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# Study of the Variations in the Vertical and Horizontal Distribution of Heavy Sand Minerals in the Hilla River Sediments

Iman A. Hameed[1,2*], Haleema Abdul Jabbar Abdul Rahman[1], Alsaadi Anmar[3]

[1] College of Agriculture Engineering Science, Baghdad University, Baghdad, Iraq
[2] College of Agriculture, Al-Qasim Green University, Babil, Iraq
[3] Ministry of Water Rescores, Baghdad, Iraq
* Corresponding authors e-mail: iyman.aziz1107a@coagri.uobaghdad.edu.iq

**ABSTRACT**

This study was conducted to investigate the effect of the Hilla River sediments on the heterogeneity of the distribution of heavy sand minerals for the fine and very fine sand classes as well as for the surface and subsurface layers. The results showed that the heavy sand minerals that were determined according to the specific gravity of each mineral and the specific gravity of the particles of minerals identified in the soils under study ranged between (2.5–4.5) and were divided into four groups in terms of the specific gravity. The first group included each of the minerals (Mica and Chlorite) of low specific gravity, while the second group contains (Pyroxene, Amphibole, Epidote Group). The third group includes minerals (Tourmaline and Garnet, Staurolite and Kyanite) and the two groups are classified as minerals of medium-specific gravity; in turn, the fourth group contains minerals of high specific gravity, namely (Zircon, Rutile and Opaques). As a result, the most important factors affecting the sedimentation, sorting and sedimentation processes are the conveyor's speed, load capacity, the size of the separation particles and their specific gravity. The complete mismatch of the horizontal distribution of the minerals of one group is due to the varying ranges of the specific gravity of the minerals within the general range of specific gravity.

**Keywords:** sediments, heavy minerals, specific gravity.

## INTRODUCTION

The erosion, transport and sedimentation process impacts the content as well as distribution of soil minerals in general and sand separation in particular with sedimentary soils. Also, these processes and the presence of sediments affect the efficiency of the river flow capacity and are important for determining the hydraulic characteristics of the unsteady flow of the river (Daham and Abed, 2020; Daham, 2021). When studying the content and distribution of sediments and their sources, from places of weathering to sedimentation, mineralogy is used, which is better than the physical properties of sediments, by studying or taking a group of different minerals or a specific group. In some studies, the mineral composition of most sediments is considered (Benedetti et al., 2006; Abu-Zeid et al., 2001; Arribas et al., 2000). Other studies that trace sediment properties from their sources focus on clay minerals (Gingele and De Deckke, 2005; Eberl, 2004). Other studies focused on the sediment content of heavy sand minerals, as in a study by Damiani and Giorgetti (2008). The selection of the appropriate method depends mainly on the particle size distribution of the sediment. Zarraq, (2012) described various minerals found in the sediments of the Tigris River, and among the most important heavy minerals that were identified are Biotite, Hornblende, Zircon, Rutile, Epidote and Muscovite, whereas their most important sources are the igneous and metamorphic rocks located in northern Iraq within the upper Tigris basin or local they are derived from the formations of Fathah and Anjana located on the banks of the Tigris River. Al-Mallah et al., (2016) The results of mineral analysis showed the presence of wide variations in the distribution of heavy metals from different sources, and these minerals showed the same distribution pattern throughout the study area as well as for the surface and subsurface layers.

Alabadi and Essa, (2016) conducted a study to determine the effect of the source of sedimentation on the mineralogical composition of sand; the result showed the low rates of the heavy metal group compared to the light metals group of the sand, with the dominance of opaque minerals followed by Staurolite, Kyanite, Rutile, and Tourmaline. The aim of the study by Al-Ahamary and Agha, (2019) was to determine the mineralogical composition of the lower Diyala River; the sediment was separated into two parts: light and heavy minerals; the heavy minerals contents are opaque minerals, Chlorite, Amphiboles, Pyroxenes, Epidote, Zircon, … etc.

Salman and Issa, (2020) referred to the role of the regulators built on the Al-Gharraf River in the direct impact on the characteristics and characteristics of the soils of the sediments of those areas and their mineral distribution, which was reflected in the variation of those soils.

Lateef et al., (2020) found that the heavy sand minerals of the excellent sand separation of the soils of the Tigris and Euphrates Rivers sediments mainly contained a group of opaque minerals and then followed by a group of Mica minerals, Celestite as well as a group of Epidote and Zircon minerals. Al-husseni et al., (2021) studied the minerals composition of the sediments of Lake Sawa in Al-Muthanna Governorate, southwestern Iraq, and the deposits have unique characteristics of interest to researchers.

Al-Mashhadani and Jassem, (2022) determined the mineral composition of the sand deposited around the Al-Dalmaj Marsh between the governorates of Wasit and Al-Qadisyah in central Iraq consisted of light and heavy sand minerals. Al-Ankaz et al., (2022) conducted a study on the mineral composition and the origin of sediments in the course of the Jabbab River, and sediment samples were taken for the Tigris River before and after the mouth of the course of the Jabbab River. The heavy sand minerals consist of opaque and transparent minerals, as well as unstable minerals. The light and heavy sand minerals reflect their source of metamorphic, igneous rocks.

## MATERIALS AND METHODS

The study area is located physiographically in the central sedimentary plain area within the administrative borders of the province of Babylon, which is characterized by typical terrain resulting from the sedimentation of rivers, ancient and modern water channels and a geographical point of view.

