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# Sedimentary State of the Middle Sebou Valley, Between Oued Inaouene and Oued Bouchabel (Pri- Rif) - Morocco

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**Abstract:** In this paper, we will study the sedimentary state of the river Sebou, which extends between the Mesopotamia, Inaouene Valley and Bouchabel Valley, which is an area of about 36 km (Figure 1). We will analyze the sedimentary components at the bottom of the oued and the level of the floodplain through the banks of the latter. This area comes directly after the confluence of Oued Sebou with Oued Inaouene, in the area of Hamria in douar Ben Hadan, as it extends to the western borders of the center of Sidi Daoud, downstream of the bridge of Sebou in douar Oulad Ben Hamou, where the Oued Sebou takes a general direction from southeast to northwest. This course draws free river confluences in the floodplain extending to the bottom of the Sebou Valley, which is surrounded by land dominated by clay hills of different heights, and overlooking the valley with long to medium slopes. In our study, we relied on fieldwork, including field observation, identification of sections to be studied and analyzed, determination of the properties of river sediments, including coarse elements and morphometric analysis of the gravel, and we relied on choreographic work to draw crosses. Sections and we worked on the identification of the types of banks and the nature of its sedimentary components, we studied the volume of coarse sedimentary elements, in addition to the study of fine sedimentary materials, including laboratory analysis of micro-sediment grains, and we worked on the morphoscopic analysis of quartz grains.

**Keywords:** Accusative Case, Middle Sebou Valley, Inaouene and Buchable Rivers, Pri- Rif (Morocco)

## 1. Introduction

In this paper, we will study the sedimentary state of the fluvial zone of the oued Sebou, which extends between the Mesopotamia, Inaouene and Bouchabel valleys, which is an area extending for about 36 km (Figure 1), and in this part, free river towers are formed in the flood plain extending at the bottom of the river Sebou.

In this paper, we will first work to study the sedimentary properties of the Sebou valley floor and its floodplain, and then we will follow and define its banks and their sedimentary components. Through this, we seek to diagnose this precipitating state [4, 5, 22, 2, 6, 8, 12, 19, 23, 14, 20, 15, 10, 21, 9, 24, 7, 17, 13, 18, 1, 11, 16], through field, laboratory and chromatographic work.

## 2. Method and Tools

To study and monitor this work, we relied on fieldwork, including field observations to locate cross sections of the floodplain and waterway, as well as to locate cross sections of the sedimentary components, sample the water galaxy and floodplain, and measure the size of the coarse components. For sedimentary materials in the course and floodplain according to the method [16], take photographs to present as evidence of this, and adopt topographic maps to draw cross sections and determine their location.

In addition, we relied on laboratory work to analyze the micro-sedimentary components of the waterway and floodplain, and morphoscopic analysis of quartz grains.

## 3. The Studied Area

The studied area is located northeast of the city of Fez, from the confluence of the Sebou Valley, the Inaouene Valley until its meeting with the Bouchabel Valley, between latitudes 34 degrees and 05 minutes, 34 degrees and 25 minutes north of the equator, and between longitudes 4 degrees and 50 minutes, 5 degrees 20 minutes west of the Greenwich line (maps of Fez East, Fez West, kalaa of Slas, and the village of Ba Mohamed 1/50000).

This area is part of the Pre-Rifaine domain, which joins the Ouazzane bed and the Pre-Rifaine domain, so that its geology is dominated by the character of mud and clay formations [1], but it knows some differences due to its location at the foot of the Middle Atlas Mountains. Therefore, the components of the latter are spread by the white clay dating from the Eocene epoch, on both sides of the stream. While the formations of clay and clay of the time of the Cretaceous dominate, and a little gypsum dating from the time of the terraces, remains the modern quadrant which covers with sedimentary materials all the floodplain of the valley.

The area under study is characterized by a different and varied topography in terms of distribution and regularity, as it consists of morphological units resulting mainly from the intersection of the Miocene hills of a clay formation, which led to the formation of hills with heights ranging from 200 to 500 m, which are unevenly distributed between the east and west sides of the course. This area has an abundant and dense hydrological network, represented by permanent and seasonal wadis, in addition to the presence of dense surface tracks. The vegetation cover is characterized by its weakness, as olive trees and vineyards cover most of the area, in addition to some sidrows, domes, mature plants... etc.

