# Holocene Morphodynamics in Northern Tunisia Flood Plain Sediments as Indicator of Soil Erosion Phases

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**Abstract**: Main goal of our study in a Mediterranean flood plain is the set-up of Holocene chronostratigraphy with the separation into periods of active and stable morphodynamics. Active morphodynamics correspond with run off and soil erosion in the headwaters of the river system and predominant fine sedimentation in the flood plain (middle course). During the Holocene, sedimentation cycles and soil formation phases alternate several times in the Oued Medjerda flood plain (northern Tunisia). From the study of key profiles in the middle course of the Medjerda River results the following standard profile: The late Pleistocene closes with an intensive soil formation. The turn from late Pleistocene to early Holocene is marked by the rhythmic deposition of relatively coarse sediments and gravel accumulation in the river bed. Between 8,000(?) and 4,800 BP we assume a first strong Holocene pedogenesis. Subsequently, clayey layers are accumulated within the flood plain due to an aridification of the climate. At the same time the river floor is filled with gravel layers. The Punic-Roman phase (c. 2,600—1,600 BP) is marked by pedogenesis and an incision of the river bed. The following period of active morphodynamics is induced by man. Social instability is one of the main reasons. In the later Middle Ages we assume a short time of morphodynamic dormancy that is marked less by soil formation than by a distinct incision of the river. The "youngest layer" is deposited at the earliest about 440 BP with corresponding extreme flooding. Thus, for the Holocene four sedimentation and three soil formation cycles are recorded, out of which the oldest pedogenesis was the most intensive and clearest.
**Keywords**: holocene, floodplain, morphodynamics, tunisia, mediterranean

## 1 Introduction

An important component for reconstructing palaeoenvironmental conditions is morphodynamics and how they are dominantly induced. According to ROHDENBURG (1971) two contrasting states with gradual transitions can be differentiated. Active morphodynamics correspond with more arid conditions, leading to a sparse vegetation cover and high run off. Consequently rivers tend to aggradation in the food plain. On the other hand, stable morphodynamic conditions are linked to a more humid climate. A dense vegetation cover allows soil formation, low run off and, therefore, river incision. Accordingly climate is regarded as the dominant factor because it regulates the basic components vegetation cover and soil within the "natural" landscape. As soon as man changes vegetation cover by cultivating a landscape, morphodynamics will change to more active processes. This all takes place during stable climatic conditions (MAY 1991). Consequently, morphodynamics can actively be regulated by human beings and identical palaeoenvironmental conditions must not be concluded from corresponding climatic situations. Clear indicators, however, which allow us to separate exactly anthropogenic and climatic impulses for morphodynamics are still missing. It is usually assumed that anthropogenic interference leads to morphodynamic activity (GIESSNER 1990, FAUST 1993). The findings concerning the flourish Roman era will show that anthropogenic influence can cause morphodynamic stability.

## 2 Environmental Setting

Our study area is the mid-Medjerda valley in northern Tunisia, a tectonical depression zone formed already during Tertiary due to the Atlas-orogenesis. The Medjerda River has incised meanders into the up to 10 km wide depression, which is filled up with Quaternary sediments. The Holocene meander belt stretches over a width of 1 km on an average. There the river has accumulated its latest Pleistocene and Holocene sediments and at the same time has also incised due to meander activities. In consequence fantastic exposure conditions have developed. The climate in the central Medjerda valley (140 m—170 m above sea level) corresponds to the Mediterranean subtropics with rainy winters and dry summers. The average annual temperature is about 17℃—18℃ with annual precipitation of about 440 mm—480 mm. The area of investigation has been populated at least since the ending Palaeolithics (about 13,000 BP with artefacts of Ibéromaurusian culture).

## 3 Methods

Detailed profile investigations are the basis of the following analytic steps as there are: Granulometry, carbonate content, organic matter content, total iron and pedogene iron, heavy metal analysis, heavy mineral analysis, $^{14}C$-dating, thin section analysis, paleomagnetics and mollusc-analysis. The presented key profiles, which were narrowly sampled according to the macroscopic findings, are all situated in the mid-Medjerda valley (Ghardimaou basin). The key profiles are mainly outer bank positions and are in our opinion very suitable to depict the Holocene sedimentation and soil formation processes within the study area in a representative and relatively compressed way. The short description of the profiles is followed by a more detailed explanation and discussion.

