (3.0 - 4.9%) which showed close values within the surface horizons. As for Rutile, (Figure 6-b), it showed low percentages compared to other minerals, as its percentage ranged between (1.2-2.4%). The reason of the decline is attributed to the source materials, which is the base rock from which these soils came.

Finally, the Table showed the lowest values for all study locations represented by the Tourmaline (Figure 6-c), with values ranging between (1.0 - 1.9%), and the reason for its decline may be attributed to weathering processes or the nature of the original material.

In order to understand the state of weathering within the horizons of the soil for heavy minerals, which have a somewhat higher resistance to weathering than light metals, the ratios of (Zircon + Tourmaline) and that of (Amphibole + Pyroxene) were adopted as an indication of the intensity of heavy minerals weathering in the soils' study (Carver, 1971).

Table 3 shows the weathering index values for heavy minerals. These index values ranged between (0.2 - 0.5%), which are low values compared to light minerals. It was noted that the weathering values for a single location are close, and this explains that these horizons within a single location were subjected to somewhat similar conditions in addition to the similarity of the original material. This is what was observed in locations (4) and (5), as the index values were equal, scoring 0.4% for all horizons of the study locations.

The other locations indicate a rise in the weathering values of the surface horizons or those below them, and this is due to the climatic conditions of heat and rain. As well as the decomposition of plant residues, which encourages microbial activity and thus helps the minerals weather and dissolve into other minerals.

Table 3. The percentages of heavy minerals in the fine sand particles of the study area soils

Locations	Depth/ cm	Opaque	Chlorite	Zircon	Garnet	Pyroxene	Amphibole	Tourmaline	Epidote	Rutile	Biotite	Muscovite	Others	Weathering Index*
		%												
Location 1	50	49.9	9.8	4.5	3.5	6.9	7.0	1.7	5.8	1.7	3.0	4.0	1.8	0.3
	100	48.4	10.7	5.9	3.8	6.8	7.5	1.0	5.2	1.9	3.4	3.8	1.9	0.3
	150	50.9	9.4	4.9	3.9	6.4	7.3	-	6.0	2.0	3.5	3.7	2.0	0.2
Location 2	50	48.6	8.9	3.7	3.7	7.0	7.7	1.4	5.9	2.2	3.8	4.9	2.2	0.3
	100	47.7	9.2	5.1	4.0	7.2	7.5	1.2	6.3	1.8	3.6	4.1	2.3	0.3
	150	49.0	10.0	5.3	4.1	6.8	6.9	1.5	5.5	1.2	3.5	4.2	2.0	0.4
Location 3	50	48.6	8.9	4.8	4.0	6.6	7.1	1.7	5.8	1.6	4.9	4.3	1.7	0.4
	100	47.9	9.7	4.6	4.5	6.9	6.8	1.6	5.5	1.8	4.3	4.5	1.9	0.4
	150	48.0	9.2	5.0	4.8	6.2	6.9	1.4	5.6	1.8	4.6	4.8	1.7	0.4
Location 4	50	47.6	9.4	5.2	5.3	6.0	7.2	1.8	6.5	1.5	3.8	3.9	1.8	0.5
	100	46.7	9.5	4.8	5.1	6.8	7.0	1.9	6.3	1.3	3.9	4.8	1.9	0.5
	150	46.8	9.3	4.4	4.9	6.4	7.5	1.8	6.8	1.7	4.0	4.2	2.2	0.4
Location 5	50	47.3	10.5	4.8	4.3	6.6	6.8	1.8	5.6	2.4	3.5	4.6	1.8	0.4
	100	46.5	9.0	5.2	4.9	7.2	6.9	1.7	6.0	1.8	4.2	4.5	2.1	0.4
	150	47.7	9.2	5.0	4.7	7.4	7.0	1.9	6.2	1.7	4.1	4.1	1.0	0.4

*The ratio of Garnet + Tourmaline / Amphibole + Pyroxene was used as an index to the heavy minerals weathering intensity (Carver, 1971).