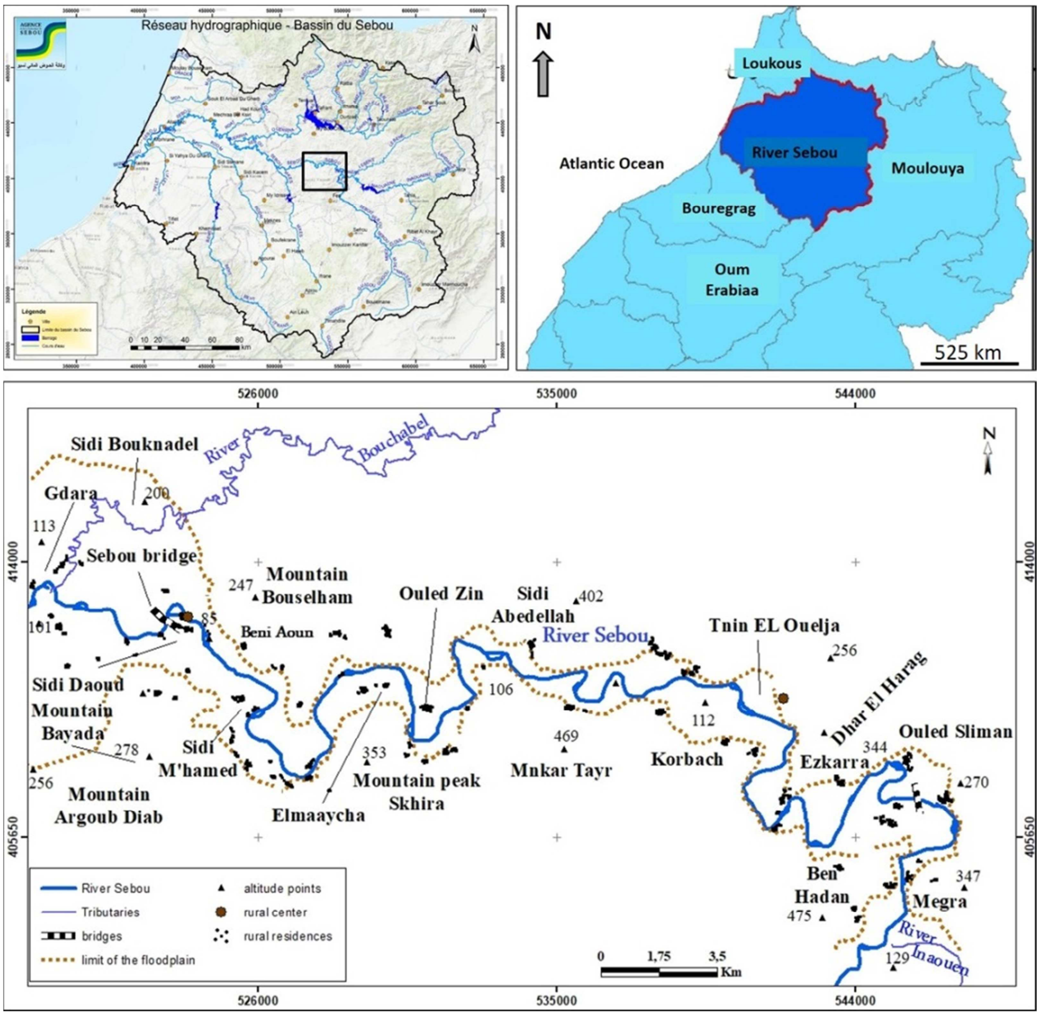



*Figure 1. Location of the study area.*

The inhabitants of the latter have settled since ancient times, but they are constantly increasing, and it is noted that most of the inhabitants who come to the area are from the mountains or hills overlooking the stream. Its population is estimated at about 74,794 individuals (Population and Housing Census 2014, they live in six village centers with a population density of about 91.7 n/km$^2$, which exceeds the national average of rural population, which is 42.10 n/km$^2$.

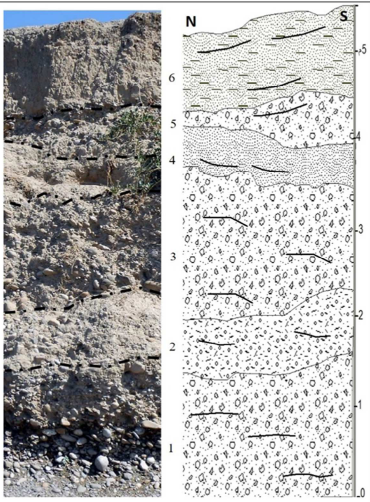
The river Sebou is considered the means of subsistence for these inhabitants and is the place where they carry out their activities, as they exploit it in mourning agriculture on the slopes overlooking the stream or in irrigated agriculture in the floodplain.

# 4. Results and Discussion

## *4.1. Floodplain Sedimentary Formations*

The sedimentary components of the floodplain differ [11, 23, 10, 17, 13, 21, 19], they are formed from materials consisting of the predominance of sand, pebble and gravel at the base of the section and the predominance of clay and silt above (Figure 2). The purpose of the description of the section is to identify the type of coarse and granular materials that make up this piece, and to identify their specificities, while trying to arrive at the state in which the flow was at that time, but before entering into the details of the analysis, we present a preliminary description of the section studied as follows.

The study section is located southwest of the Megra traffic circle on the eastern right bank at coordinates x = 545471786, y = 404503408, z = 125 m, and its sediments are approximately 5.6 m thick and consist of four levels, as shown in Figure 2.




1. **Level 1**: At the bottom of the clip, it is 1.47 m thick, composed of gravel and gravel, bound with sand, clay and silt;
2. **Level 2**: It measures 54 cm thick, made of gravel Sand, clay, silt;
3. **Level 3**: It measures 1.49 meters thick, composed of Gravel and gravel Melted with sand, clay and silt;
4. **Level 4**: It measures 47 cm thick and shaped Light brown sand;
5. **Level 5**: estimated at 61 cm thick, composed of gravel with some sand;
6. **Level 6**: its thickness is about 1.05 m, and it is dark brown level with predominance of clay and silt with presence of sand.

***Figure 2.*** *A section showing the floodplain sediments on the right bank of the river, west of douar Megra in the Ben Hadan area.*

In figure 3 and figure 4, we show the details of the floodplain, which consists mainly of coarse fluvial sediments, consisting of gravel, silt and sand, whose thickness varies generally between 2 and 3 meters, and these coarse deposits cover a fine alluvial deposit between 0.5 and 0.5 m thick on 2 m, it houses a fish of fertile land.

