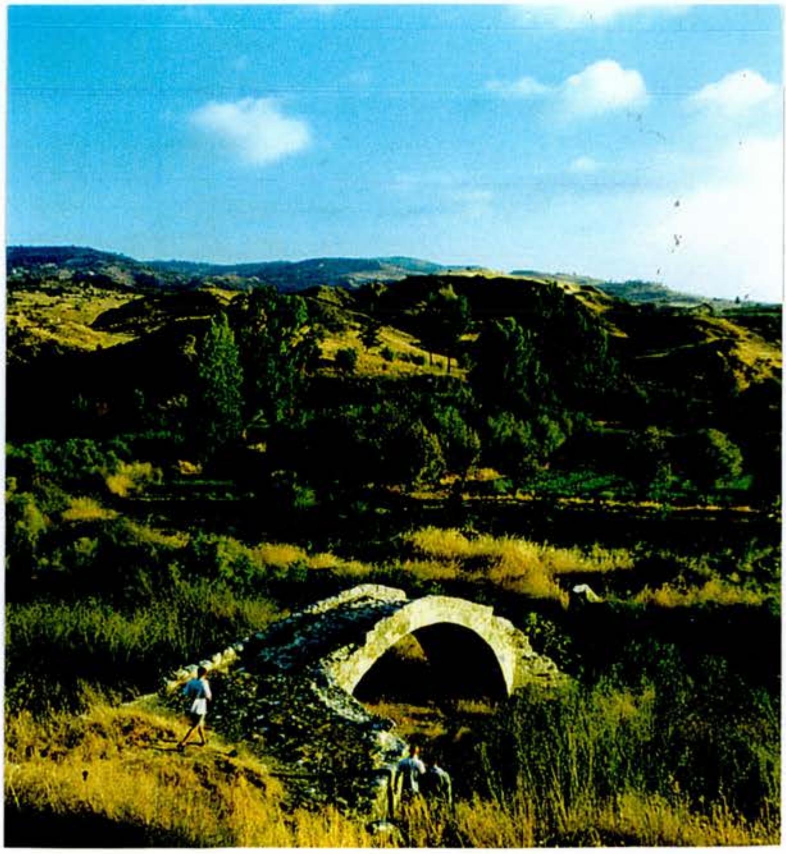
Cypriot Archaeological Sites in the Landscape: An Alluvial Geo-Archaeological Approach

By Katleen Deckers



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To my parents, my most loyal supporters

Certification of originality:

This is to certify that this thesis has been composed by the author and that the work is the authors own. Also, the work has not been submitted for any other degree or professional qualification, except as specified.

Abstract

Only little geo-archaeological work has been undertaken on Cyprus since Vita-Finzi (1969) developed the two-tiered model for landscape evolution in the Mediterranean. However, a new more differentiated, better dated model is necessarily for Cyprus. Understanding the limitations geologic processes impose on the archaeological record is imperative for gaining insight in settlement patterns. Moreover, the alluvial archive on Cyprus also indirectly contains a hitherto unexplored variety of information on human impact on the landscape, climatic evolution, earthquakes and sea level changes.

In a first part of the thesis, a hypothesis for landscape evolution is built, based on a study of literature on several variables that shaped the landscape on Cyprus: climate, sea-level, tectonic history and humans (subsistence economy, metallurgical activities and settlement history). It is concluded that the following periods are marked by a combination of factors favouring alluviation: the landnam of the Neolithic period, the Chalcolithic period, the Late Bronze Age, the Late Hellenistic and Roman period, the Frankish period and the Venetian period.

In a second part, this hypothesis is tested through geo-archaeological fieldwork and laboratory sediment investigations. The fieldwork was carried out in Western Cyprus (Paphos Area) on river terraces of the Stavros-tis-Psokas, Dhiarizzos, Ezousas and Xeropotamos. The laboratory investigations consist of loss-on-ignition, magnetic susceptibility, pH, lithological identification, clast shape analysis and particle size analysis. The crux of this thesis is establishing an alluvial chronology. Besides typology and stratigraphy, a relatively new method of Optically Stimulated Luminescence dating on 8 sediments and a thermoluminescence dating application on about 80 sherds is applied. Evidence was found of Early Prehistoric alluviation. Furthermore, also alluvium from or post-dating the Iron Age, the Hellenistic and Roman period, the Byzantine period, the Frankish period, the Venetian period and Ottoman period was found.

Subsequently, the landscape model is compared with the landscape development hypothesis based on the literature study and with the alluvial record from surrounding countries. As a consequence of this research, the causality of erosion and alluviation in Cyprus is better understood. Subsequently, the implications for the archaeological record are broadly discussed. Topics as archaeological settlements in the Cypriot landscape, impact of the environment on Cypriot humans and impact of humans on the environment are thoroughly explored. The Western Cypriot alluvial data indicate that site visibility at the modern surface is neither a reliable, nor a complete indication of what might still be present in the archaeological record

This thesis presents the best-dated, most detailed landscape model for Western Cyprus at present and is a base for future alluvial research in Western Cyprus. It is a valuable tool for any archaeological surveyor in the Western Cyprus area as it details some of the geologic processes imposed on the archaeological record.

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Introduction

Archaeologists, anthropologists and historians have yet investigated many aspects of former Cypriot life. However, in what environment past activities took place on Cyprus is still rather unknown. Moreover, what impact Cypriot people had on the landscape also has been rarely addressed. Many archaeological surveys have been conducted on Cyprus. However, only little is known of the former landscapes in which these sites were located. Furthermore, the impact of geological processes imposed on the archaeological record is mostly rather underestimated in archaeological surveys. This study focuses on these particular questionnaires in order to contribute to the understanding of Cypriot archaeological sites in the landscape.

To solve these questions, geomorphologic fieldwork has been undertaken along river terraces and fluvial exposures in Western Cyprus (cf. part I on methodology). Since Vita-Finzi's pioneering study « *The Mediterranean Valleys* » (1969) in which he proposed a model for Mediterranean landscape evolution, only little progress was made on Cyprus. Most Mediterranean geomorphologic researchers now have abandoned vita-Finzi's model and local alluvial chronologies seem necessary. Hence, a new model is also required for the Holocene landscape evolution in the Western Cypriot river valleys.

The purpose of the second part of this thesis is to build a landscape evolution model based on a study of literature on several variables, natural as well as cultural. In chapter II an environmental history of Cyprus is presented. Several environmental variables are investigated, such as climate, sea level and tectonic history. In chapter III, a study of literature is undertaken in order to gain deeper insight into the relation between humans and their landscape. Humans modified the landscape through farming (cf. III.1), herding (cf. III.1), mining and smelting (cf. III.2). On the other hand, river environments had an impact on human genes and behaviour. This will be indicated in III.3. through a study on the evidence of malaria. In chapter IV a landscape evolution model is developed, based on a combination of the evidence assembled in part II. In this chapter, several periods are identified during which several variables favoured erosion and alluviation in the river valleys. This model can then be tested against the geomorphologic fieldwork.

The third part of this thesis covers the geo-archaeological fieldwork and the laboratory research. In chapter V, an introduction is provided to the Western Cyprus Geo-archaeological Survey territory, its drainages, geology and archaeology. Subsequently, in chapter VI attention is paid towards the dating of the Cypriot alluvial record. Only a small amount of artefacts are datable by typology (VI.1.). Hence, other means to date the alluvial sequence are needed. In chapter VI.2, it is indicated that the luminescence dating method is a powerful tool to establish an alluvial chronology for Western Cyprus. Two kinds of luminescence applications are undertaken: a thermoluminescence application on about 80 sherds and an optically stimulated luminescence application on 8 sediment samples. In chapter VII details and interpretations are provided on the sediment analysis of about 30 soil sections. The following tests were undertaken on about 300 sediment samples: loss-on-ignition, magnetic susceptibility, pH, lithological identification, clast shape analysis and particle size analysis. On one hand, chapter VIII deals with alluviation and sedimentation. In that chapter, the raw data from chapter VI and VII are further interpreted. First, a summarised chronology on the alluviation is provided (cf. VIII.1). Subsequently, the origin of the deposited sediments is investigated (cf. VIII.2.). Finally, the river velocity and morphology is investigated (cf. VIII.3.). Implications for the archaeological record of the latter are considered (cf. VIII.3.2.). On the other hand, chapter IX deals with stability and soil formation and is also based on the evidence presented in chapter VI and VII. In chapter IX, present-day alluvial soils are compared with palaeosols intercalated between alluvial deposits. The degree and type of soil formation is partially an indicator of the duration of the landscape stability, but also an environmental indicator. Hence, the research of palaeosols provides chronological as well as environmental indications.

In the fourth part of this thesis, the fieldwork is integrated with previously published studies. In chapter X, the causality of the landscape changes is investigated. First, the landscape development hypothesis for Cyprus based on a study of literature (part II, chapter IV) is tested against the geo-archaeological fieldwork evidence (cf. X.1.).

Subsequently, the Cypriot alluvial data are compared with alluvial sequences from other Mediterranean valleys (cf. X.2.). In chapter XI, the implications for the archaeological record are considered more explicitly through a combination of previously published archaeological studies and the fieldwork. The alluvial data provided in this thesis makes it possible to reconsider Cypriot settlements in the landscape (cf. XI.2). Moreover, the impact of the environment on humans is discussed. More specifically, several case studies treat of the direct and indirect impact of rivers on humans, human behaviour and human genetics (cf. XI.2). Finally, several case studies illustrate the impact of ancient Cypriot humans on the environment (cf. XI.3).

Overall, this thesis indicates the importance, possibilities and necessity of alluvial research on Cyprus. Alluvial research offers landscape reconstructions, improves our understanding of settlement and site patterns, and enhances our understanding of human impact on the landscape and opposite, of the impact of the environment on humans.

In a broader scope, this thesis contributes to a wider discussion on the causality of Mediterranean alluviation by providing a preliminary alluvial chronology for Western Cyprus, a previously *terra incognita*. In general, through better insight of the variables that shaped the previous landscape, we could gain a better understanding on how to preserve that landscape.

PART I: Methodology

I. The method : alluvial archaeology

I.1. Terminology and principles

Alluvial geo-archaeology is an established archaeological sub-discipline. Several manuals on terminology, methodology and applications have been written. Most comprehensive is the book "Alluvial Geoarchaeology. Floodplain Archaeology and Environmental Change" published by Tony Brown in 1997. Moreover, in 1992, Mike Waters also wrote an important manual: "Principles of Geoarchaeology" in which a chapter was devoted to alluvial geo-archaeology. The terminology and methodology used in this thesis is explained in detail in these studies.

A river erodes into its bed or lowers its floodplain (= degradation) or either raises its bed and its floodplain (= aggradation). This river behaviour is controlled by several factors. A change in stream behaviour from aggradation to degradation causes incision into the former floodplain. As a result, parts of the old floodplain become exposed, named river terrace/ alluvial terrace/ fluvial terrace. Thus, in the strict sense, a terrace can be described as "a break in slope separating two relatively flat surfaces". However, terraces are not always visible. Hence, had the old floodplain a greater slope than the present one, the terrace would plunge under the modern floodplain surface.

Why are alluvial sediments so interesting for archaeology?

- Since terraces are normally the driest part of the floodplain, they have always been preferentially settled. Consequently, sites are often located on river terraces.

- Rivers could have covered or eroded ancient sites. In surveys and settlement pattern studies, the sites lost due to erosion and those covered by alluvium, have to be taken into account.
- Terraces are remains of former river floodplains and indicators of former river locations, which are imperative for landscape reconstruction. Additionally, because of containing palaeosols, they inform about former soil conditions and climate.
- Occurrence of river terraces, being former deposited sediments, indirectly indicates erosion of the landscape. Insight into the mechanisms for erosion is linked with climate conditions, human impact on the environment, earthquakes and sea level changes.

I.2. Alluvial archaeology in the Mediterranean

Since the end of the sixties, the pioneering study of Vita-Finzi (1969) instigated a range of alluvial studies in the Mediterranean. However, as time progressed, also the discipline evolved and new models and methods developed. In this section, a brief history of alluvial research in the Mediterranean will be provided for deeper insight into the involved presuppositions and methodological problems.

I.2.1. 1969: the start of the alluvial research era to develop landscape reconstructions

Most alluvial research in the Mediterranean has been directly or indirectly inspired by Vita-Finzi. His study *"The Mediterranean Valleys"* has started a discussion, which is still ongoing today.

Vita-Finzi undertook geomorphological research in river valleys in many parts of the Mediterranean : Libya, Tunisia, Algeria, Morocco, Spain, Italy, Greece and Jordan. He mapped many exposures with evidence for valley alluviation. As a result, he discovered a general pattern in the Mediterranean, stating that two major phases of sedimentation (alluviation) took place, the Older and the Younger Fill (Plate 1: fig.1). He dated the Older Fill about 50,000 BP based on the occurrence of Middle Palaeolithic tools. The Younger Fill was dated to historical times by the inclusion of Roman and Medieval potsherds. He ascribed the Older Fill to glacial conditions and the Younger Fill to a more recent period of cold and humid weather conditions, called the "Little Ice Age". Due to the regional synchronicity of alluviation, he suggested both the Older and Younger Fill resulted from climatic deterioration (Vita-Finzi 1969).

The importance of his research was not only based on the fact that he was the first researcher to develop a well-documented model for landscape evolution in the Mediterranean area, but also in his rejection of a uniformitarian model for Mediterranean erosion. According to his findings on rejecting an uniformitarian model for erosion, landscape degradation no longer was considered as a continuous and progressive phenomenon but a punctuated equilibrium (Bintliff 1992: 125).

In the seventies, several investigators (e.g. Bintliff 1977) followed Vita-Finzi's model for Mediterranean landscape evolution (Bintliff 1992: 125). Some scholars were even tempted to use Vita-Finzi's Mediterranean model as a dating tool. In Cyprus, this application resulted in an erroneous recognition of Upper Palaeolithic artefacts in a presumed Older Fill (see p. 12).

I.2.2. The eighties: critical examinations of Vita-Finzi's model

In the eighties, many a researcher discovered anomalous alluviation phases, not conforming to Vita-Finzi's scheme. Case studies from different parts of the Mediterranean indicated that erosion and deposition was not that synchronous in the Mediterranean area. As a matter of fact, detailed geomorphological research elucidated occurrence of alluviation phases in between the Older and Younger Fill. As a result, a shift took place in the interpretation of the erosional cause. While Vita-Finzi discovered a regional pattern, several researchers were unable to recognise any supra-regional alluviation phases anymore. As a result, the "climatic deterioration" theory lost its foundation. Hence, human impact on the landscape was suggested to have occurred earlier. Moreover, it possibly was more important a factor in causing erosion than originally thought.

On one hand, the deposition of alluvial sediments, indicative of landscape instability tended to be interpreted as human caused. The research undertaken by van Andel, Pope and Runnels in Greece (van Andel 1986, Jameson *et al.* 1994) inspired to a great extent my thesis. More specifically, the research of van Andel and his team was the first alluvial study in the Mediterranean in close collaboration with an archaeological survey. Moreover, its importance lies in the attempt to correlate the settlement and landuse history with the alluvial sequence. Noteworthy is van Andel's well-founded statement that erosion could be not only the result of rapid cultural expansion but also of cultural collapse (Plate 2: fig.2) (van Andel 1986: 103-128). Although their research was important in making detailed correlations between the alluvial history and the settlement history, a weakness of their causal explanations lies in the absence of any scope for climatic interpretations. As a consequence of this weakness, in this study I will attempt to build a more complex landscape development hypothesis for Cyprus (cf. part II), depending on more variables than those considered for Greece by van Andel and his team.

On the other hand, because the long-term climatic explanation was abandoned, some researchers developed alternative climatic interpretations as to explain the temporal and locational variety of the alluvial deposits. Gilman and Thornes stressed the role of extreme rainfall events in creating major soil stripping. They stated climatic local irregularities could have triggered catastrophic erosion, resulting in alluvial deposits (Gilman & Thornes 1985).

I.2.3. The nineties: stagnation in alluvial research

Recently, several large-scale interdisciplinary surveys took place in the Mediterranean region. An example of such large project is the ARCHAEOMEDES PROJECT, which investigates land degradation and desertification in several areas of the Mediterranean region (van der Leeuw 1995). This project investigates the transformations of the Mediterranean landscape over the very long term, so that processes at very different spatiotemporal scales could be taken into account. Research was undertaken in the Epirus (van der Leeuw 1998) and Argolid regions of Greece (Bailey *et al.* 1993), in the Vera Basin of Spain (McGlade & van der Leeuw 1998 ; Castro *et al.* 2000) and the Rhône Basin in France (Favory and van der Leeuw 1998). In these projects the archaeological survey is well integrated with the geomorphological study and other interdisciplinary research. As a consequence in these projects progress was made in interpreting the causes of sedimentation.

However, in the ninetees most projects still struggled in understanding the causality of the attested sedimentation. Lack of progress on this matter is partly due to the difficulties of precisely dating the deposits in the Mediterranean and also to the absence of proxy-data.

In the Mediterranean unlike in Britain and the USA (cf I.4), a lack of radiocarbon datable material in the sediments is observed. Most alluvial sediments are dated by artefacts belonging to the unit. Artefacts are used for *terminus post quem* datings of the deposition of the unit. As a consequence, they lack the necessary precision to recognise the exact period of deposition, let alone the recognition of short-term catastrophic events. Moreover, due to the method of using artefacts as a dating tool, sediment sections without any cultural markers were neglected in the interpretation. As a matter of fact, these specific sections lacking traces of human impact have a greater possibility of being deposited by extreme climatic irregularities. Although dating with optically stimulated luminescence (OSL) on sediments promised great possibilities, only little use was made in Mediterranean geomorphological studies. The lack of absolute dating is not only due to inherent problems in retrieving datable material, but also to failure in funding. A dating program is expensive. In contrast, in the United States, geo-archaeological researchers have a larger budget at their disposal. As an example, Waters' study on drainage reconstruction of the Amercian Southwest, chronologically pinpointed by about 200 absolute dates, is proof enough high budgets are granted in the USA (Waters 2000: conference contribution). Most

Mediterranean projects deal with no absolute dates while a few projects, notably American directed projects (e.g. University of Texas project in Italy in Abbott & Vastro 1995), have 12 absolute dates at a maximum.

Furthermore, another recurring problem remains the lack of proxy-data in the Mediterranean, resulting in difficulties in interpreting the causes of fluvial deposits. In the northern hemisphere several kinds of proxy data can be correlated with the alluvial stratigraphy, while this is not the case in the Mediterranean. Bog and lake sediments are rather scarce. As a result, providing a sequence with information on several proxy-records (like vegetation history, climate, insects, etc.) from Pleistocene through Holocene, poses a problem, which is particulary attested on Cyprus.

Moreover, the research is often influenced by the research object. What are our geo-archaeological goals? Do we want to attend a conference on "human impact on the landscape" or do we rather wish to write an article on climatic change? In Britain, a similar problem is attested as cultural or natural oriented research tends to depend on the funding body.

I.3. Previous fluvial research on Cyprus

The following account presents an overview of some case studies on fluvial research in Cyprus. Initially, Vita-Finzi inspired several geomorphologists. Subsequently, for more than 10 years, publications on this topic were interrupted for Cyprus. Recently, new interest on the alluvial sediments has resumed.

I.3.1. Idalion, a town with a lack of water?

The site of Idalion is located in one of the most barren areas of Cyprus. Though the river Yialias is only 800 m away, it does not seem to provide the city and its surroundings with the necessary water. Hence, it was thought that the ancient city lacked a sufficient water supply. However, due to a drainage study from air photographs, Koucky and Bullard suggested that the Tremithos River recently captured some of the Yialias drainage (Koucky & Bullard 1974: 12).

They indicate Idalion was founded on an island between two drainages. However, around the 5th or 3rd century, the westernmost river flowing past Idalion dried up. As a consequence, Hellenistic Idalion was concentrated for the greater part along the eastern drainage. From the Hellenistic period onward, the eastern drainage began to fail; though complete failure did not take place until the early Roman period. Accordingly, the water shortage probably triggered the inhabitants to the present day village of Dhali, nearer to the Yialias River (Koucky & Bullard 1978: 12-24).

Koucky and Bullard suggested that the cause for the capture of these drainages is evident. Originally, the Yialias was a rather short river, but has tripled its length over the past two million years. A loss of gradient due to an increase in length resulted in a lack of occurrence of high terraces along the Yialias. This phenomenon is not attested with the Tremithos river and other south draining rivers which built narrow marine terraces, maintained high gradients, and actively cut headward (Koucky & Bullard 1974: 17-19).

Unfortunately, this model for landscape evolution has never been tested geomorphologically nor dated. However, this study indicates the great potential of alluvial research in order to acquire a deep insight into site location, into its environmental setting and into the human response towards environmental deterioration.

I.3.2. Giffords' study of the paleogeography of the Larnaca Lowlands: the Tremithos River

Gifford (1978) undertook geomorphological investigations in the Tremithos river valley, simultaneously as Koucky and Bullard in the Yialias drainage (see I.3.1.). He suggested that the following landscape evolution took place along the Tremithos. During the Late Pleistocene, fan deposits stretching from north of the Main Salt Lake to the Southwest of its present mouth covered the alluvial slope. The Late Pleistocene deposits consist of a layer of homogenous mud with soil development, which is covered by coarse gravel alluvium. This gravel deposition probably occurred sometime after 16,000 BP. After this period of aggradation, the Tremithos River cut into those fan sediments. By the Bronze Age, the drainage pattern of the alluvial slope was split and the Main Salt Lake no longer received alluvium from the Tremithos River. From the Bronze Age into the first millennium BC, the surface of the alluvial slope remained covered by gravel alluvium. At some time during the 4^{th} and 7^{th} centuries AD, a period of deposition occurred in the Tremithos valley. Since Byzantine times, this most recent alluvial fill has been incised (Gifford 1978: 149-152).

This landscape model for the Tremithos River seems to fit in Vita-Finzi's model (1969) (see I.2.2.). However, Gifford observed that the Older Fill of the Tremithos River appeared to be different from the one described in Greece. Although he thought that Vita-Finzi's model was valid for the Tremithos river, Gifford was aware of "anomalous alluviations" in other parts of Cyprus, deviating in chronological terms from the Older and Younger Fill as described by Vita-Finzi.

Indeed, he mentioned a major depositional episode from the Cypro-Archaic period (7^{th}-6^{th} century BC) at Episkopi-*Phaneromeni*. Moreover, he reports evidence of a Neolithic site buried under 2 m of alluvium in the north of the Troodos (Gifford 1978: 172-173). In the Tremithos floodplain as well, Gifford found some possible anomalous deposits, not acknowledged in his general model. More specifically, he found evidence of 2 terraces in the coastal fan region, of which the lowermost contained Early Bronze Age sherds (Gifford 1978: 146). As a conclusion, more precise dating for further understanding of the landscape evolution is imperative.

I.3.3. Badou and Engelmark in the Tremithos valley: Upper Palaeolithic artefacts in an assumed Older Fill?

Interestingly, unaware of Gifford's study along the Tremithos River, Badou and Engelmark dug some test pits along a river terrace of the same river. They attributed the uppermost layers of the pits to the Roman period due to the occurrence of sherds, the youngest Roman. They concluded this layer was similar to the Younger Fill described by Vita-Finzi. In the deeper and more gravelly layers they found only lithic material which they attributed to the Upper Palaeolithic. However, Palaeolithic sites are supposedly non-existent on Cyprus. The gravel bed in which the lithic material occurred was attributed to the Pleistocene period only because it conformed to Vita-Finzi's Pleistocene Older Fill descriptions (Badou 1983: 3-8). However, the discrimination between Pleistocene and Holocene sediments is more complex. As a conclusion, except for the presumed Palaeolithic artefacts and the morphological similarities to Vita-Finzi's fills, substantial dating control is lacking. Hence, this study indicates that Vita-Finzi's model cannot be used as a dating method.

I.3.4. The Vasilikos river

Gomez (1987) investigated the river terraces and the valley fill of the Vasilikos River in southern Cyprus (about 25 km W of the Tremithos River). The valley fill was particularly interesting for geo-archaeological purposes. Research on the valley fill indicated the following sequence of Holocene events.

1. A period of downcutting in Pleistocene river deposits ;
2. Subsequently followed by a period of formation of channel zone deposits. The alluvial fill suggests a wider, shallower, more dynamic, wandering gravel-bed, which supposedly was free of riparian vegetation due to winter floods (Gomez 1987: 350).
3. At some stage, a shift from channel zone alluviation to overbank sedimentation took place. This facilitated the development of the contemporary low-sinuosity, meandering channel and its elevated floodplain (Gomez 1987: 350).
4. A subsequent undated period of downcutting resulted in the incision of the present day channel (Gomez 1987: 350).

Moreover, Gomez (1987: 357) discovered an Aceramic Neolithic fire pit *in situ* in overbank sedimentation layer 3, at a depth of 5.5 m. It was dated between 5,540 and 5,010 BC. This suggests that the Vasilikos floodplain was about 5.5 m lower in the Aceramic Neolithic period than it is at present. Overbank sedimentation was already in progress at that time as the fire pits lay above 0.4 m of silts.

About 4 m above the fire pits, he retrieved Middle Bronze Age sherds (1,900-1,650 BC) in overbank deposits. Nonetheless, Gomez argued of that they were located too high in the sequence and that they probably resulted from more recent erosion of a Middle Bronze Age site. Moreover, in pit 1 (300 m N) he retrieved 15th century AD charcoal at the same depth as the layer with the Bronze Age sherds. He concluded that the Bronze Age sherds from the other section were actually deposited around the 15th Century AD (Gomez 1987: 357) though the description of the sediments was different (see Gomez 1987: table III). Gomez' interpretation was influenced by Vita-Finzi's model.

As a conclusion, Gomez' study indicates Vita-Finzi's model is too simplistic and undifferentiated for Cyprus. Indeed, the occurrence of a Neolithic fire pit *in situ* within alluvial sediments and a possible Bronze Age alluvial layer deviate from the Vita-Finzi scheme.

I.3.5. Pleistocene river terraces throughout Cyprus

Poole (1992) investigated Pleistocene river terraces from Cyprus. He recognised 4 alluvial units, termed fanglomerates [1], formed at progressively lower topographic levels. Fanglomerate 1 was deposited during the Early to Middle Pleistocene, mainly as a result of the high rate of tectonic uplift during that period. The early Middle Pleistocene terrace, fanglomerate 2, was due to a combined cause of a high glacio-eustatic sea level, followed by surface uplift. Fanglomerate 3 was deposited between 219-184 ka BP and Fanglomerate 4 around 141-116 ka BP (Late Pleistocene). Their correlation with marine terraces suggests that they resulted from high sea levels, followed by further uplift and river downcutting. Moreover, supposedly a more humid climate during interglacials was an additional control on the deposition of sediments. The decrease in volume of the clastic sediments after the early Middle Pleistocene suggests that tectonic uplift waned from the Pleistocene to the present time (Poole & Robertson 1998: 564).

I.3.6. Palaeo-landscapes of the North Troodos foothills

Wells and her geomorphological team (2001) found evidence of two pairs of Holocene river terraces in the northern Troodos foothills. The terraces were only preliminary dated using sites as *terminus ante quem* for sedimentation. Hence, the oldest occupation on any surface yields a minimum age estimate. The oldest Holocene terrace is located about 4 to 10 m above the modern channel. On this surface exclusively Early Bronze Age and Late Chalcolithic period artefacts were discovered. Moreover, soil development and surface weathering probably confirm this surface was extant until the Late Bronze Age. On a river terrace 2 to 4 m above the modern channel, Roman period occupation was discovered. Consequently, it was estimated that stream incision was on the order of 2 and 6 m between the Bronze Age and the Roman period (Wells 2001: 135). Although some preliminary insight was gained into the chronology of the alluvial sequence of the North Troodos foothill rivers, one should be careful with these temporal annotations. First, the study

[1] Fanglomerate: coarse Pleistocene-Holocene sediments (Poole *et al.* 1998: 545)

omitted to mention whether these artefacts were in archaeological terms *in situ* or whether they were redeposited. Next, if they are *in situ* in archaeological terms they can be used as a *terminus ante quem* for the sedimentation. As a matter of fact, the sedimentation could be much older than the artefacts.

I.4. Mediterranean compared to British and American alluvial research

In this section, the state of alluvial research in the Mediterranean is briefly compared to the one in the UK and the USA. Hence, the differences will become obvious and insight from research in other parts of the Mediterranean can be gained.

I.4.1 Alluvial research in Britain

Macklin (1993) reviewed the existing literature on fluvial research in Britain (Plate 3: fig. 3). Fifty-nine studies contained 123 well-dated alluvial units (Macklin 1993: 109-110). This is a large number of dates compared to only about 35 well-dated units in the Mediterranean area. We may say the alluvial research in the Mediterranean is less developed. This is partly due to the paucity of methods in dating the alluvial deposits in the Mediterranean. In Britain 62 units were dated by radiocarbon on wood or peat, 40 units by archaeological material, 25 units by pollen and 3 by soil development (Macklin 1993: 113). In the Mediterranean, unlike Britain, wood and peat are seldom retrieved in alluvial sediments while pollen is rarely preserved.

Even more noteworthy is the discovery of a pattern in the alluviation in Britain. Major phases of alluviation took place at : 7,600-6,400 BC (in lowland Britain),
2,800-2,200 BC (country-wide),
1,800-1,300 BC (southern Britain),
0-400 AD (country-wide),
800-1,200 AD (country-wide),

1,200-1,600 AD (southern Britain)

and 1,600-2,000 AD (upland northern and western Britain).

The synchronicity of the fluvial episodes suggests that climate supposedly directly controlled the sedimentation and erosion in British rivers (Macklin1993: 109). Moreover, similarities with fluvial sequences in the USA also confirm possible more profound influence of the climatic factor. As a consequence, the British Holocene fluvial record is considered mostly a result of the climate, though also culturally blurred. Although human impact on the landscape was undoubtedly important for initiating erosion, deposition of this sediment by widespread alluviation would only have taken place during short periods of abrupt climatic shift (Macklin 1993: 119).

On the other hand, in the Mediterranean, unlike in Britain, there is a tendency towards attributing the erosion to human impact on the landscape. Indeed, the Mediterranean environment is probably more prone to human impact, though aided by its climate. However, it is difficult to disentangle both factors. The "human caused" interpretation could be mere result of the scarce chronological control. In this study, an attempt was made to use a similar method as Macklin (1993) did for the UK. More specifically, a database of dated alluvial units is composed for the Mediterranean. A major problem was encountered due to the lack of well-dated units (cf. plate 229, 230 and 231). As a consequence, this problem hampered far-reaching causal interpretations.

I.4.2. Fluvial research in the USA

In the USA, geo-archaeology has a longer tradition as a subdiscipline. This is not only due to greater scientific academic background of some archaeologists/anthropologists but also to the nature of the sites (Brown 1997: 167). Hence, this is obvious in the quantity and quality of the research. In the Mediterranean, the dating of the units is relatively scarce while in the USA more than 10 absolute dates on a drainage are a standard procedure; moreover up to 200 absolute dates are retrieved for some drainages. Examples of recent studies with good chronological control in the USA are Waters (1991, 1995) and Abrogast & Johnson (1994).

The above studies favour the causal interpretation of how far humans had an impact on the landscape and how far the climate had an impact on the alluvial sequence of the USA. Macklin noted that the alluvial sequence of the USA shows some remarkable similarities with the Holocene sequence of the UK (Macklin 1993). In the USA, Knox also identified alluvial discontinuities at 8000, 6000, 4500, 3000, 2000-1800 and 800 BP (Knox 1983). Furthermore, in a more recent study, Abrogast and his collegues discovered a regional pattern in alluviation for Kansas and the Great Plains (Plate 3: fig. 4) (Abrogast & Johnson 1994: 302). Hence, the regional synchronicity of the alluvial events implies some kind of climatic forcing.

I.5. Significance of this research

Obviously, there is an urgent need for well-dated fluvial studies in the Mediterranean and especially for Cyprus before any major progress can be achieved. As investigated above, only little attention was dedicated to the geo-archaeological subdiscipline on Cyprus. At present, the last pieces of evidence of previous landscapes are being destroyed by major land development. Hence, geo-archaeological research in Western Cyprus is jeopardised and the bulldozing of the landscape goes on.

We may say it is beyond any doubt that alluvial research can offer a variety of information for archaeologists on Cyprus.

First, it can deliver information on site locations. This has already been exemplified by the study of Koucky and Bullard (1974) for the site of Idalion. The ancient city of Idalion is not fully understood without gaining insight into its water provision. As a matter of fact, there is a striking difference between the original well-watered topography and the present barren landscape.

Secondly, before understanding the settlement patterns on Cyprus, it is imperative to acknowledge the limitations geologic processes impose on the archaeological record. More specifically, some sites have been destroyed by channel activity. This erosional process is likely to cause damage to archaeological sites close to the channel and on the outer edges of meanders. Moreover, some sites on slopes might have been eroded while other sites were buried by alluviation. The latter is more likely to occur on the lower parts of the floodplain.

Finally, alluvial research will make it possible to create landscape reconstructions and will broaden the scope from the site oriented archaeology towards a fuller understanding of the past. Humans lived in a world composed of many places. Hence, restricting our insight into Cypriot people in the past to discrete archaeological sites, unnecessarily narrows our understanding of their way of life. Changing patterns of human land use and environmental impact must be seen as an integral part of social geography. Obviously, a new model should be developed for landscape change on Cyprus as Vita-Finzi's model is outdated.

Eventually, when the Mediterranean alluvial research reaches the same standards as in the USA, deeper insight will be gained into climatic and anthropogenic impact on the landscape.

The crux of the issue here is chronology. In this thesis, attention will be paid towards the dating of the alluvial record in Cyprus (cf. chapter VI). Besides typology and stratigraphy, a relatively new method of optically stimulated luminescence dating on sediments and a quick and cheap TL-application on abraded sherds will be applied.

PART 2: A literature study: The variables

II. An environmental history of Cyprus

II.1. Climatic and ecological conditions on Cyprus

Little is known about the climatic history of Cyprus. Several attempts to retrieve pollen cores have failed because pollen is rarely preserved on Cyprus due to the highly alkaline and oxidising environments in most sediments. Moreover, only relatively few attempts were undertaken to retrieve pollen (King 1987: 6). Bottema (1966: 133) tried to retrieve pollen near the site of Kalopsidha, though discovered that the pollen preservation was bad. A new attempt at the site of Hala Sultan Tekke in 1976 resulted in the same conclusions (Bottema 1976: note on pollen). Two cores near Statos were retrieved from a closed waterlogged basin adjacent to the Ayia Moni Monastery in the upper reaches of the Ezousas river. Once more, researchers mentioned that difficulties were encountered in retaining enough pollen (Rupp 1984: 44). However, two pollen studies on archaeological sites were more successful, one at the Neolithic site of Khirokitia and another one at the Chalcolithic site of Lemba-*Lakkous* (see below). As a matter of fact, there is a lack of systematic research on other proxy-data from Cyprus, such as charcoal, speleothems[2], palaeosols, lake sediments, marine cores and tree rings. As a consequence, archaeologists have to rely partially on evidence from the main land, where a vast amount of environmental studies have been published. Recently, several syntheses on climatic evolution in the Near East have been published by specialists, such as Sanlaville (1996), Sanlaville (1998), Van Zeist and Bottema (1982) and Hillman (1996).

[2] carbonaceous cave deposits (Dincauze 2000: 119)

II.1.1. Cyprus before human colonisation; the Pleistocene and Tardiglacial

Although substantial research was done on Pleistocene sediments on Cyprus, it was oriented more towards tectonics and sea-level change rather than to palaeoclimates. Recently, Rachel Gamble[3] has undertaken research on a loess sequence at Kissonerga-*Skoroutsos* and documented environmental change in Cyprus during the last glacial. Although not absolutely dated yet, the sequence seems to be very important as it contains a lot of pure climatological information, unbiased by any human impact because the first humans probably only arrived on Cyprus around the 13th millennium BP (cf. Simmons 1996).

- The Last Glacial Maximum: 25,000-15,000 BP

Evidence from deep-sea cores and lake levels in Israel indicates that between 20,000 and 14,500/14,000 BP the climate was cold and dry over the entire region. In the Levant, the Last Glacial Maximum probably lasted from about 22,000 until 16,000 BP. The coastal ranges in Syria, Lebanon and Israel would have received winter precipitation although the lakes would have reduced in size. Pollen analysis from several locations in the Near East show that during the Last Glacial Maximum, trees were absent, but *Artemisia* and *Chenopodiaceae*, however scarce, formed a semi-desert vegetation (Sanlaville 1998: 251; Sanlaville 1996: 22; Bintliff & Van Zeist 1982).

- 14,000-11,000 BP: climatic improvement

In the Levantine area from circa 14,000 until 13,000 BP a wetter period occurred, with an annual rainfall of possibly up to 400 mm. An increase in arboreal pollen is observed during that period. In addition the temperature was higher. Temporary small lakes appeared and larger lakes expanded. From 13,000 until 11,000 BP, a

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[3] Undergraduate dissertation 2001 – University of Edinburgh

brief warm spell was followed by a warm and wet period (Sanlaville 1996: 22-23; Sanlaville 1998, van Zeist & Bottema: 289).

- 11,000-10,000 BP: Younger Dryas

Around 11,000 (until 10,000 BP) a dry and cold period followed. This dry and cold period has been attested in the whole Levantine area, but its chronology, intensity and development needs to be further detailed (Sanlaville 1998: 25). The extreme aridity during this period is attested in the pollen cores, lake levels, deep-sea cores and eolian deposits. The vegetation consisted of a high abundance of Chenopodiaceae, semi-desert sage-brush and scarcely scattered Pine trees (Sanlaville 1996: 23; Rossignol-Strick 1993: 144).

The two salient features of the Pleistocene fauna in Cyprus are the lack of species diversity and evolutionary nanism. Pleistocene fossils on the island consisted almost exclusively of the remains of two terrestrial mammals, the endemic pygmy hippotamus and the endemic dwarf elephant. It is obvious that the limiting effect of insularity on the faunal diversity seems to have been severe during the Pleistocene. The absence of small carnivores and other mammals would have meant that the island's hippopotamus and elephant population were not subject to selective pressures by predation and resource competition (Held 1992: 11-15). It is noteworthy that around the transition from the Pleistocene to the Holocene, at about the 13th millennium BP, the species became extinct. A striking fact is that the oldest evidence of humans on the island dates from that period. The puzzle of whether humans were the main agents or only the "last straw" in the extinction of the pygmy hippopotamus and elephant population has not yet been solved (Simmons 1996: 103).

II.1.2. Cyprus starting from the Neolithic colonisation; the Holocene

Cyprus was probably colonised from the Holocene onwards by Neolithic people which makes it difficult to disentangle climatic and human impact on the environment. As an example, is an observed decrease of arboreal pollen a result of human caused deforestation or rather a result of drier climatic conditions? And what was the relative impact of humans and climate on the subsequent erosion? Obviously, it is very hard to hold any one variable constant as the causal factors were inter-related.

Indeed, in the Holocene the vegetation history was not only a result of the climatic history anymore. Because people cleared space for agriculture, herded animals and exploited forests for fuel wood, the vegetation was altered. As a consequence, an increase in plants thriving in disturbed areas, is expected. Hence, the vegetation became partially the result of continued land use. In section III.1., the subsistence economy and its impact on the environment is investigated. The use of pollen in order to understand the Holocene climate becomes more difficult due to human impact on the vegetation. As a consequence, climatic evidence from the salt caves around Mount Sedon (on the shore of the Dead Sea) and from the lake level studies is crucial. In order to achieve a climatic history, Frumkin and his team used the following parameters in combination with several ^{14}C dates: the elevation of the salt cave passages, the ratio of their passage width, the formation of marl and the relative abundance of plant types (Frumkin *et al.* 1991: 191-200). As a consequence of a lack in Cypriot climatic studies, the climatic staging of Frumkin and his team will be used as a framework in this study. However, the extrapolation of Jordan Valley proxy-data for Cyprus has some weaknesses. Although the distance between the Dead Sea and Cyprus is only about 500 km, the present day rainfall amount is lower at the Dead Sea than in most parts of Cyprus and especially the "wet" Western Cyprus area. As a matter of fact, the Dead Sea is located at a transition zone between extreme desert of the Saharan type and a relatively mesic Mediterranean zone (Danin 1993: 26). However, considering the relatively short distance between the Dead Sea and Cyprus, we can presume that a change in the Dead Sea area might also have taken place on Cyprus. I will try to substantiate and complement the Dead Sea salt cave evidence with studies from other regions surrounding Cyprus and with the minimal evidence from Cyprus itself. Indeed, Frumkin's results largely agree with the syntheses by Sanlaville (1996), Sanlaville (1998), Van Zeist and Bottema (1982) and Hillman (1996).

- 10,000-7,000 BP

It is suggested by Peltenburg that Neolithic people from the main land colonised Cyprus at the beginning of this climatic phase (Peltenburg *et al.* 2000: 844). Frumkin and his team discovered that the moistest period of the Holocene could have started around 10,000 and lasted to around 7,000 BP (Frumkin *et al.* 1991: 196-197; Sanlaville 1996: 23). It is even suggested that summer precipitation could have taken place during this period (El-Moslimany 1994: 128-129). Consequently, people of the Khirokitian Aceramic Neolithic (8,000-6,500 BP) could have been exposed to this warm and wet climate. Pollen cores from several sites in the Mediterranean indicate that deciduous oak trees found sufficient moisture (that is at least 650 mm precipitation) even in summer. Forests included other deciduous trees such as *Tilia* (lime), *Corylus* (hazel), *Fraxinus* (hornbeam) and *Ulmus* (elm). The abundance of *Pistacia* around 8,000 BP indicates warm, frost-free winters (Rossignol-Strick 1993: 144). Recent anthracological research from the sites of Parekklisha-*Shillourokambos* and Khirokithia on Cyprus indicates that between 10,000 and 6,700 BP the coastal lowlands of Cyprus contained generally an abundance of *Pistacia* forming a forest steppe. However, Thiébault recognised some changes over time in the vegetation cover. The area around *Shillourokambos* first contained quite a lot of *Quercus* (oak). Over time, an increase in *Olea* (olive) took place first and was followed by a decrease in *Pistachia*. Subsequently, Thiébault observed an important increase in *Quercus* (oak) and *Pistacia* (around 8,000 BP) in the sequence of Khirokitia as noticed elsewhere in the Levant. The previous vegetation stage was then followed by a decrease in *Quercus* (oak) and subsequently by an increase in *Prunus* (around 6,500 BP). Thiébault noted that about 6,500 BP, vegetation around the site of Khirokitia was cleared (conference contribution Thiébault 2001).

- 7,000 - 5,200 BP

The end of the previous moist period was then followed by drier conditions. According to Frumkin and his team, this period probably was the driest in the Holocene (Frumkin *et al.* 1991: 197). The Dead Sea level record indicates a fall in water level immediately after 6,700 BP, which marked aridification (Goodfriend *et al.* 1986: 349). From 6,000 until 5,200 BP, again an increase in precipitation has been observed in the salt caves of the Dead Sea (Frumkin *et al.* 1991: 197). It is remarkable that all evidence of Neolithic humans on the island disappeared for a while, synchronous with deteriorating climatic conditions. From 6,500 until 5,600 BP, an apparent gap in the archaeological record of the island is attested. A deteriorating climate reducing the population on the island has been suggested (Stanley Price 1978: 34-39). The Sotira culture (4,500-3,900 cal. BC) (Peltenburg 1978) probably developed in those arid climatic conditions. However, climatic conditions improved quickly in the Chalcolithic period (starting from 3,900 cal. BC).