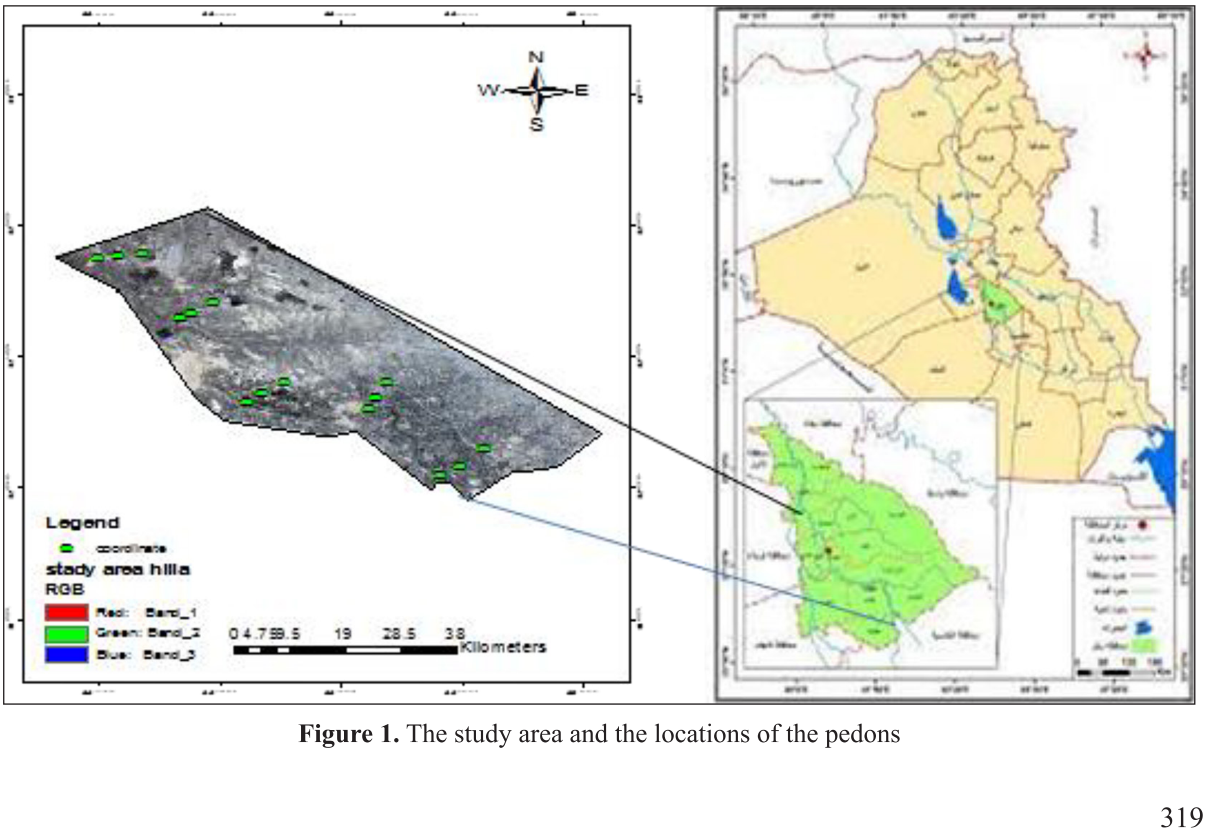


**Figure 1.** The study area and the locations of the pedons

It is located between (44° 40' 17"–44° 31' 34") in the east and latitude (32° 8' 58"–32° 50' 4") in the north. The sampling sites in the study area were selected along the eastern side of the Hilla River, which extends from the beginning of its branching from the Euphrates River at the front of the Hilla dam in the province of Babylon; the river extends southward to the back of the Nazim Sadr al-Daghara, which is located between the provinces of Babylon and Diwaniyah. The pedon sites in the study area were determined based on some aerial photographs and the (Google Earth) program, with fifteen pedons distributed over these sites in five transects perpendicular to the Hilla River. Figure 1 shows the study area and the locations of the pedons.

## LABORATORY PROCEDURES

Samples were selected from the first surface and second subsurface horizons of the soil pedons of the study according to the growth of crops that have a root zone within the surface horizons and some growing trees that have deeper roots that reach the subsurface horizons, and after separating the sand into its various parts by the wet sifting process using sieves. The fine sand was isolated from the very fine sand that will be used to separate the heavy metals from the light ones; the reason for using these two parts of the sand is because of the appropriate size range for the diagnosis under the polarized light microscope, which gives the proper optical characteristics for the process.

The process of analyzing sand minerals takes place in the following steps:

- A weight of 5 grams is taken from the fine and very fine sand fraction for the purpose of separating the heavy metal fraction from the light by means of the heavy liquid bromoform and according to the method proposed by (Folk, 1974; Carver, 1971; Tucker, 1988) using the separation funnel.
- The portion of heavy and light metals is weighed after the end of the separation process to calculate the weight percentage of heavy metals to light metals.
- Then, scattering slides are made using Canada Balsam.
- Minerals are diagnosed, and their percentage determined by the point counting method and according to the method proposed by the scientist (Fleet, 1926).

## RESULTS AND DISCUSSION

After selecting samples from the surface and subsurface horizons of pedons, the soil study was carried out. The sand was separated into different parts, and the fine sand (0.25–0.1) was isolated from the very fine sand (0.1–0.05). Then, separating the sand into its light mineral components from the heavy ones, it was found that the percentage of the light part ranged between 95.4–96.8%, and this is consistent with most of the previous studies of sedimentation, soils affected by the river, while the heavy part ranged from 3.2- to 4.6%. The focus has been on studying the vertical and horizontal distribution of (heavy) sand minerals, the specific gravity of which exceeds 2.89, due to their importance in transport and sedimentation, as well as their great importance in determining the type of mother material for the soil. The minerals of sand and the presence of minerals with high stability under different weathering conditions such as zircon, rutile and tourmaline.

## HORIZANTAL AND VERTICAL DISTRIBUTION OF STUDIED SOIL MINERALS

To study the vertical and horizontal distribution of sedimentary soil minerals, the most critical factors affecting transported sediments are identified, especially those transported by rivers. The soils of the current study are considered among the sedimentary soils in the middle of the Iraqi sedimentary plain, which were formed from the deposits of the Euphrates River. In confirmation of this assumption, it was shown (Sousse, 1945) that the Shatt al-Hilla was the main course of the Euphrates River before the construction of the Indian dam in the year 1913, so the soils of the current study and its origin material are sediments of the Euphrates River.

The current study intended to show the spatial and temporal distribution. On the horizontal and vertical levels of sand minerals of both types, light and heavy, the study of this type of distribution requires first identifying the most important factors affecting the transporting and sorting processes. Then, sedimentation of those sediments was determined so that the results of the distribution study simulated the conditions of sedimentation in the study area. Many studies (Javanbakht et al, 2022; Bowmans, 1994) showed that the most important influences in the processes of transport, sorting and sedimentation include the speed of the conveyor, its load capacity, the size of the particles of separation, and its specific gravity, in addition to what is added to the river of other sediments transported from other than the source. Therefore, the most important of these influencing factors must be determined according to the conditions surrounding the soils of the current study, as the speed and capacity of the carrier are considered equal in each group and for the same size of the separations, two types of separation sizes were studied: very fine sand (0.1–0.05) and fine sand (0.25–0.1). The speed of the stream also has an equal effect on the size of these sediments, and the authors believe that 95% of these sediments come from the source (the mountain ranges in southern Turkish Anatolia), as there is no tributary flowing into the Euphrates River from its source until its confluence with the Tigris River, which could add transferred sediments from other sources.