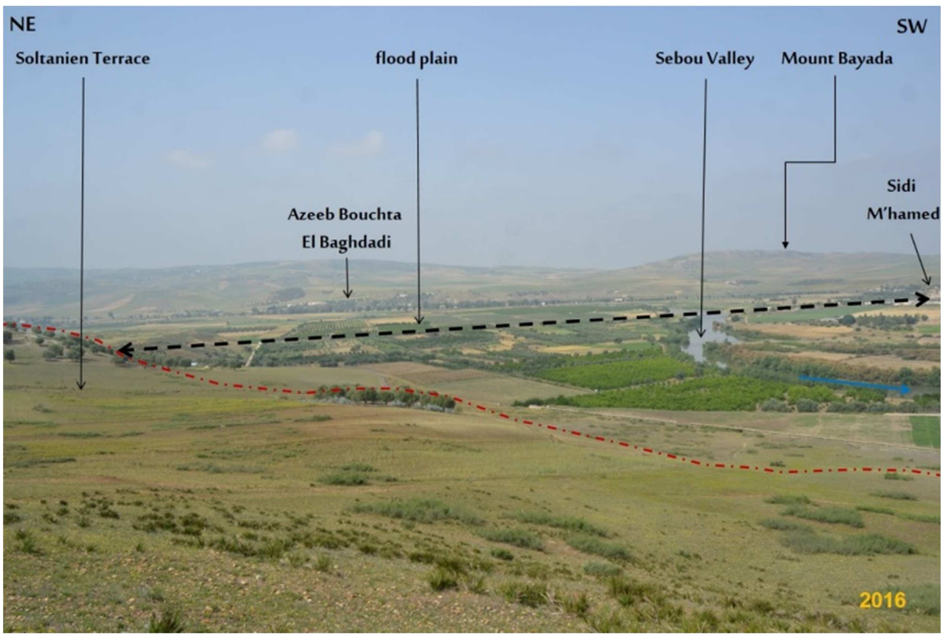



***Figure 3.*** *General view of the bottom of the Sebou valley showing the floodplain in the Sidi Daoud area (seen from the northwest).*

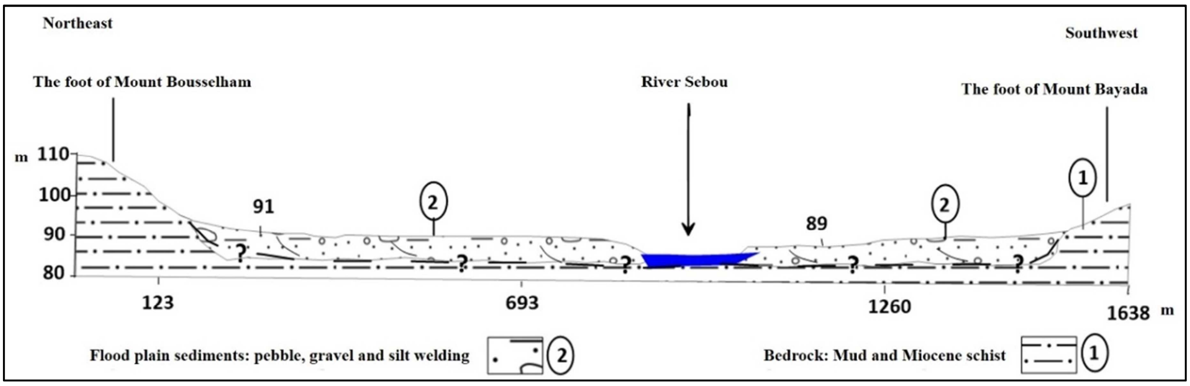



***Figure 4.*** *General cross section showing the sedimentary structure of the floodplain in the Sidi Daoud area.*

### *4.2. Types of Banks and the Nature of Their Sedimentary Components*

The banks in this field are made up of galer, gravel, clay, clay and sand, as some of its components are sand, and some of them have rough gravel components. Therefore, we will study and analyze different patterns of these banks along the studied field in this chapter.

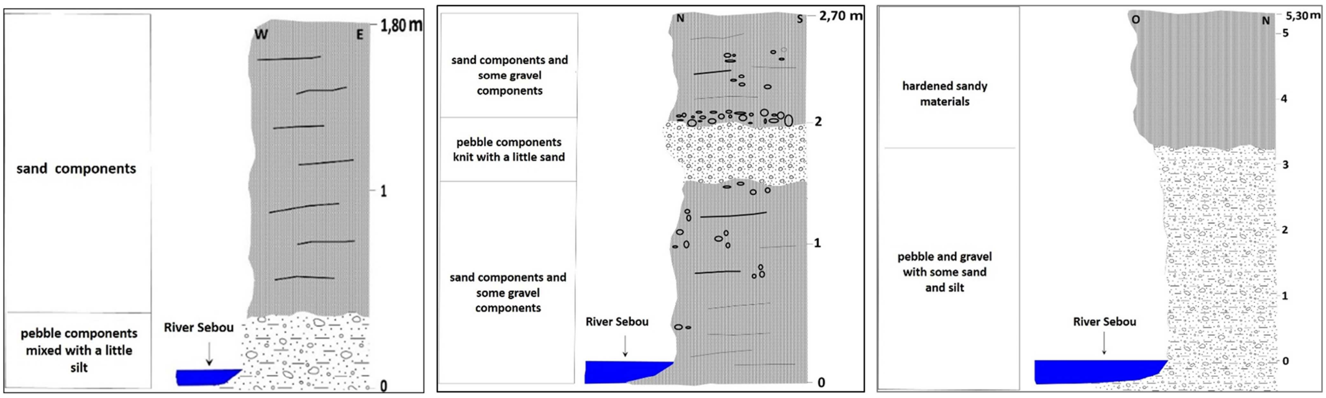
The banks of river Sebou are distinguished in this part by their morphological characteristics, by the height of their ridges and their sedimentary components we present in Figure 4 some examples of bank sections that characterize the study field.