- 5,200-4,200 BP (± 4,000 - ± 2,900/2,600 cal. BC)

From 5,200 BP on, moist conditions occurred again. This stage was the moistest period of the second half of the Holocene as evidenced by data from the Dead Sea salt caves (Frumkin *et al.* 1991: 198). Consequently, the majority of the Chalcolithic period (3,900-2,300 cal. BC) was marked by an increasingly moist climate. Pollen analysis from the Chalcolithic site Lemba-*Lakkous* revealed that although the area around the site was cleared of most trees, the climate was moist as attested by the occurrence of *Alnus* (elm) and aquatic plants in the neighbourhood of the site (Renault-Miskovsky 1985: 306-311).

- 4,200-3,200 BP (± 2,900/2,600 cal. BC - ± 1,500 cal. BC)

A decrease in rainfall which persisted until about 3,200 BP, was observed by Frumkin and his team from 4,200 BP on (Frumkin 1991: 198). Additionally, Weiss (2000) pointed to the extensive evidence of environmental degradation at the end of the 3rd millennium BC. He assembled the following data for abrupt climatic change in West Asia and the Eastern Mediterranean. Evidence from the Lake Van varve record suggests a rapid increase in aridity at ca. 2,290 continuing until ca. 2,000 BC.

Moreover, the Soreq cave isotope record and other caves of the Dead sea indicate aridification at ca. 4,150 BP. Additionally, in the Gulf of Oman, a core suggests a short dry period about ca. 2,200 BC. Furthermore, in Turkey, four available lake pollen cores reveal a consistent picture of drought for the period ca. 2,200-1,900. Lake cores from Italy, northwest Greece and Crete document lake-level reductions and synchronous dramatic reductions in arboreal pollen (Weiss 2000: 77-80). Of note is that throughout the Near East this period experienced settlement contraction, destruction, abandonment and fragmentation (Peltenburg 2000: 183-200). Pollen samples from the settlement of Lemba-*Lakkous* (Western Cyprus) dated to the mid-third millennium cal. BC suggest climatic deterioration causing resource stress. Aquatic plants disappeared in the pollen record at that time. This is interpreted as a lowering of the water table and a temporary cessation of dependable stream flows. About 2,500 cal. BC, the vegetation around the site consisted only of relict pine and a severely reduced woodland cover (Renault-Miskovsky 1985: 306). Also on Cyprus cultural changes took place during that particular period: the transition to the Bronze Age occurred around the beginning of the above mentioned drier period.

- 3,200-3,000 BP (± 1,500 cal. BC - ±1,300/1,200 cal. BC)

Some time during the Late Bronze Age, a short interval of slightly moister conditions was observed (Frumkin *et al.* 1991: 198).

- 3,000-2,000 BP (± 1,300/1,200 BC - ± 0 BC)

Climate changes took place at the transition of the Bronze Age to the Iron Age. Climate became dry compared to the slightly moister conditions in the preceding stage (Frumkin *et al.* 1991: 198). These conditions prevailed throughout the Geometric, Archaic, Classical, Hellenistic and at the beginning of the Roman period.

- 2,000-1,700 BP (± 0 BC - ± 260/380 cal. AD)

During the Roman period slightly moister conditions prevailed compared to those in the previous period (Frumkin *et al.* 1991: 198). Sometimes, the Roman period in the Near East is compared to a miniglacial. The overall wet period during Roman times reached its average peak ca. 90 AD. Crop yields in Israel were very high during the

1st century AD as noted in rabbinical sources, the Mishna and Talmud. However in the second century AD, the climate became drier. This is also attested of in the rabbinical sources, which describe a sharp drop in crop yields in the 3rd century (Bruins 1994: 307-308). As a matter of fact, Lang discovered other historical sources suggesting Cyprus was nearly depopulated due to a seventeen year of drought (Lang 1878: 238).

- 1,700-1,100 BP (± 260/380 cal. AD - ± 900/1000 cal. AD)

According to Frumkin's team, the Byzantine period was significantly drier than the Roman period (Frumkin *et al.* 1991: 199). Lamb also recognised some periods of maximal drought in the Eastern Mediterranean, more specifically between 300-400 AD and around 800 AD (Lamb 1995: 168). There is evidence that Cyprus would have known some severe droughts in the 4th century AD. According to a historical source of the Byzantine Commisioner of Cyprus in 327, the whole area around a monastery on Cyprus was infested with venomenous snakes which had multiplied catastrophically as a result of a 36 year long drought (cf. Hackett 1901).

- 1,000 cal. AD – 1,550 AD

In the Late Byzantine period and throughout the Frankish period (from 1191 AD), the climate again became slightly moister and warmer than in the previous stage (Frumkin *et al.* 1991: 199). It has been suggested that the rise and fall of the sugar industry is linked with climatic change. Between its establishment about 1000-1200 AD and its decline around 1550 AD a notably warm and wet period occurred. Temperatures could have been about 1 to 2 °C higher compared to present-day average temperatures (Galloway 1989: 46). More intensive rainfall and more extreme temperatures were observed during the Venetian period (1489-1571) (Lamb 1995: 207). Historical sources describe an extreme drought event, which harassed Cyprus. The chronicler Macharias (14th century) narrated:

> "There was a great famine for the lack of rain and all tillage was spoiled. And the famine became great, and all the waters of the springs failed, and men were going from place to place with their flocks to find water that they might live, they and their flocks. And everything dried up, both cisterns and springs; and they deserted our most admirable Cyprus." (Christodoulou 1969: 28)

Additionally, an extreme frost event was recorded in 1468, which destroyed the entire sugar cane harvest (Luttrell 1996: 168).

- The Little Ice Age : 1,550-1,700 AD

Most of the Ottoman occupation on Cyprus took place during the "Little Ice Age". Although the Little Ice Age is best documented for Europe, there is some evidence of cold and wet conditions throughout the Mediterranean, which was associated with alternating seasons of drought and flooding. However, evidence from Cyprus is very poor and nothing can be said about any effects in Western Cyprus (King 1987: 13). For this specific period on Crete, more research has been undertaken. An analysis of many documentary sources from the Venetian and Turkish periods was undertaken by Grove and Conterio. They concluded the weather conditions between 1548 and 1648 were anomalous compared to twentieth century standards. Exceptionally severe winters and summer rains and an increase in spring and winter droughts took place during that period. Some of these fluctuations could have affected vast areas and could have been caused by the extension of the southerly air masses from the Sahara. As a consequence, snowfall could have been heavier and probably lasted longer than in the nineteenth and twentieth centuries. While deluges seem to have been similar in intensity to twentieth century storm events, some may have been more extreme and widespread (Grove 1995: 223-245)[4].

- 1,700 – present day

As a matter of fact, there is more extensive climatic information available about recent periods (the end of the Ottoman period and the British colony). At the end of the 19th century several years of drought were observed on Cyprus. Lang, a British consul on the island described the year 1869 as having been very dry. During that particular year, the entire annual rainfall amounted to only 13 cm. As a consequence, a total failure of the crops was recorded (Lang 1878: 239). Nevertheless, this period

[4] Grove *et al.* (1995: 244) stated that their research is the first investigated historical data with detailed reconstructions of the Little Ice Age climate for the Eastern Mediterranean. The same potential for reconstructing the Little Ice Age climate does exist for Cyprus as it had a similar history and hence similar documents from Venetian and Turkish authorities.

of drought was followed by about 50 wet years. Since 1955, the climate has again become drier (Kutiel *et al.* 1996).

II.1.3. Present day

The present day climate of Cyprus is classified as Mediterranean with some local variations of Sahara-like desert to Alpine climate. Summer temperatures rise to about 30 °C. In winter, the temperatures decrease to about 10 to 14 degrees. Obviously, in the mountains, temperatures are colder. The peaks are even covered with snow for about 3 to 4 months (Christodoulou 1959: 19-41). Rainfall on Cyprus may be compared to precipitation in Syria where a minimum rainfall of 100 mm/year and a maximum of 1000 mm/year are observed. The Mesaoria is the driest area of Cyprus, due to its location in the rainshadow of the mountains. Overall, the Western Cyprus Geo-archaeological Survey area is marked by the highest rainfall level compared to the rest of Cyprus. The Dhiarizzos drainage outshines all other drainages in precipitation amount (over 400 million gallons of water per square mile a year) (Christodoulou 1959: 39). As a matter of fact about 80% of the rain falls from November until March (50 to 100 cm a month in Western Cyprus), sometimes in the shape of heavy rains, resulting in flash floods. The summer months are very dry, sometimes associated with a thunderstorm (5 to 15 cm a month in Western Cyprus). The precipitation strongly mirrors the elevation variation (Christodoulou 1959: 19-41).

Modern vegetation predominantly consists of a mosaic of maquis[5], garigue[6] and steppe[7] with some deciduous woodland and coniferous forest. A coniferous forest occurs mainly in the mountainous areas. Due to good conservation practices in recent times, Cyprus is one of the most forested islands of the Mediterranean region today. It is often supposed that the present-day distribution of relict vegetation

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[5] *Maquis*: evergreen trees that have been reduced to shrubby, low stature by a combination of browsing, burning and wood cutting (Rackham & Moody *et al.* 1996: 277)

[6] *Garuige*: gray-green aromatic shrubs – unlike maquis, garigue species are not young trees but undershrubs, permanently of low height (Rackham & Moody *et al.* 1996: 277).

[7] *Steppe*: herbaceous plants, including grasses, bulbous or tuberous perennials and annuals (Rackham & Moody *et al.* 1996: 277).

provides clues about the inherent capacity of the land and climate to support different vegetation formations (Christodoulou 1959: 227). Reconstructing the climax vegetation by extrapolating modern vegetation to the past, is not at all a straightforward task. However, the definition of present-day bio-climatic zones is useful for any landscape reconstruction. The Western Cyprus Geo-archaeological Survey area is located in a zone where relict oak vegetation is observed (Christodoulou 1959: 227).

II.1.4. Implications of climatic change on land degradation

Climatic changes can have a strong effect on land degradation. Explaining these changes and building a model that can be applied for the interpretation of the alluvial record on Cyprus, is imperative.

II.1.4.1. Changes in chemical precipitation of calcium carbonates

Climatic changes are likely to have had a short-term impact on the chemical precipitation of calcium carbonates in the soil (Imeson *et al.*1992: 101). Low precipitation during a period of only 50 years can already lead to the development of caliche in calcium rich soils. The resulting petrocalcic layers can have profound implications for hydrology if they are located at or near the soil surface (Imeson *et al.* 1992: 105). Precipitation translocates calcium carbonate from the surface horizon to an accumulation layer at some depth. However, when a moisture deficit is present, even seasonally, calcium carbonate is reprecipitated (Driessen & Dudal 1991: 221).

II.1.4.2. Changes in supply and breakdown of organic matter

Changes in supply and breakdown of organic matter have a huge impact on soil structure and affect soil and hill-slope hydrology. Organic material plays a vital role in soil fertility. Its high exchange capacity retains nutrients and leads to favourable micro-aggregation promoting water retention (Imeson *et al.* 1992: 105-110). An aridity increase may lead to an extended period less favourable for plant nutrition. As a consequence, there is occurrence of shifts in plant and tree species composition. Hence, a change in input of organic matter into the soil is attested. However, vegetation adjustments only occur after several decades (Imeson *et al.*1992: 106-107).

II.1.4.3. Land degradation, soil erosion and river channel change

Reduced amounts of organic matter contents result in less stable soils. Consequently, soils can respond to water by slacking, swelling, dispersion and cracking. As a result, more runoff will take place (Imeson *et al.* 1992: 115).

The erodibility of the soil is often highest after a prolonged dry spell. Research has indicated that one or two rainfall events each year produce an extremely high proportion of the total yearly soil loss (Imeson *et al.* 1992: 121).

On the one hand, a change to a drier climate leads to a decrease in vegetation cover, sheet erosion of slopes and deposition of debris flows (plate 2: fig. 2). Sheet erosion is caused by overland flow and also due to flow in shallow channels or rills. Obviously, this occurs when the slope mantle is vulnerable due to plant reduction after a prolonged drought period (van Andel 1986: 112). Increased aridity and higher rates of erosion cause transported material to accumulate on fans and only allow a reduced supply of coarse material to the river channels (Imeson *et al.* 1992: 123).

On the other hand, a change to a wetter climate leads to gully erosion (plate 2: fig. 2), concentrates runoff and produces stream-flood deposits in case the increase in precipitation is not immediately compensated by denser vegetation (van Andel 1986: 111-112).

II.1.5. Developing a landscape model taking into account only one variable: the climate

As a consequence of above mentioned climatic history research and its possible impact on the soil archive, we could build a hypothetical Holocene landscape model, which could be compared to the geomorphological fieldwork on Western Cyprus. The climatic evidence indicates that our model needs to be more elaborated than the Vita-Finzi two-tiered landscape model, consisting of an Older and Younger Fill. Vita-Finzi assigned the Older Fill to Pleistocene climatic conditions and the Younger Fill due to the Little Ice Age (1969). Climatic fluctuations during the Holocene were far more extreme compared to the Little Ice Age fluctuation as indicated by Frumkin's graphs and the Dead Sea levels (Frumkin *et al.* 1991: fig 7 and fig.8).

The following hypothesis is based only on climatic evidence. As a matter of fact, humans, earthquakes and sea-level changes accelerated erosion and deposits in the river valleys. As a consequence, these variables will be taken into account in chapter V, containing a more complex model.

The moistest period of the Holocene could have taken place between 10,000 and 7,000 BP (Aceramic Neolithic period). Hence, we can expect overbank sediments from the Aceramic Neolithic in river valleys as a consequence of frequent flood occurrence. The sudden drying of the climate around 7,000 BP might have initially had a stabilising effect on the river systems causing soil formation and river incision. However, as the vegetation grew scarcer an increase in sheet erosion might have taken place, depositing debris flow in river valleys. Subsequently, during the Early and Middle Chalcolithic (between 3,900 and 2,900 cal. BC), a very moist period followed which probably resulted in increased runoff and erosion, causing deposition of streamflood sediments in the river valleys.

In the second half of the Holocene, climatic fluctuations were less extreme and conditions were more similar to today. After 2,900 cal. BC, climatic conditions became dry persisting for about a millennium. At the beginning of this phase, we may expect a period of landscape stability, soil formation and river incision. However, in the long run (thus at the end of the 3rd millennium BC), the arid climate might have reduced the vegetation cover. This might have led towards increased sheet erosion and debris flow deposition in the river valleys. Hence, the late 3rd millennium climatic deterioration might have caused debris flow and alluviation. As a consequence of moister conditions prevailing during the Late Bronze Age, an increased runoff and sedimentation in the river valleys may be expected, especially at the beginning of this phase, when vegetation might have been scarcer.

The same cycle might have repeated around the transition to the Iron Age (1,000 cal. BC), when the climate became drier again and consequently probably resulting in river incision. Subsequently, during the Roman period moister conditions might have resulted in increased runoff, river discharge and deposition of alluvial sediments.

As a matter of fact, most of the Byzantine period was significantly drier than the previous period, and was followed by a wetter Late-Byzantine and Frankish period. Hence, the same cycle might have repeated.

From 1,300 until 1,700 AD the impact of short-term extreme rainfall events alternated with extreme droughts should not be underestimated. This climatic incidence is historically evidenced for Crete, and consequently may have taken place on Cyprus. Consequently, alluvial deposits from that period in the Cypriot river valleys may be expected.

Since 1955, climate has become drier, hence river incision may be expected.

II.1.6. Conclusions

As a conclusion, the climate probably has alternated between moist and dry periods since the last glacial. During the first half of the Holocene climatic changes were more extreme than during the second half. As a result, the climatic evidence suggests that Vita-Finzi's two-tiered landscape model is too simplistic. More specifically, the early Holocene probably underwent a succession of extreme climates supposedly resulting in deposition of alluvial sediments.

II.2. Sea level fluctuations

II.2.1. Sea level evolution in Cyprus

Sea level reconstruction is not a simple issue as not only climatic variations but also eustatic and tectonic changes (cf. II.3) affected the sea level (cf. Flemming 1978). In the context of Cyprus, at the border between the African tectonic plate and the Anatolian tectonic microplate, it is not so surprising to detect tectonic movements (cf. chapter II.3). Additionally, uplift might have occurred relatively locally, as structural contexts differ throughout the island.

However, broadly outlined, the following sea-level changes might have taken place:

After the Last Glacial Maximum, a global sea level rise due to melt-water influx was a result of the decrease of the ice-sheets. Gomez & Pease (1992 :1)suggest that the main post-glacial rise in sea level occurred between 15,000 and 11,000 BP on Cyprus. As a matter of fact, at about 20,000 BP, the mean sea level in the Mediterranean was possibly about 120 m lower than at present (Gomez & Pease 1992: 2).

By ca. 11,000 BP mean sea level had already risen to about –35 m (Gomez & Pease 1992: 2). Hence, the coastal plain was far more extensive than it presently appears when Neolithic people colonised the island. The shoreline of the north coast could have extended about 1 km further seaward. On the other hand, the shoreline of the south coast about 1.5 to 2.5 km seaward (Gomez & Pease 1992: 4).

Research indicated that the sea level continued to rise to a level of about –1 m at ca. 5,000 BP. Hence, the Chalcolithic people of Cyprus would have known a sea level only slightly lower than today (Gomez & Pease 1992: 4).

Between 5,000 and 3,500 BP, the sea level probably fell slightly, resulting in a sea level at about 2 m below present around 3,500 BP (Kayan 1996: 43).

Between 1,000 and 0 BC, a rapid rise occurred resulting in a sea level about 0.2 to 0.3 m lower than at present (Kayan 1991: 79-92). Several harbour sites on Cyprus seem to confirm the slightly lower sea level in the historical past. Evidence from an ancient anchorage at Kioni (Akamas) in use from the Cypro-Archaic until the Roman period, indicates that the sea level in the cove was about 0.5 m lower than today (Leonard 1996: 149). Also the harbour of Paphos seems to indicate a relatively lower sea level during the Roman period. At present, the ancient breakwaters are 4.5 m below the surface. However, Leonard attributes the lower sea level partially to subsidence of the coastal area (Leonard 1996: 149).

II.2.2. Impact of the sea level on the fluvial system

The sea level is the base level for most streams. Changes in base-level may influence alluvial erosion and aggradation by changing the channel gradient. A sea level fall promotes channel entrenchment throughout the basin. On the other hand, a raising sea level may promote sedimentation, at least in the coastal area (Fredrick 2001:68; Miall 1991: 501).

Indeed, as the main sea level rise after the last glacial took place between 15,000 and 9,000 BP, most impact of the sea level on the fluvial system supposedly took place during that period. During that period the rising sea level probably imposed aggradation on the rivers in Western Cyprus. The suggested continued sea level rise from 9,000 to 5,000 BP, though at a slower pace, might have favoured a mode of sedimentation in the river basins.

The slight fall in sea level between 5,000 BP and 3,500 BP might have promoted incision of the river valleys. The rapid sea level increase from 1,000 BC until 0 BC, might have favoured again aggradation.

According to Frederick (2001: 68) climatic events are more influential in controlling alluvial activity than base level. However, the effects of sea level changes ought not to be underestimated.

II.2.3. Conclusion

As a conclusion, the rising sea level after the last glacial might have favoured aggradation in the rivers in Cyprus, especially between 11,000 and 5,000 BP. Subsequently, a suggested sea level fall might have promoted incision about 5,000 until 3,500 BP. Moreover, the rapid sea level increase from 1,000 BC until 0 BC might have favoured aggradation again.

II.3. Tectonic history

Research indicates tectonic activity had impact on the alluvial sequence. As a consequence, the investigation of the archaeoseismicity of Cyprus and subsequent impact on rivers is imperative.

II.3.1. An overview of tectonic activity on Cyprus

As a matter of fact, relatively little seismic activity has been observed during this century in Cyprus (Pinar & Kalafat 1999: 217). Only 47 events of $Ms > 4.5$ have been recorded in the last century (Ambraseys & Adams 1993: 85). However, the risk of seismic events should not be underestimated (Pinar & Kalafat 1999: 219). Indeed, Cyprus is located between the north-ward moving African plate and the westward-moving Eurasian plate. The Cyprus Arc is the major tectonic line in the region, delineating the plate boundary. Hence, incidence of collision of the Eurasian and African plates have been recorded (Poole & Robertson 1998: 545).

Cyprus orginated at the bottom of the sea and consequently has known considerable tectonic uplift. Sometime after the Late Miocene, southern Cyprus began to emerge above the sea. Uplift of the Troodos Massif first started in the Late Pliocene-Early Pleistocene. This was a result of the combination of northward underthrusting of the African plate and serpentinite diapirism (Poole & Robertson 1991: 909). During the Early and Middle Pleistocene particularly rapid uplift took place. No exact measurements have been dated absolutely to detail the uplift during these periods. However, for more recent periods, as an example from 185-141 ka BP an average rate of 29 cm/ka has been recorded. Furthermore, for the last 116 ka, an average rate of 5cm/ka, with exception of Cape Greco having a rate of 12 cm/ka has been estimated (Poole 1992: 328).

While uplift of the island seems to have reduced since the Late Pleistocene, seismic activity continued throughout the Holocene. Indeed, more recent earthquakes are better documented (see Ambraseys 1993: 92-94). As a matter of fact, strong seismicity occurs in cycles of about 200 to 350 years (Ambraseys 1993).

Archaeological research indicates an earthquake sequence could have occurred throughout the Mediterranean around ca.1,500-1,200 BC. Supposedly, several Late Bronze Age sites were affected by earthquakes (Nur 1998). Evidence supports an earthquake occurrence at Kition at the end of the Bronze age (King 1987: 12).

Around 180 BC, a destructive earthquake on Cyprus was mentionted in the Sibylline Oracles (Pantazis 1996: 84).

Moreover, at about 92 BC, an earthquake resulted in tsunamis and damaged the coastal cities in Egypt, Israel, Syria and Cyprus (Mart & Perecman 1996: 151 ; Pantazis 1996: 84).

Another earthquake shook Cyprus in 70 BC, especially in the Famagusta district (Pantazis 1996: 84).

In 26 BC, Paphos was struck by an earthquake. The earthquake also affected Egypt, causing a tsunami (Pantazis 1996: 84).

In 15 BC, Paphos was compensated by the emperor Augustus for damages caused by the earthquake of 17 BC. This is documented by Dio Cassius (2^{nd}-3^{rd} centus. AD) (Leonard *et al.* 1998: 142 ; Pantazis 1996: 85 ; Guidoboni 1994: 177-178).

Orosius (5^{th} century AD) as well as Eusebius report another earthquake that probably took place in 77 AD and destroyed three towns in Cyprus (Leonard *et al.* 1998: 142 ; Guidoboni 1994: 214). One of the towns was Paphos (Leonard *et al.* 1998: 142). Additionally, Salamis and Kition fell into ruin. Moreover, the earthquake was felt on the Phoenician coastal area and in the central part of Syria (Pantazis 1996: 85).

In the fourth century AD, unusually high seismic activity took place in the Eastern Mediterranean caused by the reactivation of all plate boundaries in the region. This particular phenomenon is named the "Early Byzantine Tectonic Paroxysm" (Stiros 2001: 545). In the year 324 AD, evidence of an earthquake was recorded at the site of Soli (King 1987: 13). Moreover, Salamis was struck by an earthquake in 332, and again in 342 AD (Stiros 2001: 552; Guidoboni 1994: 247-248, 249). Furthermore, on the 21st of July in 365 AD, a devastating earthquake ruined the southern and southwestern part of Cyprus (King 1987: 13). Indeed, the destruction in Cyprus was mentioned in several ancient texts. As a matter of fact, Paphos was in ruins again shortly before 368 AD. Additionally, excavations at Kourion revealed destruction layers from late 364 AD and from September 365 AD (Stiros 2001: 550). The 365 AD tectonic event was particularly disastrous and correlates to the reactivation of the Cyprus Arc (Stiros 2001: 554-556).

On the 9th of July 551 AD another earthquake struck the Eastern Mediterranean. As a consequence, extensive damage may have occurred all throughout Cyprus (Russell 1985: 44-45).

Furthermore, about 1160 AD a powerful earthquake was recorded for the Paphos area. As a consequence, the harbourside church of Paphos was ruined at that time as stated by St. Neophytos (Leonard *et al.* 1998: 143).

In addition, even a more destructive earthquake in 1202 may have rocked Paphos, Limassol and Nicosia (Leonard *et al.* 1998: 143). Furthermore, Paphos and Limassol were also flooded by a tsunami (Pantazis 1996: 85).

On the other hand, the seismic activity on the 8th of August 1303 is well documented. It involved two earthquakes that devastated many an area in the Eastern Mediterranean. Hence, Cyprus was also probably heavily damaged by the earthquake (El-Sayed 2000: 341).

On the 25th of April 1491, a severe earthquake caused great damage in Nicosia and the Mesaoria Plain, however to a less extent in other regions of Cyprus (Pantazis 1996: 85).

Furthermore, on the 25th of April in 1567, a series of earthquakes took place and were felt throughout Cyprus. Some of the buildings in the coastal area of Limassol were ruined (Pantazis 1996: 85).

On the 28th of January 1577 a strong earthquake was felt in Cyprus. Aftershocks lasted for about 4 months (Amiran *et al.* 1994: 287).

In the 18th Century, Cyprus was struck by several damaging earthquakes: on the 10th of December 1718 (Pantazis 1996: 85), in 1735 (Amiran *et al.* 1994: 288) and in December of 1741 (Pantazis 1996: 85).

In the 19th century, seismic shocks occurred in 1872 and June 1896. The latter was felt throughout the island and caused severe damage to some buildings at Akrotiri and Episkopi (Kourion area). The shocks were also felt in other areas of the Eastern Mediterranean (Amiran *et al.* 1994: 288 ; Pantazis 1996: 85).

Obviously, this listing of tectonic activity is not exhaustive. Only one diachronic earthquake study was found for Cyprus: the study on the archaeoseismicity of Cyprus by Pantazis (1996). On the other hand, several similar studies on seismic activity in Israel were done: Amiran (1952), Amiran *et al.* (1994) and Russel (1985). As a matter of fact, the history of earthquakes in Israel is more substantial and consequently may indicate a greater incidence of earthquakes for Cyprus as well. Thus, we could presume that evidence on reported earthquakes for Cyprus were the most destructive ones.

II.3.2. Impact of tectonics on rivers in Cyprus

It is true that streams respond to vertical displacement along faults by aggradation or degradation. After displacement, when the channel segment is steeper than the original stream gradient, erosion will be initiated in this reach. If displacement results in a lower channel segment elevation or gradient, aggradation will take place in this reach (Schumm *et al.* 2000: 22). On the other hand, the rate of deformation influences the response of the river. A rapid rate of uplift causes incision and prevents lateral shifts of the river. On the other hand, slow uplift leads to channel adjustments such as widening, meandering or a channel position change (Schumm *et al.* 2000: 69). As mentioned above, significant uplift took place during the Pleistocene, especially in the Early Pleistocene. The uplift was focused on Mount Olympos (Troodos) and resulted in a radial drainage pattern. It gave rise to the present drainage pattern and caused the Fanglomerate deposition. Poole & Robertson (1991) state that the dominant factor in the Early to Middle Pleistocene was the high rate of tectonic uplift. The early Middle Pleistocene Fanglomerate unit probably relates to deposition during a sea-level high, followed by continuing surface uplift. The Late Pleistocene Fanglomerate units (F3 and F4) support deposition during a sea level high, followed by further uplift and downcutting. The decreased volume of clastic sedimentation after the early Middle Pleistocene suggests that tectonic uplift waned during the late Pleistocene to the present day (Poole & Robertson 1991: 545-564).

As a conclusion, the Pleistocene alluvial sediments of Cyprus relate clearly to tectonic uplift. As a matter of fact, the present radial outline of the rivers in Western Cyprus is a result of uplift focused on Mount Olympos. As stated above, the uplift seriously decreased starting from the Late Pleistocene. Hence, alluvial deposits of Western Cyprus are presumably not primarily a result of uplift centred on the Troodos.

However, tectonic activity in general (and not necessarily uplift centred on Mount Olympos) probably had an impact on the Holocene alluvial history of Cyprus.

Severe earthquakes often cause landslides, which can introduce large quantities of sediment into a river, sometimes forming temporary dams (Schumm *et al.* 2000: 13). Landslides have been observed after some recent earthquakes in Cyprus. Pantazis has documented observations of several landslides after the severe earthquake of the 10th of September 1953. He observed the combined effect of the earthquake and subsequent heavy rain that caused major damage to villages (Pantazis 1969: 1-20; Ambraseys 1993: 94). Additionally, the earthquake on the 9th of May 1930 caused large-scale landslides in the Paphos District. It is reported that the flow of the Ezousas river was blocked near the village Episkopi. Also in the nearby villages of Nata and Kambia landslides took place (Ambraseys & Adams 1993: 93). After the earthquake of the 16th of November 1930 landslides developed in the Pitsilias region and on other places in the Paphos and Limassol districts. They were attributed to seismic activity (Ambraseys & Adams 1993: 93). Even more landslides were caused by the earthquake of the 26th of June 1937 (Ambraseys & Adams 1993: 93). As a matter of fact, in the Western Cyprus Geo-archaeological survey area (Paphos) landslides occurred more often than in any other area of Cyprus. This is due to the fact that the most severe landslides occur in areas composed of clays or clayey marls (Pantazis 1969: 1-20).

II.3.3 Conclusion

Although tectonic uplift of Mount Olympos reduced since the Late Pleistocene, earthquakes still struck Cyprus in the Holocene. The earthquakes could have had impact on the fluvial history, mainly through landslides. As a conclusion, we may say that the Cypriot alluvial history should be correlated and compared with the known earthquake events.

III. Human influence in the Cypriot landscape

III.1. Subsistence economy

In this chapter I will investigate the subsistence economy of ancient Cypriots. The study of how Cypriot people provided themselves with caloric energy will enlighten one aspect of that particular relation between humans and their environment.

From the archaeobotanical, faunal and literary evidence we can build several hypotheses, to interpret the geomorphological data. The archaeological record makes it possible to estimate what effect food provision had on the environment and whether the environment was robust enough to buffer ecological strains. To be precise we need to answer two questions. How extensive and intensive were agriculture and animal husbandry and did the ancient people undertake measures against erosion? The influence of innovations changing agricultural and husbandry practices will be critical to this study.

As a matter of fact, this study has to be diachronic. Diachronic palaeobotanic and archaeozoological[8] studies were mostly non-existent for Cyprus. Little research was done on the Iron Age, Classical and Roman palaeo-economy. Most of the evidence for these crucial periods is non-existing.

III.1.1 Epi-palaeolithic hunter gatherers on Cyprus (12,000-11,000 BP)

The first possible evidence of humans on Cyprus dates to the 13th millennium BP, mainly from the single site of Akrotiri-*Aetokremnos*. It is assumed that these visitors were hunter-gatherers and they used a non-domestic economic strategy (Simmons 1991: 866). However, not everyone believes the Akrotiri evidence (Bunimovitz

[8] An exception is the study of Croft 1991 where the evolution in animal exploitation from the Neolithic through Chalcolithic period is investigated.

1996; Vigne 1996, Simmons 2001). While they were only supposed to be a small group (considering the single site), they were thought to be responsible for overkilling the Pleistocene endemic fauna, namely pygmy hippopotami and dwarf elephants (Simmons 1991: 866).

Somewhere in the Pleistocene, elephants and hippopotami colonised Cyprus. As they had no competitors, they would have tended to develop into dwarf species. They evolved for hundreds of thousands of years on Cyprus without extinction. It is then very striking that on the particular site of *Aetokremnos*, the youngest known pygmy hippopotami and dwarf elephants were found together with the oldest evidence of human actions on the island. More than 300 pygmy hippopotami and about 10 dwarf elephants would have been butchered at the site of Aetokremnos (Simmons 1996: 100). Speculations are that about 50 people could have been fed with those. Whether humans were the main agents or only the "last straw" in the extinction of those herbivores is uncertain (Simmons 1996: 103). Some human adaptations to this extinction might be visible in the economic shift towards more other resources as marine shells and birds (Simmons 1991: 866).

Once the island was depleted of those large herbivores, all evidence of humans on Cyprus also seems to have disappeared for about a millennium.

III.1.2 Neolithic period

III.1.2.1. Cypro-Pre-Pottery Neolithic B (Cypro-PPNB: +8,000-7,000 BC)

Cyprus was presumably colonised by Neolithic people in the second half of the 10^{th} millennium. The whole Neolithic package was probably introduced to the island at that time (Peltenburg *et al.* 2000: 844, Wilcox in press). The sites of Kissonerga-*Mylouthkia* (Peltenburg *et al.* 2000: 850) and Parekklisha-*Shillourokambos* (indicate that goats, sheep, pigs, fallow deer (*Dama mesopotamica*) and cattle were deliberately imported to the island (Vigne 2001: 55-60). The three "founder crop" cereals -domestic einkorn (*Triticum monococcum*), domestic emmer (*Triticum *dicoccum*) and domestic hulled barley (*Hordeum sativum*)- were probably also imported (Peltenburg *et al.* 2000: 849).

During the first 500 years (Early and Middle Cypro-PPNB), the colonisers had a somewhat similar economy to the mainland. They reared mainly pigs, though also hunted fallow deer and herded caprids. Cattle were probably only a minor food source. Moreover, they grew einkorn, emmer and hulled barley as was done in PPNB villages on the mainland. It was only during the Late Cypro-PPNB (at about 8500-8000 BP), that the economy started to adapt to the specific conditions on Cyprus. About that time, cattle rearing also started to disappear until the Early Bronze Age. Was cattle rearing unsuccessful on Cyprus (Simmons 1998)?

Certainly, the introduction of a Neolithic economy upon an island environment must have had some impact. However, the impact will have been rather restricted in space considering the limited evidence of occupation[9].

III.1.2.2. Khirokitian Aceramic Neolithic (7,000-5,500 BC)

During the Khirokitian, communities have adapted more to local circumstances such as demographic, environmental and social factors (Le Brun 1996: 4). This will be exemplified by mentioning some of the better-documented sites.

At Khirokitia einkorn wheat (*Triticum monococcum)* was the predominantly cultivated cereal. Emmer wheat (*Triticum dicoccum*) was less important and barley (*Hordeum)* almost non-existent. Lentils were rather scarce, while figs were common. Some olives and almonds were also attested (Hansen 1991: 231). Throughout the Aceramic Neolithic, there was a trend towards more exploitation of domestic animals; thus more caprids and pigs and fewer fallow deer (Croft 1991: 67).

[9] However, Kissonerga-*Mylouthkia* and Parekklisha-*Shillourokambos* are not the only sites.

Although Kalavassos-*Tenta* is only about 7 km away from Khirokitia, people used a different food provision strategy. Unlike at Khirokitia, einkorn and emmer were present in equal quantities at *Tenta* (Hansen 1991: 231). In spite of the fact that the animal economy of *Tenta* was deer dominated, exploitation was increased towards domestic animals (Croft 1991: 67).

On the other hand, at Cape Andreas Kastros the food strategy was again different. Emmer (*Triticum dicoccum*) was predominant and lentils were fairly abundant. Ryegrass grains (*Lolium*) evidence was so abundant that they might have been cultivated. Barley (*Hordeum vulgare)* was less important (Van Zeist 1981: 95-99). While at the beginning of the Aceramic Neolithic, caprids were dominant in the animal economy at Cape Andreas Kastros, there was a trend towards more fallow deer hunting throughout that period. Moreover, at this site marine resources were also important (Desse & Desse Berset 1994).

The palaeo-economy of other sites as e.g. Kritou *Marotou-Ayios Yiorkis* was less investigated, though the same food species as in the sites above were attested (Fox 1987: 21). Deer and pig bone elements on the site of Kritou *Marotou* indicate butchering of these species on the spot, while the few caprid bone elements originate from limbs. It is suggested that *Ayios Yiorkis* was rather a deer yarding and pig-herding hamlet associated with a larger village (Fox 1987: 26).

In short, the Aceramic Neolithic agricultural economy was based on einkorn, emmer, barley and was supplemented by lentils and peas. There are differences only in the proportions in which these crop plants were represented. Moreover, they collected wild grapes, olives, figs, almonds, and pistachios (Hansen 1991: 234). The animal economies were mainly based on 4 species; Mesopotamian fallow deer, pigs, goats and sheep. However, there were differences in exploitation trends suggesting some kind of local flexibility (Croft 1991: 67).

The longevity of the Khirokitia culture indicates that this economy may have been successful. There is no evidence of surplus production. We can therefore conclude that little effort was made to produce beyond the immediate requirements of the community. However, the farming and herding activities did have some local impact on the environment, for example in the pollen evidence from Khirokitia (Renault-Miskovsky 1987). A certain amount of woodland clearance must have taken place for cereal cultivation in this area.

III.1.2.3. Sotira Ceramic Neolithic (4,500-3,900 BC)

When appearing back (after a gap) in the archaeological record there is a slight shift in economy. At that time (around 4000 BC) two new cultigens appeared on Cyprus: bread wheat (*Triticum aestivum)* and rye (*Secale cereale).*

At Ayios Epiktitios-*Vrysi* the major foodstuffs are cereals, olive and grape. The cereals consisted of several varieties of wheat (*Triticum monococcum, Triticum dicoccum*, *Triticum aestivum)* and barley (2 and 6 row barley) and to a lesser extent oats and rye (*Secale cereale).* Also lentils and peas were attested (Hansen 1991: 234). Domestic caprids (58%) are pre-eminent in *Vrysi*, though deer (28%) and pig (12%) are also well-represented (Peltenburg 1978: 64).

At Dhali-*Agridi* (the site by the river) the highest rate of deer remains was recovered (69%). However, there is also evidence that caprines and pigs were bred (Croft 1981: 260).

The animal economy was more deer dominated at the Paralimni-*Vounistri* site. Caprines and pigs however were also represented (Flourentzos 1997: 9).

During this period, like in the Aceramic Neolithic, we can again observe a mixed economy, providing a wide spectrum of non-exclusive food species. The abundance of axes, adzes and chisels indicates that forests were extensive and must have been a physical obstacle (Peltenburg 1978: 70). Due to large amounts of tools for plant food processing observed during that period, it can be suggested that the Sotira culture was more dependant on agriculture (Fox 1987: 27). As the *Vrysi* and Sotira sites were occupied for such an extended period, rapid soil exhaustion must probably not have been the case (Peltenburg 1978: 70).

III.1.3. Chalcolithic period (3,800-2,500 BC)

The Chalcolithic inhabitants of Kissonerga utilised a variety of species as emmer, einkorn wheat, bread wheat, 2 and 6 row barley, lentils, peas, chick peas and some edible legumes as well as olives, grapes, pistachios, figs, hackberry, juniper, linseed and caper (Murray 1998: 217). Moreover, in Lemba, there is evidence of some of the above mentioned species, although less abundant. This could be due to the sampling strategy or differential preservation (Colledge 1985: 209-211 ; 101-102).

While Late Neolithic and Early Chalcolithic settlements were strongly dependant (50%) on fallow deer, the exploitation of this species greatly declined during the Middle Chalcolithic (30%) period. On the other hand, people were probably consuming more pigs and caprines, however less caprines. This was probably a result of an intensification in domestication, due to population pressure (Croft 1991).

Consistent with the above evolution in the animal economy an agricultural intensification could be expected. As a matter of fact, it is suggested that large scale storage took place from the beginning of the Chalcolithic period, indicating a change from intensive to extensive agriculture (Peltenburg 1998: 240). Other characteristics at the Kissonerga-*Mosphilia* site also confirm intensification: an increase in the number of storage containers, the appearance of new and more crop processing equipment, the emergence of a kind of storage and processing structure, the decline in deer and evidence of the expansion of arboriculture (Peltenburg 1998: 254).

With reference to agricultural intensity, it is estimated that about 25-40 ha might have been under cultivation in the Early Chalcolithic village of Kissonerga-*Mosphilia* (Peltenburg 1998: 241). This is a relatively large area probably cleared of trees. The agricultural intensification probably limited the habitat of the fallow deer, reducing the number of available deer.

Remains of some weed species at Kissonerga-*Mosphilia* indicate that sowing took place in winter and reaping in spring (Murray 1998: 220). On the other hand, they would indicate that some kind of shallow tillage of the soil took place. Probably, a type of hoe or manually pulled ard-type plough was used (Murray 1998: 220-221).

III.1.4. Bronze Age (2,500-1,050 BC)

III.1.4.1. Prehistoric Bronze Age (2,500-1,700 BC)

At the end of the Chalcolithic and at the beginning of the Bronze Age (Philia culture) some new immigrants from Anatolia probably arrived on Cyprus (Frankel 2000). Some changes in subsistence behaviour took place, though plant diet continuity is observed. Again, plant diet seems once more to have consisted mainly of wheat, barley, olives, grapes, almonds and legumes as chickpea and lentil (Adams & Simmons 1996: 225).

Despite this continuity, some remarkable changes should be mentioned.

1. Some new animal species were imported, such as cattle, a new type of goat and equids (Croft 1996: 218-220).
2. It is believed that some kind of secondary products revolution was introduced to Cyprus. That is the introduction of draft animals, the use of the plough, and the exploitation of secondary products like milk and pelt (Croft 1996: 218-220).
3. Cultivation terraces would have been developed from the Middle Bronze Age on. (Wagstaff 1992: 160). Terraces create new cultivable land, especially on slopes which were previously too steep to be cultivated. These could have been a response to the innovations mentioned under 1 and 2, trying to keep erosion levels low and production high.

It all points to some kind of intensification of the mixed farming economy.

Moreover, on several Early Bronze Age sites, caprids were most frequent, while cattle, pigs and fallow deer were also consumed. Equids were probably rather kept as draught animals (Croft 1996: 218-220). Although caprids were most frequent, their meat yield was quite low and it is suggested that cattle meat was more frequently consumed (Croft 1996: 221). The heavy reliance on deer hunting in Bronze Age Cyprus was rather unique in the eastern Mediterranean and Near East (Croft 1996: 223).

Thus, despite some profound social changes at the beginning of the Bronze Age, despite the introduction of cattle, and the secondary products revolution, the animal economy and the agriculture display some continuity from earlier times.

III.1.4.3. The Proto-historic Bronze Age (1,700-1,050 BC)

During the Proto-historic Bronze Age urban centres began to develop throughout Cyprus. To be more specific, a settlement hierarchy existed consisting of coastal centres, rural sanctuaries, agricultural and mining villages (Keswani 1989: 78). As a result of this specialisation in labour, not every individual was directly involved in food production. The stapling and redistribution of food then became a necessity.

An example of such an agricultural production village is Analiondas-*Palioklichia* (in Central Cyprus) where numerous pithos fragments, querns, rubbers, grinders and limestone vessles were found. It is suggested that this agricultural village supported the inhabitants of a mining community. Grain was probably the principal commodity involved (Webb & Frankel1994: 9).

The four-tiered settlement structure described above implies a greater need for surplus production and storage facilities. The storage jars give us a glimpse of the scale of the subsistence economy. At Kalavasos-*Ayios Dhimitrios* more than 50 pithoi in building X were used for long-term storage. They probably contained olive oil. The storage capacity of building X is estimated at approximately 50.000 liters (Keswani 1992: 141). In the settlement of Apliki-*Karamallos* 15 large pithoi could have contained about 7500 litres (Webb & Frankel 1994).

Cereals (breadwheat, emmer, naked and hulled barley), pulses (especially lentils) and perhaps olives were domesticated; and a variety of fruits (as grape, fig, pomegranate, citrus) and nuts (almonds, hazel, pistachio) were collected. Probably, by the Late Bronze Age, the olive was cultivated on Cyprus (Hadjisavvas 1992: 3). Domesticated ovicaprines and cattle provided both meat and secondary products. Fallow deer were more modestly exploited, though this was not the case in some places as Maa and Kouklia (in the Paphos area). Oxen and equids were probably used as draught animals.