As for the size of the separations, each size was studied individually in terms of the effect of the speed and capacity of the carrier on it, and in the light of the aforementioned data, the current study adopted the specific gravity of each mineral as a major influence that controls the distribution of heavy and light minerals in the soils of the study. The speed and capacity of the conveyor as well as the sizes of the particles and deposits transported from other sources were considered to have an equal effect on the processes of transport, sorting and sedimentation of these minerals.

**Table 1.** Specific gravity of heavy minerals

| Heavy minerals | Hardness | Specific gravity |
|---|---|---|
| Chlorite | 2.5–2 | 3.3–2.6 |
| Orthopyroxene | 7–5 | 3.5–3.1 |
| Clinipyroxene | 6–5.5 | 3.6–3.2 |
| Hornblende | 6–5 | 3.6–3.0 |
| Glaucophane | 6.5–6 | 3.15–3.0 |
| Actinolite | 6–5 | 3.10–3.0 |
| Biotite | 3–2.5 | 3.3–2.7 |
| Muscovite | 2.5–2 | 3.0–2.76 |
| Clinozoisate | 7–6 | 3.4–3.30 |
| Zoisate | 7–6 | 3.36–3.10 |
| Zircon | 7.5 | 4.7–4.6 |
| Tourmaline | | 3.90–2.82 |
| Rutile | 6.5–6 | 4.30–4.23 |
| Garnet | 7.5–6 | 4.30–3.5 |
| Staurolite | 7.5–7 | 3.83–3.74 |
| Kyanite | 5.0–4.5 | 3.65–3.53 |
| Others | ---- | ---- |

The specific gravity of each mineral identified in the studied soil samples was determined depending on what it came in (Muller, 1997) (Table 1). It is assumed that the carrying capacity of the conveyor is directly proportional to the specific gravity of the mineral and the amount of what is deposited from it (Zhang et al., 2015). Therefore, the quantity or percentage increases. Minerals with high specific gravity occur near the banks of the river when their levels increase during the flood season, and their quantity decreases at far distances from the river. (Thonon et al., 2007) showed that the amount of sediment is directly proportional to the velocity of the water current and inversely to the distance from the banks of the river, and this relationship is controlled by both the size of the sedimented particles and their specific gravity.

In light of the data of Table 1, it appears that the specific gravity of the metal particles identified in the soils under study ranged between (2.5–4.5), as those minerals were divided into four groups in the light of their specific gravity according to Table (2).

The specific gravity of the first group was (2.5–3.0), the second group (3.0–3.5), the third group (3.5– 4.0) the fourth group (4.0–4.5). The first group included all of the minerals (Mica and Chlorite) while the second group included minerals (Pyroxene, Amphibole, Epidote Grop). In turn, the third group included the minerals (Tourmaline, Garnet, staurolite and kyanite), whereas and the fourth group included minerals of high specific gravity, which are (Zircon, Rutile, and Opaques).

**Table 2.** Distribution of heavy minerals according to their specific gravity

| First group | Second group | Third group | Fourth group |
|---|---|---|---|
| 2.5_3.0 | 3.0_3.5 | 3.5_4.0 | 4.0_4.5 |
| Mica and chlorite | Pyroxene, amphibole, epidote grop | Tourmaline and garnet strolite and kaynite | Zircon, rutile, and opaques |
| Low specific gravity | Medium specific gravity | Medium specific gravity | High specific gravity |

The horizontal distribution of the minerals of these groups and for the horizons C1, Ap and both separated by fine and very fine sand was studied. Also, the minerals of the first group were considered minerals of low specific gravity. In contrast, the minerals of the second and third groups were classified as minerals of medium-specific gravity, while the minerals of the fourth group were classified as high specific gravity minerals.

The results of Table 3 and Figure 2 showed that the content of the general horizontal distribution of the minerals of the first group with a specific gravity (3.0–2.5) was low within the surface horizon Ap of the first pedon P1 and then begins to rise towards the third pedon P3 and for all study paths, with some exceptions. The sites where there was a discrepancy in the distribution and deviated from the general path of distribution. This discrepancy may be attributed to several reasons, including the degree of purity of the mineral minute, as the mineral composition may contain some impurities at the time of synthesis that changes the degree of purity of the mineral minute, which in turn is reflected in the specific gravity of the minute. The phenomenon of porosity also affects the mineral composition of the minute, which by increasing leads to a decrease in the specific gravity of the mineral minute, and among other causes is the mechanical bond between the surface of the mineral minute and other soil components such as carbonate

**Table 3.** Mineral distribution of sand separator for the first group with specific gravity (2.5–3.0)

| Mineral distribution of fine sand separator for plowing horizons Ap | | | | | | |
|---|---|---|---|---|---|---|
| Transect | P1 | | P2 | | P3 | |
| | Mica | Chlorite | Mica | Chlorite | Mica | Chlorite |
| T1 | 14.4 | 9.2 | 11.8 | 9.6 | 12.1 | 9.3 |
| T2 | 10.7 | 7.4 | 10.8 | 7.3 | 8.5 | 7.1 |
| T3 | 9.7 | 6.4 | 9.9 | 7.7 | 12.1 | 7.5 |
| T4 | 11.4 | 7.3 | 10.9 | 6.5 | 11.3 | 8.5 |
| T5 | 10.8 | 6.1 | 10.7 | 6.3 | 9.0 | 8.1 |
| Mineral distribution of very fine sand separator for plowing horizons Ap | | | | | | |
| Transect | P1 | | P2 | | P3 | |
| | Mica | Chlorite | Mica | Chlorite | Mica | Chlorite |
| T1 | 12.0 | 8.1 | 12.3 | 7.1 | 9.8 | 7.4 |
| T2 | 10.8 | 6.3 | 10.0 | 8.0 | 9.7 | 9.9 |
| T3 | 9.7 | 7.2 | 9.5 | 8.2 | 7.8 | 9.3 |
| T4 | 9.5 | 8.2 | 11.9 | 9.4 | 8.7 | 7.3 |
| T5 | 8.7 | 9.6 | 11.1 | 7.0 | 9.7 | 7.8 |
| Mineral distribution of fine sand separating subsurface horizons C1 | | | | | | |
| Transect | P1 | | P2 | | P3 | |
| | Mica | Chlorite | Mica | Chlorite | Mica | Chlorite |
| T1 | 11.8 | 9.6 | 12.6 | 9.3 | 9.0 | 7.9 |
| T2 | 9.2 | 8.8 | 10.8 | 9.6 | 8.6 | 7.8 |
| T3 | 8.8 | 6.5 | 11.6 | 7.8 | 7.7 | 6.6 |
| T4 | 9.5 | 6.3 | 8.6 | 6.5 | 9.1 | 6.7 |
| T5 | 8.6 | 6.5 | 10.5 | 5.9 | 8.0 | 9.6 |
| Mineral distribution of very fine sand separating subsurface horizons C1 | | | | | | |
| Transect | P1 | | P2 | | P3 | |
| | Mica | Chlorite | Mica | Chlorite | Mica | Chlorite |
| T1 | 12.3 | 7.5 | 9.8 | 7.2 | 13.0 | 8.2 |
| T2 | 12.1 | 7.9 | 8.4 | 7.4 | 11.5 | 8.5 |
| T3 | 11.4 | 6.3 | 8.8 | 6.3 | 11.0 | 5.1 |
| T4 | 9.4 | 7.2 | 9.4 | 7.5 | 9.9 | 5.3 |
| T5 | 9.3 | 7.6 | 10.5 | 5.9 | 10.0 | 7.0 |