#### *4.2.1. Banks Less Than 2 Meters High*

The example of the southern banks of the douar Sidi Abdullah on the right bank of the stream (x = 542015.377, y = 406539. 974, z = 120 m): this ridge is estimated at about 1.80 m, and its base consists of gravel components mixed with some silt and sand Its thickness is estimated at 30 cm, while the rest of the bank consists of sandy sedimentary formations, and it is also parallel to the water currents, so it is exposed to rapid erosion because it is fragile and non-resistant (Figure 5A).

#### *4.2.2. Banks Between Two and Four Meters in Height*

The example of the southeastern banks of Korbach douar in the right bank (at coordinates x = 541681.642, y = 407725.84, z = 118 m): their height is estimated at 2.70 m where the lower level is made up of fragile sandy materials with a height of about 1, 50 m, surmounted by a level composed of gravel materials welded with a little sand and an average thickness of about 50 cm, while the upper level is made up of sandy materials of a height of about 70 cm, and therefore it is an edge always exposed to the fluvial erosion, because it has fragile components and is located on a bank Parallel to the watercourses, it has a weak vegetation cover (Figure 5B).




A. Simplified section of sediments, right bank, south of douar Sidi Abd Allah

B. Simplified section of right bank sediments, south-east of douar Korbach

C. Simplified section of right bank sediments south of douar Mzab

***Figure 5.*** *Examples of bank sedimentation sections in the Middle Sebou Valley.*

#### *4.2.3. Banks of More Than 4 Meters in Height*

The example of the southern banks of the douar Mzab in the right bank (at coordinates x = 534104.904, y = 410456. 742, z = 105 m), the height of the slope here is estimated at 5.30 m, and it is divided into two parts, the lower part with a layer of materials consisting of gravel and gravel has a thickness of about 3.25 meters, topped by a level consisting of hardened sandy materials to a height of about 2.05 meters, and these materials are buttresses accumulated on the lower layer of river materials.

Water currents strike this bank near the location of the cove, especially when the stream flow exceeds its normal amount, thus subjecting it to lateral erosion and bank collapse, and is characterized by the fact that it is devoid of vegetation (Figure 5C).

### 4.3. Size of Coarse Sedimentary Elements

We studied the sediments in Levels 1 and 3 of the sectional levels, which are primarily coarse limestone-dolomitic materials, and adopted Wolman's classification method ([15]) in our study of the length of the coarse elements that comprise them. Sediments, measuring the size of each element in the sample (Figure 6), and the sizes of the components at two levels differ, as noted above:

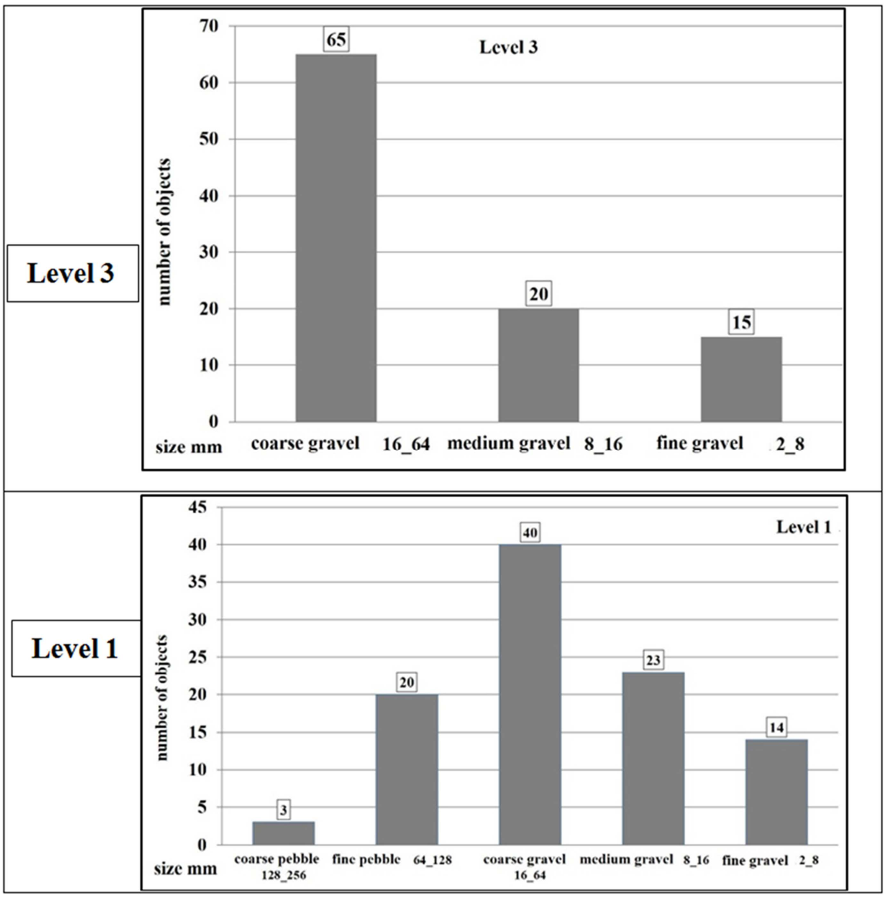



*Figure 6. Results of a study of the size of coarse elements in the floodplain sediments of the Megra section.*

As can be seen in figure 6:

1) Level 1 consists mainly of aggregate components (fine, medium and coarse) at 77%, the largest percentage of coarse aggregate of 40%, while the rest is composed of gravel (flour and coarse) of 23% with a predominance of fine of 20%, with the absence of boulder, which stands out, the sedimentation of these materials took place at a stage where the runoff was relatively strong.
2) Level 3 consists only of fine, medium and coarse gravel deposits, so that the coarse aggregate forms 65%, so it was placed at a stage where the runoff was also relatively strong, but it was lower than its predecessor according to these sediments was.