III.1.5 Cypro-Geometric Iron Age I-III (1,050 - 750 BC)

This period is mostly known from tombs. The island was divided in 7 kingdoms with centres at Salamis, Amathus, Kourion, Palaipaphos and Marion. Little palaeo-economic research has been undertaken at those sites, so we can only presume what the economy would have been like by extrapolating palaeo-economic evidence from before and after the Cypro-Geometric Iron Age.

Nobis has recently investigated the archaeozoological remains of a Phoenician sanctuary on the site of Kition. Obviously, religious behaviour was quite different from economic behaviour. However, the data from the sanctuary provide us with some indications on what was bred on the island. The majority of the animals (97.5 %) offered as sacrifice were domesticated animals. The cattle consisted of short horned type animals, unlike the long horned type in the Late Bronze Age. More sheep than goats were slaughtered for sacrifice. Pigs were found in smaller amounts. Remains of donkeys and horses were also recovered though less. Fallow deer, hare and turtle remains were also found (Nobis 2000: 121-127).

III.1.6. Cypro-Archaic Iron Age I-II (750-475 BC)

In 707 BC, the 7 Cypriot kings submitted to Sargon II of Assyria, but this does not seem to have had a strong impact on the prosperity of the Cypriot kingdoms.

Salamis developed into one of the richest and most important cities of the Eastern Mediterranean (Fejfer 1995: 22).

There is more investigated evidence of food provided to the dead, than evidence of diet of the people living in the settlements. This is also due to the fact that more cemeteries than settlements were excavated.

The best known is the necropolis of Salamis in which graves (6^{th} and 5^{th} Century BC) the same plant-species were recovered as in previous times. Cereals consisted of wheat and barley. Several pulses were found, among others lentils, chick peas, horse beans, grass peas, and better vetch. Fruits and nuts were probably more abundant in the graves than we should expect for the daily diet: figs, almonds, bullaces, olives, grapes (Renfrew 1970: 318-328 ; Hjelmsqvist 1970: 329-335).

III.1.7. Cypro-Classical I-II period (475-325 BC)

In Cyprus, an economic decline probably took place during the Classical period resulting in less prosperity and less extensive trading. From 540 BC, Cyprus was ruled by Persia, though the city states retained a high degree of autonomy (Fejfer 1995: 22). Nevertheless, Cyprus presumably exported wheat to Athens during the decline. An orator states that 14 freighters loaded with corn from Cyprus headed to Pireaus, adding that more freighters would follow (Thomson 1995: 34).

III.1.8. Hellenistic Period (325-50 BC)

From 298 BC, the island was taken by Ptolemy, king of Egypt. Nonetheless, the cities enjoyed considerable autonomy and controlled their chora. The land around big cities like Paphos and Salamis was extensive and consisted of several large estates (Michaelides 1996: 141). It was used primarily for agriculture, mainly grain. Cyprus was self-sufficient and probably had quite a lot of surplus. Indeed a decree mentions that Egypt purchased expensive grain from Cyprus to avoid a famine (Michaelides 1996: 142). Moreover, wine was an important element in the economy of Cyprus, as evidenced by its presence on the foreign market (Michaelides 1996: 142). During this period a number of innovations led to increase of olive oil production. The introduction of a mill drafted by animal power resulted in an increased output (Hadjisavvas 1992: 117-118).

One of the Ptolemy's main interests in Cyprus was timber for shipbuilding. Consequently, this exploitation of the forests must have resulted in major deforestation (Michaelides 1996: 141).

Once more, most substantial palaeobotanical material for this period derived from the necropolis of Salamis, retrieved from a grave of the end of the 4^{th} century BC. As a matter of fact, we can observe some of the basic species that occurred for centuries on Cyprus. However, some species were never found on earlier sites. Among the cereals, bread wheat (*Triticum aestivum*), emmer (*Triticum dicoccum*) and hulled barley were found, though a new species also occurred: hard wheat (*Triticum durum*). Pulses as the ones retrieved in the Archaic graves of Salamis were also found, though in more varieties: lentils, chickpea, grass pea, bitter vetch, horse bean, and pea (*Pisum sativum*). Fruit was quite abundant as well with previously known species as almond, bullace (*Prunus insititia*), hazel, vine and olive. Figs, pomegranate, pine seed and lotus fruits were species that were not found in the older graves (Hjelmqvist 1973: 232-255).

Little archaeozoological work has been done on sites of this period. Though, Aelians' *"De Natura Animalium XI.7.* gives some evidence that fallow deer were still present in the Hellenistic period. He refers to the multitude of deer, the popularity of hunting them, and their habit of taking refuge in the temple of Apollo at Kourion (Stanley Price and Frankel n.d.)

III.1.9. Roman Period (50 BC-395 AD)

The Romans annexed Cyprus in 58 BC. Within the Roman world, cities supported by surrounding agricultural hinterland were the basic economic units. According to this system, the cities manufactured the goods needed in the agricultural economy, while at the same time they were centres for redistribution of agricultural surplus (Michaelides 1995: 143). Farmsteads and small settlements, scattered around the island, produced an agricultural surplus (Hadjisavvas 1992: 121). The surplus was also traded: grain was exported to Rome and fruit as well as wine, olive oil and honey to Palestine (Michaelides 1996: 146-147). Obviously, timber continued to be exploited on a large scale as mentioned before (Michaelides 1996: 146).

In the 4th century, Ammianus Marcellinus describes Cyprus as a fertile island, abundant in products of every kind (Michaelides 1996: 144). And Strabo (1st C BC-1st AD) testifies that

"in fertility Cyprus is not inferior to any one of the islands, for it produces both good wine and good oil, and also sufficient supply of grain for its own use".

All sources indicate that Cyprus prospered during most of the Roman period, at least when it was not harassed by earthquakes (as in 370), droughts (in the 4th century) or locusts (Michaelides 1996: 139).

III.1.10. The Byzantine period (395-1191)

In the beginning of the Byzantine period, agriculture reached its peak in terms of exploitation of all tillable land. Larger areas were covered by terraces, as is evidenced in the normally previously rather unexploited area of Akamas. At the site of *Ayios Kononas*, a Roman rural villa (*villa rustica*) developed into a small village in the Byzantine period (Fejfer 1995: 85-86).

From 648-965, the Byzantines were in conflict with the Arabs. By the end of the 6th century, the administration of Justinian collapsed and an economic, environmental crisis developed, and left Cyprus open for Arab invasions. This resulted in a crisis, especially in Western Cyprus (Fejfer 1995: 22). However, in the long run, the Arab invasions could have had quite an important influence on the economy. The Islamites were responsible for introducing new crops such as cotton, sugar cane, colocasia, eggplants, watermelons, sorghum and rice. Watson calls this a real agricultural revolution. Traditionally, the growing season in the Mediterranean had always been the winter time, crops being sown in autumn and harvested in spring. In hot and dry summers the land lay fallow. The newly imported crops could grow in the great summer heat which must have altered the rhythm of the agricultural year. This way, new systems of rotation could arise, using the land more intensively. As a result of these innovations, virtually all categories of land were farmed more frequently (Watson 1985: 123).

A general trend in the Byzantine economy during the 9th century was to develop large estates at the expense of smaller ones. It is not certain whether this happened also in Cyprus around that time. As a matter of fact from the end of the 12th century on, remains of large estates were found (Gounarides 1996: 177). The estates were divided into farming lots. Every paroikos got a portion of farmland of the large estate on loan. The paroikos would pay the land owner rent. In addition to this the paroikos had to grant the land owner unpaid duty of 8-12 days a year (Gounarides 1996: 179). The monasteries owned large estates as they were given tax relief from the emperor (Gounarides 1996: 178).

III.1.11. The Frankish period (1191-1489)

Cyprus was used as a store-area for supplying the Crusader's forces in the area. As a consequence, it was a centre of local and international trade (Gounaridis 1996: 182). The Crusaders occupied Cyprus and a new economic era started. During this period cereals were the principal crop of the island, most abundant was barley. Oats were not prevalent because the animals were fed with cotton seed, leguminous plants and barley. Beans, lentils and chickpeas were important as well. A large quantity of onions were grown. Sesame and olives were crops mainly used for oil production. Among the fruit-bearing trees, carob was the most frequently grown, though also orange-, citron- and banana-trees were cultivated. Cyprus was also famous for its vineyards (Setton *et al.* 1985: 274-276). In addition to food-stuffs, people on the island of Cyprus grew also textile plants (Setton *et al.* 1985: 277).

Moreover, sugar cane was probably imported to Cyprus as a crop and as well as an industry before the Latins took over the island in 1191. This initial period of production was followed by a decline and subsequently by a revival. From 1299 to 1473 sugar was the most valuable commodity exported from Cyprus. It was grown in a considerable number of places. A large number of aquaducts were built, as sugar crops needed large quantities of water. Sugar became an agrarian industry demanding important capital investment, organization and manpower. It was mainly produced for export. The refining of sugar cane required considerable firewood (Luttrell 1996: 164-165).

Some natural disasters are well documented and destroyed the sugar cane harvest. As an example the locust plague of 1411 and exceptional severe frost in 1468 (Luttrell 1996: 168). In the Paphos and Limassol areas, the best plantations were located (Setton *et al.* 1985: 277).

As an example of the animal economy during the Frankish period, a contemporary report estimated 22,150 pairs of oxen throughout the island, which were mainly used as draft animals. A large number of cows, goats and sheep were raised for milk. Horses, asses and mules were also numerous. Camels were used for carrying loads. There was only a small consumption of pigs. On the other hand chickens were reared more often. The lagoons contained a wealthy fish supply. Hunting wild sheep and roebucks was a favourite occupation of noblemen (Setton et. al. 1985: 279).

III.1.12 Venetian period (1489-1571)

During most of the Venetian period, Cypriot grain production exceeded the needs of local consumption. Substantial amounts of wheat and barley were exported to other Venetian territories. As a consequence of the population increase, expansion in the agricultural sector was needed.

The locust plagues decimated crops causing severe shortages. Consequently, crops less vulnerable to locusts were cultivated instead. There was a tendency towards barley cultivation as this crop was less susceptible to this plague because of its earlier maturation (Arbel 1996: 185-186).

The sugar cane industry became marginal. Local landlords switched towards cotton (Arbel 1996: 186). Cotton was easier to grow and amenable to peasant cultivation (Christodoulou 1959: 138).

Towards the end of the Venetian period, stress for food resources led to social unrest (Arbel 1996: 186). Genoa and Venice both forced Cyprus to grow cotton, wine and sugar cane at the expense of the local needs of the inhabitants. The Turkish conquest appeared as an economic liberation for the islanders (Setton 1985: 281).

III.1.13. Ottoman period (1571-1878 AD)

The Turkish period marked further depression in cultivation and production. However, due to depopulation export of surplusses still existed. Formerly cultivated and prosperous areas remained uncultivated and poor (Christodoulou 1959: 123). In addition, the cotton industry declined in Ottoman times (Christodoulou 1959: 139).

Most families had no agricultural specialisation and would grow cereals, olives as well as a few vegetables. They would have a modest flock of about 10 goats or sheep. Olive oil production was mainly used for local domestic consumption (Given 2000: 216). Most people were trying to provide just for their own needs. However they did need to produce a surplus to pay taxes and to buffer themselves against the frequent droughts, locust attacks, earthquakes and plagues (Given 2000: 227).

Stockbreeding and herding on a large scale by professional herders was an entirely separate activity compared to the small-scale family-based herding (Given 200: 216). Sheep and goats were mainly pastured in the mountains. Hence, it had some pronounced impact on the forest vegetation (Thirgood 1981: 125).

Only estates and monasteries were involved in mass production (Given 2000: 217). Most estates originate from the late 17th and 18th century due to indebted peasants. The estates tried to produce as much as possible, usually cotton or cereals in order to export them. They used to own the best-irrigated lands (Given 2000: 218).
The monasteries played a major role in the rural economy. Some of them were extremely rich and powerful and as they owned a considerable estate (Given 2000: 221).

III.1.14. Under the British rule (1878-1960 AD)

At the beginning of the British rule, bad agricultural and pastoral practises were in use. The forests were in a very bad state as people kept on clearing them for cultivation and consequently exhausted the soils by erosion. Moreover, animals could free-range graze in the forests (Thirgood 1982: 126). Hence, laws were passed to restore and preserve the forest (Thirgood 1982: 128). Nowadays, Cyprus appears to be one of the most forested islands of the Mediterranean region.

When the British took over the island, 80% of the population was employed in the agricultural sector. Most farmers owned small plots and were self-employed. The church, monasteries and chiftliks (large landowners) still owned estates on which peasants worked for a share of the crops. The main products were wheat, barley, grapes, carobs, citrus fruits and olives (Angelides 1996: 211). Small plots, droughts, primitive tools and impure seeds made it impossible to produce large quantities of surplus and to export them (Angelides 1996: 211).
However, despite the above mentioned difficulties, all branches of agriculture expanded during this period. Some new crops, especially potatoes, were successfully introduced. Hence, they supplemented the traditional Cypriot diet.

As the population of people full-time employed in agriculture dropped, agriculture became neglected (Angelides 1996: 219). Agriculture remained backward during the British period due to the lack of new technology, reorganization and restructuring. (Angelides 1996: 220)

III.1.15. Conclusion

III.1.15.1. Vegetable diet

- Neolithic people probably introduced agriculture to the island in the 10th millennium BP. Basically, minimal changes are observed in the vegetable diet from the Neolithic to the Roman period. The diet consisted of barley, wheat, lentils, peas, grapes, olives, figs, almonds and pistachios. However, there is evidence of a quantitative and qualitative change through time.

  1. Quantitative change

  During the Neolithic, little effort was made to produce surplus; while in the Chalcolithic there is first evidence of larger scale storage. The increasing social stratification since the Bronze Age demanded even larger surplus. This was made possible through the introduction of the plow drafted by oxen, generating a larger output. Moreover, the construction of terraces expanded the cultivation area available on steeper slopes.

  2. Qualitative change

  Olives and grapes were initially wild fruits but were domesticated from the Late Bronze Age on. As a result, more control was gained over the output. Consequently, domesticated fruits were larger than the wild species.

  The growing season for the above mentioned species is winter time. Hence, crops were sown in autumn and harvested in spring. During the hot, dry summer the land lay falllow.

- With the Islam invasions between 648 and 965, a collection of new crops reached the island: cotton, sugar cane, colocasia, eggplants, watermelons, sorghum and rice. All these crops could stand the summer heat, although they required quite an amount of water. They were added to the original agriculture. As a result, a new rhythm of landuse began, yielding a higher productivity.

III.1.15.2. Meat provision

- Epi-palaeolithic hunter-gatherers were probably responsible for overkilling the natural fauna of Cyprus, namely dwarf elephants and pygmy hypopotami.
- Pre-Pottery Neolithic B people introduced new animals to the island: domesticated cattle, goats, sheep and pigs. Feral fallow deer was also introduced. Within the first 500 years, cattle probably disappeared from the island for about 5 millennia.
- From the Ceramic Neolithic period onwards, people became increasingly dependant on fallow deer. This trend was reversed from the Middle Chalcolithic onwards while an increase in the importance of domesticated animals, especially pigs is observed.
- In the Early Bronze Age cattle was introduced again, together with equids and a new type of goat. At this time, the secondary products revolution might have been introduced. This secondary products revolution is an intensification of the animal exploitation. While previously stock were bred mainly for their meat, from the Early Bronze Age onwards secondary products, like milk, wool and draft energy were used.
- At some point camels were introduced to Cyprus, probably by the Arab invasions.
- When exactly the fallow deer became extinct is not known.

Human impact on the environment:

Obviously, humans on Cyprus had impact on the landscape throughout their long occupation of Cyprus. As a consequence, the clearance to create cultivation and herding zones reduced the amount of trees thoroughly, at least for a period. Research on the subsistence economy indicates the incidence of crucial periods for the environment:

1. the landnam of the Aceramic Neolithic

2. the agro-pastoral intensification of the Middle Chalcolithic
3. the introduction of the ox-drawn plough in the Early Bronze Age
4. the incidence of an increased production in the Late Bronze Age
5. an increased production in the Frankish and the Venetian period by the use of new crops allowing two growing seasons.

All these activities might have had a pronounced impact on the forest vegetation, if not only locally. Of course, there must have been some periods of regeneration. However, it is not certain whether it was always possible to develop the same vegetation again, as former soils could have disappeared by erosion. On the other hand, one of the results of this deforestation might have been the disappearance of the favourite habitat of the fallow deer as is indicated by its decline during the Middle Chalcolithic and its more restricted appearance from the Late Bronze Age on. Erosion was another problem that farmers of the Mediterranean often had to cope with. Cultivated land is prone to erosion. The crucial periods described above might have left traces in the landscape: sediments eroded from the fields might have been deposited downslope, especially in the river valleys. However, people from the Middle Bronze Age tackled this problem by constructing cultivation terraces.

III.2. Metallurgical activities

From the Bronze Age on, Cyprus played a central role in the production and distribution of copper all through the Mediterranean region due to its particular geology (see chapter V). Because it was famous in the past for its copper resources, several early investigators believed that the name of the island "*kypros*" was associated with the meaning "Copper Island". Also Pliny reports the belief that the Latin adjective "*cuprius*" "Cypriot" was synonymous with copper (Michaelides 1996: 144). However, it is now known that there is no real etymological connection between the name "*Kypros*" and any Indo-European word for "copper".

The Troodos massif is made of diabase, alternated with sedimentary rocks from which volcanic scoriae of extrusive rocks and lapilli stand out. The igneous rocks containing the cupriferous minerals are scattered along the edge, which runs round the slopes of the Troodos (Muhly 1996).

III.2.1. Metallurgical impact on the environment

III.2.1.1. Deforestation

As a result of the exploitation of its metallurgical sources, the island is covered by masses of slags, estimated to about 4 millions of tons. We can question how much the copper industry affected the environment. Constantinou (1982) undertook an interesting exercise making it possible to visualise the devastating impact that the mining industry must have had on the forest cover.

> About 300 kgs of charcoal are necessary for the production of one kg of copper metal from the smelting of cupriferous sulphide ores. Data collected from the forestry Department of Cyprus suggest that a pine tree of 80-100 years old yields one cubic metre or 800 kgs of wood. For the production of 1 ton of charcoal, using sophisticated kilns, 12 cubic metres of wood are necessary, whereas, with primitive and less efficient kilns, 20 cubic meters of wood are required. The average production of a hectare of forest land in Cyprus is 80 cubic metres of wood. Based on these data it is estimated that, for the production of 200,000 tons of metallic copper, 1,200,000,000 cubic meters of pine wood or 60,000,000 tons of charcoal were used. For the

> production of this wood or charcoal 150,000 square kilometers of forest land were destroyed. Considering that the total surface area of Cyprus is only 9,300 square kilometers, it is probable that the forests of Cyprus were destroyed at least 16 times to produce the energy which was necessary for the copper mining industry (Constantinou 1982: 22-23).

These amounts clearly indicate that enormous quantities of the forest were sacrificed for the metallurgy. However, these figures do not explain where and when the forests were mainly affected. Raber tried to solve this problem for the Polis region, by undertaking a similar mathematical exercise, although with a chronological perspective. First, he calculated the slag in his survey area for each period. He found approximately 36,000 tons of slag from the Cypro-Archaic through Hellenistic periods; about 53,000 tons from the Late Roman Byzantine period and about 22,000 tons from the Late Medieval period.[10] Then, he applied a slag to ore ratio of 1:1 and a slag to metal ratio of 9.26:1 to estimate the amount of copper produced for each phase. The total production per period was then divided by the approximate duration of each period to obtain a mean annual production figure for each period. For pre-Roman times this was about 13 tons/year, for Late Roman/Byzantine times about 9.5/year and Late Medieval 7.7/year in the Polis region (Raber 1987: 304-305). The forests in that area would have been able to produce a maximum of 579 tons copper/year and minimum 87 tons copper/year with the matte smelting process. However, if hydro-metallurgical processes were in use, a maximum of 1,020 tons copper/year and minimum of 228 tons/year could be produced with the available forest. Hence, the actual production was always far below the potential production (Raber 1987: 303-304). However, Raber thinks that the copper production in the Polis region was essentially a local enterprise based on part-time, seasonal production in a peasant economy (Raber 1987: 308-310). Probably, the main copper production centres were not located in the Polis region but in the Eastern Troodos. To get a better understanding of the impact of metallurgy on the environment, these estimations should be undertaken for each area on Cyprus, however these do not exist yet. For now, we will have to rely on the raw archaeological and historical evidence to estimate the scale of impact of metallurgical production on the forest, for each period.

[10] However, some scepticism about Raber's dating of slagheaps is warranted.

Deforestation is one of the most important causes of accelerated soil erosion. The loss of soil in the uplands results in sedimentation in river valleys and coastal plains. Deforestation also upsets the whole hydrological system. As a result springs may dry up, floods become more common and silt deposits may create deltas and marshes.

III.2.1.2. Hydrological impact

The metallurgical production needs a good water supply. Hence, water availability was an important factor in the location of smelting sites. The best example of a smelting site, which is closely connected with the hydrological history is located at Politikos-*Phorades*. The site consists of a slag heap within and partly alongside an ancient river channel. Additionally, several tuyères and smelting furnaces were found (Knapp 1999a: 243). The workshop was buried in alluvial and colluvial deposits and exposed in a 4 m terrace, cut by the recent river (Given 1999: 30). The site itself probably altered the location of the ancient river.

III.2.1.3. An ancient perception of the impact of metallurgy

The word deforestation is value loaded and hence subjective. In our culture, deforestation implicitly has a negative connotation. Though at Erathostenes' time (275-195 BC), deforestation caused by metallurgy was positively valued. Here follows the passage in which Strabo refers to Erathostenes and narrates about the Cypriot forests (Muhly 1996: 45-46):

> Eratosthenes says that in ancient times the plains were thickly grown with forests, and therefore were covered with woods and not cultivated: that the mines helped a little against this, since the people would cut down the trees to smelt the copper and the silver, and that the building of the fleets helped further, since the sea was now being navigated safely, that is, with naval forces, but that, because they could not thus prevail over the growth of the timber, they permitted anyone who wished, or was able, to cut out the timber and to keep the land thus cleared as his own property and exempt from taxes.

It is clear that mining and smelting operations were perceived as beneficial and that they contribute positively towards the clearing of the land for agriculture. It is also evident from this text that these activities could not stop the growth of the forests. In addition, in Erathostenes' time the availability of wood was not a problem. Muhly compares this with a similar situation in the 19th century in the United States, where people who cleared land for agriculture could claim to free it from taxes (Muhly 1996: 45-46).

However, this is just one view on how the ancients perceived deforestation and the impact of metallurgy. From our present day point of view, the extent to which metallurgy had an impact on forests and on the environment is an interesting issue.

III.2.2. Metallurgical history of Cyprus

Due to the lack of numerical data to estimate slag heaps and the local impact of the metallurgy on the forests, I will give a short summary of each period with archaeological evidence in an attempt to gain insight into the mining activity scale.

III.2.2.1. The Chalcolithic period

The first metallurgical objects on Cyprus date from the Chalcolithic period. Although this period is called "the Copper Stone Age" (chalkos=copper, lithos= stone), only about 15 pieces were found on the island dating to this period. However, this name can only be justified if we want to stress that the beginning of metallurgy is an important qualitative change. As only a small amount of copper artefacts were retrieved, it is suggested that their production was only on a small-scale and that it must have had negligible impact on the environment. In fact, it is not even certain whether these copper artefacts were produced in Cyprus (Gale 1991: 37-61).

III.2.2.2. The Prehistoric Bronze Age

Production must have increased from the Early Bronze Age, since extraordinary wealth of local metalwork in the tombs of the cemeteries in Northern Cyprus. Abundant found in tombs as they are, they seem to indicate absence of control in their distribution and it is suggested that only part-time exploitation took place (Peltenburg 1996: 22).

Little is known about the production and extraction locations. However, there is evidence of mining activities at Ambelikou, where Middle Cypriot I pottery was found (Merrillees 1984: 7). Two additional radiocarbon dates on charcoal dates were retrieved there, calibrated to 2044-1929 BC (Knapp 1999b: 100). Probably, the copper ores were extracted to process elsewhere, more specifically in the settlement of Ambelikou-Aletri. Evidence of copper smelting and working on the spot was not extensive, although sufficient to prove the whole industrial process was practised at the site (Merrillees 1984: 7).

As a matter of fact, availability of wood was important in this early period, but certainly not a problem because as mentioned above the metallurgical sites indicate quite small-scale activities (Gale *et al.* 1996: 359).

III.2.2.3. Proto-historic Bronze Age

Gale and his team suggest that metallurgical production increased from the Late Bronze Age on due to improved technology along with new knowledge about smelting sulphidic copper ores. It is suggested that previously only the scarcely occurring oxidised copper ores were used (Gale *et al.* 1996: 401). The extensive finds of copper slag, furnace fragments, crucibles, tuyères and other copper-working accessories from that period certainly indicate an intensified copper production (Knapp 1986: 39).

As a result, the increasing foreign demand required specialisation and a different social organisation (Peltenburg 1996: 22). Keswani suggests that a four-tiered settlement hierarchy came into existence, consisting of specialised copper mining settlements, sanctuary sites where copper was refined and transhipped, agricultural villages providing the food supply for specialised workers, and coastal centres for trade (Keswani 1993: 78).

The Amarna letters dating to the 14th century BC mentioned that Alashya (often identified as Cyprus) sent large amounts of copper to the Egyptian ruler. The Amarna archive consists of hundreds of letters to and fro dozens of major and minor political entities. That no other political entity, except for Alashya, was associated with copper, makes it even more significant (Muhly 1996: 49). Hence, Cyprus was considered a significant copper source in Egypt in the 14th century.

However, there is little Late Bronze Age archaeological evidence of primary processes such as copper mining and smelting. So far, most archaeological knowledge, has been based on metallurgical finds from urban centres located on the coast where specialised metallurgical quarters were found. Nonetheless, they only may have been used for secondary metallurgy. This evidence bias is partially due to the extent of recent extraction activities at the same mines, which hide and destroy evidence from the past. As a result the only mining evidence is found at small ore bodies, indicating small-scale metallurgical activities. An example of such a small Late Bronze Age smelting site is located at Politiko-*Phorades*. The production level there indicates a rather local extraction and smelting of copper ores. Consequently, Politiko-*Phorades* does not seem to be the result of a major island wide operation under centralised control as is suggested by the textual evidence (Knapp 1998: 265). Most extensive evidence for a Late Bronze Age production centre was discovered at Apliki-*Karamallos*. This village had easy access to the rich copper deposits on the north hill at Apliki. The investigators found plenty of evidence of primary smelting such as slag, bronze, tuyères, crucible fragments and stone hammers, though did not recognise at first its Late Bronze Age date. It has recently been suggested that the village was rather industrial than domestic and thus represents the oldest mining village yet discovered on Cyprus (Knapp 1999: 100).

III.2.2.4. Iron Age (1050-325 BC)

Cyprus was among the first areas to make the transition to the Iron Age (Fastnacht *et al.*1996: 98). By the end of the 10^{th} century BC, iron was beginning to take over bronze for utilitarian objects in Cyprus. Though bronze remained abundantly used for its most suitable purposes. In general, there seems to have been an overall increase in the use of all metals (Pickles & Peltenburg 1998: 80). From an environmental point of view, it is frequently suggested that a lack of fuel could have triggered the use of iron (Pickles & Peltenburg 1998: 81). It is often assumed that smelting iron needs less fuel than smelting bronze. However, Pickles found this statement to be untrue. In fact, the smelting of copper sulphide ores is accompanied by an emission of heat, while iron oxide ores require a net input of heat (Pickles & Peltenburg 1998: 81-82). Consequently, iron smelting probably had a severe impact on the environment.

Once more, Cyprus was mentioned for its copper exploitation by early writers such as Erathosthenes (275-195 BC) (see above) and Homerus (Odyssey I, 184) who referred to mines at Tamassos (which were in use during the Archaic period) (Muhly 1996: 46).

It is suggested that from the Iron Age on, external forces constantly battled to control the Cypriot mines. A number of foreign forces successively managed to conquer Cyprus and particularly its mines, weakening its political power.

During the Geometric (1050-750 BC) and Archaic periods (750-475 BC), the exploitation of copper deposits continued without interruption, mainly within the Amathus and Tamassos region. In the mid 9^{th} century, Phoenicians settled in Kition. Soon after, their presence has been observed in Tamassos, the copper rich area near

Kition. The movement of Phoenicians on the island throughout the next centuries indicates a progressive attempt to control the mines (Raptou 1996: 250).

The Assyrians were also interested in the wealth of the Cypriot mines and by the end of the 8^{th} century a Cypriot king had become subjugated to the Assyrians. A stele found in Kition dating to about 709 BC refers to "mountain holes" in Cyprus, probably a reference to mines on the island. It is an important historical document testifying that the island's mineral wealth led to its subjugation to a dominant power (Raptou 1996: 250).

After the downfall of the Assyrian rule around 560 BC, Cyprus was controlled by the Egyptians and later in the late 6^{th} century by the Persians, both interested in its mineral resources (Raptou 1996: 250-251).

Mining reached a peak in the Classical period (475-325 BC). At that time, the mines at Tamassos, Amathus, Soloi and Marion were extensively exploited (Raptou 1996: 251).

III.2.2.5. Hellenistic (325-50 BC) and Roman period (50 BC – 395 AD)

During the Hellenistic and Roman period, copper was produced and exported on a large scale. In the Eastern Troodos area metallurgical production peaked during the Roman and Late Roman period (Knapp 1999: 103). There was an increase in metallurgical activities, as is evidenced by numerous slag heaps from the Roman period (Fox 1987: 169-175).

Textual evidence reveals that the Cypriot king provided the fleet of Alexander with copper. It is the only textual evidence from that period. Nevertheless, a document from the later part of the Hellenistic period shows the importance of the Cypriot mines towards the end of the rule of the Ptolemies, as it refers to the chief administrator of the mines (Raptou 1996: 252).

The Roman period provides more textual evidence about the mining organisation. According to Galen's account of his visit to Cyprus in 167 AD, a special inspector was appointed by the Emperor to control the mines. Most of the profits went to the Emperor, although the workforce organisation and ore shipment may have enriched people involved in these activities. According to Plyni, Cypriot copper was exported in large quantities and was used for a variety of things, including coinage (Michaelides 1996: 144). Hence, during Roman times the Empire largely controlled the exploitation of the mineral resources.

Does the historical view match the archaeological record?
A well-known metallurgical site is located at Ayia Varvara-*Almyras*. At this site remains of a Late Hellenistic open cast mine, various smelting furnaces as well as copper slags and also metal, testify copper production. However, the total amount of copper production at Almyras was a small-scale operation compared to what we might expect according to textual sources (Knapp *et al.* 1998: 226). On the other hand, investigation at Mitsero-*Kouloupakhis*, a multiperiod metallurgical production site ranging from the Classical period to Late Roman times, indicated metallurgical activities on a larger scale. The site consisted of a slag heap, workshop floors and building foundations. The slag heap must have been approximately 60 m in diameter and 15-20 m high, suggesting a production of approximately 50,000 tons of copper (Knapp 1999b: 102). This metallurgical site confirms better to the textual evidence suggesting state controlled mining operations. Other Roman metallurgical evidence was found at the site of Skouriotissa. The vast slag heap was estimated to have originally contained a million tons of slag. Zwicker has dated slag from Skouriotissa to 200 AD to 310 AD (Gale 1999: 114).

III.2.2.6. Byzantine period (395-1191)

There is less archaeological evidence for the later periods. Nevertheless, lack of research does not necessarily prove lack of metallurgical activity during this period. Interestingly, Raber found some Byzantine metallurgical sites in the Polis area. He mentions a change in the number and the distribution of metallurgical sites following the decline of the Roman hegemony. Not only was there an increase in the number of metallurgical sites but they also were larger. Though as the Byzantine period was quite long (about 800 years), the average of the yearly amount of slags produced for that period is lower. For the Late Roman and Byzantine time the production is about 9.5 metric tons a year. On average, it is less than in the previous periods (13 metric tons/year), though more than in Medieval times (7.7 metric tons/year) in the Polis area (Raber 1987: 304). Hence, there probably was an overall decline in production during the Byzantine period with relatively small quantities of ore being mined. The production was adapted to local supply and demand rather than to external economic or political forces (Raber 1987: 306).

III.2.2.7. Late Medieval times

It was wrongly believed copper sulphides mining ceased in Medieval times as the mines were closed down when the British took over the island. Evidence for copper production in Medieval times was found after Raber did research in the Polis region, Knapp in the Eastern Troodos, and Fox in the Paphos area. Though not extensive, the remains do indicate a rather localised continuity in production (Raber 1987: 306-307 ; Fox *et al.* 1987: 175 ; Given *et al.* 1999: 36). As a result, the number of metallurgical sites decreased and clustered around agricultural settlements rather than around the mines in that period. The mean annual production for the Medieval period in the Polis region is a little less than in the Byzantine period, quoted to about 7.7 tons/year (Raber 1987: 304-307).

III.2.3 Ancient metallurgy in the Western Cyprus Geo-archaeological survey area

Little metallurgical research has been undertaken in the geo-archaeological survey area. Probably, this is partially due to the fact that our survey area is located on the western side of the Troodos mountains and that the eastern side of these mountains was the main centre of metallurgical production.

However, Fox and his team investigated several metallurgical sites in the pillow lavas of the Paphos area (Fox *et al.* 1987). On the other hand Baird surveyed the Stavros-tis-Psokas drainage and found metallurgical evidence (Baird 1987).

III.2.3.1. Stavros-tis-Psokas drainage

As Baird's survey took place in the pillow lava area they found several metallurgical sites on a strip of only a few kilometers along the Stavros-tis-Psokas drainage. Late Roman slag heaps were found at Trimithousa-*Paravoulena*, Sarama-*Katavlaka* I (plate 14) and Philousa-*Leyirin*. They indicate an increased metallurgical activity in the area during that period (Baird 1987: 16-18). Additionally, while undertaking the geo-archaeological survey, we discovered 2 small possible mines in the area: one is located in a quarry at Sarama-*Alonakia* (cadastral map XXXV.38 plot 348) and the other is situated in a rock along the road at the location of Sarama-*Masari* (topographic map 35.XXIII).

III.2.3.2. Agriokalamos

The Agriokalamos is only a short drainage, which does not originate in the Troodos mountains. Hence, the river does not pass through the copper rich pillow lavas. Due to the absence of copper ores no metallurgical sites were discovered in its watershed. It does not necessarily mean the area was unaffected by deforestation due to metallurgy.

III.2.3.3. The Ezousas, Xeropotamos and Dhiarizos drainages

The Canadian Palaipahos survey (Rupp 1984: 141) located several metallurgical and mining sites in the pillow lavas of these drainages. Fox and his team examined those more extensively.

Along a tributary of the Ezousas river at the location Asproyia-*Ayios Sozondas*, 24 Medieval adits were discovered in the pillow lava. They range from 2 to 8 meters wide, 2 to 6 m high and some are over 8 m deep. Two slag heaps of about 2,000 square meters were found (Fox *et al.* 1987: 170). Another Late Roman to Early Byzantine metallurgical site within the Ezousas drainage, was located at Pano Panayia-*Kochina*. A slag dump and furnaces were found. The slag heap volume was estimated to about 875 cubic meters (Fox *et al.* 1987: 170-171).

Within the Xeropotamos drainage, two slag dumps were discovered along a small tributary. These heaps are located at Pano-Panayia-*Sarka A* on mineralised pillow lavas. Also several crucibles were found at this site. It is believed that the site was in use in Early Byzantine times. The slag heaps were estimated at about 2,650 cubic meters (Fox *et al.* 1987: 171).

The Ayios Nikolaos-*Ayios Georgios* site is situated in the Dhiarizzos watershed and probably dates to Medieval times. This smelting site is again located on pillow lava. The slag heaps are estimated to about 2,500 cubic meters (Fox *et al.* 1987: 172-171). Another Byzantine to Medieval metallurgical site in the Dhiarizzos reach was discovered at Ayios Nikolaos-*Topiarki*. The site consisted of some depressions in the hillside, interpreted as ancient mining and smelting furnaces (Fox *et al.* 1987: 173).

Although intensive archaeological surveys took place within these drainages, only a few and mostly small mining and smelting sites were discovered. In the past, the metallurgical centre was mainly located on the eastern Troodos. Nevertheless, there was quite a lot of metallurgical activity within these drainage areas during Roman times, early Byzantine and Medieval times. Earlier mining and smelting sites have not yet been discovered in this area.

III.2.4. Conclusion

As a conclusion, the absence of numeric data about slag heaps in order to estimate the actual production for each region and period on Cyprus, especially for our geo-archaeological survey area, necessitated the investigation of the Cypriot metallurgical history. This is even more vital because the practice of resmelting slags could have obliterated some evidence.

In spite of all available archaeological and historical evidence, we still seem to lack the necessary evidence to understand the exact impact of metallurgy on the environment. Most extensive mining sites were reused more recently. As a result former evidence has disappeared and accordingly only small mining sites were preserved. Hence, the archaeology of mining and smelting sites suggests rather small-scale activities. The historical evidence seems to point to more large-scale operations and organised activities, especially during Roman times but also during the Bronze Age. According to the ancient literature and correspondence Cyprus was famous for its copper. Raptou even suggested that metallurgy and shipbuilding were the basis of the island's economy in antiquity (Raptou 1996: 256). As a consequence, the importance of metallurgy on the Cypriot economy must have had a strong impact on the environment.

Additionally, if we were to doubt the importance of copper in the history and economy of the island of Cyprus, Muhly (1996: 54) advises us to visit the Skouriotissa mine:

> There is nothing anywhere in the eastern Mediterranean to compare with the estimated four million tons of ancient copper smelting slag in Cyprus (Muhly 1996: 54).

III.3. Evidence for malaria, thalassemia and indirectly for swamps

What does malaria and genetic adaptations to malaria have in common to rivers? Malaria is caused by a parasite (*plasmodium sporozoa*) living in malaria mosquitoes (*anopheles*) and is transmitted through mosquito bites. The malaria mosquitoes breed in stagnant pools and swamps. As a consequence, the occurrence of malaria requires a fluvial system with swampy, marshy and standing water. Russell mentions drying river beds as possible breeding places (Russell 1963: 203-214).

Researchers often correlate the malaria problem with human impact on the land. Russell suggests that in the Mediterranean region man has created breeding places for dangerous mosquitoes, more specifically pools, borrow pits, reservoirs, irrigation installations and canals (Russell 1963: 622). Moreover, Thirgood states that humans favoured the malaria mosquito through deforestation. Due to a lack of vegetation the topsoil was washed from the mountain crests and hillsides and deposited in the valleys and the sea. As a consequence, river estuaries were silted up and marshes were formed creating perfect breeding places for the mosquito (Thirgood 1981: 48). Malaria was mainly a coastal problem. Presently, this incidence is obvious in the gene pool of the coastal and mountain populations of Cyprus. Population studies have shown a prevalence of beta-thalassemia genes in coastal dwellers as compared to mountainous inhabitants (Fessas 1990: 119). Thalassemia is a genetic adaptation, rendering people less susceptible to the malaria parasite. Although more resistant to malaria, children with thalassemia suffer growth retardation and tend not to survive beyond early adolesence (Greene & Danubio 1997: 1-5).

The archaeological site of Khirokitia, indicating a high infant mortality, probably due to thalassemia, points to a particular state of the river surrounding the village. Indeed, recent investigations at the riverside indicate an unstable river, associated with alluviation and sedimentation in the Neolithic period (Hadjisavvas 1999: 616). Hence, geo-archaeological investigations at the site should be oriented towards specific problems to strengthen the palaeopathological evidence.

Whether a similar correlation existed between thalassemia and the fluvial system, will be investigated for the Paphos District in this study. Research indicates evidence for thalassemia at the Chalcolithic villages Lemba-*Lakkous* and Kissonerga-*Mosphilia* (Lunt *et al.*1998: 88-89). Hence, geomorphological work carried out on river sediments of the Agriokalamos could indicate a correlation between thalassemia and swampy conditions (cf. also XI.2).

III.3.1. Archaeological and historical evidence

A paper on an anthropological analysis of 252 human skeletons from the Neolithic site of Khirokitia in Southern Cyprus was published by Le Mort recently. A relatively high mortality proportion of children, mostly younger than one year old is observed. A high proportion of skeletal remains with children and infants showed incidence of porotic hyperostosis. Porotic hyperostosis is often correlated to genetic anaemias such as thalassemia (Le Mort 2000: 68).

At the Chalcolithic site Kissonerga-*Mosphilia*, dentition and bones were separately investigated, though both analyses suggested the same result: the prevalence of thalassemia among the former inhabitants (Lunt *et al.*1998: 88-89). Indeed, the shovel shaped incisors indicative of thalassemia, occurred more frequently in period 3 (3,500-2,900 cal. BC) than in period 4 (2,700-2,400 cal. BC). Even more indications of thalassemia were retrieved at another Chalcolithic site at Lemba-*Lakkous* (about 3 km westward) (Lunt *et al.* 1998: 82).

Moreover, Fischer found signs of porotic hyperostosis on skulls from archaeological sites on Cyprus. He suggests that the symptoms could be caused by thalassemia. Four out of the 160 skulls indicated an incidence of thalassemia. One skull was excavated from a Chalcolithic burial in Karavas and the remaining three were retrieved from Hellenistic burials at Halefka (Fischer 1986: 14-23).

Furthermore, two out of 40 skulls indicated porotic hyperostosis at the Late Cypriot site of Maroni, probably caused by thalassemia (Cadogan & Domurad 1989: 81).

Additionally, chemical, radiological and spectral analysis on skulls from the Late Bronze Age site of *Bamboula* was undertaken. The study indicated a prevalence of beta-thalassemia in Late Bronze Age Cypriot populations (Fessas 1990: 119).

At the Ayios Theodoros site, skulls from a Cypro-Archaic tomb were investigated. As a matter of fact, 6 of the adult skulls displayed evidence of porotic hyperostosis. Indeed, four of them showed occurrence of thalassemia mild to moderate, but two showed more pronounced bone abnormalities (Fessas 1990: 119).

Moreover, recent historical evidence of malaria in Cyprus was found. During the Venetian period, numerous visitors mentioned the "bad air" (malaria derives from the French "mal air") of the island (Christodoulou 1959: 60-61). As an example, Abbé Mariti described the so-called "bad air" that causes fevers in Cyprus in his travel book of 1259 (Lacroix 1853: 5). At that time, no correlation had been established yet between the mosquito and malaria. A population survey indicated that around 1920 every working person lost at least twelve days every year due to malaria. Additionally, his working capacity was reduced at least 7 more days (Christodoulou 1959: 60-61).

III.3.2. Impact of malaria on humans

Malaria incidence has profoundly influenced the genetic structure of human populations on Cyprus (Greene & Danubio 1997: 2). At present, about 16 % of the Cypriot population are heterozygotes, thus carriers and potential donors of the beta-thalassemia gene. As a matter of fact, this rate is considered almost the highest in the world (Fessas 1990: 119). Before getting married, people ought to check whether they do both carry thalassemia. If this is the case, they are advised not to consider having children (pers. communication Croft 2001).

Not only did malaria distort the genes of Cypriot people, it also had a major impact on their behaviour. This influence is reflected in the settlement pattern. During the "Conference on Land Use in A Mediterranean Environment" held in Nicosia, it was stated that a considerable number of the rural population had to live away from their homes for some time each year as to avoid malaria in the coastal areas (Proceedings 1947:18). With regard to the more remote past on Cyprus, Frankel suggested that the marshy coastal plains could have been an important negative factor in settlement location. The swampy coastal plains around Morphou and Salamis may only have been inhabitated in the second millennium when the climate became increasingly drier when the sea level lowered and the hazard of malaria was reduced. Hence, Frankel suggested that to some extent, reduction of malaria incidence could account for the spread of sites towards the East Coast during the Middle and Late Cypriot periods (Frankel 1974: 10).