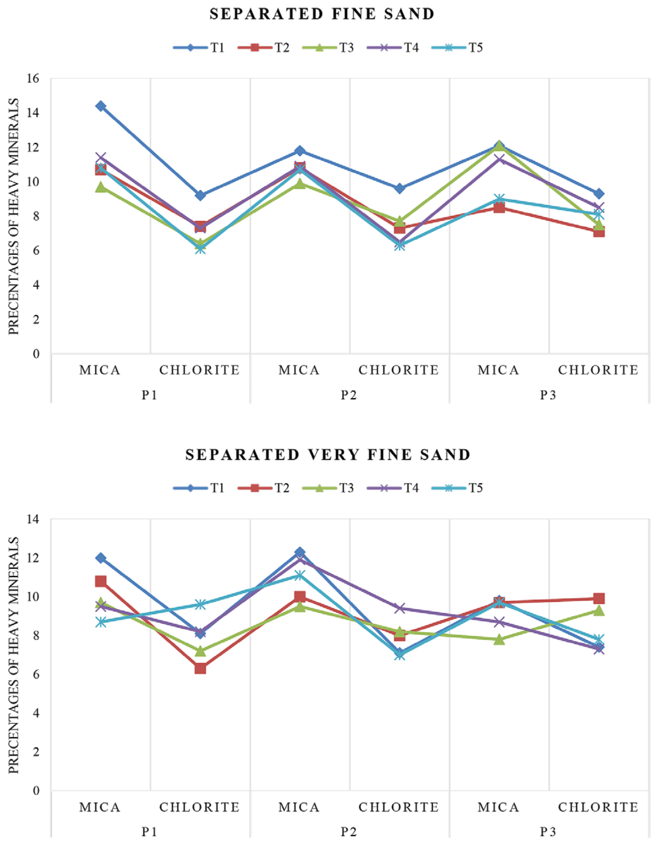


**Figure 2.** Mineral distribution of the sand separator for the first group with a specific gravity (2.5–3.0) plowing horizons Ap

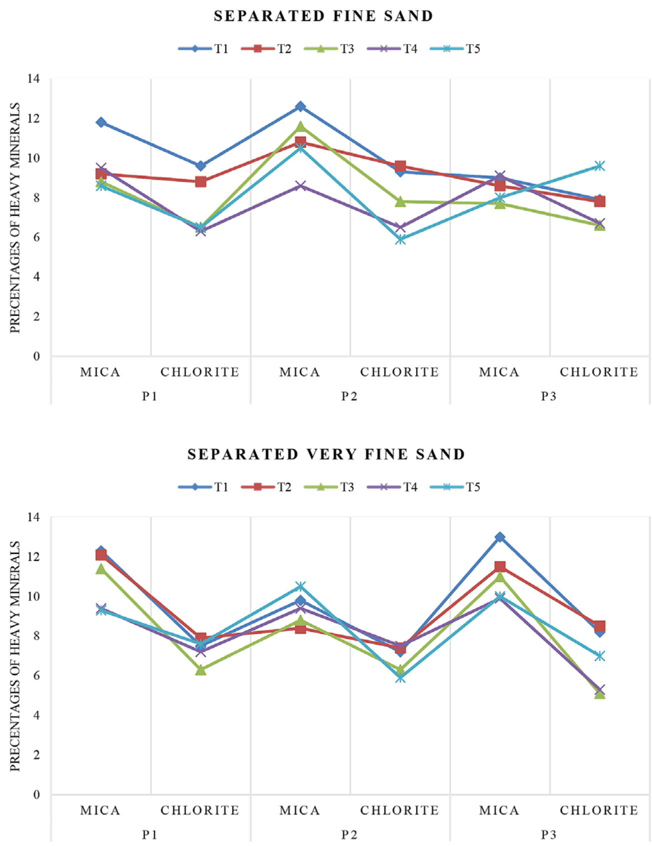


**Figure 3.** Mineral distribution of the sand separator for the first group with a specific gravity (2.5–3.0) subsurface horizons C1

minerals and organic matter, or the encapsulation of free oxides for it, all of these reasons are reflected in their effect on reducing or increasing the actual specific gravity of the mineral fine, and thus affecting the sorting and sedimentation processes.

The results of Table 3 and Figure 3 also showed that there is a discrepancy in the distribution of minerals of the same group, as the distribution of chlorite metal particles appeared identical to the general distribution of the group, which is an increase in the metal content starting from the first pedon P1 and towards the third pedon P3 in the five study paths. The results showed that the mica mineral particles were increasing beginning from the first pedon P1 to reach their peak content at the second pedon P2, then they began to decrease at the third pedon P3 in all study paths. This can be explained by the fact that the specific gravity of mica minerals (3.3–2.76) was somewhat higher than the particles of chlorite, the specific gravity of which ranged between (3.3–2.6).

As for the horizontal distribution of the minerals of the second group (pyroxenes, amphiboles, and the group of Epidote minerals), the result of Table 4 and Figures 4, 5 showed that the distribution of these minerals was increasing within the first and second pedons, then it decreased again in the third pedon in all five study tracks, except for some sites the distribution of which differed from the general distribution of these minerals.

