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Recent deposits of dejection cones and of the flood plain of the valley of Middle Beht River (South Rif corridor, Morocco): Sedimentology and environmental study

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Abstract

The watershed of the Beht River is located northwest of Morocco and occupies the southwestern part of the Sebou basin. This study focuses on the sedimentological and physico-chemical analysis of recent deposits of dejection cone and flood plain of the middle Beht River. The results revealed that the sediments exhibit an alkaline pH, low levels of carbonates, low values of the electrical conductivity and relatively high contents of organic matter mostly in the finest sediments. Deposits are organized in grano-decreasing and repetitive elementary sequences much more expressed and fines in the floodplain deposits, which is wider and extensive, than those of alluvial fan. They are the sedimentological expression of the variation of hydrodynamisme related to the succession of flood-receding floods cycles in relation to climate changes. They are set up on the often rocky texture deposits of fund of abandoned channels. The sequence of these elementary sequences, sandy and silty clay at the base and silty-sandy clay on the top, gives larger sequences grano-decreasing.

1. Introduction

The watershed of the Beht River is located North-West of Morocco in the South-West part of the Sebou catchment area (Figure 1). Within the scope of the present work linked to ongoing research on recent alluvial deposits of the Beht River and similarly to methods applied in the fluvial valley of the North slope of the High Moulouya [1, 2, 3], detailed field surveys associated to sedimentological and physico-chemical analyzes of sediments in the laboratory are carried out.

This research work aims to describe the alluviums related essentially to the geodynamical activity of the middle course of the Beht River and to understand the topographical, geomorphological, hydrological and climatic conditions of their deposit. The objective of this study is to show the interest that could provide the fluvial deposits of the dejection cones and the flood plains to highlight the hydrodynamic variations during sedimentation and their geo-environmental significance. The expected results should provide replies to the issue of intensifying the torrentiality of Moroccan rivers during periods of flood and the increase of their actual aggradation rates.

2. Investigation area

2.1 *Geographical and geomorphological context*

The studied section of the middle Beht Valley is circumscribed by a region of middle plateaus. Our area is bounded on the south by the high plateaus of central Morocco and the middle atlasic Causse, the foothills and wrinkles of the Rif Mountains from the North. To the east and west, it shares borders with the Sais plateau of Meknes and the Zemmour–Zair plateau respectively [5] (Figure 2). Before emptying into the El Kansera dam, the Beht River is fed, from upstream to downstream, by numerous rivers: Tigrigra, Ifrane, Boulhany, El Hammam, Berregeline, Ouchket, El Kell and Dkor.

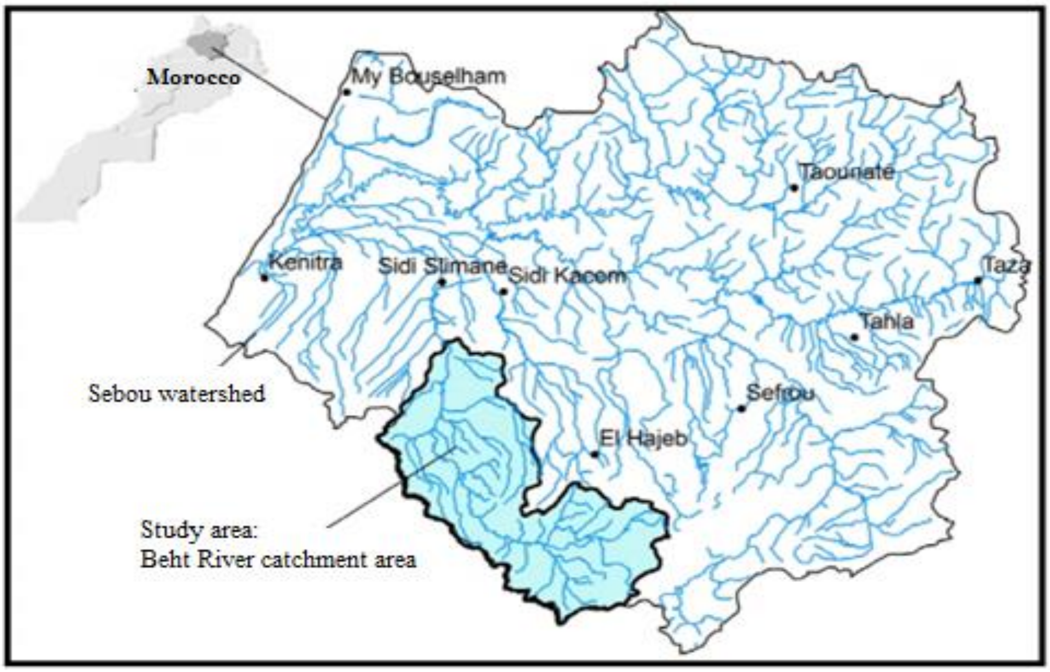

Figure 1: Geographic location of the Beht River catchment area in the Sebou watershed context [4].

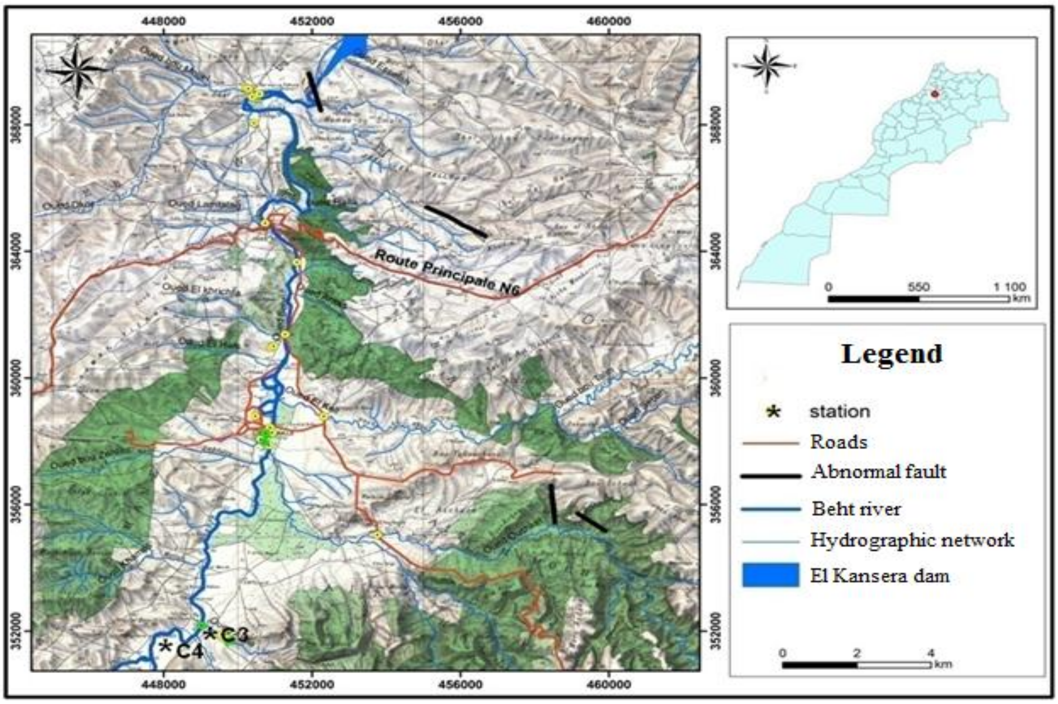

Figure 2: Topographic map of the studied area with location of the sections C3 and C4.