III.3.3. Conclusion

As a conclusion, malaria could have been one of the problems coastal people endured as rivers silted up. The parasite was probably endemic in Cyprus by the Neolithic period and is attested throughout the island's history. Hence, the fluvial system did have indirect impact on both the Cypriot people's genes and behaviour.

IV. General conclusion and hypothesis building

Several variables that supposedly affected the alluvial sequence of Cyprus have been treated separately in previous sections. In this chapter, the variables are assembled so as to build a model of landscape evolution that can be compared with the alluvial sequence.

As a result of the above study, it is suggested that the combination of several changed variables could have triggered alluviation.

The following periods are marked by a combination of factors possibly favouring alluviation (Plate 4: fig. 5):

- The Neolithic period:

From 8,000 to 5,000 BC the moistest period of the Holocene took place, which triggered overbank flooding. Additionally, the drastically rising sea level favoured sedimentation in the river valleys. Moreover, Aceramic Neolithic humans on Cyprus started to establish villages depending on agriculture and pasturing. The landnam of the Aceramic Neolithic probably resulted in local deforestation, which might have induced local debris flow in the river valleys adjacent to settlements.

- Middle and beginning of Late Chalcolithic

After an extremely dry period the vegetation might have been reduced. When rainfall initially increased, it supposedly led to increased runoff, combined with gully erosion, resulting in alluviation in the river valleys. Additionally, an agricultural intensification from the Middle Chalcolithic on might have favoured further local deforestation.

- The Late Bronze Age

The Late Bronze Age is marked by a very dry climate. This possibly reduced the vegetation resulting in sheet erosion, deposited as debris flow in the river valleys. Furthermore, this period was marked by remarkable tectonic activity, known for triggering landslides. Moreover, human impact on the landscape increased since the introduction of the secondary products revolution in the Early Bronze Age and since the intensification of metallurgical activities in the Late Bronze Age. This way, they could have reduced the vegetation cover and possibly increased sheet erosion and debris flow.

- The Late Hellenistic and Roman period

Furthermore, during the Late Hellenistic and Roman period, a moister climate established, which suggests increased overbank flooding. Additionally, a marked sea-level rise took place, causing sedimentation. In this period, copper was exploited and produced on a large scale, resulting in severe deforestation, triggering even more sheet erosion. This period was also marked by increased tectonism, especially during the 4^{th} century AD (Late Roman).

- Frankish period

The Frankish period is featured as a warm and wet climate, that probably accelerated overbank deposition. Additionally, there was a major incidence of earthquakes, triggering landslides. During this period, new crops allowing two growing seasons were increasingly produced. Hence, farming intensification might have accelerated erosion and alluviation.

- Venetian period

During the Venetian period more intensive precipitation and extreme temperatures occurred. As a result, flood events supposedly deposited thick layers of alluvium. Frequent earthquakes took also place during that period, which might have caused landslides. Additionally, human impact on the landscape was rather intensive as a consequence of the use of two growing seasons in farming practices.

This hypothesis depending on the interpretation of published literature will be tested against the geo-archaeological fieldwork undertaken in Western Cyprus in section XI.1.

PART 3: The Western Cyprus Geo-archaeological Survey: Fieldwork and laboratory investigations

V. An introduction to the survey area: geology and archaeology

The Western Cyprus geo-archaeological survey investigates river terraces in the Paphos District. The boundary of the survey area is topographically separated from other regions of Cyprus. In fact, the island is very regionalised topographically, geologically and geomorphologically. The limit of the geo-archaeological survey area in the north is shaped by Troodos mountainous outliers which reach right to the sea. In the south around Petra tou Romiou a hilly topography forms a similar barrier for communications with southern Cyprus (Stanley Price 1979: 7).

Several morphological microregions can be discerned within the survey area which are closely related to the island's orogenesis. This is why it is necessary to describe Cyprus' formation history (plate 5: fig.6). The origin of Cyprus took place at the bottom of the Thetys Sea, the precursor of the Mediterranean Sea. During the Mesozoic, the Troodos core developed at the bottom of the Thetys Sea. This core consisted of plutonic deposits of the gabbro group around which ringshaped deposits of intrusive and extrusive rocks were laid down. The intrusive stones now appear as long ridges of hard resistent rocks of the diabase group. Pillow lavas were formed as a consequence of magma in contact with cold sea-water (extrusives). This all took place under water (Cleintuar *et al.* 1977: 69). Only during the Lower Miocene (a phase of the Tertiair), uplift of the Troodos above the sea-level occurred. Additionally, in the Upper Miocene the Kythrea flysh deposits (Kyrenia) were also uplifted and reached the water surface. The main uplift took place in the Upper Pliocene (last phase of the Tertiary)-Mid-Pleistocene and a less intense uplift continued into the Late Pleistocene. Hence, during the longest part of the Tertiary, Cyprus consisted of two islands : Kyrenia and Troodos. Subsequently, the "Central Lowlands" shaped by Tertiary and recent sediments, developed between the Troodos and the Kyrenia Mountains (Cleintuar *et al.* 1977: 72).

As a result of the formation history, it is possible to discern three zones in the Western Cyprus survey area:

1. The Troodos Massif (plate 210: fig. 539): plutons, intrusive (diabase) and extrusive rocks (pillow lavas):

The imposing landscape of the Troodos is a result of Pleistocene uplift of the island, centered on the Troodos, especially on Mount Olympos. This landscape consists of a high mountain range branching off into ridges, divided by streams. The plutonic-diabase areas shape the real mountainous character of the Massif. Surfaces vary from spectacular pinnacles associated with dykes to massive rounded domal hills formed by lava accumulations, but also crumbling weathered rock and even level surfaces. The pillow lavas shape a much lower and less wild landscape. These lavas weather easily and give rise to domeshaped hills and open valleys (Christodoulou 1959: 10).

2. Paphos chalk plateau area (plate 210: fig. 539):

The surface of this area is dominated by white or light-coloured rocks, Pakhna and Lapithos formation, consisting of surfaces of plateaus falling step-like seaward, separated from each other by gigantic canyon-like valleys. Black Mamonia deposits underlie this plateau and occasionally are exposed by river erosion and earthquakes (Christodoulou 1959: 17).

3. The Ktima Lowlands (plate 210: fig. 539):

This region consists of a coastal strip of about 25 km long, and a maximum width of 5 km wide. It is characterised by a series of sea terraces while several consolidated sanddunes also occur in the area (Christodoulou 1959: 18).

As a rule, the Paphos area is geologically unstable and prone to earthquakes. For more information on the archaeoseismicity of the region we refer to II.3.

In the next sections, a short introduction on the major geological regions the investigated rivers flow through will be presented. This study will be of major importance in section VIII.2. in which the provenance of the clasts will be investigated. Additionally, the settlement history of the drainage will be investigated because its importance in the evaluation of the causality of the landscape changes. Splitting up the archaeological evidence by drainage makes sense due to the fact that eroded sites ultimately end up in the river system. Moreover, it has often been suggested for Cyprus that communications in the past mainly took place along the major river systems and less across ridges (Gomez & Pease 1992: 5). Consequently, communications in the past and water shared the same boundary.

V.1. Smaller Streams

As a matter of fact, smaller streams respond faster to anomalies such as climatic change and human impact. On the other hand, larger streams need more pronounced changed variables to imbalance the system.

V.1.1. Stavros-tis-Psokas

V.1.1.1. Geology and geography

The Stavros-tis-Psokas (plate 6: fig. 7, plate 5: fig. 6 and plate 211: fig. 540) rises in the Troodos Mountains and flows to the west through the Paphos Forest over pillow lava. Subsequently, it passes through bentonic clays/tuffaceous sandstone and limestone with a pillow lava outcrop in the middle. Finally, it flows over marls to join the Khrysokhou River to the sea. The valley is deep and narrow until it broadens out for some 8.4 km between Sarama and Evretou (Sheen 1981: 39). The river evolution was more closely investigated between these villages.

The Stavros-tis-Psokas is a meandering, perennial river. Nowadays however, the natural river has been disrupted by a dam, just W. of Evreti. Its present river bed consists of cobbles and pebbles. Leaving the forest, the river is accompanied by a gallery of trees. Although the above mentioned valley at first looks rather wild due to its green colour in springtime and the absence of dwellings, nonetheless it is an artificial landscape neatly divided in cultivated plots. Obviously, the landscape must have looked differently in the past.

Geomorphological mapping has been undertaken mainly between Sarama-*Skarphos* and Sarama-*Kamarin* (see plate 14: fig. 24). Several test pits aided the mapping. The location of the pits is indicated on fig. 24.

- Pit 1: Sarama-*Skarphos,* plot 298 on cad. XXXV.38, 50 m. SE of mill in plot 298, 20 m E of border of plot on level ground adjacent to river.
- Pit 2: Sarama-*Skarphos*, plot 300 on cad. XXXV.38, at the edge of a river terrace, 25 m E of E border of plot and 30 m N from Stavros, just S of the Chalcolithic site Sarama-*Katavlaka*.
- Pit 3: Sarama-*Skarphos*, plot 300 on cad. XXXV.38 on level ground, adjacent to Stavros-tis-Psokas, 25 m of W border of plot.
- Pit 4: Sarama-*Kambos*, plot 291 on cad. XXXV.38 adjacent to the river on S bank, pebbles which were impossible to dig through.
- Pit 5: Sarama-*Kambos*, plot 291 on cad. XXXV.38, on terrace on S bank of the Stavros, 25 m from Stavros.
- Pit 6: Sarama-*Katavlaka*, plot 381/5 on cad. XXXV.38, on edge of terrace adjacent to a former river channel, 10 m SE of mill and near Roman settlement, was bulldozed.
- Pit 7: Sarama-*Kamarin*, plot 385 on cad. XXXV.38 on level ground 175 m E from E mill, about 5 m NW of old channel in this field.
- Pit 8: Sarama-*Skarphos*: plot 293 on cad. XXXV.38 on gently sloping ground, 75 m SW of middle mill, 30 m N of Stavros-tis-Psokas.
- Pit 9: Sarama-*Alonakia,* plot 394 on cad. XXXV.38 at E edge of the plot, which is a small terrace of Stavros.
- Pit 10: Sarama-*Skarphos*, plot 83 on cad. XXXV.38, 50 m N of the eastern mill.

- Pit 12: Sarama-*Katavlaka*, plot 386/1/3 on level ground 225 m E of easternmost mill, 125 m N of Stavros-tis-Psokas.

Furthermore, at Sarama-*Kamarin* (XXXV.38, plot 353) an exposure was investigated just NE of the junction of the Argakin Pyroia and the Stavros-tis-Psokas. The sections were called TA and TB. At this location the geomorphological research started from a pronounced query. The Argakin Pyroia, nowadays a steeply incised channel, divides two Bronze Age artefact scatters from each other. Baird questioned previously whether the Argakin Pyroia also did exist in the Bronze Age (cf. survey notes D. Baird).

V.1.1.2. Archaeology

The area from Evretou to Sarama was first surveyed by Alun Sheen in 1979 (Peltenburg *et al.* 1981: 37). A complementary survey was undertaken by Douglas Baird in 1985 (Baird 1987: 15-18). In 1999, some Prehistoric sites were re-surveyed by the Lemba Archaeological Project, but the detailed analysis has not been finished yet. As a consequence, a relatively good knowledge of the settlement history along that part of the river valley resulted from these surveys.

- An abundance of Late Neolithic activity took place in this area at both sides of the Stavros-tis-Psokas : six Late Neolithic sites within a strip of 3.5 km long and 1 km wide. Late Neolithic sites occurred at Anadhiou-*Pappares*, Evretou-*Amakharos*, Philousa-*Koprikoes*, Sarama-*Alineri* (plate 14: fig. 24), Sarama-*Katavlaka* (plate 14: fig. 24) and Sarama-*Spilios*. Settlement drift may be responsible for part of this dispersed pattern, but not necessarily for the entire pattern.
- Chalcolithic sites followed up the above mentioned Late Neolithic sites. Especially the Early Chalcolithic period is well represented in the area. However, a Late Chalcolithic site was discovered at Sarama-*Katavlaka* II (plate 14: fig. 24), associated with some earlier material.
- In the following Early Cypriot/Middle Cypriot periods, this zone was again extensively exploited. Two settlements occupy large areas : Sarama-*Kamarin*

/Liphonia and Sarama-*Terracha* (plate 14: fig. 24). Perhaps did Samara-*Kamarin/Liphonia* extend until Samara-*Pernarka* and was Sarama-*Alineri* II/*Katavlaka* IV connected with Sarama- *Terracha*. However, it was only suggested and further research will be necessary to confirm it. Moreover, it is unsure whether they represent a single site without the present day natural division. More specifically, did the gully Argakin Pyroia exist at the time the site(s) was (were) occupied? Sections TA and TB will explore this hypothesis more extensively. Several Early and Middle Cypriot burial grounds were also found dating to that period.

- No Late Bronze Age sites were identified in the area.
- A pattern of densely distributed small sites probably existed in this area during the Cypro-Geometric II - Cypro-Archaic II period. This occurrence of sites is in contrast to the limited evidence for sites of the Cypro-Geometric I - Cypro-Geometric II periods. Six separate Iron Age components were found. Two settlements and two cemetery sites can be assigned to the Cypro-Geometric III - Cypro-Archaic II periods and all sites date to the Cypro-Archaic I period. Two small components lacked sufficient diagnostic material to be assigned to a specific period within the Iron Age: a cemetery site at Evretou-*Agyia Mavri* and a small, possible settlement component at the edge of Evretou-*Amakharos*.
- Several Roman and Byzantine sites were found. Characteristic is their association with slag. Slag heaps were found at Trimithousa-*Paravoulena*, Sarama-*Katavlaka* I (plate 14: fig. 24) and Philousa-*Leyirin*. The occurrence of slag implies certain developments in the organisation of the metal extraction industries (see also III.2.3.1).
- More recent evidence of landscape alterations since Venetian times is attested at Sarama-*Skarphos* (plate 14: fig. 24). In recent times, the river channel has abandoned the passage under the Venetian bridge at this locality (cf. cover fig). We may say that at a given time after the Venetian period, the river filled her own channel with alluvium and was due to find a new way. Moreover, ruins of Medieval corn mills are ubiquitous in the landscape along the Stavros. In the past, they were driven by water, though no evidence of water channels was

retrieved. Additionally, in the present-day Stavros forest at the foot of the Troodos mountains old walls testify former cultivation (Thirgood 1987 : 27).

As a matter of fact, archaeological sites are mostly concentrated on level, gently sloping, good arable land immediately north of the river between Sarama and the outlying pillow lavas to its west. Some smaller sites occur on the less fully sampled, more broken, southern slopes. However, differential erosion factors may be responsible for this pattern. Moreover, pre-Bronze Age sites are located on the open slopes N and S of the river, whilst larger Bronze Age components occupy the more commanding limestone plateau W of Sarama (Baird 1987 : 16-18).

V.1.2. Agriokalamos

V.1.2.1. Geology and geography

The Agriokalamos (plate 6: fig. 7, plate 212: fig. 541) is a minor stream of only 4 km long; originating in the limestone plateau zone, subsequently flowing through the calcarenite area, passing some serpentinite and Mamonia formation outcrops. The river valley widens out near the coastal plain and finally joins together with the Argakin tou Taisi.

The Agriokalamos is a meandering river and is accompanied by reed vegetation.

Fieldwork was carried out on an exposure bulldozed into alluvial sediments on the westernmost bank of the Agriokalamos (plate 31: fig. 66 and plate 30: fig. 65), cadastral XLV/49 and 50, plots 48, 46 and 43. The investigated exposures, KAGA, KAGB, KAGC and KAGD are located about 450 m E from the coast, 50 m N of the present river bed of the Agriokalamos and bordering a track which is leading to a coastal road to Paphos.

V.1.2.2. Archaeology

Most prominent in this research is the location of the Chalcolithic settlement of Lemba-*Lakkous* (Plate 31: fig. 66) on the interfluve of the Agriokalamos and the Argakin tou Taisi (Peltenburg 1985: 6). Nowadays the site sits on a ridge which slopes towards the Argakin tou Taisi. From 3,500 until about 2,400 BC the site was occupied. The excavation reports of the site mention slope-wash and gullies in Prehistoric contexts, being an important element in this study (Peltenburg 1985: 11 and fig.35). Consequently, it was obvious to investigate the river sections nearby more accurate as to have a clear understanding of the erosional processes that affected the site of Lemba. As a result, a better topographical insight of Lemba will be acquired. It is obvious that people building their dwellings on a ridge, trampling and channeling of runoff by structures, trails or streets will cause deep gullies on the slopes below, exposing bare rock around the settlement. Within a radius of 3 km from Lemba, two other Chalcolithic sites have been discovered though occurring outside the Agriokalamos watershed (Hadjisavvas 1977: 223). As a consequence, the region was relatively densely inhabited during the Chalcolithic period.

Additionally, on the other bank of the Agriokalamos there is evidence of an Early Cypriot settlement and necropolis at Kissonerga-*Ammoudhia* (Plate 31: fig. 66) (Hadjisavvas 1977: 223).

Furthermore, Roman and Hellenistic remains are ubiquitous in the landscape as Paphos was an important centre during these periods and its hinterland was exploited to support the town (Hadjisavvas 1977: 233).

Moreover, Medieval settlement was located at Lemba-*Ayia Marina* (Plate 31: fig. 66). Written as well as archaeological evidence indicates a prosperous sugar cane industry from the 15th century associated with the Medieval village (Peltenburg 1985: 5; von Wartburg 2000: 385).

V.2. Major rivers

The Dhiarizzos, Ezousas and Xeropotamos (Plate 6: fig. 7) are major drainages of the island which will be investigated in this study. Their headwaters are located in the Troodos and flow radially out of the mountains to the west. Although perennial, the extensive use of irrigation dries out their river beds in summer.

The above rivers all have a braided river morphology, with multiple meandering channels after leaving the mountain range. The channels are shallow and have a low sinuosity. The river plains are scattered with gravel. In the Troodos and at its foothills the rivers are bordered by trees. More towards the sea, trees get scarce.

The settlement history of these drainages is well-known because the Canadian Palaipaphos survey has located multiple sites since the eighties.

V.2.1. Dhiarizzos

V.2.1.1. Geology and geography

The Dhiarizzos (plate 6: fig. 7, plate 5: fig. 6 and plate 210: fig. 539) has its source on the Western side of the Troodos mountains. Its physiography reflects the underlying geological formations. First, it passes through the foothills of the Troodos Mountains, underlain by the Mesozoic igneous complex and associated volcanics. Further downstream the river dissects deeply a chalk, limestone, marl and gypsum plateau and the tectonically displaced Mamonia Complex. Finally, it reaches the coastal plain built up by Holocene alluvial clay (Rupp 1984 : 134).

In this study, fluvial exposures have been investigated at several locations along the Dhiarizzos river, in the coastal plain as well as in the limestone area and further inland at the Troodos foothills.

- Two soil sections were investigated at the mouth of the Dhiarizzos, here named KOL1 and KOL2. KOL1 is located at Kouklia-*Terchioti* at a natural exposure on the W bank of the present river bed (Plate 57: fig. 136), cadastral map LI.48, border of plot 178 and 180. On the other hand, KOL2 is located on the E side of the present day river (Plate 57: fig. 136). The latter is also a natural exposure, incised by the present day river, only 10 m away from the newly built main road.

- A next prominent and interesting exposure was located inland, from Kouklia at the deserted village of Souskiou: here named SOA, SOB, SOC and SOD (Plate 68: fig. 167). On this location, several meters of fan deposits are exposed, developed at the juncture of the Dhiarizzos and the Fonias, cadastral LII.25 and topographic map 52.IX. SOA and SOB are located at the edge of the village, at a distance of only a few meters from each other, SOA more southerly than SOB. SOC and SOD are located on the lower river terrace exposed by the present river.
- Another investigated section was located just south of Phasoula beside of a small bridge, here named section PH1. Nevertheless, the exact location of this exposure has not been identified yet. The section was exposed by the present channel.
- Further inland, several sections have been investigated near Prastio: here named PR1, MA and MB. PR1 is situated at the locality Prastio-*Potami* near a track along the river, adjacent to a prominent rocky outcrop (cadastral LII.4) on the border between plot 117 and 158 (topographic map 52.IV). E of the section is a track leading to the village Prastio (Plate 97: fig. 245). Sections MA and MB are situated about 250 m N of the deserted village Prastio at the junction of two streams: a small unnamed stream coming from the SE and the main river the Dhiarizzos. Section MB is located on the corner of plot 403. Section MA is located at a lower elevation, closer to the Dhiarizzos on the W border of plot 104 (cadastral XLVI.61, topographic 52.V. and 46.XXIX) (plate 105: fig. 265).
- In the Troodos foothill area, a section exposed by the present day Dhiarizzos was investigated, here named KIS1, at the locality Kithasi-*Skales* (Plate 118: fig. 301). The section is located at the bridge over the Dhiarrizzos to Kithasi, cadastral XLVI.54, W edge of plot 259, topographic map 46.XXX.

V.2.1.2. Archaeology

A. Settlement history of the drainage

The first evidence for inhabitants along the Dhiarrizos dates from the Aceramic Neolithic period. Though, the occupation in this region was rather scarce. Subsequently, in the Ceramic Neolithic, some occupation took place in this region, though not dense. Indeed, early inhabitants of Cyprus well and truly colonised this region (Rupp 1987: 34).

Throughout the Chalcolithic period, settlements were probably more extensively and uniformly distributed throughout the drainage than in preceding periods (Rupp 1987: 34).

In the Early Bronze Age, the Dhiarizzos drainage area was probably almost uninhabited[11] (Rupp 1987 : 34). The following Middle Bronze Age sites represent a repopulation of the area as extensive as in the Chalcolithic period (Rupp 1987 : 34). However, during the Late Bronze Age, an even more dramatic increase took place in the number of components. As a matter of fact, most of the sites cluster around the eastern and southern edges of the village of Kouklia. Hence, the changed settlement pattern suggests an increase in population and the development of the settlement at Palaepaphos into a central area (Rupp 1987 : 34). We may say, there is little evidence for habitation sites from the Cypro-Geometric I-II period. However, the extensive bulldozing of the countryside has accidentally revealed numerous isolated tombs and cemeteries dating from the later part of the Cypro-Geometric III and Cypro-Archaic II period. Notwithstanding the numerous components from the Middle Iron Age, only few settlements can be securely assigned to this period. The significant decrease in the number of sites from the Cypro-Classical period may be a result of the siege of Palaepaphos by the Persians in 498/7 BC (Rupp 1987 : 35).

[11] However, this may also be a matter of archaeological visibility.

On the other hand, in the Hellenistic and Earlier Roman period, the region must have been prosperous. A high concentration of sites in the lower portion of the river drainage, was a result of the proximity of the provincial capital at Nea Paphos and the international sanctuary of Aphrodite at Palaipahos. Moreover, another reason for the increase in occupation must be connected with smelting and mining activities in this region as is attested by slag (see III.2.3.3) (Rupp 1987 : 35, 38).

The extreme paucity of components that can be attributed to the Late Roman period is probably a result of the devastating effect of a series of earthquakes from 332 to 365 AD (see II.3) (Rupp 1987 : 38).

In the Early Byzantine period (5^{th} through mid-7^{th} century AD) a limited recovery of activity took place in this area (Rupp 1987 : 38).

This stable politico-economic situation changed abruptly in 648 AD, when the first Arab raid took place. More Arab incursions from 653-965 AD brought destruction and poverty. The coastal settlements were abandoned. Moreover, a bubonic plague in 747 AD accelerated the population decline (Rupp 1987 : 38).
Although the island was under Byzantine control again from 965 AD, there is little settlement evidence in the drainage area (Rupp 1987 : 38).

By the 13^{th} century, stability and economic prosperty returned as a result of the foundation of the Lusignan kingdom on Cyprus. The distribution of Medieval components is widespread and numerous. Ubiquitous evidence for sugar cane production was found in the lower Dhiarizzos valley, mainly on the coastal plain (Rupp 1987 : 39).

Under the Venetian rule, neglect and exploitation caused a noticeable decline in the economy of the region (Rupp 1987 : 39).

B. Archaeological evidence in the neighbourhood of geomorphological sections

➢ Kouklia : KOL1 and KOL2

The settlement history of the KOL sites is closely related to the centre at Kouklia (Palaepaphos) (see plate 57: fig. 136), a main focus of human activities throughout history which is located less than 1 km away. From the Late Bronze Age on, Palaepaphos first was important and developed into a town of economic, artistic and religious importance (Maier & Von Wartburg 1985: 147-152). Although little settlement evidence has been discovered from the Geometric period, Palaepaphos probably remained important because of the finds at the extremely rich Kouklia-*Skales* cemetery. Evidence from walls of the 8th century BC indicates that the inhabited area had enlarged by the Archaic period (Maier & Von Wartburg 1985: 152). Palaepaphos remained a religious centre throughout the Iron Age (Maier & Von Wartburg 1985: 155). In 498 BC, the Persians attacked the town. Hence, it was a turbulent period for Palaepahos (Maier & Von Wartburg 1985: 157). By ca. 300 BC, the inhabited area of Palaepahos shrank considerably. We may say this process was connected to the new foundation of the harbour town at Nea Paphos as part of the population had been transferred to this place (Maier & Von Wartburg 1985: 159). Hence, the beginning of the Hellenistic period marked a change for the importance of Palaepahos. As a matter of fact, the centre of southwestern Cyprus became a sanctuary town (Maier & Von Wartburg 1985: 159). Nevertheless, Palaepaphos remained a town of some wealth well into the Late Roman period (Maier & Von Wartburg 1985: 160). Though the sanctuary was destroyed in the 4th century AD, the town continued existing. According to Maier, an ancient writer recorded that the buildings of the town even streched down to the coastal plain. The site was inhabited until at least the 7th century AD (Maier & Von Wartburg 1985: 162). Subsequently between the 8th and 11th century, there was a gap in occupation at Palaepaphos due to Arab raids (Maier & Von Wartburg 1985: 162). Under the Lusignan dynasty Palaepahos became an important centre again, as a result of its cane sugar production. The Royal Manor House of Couvoucle and its industrial buildings on the sanctuary site and at the locality *Stavros* (only 200 m away from investigated soil section) were the main headquarters of the Royal sugar cane estates in the Paphos area (see plate 57: fig. 136). Between these three production sites remains of an aqueduct were found. Hence, the scale of operations must have been industrial (Maier & Von Wartburg 1985: 165-166). As a result of the sugar industry a Medieval settlement developed above the ruins of the former city (Maier & Von Wartburg 1985: 169).

➢ **Souskiou : SOA, SOB, SOC and SOD**

The deserted village of Souskiou (plate 68: fig. 167) is located on a huge fan on the eastern bank of the Dhiarizzos river, about five km north of Kouklia. Most of the discovered sites, were found in a confined area close to the river Dhiarrizos and to the Vathyrkakas stream. This small area was intensively inhabited from Prehistoric to Medieval times. Indeed, some remains of the subsequent habitation periods are scattered over the fields. Abundance of water in the area obviously was the main reason for this intensive habitation (Hadjisavvas 1977 : 228).

Chalcolithic period:

- Souskiou-*Laona*: Middle Chalcolithic settlement and cemetery (cf. unpublished data Lemba Archaeological Project).

The site is about 1.5 km south-west of Souskiou village on a prominent hill overlooking the Dhiarizzos river and the Vathyrkakas stream. The remains of a settlement are scattered over the entire surface of the hill (Hadjisavvas 1977 : 288).

- Souskiou-*Vathyrkakas*: Middle Chalcolithic cemetery

The site is located about 2 km from the village Kouklia, on the flat top of a plateau overlooking the Vathyrkakas stream (Hadjisavvas 1977: 288).

Bronze Age:

- Souskiou-*Grikellati* 1: Late Cypriot and Roman settlement (Hadjisavvas 1977: 230).
- Souskiou-*Grikellati* 2: Late Cypriot cemetery, close to the north of the Late Cypriot settlement (Hadjisavvas 1977 : 230).

- Souskiou-*Paralonia* 1: Late Cypriote site 2.5 km S of the village on the top of a flat hillock. Stones and pottery mark the area of the settlement (Hadjisavvas 1977 : 230).
- Souskiou-*Teratsoudhia*: multiperiod installations 1.5 km SE of Souskiou village (Hadjisavvas 1977: 230).

Iron Age:

- Souskiou-*Paralonia* 1: settlement (Hadjisavvas 1977: 230)
- Souskiou-*Paralonia* 2: necropolis close to the settlement site of Souskiou-*Paralonia* (Hadjisavvas 1977 : 230)
- Souskiou-*Teratsoudhia*: multiperiod installations 1.5 km SE of Souskiou village (Hadjisavvas 1977: 230).

Roman period:

- Souskiou-*Arkossilleri*: a large settlement 1.5 km south-west of Souskiou village on the plateau overlooking the Vathyrkakas stream and just east of the Chalcolithic necropolis (Hadjisavvas 1977 : 230).
- Souskiou-*Plakota*: cemetery about 400 m W of the village on the opposite bank of the Dhiarrizos river (Hadjisavvas 1977 : 231) (see plate 68: fig 167).
- Souskiou-*Mandroudhes*: settlement about 400 m W of the village on the hills overlooking the western bank of the Dhiarrizos river (Hadjisavvas 1977 : 231) (see plate 68: fig. 167).
- Souskiou-*village* is now deserted. While visiting the village in 1991, Niels Hannestad found numerous reused stones of Roman date in the present day deserted village of Souskiou. He suggests a Roman settlement of some size (either large villa or small village) was located at this place (Bekker-Nielsen : 1995: 131).
- Souskiou-*Grikellati*: settlement (Hadjisavvas 1977: 230).
- Souskiou-*Paralonia*: settlement (Hadjisavvas 1977: 230)
- Souskiou-*Tratsoudhia*: multiperiod installations 1.5 km SE of Souskiou village (Hadjisavvas 1977: 230)

Medieval period:

- Souskiou-*Mandroudhes*: Roman settlement was reused in Medieval times (Hadjisavvas 1977: 231) (plate 68: fig. 167).

- Souskiou-*Engleistron*: Medieval settlement about 1.5 km south-east of Souskiou village, in the valley north of the Vathyrkakas stream. A chapel dedicated to Ayios Konstantinos and the remains of other buildings mark the area of a Medieval settlement (Hadjisavvas 1977 : 231).

➢ **Prastio : PR1, MA and MB**

Several archaeological sites have been located in the area previously and possibly had an impact on the alluvial history (see plate 97: fig. 245 and plate 105: fig. 265).

Neolithic:

- Prastio-*Kokkinolaona A*: Late Neolithic site on top and on gentle to moderately sloping sides of short ridge overlooking Dhiarizzos river (Rupp *et al.* 1992 : 289) (plate 97: fig. 245).

Chalcolithic:

- Prastio-*Ayios Savvas tis Karonis*: Early and Middle Chalcolithic site on top and gently sloping sides of terraced ridge overlooking the Dhiarizzos floodplain (Rupp *et al.* 1992: 289) (plate 97: fig. 245).
- Prastio-*Kokkinolaona A*: Early Chalcolithic site on top and on gentle to moderately sloping sides of short ridge overlooking Dhiarizzos floodplain (Rupp *et al.*1992: 289) (plate 97: fig. 245)
- Prastio-*Mesorotsos*: Middle Chalcolithic specialised flint-knapping site and/or hunting-herding outlook post on the eastern side of a prominent rocky outcrop adjacent to the Dhiarizzos river, 150 m S of the village Polemidhia and 300 m NW of the deserted village Prastio. There is a track that leads S-ward to the site on the point where the road to Trachypedoula diverges from the main road to the Troodos. The site is bordered by two unnamed gullies leading to the Dhiarizzos (unpublished information Lemba Archaeological Project) (plate 105: fig. 265).

Bronze Age:

- Prastio-*Lakries*: Middle Cypriot settlement and tombs above right bank of Dhiarizzos (Rupp *et al.*1992: 289) (plate 105: fig. 265)
- Prastio-*Argkanthera*: Late Cypriot IA tombs (Rupp *et al.* 2000: 204)

Iron Age:

- Prastio-*Ayios Savvas tis Karonis Monastery*: a sanctuary dating from ca. 350 to 50 BC (Rupp *et al.* 2000: 205) (plate 97: fig. 245).

Roman:

- Prastio-*Kokkinolaona B*: Late Roman site and cemetery (Rupp *et al.* 2000: 205) (plate 97: fig. 245).

Medieval:

- Prastio-*Ayios Savvas tis Karonis* (plate 97: fig. 245): the monastery was founded ca. 1120 AD. The ceramic remains suggest that activity at the monastery increased in the 15^{th} and reached its height in the 16^{th} century AD. After that period, increasingly less evidence was retrieved for its use, though restoration works were undertaken until 1929. The conclusions of the archaeological investigations undertaken at this location are important for this study. It is suggested that the intensive agricultural utilisation of the landscape around the monastery during the 15^{th} and the 16^{th} centuries caused significant erosion and destroyed several archaeological sites (Rupp *et al.* 2000 : 205-206). Testing the above evidence with the alluvial sequence is imperative (cf. chapter XI.1).
- Prastio-*Lakries*: Medieval settlement (Rupp *et al.*1992: 289) (plate 105: fig. 265)

➢ **Kithasi: KIS**

- Kithasi-*Ayia Mavri*: Prehistoric site on left bank of Dhiarizzos river (Held 1992: 135).
- Kithasi-*Plevra*: Late Neolithic and Hellenistic/Roman site on moderately sloping terraced hillside above a small stream leading to the Dhiarizzos (Rupp 1992 : 292).
- Kithasi-*Foutsi*: tomb (BCH 1995: 809)
- Kithasi-*Plevra*: tomb, Late Neolithic and Hellenistic/Roman settlement (BCH 1995: 809, Rupp 1992: 286)
- Kithasi-Asproyi (Rupp 1992: 292)
- Kithasi-*Spilios* (Rupp 1992: 292)
- Kithasi-*Mylona*: Hellenistic/Roman settlement with isolated tombs (Rupp 1992: 286).

- Kithasi-*Phrakti tou frangou*: Hellenistic/Roman and Medieval settlement with possible Prehistoric component (Rupp 1992: 286).
- Kithasi-*Old Village*: Medieval to recent settlement (Rupp 1992: 286) (plate 118: fig. 301).

V.2.2. Ezousas

V.2.2.1. Geology

The Ezousas river (plate 6: fig. 7) is the largest perennial river of the three investigated large rivers. It leaves from the mountainous basal group, passes through the lower pillow lava just north of Kannaviou and further through the upper pillow lava, the Kannaviou formation marl, some serpentinite outcrops just S of Kannaviou and also chalks, marls and gypsum further on its way SSW. Finally, it reaches the coastal plain (plate 5: fig. 6).

Soil sections were investigated at sea-side locations as well as at the Troodos foothills.

- Investigated river terrace locations inland on the territory of the village Ayia Varvara:

EZA is located at Ayia Varvara-*Pervoloudhin* on the edge of the modern floodplain, 350 m NW of the village Ayia Varvara, about 7 km from the sea, cadastral LI.22, plot 51, topographic map: 51.XIV (plate 126: fig. 320).

EZB represents about the same fluvial history as EZA and is located only 50 m N of EZA, cadastral: LI.22, plot 288, topographic map: 51.XIV (plate 126: fig. 320).

EZC is located 50 m N from EZA and represents a river terrace exposed by a present day river channel. It is located adjacent to a track coming from Ayia Varvara (plate 126: fig. 320).

EZD is situated 950 m N of the village Ayia Varvara at the locality *Avlakin tou Aylou*, cadastral: LI.14, E edge of plot 236, topographical map: 51.VI. The section was exposed by bulldozing activities (plate 146: fig. 375).

EZE and EZF are located about 150 m N of EZD, at the locality Ayia Varvara-*Loura*, cadastral: LI.14, plot 238, topographical map: 51.VI plate 146: fig. 376).

- Investigated geomorphological sections at the Troodos foothills

EZG is situated at the edge of the Troodos mountains and forest, N of the village Kannaviou, off the main road before the bridge over the Ezousas, E of the track to Ayia, cadastral: XXXVI.49, at the W edge of plot 349, topographic 36.XXV, at the locality Kannaviou-*Potamos* (meaning river) (plate 164: fig. 421).

EZH was investigated at the other side of the river, only 50 m NW of EZG, at the locality Kannaviou-*Kathistra*, cadastral: XXXVI.49, at the E edge of plot 400, topographical map: 36.XXV (plate 164: fig. 421).

V.2.2.2. Archaeology

A. Settlement history of the drainage basin

Some Prehistoric activity took place at the northern and southern part of the Ezousas (Sørensen 1993).

In the later Geometric and Archaic period, a marked increase in occupation in the Ezousas drainage area and more specifically in the coastal area, took place (Sørensen 1993).

Towards the end of the Archaic period a reduction of sites occurred and continued throughout the Classical period, especially in between the lower Xeropotamos and the Ezousas area. On the other hand, an increase in habitation to the east of the Ezousas took place (Sørensen 1993).

Moreover, activity intensified along the Ezousas river in the Hellenistic period, resulting in a greater density in the upper Ezousas.

This trend continued into the Early Roman period. In particular, the lower drainage of the Ezousas was densely inhabited. However, a slight population decrease in the area is suggested in the late Roman period.

Sometime in the Early Byzantine period, around 650 AD, a new decline has been observed. In the upper Ezousas drainage, the site of Lapithiou-*Ayia Paraskevi* played a capital role in the control of the metallurgical activity in the region (Rupp 1986: 38).

Kannaviou-*Khryseleousa* was the only 12th century site found in the Ezousas drainage area on the upper portion of the Ezousas. It is situated on an isolated location (Rupp 1986: 39). However, from the 13th century on, an increase in activities took place in this area. Indeed, under Lusignans, a major sugar cane production centre was in use at Akheleia (near Ayia Varvara where soil sections were investigated) (Rupp 1986: 39; von Wartzburg 2000: 383).

B. Archaeological evidence in the neighbourhood of geomorphological sections

➢ Locations inland on the territory of the village Ayia Varvara

Sections EZA to EZF are located on the territory of the village Ayia Varvara. Several sites have previously been discovered:
Bronze Age activity at:

- Ayia Varvara-*Hadji Yiannakoudhes* (Rupp 1984: 150)
- Ayia Varvara-*Pladhia Petra*: Late Cypriot tomb on lower river terrace (Rupp 1984: 150)
- Ayia Varvara-*Teratsin A*: Middle Cypriot/Late Cypriot site

Iron Age activity at:

- Ayia Varvara-*Hadji Yiannakoudhes* (Rupp 1984: 150) (plate 146: fig. 375).
- Ayia Varvara-*Kokkinokhoraphon*: Cypro-Geometric III/Cypro archaic tombs on steep hill slope (Rupp 1984: 150) (plate 126: fig. 320).
- Ayia Varvara-*Ambeloudhin*: Cypro-Archaic site on steep hill slope (Rupp 1984: 150) (plate 126: fig. 320).
- Ayia Varvara-*Pavoulis*: probably Cypro-Archaic, Cypro-Classical or Hellenistic necropolis and isolated farmstead on lower river terrace (Rupp 1984: 150).

Hellenistic and Roman activity at:

- Ayia Varvara-*Hadji Yiannakoudhes*: large settlement and tombs on river flood plain and lower river terrace (Rupp 1984: 150) (plate 146: fig. 375).
- Ayia Varvara-*Argakin tou Karkoti*: Early Roman site (Rupp 1984: 150).
- Ayia Varvara-*Pladhia Petra*: an early Roman tomb on lower river terrace (Rupp 1984: 150)
- Ayia Varvara-*Spiliorotsos*: Late Hellenistic-Early Roman settlement (Rupp 1986: 35).

Byzantine activity at:

- Ayia Varvara-*Ambeloudhin*: Early Byzantine site on steep hill slope (Rupp 1984: 150) (plate 126: fig. 320)

Medieval activity at:

- Ayia Varvara-*Argakin tou Karkoti* (Rupp 1984: 150)

Unidentified:

- Ayia Varvara-*Pianos*: necropolis on lower river terrace (Rupp 1984: 150) (plate 126: fig. 320).

➢ Sites located at the Troodos foothills: Kannaviou

Sections EZG and EZH are located at the foothills of the Troodos on the territory of the village Kannaviou. Previous archaeological surveys located some sites in this neighbourhood.

Neolithic site at:

- Kannaviou-*Kochina*: Aceramic Neolithic site on second river terrace overlooking Ezousas river (Held 1992: 149).

Chalcolithic:

- Kannaviou-*Vouni*: Chalcolithic site on gently sloping hillside near side drainage of Ezousas river (Held 1992: 154).

Iron Age site at:

- Kannaviou-*Alonia*: small Cypro-Geometric/Cypro-Archaic site (Rupp 1984: 152).
- Kannaviou-*Kapsala*: Cypro-Geometric III/Cypro-Archaic necropolis on a gentle hill slope (Rupp 1984: 152).

Roman:

- Kannaviou-*Anaolos*: small Roman site on lower river terrace (Rupp 1984: 152)

Medieval:

- Kannaviou-*Khryseleousa*: 12^{th} century AD site on hilltop in an isolated location (Rupp 1986: 39).
- Kannaviou-*Khaftaras*: Medieval monastery in river flood plain (Rupp 1984: 152).
- Kannaviou-*Anaolos*: small Medieval site on lower river terrace (Rupp 1984: 152).
- Asproyia-*Ayios Sozondas*: Medieval mining and smelting site (Fox *et al.* 1987: 170)

V.2.3. Xeropotamos

V.2.3.1. Geology and geography

The Xeropotamos traverses similar geological regions as the Ezousas (plate 5: fig. 6, plate 6: fig. 7 and plate 210: fig. 539). Its headwaters lie in the Western Troodos mountains, mainly in the pillow lava zone. Subsequently, it reaches the gypsum, marl and limestone formations with several Mamonia and occasionally chert outcrops. The valley broadens out towards the coastal plain consisting of calcarenites and alluvial deposits.

Several sections were investigated in the coastal plain where extensive alluvial deposits were exposed (plate 175: fig. 450):

XA is situated at the locality Kouklia-*Maratheri*, bordering the recent river and exposed by it, cadastral: LI.47, topographic map: 51. XXIII.

XB is located at the edge of a diamond bar in the recent river, cadastral: LI.47 not drawn on map, topographic map: 51.XXIII.

XC at Mandria-*Xeroudhoes* is located on the W border of a small track to the S, just off the main road from Paphos to Limassol. An extensive exposure is visible on the W side of the track. Cadastral: LI.47, edge of plot 287, topographic map: 51.XXIII.

XD and XF at Mandria-*Xeroudhoes* are located in a quarry S of the new main road. The quarry cobbles were used for the construction of the new bridge. Visiting the site half a year later, the sections had disappeared and the ground was leveled out. Cadastral: LI.47, plot 281. Topographic map: 51.XXIII.

XE at Kouklia-*Maratheri*, is a natural exposure just beside a track on the E side of the river, about 50 m from the present day river bed, cadastral: LI.47, at the edge of plot 156, topographic map: 51.XXIII.

V.2.3.2. Archaeology

It has been observed that the Xeropotamos drainage area was less densely settled in the past than the Ezousas or the Dhiarizzos (Rupp 1986: 31).