**Table 4.** Mineral distribution of sand separator for the second group with specific gravity (3.0–3.5)

| Mineral distribution of fine sand separator for plowing horizons Ap | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Transect | P1 | | | P2 | | | P3 | | |
| | Ep. | Amp. | Pyro. | Ep. | Amp. | Pyro. | Ep. | Amp. | Pyro. |
| T1 | 5.5 | 11.0 | 7.8 | 6.5 | 10.1 | 7.7 | 5.9 | 9.8 | 7.8 |
| T2 | 4.7 | 9.2 | 7.7 | 6.5 | 9.9 | 7.1 | 6.2 | 8.2 | 8.1 |
| T3 | 5.1 | 8.8 | 7.7 | 6.8 | 7.8 | 7.4 | 5.9 | 7.8 | 7.8 |
| T4 | 5.5 | 8.0 | 5.8 | 6.8 | 8.8 | 7.7 | 5.5 | 10.1 | 5.8 |
| T5 | 5.5 | 10.3 | 5.8 | 6.7 | 7.0 | 7.1 | 5.9 | 6.8 | 7.9 |
| Mineral distribution of very fine sand separator for plowing horizons Ap | | | | | | | | | |
| Transect | P1 | | | P2 | | | P3 | | |
| | Ep | Amp. | Pyro. | Ep. | Amp. | Pyro. | Ep. | Amp. | Pyro. |
| T1 | 6.3 | 10.0 | 5.4 | 5.1 | 9.9 | 6.1 | 5.5 | 10.8 | 7.1 |
| T2 | 5.7 | 10.1 | 7.1 | 4.7 | 9.1 | 6.4 | 4.3 | 7.8 | 6.7 |
| T3 | 6.7 | 10.3 | 5.3 | 4.5 | 10.1 | 6.5 | 3.5 | 8.8 | 6.7 |
| T4 | 6.2 | 8.1 | 5.4 | 4.7 | 10.3 | 6.4 | 5.9 | 6.5 | 7.4 |
| T5 | 4.5 | 8.6 | 4.7 | 5.3 | 7.9 | 6.4 | 5.6 | 6.7 | 6.5 |
| Mineral distribution of fine sand separating subsurface horizons C1 | | | | | | | | | |
| Transect | P1 | | | P2 | | | P3 | | |
| | Ep | Amp. | Pyro. | Ep. | Amp. | Pyro. | Ep. | Amp. | Pyro. |
| T1 | 5.5 | 10.2 | 7.7 | 4.5 | 9.4 | 8.0 | 8.6 | 10.3 | 7.8 |
| T2 | 5.8 | 10.0 | 5.6 | 4.7 | 8.1 | 8.0 | 6.8 | 10.6 | 7.8 |
| T3 | 5.5 | 10.2 | 7.5 | 5.5 | 7.3 | 7.9 | 8.3 | 9.8 | 6.8 |
| T4 | 5.5 | 10.5 | 7.7 | 6.7 | 8.9 | 8.0 | 6.3 | 10.6 | 7.9 |
| T5 | 5.6 | 8.4 | 5.6 | 4.8 | 9.0 | 7.9 | 8.6 | 9.6 | 7.4 |
| Mineral distribution of very fine sand separating subsurface horizons C1 | | | | | | | | | |
| Transect | P1 | | | P2 | | | P3 | | |
| | Ep. | Amp. | Pyro. | Ep. | Amp. | Pyro. | Ep. | Amp. | Pyro. |
| T1 | 6.5 | 10.3 | 7.4 | 6.2 | 11.1 | 7.3 | 6.4 | 9.5 | 5.5 |
| T2 | 4.3 | 8.6 | 6.8 | 4.6 | 8.3 | 6.9 | 7.0 | 8.8 | 5.4 |
| T3 | 6.8 | 8.4 | 7.0 | 6.4 | 8.1 | 6.8 | 6.4 | 10.3 | 5.9 |
| T4 | 6.4 | 10.4 | 7.4 | 7.1 | 8.2 | 9.3 | 6.7 | 7.1 | 6.0 |
| T5 | 6.5 | 8.3 | 5.6 | 6.6 | 8.1 | 7.4 | 6.9 | 9.3 | 5.9 |

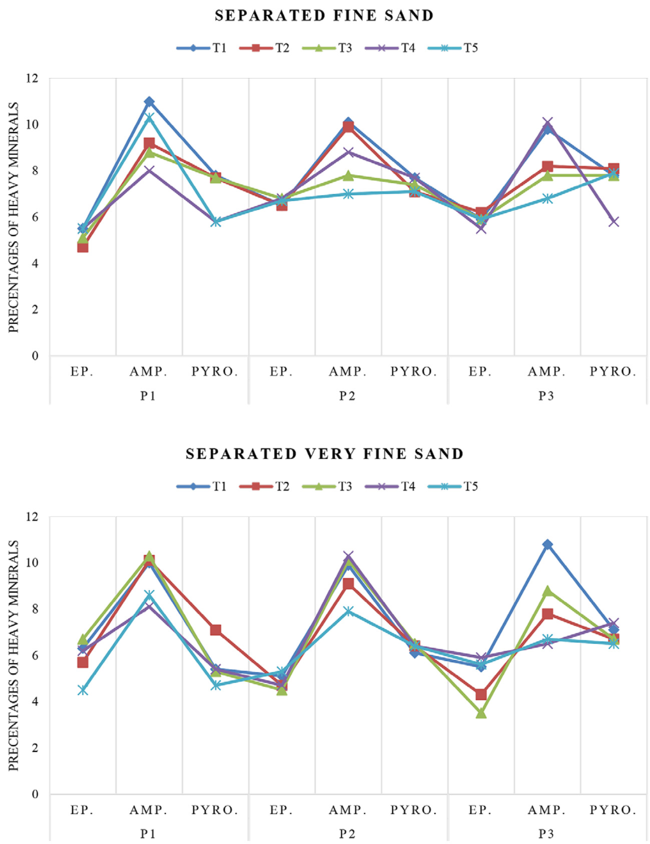


**Figure 4.** Mineral distribution of the sand separator for the second group with a specific gravity (3.0– 3.5) plowing horizons Ap