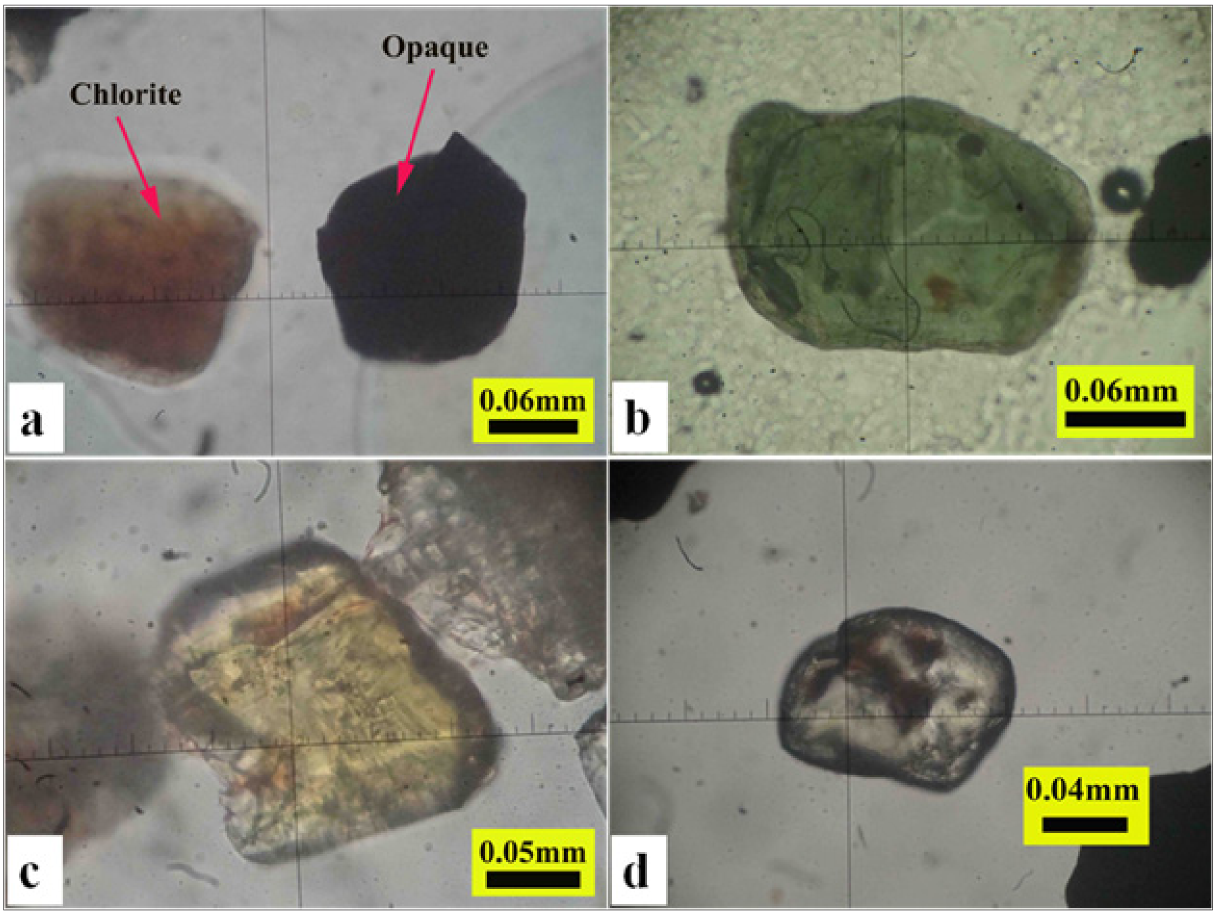

Figure 5. Shows three types of heavy minerals in the study soils a) Chlorite and Opaque Grains, Sample number L5-2, b) Green Chlorite, Sample Number L4-1, c) Epidote, sample number L2-1, and d) Colorless Zircon, Sample Number L3-1