This section is formed by two synclinal depressions separated by an anticlinal dome of tectono-diapiric origin. Former studies [6, 7] revealed the aspects of the modern sediment dynamics and the deposits typology of the different sedimentary units as well as their spatial-temporal changes. The morpho-sedimentary typology of the fluviatile sedimentary environments of the study area, their spatial distribution and development are linked to the morpho-structural conditions along the valley which closely control the determination of the typology of the fluvial styles [6]. Indeed, the most frequent styles are the meandering style with anastomosed tendency and the straight to weakly sinuous style with braid tendency. The first style is developed in the present riverbed where the valley is wide and carved in depressions with synclinal structure and composed of clayey and marshy tender terrains of Triassic and Miocene age. The second style appears when the valley becomes narrow and strongly incised in an anticlinal dome, formed of hard carbonate terrains of Jurassic age [7].

2.2. *Climatic framework*

The watershed of the Beht Oued presents a mediterranean-type climate submitted to oceanic and continental influences from the Atlantic Ocean and the Saharan domain, located respectively in the west and east of the northern part of Morocco. The average annual rainfall does not exceed 700 mm over the entire basin with variations ranging from 400 mm in the deep valley of the high Beht, in the central plateau and 1000 mm in the high humid reliefs of the northern Middle Atlas (Figure 3). The annual and interannual distribution of rainfall shows an important irregularity which has been farther accentuated during the last three decades of which the climatic evolution exhibits an overall tendency marked by an increasingly aridification of the modern climate [4]. The geographic distribution of rainfall depends on several factors, such as latitude, altitude, continentality and slope exposure. Rainfall occurring at high altitudes in the form of snow during the colder months of the year, which generally correspond to January and December, decrease particularly with the latitude which is the main influence parameter when the relief does not complicate the normal general scenario [8]. During the spring, the autumn and even the summer seasons, precipitation often occurs in the form of thunderstorms generating sometimes violent floods which are expressed in the valleys by torrential flows. The prevailing winds are of two types: the "Rharbi", which comes from the West and the North-West, is loaded with moisture coming from the Atlantic Ocean providing atmospheric disturbances generating rain and snow, and the "Chergui", dry and warm, comes from the East and Southeast.

Average annual temperatures range from 15 °C to 19 °C depending on altitude and continentality. Summer temperatures are high. The warmest months are July and August with average maxima of 34 to 36 °C, whereas the coldest months are December, January and February. The mean of the minima is 3 to 7 °C [9]. During the wet and cold season, the daily temperature differences between the nocturnal and diurnal temperatures are high and are expressed by alternating cycles of freezing and thawing.

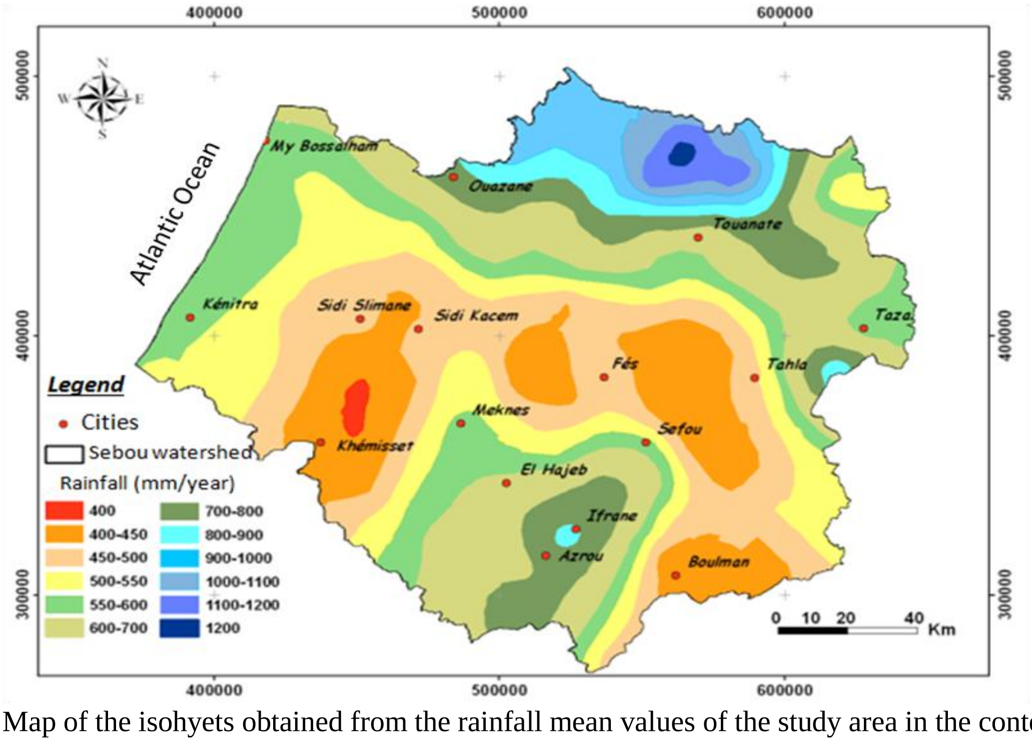

Figure 3: Map of the isohyets obtained from the rainfall mean values of the study area in the context of the Sebou basin for the period 1973-2008 [4].

2.3 *Geological setting*

The watershed consists of terrains spanning in age from the Paleozoic to the Quaternary [10] (Figures 4 and 6). The geological formations of the Paleozoic bedrock are exposed at surface in the Plateau of Central Morocco and are mainly composed of schists, sandstones and quartzites. These terrains, highly tectonized and affected by epizonal metamorphism, are locally capped by superficial formations composed of alluvium and quaternary basalts [11].