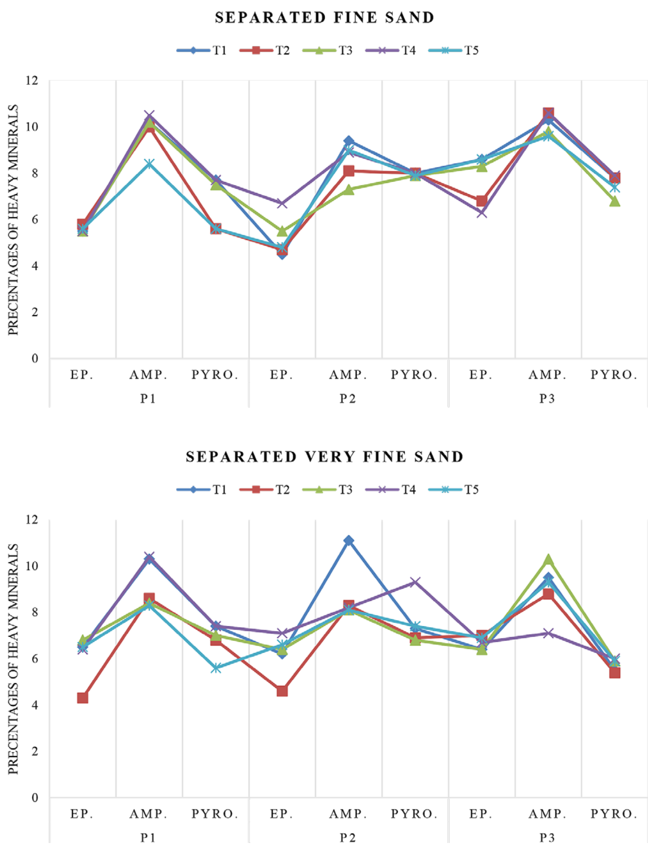


**Figure 5.** Mineral distribution of the sand separator for the second group with a specific gravity (3.0– 3.5) subsurface horizons C1

**Table 5.** Mineral distribution of sand separator for the third group with specific gravity (3.5–4.0)

| Mineral distribution of fine sand separator for plowing horizons Ap | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Transect | P1 | | | | P2 | | | | P3 | | | |
| | Ky. | Sta.. | Gar. | Tour | Ky. | Sta.. | Gar. | Tour | Ky. | Sta.. | Gar. | Tour |
| T1 | 1.5 | 2.1 | 4.5 | 3.5 | 1.5 | 1.4 | 5.1 | 4.4 | 1.8 | 2.4 | 3.7 | 4.2 |
| T2 | 1.8 | 2.4 | 4.7 | 3.3 | 1.8 | 1.1 | 3.3 | 3.2 | 1.4 | 2.2 | 3.4 | 4.5 |
| T3 | 1.3 | 2.4 | 3.3 | 2.7 | 1.4 | 1.5 | 5.3 | 4.5 | 1.8 | 2.4 | 2.7 | 3.2 |
| T4 | 1.3 | 1.1 | 4.5 | 3.5 | 1.7 | 1.5 | 3.2 | 4.3 | 1.7 | 2.6 | 3.5 | 4.2 |
| T5 | 1.9 | 2.2 | 2.4 | 3.9 | 0.5 | 1.4 | 3.6 | 4.7 | 0.8 | 2.7 | 3.5 | 4.2 |
| Mineral distribution of very fine sand separator for plowing horizons Ap | | | | | | | | | | | | |
| Transect | P1 | | | | P2 | | | | P3 | | | |
| | Ky. | Sta.. | Gar. | Tour | Ky. | Sta.. | Gar. | Tour | Ky. | Sta.. | Gar. | Tour |
| T1 | 1.2 | 1.5 | 5.7 | 4.4 | 2.1 | 2.4 | 5.4 | 4.4 | 1.2 | 2.1 | 5.4 | 3.6 |
| T2 | 1.1 | 1.7 | 3.5 | 5.6 | 2.3 | 2.6 | 3.5 | 4.3 | 1.6 | 2.7 | 4.3 | 3.7 |
| T3 | 1.1 | 1.4 | 2.9 | 4.3 | 2.0 | 2.1 | 5.3 | 3.5 | 1.3 | 2.3 | 3.6 | 3.6 |
| T4 | 1.1 | 1.0 | 5.8 | 4.5 | 2.1 | 2.4 | 3.4 | 2.4 | 1.5 | 2.2 | 5.4 | 3.7 |
| T5 | 1.7 | 2.1 | 5.5 | 4.7 | 1.3 | 2.3 | 4.5 | 4.1 | 1.5 | 2.3 | 2.2 | 3.7 |
| Mineral distribution of fine sand separating subsurface horizons C1 | | | | | | | | | | | | |
| Transect | P1 | | | | P2 | | | | P3 | | | |
| | Ky. | Sta.. | Gar. | Tour | Ky. | Sta.. | Gar. | Tour | Ky. | Sta.. | Gar. | Tour |
| T1 | 1.5 | 1.4 | 5.1 | 5.0 | 1.8 | 2.4 | 3.7 | 4.2 | 2.2 | 2.0 | 4.2 | 4.4 |
| T2 | 1.7 | 1.2 | 5.2 | 5.2 | 1.6 | 2.7 | 2.5 | 4.4 | 1.5 | 1.3 | 3.1 | 4.5 |
| T3 | 1.6 | 1.3 | 5.4 | 5.5 | 1.3 | 2.3 | 3.9 | 4.2 | 1.5 | 2.1 | 3.1 | 4.2 |
| T4 | 1.7 | 1.5 | 3.1 | 3.1 | 1.6 | 2.2 | 4.9 | 4.5 | 1.1 | 2.1 | 2.2 | 4.1 |
| T5 | 1.6 | 1.5 | 2.2 | 5.2 | 0.7 | 0.7 | 3.5 | 4.4 | 2.6 | 2.6 | 4.1 | 4.5 |
| Mineral distribution of very fine sand separating subsurface horizons C1 | | | | | | | | | | | | |
| Transect | P1 | | | | P2 | | | | P3 | | | |
| | Ky. | Sta.. | Gar. | Tour | Ky. | Sta.. | Gar. | Tour | Ky. | Sta.. | Gar. | Tour |
| T1 | 1.4 | 1.5 | 4.6 | 4.7 | 1.2 | 2.1 | 5.4 | 3.5 | 2.1 | 1.8 | 4.4 | 5.5 |
| T2 | 1.3 | 1.6 | 2.5 | 4.8 | 1.5 | 2.5 | 4.7 | 3.2 | 2.5 | 1.4 | 2.8 | 3.4 |
| T3 | 1.6 | 1.6 | 4.9 | 4.7 | 1.1 | 2.6 | 4.8 | 3.5 | 2.2 | 1.7 | 4.4 | 5.6 |
| T4 | 1.2 | 1.6 | 4.5 | 2.6 | 0.5 | 2.3 | 4.2 | 3.6 | 2.6 | 1.5 | 4.4 | 4.2 |
| T5 | 1.2 | 0.9 | 3.4 | 4.4 | 1.5 | 2.4 | 3.1 | 3.3 | 2.2 | 1.6 | 3.9 | 5.2 |

The results showed that the general distribution of these minerals was more evident in the larger separations (fine sand), as Zhang et al., 2015 showed that the separation size greatly affects the transport, sorting, and sedimentation processes. Tian et al., 2020, shared this opinion, as they found a logarithmic relationship between particle sizes and mineral content of non-clay mineral particles of river sediments after flooding. Just as the results of Table 5 and Figures 6 and 7 showed, the horizontal distribution of the minerals of the third group (Tourmaline, Garnet, Staurolite, and kyanite) was largely identical to the horizontal distribution of the minerals of the second group, as it was observed that their content increased in the first pedon or the second, then it returns to decrease in the third pedon in the paths of all study areas in general.