### 4.4. Study of Fine Sedimentary Materials

We relied on the collection of fine material samples in the field for study in the laboratory, and the study focused on granular analysis and morphoscopic analysis of these materials.

Most quartz grains are formed of three types, which we will know later, and we relied on microscopic observation to know the most important types that characterize our study area, as we will see.

#### 4.4.1. Granulometric Analysis of Micro-sediments

We first isolated sandy materials from fine materials of clay and silt, and we show in Table 1 the results obtained at different levels of the section, so that the proportions of sand vary between 34.5% and 75.52% against 65.5% and 24.48% of clay. Thus, these results confirm the difference and variation of the sediments that make up each level, so that the proportion of sand in levels 1, 2 and 3 is equal to two thirds in levels 1 and exceeds half in levels 1 and 2, except for level 4 where the proportion of clay and silt exceeds the proportion of sand (Table 1).

*Table 1. Proportions of sand, clay, and silt in the samples studied.*

| Level | The percentage of sandy material | The proportion of clay and silt |
|---|---|---|
| 1 | 75,52 | 24,48 |
| 2 | 58,06 | 41,94 |
| 3 | 58,85 | 41,14 |
| 4 | 34,5 | 65,5 |

Then we worked on the particle size analysis of the sand and obtained the results presented in Table 2 and Figure 6, and from these results it was found that coarse sand is available in more proportions in the two levels consisting of coarse materials in the section as follows: 1 with 23.78% and 3 From 21.34%, and this is confirmed by the median values respectively: 0.21 mm in level 1 and 0.12 mm in level 3. If the fine sand prevails in levels 2 and 4, it exceeds 90%, but the median takes in these two levels equal minimum values in second with the third and below them in the fourth is equal to only 0.11 mm.

***Table 2.*** *Results of granular analysis of sand samples with sediments in micro-section.*

| Level | Coarse sand % | Medium sand % | Fine sand % | Median value - mm |
|---|---|---|---|---|
| 1 | 23,78 | 20,32 | 55,90 | 0,21 |
| 2 | 0,52 | 3,22 | 96,26 | 0,12 |
| 3 | 21,34 | 11,63 | 67,04 | 0,12 |
| 4 | 1,58 | 4,01 | 94,35 | 0,11 |

The cumulative curves presented in figure 7 represent these sediments, and they show that the sand curves of coarse levels 1 and 3 are asymmetrical and of poor overall order, while the second is composed of fine levels 2 and 4 well arranged and symmetrical, and this indicates the difference in hydrodynamic conditions during sedimentation: strong flow in relation to levels 1 and 3 and relatively calm in the case of levels 2 and 4. This is also confirmed by the indicators of arrangement and symmetry in these samples, where the following can be concluded:

For coarse levels 1 and 3:

In level 1: the median reaches 0.21 mm, so the order is good according to the TRASK index, which is equal to So = 2.07 because So <2.5, and these deposits are also well arranged according to the INMAN index, being equal to σ° = 0.31, the same according to the FOLK and WARK index which is σ1 = 0.33. The symmetry coefficient according to TRASK is SK = -1.71, so it is an asymmetric and well-ordered distribution towards the coarse sands because SK <1.

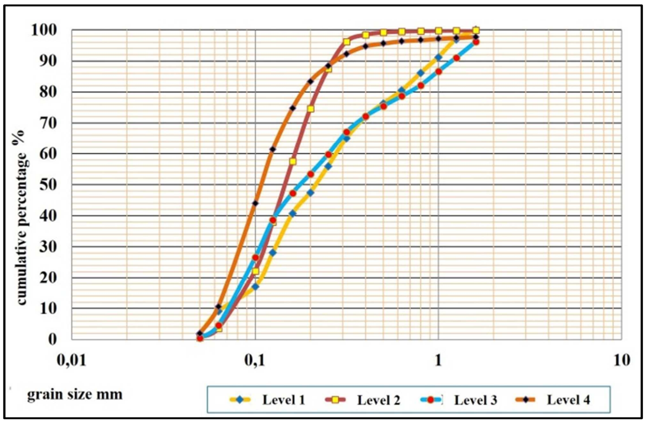



***Figure 7.*** *Cumulative curves of the particle size analysis of fine sediment deposits.*

At level 3: the median is 0.12, and its credits are very well ranked according to TRASK because the ranking index is So = 2.59, and its deposits are isolated and well arranged according to INMAN indices that reach σ° = 0.32 and FOLK and WARK Because its index reaches σ1 = 0.34, the sediments at this level are asymmetrically distributed, but they are of good order for coarse sands because TRASK coefficient stiffens SK = -2.63.

According to Figures 6 and 7 and data analysis of this level, the flow condition during the laying stage of its materials was medium to some strong strength as it deposited various coarse and fine materials.

For specific levels 2 and 4:

At level 2: The median of this level reaches 0.12, so its components are more than fine materials, and what distinguishes it from its predecessor is that its deposits are of good to very good order and insulation according to TRASK indices, given that its rating index is equal to So = 1.26. This is confirmed by the INMAN indicators in which the rate is equal to σ°= 0.06 and FOLK and WARK in which the ranking index reaches σ1= 0.05. As for the symmetry coefficient, it is equal to SK = -0.50 at this level according to TRASK, so its distribution is asymmetric but it is of good order for coarse sands. In addition, this level has no cobble sediments, which indicates that the flow condition was low to medium strength when its materials were laid down.