## 4 Key Profiles

The **Ghardimaou I** profile (Fig. 1) indicates relatively young material and contains within the bottommost sequence a humic horizon (layer A; in Fig. 1 only these layers are marked, which are also mentioned in the text) with a sub angular blocky structure and calcified plant remnants. This points towards a pedogenesis setting in around 2,500 BP (according to dated charcoal remains). The **Ghardimaou III** profile consists of relatively young sediment sequences as well. However, a mid-Holocene soil (D) is developed at the base. Most conspicuous series in **Oued Mliz** profile (Fig. 1) are the layers F and G. Due to the field observations (aggregation and colour) we can assume that in layer G a strong pedogenesis has taken place (ZIELHOFER *et al.*, i.p.). This also effects layer F and has induced a (intense) reddening there. The decreasing calcareous content leads to the assumption of a partial decalcification. Other important aspects of the Oued Mliz profile are the rhythmic, thin alternating sediments (E) above a 13,000 years-old fire-site. River shells within the rhythmic depositions indicate a then more turbulent, oxygen-rich and less suspension loaded discharge. In the **Chemtou I/II** profiles (Fig. 1) a late Pleistocene soil (H) is developed whose A-horizon was obviously eroded. The clayey B-horizon (H) is totally non-calcareous and characterised by a angular blocky structure and clay cutanes at its aggregate surfaces. The fraction of 32 % of dithionite-soluble iron in total iron is relatively high, and the strong reddening (5—7.5 YR 4/6) underlines the intense pedogenesis. Above the reddish soil (H) a cultural in situ layer (Fig. 1; I) of 50—70 cm thickness is developed. This cultural layer (called *escargotière* in the Tunisian literature [BOURGOU 1993]) consists of a lot of sharp-edged rubbles, charcoal remains, snail's shells and bones. The dated in situ charcoal points at a $^{14}C$-age of 13,200 to 12,990 cal BP (BETA-135726). Another important observation is the weakly rubefated soil (Fig. 1; horizon L and K) within in the vicinal **Chemtou II** profile. In both Chemtou profiles mighty gravel accumulations are noticeable (Fig. 1; J). They contain a lot of Roman ceramic fragments. The gravel accumulations mark the post-Roman level of the river bed. Outside the stream line, post-Roman flood plain sediments are deposited that can be observed in all profiles (Fig. 1; series S4). In the Ghardimaou I profile the S4 sequence terminates with a medieval soil formation (Fig. 1; B) finished around 500 BP. The “youngest layer” (Fig. 1; C) indicates an ubiquitous deposition of finely banded clayey to loamy sediments.

## 5 Explanation and discussion

### 5.1 Late pleistocene

In the mid-Medjerda valley the Pleistocene closes with a well-developed, rubefacted and non-calcareous soil (Chemtou profile). The soil formation finally seems completed around 13,000 BP due to the dated in situ charcoal remains inside an overlying Ibéromaurusian layer (13,000 cal BP). The beginning of the pedogenesis can not without doubt be stated so far.

### 5.2 Shift pleistocene-holocene – old rharbian (ca. 13,000 – 8,000 BP)

The Holocene starts with a rhythmic sedimentation (Fig. 2; **S2**) of finely stratified, rather coarse layers due to turbulent water dynamics in the Medjerda River. A latest Pleistocene fire-site in the Oued Mliz profile (Fig. 1) is dated to 13,500 to 13,160 cal BP (BETA-135718). Shortly above this fire-site the rhythmic, coarsely grained alternating stratification sets in. Consequently, these alternations must have begun around 13,000 BP at the earliest. Analogically, STEINMANN & BARTELS (1982: 107) describe a strong sedimentation phase between 11,000 and 9,000 BP (non-calibrated) in the neighbouring Oued Siliane basin. We parallelize the early Holocene flood plain sedimentation and corresponding soil erosion in the Medjerda catchment area with an aridification of the climate (FAUST & ZIELHOFER, i.p.).

### 5.3 Middle rharbian (until 4,800 BP)

The mid-Rharbian is marked by receding flood plain sedimentation and a subsequent well-developed soil. This rubefacted soil can be detected in the most important profiles (Fig. 1; Ghardimaou III, D; Oued Mliz, F and G; Chemtou II, K and L). The beginning of this mid-Holocene pedogenesis can not be clarified without doubt. For southern Spain FAUST & DIAZ DEL OLMO (1997: 282) describe a hygric and thermic optimum, the so-called "*Neolithic Pluvial*", in whose course soils were developed. During that climatic optimum soils were also developed in Morocco (SABELBERG 1977) and central Tunisia (MOLLE 1979: 83). The soil formation of the "Neolithic pluvial" we put in a time before 4,800 BP according to our stratigraphical results. The shift towards more humid conditions in the course of the mid-Rharbian caused stable morphodynamics with low run off in the Medjerda headwaters and decreasing flooding with river incision in the Medjerda plain itself.