The discrepancy in the distribution of these minerals and their non-conformity with the general horizontal distribution of the minerals of the second and third groups is also due to the degree of stability of some minerals. Al-Jubouri and Al-Miamary, (2009) indicated that Pyroxenes, Amphiboles and Garnet are considered unstable heavy minerals, while Staurolite and kyanite minerals were classified as moderately stable, leading to irregular distributions during sorting and sedimentation.

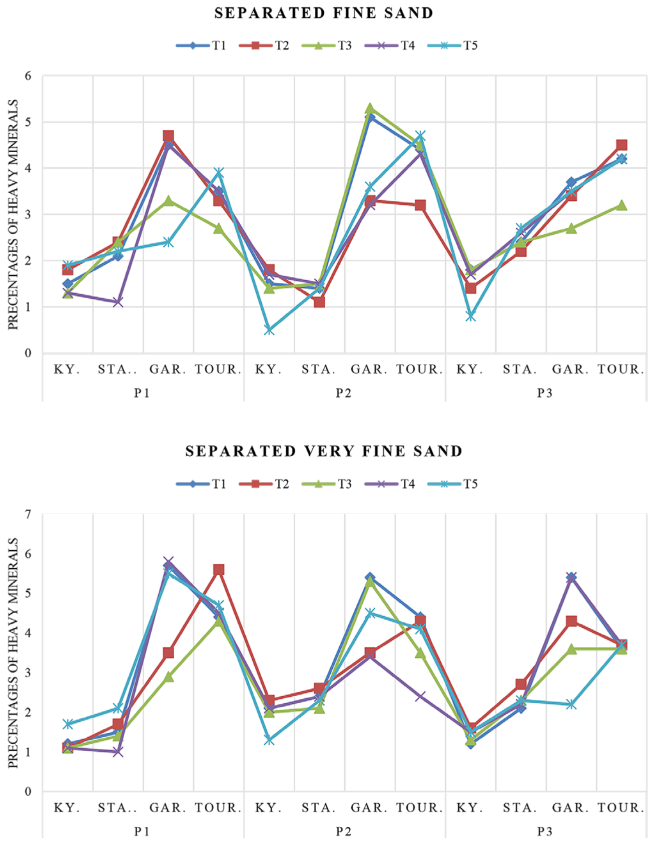


**Figure 6.** Mineral distribution of the sand separator for the third group with a specific gravity (3.5–4.0) plowing horizons Ap

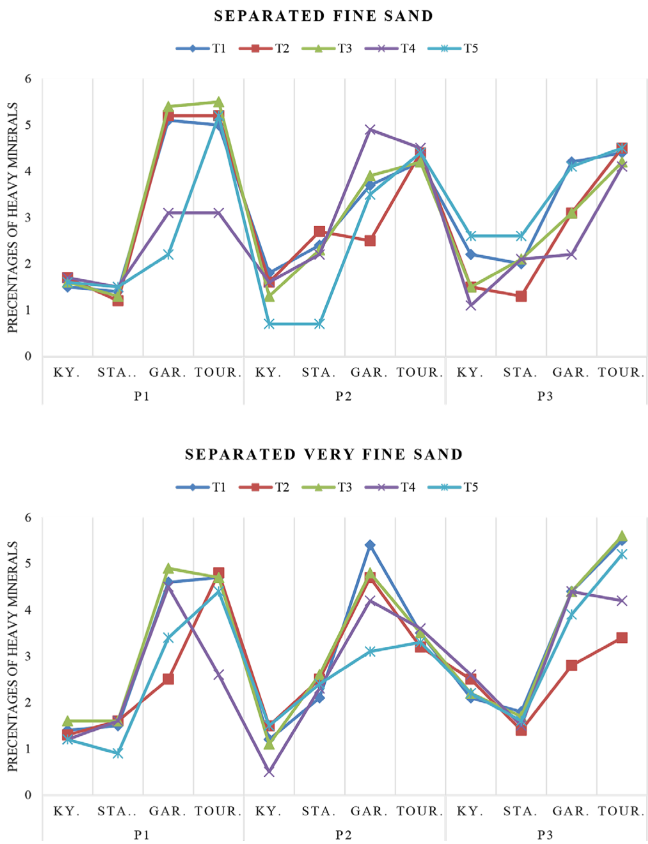


**Figure 7.** Mineral distribution of the sand separator for the third group with a specific gravity (3.5–4.0) subsurface horizons C1

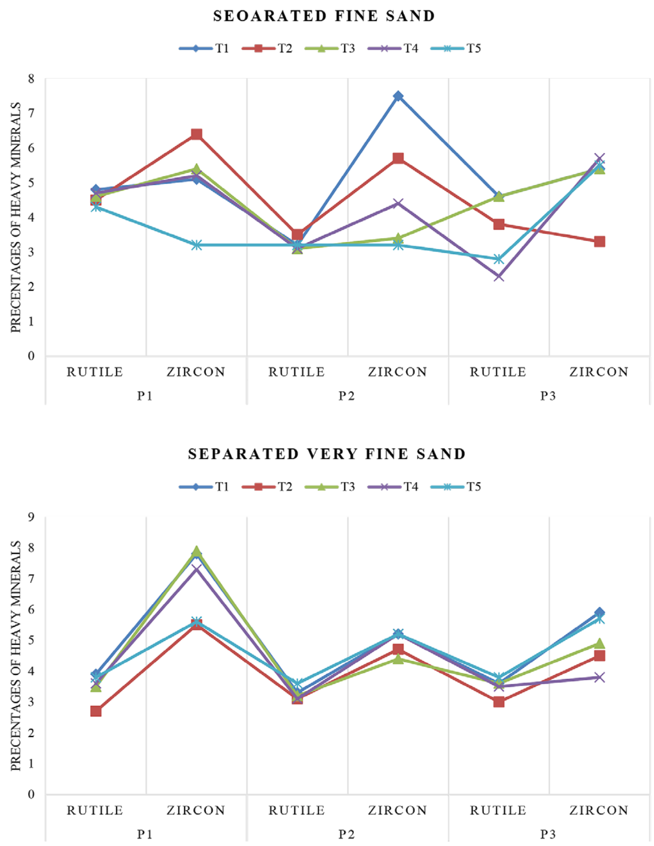


**Figure 8.** Mineral distribution of the sand separator for the fourth group with a specific gravity (4.0– 4.5) plowing horizons Ap