In level 4: the median of this level is equal to 0.11, and its components are dominated by fine materials that reach a rate of 94.35%, which shows that its materials are very well classified according to the TRASK classification index, which reached So So = 1.22, and its deposits are considered isolated It is very well classified according to INMAN indices as equal to σ°= 0.05 and FOLK and WARK as it is worth σ1 = 0.07. The distribution of its deposits is asymmetrical according to the TRASK symmetry coefficient which is equal to SK = -0.36, and the order of materials is good towards coarse sand.

All these results indicate that the sedimentation occurred in a relatively low runoff, because the precipitated materials are precise in their sizes and because the level is without gravel sediments and contains about 94.35% of fine sand.

***Table 3.*** *Results of microscopic observation and morphoscopic analysis of quartz grains.*

| Type of grain | Level 1 | Level 3 | Level 4 |
|---|---|---|---|
| Unworn kernels % | 18% | 20% | 17% |
| Shiny dull grains % | 42% | 38% | 29% |
| Rounded kernels % | 40% | 42% | 54% |
| Sum | 100% | 100% | 100% |

### *4.4.2. Morphometric Analysis of Quartz Grains*

After the morphoscopic analysis of sand grains, we obtained the data in Table 3, which shows that the state of transport and deposition of these grains makes them different materials in terms of shape, so that the percentage of frictionless granules with sharp parts is 18% in level 1, 20% in level 3 and 17% in level 4 The problem of the lower ratio between the particles, which indicates that the distance of friction and transmission of these materials is short, so they are not exposed to friction. However, the percentage of shiny particles differs from one level to another, as they occupy the highest percentage with 42% in level 1 and second with 38% in level 3 and 29% in level 4, which refers us to that they carried a longer distance than their predecessor and were exposed to more friction than the previous, and this is what appears on their friction and glossy corners. The largest percentage of granulated particles is 42%, in level 3 and 54% in level 4, but they occupy the last rank in level 1 with 40%, so these particles may be inherited from the ancient rocks of the Sebou basin.


***Figure 8.*** *Examples of the types of sediments that prevail in the Sebou Valley.*

## 5. River Sediment Properties

The sediments of the river course differ and vary from place to place. They are mainly composed of coarse material consisting of cobble and gravel and fine material consisting of clay and silt. The types of materials deposited in this section differ slightly from the previous section, and their settling environments differ and vary, and this is what we explain in figure 8, it looks like this:

1) Deposits consisting of gravel, sludge and some coarse sand blocks welded on the side of a convex bank (south of douar Korbach);
2) Coarse sandy deposits resting on the convex bank above the gravel sediments (west of douar Megra);
3) Coarse sediments consisting of pebble and gravel, which were placed on the site of a sill, at the beginning of concave and in the middle of the stream (north of douar Megrah);
4) Fine sediments consisting of sand and silt, deposited on the left side of the stream due to the presence of a vegetative barrier, and after the retreat of the water current (south of douar Haoud El Khinzir).

To assess the size of the coarse sediment elements, we worked on the study of its longitudinal dimension by measuring the gravel elements, and we also worked on the morphometric analysis of the pebbles, in order to control the homogeneity and indicators of coarse flattening in the field, in addition to the granulometric and morphoscopic analysis of sand samples in the laboratory.

### *5.1. Size of Coarse Elements*

Sedimentary elements form gravel materials of different sizes in the stream. They are dominated by the gravel character of its three categories (fine, medium, and coarse), and pebble elements are also found, as shown in Figure 9.

The coarse sediments differ slightly from each other in this area, with the proportion of pebble (fine and coarse) about 26% and the proportion of gravel (fine, medium, and coarse) about 74% with the predominance of coarse gravel, and the vein appears in the length of the 16-64 mm class.

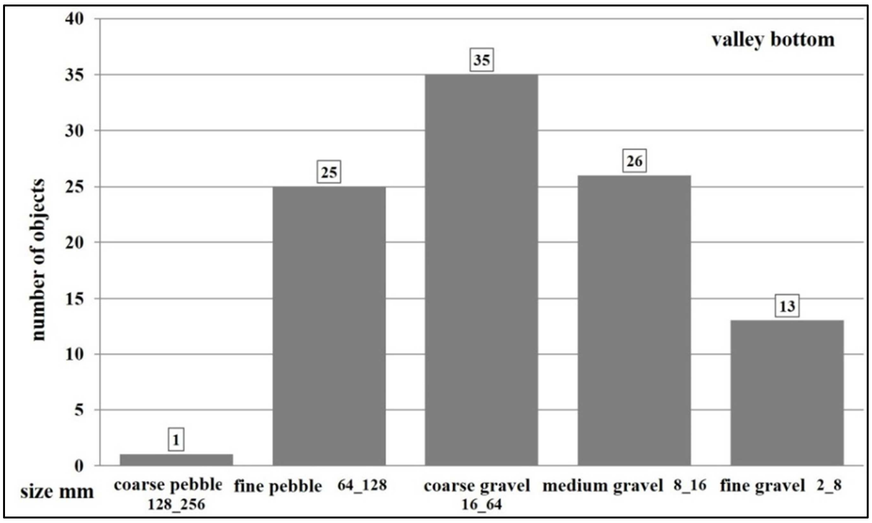



***Figure 9.*** *Results of a study of the size of coarse elements in river sediments, Megra area.*

### *5.2. Morphometric Analysis of the Pebbles*

We calculated the flattening indices (If), blunt indices (IB), and asymmetry (Ia), and approved 100 elements for each sample.

#### *5.2.1. The Kurtosis Index (Ik)*

The index is calculated using the following equation:

$$If=(L+w)/2th$$

So that: (L = length, l = width, th = thickness), then in the case of the gravel is round then: Ia = 1, and the higher this index the further the shape of the gravel is from the roundness, and in general, the flatness index is between 1 and 4 (Figure 10).