In the Middle Atlas, these terrains of the base are overcome, in angular unconformity, by cover lands of Mesozoic age. These are constituted by clays and reddish gypso-saliferous silts with intercalation of doleritic basalts often altered that cover carbonates of liasic age, composed of dolomites, dolomitic limestones, flint bioclastic limestones and marly interlayers. These carbonate, liasic and maritime platform deposits are, locally masked by continental deposits, composed of detrital materials ranging from silt to gravel or conglomerate, and continental carbonate, consisting of travertines and lacustrine limestones of plio- Quaternary age [12, 13, 14].
At the level of the South Rifain trench, the basement and cover lands are submerged under younger formations of upper Miocene and Quaternary age. The Miocene formations have a marine origin, they are formed of gray sandy marls and yellowish bioclastic sandstones. The quaternary superficial formations are composed of detrital deposits, consisting of alluvium, colluvium, spreading cone spreads and scree. According to the morpho-structural conditions, the ancient alluvial deposits of the Middle Ouhed Beht valley take various forms: terraces, cones-terraces and nested glaze-terraces [16,17]. These conditions are manifested by the existence of two large depressions separated by a dome. The depressions correspond to soft material synclines composed of upper Miocene gray sandy marls and reddish Triassic clays and gypsum salts, while the dome is an anticline of tectono-diapiric origin with carbonate and silo-clayey- gypsum-salifer material of Jurassic and Triassic age respectively.

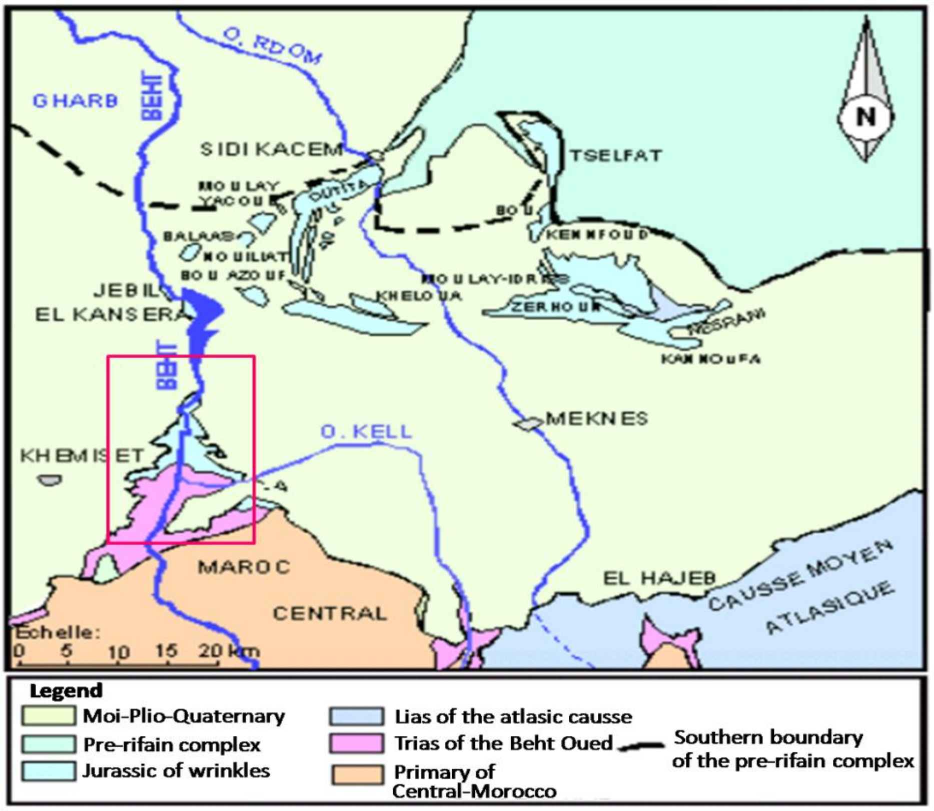

Figure 4: Geological map of the study area [15]. The red rectangle represents the investigated area.

On both sides of the Middle Beht valley, the marine formations of the upper Miocene and even of the lower and middle Pliocene are topped by continental deposits of upper Pliocene-Quaternary age, corresponding to the red formation of the Maamora to the west and to the lacustrine limestones of Sais in the East.
North of the south-Rifain trench, the South-Rifal wrinkles are developed. The westernmost South-Rifal wrinkle, which borders the studied valley towards the North, is represented by two reliefs, Jbel Kansera and Jbel Jebil, elongated N-S and formed of Jurassic terrains separated by a depression with Mio-Pliocene materials [18]. The Jbel El Kansera is formed by Jurassic lands of lower and middle Lias age that are outcropping at the Oued Beht cluse where the El Kansera dam is located. Above these terrains, the Miocene overlies in angular unconformity. From a structural point of view, the el Kansera jbel shows straightened layers, folded and faulted on the western edge, with sub-vertical dip which becomes reversed (Figure 5). In terms of lithology, the Beht watershed consists of relatively impermeable soils which favor runoff and increase losses due to evaporation reaching 1700 mm / year [9].

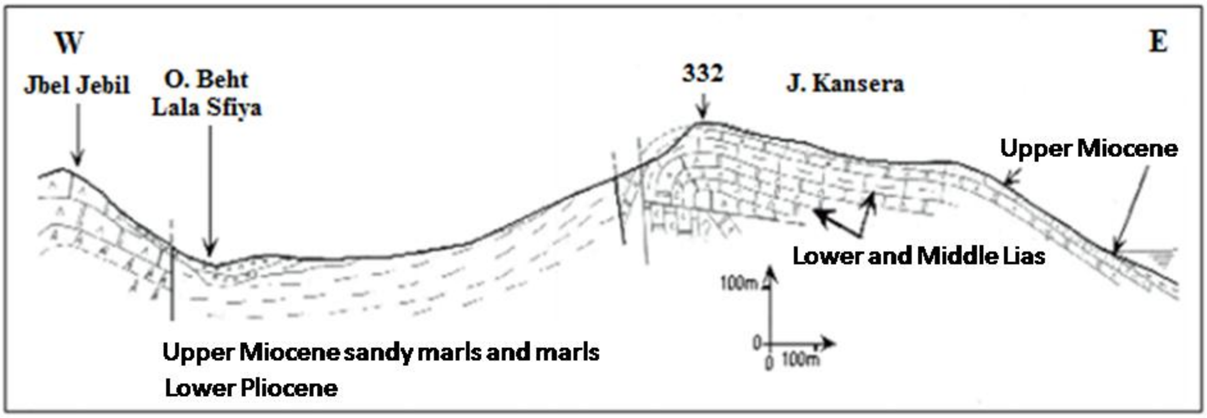

Figure 5: Geological cross-section of Jbel El Kansera [15].