A. Settlement history of the drainage

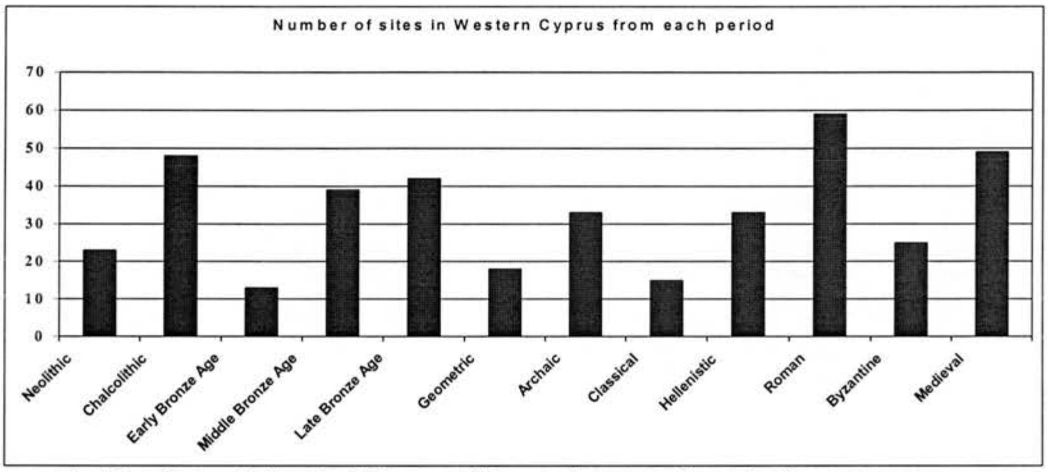
Little Neolithic evidence is retrieved from the Xeropotamos area. Only from the Middle Cypriot period onwards, more occupation evidence is found in the Xeropotamos drainage. A marked increase in occupation in the region took place in the Hellenistic period, with further extensive settlements throughout the Roman period. A population decline occurred in the Early Byzantine period. The area was again intensively occupied from the Late Medieval period on (Rupp 1986: 32).

B. Archaeological sites near the geomorphological sections in the coastal plain

Several sites have been discovered at the mouth of the Xeropotamos, on the eastbank, mostly dating to the Classical and Hellenistic components (Rupp 1981: 258). Moreover, some Late Roman components were found at the mouth of the Xeropotamos on the eastern as well as on the western bank (Rupp 1981: 259) The area was also occupied in the Late Byzantine period as evidenced by a settlement just E of the Xeropotamos (Rupp 1981: 259).

V.3. General overview of archaeological sites in Western Cyprus

In order to understand better the human impact on the landscape during a certain period, it is necessary to gain some insight into the regional settlement pattern. To gain some idea of the number of sites which were discovered for each period, scheme 1 summarises the evidence of sites in Western Cyprus by period. This summary is based on survey reports from Rupp (1981, *et al.* 1984, *et al.* 1986, *et al.* 1992), Baird (1987) and Sheen (in Peltenburg *et al.* 1981). It can only be used as a tentative scheme.



Scheme 1: Number of sites in Western Cyprus from each period

We may say that the main findings of the archaeological surveys in Western Cyprus indicate that Neolithic sites are relatively scarce. Furthermore, a larger number of Chalcolithic sites has been attested in Western Cyprus. However, they are relatively scarce and small inland along the larger rivers. Along the smaller rivers, such as the Agriokalamos and the Stavros-tis-Psokas more prehistoric sites have been recovered. Only a few Early Bronze Age sites are known in Western Cyprus. From the Middle Cypriot period onwards, a population increase seems to have taken place along the major rivers. The northern and southern part of the Ezousas and the upper part of the Dhiarizzos probably were focal areas of habitation during the Middle and Late Cypriot periods. Middle and Late Cypriot sites have also been attested along the Stavros-tis-Psokas and the Agriokalamos, while no Late Cypriot habitation evidence has been found in these regions. An increase in the number of sites has been attested for the later Geometric and the early Archaic period. However, only a few sites have been discovered from the end of the Archaic and Classical period along the main rivers. Much more evidence of Hellenistic sites has been detected, which seems to suggest an increased population density in Western Cyprus. Especially in the Upper and Lower Ezousas, an increase in Hellenistic sites is observed. This trend probably continued during the Early Roman period. However, during the period between 200 to 400 AD, the number of sites seems to have decreased. Furthermore, Byzantine period sites are scarcer along the major drainages. From the 13^{th} century onwards, a population increase probably took place as more sites have been detected from this period onwards.

VI. Establishing a chronology

As mentioned earlier in this study, a lack in well-dated alluvial sequences in the Mediterranean is observed, especially when compared to alluvial research in the United States. The dating of fluvial sequences is not only important to reconstruct the landscape, but also to gain insight as to why these landscape changes took place. As a matter of fact, in Cyprus, the previously studied fluvial sequences were also only poorly dated. Gifford utilised a couple of sherds to date the fluvial sediments. Gomez used sherds as a dating tool for deposition. Geo-archaeologists face problems when utilising sherds to date alluvial sediments as will be further detailed in this chapter. Moreover, Wells recently used surveyed sites on river terraces to gain basic chronological understanding of the fluvial history. Nevertheless, artefact scatters on top of the terrace as *terminus ante quem* for the deposition of the sediment can raise problems as the artefact scatter could be in a secondary context. Consequently, no reliable Holocene alluvial chronology has been established yet for Cyprus.

Obviously, several problems initially hampered the dating in this study.
First, morphological mapping difficulties were faced as a result of severe landscape destruction. River terraces were often bulldozed making mapping impossible. Older, similar and younger terraces along the same river could not be correlated properly by mapping, and consequently made their relative chronology questionable[12]. Secondly, organic material for ^{14}C dating was retrieved only in the upper, recent layers of the sediment sequences. King noticed this problem previously:

> "Unfortunately, the general lack of datable organic material associated with the coarse alluvial deposits, which are such a conspicuous feature of the present river valleys elsewhere in western Cyprus, has precluded the creation of a reliable chronology for these deposits." (King 1987: 10)

[12] Aereal mapping of river terraces could improve the correlation of the terraces and enhance their chronology.

A third attested difficulty was the lack of datable artefacts. As all geomorphological work was undertaken off-site, sherds were rarely found. Sometimes it took hours to find some pieces of pottery, which were mostly unidentifiable in typological terms because they were so rolled by river action.

VI.1. Typology

VI.1.1. Pottery

As mentioned above, the sherds were often rolled by river action. However, three sherds could be dated by typology. Dr. Fryni Hadjichristophi identified them (plate 7: fig. 8).

- KIS2 - Late Roman/Early Byzantine
- EZD1 – 15^{th}/16^{th} Century AD
- TA105 – Late Roman/Early Byzantine

VI.1.2. Lithic artefacts

Dr. Carole McCartney identified the following lithic artefacts. As a matter of fact, dating lithic artefacts is a more difficult issue than dating pottery.[13]

At the exposure under the village of Souskiou, several lithic artefacts were recovered (plate 7: fig. 9).

- SO1: tested blade/flake core – could be Ceramic Neolithic, but possibly later, even Dhoukani[14] (=historical).
- SO6: tested blade core exhibiting decortification flake preparation – could be Neolithic or Chalcolithic.

[13] Dr. Carole McCartney noted that her type and chronological designations were made without the benefit of knowing the context from which the material was collected. She therefore gave her best estimates, but would urge caution in using any of the chronological designations too strictly.
[14] Dhoukani= flints from the under-side of a treshing sledge.

- SO10: distal end of cortical/naturally backed flake, exhibiting light edge damage opposite the cortical edge – cultural, but could relate to any period, even Dhoukani (=historical).
- SO12: large tested core, sub-discoidal form from decortification of nodule with possible attempt to establish a crest down "front" face – suggesting a late Aceramic Neolithic (Cypro-LPPNB) date.
- SO13: Chunky, perhaps natural flake exhibiting a partial coarse cresting and wear or edge damage, primarily inverse creating a "notch" on one lateral edge – could belong to any period, but probably late (judging from its coarseness)
- SO14: Chunky possibly splintered piece - could belong to any period, but commonly found in the Chalcolithic period.
- SO154: natural, large corner cortical flake from pebble
- SO155: large tabular natural flake, exhibiting possible cultural use in the form of irregular retouch or edge damages about the distal end – could be of any period, probably from Chalcolithic onwards.

Discussion of the Souskiou material

Interestingly, three of the eight pieces are tested cores suggesting if these pieces were recovered in the same general context that the gravel bed may represent a quarrying area. These cores were discarded due to the inferior quality of the raw material. While SO1 and SO6 are more generic at home in either the Ceramic Neolithic or Chalcolithic, the shaping of SO12 and the type of raw material are more indicative of the type of core preparation utilised in the later Aceramic (Cypro-LPPNB). SO10, SO13, SO154 and SO155 represent irregular flake tools which, if cultural, would fit in with the less formal tool types seen in assemblages from the Chalcolithic period onwards. SO14 is probably cultural, representing general core reduction debris.

From soil section TB of Sarama-Teracha, some lithic artefacts were retrieved and again identified by Dr. McCartney:

- TB bag 4: non orientable fragment

- TB bag 4: butt end of platform rejuvenation flake – could be of any date, probably Neolithic (generic) or Chalcolithic.
- TB 8: butt end of non-cortical blade, exhibiting edge damage or retouch on lateral edge opposite to edge, damaged lateral edge – could represent any period, probably Neolithic (generic) or Chalcolithic.
- TB 10: Non-cortical flake exhibiting facetted butt and unidirectional dorsal scars, with possible edge damage related to use – could represent any period, probably from Chalcolithic onwards.

VI.1.3. Conclusion

Artefact typology can only seldom be applied to date the artefacts in the alluvial sections. First, there is a lack of identifiable pottery sherds in the alluvial deposits. Secondly, the lithic artefacts are far more difficult to date by typology.

However, the discovery of an ancient quarrying area is interesting. It has been suggested that the raw material for lithic artefacts was recovered from ancient river beds on Cyprus (e.g. Elliott 1991: 95-105). However, this hypothesis has never been documented by real finds in those ancient river beds. The lack of such archaeological finds is probably partly due to a lack of substantial architectural remains at these places as well as the fact that these sites are mainly located in unstable areas, either covered by meters of alluvium or eroded by river incision.
It is therefore obvious that other means to date the alluvial sections are necessary.

VI.2. Luminescence dating applications

In this section it will be demonstrated that the luminescence method is a powerful tool to gain more chronological insight into the alluvial history of Western Cyprus.

VI.2.1. Basic principles of the method

When a small quantity of terracotta is heated to about 500 °C, a minimal quantity of the so named thermoluminescence (Tl) light is emitted and can be measured by highly sensitive equipment. When this heating is repeated, the thermoluminescence phenomenon does not appear anymore. The TL-phenomenon is a result of an abrupt emptying of the light centres in the crystal grate of the mineral components of ceramic. In the course of time, the light centra would be filled by ionising radiation. The degree of infill depends on two factors: the intensity of the ionising radiation and the time of exposure to it. Thus, the amount of released thermoluminescent light, is a measure for the total dose ionising radiation to which the object was exposed over time (Van den Haute *et al.* 1994: 366).

The ionising radiation responsible for filling in the light centra of the pottery is mainly produced by small quantities of radioactive substances in the pottery and the soil in which it was buried. As a matter of fact, three kinds of ionising radiation exist: alfa, beta and gamma rays. Each of these radiation types filled in the light centra of the crystal grate. An important element is that each of them has a different carrying capacity: alfa rays reach only 0.01 to 0.04 mm; beta rays 1 to 2 mm and gamma rays some 10 cm. Apart from radioactive radiation there is also energy derived from cosmic radiation, which is about 0.2 mGy a year (Van den Haute *et al.* 1994: 366)

VI.2.2. Dating with TL

The quantity of thermoluminescent light stored in the pottery is a measure for the total dose of ionising radiation to which it has been exposed in the past. This palaeodose is the result of the multiplication of the radiation intensity and the duration.

When the radiation intensity is known, the radiation duration can be calculated by the following simple equation:

$$\text{Radiation duration} = \frac{\text{palaeodose}}{\text{yearly dose}}$$

In practice, the palaeodose is known by:

1. A measurement of the natural accumulated TL in the pottery
   In practice, a very small amount of pottery is sedimented on aluminium discs. The measuring equipment consists of a micro-heating element, a photo-sensitive cel, an electron multiplier and an amplifier. Each disc is heated and the light emission is measured and amplified, while at the same time the temperature is registered. First, the natural TL-signal is measured which was accumulated since archaeological times. Usually, the average of the result of about 5 discs is sufficient. Subsequently, the plotted natural glowing curve has to be tested to control its stability before using it for dating purposes. Not all light centra are stable and part of the accumulated light signal might have been lost over time. For this purpose, another set of discs are radiated with a gauged dose of beta-radiation. The glowing curve of these discs is also measured, averaged and compared with the natural glowing curve. The curve needs to have a plateau, a temperature zone in which the natural luminescence over the natural luminescene + beta is constant. On average, this temperature is around 325° and 425°C. If this is not the case, it is impossible to date the pottery (Van den Haute *et al.*1994: 367-368).

2. Measuring the TL-sensitivity of the material
   To determine the TL-sensitivity, a series of new sample discs is prepared and systematically radiated by an increasing amount of beta dose. Their TL-signal is then measured. The light is plotted as a function of their respectively beta dose. This so called addition method results in a rectilinear

curve. Its slope is a measure for the TL-sensitivity and as a result extrapolation gives the equivalent beta dose, which is the dose necessary to cause the natural signal. In recent pottery the signal is sometimes not linear from the beginning but has a supra-linear, slower, growing phase. To check whether there is such a phase, the regeneration method is undertaken. Several discs are totally zeroed and subsequently radiated with a beta-dosis from zero on. If there is a preamble, this can be corrected. The same method is used to find the alfa sensitivity (Van den Haute *et al.* 1994: 368-369).

The yearly dose has to be measured in the field with a gamma spectrometer. It is important to realise that the alfa and beta radiation to which the sherd was exposed, all derive from the radioactive substances in the artefact itself. Gamma radiation derives mainly from the sediment in which the artefact was buried. In order to get an exact dating, it is necessary to measure the gamma radiation exactly in the place where the artefact was recovered (Van den Haute *et al.* 1994: 369). Due to the necessity of numerous measurements to achieve one date and due to other factors such as radon emanation and anomalous fading, the TL-method only has a relatively small precision. However, the method is very useful for authenticity research and for sites with badly known contexts (Van den Haute *et al.* 1994: 270-371).

VI.2.2.1. An application

Due to the lack of typologically datable sherds and due to difficulties in mapping because of the destructive effects of bulldozing, it was impossible to get a chronological insight during the fieldwork. The Scottish Universities Reactor and Research Centre in East Kilbride proposed a quick and cheap dating method to solve this problem. This method lacks the precision of the fully applied dating method, though gives some rough idea of how old the sherds are. This method is very valuable for alluvial research in the Mediterranean, where well-dated sediment sequences have been scarce until now. Sherds in alluvial contexts often derive from eroded archaeological sites and thus can only be used as *terminus post quem* for the deposition of the sediment. Often, sherds in the same sediment deposit derive from different sites and periods. In this case, the youngest sherd gives the best *terminus post quem* date for the deposition of the sediment.

The method consists of the following measurements:
First, the natural TL was measured (plate 8: fig.10). For the second measurement, the zeroed samples were radiated with a dose of 5 gray, which equals the accumulated energy over about 2,000 years in the Mediterranean (plate 8: fig. 10).
It was then important to plot the ratio of the natural TL over the 5 Gray glow curve. The measurements could be used where the ratio natural TL/5 Gray glow curve formed a plateau. This was normally around 350°C (plate 8: fig. 11).

Finally, it is only a matter of counting when we know that 5 Gray equals 2,000 years. The two subsamples of each sherd are averaged.

Thus, the measurements of this TL application do not exactly follow the working method for precise datings and further cannot be used as exact datings. Not only do they lack a precise measurement of the sensitivity of the material but also a measurement of the yearly dose. However, this is estimated in the 5 Gray for 2,000 years.

The advantage of this method is that it provides a quick insight into the approximate age of the sherds. Moreover, if there is a TL-laboratory, the geo-archaeologist can undertake the preparation and measurements relatively cheaply and quickly.

VI.2.2.2. Sample preparation[15]

The sample preparation and measurements all have to be prepared in a dark room under red light. A part (about 0.5 to 1 g) of the sherd is broken off and smashed by a pestle in a mortar. Subsequently, the sample is wet sieved and the residue between 90 and 150 µm retained. Then, 1 M HCl is added to the sample for 30 minutes in order to remove the carbonates. Three de-ionised water rinses follow. Subsequently,

[15] Working method as proposed by Dr. David Sanderson of SURRC

the sample is washed three times with acetone. Next, the sample is put through a filter, retaining the sediment. And finally the samples are put on a small disc using silicone.

VI.2.2.3. Results

About 80 sherds were approximately dated using this method. The results are presented in the following table (table 1). Some of the dated sherds are depicted on plate 9, 10, 11 and 12.

Sherd label	Subsample 1 in Gray	Converted to calender date	Subsample 2 in Gray	Converted to calender date	Average	Standard deviation
Sarama Taracha						
TA101	3.11	753 AD	NA	NA	753 AD	NA
TA101	5.51	207 BC	3.82	471 AD	339 AD	132
TA101	12.29	2919 BC	14.77	3909 BC	3414 BC	495
TA101	11.58	2635 BC	13.76	3605 BC	3120 BC	485
TA101	6.2	482 BC	NA	NA	482 BC	NA
TA101	17.81	5125 BC	17.42	4971 BC	5048 BC	77
TA101	22	6801 BC	23.53	7415 BC	7108 BC	307
TA103	11.91	2774 BC	12.92	3170 BC	2972 BC	198
TA104	10.96	2387 BC	11.43	2575 BC	2481 BC	94
TA105	4.41	235 AD	4.08	366 AD	300 AD	65,5
TA105	15.16	4066 BC	3.95	417 AD	2241 BC	1824
TA105	13.06	3226 BC	12.11	2847 BC	3036 BC	189,5
TA100	11.09	2238 BC	10.82	2328 BC	2533 BC	45
TA100	12.06	2826 BC	12.85	3142 BC	2984 BC	158
TB2	8.08	1232 BC	8.02	1208 BC	1220BC	12
TB4	6.5	600 BC	9.64	1856 BC	1220 BC	636
TB5	5.58	232 BC	5.38	152 BC	190 BC	38
TB7	4.46	216 AD	6.2	480 BC	130 BC	350
TB8	6.07	428 BC	4.97	12 AD	208 BC	220
TB9	5.39	156 BC	4.86	56 AD	50 BC	106
TB9	8.05	1220 BC	9.75	1900 BC	1560 BC	340
TB bag 1	4.32	272 AD	3.31	676 AD	474 AD	202
TB bag 1	10.3	2120 BC	NA		2120 BC	
TB bag 2	6.16	464 BC	7.47	988 BC	726 BC	262
TB bag 2	9.02	1608 BC	13.58	3432BC	2520 BC	912
TB bag 2	8.37	1348 BC	13.23	3292 BC	2320 BC	972
TB bag 2	16.32	4528 BC	18.59	5436 BC	5000 BC	436
TB bag 3	14.78	5912 BC	8.02	3208 BC	2450 BC	758
TB bag 3	7.14	856 BC	9.39	1756 BC	1300 BC	456

TB bag 6	7.1	840 BC	14.25	3700 BC	2270 BC	1430
TB bag 6	10.92	2368 BC	10.81	2324 BC	2346 BC	22
TB bag 6	12.87	3148 BC	15.7	4280 BC	3714 BC	566
TB bag 6	14.49	3796 BC	14.62	3848 BC	3822 BC	26
TB bag 6	12.59	3036 BC	10.32	2128 BC	2582 BC	454
TB bag 6	4.7	120 AD	4.87	52 AD	90 AD	38
TB bag 6	10.68	2272BC	11.62	2648 BC	2460 BC	188
Agriokalamos						
KAG	13.7	3480 BC	10.42	2168 BC	2820 BC	652
KAGB9	16	4400 BC	14.47	3788 BC	4090 BC	302
Ezousas						
EZA3	8	1200 BC	10.87	2348 BC	1170 BC	1178
EZA2	5.9	360 BC	7.3	920 BC	640 BC	280
EZA4	5.8	320 BC	5	0 BC	160 BC	160
EZD1	1.81	1274 AD	2.07	1169 AD	1221 AD	52,5
EZD4	4.22	309 AD	1.43	1427 AD	868 AD	559
EZD5	4.09	364 AD	4.06	375 AD	369 AD	5,5
EZG1	2.1	1160 AD	2.2	1120 AD	1140 AD	20
Dhiarizzos						
MA2	5.14	56 BC	5.13	52 BC	54 BC	2
MA3	3.86	456 AD	3.74	504 AD	480 AD	24
MA4	1.55	1380 AD	1.85	1260 AD	1320 AD	60
MA5	4.86	56 AD	4.55	180 AD	118 AD	62
MA6	4.39	244 AD	4.04	384 AD	314 AD	70
MA7	12.5	3000 BC	8.54	1416 BC	2208 BC	792
MA8	8.8	1520 BC	8.4	1360 BC	1440 BC	160
MA9	7.56	1024 BC	5.63	256 BC	638 BC	382
MB4	NA	NA	3	800 AD	800 AD	NA
MB8	2.4	1040 AD	5.27	108 BC	466AD	574
MB9	4.21	316 AD	4.69	124 AD	220 AD	96
KIS1	6	400 BC	6.35	543 BC	471 BC	71.5
KIS2	3.35	656 AD	3.11	752 AD	704 AD	48
KIS4	3.39	644 AD	2.14	1144 AD	894 AD	250
KOL1/1	4	400 AD	6.7	680 BC	140 BC	540
KOL1/4	NA	NA	18.96	5584 BC		
KOL1/5	14.6	3840 BC	17.5	5000 BC	4420 BC	580
KOL1/6	1.1	1560 AD	1.1	1560 AD	1560 AD	0
PR1/1	6.12	450 BC	6.21	484 BC	467 BC	17
PR1/2	3.2	720 AD	NA	NA	NA	NA
PR1/3	2.25	1100 AD	2.33	1068 AD	1084 AD	16
PR1/4	2	1200 AD	2.3	1080 AD	1140 AD	60
SO8	11.03	2412 BC	6.2	480 BC	1446 BC	966
SO103	2.68	928 AD	1.86	1256 AD	1092 AD	164
SO104	4.85	60 AD	5.61	244 BC	92 BC	152
Xeropotamos						
XA1	7.56	1024 BC	4.6	160 AD	432 BC	592

XD1	3.3	680 AD	4.9	40 AD	360 AD	320
XD2	0.5	1800 AD	0.85	1660 AD	1730 AD	70
XD3	0.7	1720 AD	0.7	1720 AD	1720 AD	0

Table 1. A TL-application on sherds: results

The results of the subsamples are sometimes remarkably similar, indicating a relatively precise measurement and dating. However, some of the subsamples differ from each other. The subsamples of 37.9 % of the sherds have a standard deviation of less than 101 years, 17 % between 101-201 years, 7% between 202-302 years, 7% between 303-403 years, 7 % between 404-504 years, 8.5 % between 505-605 years, 2.8 % between 606-706 years, 4.3 % between 707-807 years, 4.3 % 909-1009 years, 1.4 % between 1111-1211 years, 1.4 % between 1414-1514 years and 1.4 % between 1821-1921 years. 69 % of the samples have a standard deviation of less than 400 year (Plate 13: fig. 22). The measurements corroborate the TL-application is essential to date rolled, non-diagnostic sherds.

A confrontation between the typological data and the TL-application data acknowledges the accuracy of the dating method. It enhances the credibility of the results of the TL-application. KIS2 was dated by typology to the Late Roman or Early Byzantine period. The TL-application approximately dated the sherd to 704 ± 48 AD. This seems to match an Early Byzantine date. EZD1 was dated to the 15th/16th Century AD using typology. The TL-dating seems to indicate that the sherd is slightly older, approximately dated at 1221 ± 52.5 AD. TA105 was dated with the TL-method to 300 ± 65.5 AD. The typological identification as Late Roman to Early Byzantine confirm the dating.

VI.2.2.4. Interpretation and discussion

A quick glance at the dates highlights the fact that the archaeological record has been affected by erosion as pottery of all periods have ended up in alluvial sediments. When exactly erosion took place needs further study.

VI.2.2.4.1. Stavros-tis-Psokas

A. TA (plate 19: fig. 34)

At the bottom of the section, two Prehistoric sherds (TA105: 2241 ± 1824 BC, TA105: 3036 ± 189.5 BC) and a Late Roman (TA105: 300 ± 65.5 AD) sherd were retrieved. Consequently, more than 3 meters of sediment is deposited after 300 ± 65.5 AD. The sherd which was dated in the next layer (TA2) does not add much to our chronological understanding as it is as well a Prehistoric sherd (TA103: 2972 ± 198 AD) deposited sometime after 300 ± 65.5 AD. In TA6, a mix of sherds was discovered with Roman, Chalcolithic, Cypro-Archaic dates (samples TA101) as well as one Byzantine sherd dated to approximately 753 AD. Consequently, almost 1.5 m of sediments was deposited sometime after 753 AD.

B. TB (Plate 25: fig. 50)

From this soil section several artefacts were retrieved and dated. The bottom layer of the section contained a mix of sherds (bag 2, bag 3) dating to 2,450 ± 758 BC; 1,300 ± 456 BC; 2,520 ± 912 BC and the youngest one dating to the 726 ± 262 BC. This means that everything above these layers is certainly younger than the Cypro-Archaic period. Adding the evidence from section TA, it is obvious that an even preciser *terminus post-quem* can be reached for layer TB7. Sherd TA105 in the equivalent layer of TA dates to 300 ± 65.5 AD which means that about 4 meters of sediments have been deposited sometime after that date. In unit TB3, there is evidence of a Hellenistic sherd (TB5) dating to approximately 190 ± 38 BC, however it does not add to our chronological understanding. From unit TB2 above TB3, many pieces of pottery were collected and dated. They derive from a mix of periods: Bronze Age, Roman period, Neolithic, Chalcolithic and Byzantine period. This Byzantine period sherd (TBbag 1) is the youngest sherd among them and indicates that unit TB2 post-dates 474 ± 202 AD. However, section TA gave a more precise date after which the upper 1.5 m of sediments were deposited. It is unlikely that these 4 meters from the bottom of sections until the top of the sediment were all deposited after 753 AD. This is visible in the field descriptions (colour changes and different sediments) and is observed in the laboratory tests, indicating an incipient palaeosol between TB5/TA3 (see IX.3.1.1).

VI.2.2.4.2. Agriokalamos (plate 32: fig. 67 and plate 34: fig. 71)

In the sections exposed by the river Agriokalamos, only 2 sherds were retrieved, both dating to early Prehistoric times, Chalcolithic (KAG: 2820 ± 652 BC) and Neolithic (KAGB9: 4090 ± 302 BC). They occurred low down the section under several palaeosols, suggesting an old date for the deposition of the sediments.

VI.2.2.4.3. Dhiarizzos

A. KOL1 (plate 58: fig. 137)

In this 3 m deep alluvial exposure, several sherds were found. From the bottom (3.1 m deep) until 0.80 m deep the following sherds were found: KOL1/4 a Neolithic sherd, KOL1/1 Cypro-Archaic, KOL1/6 16th Century AD and KOL1/5 Neolithic. From the geomorphological observations, it is supposed that all the sherds belong to the same sediment, thus approximately post-dating 1560 AD. This means that more than 3 meters of sediment were deposited after the mid-16th Century AD. Moreover, the erosion affected a Neolithic and Archaic site.

B. SO (plate 69: fig. 168)

The enormous exposure at Souskiou contained some sherds. Two sherds were found at the edges of the fan, dating to the Hellenistic (1st Century BC) and Byzantine (11th Century AD) period. However, their relationship with the main fan deposits is not clear. The lithic artefacts SO1, SO6, SO12, SO10, SO13, SO154 and SO155 assigned to the Neolithic and Chalcolithic period were located at the bottom of the section. It is suggested that they could represent the remains of ancient quarrying activities in the gravels.

C. PR1 (plate 99: fig. 248)

Four pieces of pottery were found throughout this 2 m deep section. At the bottom of the section the sherd dated to about 1140 ± 60 AD. In the middle of the section, a sherd dated to 1084 ± 16 AD, and at the top a sherd of approximately 720 AD and one dating to 467 ± 17 BC was found. An inversed stratigraphy is observed in this section, as the oldest sherd is located in the youngest sediment. This is due to the erosion of a site somewhere around or after 1140 AD. The inverted stratigraphy suggests severe erosion of the Byzantine site, with the disappearance of several archaeological strata from 1140 AD until the lower strata dating to 720 AD. The erosion also affected a Cypro-Classical site.

D. MA (plate 106: fig. 266)

Throughout the section, several sherds were found, dating to various periods. At the bottom at a depth of between 2.20 m and 1.90 m 3 sherds were retrieved: MA4, MA8 and MA9. MA8 dates to the Late Bronze Age (1440 ± 160 BC), MA4 to the Frankish period (1320 ± 60 AD) and MA9 approximately to 638 ± 382 BC. MA4 indicates that the whole deposit was laid down sometime after 1320 ± 60 AD. MA7 was found in overbank deposits above the previously described gravelly deposit. This sherd only gives little chronological information about the deposition of the sediment as it dates to the Chalcolithic period and we know that all the sediment was deposited from the 14^{th} century AD on. However, the sherd includes important information about the post depositional processes taking place at a Chalcolithic site in the neighbourhood. In the uppermost unit three (MA5, MA2 and MA3) more sherds were dated. All three date to the Roman and the Late Roman period. Again, they are evidence of a Roman site, which eroded sometime around or after the 14^{th} century AD.

E. MB (plate 110: fig. 278)

MB is a higher terrace at the same location and should be older than MA. In the upper 1.5 m of the section, several sherds were found. In the gravelly deposit between 1.50 m deep and 0.80 m, MB8 dates to 446 ± 574 AD and MB 4 to the Byzantine period (approximately 800 AD). In the upper layers, a sherd dating to the 3rd century AD was found. Section MB could indeed be older than MA. River incision supposedly took place in MB sometime between post 800 AD and pre 14th century.

F. KIS1 (plate 119: fig. 302)

A 3.5 m alluvial deposit at Kithasi contained several sherds of which 3 were dated. KIS 4 at a depth of 2 m, may date to the Byzantine period (894 ± 250 AD). Also KIS2 which is located about a meter higher in the section dates to the Byzantine period (704 ± 48 AD). KIS1 at the same level as KIS2 is less indicative in that it is an Early Iron Age sherd, deposited sometime after 894 ± 250 AD. Consequently, sometime after the 9th century (though maybe the 7th or 8th century AD), about 2.5 meters of sediment were deposited.

VI.2.2.4.3. Ezousas

A. EZA (plate 127: fig. 321)

At a depth of 3 meters in the exposure, three sherds were found: one dating to 1170 ± 1178 BC, another one to 640 ± 280 BC and a third one to 160 ± 160 BC. The last mentioned is the most informative to the time of sediment deposition, which consequently must have taken place sometime after 160 ± 160 BC. Moreover, 2 palaeosols being indicative of landscape stability, occurring in this section, supports an old age of the deposits.

B. EZD (plate 147: fig. 376)

Three sherds were found at the bottom of the section (at a depth of 3 meters), two of which were dated. Sherd EZD5 dates to approximately 369 ± 5.5 AD and sherd EZD4 to approximately 868 ± 559 AD. Hence, this layer (EZD5) certainly post-dates 309 AD. Sherd EZD1 in the top unit dates to 1221 ± 52.5 AD. As a consequence, the uppermost unit was certainly deposited after that date. The laboratory tests suggest there may have been some time between the deposition of the lowermost layers EZD5/EZD4/EZD3 and the uppermost units EZD2 and EZD1 as some incipient soil formation has been detected (cf. VII.2.4.4).

C. EZG (plate 165: fig. 422)

At the bottom of the 2.6 m long section, a Byzantine sherd was found, dating to 1140 ± 20 AD. Hence, the 2.6 m of sediments is deposited in or after the 12^{th} century AD.

VI.2.2.4.5. Xeropotamos

A. XA (plate 176: fig. 451)

Only one sherd was collected from this section, dating to approximately 432 ± 592 BC. This reveals that all the sediments were deposited sometime later than 432 ± 592 BC, but the exact period is still unknown.

B. XD (plate 193: fig. 495)

From the upper 2 meters of this section, three sherds were dated, ranging from the 18^{th} Century (XD2: 1730 ± 70 AD and XD3: 1720 ± 0 AD) to 360 ± 320 AD. Obviously, the upper 2 meters of the section were deposited around or post 18^{th} century AD.

VI.2.2.4.6. Conclusion

As a consequence of the above detailed investigation, which aimed to establish a chronology for the alluvial events in Western Cyprus, it is observed that off-site sherds in alluvial sediments are rather difficult to interpret accurately. A precise date for the deposition of the sediment does not follow as a matter of course when dating the sherd. Indeed, the sediments could post-date the potsherds occurring in the sediments. Moreover, the older the sherds are, the longer the period *post quem* could be and the greater the risk of interpretation errors. Hence, there is more certainty about dating of sections with recent sherds than of dating sections with older sherds. As a conclusion, we may say that it is imperative to date the sediments themselves, especially the supposedly old sediments requiring a higher dating precision.

With exception of the above mentioned limitations, the dating program was highly successful in demonstrating difficulties involved with using sherds as chronological markers in alluvial deposits. As frequently attested, if a couple of sherds of the same period are found in an alluvial sediment, the sediment may be wrongly assigned to the period of the sherds.

Moreover, artefacts in alluvial sediments are often the ultimate evidence of sites lost by erosion, rather than chronological markers. Table 1 indicates that sites of all periods were severely affected by erosion in Western Cyprus. As an example, the section at Prastio (PR1) with an inversed stratigraphy, marked by the oldest pottery at the top of the section while the youngest artefacts at the bottom, indicates that sites might have been lost by erosion. Consequently, understanding geological processes imposed on the archaeological record is prerequisite to interpreting settlement patterns on Cyprus.

As a matter of fact, have we gained any insight so far into when these archaeological sites were eroded and when these alluvial sediments were deposited? Obviously, the dating program on the sherds resulted in some negative conclusions when considering the difficulties in using potsherds to date the sediments. However, some insight was gained in the chronology of the sediments as a consequence of relatively recent alluvial deposit finds.

On the one hand, for sediments in which recent sherds occurred, the period *post quem* for the deposition of the sediment is relatively small. Hence, the accuracy probability of how much later the sediments were deposited compared to the date given for the sherds, is thus smaller. Indeed, section EZG along the Ezousas indicated that more than 2.5 m was deposited sometime around or after the 12th Century AD. Moreover, at Prastio, more than 2 m of sediment was deposited sometime around or after the 14th century. In addition, only about 500 m westward from the last mentioned soil section, 2 meters of alluvium were found, post-dating 1200 AD. At Kithasi, along the Dhiarizzos as well, there are finds of about 2 m of alluvium deposited after the 7th (8th or 9th) century. At the mouth of the same river (at Kouklia-*Lakkos*), more than 3 m of sedimentation took place around or after the 16th Century AD. Furthermore, at the mouth of the Xeropotamos, evidence was found of 2 m of alluvium deposited around or sometime after the 18th Century AD.

On the other hand, evidence for older deposits is more suggestive and should be further investigated as the old sherds could have been recently deposited. First, a possibly old section is located along the Agriokalamos, with evidence of Chalcolithic and Neolithic sherds. Bearing in mind the problem in using sherds as chronological markers for the deposition of the sediment, it is suggested that the sediment in which these sherds were buried, is Prehistoric as several palaeosols were attested above this layer. Secondly, a similar situation was observed at EZA (Ezousas A) as the combination of not only an approximate Iron Age date of the youngest sherd at the bottom of the section but also the superimposed palaeosol indicates an early date for all sediments under the palaeosol. Additionally, it is suggested that Prehistoric quarrying activities took place at the alluvial fan at Souskiou. Hence, the sediment at the bottom of the section could be Prehistoric. Notwithstanding, it remains questionable whether the deposition of the alluvium at the bottom of the 2 m deep deposit at XA (Xeropotamos A) could be dated anytime around the 11th Century BC, as the dated potsherd itself. Hence, another technique should be applied for dating possible older sediments more accurately.

As a consequence, the method of using roughly dated sherds to receive a first chronological insight into the time of sedimentation is obviously more successful with younger deposits. The possible older deposits require different techniques to corroborate their antiquity. Moreover, in this study the sediments lacking artefacts have been discriminated from any possible chronological indications so far.

Hence, an alternative method will be presented in the next section of this study to proceed with testing out not only some of the suggested older sediments, but also sediments without artefacts.

VI.2.3. Optically Stimulated Luminescence-dating (OSL) on sediments

VI.2.3.1. Method

The application of the luminescence method to date recent geological deposits is quite a recent development, dating from the eighties. This new technique employs light rather than heat to release the stored energy in dating minerals, producing what is generally termed optically stimulated luminescence (Van den Haute 1994: 365). Sediments may contain two types of light-sensitive mineral grains: quartz and feldspars, which can both be used for dating. For sediments to be suitable for dating it is prerequisite to be zeroed before burial so that any stored energy would have been reduced to a negligible level. This process, called bleaching, occurs when minerals such as quartz and feldspar are exposed to sunlight, resulting in the signal erasion. After burial, their stored energy increases over time at a rate, depending not only on the radioactivity of the surrounding medium but also on such factors as water content of the burial medium. Two measurement procedures have to be applied for sediment dating. The total accumulated energy since burial has to be measured as well as the annual stored energy (Bailiff 1992: 27-28).

Sampling was undertaken in the dark by hammering copper tubes into the sections. Additionally, gamma spectrometry was accomplished in the field (plate 12: fig. 23). The samples were then handed over to the Scottish Universities Research and Reactor Centre. Dr. Joel Spencer and Dr. David Sanderson performed the dating (see appendix 1).

Alluvial sediments on Cyprus have never before been dated using the OSL-method. At first, it was questionable whether the method would work at all, whether quartz occurred in the fluvial sediments, whether it was sensitive enough and whether it had been bleached. Two recent studies indicated that the OSL-method could be used successfully to date alluvial sediments in the Mediterranean. A study in Greece (Fluchs *et al.* 2000: conference contribution) indicated that OSL-dates on quartz from alluvial fan sediments were adequate. A relatively high precision dating on Jordanian sediments, more specifically on well-bleached sandy lenses, was obtained by Tipping (pers. communications with Dr. David Sanderson 2001).

The luminescence method recently went through some innovations with the development of single aliquot measurements. This procedure enhances considerably the precision and comprehension of the dating of sediments. The SAR (single aliquot regenerative) protocol, used in this study for dating the Cypriot sediments, has been described in Murray and Wintle (2000).

VI.2.3.2. Results

Sample	Age
KAGB15	66.5 ± 12.4 ka
KAGB12	74.4 ± 13.2 ka
KAGB10	55.5 ± 10.4 ka
KAGB6	35.2 ± 14.6 ka
SOA2	13.1 ± 6.5 ka
SOA10	3.8 ± 1.1 ka
EZA9	2.8 ± 1.1 ka

EZA5	2.3 ± 1.4 ka

Table 2: Results of OSL-dating

The results are presented in table 2. The full report on the OSL-dating by Dr. Joel Spencer and Dr. David Sanderson is attached in appendix 1.

Further experiments were undertaken on the sediments of unit EZA5 to gain a higher dating precision. The number of investigated small aliquots was increased to 96. The exact procedure has been described in appendix 1. The results indicate that the conventional SAR results for EZA5 are scattered through variable solar bleaching and environmental mixing processes. However, through extrapolation Spencer and Sanderson were able to achieve a more precise date for the deposition of the sediment. This more precise modal date is 1.64 ± 0.15 ka BP.

VI.2.3.3. Interpretation and discussion

As mentioned in VI.2.4.1., OSL-dating on fluvial sediments from Cyprus has never been applied before. Consequently, little is known of their suitability for OSL-dating. In fact, is OSL-dating on alluvial sediments from Cyprus possible? Dating requirements were met. As a matter of fact, quartz did occur in the samples and was sensitive enough for dating purposes. However, some additional problems arrised. According to the dates in table 2, it is obvious that in some cases only a relatively small dating precision could be reached. This is resulting from mixed dose distributions, typical for fluvial processes. Quartz grains in fluvial and colluvial environments are heterogenously bleached. Saltating bed-load transport in turbit rivers only exposes grains to light when emerging to the water surface. Additionally, previously unexposed bed-load will only be reset at the surface of the deposit. Moreover, night-time transport and deposition of sediments eroded from channel banks will result in mixed dose distributions (Murray & Olley 1999: 131). Furthermore, in order to gain insight into the bleaching process of fluvial sediments, research on modern river sediments was undertaken. A flood-deposited sandy sediment historically known to have been deposited 70 years previously, was dated by using SAR. It is stunning that of the 78 aliquots investigated, only 5 % of the aliquots gave a date of 64 ± 7 BP and 95 % overestimated the date of the deposition of the sediment (Murray & Olley 1999: 132-133). This is proof enough heterogenous resetting of the OSL-signal is the rule rather than the exception. Hence, the single aliquot protocol enables understanding the heterogenity of the sediment whereas previous multiple aliquot methods averaged out the heterogenity, resulting in often overestimated dates. The single aliquot method makes the heterogenity of the sample more comprehensive. Additionally, the more aliquots are used, the better insight into a pattern within the heterogenity.

VI.2.3.3.1. KAG (plate 34: fig. 71)

The OSL-dates from the Agriokalamos are much older than anticipated (cf. VI.2.2.3.2) and thus causing some interpretation problems. KAGB15 was dated to the Pleistocene, at 66.5 ± 12.4 ka BP. KAGB12 stratigraphically located above KAGB15 was dated at 74.4 ± 13.2 ka BP. The imprecision of the dates could have led to the apparent inverted stratigraphy. KAGB10 was younger and dated at 55.5 ± 10.4 ka BP and seems to match the expected increasingly younger date with decrease in depth. In addition, KAGB6 was dated at 35.2 ± 14.6 ka BP.

However, these dates are causing problems. As mentioned above, two sherds were retrieved from the Agriokalamos sections, one deriving from KAGB9 and another from the nearby section KAGA. The sherd in KAGB9 was dated to 4,090 ± 302 BC. The other sherd KAG in KAGA12 was dated to 2,820 ± 652 BC. The correlation with the units of KAGB is however not attested, though the sherd is definitely located relatively further down in the soil section. As a consequence, on one hand the sherds indicate this section represents a Holocene sequence from KAGB9 on, whereas on the other hand, the sediment OSL-dates suggest the sequence is Pleistocene. How do we solve this impasse?

Three solutions are possible:

- The sediment is Pleistocene, the sherds are out of context.
- The sherds are *in situ* (geological) and the OSL-date does not date the deposition of the sediment.
- The sediment dates are indeed dating the deposition of the sediment and the sherds are *in situ*. The combination of these apparently controversial facts can be explained in a geological process.

Pro's and contra's will be further detailed:

First, it is suggested that the OSL-date did not date the deposition of the sediment because the sediment was not fully reset at the time of its deposition. This hypothesis might find some support in that the report mentioned mixed dose distributions in KAGB15, KAGB12 and KAGB6. However, Dr. Sanderson and Dr. Spencer acknowledged the dose in KAGB10 was coherent at about 6 of the 8 discs. Hence, the Pleistocene date for KAGB10 indicates that the sediment was indeed deposited in the Pleistocene. Additionally, not a single disc of the 32 investigated in KAGB indicated a Holocene date. If the sediments had been deposited in the Holocene but not completely reset, we would have expected at least a few discs with a Holocene date, which is not the case.

Secondly, it may be the sherds might not have been in their authentic geological context. However, during the fieldwork, special attention was paid to check whether they were found indeed (geologically) *in situ*. The soil sections were cut back further to investigate whether the sherds were not located in terrace collapse. We can truly state that the sherds were retrieved in authentic geological contexts. It is unlikely that neotectonics changed the location of the sherds. However, some roots were observed within the sediment which might have translocated the sherds from top to bottom, though this is quite a long distance.