This river does not have perfectly round pebbles, but it is dominated by the semi-elliptical to semi-flat group with an index between 2 and 3.98 of 83%, with a decrease of 7% in the category oscillating between 2.00 and 3.00 and an increase of 9% in the category between 3.00 and 3.98, but about 12% of them are semi-round, because their index oscillates between 1.39 and 1.98 while 5% is almost flat because this index is equal to 4.00 Its pattern forms the category that exceeds 3.5, with an average of 0.62, which confirms that it is transported from a place a little distant (Middle Atlas, Upper Oued Sebou or Upper Oued Inaouen) with the same factor.

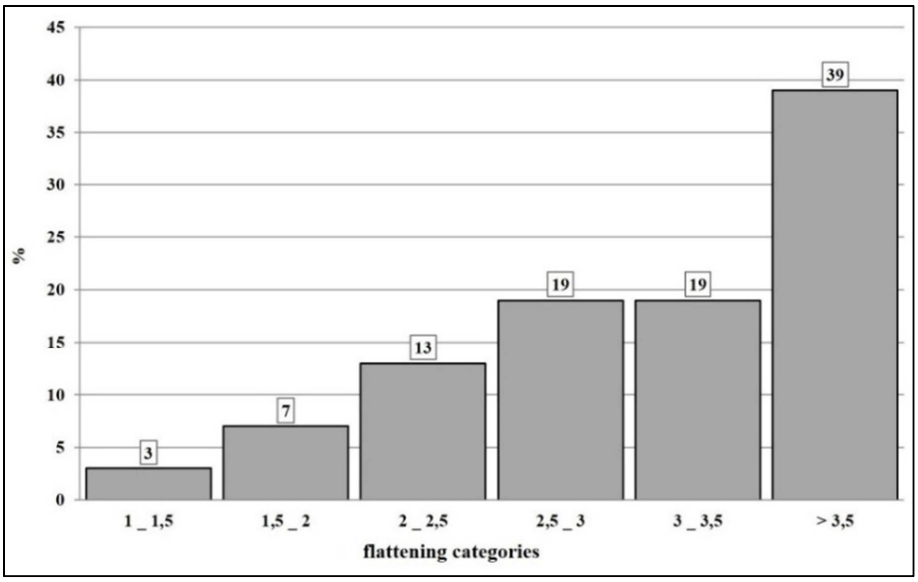



***Figure 10.*** *Percentage of flattening indicator categories.*

#### *5.2.2. The Bluntness Index (IB)*

This indicator is applied to pebbles that appear on their facade to be demolished. To avoid fractional numbers, we calculate the following equation:

$$IB = 2r/L \text{ or } IB= (2r \times 1000)/L$$

r = radius of the smallest circle on the pebble. L = the length of the roller.

In the case where the pebbles are round and the pebbles are too large, then IE = 1, (or 1 x 1000), and the lower this indicator is, the less stones will be destroyed (Figure 11).

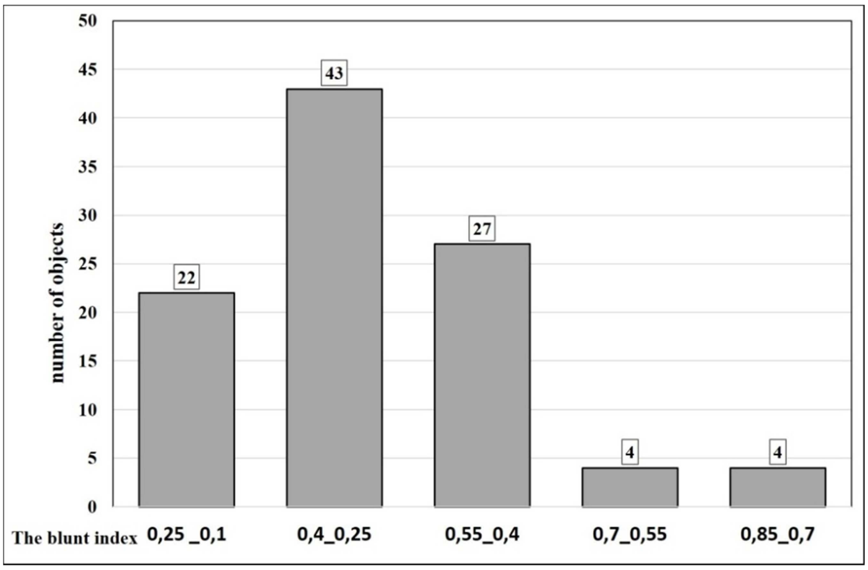



***Figure 11.*** *The sediment bluntness index.*

The index of bluntness in this course is less dispersed, as it did not exceed the limit specified for it 1 (1000), which emphasizes that all the pebbles range from flat to oval, as their index varies between 0.15 and 0.77, with a pattern that oscillates between 0.25 and 0.4, and an average of 0.80, which makes us confirm what we have talked about through the index above.

### *5.2.3. The Index of Dissymmetry (Id)*

This indicator is calculated by applying the following equation:

$$Id= Ac/L \text{ or } Id= (Ac*1000)/L$$

Where Ac: the distance between the highest and furthest point of the rock or pebble, and the higher this index is in Ac> L / 2, the more inhomogeneous the pebble becomes and for the gravel completely rounded, Id = 0.5 Or 500 if we multiply 0.5 by 1000 (Figure 12).