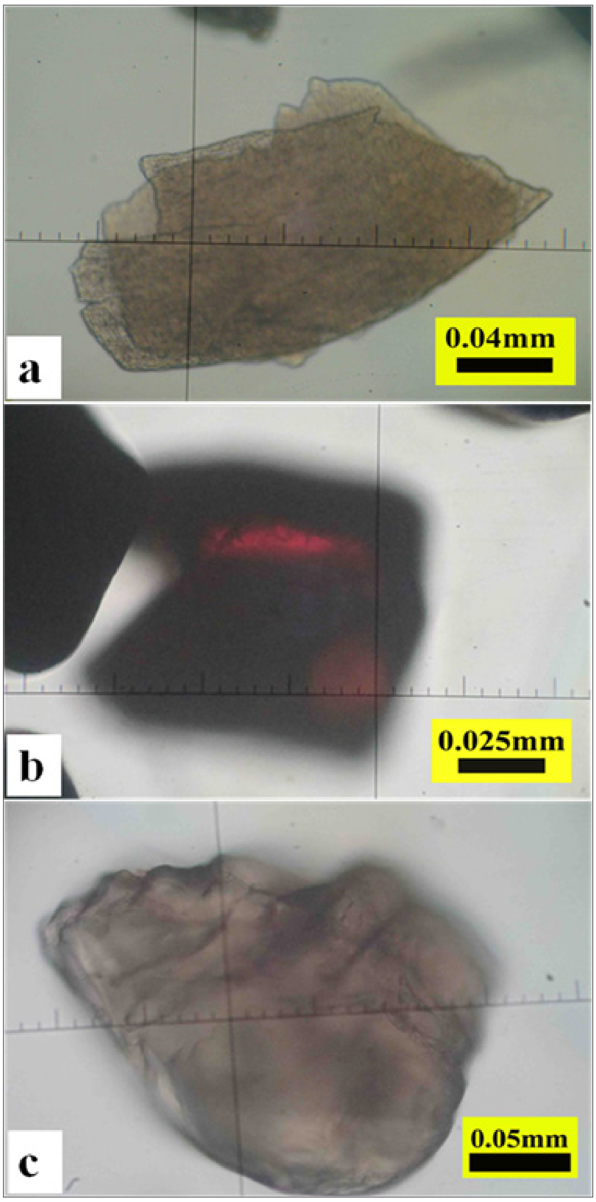

Figure 6. Shows three types of heavy minerals in the study soils: a) Flacky Biotite, Sample Number L2-1, b) Deep Red Rutile, Sample Number L4-1, and c) Tourmaline, Sample Number L1-2

4. Conclusion

Based on the results of this research, it was found that th calcite was dominant in general for all study horizons, as it reached 45.7%. This dominance indicates that the soil-forming material of sedimentary rocks was rich in carbonate. Quartz came in the second place, in dominance, which is one of the most common minerals found in Iraqi soils because of its high resistance to weathering. Weathering values for light minerals showed high values, reaching 9.6%, and this indicates that these soils were subjected to significant weathering, especially in the surface horizons that is due to climatic factors such as heat, wind, and rain.

For the heavy minerals, researchers concluded the dominance of Opaque grains with a ratio of 50.9%, This result indicates that the basic rocks that formed these soils are rocks rich in oxides such as iron and magnesium. Weathering values for heavy minerals were low relative to light minerals, and this finding indicates the severity of weathering to which light metals were exposed in the studied soils.

Based on the types and concentration of heavy minerals present in the studied soil samples, the source of these deposits must be rich in metamorphic and igneous rocks. secondly, it is rich in sedimentary rocks. Therefore, the proposed source for these deposits is the Arabian Shield, in addition to the presence of some sediments transported from sedimentary rocks in the neighboring areas. The high presence of unstable and medium stable heavy minerals, such as Pyroxene and Hornblende, which can indicate the strong influence of transport factors and mechanical weathering compared to the effect of chemical weathering factors, and therefore the most important factor for the transfer of these deposits is wind.

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Conflict of Interests

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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