A third hypothesis that should be tested is that the OSL-dates date the deposition of the sediment and that the sherds are in situ. We may say that it is remarkable that both sherds have been retrieved from channel deposits. Hence, it could be suggested that a Holocene meandering channel incised a Pleistocene terrace. However, this is unlikely as the gravel is well incorportated in the depositional sequence and shows evidence of soil formation.

What future investigations can be undertaken to gain better insight into the chronology of the sequence? First, another attempt should be undertaken to retrieve some more sherds from this section. Secondly, a radiocarbon date on the humate fraction of the palaeosols in KAGB4 and KAGB8 could test the OSL-dates.

VI.2.3.3.2. SOA (plate 71: fig. 171)

Sediment SOA2 at the bottom of the section was dated at 13.1 ± 6.5 ka BP, which indicates that this sediment was deposited between 16,600 BC and 4,600 BC. This seems to match the find of a possible Early Prehistoric quarry site at about this level (see above). Sediment SOA10 is supposedly much younger, with dates of 3.8 ± 1.1 ka BP. This indicates a date between 2,900-700 BC. This evidence certainly indicates that more than 2 meters of sediment were deposited before the "Younger Fill", widely attested in the Mediterranean.

The dates being inaccurate is a result of the occurrence of a mixed sediment.

VI.2.2.3.3. EZA (plate 127: fig. 321)

The sherds at the bottom of EZA (unit EZA12) indicated that all sediment above this layer must be younger than 160 ± 160 BC. The OSL-date in EZA9 is relatively imprecise due to a mixing of bleached and not completely bleached grains. It was dated to 2.8 ± 1.1 ka BP. This means that the deposition date of the sediment is sometime between 1900 BC and 300 AD. On the other hand, sediment EZA5 is less precise and was dated at 2.3 ± 1.4 ka BP, thus between 1,700 BC and 1,100 AD.

However, a new small aliquot procedure reached a higher precision dating at 1.64 ± 0.15 ka BP, which indicates that the sediment was deposited between 210 and 510 AD. Obviously, between 160 ± 160 BC and 300 AD, about 1.5 m of sediment has been deposited. Moreover, sometime between 160 ± 160 BC and 510 AD, more than about 2.30 m of sediment were deposited.

VI.2.3.3.4. Conclusion

The OSL method appears to be a promising technique to develop a chronological framework for the fluvial deposits on Cyprus. In most cases, the quartz SAR method produces results consistent with the field evidence and which add to the information available. Although the dating precision using the conventional OSL-SAR procedures is rather limited due to incomplete bleaching in fluvial contexts, a new small-aliquot SAR procedure may be able to overcome these limitations in future work.

VII. Sediment analysis

Several laboratory tests have been undertaken on the sediments to gain insight into their transport processes, their depositional and post-depositional processes. In this chapter I will discuss briefly the methodology and aims of the tests. Subsequently, the results and interpretations of the tests will be presented by soil section.

VII.1. Methodology

VII.1.1. Loss-on-ignition

VII.1.1.1. Aims

As the name suggests, loss-on-ignition measures the weight loss when a sediment sample is heated at high temperatures. The weight loss approximately corresponds to the organic carbon combusted to carbon dioxide. In this way, an approximate measure of organic matter in the sample is gained (Ball 1964: 84). This test will make it possible to find the A-horizon of palaeosols identifiable by a high weight loss after heating.

However, there are some complications. Some clays lose structural water at temperatures less than 500 °C and consequently result in artificially high values for organic matter. Moreover, calcium carbonate is broken down into lime around 770 to 850 °C, so the temperature gauge has to work correctly to ascertain that the calcium carbonate is not reduced (Ball 1964: 85-86).

VII.1.1.2. Laboratory procedure

A dry clean crucible was weighed. About 10 g of soil was put into the crucible; the weight was recorded. Then the sample was dried in an oven overnight at 100 °C. The sample was reweighed. Next, the sample was placed in a muffle furnace at 475 °C for 4 hours. Subsequently, the sample was reweighed.

The organic matter percentage is found using the following equation:
Organic matter %= (mass of oven dry soil – mass of ignited soil)/ mass of oven-dry soil x 100

VII.1.2. Magnetic susceptibility

VII.1.2.1. Aims

Magnetic susceptibility (χ) is a measure of how easily a material can be magnetised (Peters 1998: 4). Sediments contain a complex mix of magnetic grains that differ in their concentration, mineralogy and domain state. Domain state is linked to the particle size and classified in this way with increasing grain size; superparamagetic (SPM), single- domain (SD), pseudo-single domain (PSD) and multi-domain (MD). Different domain states have different magnetic characteristics (Peters 1998: 2-3).

Magnetic susceptibility can deliver the following information:

- A-horizons:

First, a typical magnetic enhancement occurs in most A-horizons. This is due to higher concentrations of fine grained ferrimagnetic minerals in surface layers (Oldfield 1983: 150). However, for alluvial sediments the situation can be more complicated where topsoils eroded and ended up in the alluvial sequence. This also results in high magnetic susceptibility values.

- B-horizons:

Secondly, B-horizons are often recognised by a peak in magnetic susceptibility where iron illuviation took place (Oldfield 1983: 152).

- Sediment source:

Thirdly, the magnetic susceptibility could also inform us on the sediment source. (Oldfield 1983: 155). Volcanic sediments will be marked by high magnetic susceptibility values. On the other hand, magnetic susceptibility measurements may be reduced over chalk subsoils (Aitken 1974: 222-223).

- Anthropogenic influence:

And fourthly, magnetic susceptibility can give information on metal-rich discharge from metallurgical sites, indicated by high susceptibility values (Oldfield 1983: 150). Additionally, archaeological sites and human impact are often related with the occurrence of superparamagnetic domain state grains (Peters 1998: 5).

Two kinds of susceptibility have been measured for this study: mass specific and frequency dependent susceptibility. Mass specific susceptibility provides a rough indication of the magnetic concentration of a sample. Frequency dependent susceptibility can determine the type of domain state present (Peters 1998: 5-6).

% χfd	Domain state grain
0-5	Single-domain – multi-domain
5-10	Single-domain – pseudo-single domain
10-15	Superparamagnetic
15+	Error/ metal or other such deposit

Table 3: The correlation between domain state and frequency dependent susceptibility

VII.1.2.2. Laboratory procedure

A Bartington MS2B sensor was used.

A small plastic container was filled with dried, sieved sediment with a lid placed on. A north point was drawn on the lid as to measure the low and high frequency of the sample each time in the same direction.

Susceptibility was measured at low and high frequency.

- Mass specific (initial) susceptibility was calculated using the equation:

$$\chi lf = (Klf/\text{mass (g)})/10$$

Klf is the dimensionless low frequency measurement corrected for magnetic drift:

$$Klf = \text{K sample} - ((\text{K first air} + \text{K second air})/2)$$

- Frequency dependent susceptibility was calculated using the equation:

$$\chi fd\,\% = ((Klf - Khf)/\,Klf)) \times 100$$

VII.1.3. pH

VII.1.3.1. Aims

The pH value reflects the acidity or alkalinity of a given sediment or soil. The pH value is affected by many factors such as nutrient content, texture, organic activity, structure and drainage and is hence not straightforward to interpret. However, the pH test could be also useful in that it is often regarded as an index of soil fertility. Changes in external inputs such as the deposition of material as well as internal changes within a soil can be detected through pH analysis.

VII.1.3.2. Laboratory procedure

The Hannah turtle equipment was used for these measurements. The pH turtle is attached to the computers and calibrated using buffers 4 and 7. In between readings the electrode was placed in a beaker of distilled water.

1. 10 g of fresh sediment was put into a 250 ml beaker
2. 25 ml of distilled water was added
3. The sample was stirred for 5 minutes
4. Then, the electrode was inserted to the sample
5. After 1 minute the pH value was read.

VII.1.4. Lithological identification

VII.1.4.1. Aims

Lithological identifications document on the sources of the sediments. They can provide information as to where the erosion took place. However, weathering may also entirely remove some components that make impossible tracing back the source of the clasts. For example, in sediments derived from an area with limestone and sandstone, solution may cause complete loss of the limestone (Briggs 1981: 22-23).

VII.1.4.2. Method

For the lithological identification, the reference collection in the Lemba archaeological field station was used.

VII.1.5. Clast shape analysis

VII.1.5.1. Aims

The shape of the clasts can provide information on the mode of transport that the sediment went through (Briggs 1981: 111). The four major influences upon particle shape are: original shape of the material, lithology, duration and type of weathering during transport and duration and type of weathering after deposition (Briggs 1981: 129). Angularity is a product of weathering during and after transport. Angular stones are the result of processes such as chipping and splitting and are more likely to be the result of slope effects. On the other hand rounded particles are created by attrition and solution and are often related to the movement in water. Clasts in streams tend to have a marked rounding through the combination of mechanical and chemical weathering. The effect of weathering processes increases with transport distance. As a result clasts tend to be more rounded downstream than upstream (Briggs 1981: 131).

Also other parameters such as Cailleux's flatness and Krumbein's sphericity index were used on the samples to define the clasts in order to understand transportation environments. However, these parameters are not as sensitive as Powers' roundness index. Zingg's classification in comparison to the flatness and sphericity index, was a better method to define the sample. Briggs (1981) also mentions that in general Powers' roundness index gives a better indication for the transportational environment than the indices flatness or sphericity (Briggs 1981: 130). This was also attested on the samples for Cyprus where bivariate scatterdiagrams with flatness and sphericity showed little differentiation whereas Power's visual and Zingg's classification could differentiate between depositional environments.

Van Andel (1986: 111) described several categories of sediments from Greece which are useful to classify the Cypriot sediments:

1. Debris flow is marked by chaotic beds of badly sorted, largely angular boulders, cobbles and pebbles surrounded and supported by a matrix of finer material.

2. Stream-flood deposits consist of stratified sediments with lenticular beds of fairly well sorted rounded gravel and sand.
3. Sandy overbank loam is another common alluvial deposit, often accompanied by thin pebble layers.
4. Colluvium or slope wash ranges from angular gravels to loam.

VII.5.1.2. Procedure

This involved the measurement of 50 stones of each sample to characterise the clasts by their longest axis (a), their intermediate (b) and their shortest (c) axis. Additionally, the stones were classified according to visual comparison charts (Briggs 1981: 120). Several indices were used to characterise the shape of each stone (see also Briggs 1981: 111-121).

1. Zingg's classification (Briggs 1981: 113-115):

Zingg identified 4 categories of clasts by the ratios: b/a and c/b

Spheres: $b/a > 0.67$ and $c/b > 0.67$
Discs: $b/a > 0.67$ and $c/b < 0.67$
Rods: $b/a < 0.67$ and $c/b > 0.67$
Blades: $b/a < 0.67$ and $c/b < 0.67$

2. Krumbein's sphericity index (Briggs 1981: 115-116):

$\psi = \sqrt[3]{bc/a^2}$

3. Cailleux's flatness index (Briggs 1981: 117-118):

Flatness = $a+b/2c.100$

VII.1.6. Particle size analysis

VII.1.6.1. Aims

Measurement of the particle size of the sediments is one of the most important and useful techniques of sediment analysis. It provides information on the processes of transport, the deposition of the sediment and soil formation (Briggs 1981: 55).

VII.1.6.2. Laboratory procedure

- Coarse fraction

Coarse grained particle size analysis was carried out using an eight piece shaker sieve set from 16 to 2 mm. The sample was weighed prior to sieving and the amount left in each sieve after 10 min. on the shaker was recorded.

- Small fraction

An extensive amount of literature exists on diverse methodologies for particle size analysis (see Gee & Baudes 1986: 383-411, Day 1965: 545-567, Briggs 1981: 55-110). For this thesis, a Coulter LS230 particle size analyser was used. The size of the particles is measured by light diffraction proportional to their diameter. This method is relatively rapid compared to the other methods and is very accurate in optimum conditions.

The following pretreatment of samples was necessary to dissolve organic matter (with hydrogen peroxide) and calcium carbonate (with hydrogen chloride)[16]:

1. place a sediment sample into a 250 ml wide necked, labelled pyrex conical flask
2. Add approximately 10 ml HCl 10 %
3. Put the flasks on a hotplate inside a fume cupboard
4. Once the acid has started to bubble, remove flasks from the hotplate.

[16] Method was suggested by Dr. R.D. McCulloch

5. Working within the fume cupboard, add between 30 to 100 ml of H_2O_2 30% to each sample. Caution because samples can react violently and overflow.
6. When the reaction of the samples is calm, the flasks can be returned to the hotplate until only a small amount of liquid is left at the bottom of the flasks. If a sample is blocky, stir gently using a PTFE rod. If the reaction with H_2O_2 continues, add more H_2O_2. Do not allow the flasks to boil dry.
7. Decant the suspension into a centrifuge tube and spin at 3000 rpm for 10 minutes.
8. Decant the clear liquid from the centrifuge tube leaving the sample pellet at the bottom of the tube and refill with distilled water. Shake the tube so that the sediment mixes with the clean water and centrifuge at 3000 rpm for 10 minutes again. Repeat this washing process 2 to 3 times.

First, two subsamples were measured both 5 times and then averaged. However, the results were always so similar that it was not necessary to repeat every subsample twice. As a result, 5 measurements were undertaken on only one subsample and then averaged.

VII.2. Results and interpretation

VII.2.1. Stavros-tis-Psokas (plate 14)

VII.2.1.1. Pit 8 (plate 15: fig. 25 and plate16: fig. 27)

A. Results

Unit 1 has a high organic matter content (about 9%) compared to the other layers (plate 15: fig. 26). Additionally, in unit 3 magnetic enhancement has been observed. Moreover, the pH value (plate 16: fig. 28) in unit 1 is relatively high (8.4). In unit 2, the pH value drops to 7.9. While from unit 3 on, it increases again slightly over the next few layers with a maximum value in unit 5, with measurements of 8.5.

The particle size analysis (plate 17 and plate 18: fig. 32) indicates that gravel unit 5 consists of a large proportion of stones (84%). The stones are distributed evenly by size group (in weight proportion). The small fraction is composed of sand.

Furthermore, unit 4 consists almost only of fine fractions (95%) (plate 17: fig. 29), silty sand.

On the other hand, unit 3 is composed of a larger proportion of stones (66% in weight) (plate 17: fig. 29). The matrix, which is 34% of the sample weight, consists of sand.

Unit 2 is again matrix dominated (as unit 4), with 94% of the total weight of the sample consisting of silty sand (plate 17: fig. 29 and 31). The particle size distribution is bimodal with peaks in the volume percentage of the clay to medium silt fractions.

Unit 1 consists for 85% of small fractions, thus contains only a small proportion of stones (plate 17: fig. 29). The fine fraction however is much finer than in the previous layer and is less bimodal. It is clayey silt, which ranges between clay and coarse sand, with a peak in the particle volume percentages between clay and coarse silt, and slightly lower levels throughout the sand fractions.

B. Interpretation

At a certain time, the gravel channel of the Stavros-tis-Psokas was located about 30 m N of the present day stream (unit 5). However, the fining up indicates that the velocity decreased and that the channel was abandoned after a flood (unit 4). At some time, probably soon after, the channel was again in use (unit 3). Though the fining up indicates that the velocity decreased once more and that the river channel moved to a location further away. This is indicated through the clayey silt overbank deposits (unit 1). That unit 1 was built up over time and was not deposited at once is attested through the laboratory tests. Unit 2 possibly represents an E-horizon with marked low pH values possibly as a result of carbonate leaching. As a consequence, the present day A-horizon is far removed from the presumed E-horizon. Hence, the suggested E-horizon may belong to a palaeosol of which the A-horizon was missed out through sampling by sedimentological unit. Unit 3, 4 and 5 possibly represent the incipient B_k-horizon of that palaeosol as high pH values indicate carbonate redeposition in these units. Moreover, incipient clay illuviation to the depth of unit 3 is suggested by magnetic enhancement.

After this time of stability (soil formation), some more overbank sediments were deposited. The present day soil surface indicates incipient soil formation, with higher organic matter values in the topsoil.

VII.2.1.2. TA and TB (plate 18: fig. 33, plate 19: fig.34, plate 24: fig. 49 and plate 25)

A. Results

An organic matter content (plate 20: fig. 35 & plate 26: fig. 51) and peak was observed in TA3 (9.2%) / TB5 (9.7%). The graphs of TA and TB show a similar magnetic susceptibility pattern throughout the section (plate 20: fig. 36 and plate 26: fig. 52), with especially magnetic enhancement in TB1/TA8. An obvious depression in magnetic susceptibility is observable in TB4/TA4. Slightly higher magnetic susceptibility values have been observed in TB6/TA2. Throughout both sections, the frequency dependent susceptibility levels are relatively high.

Relatively large pH differences are observed between the samples of TA and TB. In more detail for section TA (plate 21: fig. 38), sample TA8 at the top of the section has a pH value of 8.7. Over depth, the samples become increasingly alkaline, with a value of 8.9 in TA7 and 9.1 in TA6. Subsequently, a small decrease in alkalinity is observed in TA5. In the next layer, TA4, an alkalinity peak is observed. Over the next layers, pH values decrease over depth, with a value of 9 in TA3, 8.9 in TA2 and 8.8 in TA1.

On the other hand, in section TB (plate 27: fig. 54), the first three units indicate a similar pH value of 8.6 for TB1, TB2 and TB3. Subsequently in TB4 (similar as in TA4), an alkalinity peak is observed. In the layers underneath, the pH value decreases to 8.8 in TB5, 8.7 in TB6 and 8.8 in TB7. Thus, the most striking similarity between the pH values of both sections is the high alkalinity of TB4 and TA4, which represent the same layer.

The stones in the samples consist almost only of chalks, in most layers approximately 90% (see fig. 55 on plate 27 and fig. 39 on plate 21). Sample TA8/TB1 is an exception, containing a greater variety of stones, especially more igneous stones.

The stones at the bottom layers are slightly more angular than in the upper layers (from TA5/TB3 on). However, the stones in general are very angular (see plate 22: fig. 41 and plate 28: fig. 57).
Spheres are mostly the dominant shape group. Although, in TA5 almost equal amounts of discs and spheres are present (see plate 27: fig. 56 and plate 21: fig. 40).

TA1/TB7 consists of about 90% small fractions (plate 22: fig. 42 and plate 28: fig. 58). The fine fraction distribution curve (plate 22: fig. 43) shows a peak in the volume of fine silt (at about 2 to 6 μm), though the sample also contains a relatively large volume of clay. Some fine sand fractions of about 150 μm are also present. The sediment was earlier identified as silty clay by field methods.

TA2/TB6 is composed of about 10 to 15% medium to large gravels and 70 to 80% small fractions (plate 22: fig. 42 and plate 28: fig. 58). The small fraction particle size distribution (plate 23: fig. 44 and plate 28: fig. 59) differs slightly from TA1/TB8 in that there is less clay and silt, though more medium to coarse sand. It was noted in the field that this layer is sandier. The matrix was identified as sandy silt with some very large sand particles.

TA3/TB5 is constituted of slightly less stones than the underlying layer and consists of about 90% small fractions (plate 22: fig. 42 and plate 28: fig. 58). The sediment is very similar to TA1/TB7 (plate 23: fig. 45 and plate 29: fig. 60).

TA4/TB4 contains almost no stones at all (plate 22: fig. 42 and plate 28: fig. 58). The matrix is dominated in volume by silts (plate 23: fig. 46 and plate 29: fig. 61) and in number by clays (plate 30: fig. 64). It is composed of silty clay, again very similar to TA1/TB7 and TA3/TB5.

TA5/TB3 contains much more stones than in the previous layer (plate 22: fig. 42 and plate 28: fig. 58). Depending on where the sample was taken, it consists for about 20 to 60% in weight of medium to large gravels. The matrix (plate 29: fig. 69), which is

80 to 40% of the sample weight is very similar to the matrix of TA1. It is composed of silty clay with quite a lot of sand.

TA6/TA7 and TB2 (plate 22: fig. 42 and plate 28: fig. 58) contain slightly less clasts than TA5 and TB3. The small fraction distribution (plate 23: fig. 47) is almost identical to that of TA5/TB3. However, TA6/TA7 and TB2 are composed of slightly less clay and more silt. The matrix is identified as silty clay with some fine to medium sand grains in it.

Samples TA8 and TB1 are dissimilar, probably depending on where the sample was retrieved. Sample TB1 was collected at a lower location than TA8. Both samples contain almost no gravel and consist mostly (about 90%) of fine fractions (plate 22: fig. 42 and plate 28: fig. 58). The fine fraction of TB1 (plate 29: fig. 63) consists mainly of silt and clay. Only a small volume percentage of sands have been observed. TA8 compared to TB1 contains less clay and more sand.

B. Interpretation

At the junction of the Stavros-tis-Psokas with the Argakin-Pyroia coming from the north, an alluvial fan has formed. The exposed sequence indicates that more than a meter of sediments (TB7/TB6/TB5) were deposited sometime after 300 ± 65.5 AD. Probably, TA1/TB7 at the bottom of the section represents a mudflow deposit, marked by angular chalks deriving from upslope and badly sorted sediments. Sandy silt TA2, probably represents an overbank deposit, though also contains some colluvial input. TA3 represents again mudflow, marked by angular chalks deriving from upslope and badly sorted sediments. Subsequently, a period of landscape stability took place. Consequently, an incipient soil could develop. The A-horizon in TB5/TA3 is mainly recognised by its high organic matter content. A peak in magnetic susceptibility indicates that sample TB6/TA2 may represent a B_t-horizon. Next, a new phase of deposition took place. At first, overbank flooding of a stream resulted in the deposition of unit TA4/TB4. Unit TA4/TB4 is waterlain as suggested by its absence of stones and its moderately well sorted clayey silt matrix.

Subsequently, debris flow was deposited above this unit, recognisable by the poorly sorted local stones. Finally, more mudflow was deposited, recognisable by its poorly sorting and the abundance of local angular chalks. There is only little unit differentiation identifiable throughout the upper 2.5 m. Hence, it is supposed that they were deposited at once, sometime after ± 753 AD. Some soil formation took place on top of the section. This is especially observable in section TA, which shows evidence of incipient soil formation. More precisely, magnetic enhancement in topsoil TB1/TA8 indicates the occurrence of an A-horizon. Moreover, carbonate translocation has been observed from TA8 towards TA4.

VII.2.2. Agriokalamos

VII.2.2.1. KAGB (plate 34: fig. 71, plate 35: fig. 72 and plate 33: fig. 70)

A. Results

Two peaks in organic matter content (plate 35: fig. 73) are observed, one in KAGB6 (10% organic matter) and one in KAGB8 (7.8%). Moreover, the mass specific susceptibility (plate 36: fig. 74) shows peaks in KAGB3, KAGB6, KAGB8, KAGB11 and KAGB14. Remarkable is that the peaks in KAGB8, KAGB11 and KAGB14 are associated with reddish horizons. The pH test indicates the following pattern (plate 36: fig. 76). A pH of 8.6 is observed in KAGB1, which increases in KAGB2 to 8.8, decreases again over the next three units from 8.6 in KAGB3, to 8.2 in KAGB4 and 7.7 in KAGB5. In KAGB6 the alkalinity increases to 7.9 and increases also over the next few units: 8.3 in KAGB7, 8.8 in KAGB8, KAGB9, KAGB10 and 9.4 in KAGB11. A slight decrease is observed in KAGB12 to a value of 9.2. Over the next three units (KAGB13, KAGB14 and KAGB15) the pH remains stable.

A graph on the lithological distribution of the stones throughout the section is presented on plate 37: fig. 77. Silicified chalks occur frequently (about 40%) in the lower units until KAGB4. From KAGB3 upward, silicified chalks seem to be replaced by un-silicified chalks. Moreover, cherts, sandstones, basalt stones and limestones are present throughout the section, though mostly in minor quantities.

The clasts of the gravel units KAGB11, KAGB9 and KAGB5 are quite rounded, with respectively 50%, 40% and 45% rounded and sub-rounded clasts. However, the clasts of gravel unit KAGB3 are more angular (see plate 37: fig. 79). Shape analysis of the clasts (plate 37: fig. 78) indicates that the gravel units KAGB11 and KAGB10 contain mostly discs. Gravel unit KAGB5 contains about equal amounts of discs, spheres and blades. From KAGB4 upward, spheres are the dominant clast shapes in the upper units of the section.

Unit KAGB15 contains only a small weight of stones, 19% of the total sample weight, mostly large stones (15% of the sample weight) (see plate 38: fig. 80). The matrix, which is 81% of the sample weight, is composed of clayey silt.

Unit KAGB14 contains stones for only 4% of the total sample weight (plate 38: fig. 80). The abundant matrix, which is 96% of the sample weight, consists of clayey silt as well.

Unit KAGB13 is similar to the previous units and again contains only a small proportion of stones (only 5% of the total sample weight) (plate 38: fig. 80). The matrix, which is 95% of the sample weight, consists of clayey silt as in the previous units.

Unit KAGB12 is again composed mainly of matrix, which is 98% of the sample weight (plate 38: fig. 80). However, the matrix is slightly coarser than in the previous units as it is sandy silt.

Gravel unit KAGB11 (plate 33: fig. 70) has a larger weight proportion of stones than the previous units, 78% of the total sample weight (plate 38: fig. 80). An average stone measures 2.5 x 1.8 x 1.1 cm. The matrix, which is 22% of the sample, is composed of coarse sand.

KAGB10 contains a smaller weight proportion of stones than in the previous unit (KAGB11), only 24% of the sample weight (plate 38: fig. 80). The matrix, which is 76% of the unit, consists of silt.

Gravel unit KAGB9 consists of a larger weight proportion of stones than in the previous unit, 77% of the sample weight (plate 38: fig. 80). The stones range from all size groups, though there is an increasing weight percentage according to size increase. The matrix (plate 38: fig. 81), which is 33% of the sample weight, is composed of silty sand, with a bimodal distribution having a peak at the clay/medium silt fractions and another one in the fine sand fraction.

Unit KAGB8 contains a smaller proportion of stones than in the previous unit (KAGB9), only 17% of the sample weight (plate 38: fig. 80). The matrix (plate 38: fig. 82), which is 83% of the sample weight, is composed of sandy silt, having a bimodal volume distribution curve with a peak in the clay/medium silt fraction and another peak in the fine sand fractions. Hence, the matrix almost has a similar composition as the one of KAGB9.

Unit KAGB7 has a smaller weight of stones compared to the previous unit (KAGB8), only 5% of the sample weight (plate 38: fig. 80). The matrix, which is 95% of the sample weight, is composed of clayey silt (plate 39: fig. 83).

Unit KAGB6 is composed of a small proportion of stones, only 7% of the sample weight (plate 38: fig. 80). The matrix, which is 93% of the sample, is composed of silt (plate 39: fig. 84).

Gravel unit KAGB5 contains a smaller proportion of stones, 27% of the sample weight, mainly fine to medium stones (plate 38: fig. 80). The matrix, which is 73% of the sample, consists of silty sand (plate 39: fig. 85).

Unit KAGB4 contains a smaller proportion of stones than in KAGB5, only 14% of the sample weight (plate 38: fig. 80). The small fraction, which is 86% of the sample weight, consists of silt.

Unit KAGB3 consists of a larger weight proportion of stones, 60% of the sample weight (plate 38: fig. 80). The stones range from all size groups, though there is an increasing weight percentage according to size increase. The matrix (plate 39: fig. 86), which is 40% of the sample weight, was identified as silt, though the particle size analysis indicates a bimodal volumetric distribution, with a peak within the clay/silt range and another one in the fine sand fraction.

Unit KAGB2 contains again a smaller weight proportion of stones, only 16% of the total sample weight (plate 38: fig. 80). The stones range between medium gravel and fine gravel. The matrix (plate 40: fig. 87), which is 84% of the sample, is bimodal in its volumetric distribution, with a peak within the clay/silt range and another one in the fine sand fraction. Hence, the matrix is composed of sandy silt.

Unit KAGB1 contains only 20% of stones (plate 38: fig. 80). The matrix (plate 40: fig. 88), which is 80% of the sample weight, has a bimodal particle size distribution, with peaks in the volume of clay/medium silt and in the fine/medium sand fractions.

B. Interpretation

Clayey silt units KAGB15, KAGB14, KAGB13 and sandy silt unit KAGB12 at the bottom of section KAGB represent overbank deposits of the Agriokalamos. This is suggested by their absence of stones. Subsequently a period of landscape stability took place, long enough for soil development. A magnetic susceptibility peak in KAGB14 shows the incipient B_t-horizon of that soil. However, the A-horizon was obliterated by a gully which also cut through KAGB12. Gravel unit KAGB11 represents the gully fill. The gully originated Northwards as is indicated by the S-ward orientation of the clasts. Hence, KAGB11 probably does not represent a channel of the Agriokalamos. However, the gully was relatively powerful as the average stone in the deposit measures 2.5 x 1.8 x 1.1 cm. The clasts of the gully show some grading marked by fining upwards, which indicates that the velocity suddenly decreased. Subsequently, overbank sediments were deposited (KAGB10) again, as is evidenced by the silt, mostly lacking stones. Unit KAGB9, consisting of an abundance of very small stones, represents bedload deposits of the Agriokalamos. However, the small size of the clasts and the undeep deposit indicate that the channel of the Agriokalamos was not at this location, but rather that the low velocity at this location was related to a flood. Slight upward fining is observed in KAGB9. Sandy silt unit KAGB8 represents the further fining upward. Subsequently, another period of landscape stability took place, which lasted for some time as a soil could develop. The formation of an A-horizon in KAGB8 is identified by the combination of a high organic matter content and a magnetic susceptibility peak. A B_t-horizon formed in KAGB11, marked by a red colour and a magnetic susceptibility peak. Moreover, KAGB11 also shows some evidence of calcium carbonate illuviation, thus an incipient B_k-horizon. Subsequently, renewed overbank deposition took place (units KAGB7 and KAGB6) and about 0.5 m of sediments were deposited. Successively, soil formation took place marked by an A-horizon in KAGB6 (cf. high organic matter content) and downward movement of calcium carbonate (cf. increasing pH levels underneath KAGB6). However, this soil formation is blurred by earlier soil formation. The tiny gravel layer KAGB5 represents a similar flood event as KAGB9. After this flood, some bedload sediments were deposited, though the small stone size suggests a low velocity. More overbank deposits are present in KAGB4. From KAGB3 on, a greater influx of colluvial input is observed as noted by the larger amount of angular, local chalks occurring in the sediment, unlike more rounded silicified chalks in the previous layers.

VII.2.2.2. KAGC (plate 41 and plate 42)

A. Results

Samples KAGC2 (= unit KAGC3), KAGC3 (= unit KAGC4), KAGC6 (= unit KAGC7) and KAGC9 (= unit KAGC10) have a relatively high organic matter content, respectively 3.8%, 2.8%, 4% and 3.2% (see plate 43: fig. 93). However, overall, the organic matter content is much lower than in section KAGB. Moreover, peaks in magnetic susceptibility have been identified in sample KAGC5 (= unit KAGC6) and sample KAGC10 (= unit KAGC11) (plate 43: fig. 94). The pH test indicates the following pattern in KAGC (plate 44: fig. 96). Sample KAGC2 (= unit KAGC3) has a pH value of 8.6. KAGC3 (= unit KAGC4) has a lower alkalinity of 8.2. The pH increases in depth from 8.4 in KAGC4 (= unit KAGC5), to 8.9 in KAGC5 (=unit KAGC6) and 8.9 in KAGC6 (= unit KAGC7). From sample KAGC7 (= unit KAGC8) onwards, the pH increases drastically to a value of 9.5 in KAGC7 (=unit KAGC8), 9.5 in KAGC8 (= unit KAGC9), 9.7 in KAGC9 (= unit KAGC10) and 10.2 in KAGC10 (= unit KAGC11). In KAGC11 (= unit KAGC12), the pH drops to 9.7.

In KAGC, the stones consist for a large proportion of silicified chalks (60%) (plate 44: fig. 97). Except in sample KAGC8 (=unit KAGC9), mainly rip-up clasts occur. Furthermore, limestone, sandstone, chert, shale, serpentinite are also present in most units, though in smaller amounts. Basalt is only present in KAGC3.
The stones in KAGC10 (=unit KAGC11) and KAGC8 (= unit KAGC9) are very angular with about 80 to 90% angular and sub-angular stones. From KAGC7 (= unit KAGC8) on, the stones are more rounded (see plate 45: fig. 99). Throughout the section, spheres and discs are most present, however slight variations occur in their relative proportion (plate 44: fig. 98). In KAGC10 (= unit KAGC11) as well as in KAGC8 (= unit KAGC9), spheres are more present than discs. On the other hand, in KAGC7 (= unit KAGC8), discs are most present. A larger proportion of spheres occurs in KAGC5 (= unit KAGC6) and from KAGC4 (= unit KAGC5) on, spheres are clearly predominant.

Unit KAGC12 (=sample KAGC11) consists of 64% weight of stones (plate 45: fig. 100). The matrix (plate 45: fig. 101), which is 46% of the sample weight, has a bimodal volume distribution with peaks in the clay/medium silt fraction and in the fine sand fraction (plate 45: fig. 101). The matrix was identified as clayey silt.

Unit KAGC11 (sample KAGC10) contains a smaller weight percentage of stones (plate 45: fig. 100). All size groups have an equal weight proportion of stones. The matrix, which is 40% of the sample, consists of sand.

Unit KAGC10 (sample KAGC9) contains about 42% weight of stones (plate 45: fig. 100). The size groups between fine and medium gravel are most represented in weight. The matrix (plate 46: fig. 102), which is 58% of the sample weight, consists of an almost unimodal sandy silt, ranging between fine clay particles to coarse sand particles.

Unit KAGC9 (sample KAGC8) has a relatively large weight proportion of stones, 62% of the total sample weight (plate 45: fig. 100). The matrix (plate 46: fig. 103), which is only 38% of the sample weight, consists of a larger volume of clay and silt particles and a smaller volume of sand fractions than in KAGC10.

Unit KAGC8 (sample KAGC7) contains a relatively large proportion of stones, 86% of the sample weight (plate 45: fig. 100). The group of stones larger than 16 mm has the largest weight. The matrix (plate 46: fig. 104), which is 14% of the sample weight, consists of unimodal coarse sand.

Unit KAGC7 (sample KAGC6) is composed of a small proportion of stones, only 7% of the sample weight (plate 45: fig. 100). The matrix (plate 46: fig. 105), which is 93% of the sample weight, consists of silty clay with particles ranging between fine clay and coarse sand. However, from the medium silt fraction on, there is a smaller volume.

Unit KAGC6 (sample KAGC5) is constituted of a small proportion of stones, only 14% of the sample weight (plate 45: fig. 100). The stones are equally distributed over the clast sizes. The matrix (plate 47: fig. 106), which is 86% of the sample weight, consists of silty sand and is coarser than in unit KAGC7. The matrix resembles the matrix of unit KAGC8.

Unit KAGC5 (sample KAGC4) contains a small proportion of stones, only 23% of the sample weight (plate 45: fig. 100). The sample contains more stones larger than 16 mm than in KAGC6. The matrix (plate 45: fig. 107), which is 77% of the sample weight, consists of clayey silt, similar to the matrix of unit KAGC7, having a particle size distribution between fine clay and coarse sand with less volume of particles from the medium silt fraction onwards.

Gravel unit KAGC4 (sample KAGC3) is composed of a large proportion of stones, 90% of the total sample weight (plate 45: fig. 100). The matrix (plate 47: fig. 108), which is only 10% of the sample weight, consists of coarse sand, though also contains some silt and clay fractions.

Unit KAGC3 (sample KAGC2) contains a small proportion of stones, only 8% of the total sample weight (plate 45: fig. 100). The matrix (plate 47: fig. 109), which is 92% of the sample weight, is clayey silt with an almost unimodal volume distribution within the range from clay to medium sand.

Additionally, the particle size analysis indicates that from unit KAGC10 (sample KAGC9) to unit KAGC12 (sample KAGC11) a larger percentage of clay fractions occur (plate 48: fig. 110).

B. Interpretation

Unit KAGC12 represents clayey silt overbank deposits of the former Agriokalamos. Gravel unit KAGC11 with a sand matrix may be overbank sediments deposited after a flood, nearby a river channel. Sandy silt unit KAGC10, containing only a few clasts represents overbank sediments as well. Though these overbank deposits are much finer than those of unit KAGC11, suggesting a location further away from the channel. Subsequently, soil formation took place on unit KAGC10 as is evidenced by a relatively high organic matter content in this unit. Some B_t-horizon formation might have taken place in KAGC11 as attested by a magnetic susceptibility peak. Moreover, the downward movement of clay is also suggested by the particle size analysis, which indicates an increase in clay content over depth from unit KAGC10 to KAGC12. Subsequently, the river passed through this location (unit KAGC9). Remarkable is that its bedload was dominated by rip-up clasts, probably deriving from a local lake, possibly an abandoned meander. Subsequently, unit 8 was deposited with a fining upward sequence in stones size. However, the particle size analysis indicates that the matrix is coarser than in the previous unit. This is probably related to the source of the deposit. Indeed, there is an absence of rip-up clasts in unit KAGC8. Next, finer overbank sediments (silty clay) were deposited (KAGC7). Hence, the river became even further removed from this location than previously. Subsequently, another period of landscape stability took place at this location as some incipient soil formation took place. An A-horizon started to develop in KAGC7, identifiable by its relatively high organic matter content. Some time later, more sandy overbank sediments were deposited (unit KAGC6), indicating that the river was again nearer this location. The grading in KAGC6, consisting of two small pebble layers, indicates that this unit was deposited in two flood events. Clayey silt unit KAGC5 represents more overbank deposits. Subsequently, the river passed through this location as is evidenced by the abundance of rounded stones having a W-ward orientation. These bedload sediments of the former river were deposited in three events as is indicated by three couplets. Then, the channel became abandoned and consequently moved to another location. More overbank sediments were deposited at the location of the section (KAGC2). Subsequently, another period of landscape stability took place and a soil developed. KAGC3 has a relatively high organic matter content and a remarkable red colour, suggesting that it might have been an A-horizon. Moreover, a magnetic susceptibility peak in KAGC6 has been observed, suggesting the occurrence of a B_t-horizon at this depth. Additionally, increasing pH values through depth from KAGC3 to KAGC6 indicate the downward translocation of calcium carbonate. After this period of landscape stability, colluvium was deposited, as is indicated by the relatively large clasts within the clayey silt unit.

VII.2.2.3. KAGD (plate 48: fig. 111 and plate 49: fig. 112)

A. Results

KAGD4, KAGD5, KAGD8, KAGD12 and KAGD15 have a higher organic matter content, respectively 8.6%, 9.1%, 7.4%, 8.1% and 7.9% (plate 50: fig. 113). Furthermore, a magnetic susceptibility peak is attested in KAGD5 and KAGD10 (plate 50: fig. 114). The pH test (plate 51: fig. 116) indicates a value of 8 in KAGD5, an alkalinity increase to 8.7 in KAGD6. From KAGD7 on the alkalinity decreases to about 8 and remains relatively stable over the next few layers (7.9 in KAGD8, 8 in KAGD9 and 7.9 in KAGD10). In KAGD11 however, the pH drops to 7.7. Subsequently, in KAGD12 it increases again to 7.9 and to 8.1 in KAGD13. From KAGD14 on, the pH drops again slightly to 8 and 7.8 in KAGD15. However, in KAGD16, the alkalinity increases to 8.1 and to 8.3 in KAGD17. A slight decrease to 8.1 is observed in KAGD18.

Throughout the section, silicified chalks are most present, except in unit KAGD16, KAGD16, KAGD14 and KAGD10 (plate 51: fig. 117). In units KAGD16 and KAGD14 rip-up clasts occur instead and in KAGD10 un-silicified chalks prevail. Furthermore, sandstones, limestones, cherts and serpentinites are also present, though in smaller quantity.

Most units contain only very small stones, with exception of units KAGD16, KAGD6 and KAGD3. In unit KAGD16, the stones measure on average 1.3 x 1 x 0.6 cm. Moreover, in unit KAGD6, the stones measure on average 1.5 x 1.1 x 0.7 cm. The stones of unit KAGD3 also are larger than in the other units though it was impossible to sample them.

Throughout the section, discs and spheres are most present, except in KAGD8 where rods and blades replaced some spheres and in KAGD5 where discs are less occurring (see plate 51: fig. 118).

The clasts are relatively well-rounded in KAGD18, KAGD17 and KAGD16 (plate 52: fig. 119). Then, in KAGD14 and KAGD10, the clasts become slightly more angular. From KAGD9 to KAGD6, clasts are again more rounded. In KAGD5, the clasts are very angular.

Unit KAGD18 consists of a small weight proportion of stones, only 6% of the sample weight (plate 52: fig. 120). The matrix (plate 52: fig. 121), which is 94% of the sample weight, is composed of silty clay with particles ranging between fine clay and fine sand.

Unit KAGD17 contains, as in KAGD18, only a small proportion of stones. The matrix is composed of silty sand and is coarser than in the previous unit (KAGD18).

Gravel unit KAGD16 is constituted of a large proportion of stones, 76% of the total weight of the sample (plate 52: fig. 120). The matrix (plate 53: fig. 122), which is 24% of the sample weight, is composed of silt, though contains also quite a lot of clay as well as sand particles.

Unit KAGD15 consists of a very small proportion of stones, only 6% of the sample weight (plate 52: fig. 120). The matrix (plate 53: fig. 123), which is 94% of the sample weight, was identified as clayey silt. The matrix is finer than the matrix of

KAGD16, though has a similar volume percentage distribution curve, except a lack of medium sand fractions.

Unit KAGD14 contains a small proportion of stones, only 18% of the sample weight (plate 52: fig. 120). The matrix (plate 53: fig. 124), which is 82% of the sample weight, is composed of sandy silt. The matrix has several peaks: the largest in the silt fraction, one in the fine sand fraction and another one in the coarse sand fraction.

Unit KAGD13 contains a small proportion of stones, only 11% of the sample weight (plate 52: fig. 120). The matrix (plate 53: fig. 125), which is 89% of the sample weight, is silty sand; which has a bimodal volume distribution with peaks in the fine/medium silt fraction and in the medium/coarse sand fraction.

Unit KAGD12 is composed of a small proportion of stones, only 10% of the sample weight (plate 52: fig. 120). The matrix, which is 10% of the sample weight, is constituted of clayey silt with some sand fractions.

Unit KAGD11 contains a small proportion of stones. The matrix (plate 54: fig. 126) is composed of sandy silt with a similar particle size distribution as in KAGD13, except for a smaller peak within the sand range.

Unit KAGD10 contains a very small proportion of stones, only 5% of the sample weight (plate 52: fig. 120). The matrix (plate 54: fig. 127), which is 95% of the sample, consists of sandy silt, with a peak in the silt fraction and another one in the fine sand fraction.

Unit KAGD9 is composed of a small proportion of stones, only 6% of the sample weight (plate 52: fig. 120). Most of the stones are larger than medium gravel. The matrix (plate 54: fig. 128), which is 94% of the sample weight, consists of sandy silt having a volumetric peak in the fine silt fraction.

Unit KAGD8 contains a small proportion of stones: 16% of the sample weight (plate 52: fig. 120). The largest weight proportions of stones is within the fine gravel size groups. However, a large weight in the group between 11.2 and 16 mm has also been observed. The matrix (plate 54: fig. 129), which is 84% of the sample weight, consists of clayey silt.

Unit KAGD7 is composed of only a very small weight proportion of stones: 2% of the total sample weight (plate 52: fig. 120). The matrix (plate 55: fig. 130), which is 98% of the sample weight, consists of sandy silt, similar to the matrix of KAGD9, though KAGD7 has a larger proportion of silt fractions.