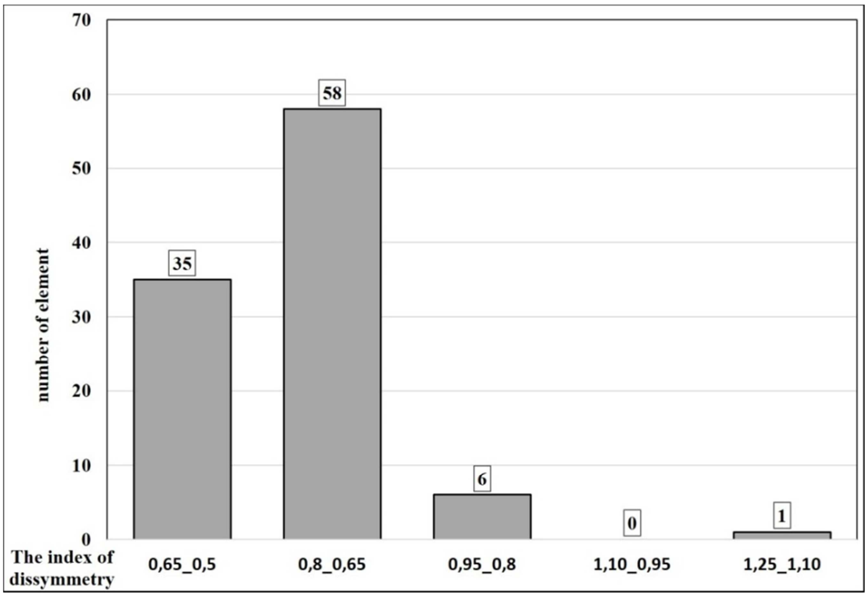



***Figure 12.*** *Homogeneity index of sedimentary materials.*

The coarse sedimentary components (pebble) dance between 0.5 <Id <1.25, all but one exceeding the roundness rate specified in Id = 0.5, with a pattern oscillating between 0.65 and 0.8 with an average of about 0.68 and so it is completely heterogeneous, which forces us to say that it transferred something from a far field in the same way it transported the materials of the first part, and perhaps with an increase in flow power of something from its predecessor as mentioned earlier, and so the transfer and sedimentation and runoff condition we have been talking about causes us to insert the following fine sediments to make sure.

### 5.3. Analysis of Granular River Sediments

We studied a sandy stream sediment sample taken from the bottom of the stream, and after the granular analysis of the sample, we obtained the cumulative graph in Figure 13.

The average material of the sand is 0.21 mm, and it is of good order and medium symmetry according to the shape of the graph, as confirmed by the classification indicators. The data show that the order of its deposits is very good according to TRASK, as the ranking index is equal to So = 2.11, and the isolation and arrangement of materials is very good according to INMAN as it is equal to σ∘= 0.35 and according to FOLK and WARK as it reaches σ1 = 0.35 also.

The symmetry coefficient according to TRASK is equal to SK = -2.14, so the distribution of its sediments is asymmetric but their disposition is good towards coarse sands.

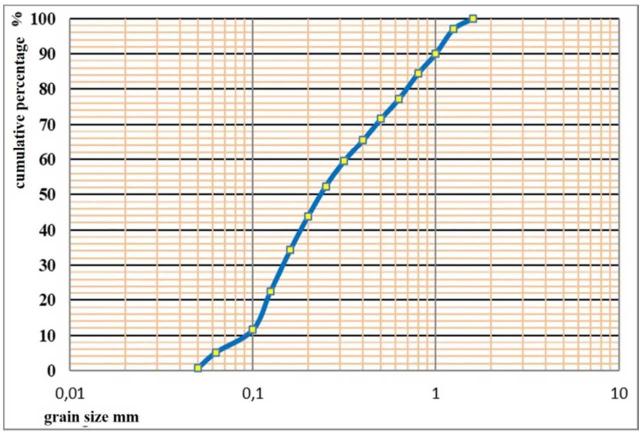



***Figure 13.*** *Example of cumulative curve of the results of the granulometric analysis of sandy sediments at the bottom of the river of oued Sebou northwest of douar Megra.*

### 5.4. Morphoscopic Analysis of Sand Grains

After the morphoscopic analysis of the sand grains, we arrived at the results presented in Table 4, such that round granules are the majority at 46%, followed by blunt shiny granules of 34%, and then granules without rounding with angles of 20%. This indicates that the sandy sediments in the creek are characterized by a mixture of sediments from the upper and adjacent slopes, with the presence of predominantly round grains that may be due to ancient sedimentary legacies (Table 4).

***Table 4.*** *Results of morphoscopic analysis of sand grains at the foot of the course of oued Sebou northwest of douar Megra.*

| | |
|---|---|
| Unworn kernels | 20% |
| Shiny blunt kernels | 34% |
| Rounded kernels | 46% |
| Sum | 100% |

## 6. Conclusion

The floodplain of the study area is mainly made up of coarse fluvial sediments, which are pebbles, rubble and sand, whose thickness generally varies between 2 and 3 meters, and these components differ so that this floodplain is formed of materials consisting of the predominance of sand, pebble and gravel at the base of the section and its predominance clay and silt above.

The proportion of sand in levels 1, 2 and 3 is equal to two thirds in level 1, and it exceeds half in levels 1 and 2, except for level 4 where the proportion of clay and silt exceeds the proportion of sand, and the results obtained indicate that the sedimentation occurred in a state of relatively low runoff, because the materials precipitated are precise in their sizes and because the level is free of gravel sediments and contains about 94.35% of fine sand.

The coarse sediments differ slightly from each other in this area, with the proportion of pebble (fine and coarse) of about 26% and the proportion of gravel (fine, medium and coarse) of about 74% with the predominance of coarse gravel and fine sand sediments of the stream are characterized by a mixture of sediments from the upper and nearby slopes, with the presence of predominantly round grain, perhaps due to ancient sedimentary inheritance.

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