3. Materials and methods

The field of the first synclinal depression (located between the Oued Beht exit of the high plateaus of central Morocco and the western part of the Middle tabular Atlas to the South, and the tectonic-diapiric anticlinal ridge of Oued Beht in the North) was investigated in order to choose the appropriate sections. Two sections C3 and C4 were chosen on the right actual riverbed (Figures 2, 4 and 6) and studied according to the method followed by several authors in the upper Moulouya valley [1, 2, 3 and 4].

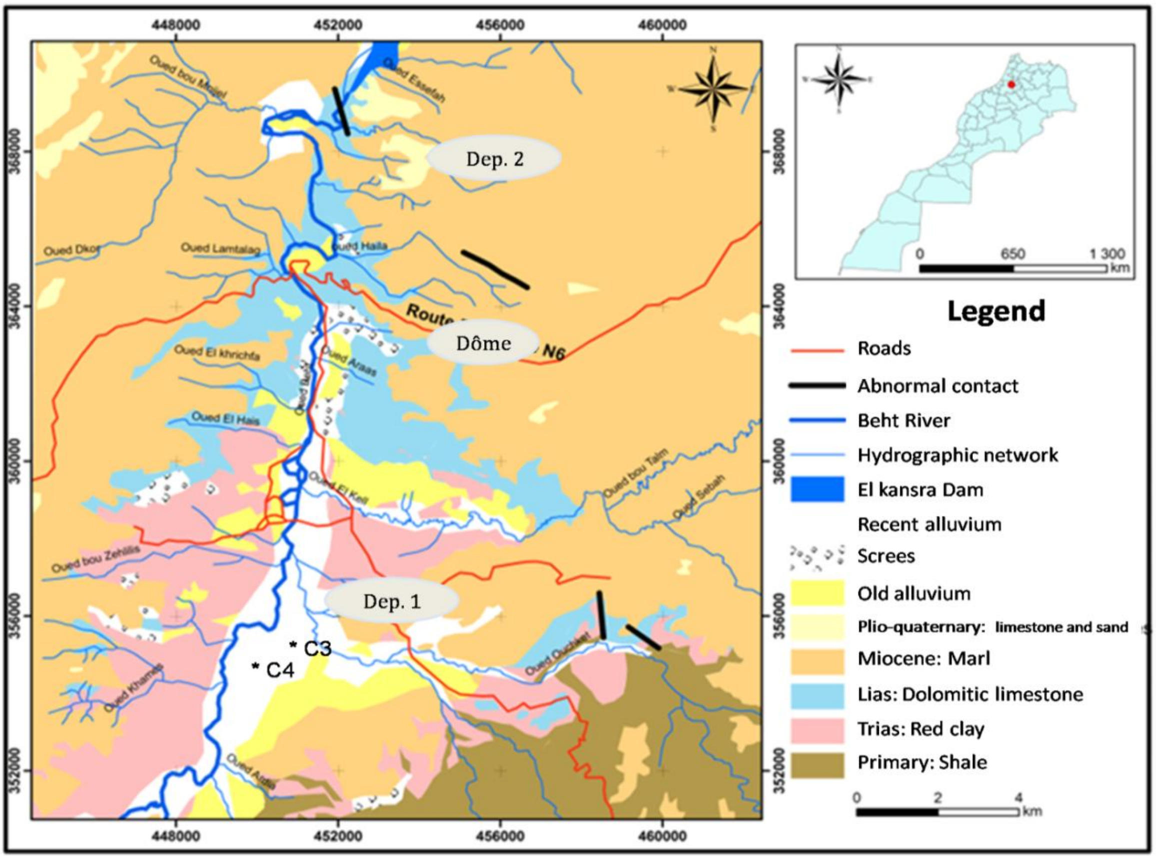

Figure 6: Geological Overview with hydrographic and structural networks of the Middle Beht watershed. From the modified 1/1000000 geological map of Meknes North [10]. Dep. means depression.

Thus, after previous cleaning, these sections have been established, level by level and described in detail. For each level, several characteristics were noted, namely the thickness, color, apparent sediment texture, relative abundance of pebbles and gravels as well as their petrographic nature and the presence or absence of sedimentary figures (gully surface; oblique, horizontal or curved stratification, etc.).

In the laboratory, detailed granulometric study basing on the sediment washing with the sieve 63 μm allowed to separate the sand (> 63μm) and silt-clayey fractions (< 63 μm). The fine granulometry was carried out by sedimentometry using the Anderson pipette to reveal the different silty fractions (63μm > ϕ > 2μm) and the clay fraction (< 2μm). The carbonate contents (% $CaCO_3$) were determined by calcimetry using the Bernard calcimeter. The amount of Calcium carbonate was determined by measuring the volume of CO_2 released by the action of hydrochloric acid on finely ground sediment. The experimental protocol has been performed and adapted according the Brest EPSHOM [19, 20]. The sensitivity threshold of the method is around 1%. The contents of organic matter were determined by weights difference before and after combustion at 450 ° C. for 2 hours [21]. The following physico-chemical parameters: water pH, KCl pH and Electrical Conductivity were measured using an Orion 4 Star multiparameter.

4. Results and discussion

4.1. *Lithostratigraphy, Sedimentology and physico-chemistry of the C3 section*

The section C3 is situated on the right bank of the wadi Beht (Figure 7). It is located morphologically in the distal zone of a dejection cone built by Wadi Ardia at its confluence with the Beht River. The deposits of this cone, inserted in floodplain deposits, come to interlock into younger spreading of the same cone (Figure 8).

The section C3 has a thickness of 2.20 m and shows upwards 9 lithostratigraphic levels distributed in six strato and grano-descending elementary sequences of 5 to 30 cm in thickness each (Figure 7). The elementary sequences of the lower ¾ of the cut, with more or less gully bases, are coarse and have a stony texture, gray in color and decimetric in thickness. At the section base, they have an arched stratification of decimetric scale; and horizontal, more or less evident, towards the top. the elements reveal a fining-upward trend and range in size from 25 cm to 5 cm. The pebbles and gravels are generally subangular and bulked with locally an imbrication indicating a way flow from the SE to the NW which conforms respectively to the paleo-currents direction given by the channeling structures and the actual flow of the Ardia river. The petrographic nature of the elements is varied; the most dominant are the sandstones, quartzites, schists and the Paleozoic vein quartz. There are also some elements of doleritic and sandy basalts of the Triassic, carbonate of the Jurassic and yellowish sandstones of the Miocene.