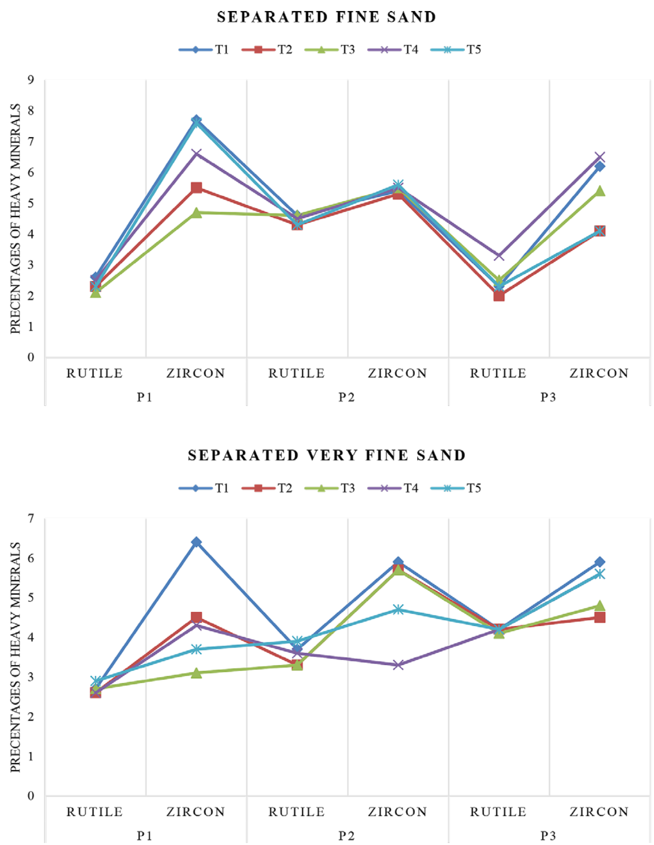


**Figure 9.** Mineral distribution of the sand separator for the fourth group with a specific gravity (4.0– 4.5) subsurface horizons C1

**Table 6.** Mineral distribution of sand separator for the fourth group with specific gravity (4.0–4.5)

| Mineral distribution of fine sand separator for plowing horizons Ap | | | | | | |
|---|---|---|---|---|---|---|
| Transect | P1 | | P2 | | P3 | |
| | Rutile | Zircon | Rutile | Zircon | Rutile | Zircon |
| T1 | 4.8 | 5.1 | 3.2 | 7.5 | 4.6 | 5.4 |
| T2 | 4.5 | 6.4 | 3.5 | 5.7 | 3.8 | 3.3 |
| T3 | 4.6 | 5.4 | 3.1 | 3.4 | 4.6 | 5.4 |
| T4 | 4.7 | 5.2 | 3.1 | 4.4 | 2.3 | 5.7 |
| T5 | 4.3 | 3.2 | 3.2 | 3.2 | 2.8 | 5.5 |
| Mineral distribution of very fine sand separator for plowing horizons Ap | | | | | | |
| Transect | P1 | | P2 | | P3 | |
| | Rutile | Zircon | Rutile | Zircon | Rutile | Zircon |
| T1 | 3.9 | 7.8 | 3.3 | 5.2 | 3.6 | 5.9 |
| T2 | 2.7 | 5.5 | 3.1 | 4.7 | 3.0 | 4.5 |
| T3 | 3.5 | 7.9 | 3.2 | 4.4 | 3.6 | 4.9 |
| T4 | 3.6 | 7.3 | 3.1 | 5.2 | 3.5 | 3.8 |
| T5 | 3.8 | 5.6 | 3.6 | 5.2 | 3.8 | 5.7 |
| Mineral distribution of fine sand separating subsurface horizons C1 | | | | | | |
| Transect | P1 | | P2 | | P3 | |
| | Rutile | Zircon | Rutile | Zircon | Rutile | Zircon |
| T1 | 2.6 | 7.7 | 4.6 | 5.4 | 2.3 | 6.2 |
| T2 | 2.3 | 5.5 | 4.3 | 5.3 | 2.0 | 4.1 |
| T3 | 2.1 | 4.7 | 4.6 | 5.5 | 2.5 | 5.4 |
| T4 | 2.5 | 6.6 | 4.5 | 5.5 | 3.3 | 6.5 |
| T5 | 2.3 | 7.6 | 4.3 | 5.6 | 2.3 | 4.1 |
| Mineral distribution of very fine sand separating subsurface horizons C1 | | | | | | |
| Transect | P1 | | P2 | | P3 | |
| | Rutile | Zircon | Rutile | Zircon | Rutile | Zircon |
| T1 | 2.7 | 6.4 | 3.7 | 5.9 | 4.2 | 5.9 |
| T2 | 2.6 | 4.5 | 3.3 | 5.7 | 4.2 | 4.5 |
| T3 | 2.7 | 3.1 | 3.3 | 5.7 | 4.1 | 4.8 |
| T4 | 2.6 | 4.3 | 3.6 | 3.3 | 4.2 | 5.6 |
| T5 | 2.9 | 3.7 | 3.9 | 4.7 | 4.2 | 5.6 |

The results of Table 6 and Figures 8 and 9 showed the horizontal distribution of the minerals of the fourth group (Zircon, Rutile, and Opaque minerals) with a high specific gravity to the high content of those minerals, generally within the first pedon of the five study area paths. This is expected because they have a high specific gravity; they are separated first during the sorting process for the river load. Many studies indicated that each of the minerals, i.e. Zircon, Rutile, and Opaque minerals are separated and deposited in the upper regions of the river and decrease as the river flows southward due to the high specific gravity that is commensurate with the capacity of the river (Tian et.al, 2020, Al-Juboury and Al-Miamary, 2009). Tables 3 to 6 show the distribution of minerals in the study area horizontally and vertically.

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