### 5.4 C. 4,800 – 1,800 BP

All investigations concerning Holocene morphodynamics in the western Mediterranean indicate around 4,800 BP an abrupt change towards much drier conditions (ROHDENBURG 1977; SABELBERG 1977; MOLLE 1979; DIAZ DEL OLMO *et al*. 1993; FAUST 1995). The development of thick, humic soils is thus finished. In the Medjerda flood plain a deposition of fine sediments (Fig. 2; **S3**) sets in that can be observed in most profiles (Fig. 1; Ghardimaou I, A; Ghardimaou III, above D; Oued Mliz, above G; Sidi Abdallah, series S3). This fine sedimentation closes with a weak pedogenesis (Fig. 1; e.g. Ghardimaou I, A). However, pedogenesis can not in all cases be proven by thin sections. Analogically to the results of GEYH & JÄCKEL (1974), who report a more humid phase between 2,600 and 2,000 BP in the central Saharan region, and the results of ROHDENBURG (1977), who describes Rendzina development on Balearic Islands around 2,000 BP, we parallelize the weak soil formation - supported by $^{14}$C-datings (2680 BP) from the Ghardimaou I profile (Fig. 1) - with the time of the Punic and Roman colonisation.

### 5.5 C. 1,800 – 1,000 BP

The late to post-Roman era changes towards active morphodynamics. In Chemtou mighty cobble layers (Fig. 1; J) indicate a fill-up of the river bed. Big flooding completely cover the entire Medjerda plain including the originally flood-free Roman settlement level. The post-Roman fill-up is present as a key series (Fig. 2; **S4**) in nearly all recorded profiles and can easily be classified chronostartigraphically due to the presence of a great number of Roman ceramics. Active morphodynamics starting from the end of the Roman era is known from other Mediterranean regions as well (VAN ZUIDAM 1975; ROHDENBURG 1977; MAY 1991; MAY *et al*. 1992; SCHULTE 1995; FAUST 1997). In any case it is caused by the intensity of land use at the end of the Roman era. However, it is indicated that not the intense land use itself, but rather its collapse due to territorial conflicts implicates run off and soil erosion (FAUST 1993; BARKER 1996). This phase is called "*Crise Romaine*" in Tunisian literature (BOURGOU 1993). Powerful gravel deposits are accumulated in the headwaters, while in the Medjerda basin itself extreme flooding occurs more frequently. According to GEYH & JÄCKEL (1974) an accentuated aridification of the climate at least in the central Saharan region must be assumed as well.

### 5.6 C. 1,000 – 440 BP

The youngest A-horizon in the Medjerda flood plain (Fig. 1; Ghardimaou I, B) indicates a medieval pedogenesis phase from 1,000 to <440 BP. The dating of an in situ fire-site below the "youngest layer" (Fig. 1; C) covering the entire flood plain results in an $^{14}$C-age of 440 BP. At that time at the earliest the medieval pedogenesis was finished. In southwest Spain FAUST *et al*. (2000) have also proven a soil formation period around 800 BP.

### 5.7 C. 440 BP until today

From about 440 BP, disastrous flooding set in once more which leave behind the uppermost "youngest layer" in the entire mid-Medjerda flood plain (Fig. 1; C). The youngest layer (Fig. 2; **S5**) is characterized by a fine banding shift of fine sandy to silty clayey loam without recognizable soil formation features. Within the Holocene meander belt the continuing lateral shifting of the Oued Medjerda lead to inner bank accumulations with resulting youngest inner bank terraces.

## 6 Conclusion

During Holocene we are able to distinguish four sedimentation and three soil formation cycles within the Medjerda flood plain. The Holocene sediment cycles (S2 to S5) are illustrated in Fig. 2. All sedimentation phases correspond with a fill-up of the river bed usually with coarser material and the deposition of fine sediments in the spacious flood plain itself. In the headwaters of the Medjerda River sedimentation processes do not indicate active morphodynamics, but run off and soil erosion. Alternating hygric conditions (GEYH & JÄCKEL, 1974; MOLLE 1979) in the course of the early and mid-Holocene caused the deposition of older flood plain sediments (S2 and S3) within the mid-Medjerda valley. The Punic-Roman period (about 2,600 – 1,700 BP) is marked by pedogenesis and an incision of the Medjerda river in the flood plain. In our point of view subsequent active morphodynamics is induced by man (ZIELHOFER & FAUST, i.p.) and not by climate. Climate now plays a secondary role, but may accelerate some processes. The spreading of Arabian culture (1,000 BP) all over the Maghreb was accompanied by more humid climate (HSÜ, 2000) but may have induced active morphodynamics with sedimentation in the Medjerda flood plain. This post Roman active phase lasted from about 1,600 – 800 BP and began with high flooding that for the first time took the river completely out of his meander bed. The clearly risen water level amplitude may be a signal of man induced activity (FAUST & ZIELHOFER, i.p.). During this phase the soils formed on the hills before, were eroded as seen in the reddish and dark coloured layers full of Roman artefacts. Therefore, one has to take into account that it is sometimes difficult to distinguish between in situ soil formation within the flood plain and the redeposition of soils formed elsewhere.

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