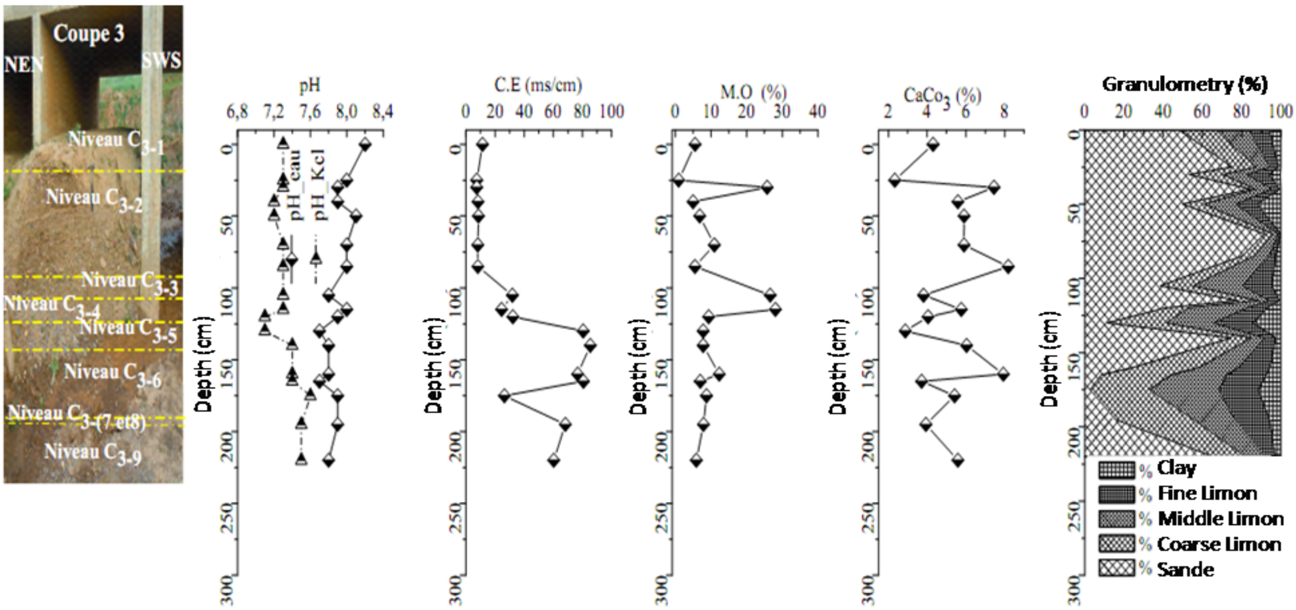

Figure 7: Vertical profiles of the lithological, sedimentological and physico-chemical parameters of the section C3. C.E: Electrical Conductivity, M.O.: Organic Matter, $CaCO_3$: Carbonates.

The lateral passage towards distal deposits far about twenty meters from the section C3 shows much more complete elementary sequences with two to three terms, namely coarse gravels with dominant pebbles, coarse gravels with predominant finer gravels and more or less gravelly sands (Figure 9).

The summit of the C3 section is constituted by an elementary sequence equally decimetric ranging from 50 to 70 cm in thickness. The stratification is horizontal but becomes curved with the increase in the thickness of the deposit, this one presents laterally and on the scale of the outcrop a channelized lenticular stratification of metric extention. The deposits, beige in color at the base and blackish at the top, have a sandy-clayey texture much finer than the lower elemental sequences which have a stony texture. The ultimate deposits at the top of the sequence are formed by silts and clays rich in organic matter with horizontal bedding, locally undulating and affected by desiccation cracks. These undulations are expressed in cross-section by a succession of wide ridges ranging from 15 to 20 cm and dips of 25 to 30 cm (Figure 9).

Figure 8: Modern spreading of the cone, nested in the oldest sprays (section C3) at the confluence of Oued Ardia with Beht river.

Figure 9: Cross-section into lateral distal deposits of the C3 section.

The granulometric analysis of the sand-silt-clayey matrix of the stony sequences exhibits an organization of the deposits into 5 grano-decreasing elementary sequences. From the bottom up, the lower elementary sequence shows a reduction of the sand contents by 40 to 5% in favor of an increase in the silt and clay contents respectively of 60 to 85% and 5 to 10 %. The vertical evolution is accompanied by a decrease in the content of pebbles and gravels compensated by an increase in the fine fractions contents. The carbonate contents are low and increase slightly by 2% in the matrix of the coarser gravels to 8% in the silt-sand-clayey level. The pH remains alkaline with oscillating values around 8. Organic matter levels tend to stabilize around 10 % at the base and show fluctuations between 5 and 30% towards the top with the highest contents in the fine levels. The electrical conductivity shows an upward decrease from 80µs/cm to 20µs/cm (Figure 7).

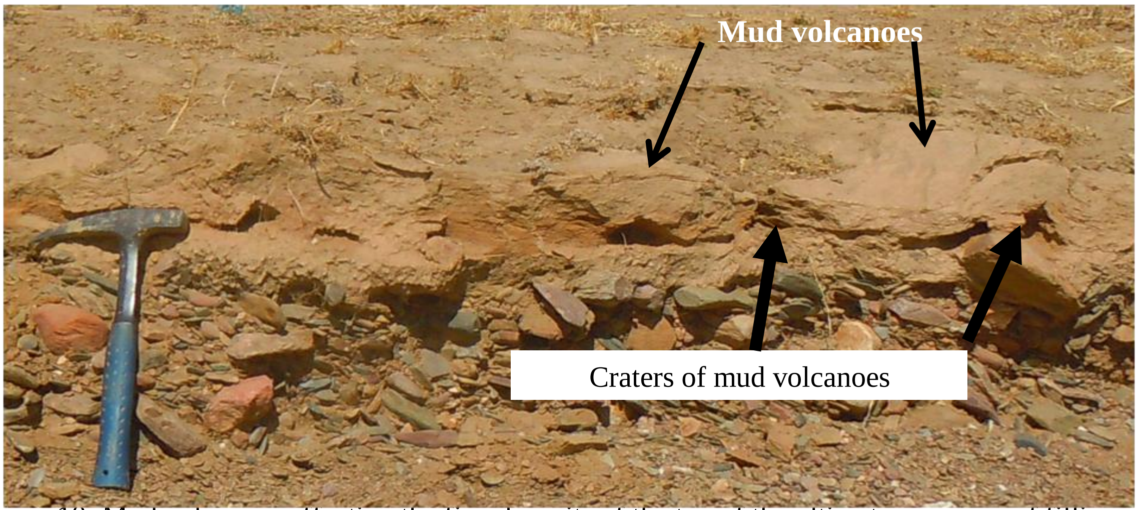

Figure 10: Mud volcanoes affecting the fine deposits of the top of the ultimate sequence of filling an abandoned channel at the top of the C3 section.