Gravel KAGD6 consists of a large proportion of stones. The matrix (plate 55: fig. 131), which is only a small proportion of the total sample weight, is composed of silty sand.

Unit KAGD5 only contains a small weight proportion of stones: 12% of the sample weight (plate 52: fig. 120). The stones between 11.2 and 16 mm show the largest weight occurrence. The matrix (plate 55: fig. 132), which is 88% of the sample weight, consists of clayey silt, with peaks in the clay/medium silt range and in the fine sand fraction.

Sample KAGD4 contains no clasts, however some clasts have been observed in the field (plate 52: fig. 120). The matrix (plate 55: fig. 133) is composed of silty clay, though also consists of some sand. The matrix is similar to the matrix of KAGD5, though KAGD4 has a larger volume of clay and silt.

Furthermore, the particle size analysis indicates that the following units have a larger number of fine clays: KAGD4, KAGD5, KAGD14 and KAGD11 (plate 56: fig. 134).

B. Interpretation

KAGD18 and KAGD17 represent overbank sediments, showing some coarsening upward, which might indicate that the river channel was moving towards this section. Subsequently, the channel reached this location (KAGD16). The bedload of the channel consists of local rip-up clasts. These clasts derived from a shallow depression in the neighbourhood, possibly an abandoned meander. The river passed through this depression and the clasts were ripped up and rounded by river action. A little further downstream, they were deposited when the velocity quickly decreased after a flood and the river moved to another location. Subsequently, overbank sediments were deposited (KAGD15). Then, a period of landscape stability took place during which soil formation could take place. An A-horizon probably formed in KAGD15 as is attested by the higher organic matter content in this unit. Moreover, a pH increase from KAGD15 to KAGD17 indicates the downward translocation of calcium carbonate. After this period of landscape stability, some more overbank sediments were deposited at this location: sandy silt unit KAGD14, silty sand unit KAGD13 and clayey silt unit KAGD12. Sandy silt unit KAGD14 contains rip-up clasts as well, probably derived from a local depression, possibly abandoned meander. Subsequently, landscape stability took place, resulting in the formation of an A-horizon in KAGD12, suggested by the relatively high organic matter content and combined low pH value. KAGD14 probably represents a B_t-horizon of that soil as is suggested by the higher number of clay particles than in the other units (cf. particle size analysis). After this period of stability, about 80 cm overbank sediments were deposited : sandy silt layer KAGD11, sandy silt layer KAGD10, fine silt layer KAGD9 and clayey silt layer KAGD8. Another period of landscape stability took place. This is visible in the slighlty higher organic matter content of KAGD8 and its darker colour. Moreover, a marked magnetic susceptibility peak in KAGD10 suggests the occurrence of a Bt-horizon, which is also supported by its reddish colour and its prismatic structure. Moreover KAGB9 has a higher pH value indicating that some carbonate illuviation might have taken place in this unit. Subsequently, another 50 cm of sandy silt overbank sediments were deposited. Then, as a consequence of a flood, a thin gravel layer was deposited.

Shortly after, some more overbank sediments were deposited. Another period of landscape stability took place as is indicated by the combination of a high organic matter content and a magnetic susceptibility peak in KAGD5, which possibly indicates the occurrence of an A-horizon. Subsequently, more overbank sediments were deposited, about half of KAGD4. Once more, the landscape was relatively stable and an A-horizon could develop as observed in the higher organic matter content. The A-horizon of the palaeosol then possibly became a B_t-horizon as is indicated by its reddisch colour. Hence, cumulative soil formation took place, which blurs the laboratory tests and hampers the clear differentiation between horizons. Then, some more overbank sediments were deposited ; the other half of KAGD4. At a certain time, a gully cut through this sediment. The S-ward orientation of the clasts of KAGD3 and their poor sorting suggest that they represent gully bedload. Once more, sediments were deposited at this location, probably rather colluvial in origin. However, this could not be further investigated as this unit could not be sampled. Its colour suggests that it may be a thickened A-horizon as a result of slow accumulation over time. However, tests are necessary to prove this.

The four investigated sections (KAGA, KAGB, KAGC and KAGD) represent an important lateral facies variability which reflects the geological complexity of the valley and the local geomorphological variations.

VII.2.3. Dhiarizzos

VII.2.3.1. KOL1 (plate 56: fig. 135 and plate 58: fig. 137)

A. Results

Unit KOL1.1 has slightly higher values of organic matter content (plate 58: fig. 138) and slightly enhanced magnetic susceptibility values (plate 59: fig. 139). A real peak in magnetic susceptibility was observed in KOL1.2. Furthermore, it is noteworthy that the magnetic susceptibility is high throughout the soil section. KOL1.1 and KOL1.2 have a similar pH (8.9). KOL1.3 and KOL1.4 have a higher alkalinity degree, with an increasing pH respectively from 9.2 to 9.3 (see plate 59: fig. 141).

Gravel layer KOL1.4 is composed of 75% of stones (plate 60: fig. 145). Sandstones are most present, while limestones, chalks and cherts in smaller amounts. There is only a small proportion of igneous clasts (see plate 59: fig. 142). 70% of the stones is rounded and sub-rounded (see plate 60: fig. 144). Additionally, discs are predominant (40%), but spheres are also abundant (30%) (plate 60: fig. 143). Medium sized gravels are most present (48% of the total weight) (plate 60: fig. 145). Moreover, an average stones measures 1.7 x 1.2 x 0.7 cm. The sample consists for only 25% of the total weight of small fractions, being unimodal coarse sand (plate 60: fig. 146).

Gravel layer KOL1.3 is composed of 93% of stones (plate 60: fig. 145), mostly limestones, though chalks and sandstones are also frequent, respectively 30% and 20% (plate 59: fig. 142). Discs and spheres are about equally abundant (about 30%) (plate 60: fig. 143). The stones in the sample are for 80% rounded and sub-rounded (plate 60: fig. 144). Stones larger than medium gravel are most frequently present (63%). An average sampled stones measures 2.3 x 1.6 x 1 cm and is slightly larger than in the previous layer. The matrix (plate 61: fig. 147), which is 7 % of the sample, consists of coarse sand and is slightly coarser than in the previous unit.

Imbricated gravel layer KOL1.2 contains a slightly smaller weight percentage of stones (73%) than in the previous layer (plate 60: fig. 145). Equal amounts of sandstones, limestones and chalks (about 30%) are present (plate 59: fig. 142). The stones are equally rounded as in the previous sample (KOL1.3) (see plate 60: fig. 144). An increase in discs (compared to the previous layer) is observed (plate 60: fig. 143). As a result, they are now the dominant shapes in this layer (55%). Although the 50 sampled stones measure 2.3 x 1.7 x 1 cm on average (= similar size as in KOL1.3), the field observations noted the stones in the sediment were smaller than in the previous layer. The matrix (plate 61: fig. 148), which is 27 % of the sample, is composed of coarse sand.

KOL1.1 contains almost solely small fractions (99%) (plate 60: fig. 145). They are composed of silty sand, slightly bimodal with peaks around the fine to medium silt fraction and the fine silt fraction (plate 61: fig. 149).

Sample KOL1.1 contains less clay particles than KOL1.2. Additionally, also samples KOL1.3 and KOL1.4 have more and finer clay fractions than are present in KOL1.1 (see plate 61: fig. 150).

B. Interpretation

The rounded gravels indicate that a channel of the Dhiarizzos was situated at this location. Moreover, the sherds suggest a date around or after 1560 AD. The large size of the clasts indicates that it was a strong river (cf. VIII.3.1), a bedload dominated stream. After a flood, the river probably became choked by its own alluvium and changed its channel. This is identifiable through the occurrence of smaller stones higher up in the gravel (KOL1.2), indicating a lower velocity at this location.

Subsequently, this location was still within the floodplain of the new river-course. As a result of flooding, almost a meter of overbank sediments were deposited (KOL1.1) on top of the previous channel deposits. It is indicated that some time elapsed since the deposition of the overbank sediment by the soil formation that took place at the surface. A high organic matter content in KOL1.1 indicates that the sample was retrieved within the present day A-horizon. Sample KOL1.2 probably represents an incipient B_t-horizon, identifiable by a high mass specific magnetic susceptibility. Additionally, samples KOL1.3 and KOL1.4 are marked by a higher alkalinity possibly related to a higher carbonate content. Consequently, adding to the previous evidence, it possibly represents a carbonate enrichment horizon, an incipient B_k-horizon. Moreover, the above described soil formation is also identifiable in the number percentage distributions of clay in the section. Clay illuviation is observed in KOL1.2, KOL1.3 and KOL1.4.

VII.2.3.2. KOL2 (plate 62: fig. 151; plate 63: fig. 152)

A. Results

Note that gravel unit KOL2.3 is represented through three samples, labelled as sample KOL2.5, sample KOL2.4 and sample KOL2.3.

The graphs show a slight increase in organic matter in KOL2.4 and KOL2.5, though levels are still very low (3.2%) (plate 63: fig. 153). Additionally, the mass specific magnetic susceptibility test indicates relatively low values in KOL2.1, enhanced values in KOL2.2 and KOL2.3; and again lower values in KOL2.4 and KOL2.5 (plate 64: fig. 154). The pH in KOL2.1, KOL2.2 and KOL2.3 is similar to KOL1.1 and KOL1.2 (8.9 to 9). KOL2.4 drops in alkalinity with a pH value of 8.2 and sample KOL2.5 is again more alkaline with values of 8.9 (plate 64: fig. 156).

Sample KOL2.5, deriving from the imbricated gravel layer KOL2.3 is composed of a large weight proportion of gravels and cobbles (87%) (plate 66: fig. 160). They have been identified as sandstone, limestone, silicified chalk, chert and igneous stones and are present in almost equal amounts (plate 65: fig. 157). 70% of the stones are rounded or sub-rounded (plate 65: fig. 159). Disc shapes are most frequent, followed by spheres (25%) and rods (about 20%) (plate 65: fig. 158). The group of stones larger than medium gravel is most represented. The average stone within the sample measures 2.5 x 1.8 x 1.1 cm. The matrix, which is 13% of the sample (plate 66: fig. 160), is composed of coarse sand, with additional volumetric peaks within the fine sand and silt range (plate 66: fig.161).

Sample KOL2.4 from the imbricated gravel layer KOL2.3 consists for a large weight proportion of stones (85%) (plate 66: fig. 160) similar to the previous sample. The lithological composition of the stones is very similar to KOL2.5, though KOL2.4 contains slightly more sandstones (plate 65: fig. 157). The stones are also equally rounded as in KOL2.5 with 70% of rounded and sub-rounded stones (plate 65: fig. 159). Slightly more spheres (30% compared to 25% in the lower sample) but fewer discs (30% compared to 40% in the previous sample) are present (plate 65: fig. 158). Stones larger than medium gravel dominate in weight occurrence (72%) (plate 66: fig. 160). The average stone in the sample measures about 2.7 x 1.8 x 1.2 cm. The matrix, which is 15% of the total sample weight (plate 66: fig. 160), is similar to the one in the previous sample (plate 66: fig. 162). However, it is slightly finer, with larger volume proportions of fine sand and fine silt. It was identified in the field as coarse sand.

Sample KOL2.3 from the imbricated gravel layer KOL2.3, contains an equal weight percentage of stones as in the previous layers (87% of the total sample weight) (plate 66: fig. 160). It is lithological very similar to the previous sample (plate 65: fig. 157). However, the clasts are more angular, with about 52% rounded and sub-rounded clasts (compared to 70% in the previous sample) (plate 65: fig. 159). The shape distribution is similar to KOL2.4 (plate 65: fig. 158). The matrix, which is 13% of the sample weight (plate 66: fig. 160), is again composed of coarse sand (plate 67: fig. 163).

Unit KOL2.2 contains slightly less stone weight than the previous layers (only 74% of the total weight of the sample) (plate 66: fig. 160). However, the stones have a similar lithological variety as in the previous layer (plate 65: fig. 157). The shapes are composed of more discs (40%) and less spheres than in KOL2.3 (plate 65: fig. 158). The stones are slightly more rounded (65% compared to 52% in the previous layer) (plate 65: fig. 159). The group of stones larger than medium gravel is represented in most weight (plate 66: fig. 160). The matrix, which is 26% of the sample (plate 66: fig. 160), consists of coarse sand, with additional large volume percentages of fine sand and silt (plate 67: fig. 164).

KOL2.1 is composed almost solely of fine fractions (98%) (plate 66: fig. 160). It is silty sand, marked by some bimodality with peaks in the fine silt and fine sand fractions (plate 67: fig. 165).

The number percentage distribution curves of the fine fractions of all samples indicates no marked changes in clay occurrence (plate 67: fig. 166).

B. Interpretation

At some time, a channel passed through this location (unit KOL2.3 and KOL2.2). Finally, 2 m of overbank sediments were deposited. There is hardly any evidence of soil formation, which indicates a recent date of deposition.

VII.2.2.3. SOA (plate 71: fig. 171, plate 70: fig. 170)

A. Results

A higher organic matter content has been observed in the following samples: SOA2 (5%), SOA9 (about 6%), SOA13 (about 6%), SOA15 (about 6%) and SOA17 (about 5.5%) (plate 72: fig. 172). The magnetic susceptibility levels are overall very low (plate 72: fig. 173). A marked peak in magnetic susceptibility has been observed in SOA17. Apart from a slight enhancement in samples SOA8 and SOA9, no other peaks have been found. Sample SOA6 contains superparamagnetic grains (plate 72: fig. 174). The pH test (plate 175: fig. 175) indicates a high alkalinity in topsoil sample SOA17 (8.9). The pH value drops to 8.5 in SOA16 and is even lower over the next three samples (8.1 in SOA15, SOA14 and SOA13). Sample SOA12 has again a slightly higher alkalinity (8.3). The alkalinity degree decreases again slightly in the next three samples SOA11, SOA10 and SOA9 (respectively 8.2, 8.2 and 8.1). Sample SOA8 is again more alkaline (8.3). Underneath this sample, SOA7 drops in alkalinity (7.9). Sample SOA6 again peaks in alkalinity with a value of 8.3. In the next two layers, the alkalinity decreases from 8.1 to 7.9 from SOA5 to SOA4. In sample SOA3, the alkalinity increases again (8.2), it subsequently decreases to 8 in SOA2. Finally, the pH increases again to 8.1 in SOA1.

Gravel unit SOA1 consists for 67% weight of stones (plate 74: fig. 179). They consist for 88% of silicified chalks and about 10% cherts (plate 73: fig. 176). The stones are relatively angular with more than 60% of angular and sub-angular stones (plate 74: fig. 178). Discs are the most occurring shape (more than 40%) (plate 73: fig. 177). Spheres and rods are about equally present (about 20%). An average stone measures 2.3x 1.7 x 1.1. However, the stones are poorly sorted as the standard deviation is 1.1 x 0.7 x 0.5 cm. A larger weight proportion of the stones is larger than 4 mm (plate 74: fig. 179). The matrix, which is 33% of the sample weight, consists of silty sand (plate 75: fig 180).

Unit SOA2 contains a small proportion of stones, 3% of the total sample weight (plate 74: fig. 179). Most of the stones consist of very small, slightly silicified chalks (plate 73: fig. 176). The matrix, which is 97% of the total sample weight, consists of sandy silt (plate 75: fig. 181).

Gravel unit SOA3 is composed of 80% of the total sample weight of stones, mainly larger than 16 mm (plate 74: fig. 179). Slightly more silicified chalks and less cherts are observed than in unit SOA2 (plate 73: fig. 176). Moreover, the clasts are also more angular than in SOA2, consisting of more than 95% angular and sub-angular clasts (plate 74: fig. 178). Discs and rods are the most occurring shape groups and are about equally present (about 30%) (plate 73: fig. 177). On average, the stones are larger than in gravel SOA1, having an average size of 4 x 1.1 x 1.6 cm. The matrix, which is 20% of the total sample weight, consists of sandy silt (plate 75: fig. 182).

Unit SOA4 contains a much smaller proportion of stones than in the previous unit, only 15% of the total sample weight, mostly very small stones (plate 74: fig. 179). Silicified chalks occur most frequently (55%), though cherts are also often present (45%), especially on comparison with the other units of SOA (plate 73: fig. 176). The stones are slightly less angular than in the previous layer, consisting for 65% of angular and sub-angular stones (plate 74: fig. 178). Spheres and discs are the dominant shape group (about 30%) (plate 73: fig. 177). The stones are much smaller than in the gravel units, measuring on average 0.6x 0.4 x 0.3 cm. This is also attested in the particle size analysis: 12% of the sample weight consists of stones between 2 mm and 0.71 mm (plate 74: fig. 179). The matrix, which is 85% of the sample weight, is composed of coarse sand (plate 75: fig. 183).

Unit SOA5 contains only 2% of its weight stones (plate 74: fig. 179). The matrix, which is 98% of the total sample weight, consists of silt.

Unit SOA6, a tiny gravel layer consists for 17% of the total weight of stones, mainly larger than 16 mm (plate 74: fig. 179). On average, a stone in the unit measures 1.3 x 0.9 x 0.6 cm, which is much less than the average stone measurement for SOA2. Silicified chalks are most often present, though cherts occur also (about 20%) (plate 73: fig. 176). The clasts are slightly more angular than in SOA5, consisting of about 80% angular and sub-angular clasts (plate 74: fig. 178). Spheres are the most common shape for the stones (40%) (plate 73: fig. 177). The matrix consists of silt.

Unit SOA7/SOA8[17] (= sample SOA7) contains very few clasts. The matrix, which is a large proportion of the sample, consists of silt.

Gravel unit SOA9 (= sample SOA8) is composed of 27% weight of stones, of which a large weight proportion consists of stones larger than 16 mm (18% of the sample weight) (plate 74: fig. 179). An average stone measures 1.1 x 0.8 x 0.6 cm.

[17] Note that the sample number is different from the unit number from here on as layer SOA7 and SOA8 were sampled as one unit.

Most stones consist of silicified chalks, though cherts (15%) and sandstone (3%) are also present (plate 73: fig. 176). The clasts are slightly more angular than in SOA6 and spheres are the most common shape and make up for 60% of the clasts (plate 73: fig. 177). The matrix, which is 73% of the sample weight, is composed of sandy silt.

Unit SOA10 (= sample SOA9) is composed of 19% weight of stones (plate 74: fig. 179). An average stone is about equally large as in the previous unit and measures 1 x 0.8 x 0.5 cm. Chalks, unlike silicified chalks in other units, are mostly present (plate 73: fig. 176). Moreover, some cherts (about 10%) also occur. The stones are more angular than in SOA9 and SOA7/8 and almost equally angular as in SOA4 (plate 74: fig. 178). Spheres and discs are the most represented shape groups (plate 73: fig. 177). The matrix, which is 81% of the sample weight, is composed of sandy silt (plate 76: fig. 184).

Gravel unit SOA11 is represented by samples SOA10, SOA11 and SOA12. Sample SOA10 contains a large proportion of stones, 79% of the sample weight (plate 74: fig. 179). Especially the group of stones larger than 16 mm constitute a large proportion (58% of the total sample weight). An average stone measures 2.6 x 1.8 x 1.2 cm. Silicified chalks are mostly present, though chalks (almost 10%), sandstone (15%) and cherts (15%) are also occurring (plate 73: fig. 176). The stones are more angular than in SOA10, SOA9 and SOA7/8, consisting of about 60% angular and sub-angular stones (plate 74: fig. 178). Spheres and discs are the shapes most present (plate 73: fig. 176). The matrix, which is 21% of the sample weight, is composed of silty sand.

Sample SOA11 is composed of a large proportion of stones, 87% of the sample weight, which are more equally distributed over the size groups (plate 74: fig. 179). An average stone measures 2 x 1.4 x 0.9 cm, which is smaller than in the previous sample. The sample has a similar lithological distribution as sample SOA10 of the same unit (cf. plate 73: fig. 176). Silicified chalks are present for 60%, sandstones 10%, cherts 15% and chalks 5%. However, the stones are much more angular than in the previous sample, consisting of more than 90% sub-angular and angular stones (plate 74: fig. 178). Spheres and discs are mostly present as was also attested for sample SOA10 (cf. plate 73: fig. 177).

Sample SOA12 is composed of 85% weight of stones (plate 74: fig. 179). Especially, the group of clasts larger than 16 mm, is well present and makes up for 42% of the sample weight. An average stone measures 1.6 x 1.1 x 0.7 cm. Silicified chalks occur most, though cherts and sandstones are also present, respectively 15% and 5% (plate 73: fig. 176). The stones are less angular than in sample SOA11, consisting of about 70% angular and sub-angular clasts (plate 74: fig. 178). Discs and spheres occur most. The matrix, which is 15% of the sample weight, is composed of silty sand (plate 76: fig. 186).

Unit SOA12 (= sample SOA13) is composed of a small proportion of stones, only 16% of the total sample weight, most of which have a very small size (plate 74: fig. 179). Chalks are most present (about 70%), though a relatively large amount of cherts is also present (25%) (plate 73: fig. 176). The stones are about equally angular as in sample SOA12, consisting of about 70% angular and sub-angular clasts (plate 74: fig; 178). Moreover, there is also an equal amount of spheres and discs present as in sample SOA12 (plate 73: fig. 177). The matrix, which is 84% of the sample weight, consists of sandy silt (plate 76: fig. 187).

Gravel unit SOA13 (= sample SOA14) consists for 70% of its total sample weight of stones (plate 74: fig. 179). The stones are distributed over all sizes. Hence, the sample is poorly sorted. An average stone measures 2.8 x 2 x 1.3 cm. Silicified chalks are predominant (more than 95%), though some cherts are also present (plate 73: fig. 176). The clasts are very angular, with more than 90% of angular and sub-angular stones (plate 74: fig. 178). Spheres and discs are almost in equal amounts present (plate 73: fig. 177). The matrix, which is 30% of the sample weight, is composed of silty sand (plate 77: fig. 188).

Unit SOA14 (= sample SOA15) is constituted of a small proportion of stones, only 6% of the sample weight (plate 74: fig. 179). Moreover, the stones are mostly very small and measure on average 1.15 x 0.83 x 0.6 cm. However, some grading has been observed in the field: from small stones to large stones (could also be parts of a structure) to small stones. The sample was retrieved in a small stone zone of the unit. Silicified chalks are mainly present (90%), though some cherts occur as well (10%) (plate 73: fig. 176). The stones are much rounder than in gravel unit SOA13: 60% of angular and sub-angular stones (plate 74: fig. 178). Slightly more spheres than discs are observed (plate 73: fig. 177). The matrix, which is 94% of the sample weight, consists of silt.

Gravel unit SOA15 (= sample SOA16) contains 59% of the sample weight stones, mostly larger than 16 mm (36% of the sample weight) (plate 74: fig. 179). An average stone measures 1.8 x 1.2 x 0.9 cm. The stones consist almost all of silicified chalk (98%); only 2% cherts occur (plate 73: fig. 176). The stones are slightly more angular than in unit SOA14 (plate 74: fig. 178). The matrix, which is 41% of the sample weight, consists of silt.

Unit SOA16 (= sample SOA17) is constituted of a small proportion of stones, only 9% of the sample weight (plate 74: fig. 179). An average stone measures 1.5 x 1.1 x 0.7 cm. The stones consist mostly of silicified chalks (about 86%), except for some cherts and sandstones (both present for less than 10%) (plate 73: fig. 176). The stones are more angular than in unit SOA15 (70% of rounded and sub-rounded) (plate 74: fig. 178). Spheres remain the dominant shape (plate 73: fig. 177). The matrix, which is 91% of the sample weight, consists of sandy silt.

B. Interpretation

The poorly sorted gravel unit SOA1 is a gully deposit. The gully came from the East as suggested by the occurrence of stones which could provenance only from the East. Additionally, the W-ward orientation of the clasts also indicates that the gully came from the East. Around 13.1 ± 6.5 ka BP, as a consequence of a flood, sandy silt overbank sediments were deposited at the here described section SOA. Probably, some landscape stability took place at this location as suggested by the higher organic matter content in SOA2 which might indicate the establishment of vegetation on that surface. However, the soil formation probably did not last long and more gully gravels were deposited (SOA3). The subsequent coarse sand (SOA4) and silt (SOA5) units, probably represent overbank sediments of a gully as is indicated by the lack of stones. The fining upwards suggests that the gully moved its location further away. Subsequently, debris flow was deposited at this location, indicating a reduction of the vegetation. It is remarkable that exactly in this unit, superparamagnetic minerals were attested, which are often associated with human impact on the landscape. Possibly, unit SOA6 was deposited as a consequence of human impact on the landscape. Units SOA7 and SOA8 respresent mudflow, as is indicated by the poor sorting. Subsequently, gully bedload was deposited at this location (SOA9), possibly after a flood. About 3.8 ± 1.1 ka BP, this was followed by overbank deposits (unit SOA10). In a following stage, some soil formation might have taken place on SOA10. This is suggested by the combination of a high organic matter content and a magnetic susceptibility enhancement in SOA10, indicating an A-horizon. Moreover, the relatively high pH of SOA9 might be correlated with B_k-horizon formation. Then again a gully was located in section SOA. After the gully left this location, mudflow was initiated (unit SOA12). Subsequently, a period of landscape stability took place at this locality as is indicated by soil formation, especially a relatively high organic matter content in unit SOA12, suggesting the formation of an incipient A-horizon. After that period, mudflow started again, resulting in the deposition of the poorly sorted unit SOA13 and the bottom of SOA14. Probably, at that time some buildings were built on the fan. Some stability might be suggested also by the possibility of an incipient A-horizon in the bottom part of unit SOA14. However, the fan did not remain stable and more mudflow was deposited (the upper part of unit SOA14), followed by debris flow (SOA15) and again mudflow (SOA16). At present, soil formation takes place. An incipient A-horizon can be identified in SOA16 by a slightly higher organic matter content and a magnetic enhancement.

VII.2.2.4. SOB (plate 78: fig. 191 and plate 79: fig. 192)

A. Results

Gravel unit SOB1 consists for a large proportion of stones. The lithological distribution consists of about 50% chalks, 40% cherts and about 10% of silicified chalks, shales and calcarenite (plate 79: fig. 193). Discs are mostly present; spheres, rods and blades only in minor quantities (plate 80: fig. 194). The clasts are relatively angular (about 70% of angular and sub-angular stones) (plate 80: fig. 195). An average stone measures 2.9 x 1.9 x 1.3 cm. The unit is poorly sorted as the largest sampled stone measures 8.3 cm and the smallest 1 cm. The matrix, which is only a small proportion of the sample, consists of silty sand.

Unit SOB2 only has a small proportion of stones, 10% of the total sample weight (plate 80: fig. 196). Slightly more chalks occur than in the previous unit (65% compared to 50% in SOB1), though slightly less cherts (plate 79: fig. 193). The stones are more angular than in SOB1, consisting of 90% angular and sub-angular stones (plate 80: fig. 195). Discs are the dominant shape present (plate 80: fig. 194). An average stone measures 1 x 0.8 x 0.5 cm. The matrix, which is 90% of the sample weight, consists of silt.

Gravel unit SOB3 contains a large proportion of stones. 98% of the stones are chalks (plate 79: fig. 193), which are much more rounded than in the previous unit as 50% of the stones is rounded or sub-rounded (plate 80: fig. 195). Discs are most present and spheres occur less than in SOB2 (plate 80: fig. 194). An average stone in this unit measures 2.7 x 2 x 1.2 cm. The largest stone in the sample measures about 9 cm, the smallest about 1 cm. Hence, the sample is poorly sorted. The matrix, which is only a small proportion of the sample, consists of silty sand.

Unit SOB4 contains only a few stones, mainly chalks. They are equally angular as in unit SOB3, consisting of about 55% angular and sub-angular stones (plate 80: fig.

195). An average stone measures 1.4 x 1.1 x 0.7 cm. The matrix, which is a large proportion of the sample, consists of silt.

Gravel unit SOB5 is composed of a large proportion of stones, 71% of the total sample weight (plate 80: fig. 196). The lithological composition of this gravel resembles SOB3 (plate 79: fig. 193). Chalks are mostly present, though cherts have been frequently attested as well. The clasts are slightly more angular than in SOB4, consisting of about 60% angular and sub-angular stones (plate 80: fig. 195). An average stone measures 2.1 x 1.4 x 1 cm. The matrix, which is 29% of the sample weight, is composed of silty sand (plate 81: fig. 197).

Unit SOB6 contains only a few stones. The lithological distribution of stones is similar to that of SOB5 and SOB1, consisting of 45% chalks, 40% cherts and a small proportion of sandstones and calcarenites (plate 79: fig. 193). The stones are more angular than in SOB5, consisting of 70% of angular and sub-angular stones (plate 80: fig. 195). Spheres are most present, though discs also occur (plate 80: fig. 194). An average stone in this unit measures about 1.7 x 1.2 x 0.8 cm. The matrix, which is a large proportion of the sample, consists of silt.

Gravel unit SOB7 is composed of a large proportion of stones, mostly chalks (70%), though cherts are also frequently occurring (30%) (plate 79: fig. 193). The stones are very angular, consisting of 80% angular and sub-angular clasts (plate 80: fig. 195). Slightly more spheres (35%) than discs (30%) occur (plate 80: fig. 194). The other shapes are less present. An average stone measures 2.2 x 1.5 x 1 cm. The matrix, which is a small proportion of the sample, consists of sandy silt.

Unit SOB8 is constituted of 33% weight of stones of all sizes (plate 80: fig. 196). They are composed almost only of chalk (plate 79: fig. 193). 75% of the stones is angular and sub-angular (plate 80: fig. 195). SOB8 contains an almost equal amount of rods, discs and spheres (plate 80: fig. 194). An average stone measures 2.1 x 1.5 x 1 cm. The matrix, which is 67% of the sample weight, is composed of sandy silt (plate 81: fig. 198).

Unit SOB9 possibly contains an archaeological feature. It was impossible to sample or investigate the sediment.

Unit SOB10 contains a small proportion of stones, only 11% of the sample weight (plate 80: fig. 196). Moreover, the stones consist mainly of chalk (plate 79: fig. 193). The stones are less angular than in SOB8 (62% of angular and sub-angular stones compared to 75% in SOB8) (plate 80: fig. 195). Discs are the most occurring shapes (plate 80: fig. 194). An average stone measures 1.4 x 1 x 0.7 cm. The matrix, which is 89% of the sample weight, is composed of silt.

Unit SOB11 is composed of a larger proportion of stones than SOB10: 39% of the sample weight (plate 80: fig. 196). The stones consist almost only of chalks and mostly have a spherical shape (plate 80: fig. 194). 70% of the stones is angular or sub-angular (plate 80 : fig. 195). An average stone measures 2.1 x 1.5 x 1 cm. The matrix, which is 61% of the sample weight, consists of sandy silt (plate 81: fig. 199).

Unit SOB12 is composed of a slightly smaller amount of stones than SOB11. Most stones consist of chalk, though also some chert, sandstone and calcarenite is present (plate 79: fig. 193). The stones are slightly more angular than in unit SOB11: 75% of the stones is angular or sub-angular (plate 80: fig. 195). Discs are most present (plate 80: fig. 194). An average stone measures 1.5 x 1.1 x 0.7 cm. The matrix, which is a large proportion of the sample weight, consists of silt.

Unit SOB13 consists of 22% of the total sample weight of stones (plate 80: fig.196). They are mostly chalks, though some cherts, sandstones and calcarenites occur as well (plate 79: fig. 193). The clasts are very angular, consisting of about 83% angular and sub-angular clasts (plate 80: fig. 195). Discs and spheres are about equally present (plate 80: fig. 194). An average stone measures 1.8 x 1.3 x 0.9 cm. The matrix, which is 88% of the sample weight, consists of silt (plate 81: fig. 200).

B. Interpretation

It was impossible to test the organic matter content, the magnetic susceptibility and pH of the samples from section SOB. Hence, it is impossible to recognise periods of stability at the location of section SOB. The lowermost 3 meters of the section contain mainly gully deposits (unit SOB1, unit SOB3 and unit SOB5) of a gully with a source in the W, as is indicated by the poor sorting of the sediment and the W-ward orientation of the clasts. The gully migrated several times to another location as is indicated by the fine overbank sediments in between the gully deposits, which indicate a decreased velocity at this location (cf. unit SOB2, SOB4 and SOB6). From unit SOB6 on, there is a change in depositional environment, consisting of a larger proportion of mudflow and debris flow. This might be related to human exploitation of the area. Indeed, in unit 9 evidence was found of a structure. Presumably at that time, a period of landscape stability took place at this location (cf. also at section SOA). However, the landscape did not remain stable and since then, about 1.5 meters of mudflow have been deposited at this location.

VII.2.2.5 SOC (plate 82: fig. 201)

A. Results

SOC1 has a slightly higher organic matter content than SOC2 (4%) (plate 83: fig. 202). Furthermore, SOC3 has a relatively high organic matter content of 6.6%. Moreover, SOC6 shows a magnetic susceptibility peak (plate 83: fig. 203). SOC1 and SOC2 have a high pH value of respectively 9.6 and 9.7 (plate 84: fig. 205). However, in SOC3 the alkalinity decreases to 8.9. Over the next few layers, the pH increases again from 9.2 in SOC4, 9.25 in SOC5 and 9.8 in SOC6.

Gravel unit SOC6 contains a large proportion of stones, 93% of its weight (plate 85: fig. 209). The lithological distribution consists of a variety of stones (plate 84: fig. 206). The chalk group (chalks and silicified chalks) makes up for 30% of the sample. Moreover, limestone and sandstone are present in equal amounts (20%).

Additionally, also chert, diabase and basalt occur relatively frequently. Serpentinite and gabbro are a minor component. The clasts are well rounded, consisting of about 70% of rounded and sub-rounded stones (plate 85: fig. 208). Discs are most present (about 45%), though blades occur also frequently (30%) (plate 84: fig. 207). Spheres and rods are present only in small quantities. The matrix, which is 7% of the sample weight, consists of silty sand.

Unit SOC5 only contains a few stones (8% of the sample weight) (plate 85: fig. 209). The matrix, which is 92% of the sample weight, consists of silty clay (plate 85: fig. 210).

Unit SOC4 is composed of a small proportion of stones, only 6% of the sample weight (plate 85: fig. 209). They are very small, measuring on average 0.6 x 0.4 x 0.2 cm. Among the stones, cherts are more present than in SOC6 (10% compared with 25% in SOC6), but limestones less than in SOC6 (10% compared with 20% in SOC6) (cf. plate 84: fig. 206). Moreover, sandstone (18%), basalt (12%) and diabase (8%) have been attested as well. The stones are slightly less rounded than in SOC6 (60% of rounded and sub-rounded stones) (plate 85: fig. 208). Discs are the most occurring shapes, though spheres and rods are often present (plate84: fig. 207). The matrix, which is 94% of the sample weight, consists of sand (plate 86: fig. 211).

Unit SOC3 contains a small proportion of stones, only 8% of the sample weight (plate 85: fig. 209). They are very small, measuring on average 0.7 x 0.4 x 0.3 cm. Chalks (silicified and un-silicified chalks) (2% compared with 2% in SOC4) and basalt (6% compared with 12% in SOC4) are less present than in unit SOC4, while sandstones (30% compared with 18% in SOC4), limestones (26% compared with 10% in SOC4) and shales (12% compared with 4% in SOC4) occur more frequently (plate 84: fig. 206). Moreover, the clasts are more angular than in SOC4, consisting of 54% of rounded and sub-rounded stones (plate 85: fig. 208). Discs are the most frequent occurring shapes, though spheres and rods are also often present (plate 84: fig. 207). The matrix, which is 92% of the sample weight, consists of sand (plate 86: fig. 212).

Unit SOC2 consists of a very small proportion of stones, 3% of the sample weight (plate 85: fig. 209). The matrix, which is 97% of the sample weight, is composed of silty sand (plate 86: fig. 213).

Unit SOC1 contains a very small proportion of stones, only 9% of the sample weight (plate 85: fig. 209). The matrix, which is 91% of the sample weight, is composed of clayey silt (plate 86: fig. 214).

The particle size results indicate that samples SOC3 and SOC4 contain a slightly larger number of clay particles (plate 92: fig. 230).

B. Interpretation

The imbricated gravel unit SOC6, containing W-ward orientated, rounded gravel, represents the bedload of a former channel of the Dhiarizzos. The observed grading with larger clasts at the bottom and smaller clasts at the top of unit SOC6, suggests a decrease in velocity of the channel. This decrease in velocity was associated with channel abandonment after a flood. Indeed, the following unit contains silty clay overbank deposits (SOC5) suggesting that the river was located relatively removed from this location. Subsequently, coarser grained sediments were deposited (SOC4 and SOC3), which suggest that the river was situated again nearer this location. Subsequently, soil formation took place as is suggested by the magnetic susceptibility, pH and loss-on-ignition test. The combination of magnetic enhancement and a high organic matter content indicates that SOC3 might represent an A-horizon. Moreover, the pH test, showing increasing pH values over depth suggests some calcium carbonate translocation took place. Consequently, SOC6 may represent an incipient B_k-horizon. However, after this period of landscape stability, renewed alluvial deposition took place, first in the shape of silty sand overbank deposits and subsequently in the shape of clayey silt overbank deposits. The high alkalinity degree of these upper units (SOC1 and SOC2) is probably a result of present day ploughing and cultivation. A recent channel of the Dhiarizzos incised this section and consequently exposed it.

VII.2.2.7. PH (plate 92: fig. 231 and plate 93: fig. 323)

A. Results

The organic matter content is relatively low throughout the section, with 3.4% of organic matter in PH1, 2.9% in PH2 and 3.4% in PH3 (plate 94: fig. 233). Additionally, the magnetic susceptibility is relatively high in PH1 and PH2 (plate 94: fig. 234), respectively 3.91 and 3.88 $\mu m^3\ kg^{-1}$ and slightly lower in PH3 (3.74 $\mu m^3\ kg^{-1}$). Also the pH test indicates little differentiation throughout the section (plate 94: fig. 236). The pH values hang around 8.7.

Gravel unit PH3 contains most weight of stones (67%) (plate 95: fig. 240). They consist mostly of sandstones (30%) and chalks (mainly silicified chalks) (plate 95: fig. 237). Limestones, cherts and igneous clasts are also present, though in minor quantities. The clasts are dominantly angular (60%) (plate 95: 239). Discs occur most (40%); spheres, rods and blades in equal amount (20%) (plate 95: fig. 239). All sizes of stones are present in the sample, though the larger the clasts, the more represented they are in weight. An average clast measures 2.3 x 1.5 x 0.9 cm. The matrix, which is 23% of the sample, is composed of coarse sand with some silt. It was identified in the field as silty sand (plate 96: fig. 241).

Unit PH2 is composed of only 5% (of the total sample weight) of stones (plate 95: fig. 240). The lithological composition of the sample is very similar to the previous layer (plate 95: fig. 237). However, a slightly higher occurrence of cherts (30% compared to about 15% in the previous layer) and less occurrence of sandstones and limestones has been observed. Additionally, the shape distribution is also similar to the previous layer, marked by a large frequency of discs (plate 95: fig. 238). The stones are more rounded (60% rounded and sub-rounded clasts compared to 40% in the previous layer) (plate 95: fig. 239). On average, the stones are smaller than in the previous layer: 1.7 x 1.1 x 0.7 cm. The matrix, which is 95% of the sample, consists of unimodal coarse sand (plate 96: fig. 242).

Gravel unit PH1 is composed of a larger weight percentage of stones than in the previous layer, 82% of the total weight of the sample (plate 95: fig. 240). The lithological composition of the stones is similar as the one in PH3 (plate 95: fig. 237). There is a slight increase in the occurrence of discs (plate 95: fig. 238). The clasts are also slightly rounder than in the previous layers (plate 95: fig. 239). The average clast is larger than in PH3 and much larger than in PH2: 2.7 x 1.9 x 1.1 cm. A large weight proportion consists of stones larger than medium gravel. The matrix, which is 18% of the sample weight, is composed of silty sand and contains quite a lot of silt, fine sand and coarse sand (plate 96: fig. 243).

The particle size analysis indicates a higher number of clay particles in PH2 (plate 96: fig. 244).

B. Interpretation

This section represents a sequence of river channel deposits of the former Dhiarizzos. The velocity was relatively high as is indicated by the large stones present in the section. The roundness of the clasts suggests that they were transported over quite a long distance. At some time, the velocity decreased slightly at this location (PH2). Subsequently, the velocity increased again (PH1). Then, this channel was abandoned. The lack of soil formation seems to indicate that the deposits PH3, PH2 and PH1 are relatively recent.

VII.2.2.7. PR1 (plate 99: fig. 248 and plate 98: fig. 247)

A. Results

The loss-on-ignition test indicates that PR1.5 is marked by a considerable increase in organic matter content (6.5%) (plate 100: fig. 249). Additionally, also PR1.1 has a relatively high organic matter content (4.9%). The mass specific magnetic susceptibility test indicates that PR1.7 has a high susceptibility of 11.4 $\mu m^3\ kg^{-1}$ (plate 100: fig. 250). The pH test (plate 101: fig. 252) indicates that from PR1.1 to PR1.4, the pH value is relatively stable at 8.5. From PR1.5 on and especially in PR1.6 and PR1.7, the pH values increase respectively from 8.7 to 9 and 9.2.

Gravel unit PR1.7 is composed of 76% of stones (plate 102: fig. 256). The stones range from fine to coarse gravels with an occurrence of an increasingly larger proportion. The matrix, which is 24% of the sample weight, consists of coarse sand.

Unit PR1.6 only contains 19% of stones, mostly fine gravel (plate 102: fig. 256). Silicified chalks are most present (30%) (plate 101: fig. 253). Sandstones, limestones, cherts and diabase stones occur in smaller amounts. The clasts are composed of an equal amount of rounded (52%) and angular clasts (48%) (plate 102: fig. 255). Sphere shapes are dominant (about 50%) (plate 101: fig. 254). Overall, the clasts within this unit are relatively small, on average 1.1 x 0.8 x 0.6 cm. The matrix, which is 81% of the sample (plate 102: fig. 256), consists of sandy silt with a particle size distribution between fine clay and coarse sand (plate 102: fig. 257). The volumetric distribution curve is slightly bimodal with peaks between 4 and 30 μm (fine to coarse silt) and between 100 and 800 μm (fine to coarse sand). Hence, the fine fraction is sandy silt.

Unit PR1.5 consists almost only of small fractions and only contains 3% of the total weight stones (plate 102: fig. 256). The matrix, which is 97% of the sample, consists of sandy silt (plate 103: fig. 258), though is much finer than in the previous layer. It also contains a large amount of clay particles.

Unit PR1.4 is mostly composed of small fractions as well (95%) (plate 102: fig. 256). Only 5% of stones are present in the sample. The matrix is coarser than in PR1.5 with much more fine sand (plate 103: fig. 259). However, it was again identified as sandy silt.

Gravel unit PR1.3 contains a much larger weight proportion of stones (88%), especially of the size groups larger than medium gravel (plate 102: fig. 256). The lithological distribution of the stones is similar to PR1.6 (plate 101: fig. 253). The stones are also equally rounded (55% rounded and sub-rounded) (plate 102: fig. 253). However, the clast shapes vary slightly in that there are more discs (45% compared to only 15% in PR1.6) than spheres (about 30% compared to 48% in PR1.6) (plate 101: fig. 254). An average stone in this unit measures 2.2 x 1.5 x 1 cm. However, of note is that some fining upwards has been observed. The matrix, which is 12% of the sample (plate 102: fig. 256), consists of medium sand, ranging between the clay and coarse sand fractions, with a peak within the coarse sand volume (plate 102: fig. 260).