Interpretation and reconstruction of deposits environments

The deposits of the C3 cut correspond to the spreading of a dejection cone located under a bridge at the confluence of Oued Ardia with Oued Beht. They are organized in strato-grano-decreasing elementary sequences with two terms [22]:

The first term is composed of heterrometric and polygenic gravels with more or less abundant sand-silo-argillaceous matrix with arched and horizontal stratification. These deposits, of debris flow type, have been put in place by by torrential flows during periods of floods triggered by stormy precipitation in a semi-arid climatic context. Channelized bulk or deposits with very evident arched stratification correspond to channels fillings. However, deposits of the same type but with horizontal stratification correspond to deposits of longitudinal bars [23]. These coarse discharges witness significant detrital erosion in the catchment area which has a more distinct relief and low forest cover. The polygenic character of the gravels expresses a relief formed by lands of varied petrographic nature predominantly sedimentary and spanning the time interval from the Paleozoic to the Upper Miocene.

The second term, which is visible only about 20 meters away from the present bed of Oued Ardia, is formed by silt-clayey sands with oblique, flat to curved and horizontal stratification. This term indicates a decrease in the flows turbulence due to the divergence of the flows at the distal part of the dejection cone. Its absence in the C3 section is due to its complete erosion during floods in the proximal part of this cone [24].

The summit elementary sequence corresponds to deposits of filling of an abandoned channel put in place during overflows at the time of floods. The abandonment of this channel is linked to the construction of the bridge which channeled the flows increasing thus their turbulence and their incision in the previous deposits. This anthropogenic dynamics is responsible for the abandonment of this channel in perched position and which is invaded by the waters only in periods of important floods. These release fine deposits more or less rich in organic matter. The ripples affecting the ultimate fine deposits correspond to synsedimentary deformations related to mud volcanoes generated by a release of gas from the degradation of the organic matter in a hot and dry climatic environment. The presence of desiccation cracks in these levels indicates a strong evaporation responsible for the emergence of deposits. Nowadays, these mud volcanoes continue to function during the dry season in muddy deposits rich in organic matter of channels and puddles [25].

The Oued Ardia bridge was built in 2008 [9]. The thickness of the sediments deposited under this bridge was of the order of 2.20 m in 2012. The sedimentary pile deposited in four years indicates a sedimentation rate of about 55 cm / year. This high rate testifies to strong erosion in the Oued Ardia sub-basin linked to the aridification of the climate and to the accentuation of the anthropic action which was expressed by an intense degradation of the forest in the watershed. Indeed, the rainfall data recorded from 1963 until 2010 [26] show a certain tendency towards aridification of the modern climate with small wet periods of 3 to 4 years such as the interval time between 2008 and 2010 which was preceded by a longer period of arid tendency. The succession of such periods is manifested hydrologically by violent floods containing excessive amounts of sediments. Consequently, the high rate of sedimentation is linked to major floods in Wadi Ardia following heavy rains during the wettest period between 2008 and 2010, with 860 mm (Figure 11, [26]). These heavy rains were expressed by strong water erosion in the catchment area weakened by the scarcity of the forest cover. The high siltation rate cannot be due to the role of obstacle played by the bridge; the section C3 located at the outlet of the bridge indicates that this one had rather acted inversely by channeling the waters causing thus their torrentiality increase and therefore disadvantages the sedimentation (Figure 12).

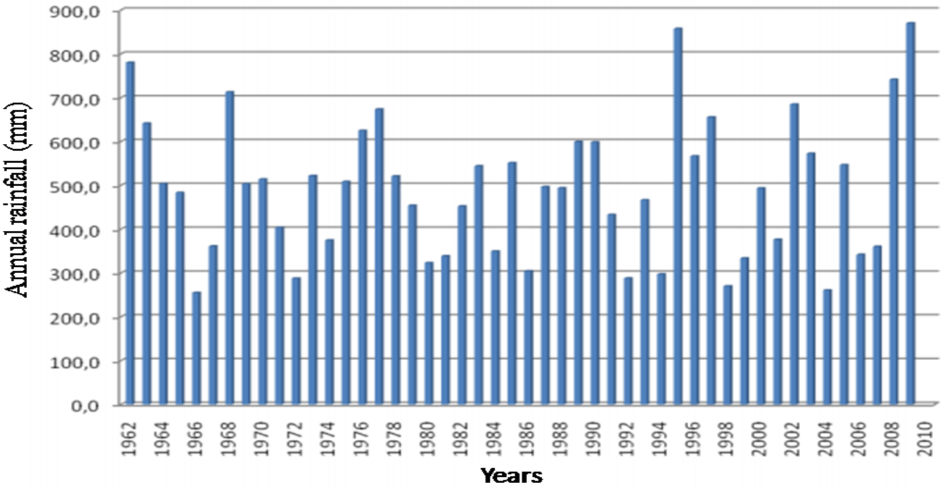

Figure 11: Variation of annual rainfall averages at the Azib Soltane station [26].

The low carbonate content reflects the petrographic nature of the flush terrains formed mainly of schists, sandstones and quartzites Paleozoic in addition to clays and gypsum-salt silts with intercalations of Triassic doleritic basalts.

Figure 12: Deposit showing alluvium filling under the bridge of Oued Ardia.

The low electrical conductivity values of the deposition cone sediments, despite the presence of gypsum and salts in the area, are due to the leaching phenomenon. The slight values difference between the base and the top of the section C3 can be explained by the effect of the water table whose waters contain chlorides and sulphates in small quantities coming from clays and triassic gypsum salts exposed at surface in the watershed [27].

4.2. *Lithostratigraphy, Sedimentology and physico-chemistry of the C4 section*

The section C4 was chosen from a floodplain located on the right bank of the Oued Beht (Figures 6 and 13). It shows upwards 9 levels divided into three grano-decreasing sequences: a lower sequence thick of 0.5m, a middle sequence thick of 0.65m and a upper sequence thick of 0.35m (Figure 13).

The lower sequence, more complete, overlies through a gully surface the grayish deposits of the Oued Beht paleo-bed. The stratification of these deposits is arched, lenticular and horizontal ; the texture is conglomerate with rollers characterized by polygenic, heterometric and sand-gravelly matrice (Figure 14).

This sequence begins with a channeled conglomerate lens with a gully base of 10 to 15 cm maximum thickness (C4-9 to C4-7). It is followed first by medium sands with curved oblique to plane and intersected stratifications;

then by fine pinkish to brownish sands with undulated to plane and horizontal stratifications that cover clayey silts finely bedded and locally rich in organic matter.

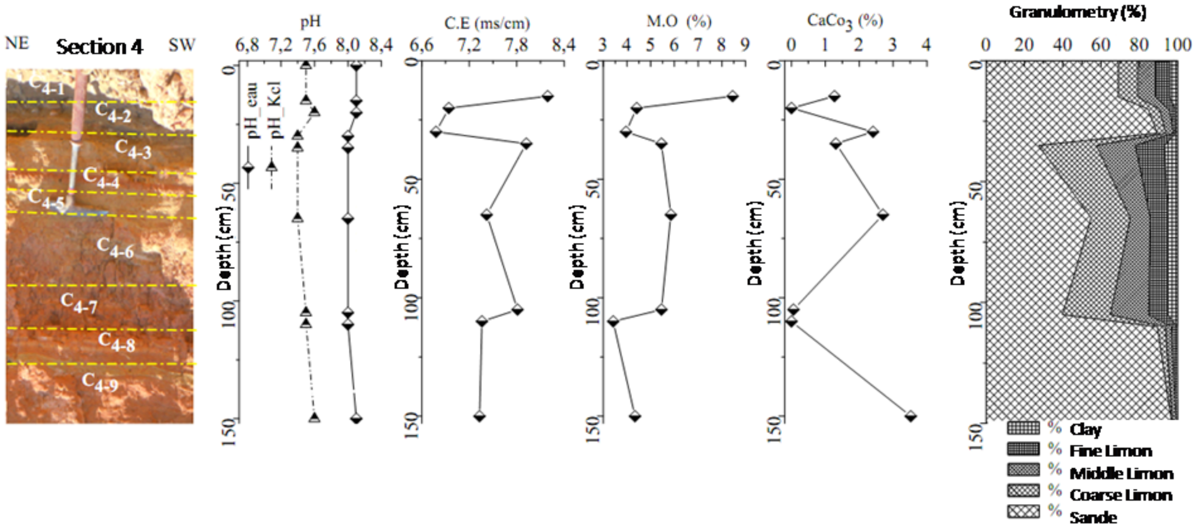

Figure 13: Vertical profiles of the lithological, sedimentological and physicochemical parameters of the C3 section. C.E: Electrical Conductivity, M.O.: Organic Matter, $CaCO_3$: Carbonates

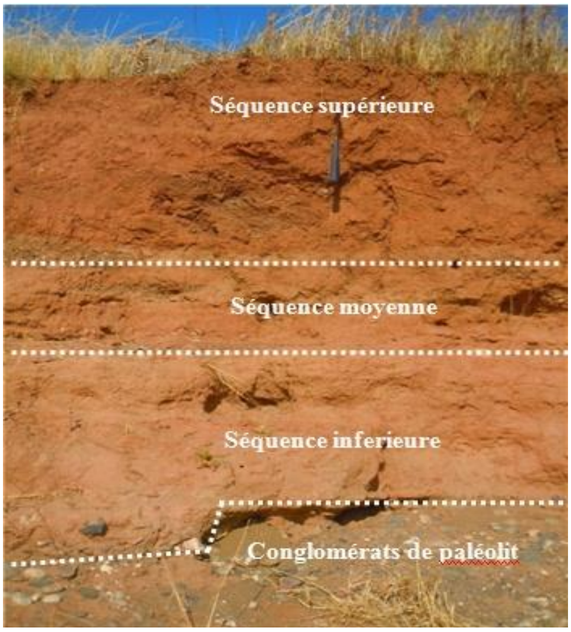

Figure 14: Section C4 on the right bank of the Beht River.

The granulometric analysis shows a fining upward expressed by a clear decrease in the sand contents from 90 to 40% and by a marked increase in the silt contents from 5% to 50% and clays from 0 to 10%. The carbonate contents are low and range from 3% in the sands of the sequence base to 0% in the sandy silty levels of the top.
The organic matter contents are relatively low by 4%. The pH is alkaline and varies slightly around 8. The electrical conductivity is overall very low by 7,2µs/cm.
The intermediate sequence overlies the preceding sequence via a weakly expressed gully surface. This sequence begins with a centimeter level chenalised from gray gravelly sands to few mainly carbonated pebbles. It is followed by silty-clayey-sandy deposits organized in horizontal layers of centimeter thickness that are differentiated by their more or less pinkish color. These layers contain intercalations of chenalised lenses with grayish ? sandy-silty texture and locally show undulations.
The granulometric analysis shows a positive grano-classification from the base to the top with a reduction in the sand contents from 35% to 30% in favor of a slight increase in the silt contents from 65 to 70%; the clay contents remain practically constant and oscillate around 10% throughout the sequence.

The carbonate contents are very low by about 2%. The contents of organic matter remain constant and oscillate around 5.5%. The pH remains alkaline with values oscillating around 8.2. The electrical conductivity remains very low by about 8µs/cm.

The upper sequence overlies through a gully surface the preceding sequence. It is 35cm thick but can reach laterally up to 90cm. It begins with a sandy- gravelly level, chenalised, greyish color and of centimetric thickness. It is followed by fine pinkish deposits of silto-clayey-sandy texture with intercalations of sandy, gravely and channelized lenses with gully bases. The deposits, which become thinner towards the summit, are rich in roots traces and contain charcoal fragments and gastropods shells. These deposits are capped by the current soil. The granulometric analysis shows a fining upward with a reduction in the sand contents from 90% to 70% in favor of an increase in the silt and clay contents respectively of 10 to 25% and of 0 at 5%.

The carbonate contents are very low by about 2%, the organic matter contents increase by 4 to 9% from the base to the top. The pH remains alkaline with values oscillating around 8.1. The electrical conductivity remains very low at 8.4µs/cm.

Interpretation and reconstruction of deposits environments

The substrate deposits of the C4 section are formed of gravel with sand-gravelly matrix and have a large-scale lenticular and arched stratification. These deposits correspond to alluvial filling of a minor paleo-bed of meandriform type as shown on the one hand by the lateral extent and the considerable thickness of the floodplain and on the other hand by the intercalation of filling deposits of abandoned meander between the fine deposits of the floodplain and the coarse ones of the active paleo-bed meandriform [28] (Figure 15). The influx of heterrometric coarse deposits, of “debris flow” type, was assured by turbulent flows of torrential type during periods of floods in a meandering river system [29].

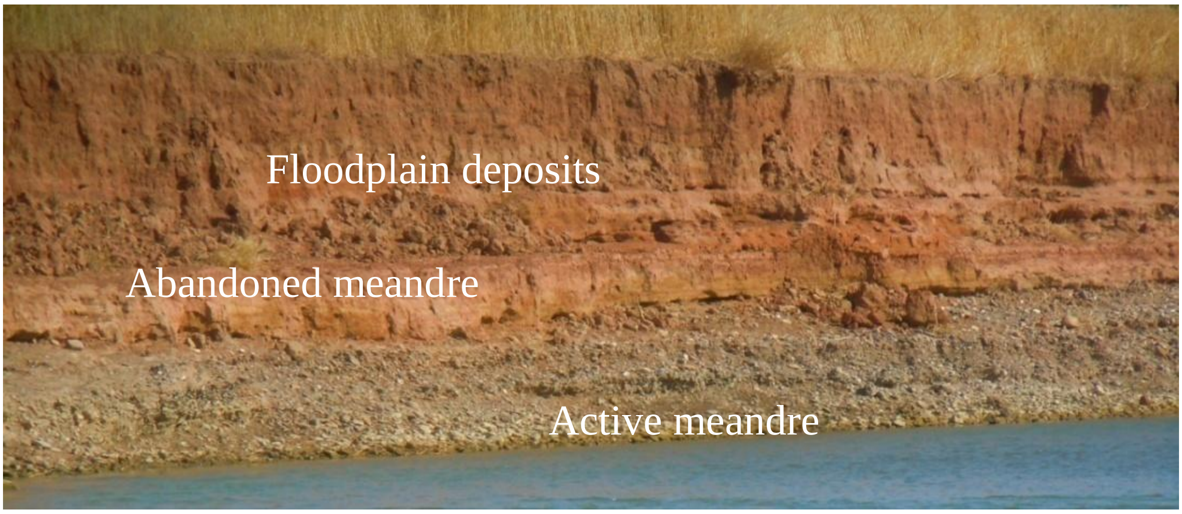

Figure 15: Floodplain deposits overlying those of a meandre first active then abandoned of Beht River.

In terms of lithology and sedimentology, the C4 section shows three positive sequences, each starting with channeled coarse deposits at the base and overlying silt-sandy-clayey and finely stratified deposits of floodplain at the top. The coarse levels with sandy-gravelly texture correspond to fillings of spreading secondary channels that drain the flood flows at the onset of floods before complete flooding of the floodplain [30]. The finest deposits of silty-sandy-clayey texture are deposited during periods of flooding of the alluvial plain. The intercalations of channelized sandy-gravely lenses correspond to deposits of channel bottoms ensuring the recharge and the water recedes at the beginning of the rise and fall of the water level [31, 32]. The presence of these channel fillings within the floodplain reflects significant hydrological variations, which are expressed in large variations of the water column on the floodplain surface. These variations are related to the very irregular and stormy rainfall regimes corresponding globally to a semi-arid climate [33].

The undulations, affecting the stratified deposits of the floodplain, correspond to mud volcanoes juxtaposed and superimposed. These diagenetic figures are related to the escape of gases coming from the degradation and fermentation of the organic matter contained in the fine deposits of water puddles and of the wetlands under reducing and hot conditions. Moreover, this phenomenon is actually observed in fine deposits of channels borders during the summer period [34] (Figure 16).

Figure 16: Small juxtaposed mud volcanoes affecting, during a low-flow period, silt-sand-clayey deposits with currents wrinkles in a lower meander bar on a bank of Beht River.

The alkaline pH is due to the lithological context and the soils nature of the watershed. The low carbonate content and the low value of the electrical conductivity would probably be related to the lithological origin of the inputs formed mainly by the Paleozoic schistous soils and especially by the Triassic clayey-saliferous silts. The low electrical conductivity values testify a significant leaching of the salts downstream, which threatens the degradation of the physicochemical and therefore the biological waters quality of the El Kansera dam reservoir [35].

The relatively high levels of organic matter reflect important erosion in the upstream zones due to the degradation of vegetation cover related to the combined actions of anthropism and climate aridification. This significant soil erosion constitutes a silting threat to the El Kansera dam. The thin layers of fine deposits indicate settling by decantation in periods of overflow on the alluvial plain. The richness of these silt-sandy-clayey deposits in traces of roots and in the shells of gastropods, often unfragmented, indicates more or less prolonged emersion phases which accompany pedogenesis phenomena which are expressed by a browning of deposits related to a certain enrichment of the soils in organic matter.

Conclusions

The two sections studied in this work are composed of grano-decreasing elementary sequences. However, they are much more pronounced in spreading of dejection cones than in floodplain deposits. Indeed, the sequences of dejection cones deposits present a basal term of stony texture much thicker with rollers of low to medium wear and mostly arranged in bulk or diffuse stratification. However, the thinner term is much finer, more developed, richer in pedogenetic indices (traces of roots) and with much evident stratification in the floodplain deposits. The gully surfaces are much more expressed in the dejection cones deposits; this explains the truncated nature of its elementary sequences.

Differences in sedimentological and physico-chemical characteristics between deposits of the dejection cones and those of the floodplain are related to differences in the hydrodynamic conditions of their deposition. Indeed, most of the spreading cones are deposited by very turbulent flows during periods of floods in relation to the morphology and topography of the tributaries valleys which are narrow and have a steep longitudinal slope compared to that of the right side of the Beht river. However, the floodplain deposits are mainly settled by decanting suspensions transported by relatively quieter waters during their overflows at the time of floods on substantially flat to slightly depressed topographies. The much lower sediment dynamics of the flood plains promotes a much more complete record of the hydrological cycles of floods and recession and consequently climate.

The high sedimentation rate in the spreading of the studied dejection cone is linked to significant floods of Oued Ardia following heavy rains between 2008 and 2010 and during the wettest period since 1963 with 860 mm. These heavy rains have been expressed by strong water erosion in the watershed due to a scarcity of forest cover

which is related to the combined effects of anthropogenic action and the intensification of the aridification of the actueal climate in the Beht Oued catchment area.
The low electrical conductivity values of sediments despite the presence of gypsum and salts in the region are due to the leaching phenomenon. The slight difference in their values between the base and the top of the sections could be explained by the water table effect. The relatively high organic matter content reflects the importance of soil erosion in upstream areas, thus posing a siltation threat to the El Kansera dam.

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