Unit PR1.2 consists again of a smaller weight proportion of stones, only 24% of the total weight (plate 102: fig. 256). The stones are mostly silicified chalks (plate 101: fig. 253). They are about equally angular as in the previous unit, with an occurrence of 50% angular and sub-angular clasts (plate 102: fig. 225). Discs again are mostly present (35%), though other shapes occur as well (plate 101: fig. 254). An average stone measures 1.1 x 0.8 x 0.5 cm. The matrix, which is 76% of the sample (plate 102: fig. 256), is composed of silty clay, with particle sizes ranging between clay and coarse sand (plate 103: fig. 261).

Unit PR1.1 contains only a moderate amount of stones. They consist mostly of silicified chalks (plate 101: fig. 253). The stones are slightly more angular than in the previous layers (plate 102: fig. 255). Discs are again most abundant (50%) (plate 101: fig. 254). An average stone in the sample measures 1.2 x 0.9 x 0.6 cm. A large volume of the matrix is composed of coarse sand (plate 104: fig. 263). The particle size distribution is similar to the previous layer (PR1.2) though has fewer fine particles and slightly more sand fractions. Hence, the matrix is composed of sandy silt.

The particle size analysis of the small fractions indicates that PR1.1 and PR1.5 have a higher percentage of clay particles compared to the other units (plate 104: fig. 263).

B. Interpretation

The gravelly bedload sediment of unit PR1.7 indicates that the former channel was situated at this location, sometime after 1140 ± 60 AD. Later on, the river abandoned this location, though the section was still within the reach of overbank sediments. However, the particle size analysis indicates a colluvial as well as an alluvial component in units PR1.6, PR1.5. Especially in PR1.5, a larger colluvial input is observed, marked by a higher occurrence of angular chalks. Subsequently, a period of stability took place as some incipient soil formation has been observed with an A-horizon in PR1.5, marked by a high organic matter content. Additionally, some carbonate leaching occurred, observable in the increasing pH values from PR1.5 to PR1.7. Next, unit PR1.4 was deposited. During a flood, the river reached this location again (unit PR1.3) and left this channel shortly after. As a result, more overbank sediments were deposited as units PR1.2 and PR1.1. PR1.1 received greater colluvial input, marked by a greater quantity of locally occurring, angular silicified chalks. The upper half of the section has recently been deposited as indicated by laboratory results. Only very slight soil formation, consisting of A-horizon development, could be observed.

VII.2.2.8. MA and MB (plate 104: fig. 264; plate 106: fig. 266 and plate 110: fig. 279; plate 112: fig. 279)

A. Results

- MA1 has a slightly higher organic matter content (though only 2.5%), than unit MA2 and MA3 (plate 107: fig. 267). Additionally, MA1 has the highest magnetic susceptibility value (plate 107: fig. 268). The pH test indicates that MA1 has a relatively high alkalinity of 8.8 (plate 107: fig. 270). However, in sample MA2, the alkalinity decreases to 8.3. In MA3, the alkalinity increases considerably to 9.3.

  Throughout section MA, the stones consist almost only of silicified chalks (plate 108: fig. 271). Variations in shape and size are however present (plate 108: fig. 272 and fig. 273).

  Gravel unit MA3 is composed of 67% of stones (plate 108: fig. 274). They range from fine gravel to cobbles with increasing weight percentages. Discs are the dominant shapes (45%) in this sample (plate 108: fig. 272). Most clasts are rounded or sub-rounded (72%) (plate 108: fig. 273). The average clast measures 1.9 x 1.3 x 0.7 cm. The matrix is constituted of coarse sand, with some clay and silt fractions (plate 109: fig. 275).

  Unit MA2 contains less weight of stones, only 5% of the total weight of the sample (plate 108: fig. 274). The stones are more angular than in MA3, with 70% of angular and sub-angular stones (plate 108: fig. 273). Spheres instead of discs are the most occurring clast shapes (plate 108: fig. 272). The matrix, which is 95% of the sample (plate 108: fig. 274), is composed of silty sand, with some bimodality with a volume percentage peak around the fine sand fraction and a much smaller peak around the clay-silt fraction (plate 109: fig. 276).

Gravel unit MA1 consists of 82% of stones, ranging from fine gravels to cobbles, their weight increasing in proportion to size (plate 108: fig. 274). Angularity and shape of the stones in MA1 are similar to those of MA2 (plate 108: fig. 273). However, the MA1 stones are much larger, having an average size of 2.8 x 1.9 x 0.9 cm, compared to 0.8 x 0.6 x 0.4 cm in the previous layer. The matrix, which is 18% of the total weight of the sample (plate 108: fig. 274), consists of coarse sand (plate 109: fig. 277).

The particle size analysis indicates that MA2 contains slightly higher clay levels than the layers MA1 and MA3.

- MB1, indicating a 4.4% organic matter content, shows a higher organic matter content than MB2, MB3, MB4 and MB5 (plate 111: fig. 280). Additionally, MB1 also has relatively high magnetic susceptibility value (0.28 $\mu m^3 \, kg^{-1}$) (plate 112: fig. 281). Slight enhanced magnetic susceptibility values are also observed in MB3 (0.09 $\mu m^3 \, kg^{-1}$). The pH test (plate 112: fig. 283) indicates increased alkalinity in proportion to depth from MB1 to MB5, with values of 8 in MB1 and 9 in MB5. In MB6 and MB7 the pH slightly decreases to 8.8. MB8 is the most alkaline unit of the section with a value of up to 9.2. The alkalinity decreases again in MB10 to 8.7. In MB11, it increases again to 9.

The lithology of the clasts within this section almost only consists of silicified chalks (plate 113: fig. 284).

Sample MB11 consists of 36% of stones (plate 114: fig. 287). Some large boulders were found within this layer, but were impossible to sample. More than 80% of the stones are angular to very angular (plate 113: fig. 286). Discs are most abundant, though spheres are also present; blades and rods occur only in very small amounts (plate 113: fig. 285). The stones consist to the greater extent of clasts larger than medium gravel (plate 114: fig. 287). The matrix, which is 64% of the total sample weight, consists of silty sand, with a peak within the silt range and a peak within the fine sand fraction (plate 114: fig. 288).

Sample MB10 contains a larger weight proportion of stones (60%) than in the previous sample (plate 114: fig. 287). There is a relative large occurrence of clasts larger than 8 mm. Almost 70% of the stones are angular or sub-angular (plate 113: fig. 286). Within the shapes, discs are most abundant, though spheres are also present (plate 113: fig. 285). Blades and rods occur only in very small amounts. The matrix, which is 40% of the total sample weight (plate 114: fig. 287), is similar to the previous sample, though the sand fraction distribution is further expanded into the coarse sand. Hence, the matrix is composed of silty sand, with a bimodal distribution (plate 114: fig. 289).

Unit MB9 is composed of a small amount of stones, only 8% of its total weight (plate 114: fig. 287). Additionally, the stones are very small. The matrix is similar to the previous layers, though contains slightly more clay and silt (plate 115: fig. 290). Hence, the matrix is composed of silty sand with a bimodal volumetric distribution.

Unit MB8 contains more stones than MB9, namely 81% of the total sample weight (plate 114: fig. 287). The stones of this unit are equally angular as in MB11 and MB10 (plate 113: fig. 286). An average clast measures 2.7 x 1.9 x 0.9 cm. The matrix, which is 19% of the total weight of the sample (plate 114: fig. 287), consists of silty sand, overall coarser than in the previous layers, with a peak in the fine silt fraction, another one in the fine sand fraction and also one in the coarse sand fraction (cf. plate 115: fig. 291).

Unit MB7 contains a smaller weight of stones than MB8, only 23% of the total sample weight (plate 114: fig. 287). There is most weight of stones in the size groups larger than medium gravel. The stones are markedly more rounded than in the previous layers, with about 62% of rounded and sub-rounded stones (plate 113: fig. 286). Quite a large quantity of spheres (30%) and discs (35%) have been attested, though fewer rods and blades (plate 113: fig. 285). The average stone is very small and measures about 1 x 0.7 x 0.4 cm. The matrix, which is

77% of the sample weight (plate 114: fig. 287), consists of silty sand (plate 115: fig. 292) with a bimodal particle size distribution, with a peak in the clay/silt fraction and a peak in the fine sand fraction.

Gravel unit MB6 contains 62% of stones (plate 114: fig. 287). The stones range from all size groups, though there is an increasing weight percentage according to size increase. The matrix, which is 38% of the sample weight, is finer grained than in the previous layer (plate 115: fig. 293). It has a volumetric peak within the fine and coarse sand fractions and also an additional high volume percentage of silt and clay. It was identified in the field as silty sand.

Unit MB5 is composed of only a small weight percentage of stones, 5% of the total sample weight (plate 114: fig. 287). The stones are similarly rounded as in MB7 with 60% rounded and sub-rounded stones (plate 113: fig. 286). Spheres are again more frequent than in the previous layer, with an amount of 45%, though discs are also quite abundant, 35% (plate 113: fig. 285). The average stone is much smaller than in the previous layer: 0.5 x 0.5 x 0.3 cm. The matrix, which is 95% of the total weight of the sample (plate 114: fig. 287), consists of silty sand (plate 116: fig. 294). It has a bimodal distribution with a volumetric peak in the clay/medium silt fraction and also a peak in the fine sand fraction.

Gravel unit MB4 contains a larger weight of stones than MB5 (plate 114: fig. 287). The distribution within the stones shows increasing weight percentages according to increasing size. The stones are slightly more angular than in MB5, consisting of 55% of rounded and sub-rounded stones (plate 113: fig. 286). Discs are the dominant shape group (60%) (plate 113: fig. 285). The average stone is larger than in the previous unit (MB5), having a size of 2.1 x 1.4 x 0.8 cm. This is equivalent to the average size of stones in MB6. The small percentage of matrix is almost similar to MB6 (plate 114: fig. 287). The distribution curve shows a peak around the clay to medium silt fraction and a peak around the fine to coarse sand fractions (plate 116: fig. 295).

Unit MB3 only contains again a small percentage of stones (10%) (plate 114: fig. 287). The stones are very angular (80% angular and sub-angular) (plate 113: fig. 286). Discs are the most occurring shapes (55%) (plate 113: fig. 285). An average clast measures 2 x 1.38 x 0.8 cm. The matrix, which is 90% of the total weight of the sample (plate 114: fig. 287), is finer than in the previous unit, with a smaller volume percentage of coarse sands (plate 116: fig. 296). Hence, it was identified in the field as silty sand.

Gravel unit MB2 contains a larger weight of stones (63% of the total sample weight) than in MB3 (plate 114: fig. 287). Moreover, the stones are more rounded than in the previous unit, with a proportion of 50:50 of angular to rounded stones (plate 113: fig. 286). The shapes are similar to the previous layer with a dominance of discs, 40% in this unit (plate 113: fig. 285). The distribution within the stones shows increasing weight percentages, according to increasing size (plate 114: fig. 287). An average stone in this unit measures 2 x 1.4 x 0.8 cm. The matrix, which is 37% of the sample, is similar to the previous samples MB6 and MB4 and coarser than the previously described layer (MB3) (plate 116: fig. 297).

Unit MB1 is composed of a smaller proportion of stones than in the previous unit, only 36% (plate 114: fig. 287). The stones are very angular, consisting of 80% of angular and sub-angular clasts (plate 113: fig. 286). Discs are the dominant shapes present (50%) (plate 113: fig. 285). The matrix, which is 64% of the total weight of the sample (plate 114: fig. 287), is composed of sandy silt (plate 117: fig. 298), having volumetric peaks within the clay to medium silt fraction, within the fine sand fraction and also within the coarse sand fraction.

The particle size analysis indicates that MB2 has a slightly higher number percentage of clay than the other layers (plate 117: fig. 299) .

B. Interpretation

- Unit MA3 is a channel sediment, identifiable by its rounded clasts, their relatively large size and orientation, deposited sometime after 1320 ± 60 AD. Unit MA2 represents overbank deposits, recognisable by the occurrence of only small, more angular clasts. Again, unit MA1 represents channel deposits, though deriving from a stream with a higher velocity, as the stones are larger. It is suggested that the silicified chalk is a relatively local product, made available by the small unnamed stream coming from the east where the Pakhna formation occurs. On MA1, some incipient soil formation took place, as identifiable through the higher organic matter content in MA1, indicative of A-horizon formation. Moreover, a slightly higher clay content has been observed in MA2, indicative of the illuviation of clay. Also the pH test might indicate some translocation of calcium carbonate.

- The sediments in section MB represent fan deposits, deriving from an unnamed gully with a source upslope in the east. MB11 and MB10 are gully channel sediments, which were deposited after a rainfall event. The angularity of the clasts indicates a sheet-flow mode of transport, typical for gullies with a shallow channel at the fan-head. Large boulders suggest that the gully was quite powerful. Sample MB10 represents some fining upwards, possibly related to decreased velocity. As the gully channel might have been shallow, it became easily choked with sediments and shifted its location. However MB9 was still within the reach of overbank sediments. Subsequently, the channel moved back to this location (unit MB8). However, shortly after, it moved again away from this location as is evidenced by the overbank sediments in unit MB7. This cycle was repeated three more times (MB6-MB5, MB4-MB3 and MB2-MB1). The last mentioned cycle, which is represented by gully deposits in MB2 and overbank deposits mixed with colluvial deposits in MB1, post-dates ± 800 AD. Noteworthy is the following observation: the gully in MB2 transported more and larger stones than the gullies MB4 and MB6. The deposition of sediment MB2 due to increased human activity in the area, is a possible explanation. This is suggested by a larger colluvial input in MB1 with more angular and larger stones. Since then, incipient soil formation took place, with some A-horizon development marked by a slightly higher organic matter content. Additionally, samples MB2 and MB3 indicate that some clay translocation took place in the section with possible redeposition in MB2 (cf. higher clay number percentage) and MB3 (cf. slightly higher magnetic susceptibility). Moreover, the pH test indicates that some incipient soil formation took place. The successively increasing alkalinity from MB1 to MB5 indicates that calcium carbonate has been translocated and redeposited.

VII.2.2.9. KIS1 (plate 117: fig. 300; plate 199: fig. 302 and plate 120: fig. 303)

A. Results

KIS1.1 shows a high organic matter value (6.5%). Additionally, KIS1.6 also has a relatively high organic matter content of about 4.6% (cf. plate 120: fig. 304). A mass specific magnetic susceptibility peak is observed in KIS1.7 (plate 121: fig. 305). Furthermore, the frequency dependent susceptibility indicates the occurrence of superparamagnetic minerals in KIS1.5 (plate 121: fig. 306). The pH test (plate 121: fig. 307) indicates that KIS1.1 is relatively alkaline (8.5). Values are slightly lower in the next unit KIS1.2 (8.4). KIS1.3 is again more alkaline (8.6). In KIS1.4, the pH levels drop considerable, with values of only 8.1. Subsequently, KIS1.5 has a high pH value of 8.4. KIS1.7 has a similar high pH level as in KIS1.3 (8.6).

The stones in all units of section KIS1 consist of almost only silicified chalks (plate 122: fig. 308). Throughout the section, discs are the dominant stone shape in all layers of the section, with a quantity of 45% (plate 122: fig. 309).

Unit KIS1.7 contains 24% of the sample weight stones (plate 123: fig. 311). The stones are mostly rounded and sub-rounded (65%) (plate 122: fig. 310). An average clast measures 1.2 x 0.9 x 0.5 cm. The matrix, which is 76% of the sample (plate 123: fig. 311), is bimodal with a peak in the fine silt volume and a peak in the fine sand fraction volume (plate 123: fig. 312). Additionally, a large volume of clay is observed in the sample.

Gravel unit KIS1.6 contains 95% of the total sample weight stones (plate 123: fig. 311). The stones are rounder than in the previous unit, with 75% of rounded and sub-rounded stones (plate 122: fig. 310). An average stone measures 2.1 x 1.5 x 0.9 cm. The matrix, which is 5% of the total sample weight (plate 123: fig. 311), is similar to the previous unit, with a bimodal distribution and peaks at the fine silt and at the fine sand fraction, though containing a considerable amount of clay (cf. plate 123: fig. 313).

Unit KIS1.5 is composed of only 24% of stones (plate 123: fig. 311). The small group of clasts consists mainly of fine gravel. Additionally, the stones are also more angular than in the previous layer, having only 55% within the rounded and sub-rounded range (plate 122: fig. 310). The matrix, which is 76% of the sample weight (plate 123: fig. 311), is constituted of sandy silt (plate 124: fig. 314), similar to the fine fractions of KIS1.7 and KIS1.6.

Slightly imbricated gravel unit KIS1.4 contains a large volume proportion of stones, especially those larger than medium gravel (plate 123: fig. 311). On average, the stones have about a similar size as in KIS1.6, being 2.2 x 1.6 x 0.9 cm. The matrix is almost similar to the matrix of the previous units. However, it contains slightly less clay and silt and ranges further into the coarse sand fraction (cf. plate 124: fig. 314).

Unit KIS1.3 contains a smaller weight of stones (30% of the total sample weight), most of the stones being larger than medium gravel (plate 123: fig. 311). The matrix, which is 70 % of the total sample weight, indicates some bimodality with a peak around the clay/fine silt fraction and a much smaller peak at the fine sand fraction (plate 124: fig. 316). It was identified in the field as silty clay.

Gravel unit KIS1.2 is composed of a large proportion of stones, 96% of the total sample weight (plate 123: fig. 311). Especially the groups larger than medium gravel are mainly present. The stones are equally rounded as in gravel unit KIS1.4 (plate 122: fig. 310). Moreover, on average the stones are as large as in KIS1.4, namely 2 x 1.5 x 0.9 cm. The matrix, which is 4% of the sample weight (plate 123: fig. 311), is bimodal, with peaks around the clay/fine silt fraction and the fine sand fraction (cf. plate 125: fig. 317). However, there is a larger volume of clay/silt than sand. This is the reason why the sediment was identified as clayey silt in the field.

Unit KIS1.1 contains less stones, only 60% of the total weight (plate 123: fig. 311). There is a large amount of fine gravel, some medium gravel and a considerable quantity of coarse gravel and cobbles. The matrix, which is 40% of the sample weight, is slightly bimodal, with a peak in the clay/silt fractions and another peak within the coarse sand fraction (cf. plate 125: fig. 318). However, the matrix was identified in the field as clayey silt.

Additionally, the particle size analysis indicates that samples KIS1.3 and KIS1.4 contain a relatively higher number of clay particles (plate 125: fig. 319).

B. Interpretation

The lithology of the stones indicates that the sediment source area is located to the east, within the Pakhna or Terra formation. The imbricated gravel unit KIS1.7 and the gravel unit KIS1.6 represent channel deposits, with a flow direction similar to the present day Dhiarizzos. Unit KIS1.7 shows some fining upwards suggesting that the flow velocity decreased. Subsequently, a period of stability took place at this location and a soil could develop. The higher organic matter content of sample KIS1.6 indicates A-horizon formation. Additionally, KIS1.7 may represent an illuviation horizon, with enhanced magnetic susceptibility, pointing to clay illuviation and also with higher pH value, indicating the reprecipitation of calcium carbonate. After this period of landscape stability, new sediments were deposited. The increased angularity of the stones within the sediment, may indicate an increased colluvial input within the overbank deposits. Remarkably, the magnetic susceptibility test in this layer attested the occurrence of superparamagnetic minerals, which often have been associated with human activity, especially with fire and burning. Just above this layer all potsherds were found in the section. It may be that KIS1.5 testifies for burning activities in the area, possibly related to depleting the forests. Unit KIS1.4 indicates the result of these activities. Sometime after 894 ± 250 AD, erosion upslope led to the deposition of an alluvial layer (KIS1.4). The occurrence of some large boulders, unlike the previous gravel deposits, indicates that the velocity of the stream was higher. Subsequently, the river changed its channel again and overbank sediments containing more angular stones were deposited (KIS1.3). The channel returned again to this location (KIS1.2) and finally left it. KIS1.1 containing a large proportion of angular stones, is composed of a colluvial as well as an overbank component. Since then, soil formation took place. The present day topsoil KIS1.1 has a high organic matter content and may represent an A-horizon. Additionally, the pH test indicates that the relatively low alkalinity in KIS1.2 may be the result of the eluviation of carbonates and the formation of an E-horizon. Moreover, subsequent higher alkalinity levels in KIS1.3 may indicate the redeposition of calcium carbonate and B_k-horizon formation. Furthermore, the higher number of clay particles in KIS1.3 and KIS1.4 might indicate incipient B_t-horizon formation.

VII.2.4. Ezousas

VII.2.4.1. EZA (plate 127: fig. 321 and plate 128: fig. 322)

A. Results

The loss-on-ignition test indicates two peaks in organic matter content, one in EZA4 and another in EZA8 (plate 128: fig. 322). Both units contain about 7% of organic matter. Additionally, the mass specific magnetic susceptibility peaks in EZA10 and EZA12 (plate 129: fig. 324). Moreover, the frequency dependent susceptibility indicates the occurrence of superparamagnetic grains in unit EZA7 (plate 129: fig. 325). The results of the pH test (plate 129: fig. 326) indicate the following pattern. From EZA1 to EZA3, the pH decreases slightly from 8.4 to 8.2. A sharper drop in pH is observed in EZA4, with a value of 7.6. The subsequent units are again much more alkaline, with a value of 8.2 in EZA5, 8 in EZA6 and 8.2 in EZA7. A marked drop in alkalinity is observed in EZA8. Subsequently, EZA9 is much more alkaline. However, over the next two units (EZA10 and EZA11), the alkalinity decreases slightly to respectively, 8.3 and 8.1. EZA12 is very alkaline, with a value of 8.6. Noteworthy is that the units with a marked higher organic matter content, have relatively low pH values.

The particle size analysis provides the following results:

Gravel unit EZA12 contains a larger proportion of stones. There is only a small proportion of matrix, consisting of sand.

EZA11 is composed of only 16% stones (of the sample weight) (plate 131: fig. 330). The stones are mostly very small, though there is some occurrence of stones up to medium gravel. The matrix, which is 84% of the total sample weight, is composed of sandy silt (plate 131: fig. 331), with a large volume percentage of fractions between clay and fine sand.

EZA10 contains a larger weight of stones than in the previous sample, namely 64% of the total sample weight (plate 131: fig. 330). An equal weight percentage distribution over the several stone size groups is observed as in the previous unit, except for a lack of clasts larger than 16 mm and clasts between 11.2 and 8 mm. The matrix is 36% of the total sample weight and consists of sand (plate 131: fig. 332).

Unit EZA9 only contains a small weight percentage of stones. The matrix, which is a large proportion of the sample, is composed of poorly sorted sediment, ranging between the clay and fine sand fraction (plate 132: fig. 333).

EZA8 contains a small proportion of stones, only 2% of the total sample weight (plate 131: fig. 330). The matrix, which is 98% of the total sample weight, is composed of bimodally distributed clayey silt, with a volumetric peak in the clay/fine silt fractions and one in the fine sand fraction (plate 132: fig. 334).

EZA7 only contains a few stones, 10% of the total sample weight (plate 131: fig. 330). The matrix, which is 90% of the sample, is very similar to the previous unit, containing the same volumetric peak between the clay/fine silt fraction and also another one in the fine sand fraction. However, the latter peak is smaller than in the previous unit. The matrix is identified as clayey silt and is similar to the matrix of the previous unit (EZA8) (cf. plate 132: fig. 335).

EZA6 is predominantly composed of small fractions. Only 10% of the sample weight consists of stones (plate 131: fig. 330). The matrix, which is 90% of the sample weight, is similar to the matrix of the previous units. However, it contains some more medium and coarse silt. Consequently, the sediment was identified as clayey silt (plate 132: fig. 336).

EZA5 contains a considerable small proportion of stones, only about 6% of the total weight (plate 131: fig. 330). The matrix, which is 94% of the total sample weight, consists of a more unimodal grain size, similar to EZA9 and EZA11. The matrix is composed of clayey silt with a high volume percentage ranging between clay and medium sand (plate 133: fig. 337).

EZA4 consists almost only of small fractions, namely 91% of the sample weight (plate 131: fig. 330). The matrix is similar to the one of the previous unit, except for some more bimodality as a result of the reduced occurrence of fractions between 10 and 100 μm (namely medium silt and fine sand) (cf. plate 133: fig. 338).

EZA3 is constituted of only a small weight proportion of stones, namely 20% of the sample weight (plate 131: fig. 330). The matrix, which is 80% of the total sample weight, is similar to the matrix of EZA4, though containing slightly less medium sand fractions. Hence, once more the matrix consists of clayey silt (plate 133: fig. 339).

EZA2 contains a larger proportion of stones than in the previous unit, namely 39% compared to 20% in the previous unit (plate 131: fig. 330). The matrix, which is 61% of the total sample weight, is similar to the small fraction of the previous unit, with low volume percentages at the medium silt/coarse sand fractions and high volume percentages within the clay/fine silt range. Once more, the matrix was identified as clayey silt (plate 134: fig. 340).

EZA1 is constituted of 30% of stones (plate 131: fig. 330). The matrix, which is 70% of the total sample weight, is similar to the matrix of EZA4 and EZA5 and is marked by bimodality with a peak in the clay/fine silt fraction and also one in the fine sand fraction (plate 134: fig. 341). The matrix is identified in the field as silt.

The particle size analysis indicates relatively higher numbers of clay occurrence in EZA2, EZA3, EZA8 and EZA10 (plate 134: fig. 342 and plate 135: fig. 343).

The lithological identification gives the following results (plate 130: fig. 327). Gravel unit EZA12 at the bottom of the section consists of almost equal amounts of sandstones, chalks and silicified chalks, limestones and cherts. EZA11 has a similar lithological constitution. EZA10 and EZA9 contain slightly more sandstones and cherts than the previous units. As described above, EZA8, EZA7, EZA6 as well as EZA5 contain almost no stones. From EZA4 onwards, a lithological change is observable, marked by an increased amount of chalks and of silicified chalks and also a decreased number of igneous stones. EZA3 contains remarkably much sandstones. Additionally, the clast shape analysis indicates a change (plate 130: fig. 329). From EZA12 to EZA9, there is a relatively large proportion of rounded and sub-rounded stones. From EZA4 to EZA1 the stones are more angular, 70% of which being angular or sub-angular.

B. Interpretation

Sometime after 160 ± 160 BC, the channel of the Ezousas was situated at this location. The orientation of the imbricated stones, orientated towards the W and the occurrence of some non-locally occurring clasts, all indicate that this unit represents a previous channel of the Ezousas. However, soon after, the river changed location, though the channel was still in the proximity, according to the observed overbank sediments in this section (EZA11, EZA10, EZA9 and EZA8). Subsequently, before 300 AD, a period of landscape stability took place, with incipient soil development from EZA8. Unit EZA8 may represent an A-horizon, as indicated by its colour and organic matter content. EZA10 with a high magnetic susceptibility could represent an incipient B_t-horizon. Indeed, the particle size analysis indicates that in EZA10, the clay fractions are present in slightly larger quantities. Sometime after, almost 1 meter of overbank sediments were deposited (units EZA7, EZA6, EZA5 and EZA4), identifiable by its absence of stones. Unit EZA5 was deposited before 510 AD. Subsequent the deposition of unit EZA4, a relatively long period of landscape stability took place, sufficient to develop an A-horizon in EZA4 (marked by a high organic matter content), sufficient to translocate calcium carbonate (indicated by relatively high pH values in EZA5, EZA6 and EZA7). After this period of landscape stability, once more, deposition of sediments took place at this location, however probably caused by depositional processes different from the previous units. The occurrence of larger, more and angular local chalks and also of the poorly sorted matrix, suggests that units EZA3, EZA2 and EZA1 are colluvial in origin. Subsequently, on top of this section, during a flood, the channel of the Ezousas deposited once more its bedload (cf. the remains of gravel unit on top of the section). Some soil formation took place on that surface, identifiable in B_t-horizon formation in EZA2. However, the upper unit was partly removed and further soil formation took place, developing a new B-horizon in EZA4. Indeed, clay illuviation took place in EZA2, EZA3 and EZA4 as observed through the higher occurrence of clay particles in these units and also its red colour.

VII.2.4.2. EZB (plate 135: fig. 344 and plate 136: fig. 345)

A. Results

The loss-on-ignition test indicates that sample EZB3 has a relatively high organic matter content of 6.5% (plate 137: fig. 346). The organic matter content is real as proven by the pH test, which indicates that this unit contains relatively little calcium carbonate (low pH value) that could be lost on ignition. Hence, in sample EZB3 6.5% of organic matter was lost on ignition. Additionally, gravel EZB4 has a peak in mass specific magnetic susceptibility, similar to the one in gravel EZA12 (plate 137: fig. 347). Moreover, EZB4 contains superparamagnetic minerals (plate 137: fig. 348). From EZB1 to EZB3 the pH value drops from 8.8 to 8.4. However, in EZB4 a peak in alkalinity is observed (plate 137: fig. 349).

Gravel unit EZB4 consists of a large proportion of stones, namely 96% of the sample weight (plate 138: fig. 353). Especially, medium gravel, coarse gravel and cobbles are frequently present. The largest stone measures 10.4 cm, while an average stone measures 3 cm. Sub-rounded and rounded stones are slightly more present (plate 138: fig. 352). Stone shapes range from spherical flat stones to less spherical rounder stones (plate 138: fig. 351). The matrix, which is 4% of the total sample weight (plate 138: fig. 353), is composed of coarse sand (plate 139: fig. 354).

Unit EZB3 is composed of 24% of stones (plate 138: fig. 353). They are predominantly angular (plate 138: fig. 352). The matrix, which is 76% of the total sample weight (plate 138: fig. 353), has a bimodal particle size distribution with a peak in the clay to medium silt fraction and another peak in the fine silt fraction (plate 139: fig. 355). It was identified in the field as clayey silt.

Unit EZB2 contains a slightly larger weight proportion of stones than in the previous unit. Moreover, the stones are less angular than in the previous unit (plate 138: fig. 352). The matrix is less bimodal than in the previous unit and ranges between clay and coarse sand fractions, with slightly less volume percentages from the coarse silt fraction onwards (plate 139: fig. 356).

Gravel unit EZB1 contains a larger proportion of stones, namely 57% of the total sample weight (plate 138: fig. 353). The stones range between all sizes, with high weight percentages in the groups larger than medium gravel. The largest stone in EZB1 measures 7.7 cm, the average stone 2.4 cm. The matrix, which is 43% of the sample weight, is composed of silty sand (plate 139: fig. 357).

The particle size analysis (plate 140: fig. 358) indicates that EZB4 contains slightly higher amounts of smaller clay fractions than EZB3. No additional obvious changes in clay particle numbers are observed.

B. Interpretation

EZB, only 50 m removed from EZA along the same exposure, is slightly different from EZA. EZB4 is the bedload of an ancient channel of the Ezousas, similar to EZA12. Indeed, the orientation of the stones towards the W , the occurrence of some igneous stones and their roundness, all suggest that unit EZB4 represents a palaeochannel of the Ezousas. Some units, absent in EZB but attested in EZA, may be explained by the fact that the gravel unit at the bottom of EZB is more extensive than that in the gravel unit in EZA. Probably, the stream channel passed through this location for some longer time than in EZA. As a result, more bedload sediments were deposited. As only one sample was taken within unit EZB4, it was impossible to recognise the soil formation as was identified in EZA. However, the relatively high organic matter level of EZB3 suggests that some A-horizon formation, similar to the one in EZA4, took place. A colluvial sheet (EZB3, EZB2), similar to EZA3, EZA2 and EZA1 was subsequently deposited. Units EZB3 and EZB2 are no overbank deposits but colluvial deposits, suggested by the poor sorting and the occurrence of angular, local stones (some of them very large). Shortly after (as no soil formation took place in between), the Ezousas stream was once more situated at this location. Subsequently, it left its bedload behind after flooding. Since that time, soil formation took place, consisting of the development of a B_t-horizon in EZB3.

VII.2.4.3. EZC (plate 140: fig. 359; plate 141: fig. 360)

A. Results

EZC1, at the top of the section, shows a peak in organic matter content (11%) (plate 141: fig. 361). No other peaks were observed. Additionally, the mass specific magnetic susceptibility was slightly higher in EZC3 (plate 142: fig. 362). The pH test (plate 142: fig. 364) indicates that EZC1 has a relatively low pH level. However, EZC2 and EZC3 are more alkaline (respectively 9.1 and 8.8) .

Sedimentary stones make up for about 90% of the total amount of clasts, even more in the upper units EZC1 and EZC2 (plate 142: fig. 365). Igneous stones are represented for about 10%, obviously more present in the lower units EZC4 and EZC3.

Unit EZC4 is constituted of 30% of stones, all of them smaller than fine gravel (plate 143: fig. 368). Hence, the stones are relatively small, on average 0.9 cm. Discs are the dominant shape present (plate 143: fig. 366). The matrix, which is 70% of the sample weight, is composed of sandy silt (plate 144: fig. 369).

Gravel unit EZC3 contains a large proportion of gravels and cobbles, 95% of the total sample weight (plate 143: fig. 368). The stones are much larger than in the previous layer and measure 2.6 cm on average. Most stones have a disc shape (plate 143: fig. 367). The matrix, which is 5% of the sample weight, consists of coarse sand (plate 144: fig. 370).

80% of gravel unit EZC2 is composed of stones, ranging from all sizes between fine gravels and cobbles (plate 143: fig. 368). However, the stones are slightly smaller than in the previous unit, with an average size of 1.9 cm. Once more, discs are the dominant shape of the stones (plate 143: fig. 366). Only about 20% of the sample weight is matrix, ranging between fine and coarse sand, though with a volumetric peak in the coarse sand fractions (plate 144: fig. 371).

Unit EZC1 is similar to EZC2 as it only has a small weight proportion of stones (15%) and a much larger proportion of matrix (85%) (plate 143: fig. 368). Again, in unit EZC1, discs are the dominant shapes of the stones (plate 143: fig. 366). Additionally, the stones are smaller than in unit EZC2, measuring on average 0.9 cm. The matrix, which is 85% of the sample weight, consists of sandy silt (plate 144: fig. 372).

Additionally, the particle size analysis indicates a slightly higher number of clay particles in EZC1 (plate 145: 373).

B. Interpretation

Section EZC mostly represents the remains of bedload deposits. In general, the section shows a fining upward sequence, reflecting the decreased rate of flow of the ancient river, after a flood event. Some time elapsed since the depositional event as is suggested by the incipient soil formation on EZC1. The high organic matter content in unit EZC1 suggests that this unit represents the present day A-horizon. The magnetic susceptibility peak in EZC3 suggests the occurrence of an incipient B_t-horizon.

VII.2.4.4. EZD (plate 145: fig. 374 and plate 147: fig. 376)

A. Results

An organic matter peak in EZD3 of 15% is suggested by the loss-on-ignition test (plate 148: fig. 377). The magnetic susceptibility test on the other hand, indicates a peak in EZD5 (plate 148: fig. 378).
From EZD1 to EZD3, the pH drops from 8.4 to 8.1. Subsequently, from EZD4 on, the alkalinity increases from 8.2 to 8.5 in EZD5 (plate 149: fig. 380).

The stones in EZD mostly consist of angular (between 80 and 90%) sedimentary (between 80 and 99%) stones, mostly sandstones and chalks (plate 149: fig. 381). All types of shapes are present in almost equal amounts, except that there are slightly fewer blades (plate 149: fig. 382).

EZD5 consists of a large weight proportion of stones, about 70% of the total sample weight (plate 150: fig. 384). The stones range between cobbles and fine gravel. An average stone measures 1.4 x 1 x 0.7 cm. The matrix, which is 30% of the sample weight, is composed of coarse sand (plate 150: fig. 385).

Unit EZD4 contains a smaller proportion of stones, only 40% of the total sample weight (plate 150: fig. 384). The stones range from fine to medium gravel. On average, the stones measure 1 x 0.7 x 0.5 cm, which is smaller than in the previous unit. The matrix, which is 60% of the sample weight, ranges from clay to coarse sand, with volumetric peaks at the silt fraction and the coarse sand fraction. As a consequence, the matrix is sandy silt (plate 151: fig. 386).

Unit EZD3 is composed of only a small weight percentage of stones (20%) (plate 150: fig. 384). An average stone measures 0.7 x 0.4 x 0.3 cm. The matrix, which is 80% of the sample weight, is constituted of silty sand, though ranges from the clay fraction to the coarse sand fraction (plate 151: fig. 387).

Unit EZD2 consists of a larger proportion of stones (40% of the sample weight), ranging from fine to medium gravel (plate 150: fig. 384). The average size of a stone is 1 x 0.7 x 0.5 cm. The matrix, which is 60% of the sample weight, is composed of silty sand (plate 151: fig. 388), very similar to the matrix of EZD3.

EZD1 contains a smaller weight of stones, only 23% of the total sample weight, ranging in sizes from fine to medium gravel (plate 150: fig. 384). An average stone is almost equally large as in the previous unit. The matrix, which is 87% of the sample weight, consists of silt with some sand inclusions (plate 151: fig. 389).

B. Interpretation

Units EZD5 to EZD3, deposited sometime after 868 ± 559 AD or 369 ± 5.5 AD, represent the remains of a gully, fining upwards. Subsequently, some soil formation took place at this location. More specifically, EZD3 may be an A-horizon of a palaeosol, as suggested by its higher organic matter content. Moreover, EZD5, marked by a peak in susceptibility may represent the B_t-horizon of the same palaeosol. Additionally, some possible carbonate redeposition may be observed in EZD4 and EZD5, as suggested by the relatively high alkalinity. From EZD2 on, the depositional environment changed and a larger influx of colluvial sediments occurred. EZD1 was deposited sometime after 1221 ± 52.5 AD. There is not much evidence of soil formation on the present day surface, apart from a slightly higher organic matter content in EZD1, which suggests that not much time elapsed since the deposition of EZD1.

VII.2.4.5. EZE (plate 152: fig. 390 and plate 153: fig. 391)

A. Results

EZE1 contains 6.4% of organic matter, which is higher than in unit EZE2, EZE3 and EZE4 (plate 153: fig. 392). The mass specific magnetic susceptibility is higher in EZE2 and EZE3 than in EZE1 (plate 154: fig. 393).

The imbricated gravel unit EZE4 contains a large weight proportion of stones and only a small percentage of matrix (plate 155: fig. 398). The stones consist mostly of limestone (16%) and sandstone (14%) (plate 154: fig. 395). Additionally, chert is also relatively often present (8%). There is a predominance of rounded and sub-rounded stones (about 60%) (plate 155: fig. 396). The matrix consists of silty sand.

Unit EZE3 is composed of almost no stones (only 10% of the total weight), and a large weight proportion of matrix (90%) (plate 155: fig. 398). The matrix is composed of silt (plate 156: fig. 399).

Gravel unit EZE2 is comparable to EZE4. It is also composed of a large weight proportion of stones (80%), ranging from fine to medium gravel (plate 155: fig. 398). Unit EZE2 contains less limestone (9%) and sandstone (8%) than in EZE4 and received a larger input of chert (12%) (plate 154: fig. 395). Overall, the clasts in EZE2 are more rounded than in EZE4 (plate 155: fig. 397). The matrix, which is 20% of the sample weight, consists of sandy silt (plate 156: fig. 400).

Unit EZE1 is composed of only a small proportion of stones (20%), ranging from fine to medium gravel (plate 155: fig. 398). The lithology of the stones in EZE1 is similar to the lithology in EZE2 , apart from slightly fewer igneous stones in EZE1 (plate 154: fig. 395). The stones are also more angular (60% of angular and sub-angular stones) than in EZE2 and EZE4 (plate 155: fig. 397). The matrix, which is 80% of the sample, is composed of sandy silt, similar to the matrix of EZE3 (plate 156: fig. 401).

The particle size analysis indicates a slightly higher number of clay particles in EZE2 (plate 156: fig. 402).

B. Interpretation

At some time, a former channel of the Ezousas was situated at the location of this section. After a flood, the channel was abandoned. Subsequently, silty overbank sediments were deposited. The channel returned to this location, though abandoning it again shortly after. From then on, a mixture of overbank sediments and colluvium was deposited. Some time elapsed since the deposition of EZE, as is evident from the soil formation that took place on EZE1. More specifically, an A-horizon could develop in EZE1 (cf. high organic matter content) and an incipient B_t-horizon could develop in EZE2 and EZE3 (cf. high magnetic susceptibility and high clay percentage).

VII.2.4.6. EZF (plate 157: fig. 403 and plate 158: fig. 404)

A. Results

EZF1 has the highest organic matter content of all units (7.3%) (plate 158: fig. 405). Additionally, samples EZF4 and EZF7 have a high magnetic susceptibility (plate 159: fig. 406). Unit EZF1 has relatively low pH values (8). Subsequently, EZF2, EZF3 and EZF4 are more alkaline (pH value of about 8.5). Unit EZF5 is even more alkaline, with a pH value of 8.8. In EZA8, the pH then drops to 8.2 (cf. plate 159: fig. 408).

Gravel unit EZF7/EZF8 contains about 77% weight of stones, with 37% of the stones being larger than coarse gravel and cobbles (plate 161: fig. 412). Lithological, the stones consist of sandstone (about 18%), silicified chalk (about 16%) and limestone (8%) (plate 160: fig. 409). Discs are the predominant clast shape (35%) (plate 160: fig. 410). Most clasts (70%) are rounded or sub-rounded (plate 160: fig. 411). The clasts are relatively large with sizes ranging up to 10.6 cm. The matrix, which is 23% of the sample weight, is composed of the largest volume of sand, though also contains some silt (plate 161: fig. 413 and 414). As a result, it was identified in the field as silty sand.

Unit EZF6 contains a smaller proportion of stones, only 17% of the sample weight, of which a large fraction consists of stones larger than medium gravel (plate 161: fig. 412). Lithological, there is occurrence of a large number of cherts (17%), unlike in the previous unit (plate 160: fig. 409). Moreover, sandstone, chalk and diabase are also relatively well present (respectively 13%, 8% and 5%). The stones in this unit are more angular than in EZF7/EZF8 (plate 160: fig. 411). Moreover, an increase in the amount of spheres and a combined decrease in the amount of blades are observed, compared to EZF7/EZF8 (plate 160: fig. 410). The stones are also much smaller than in the previous unit. The matrix, which is 83% of the sample weight (plate 161: fig. 412), is composed of a large volume percentage of sandy silt (plate 162: fig. 415).

Gravel unit EZF5 is constituted of a large weight proportion of stones, about 86% of the sample weight, with a very large proportion of clasts larger than medium gravel (plate 161: fig. 412). The lithology of the stones mostly consists of sandstone (17%), though limestone (12%), silicified chalk (6%) and chert (7%) are also present (plate 160: fig. 409). 55% of the clasts are angular and sub-angular, thus more angular than in the previous unit (plate 160: fig. 411). On average, the stones have a similar size as in EZF8 (2.7 x 1.9 x 1.1 cm). The matrix, which is 14% of the sample weight (plate 161: fig. 412), consists of silty sand with a peak in the coarse sand volume (plate 162: fig. 416).

Unit EZF4 consists of a relatively large weight proportion of stones (about 87% of the sample weight), with a large proportion of stones larger than medium gravel (37% of the total weight) (plate 161: fig. 412). The matrix, which is 13% of the sample weight, consists of silty sand with a peak in the coarse sand volume (plate 162: fig. 417).

Gravel unit EZF3 consists of a large weight proportion of stones (94%), especially very large stones (76% of the total weight) (plate 161: fig. 412). There is a relatively high percentage of sandstone (19%), silicified chalk (15%) and chert (7%) (plate 160: fig. 409). The stones are more angular than in the previous unit. An average stone measures 2.9 x 2 x 1.3 cm, a similar average size as in gravel unit EZF5. The matrix, which is 6% of the sample weight (plate 161: fig. 412), is composed of silty sand, with a large volume percentage of coarse sand (plate 163: fig. 418).

Unit EZF2 contains only a small weight percentage of stones (33%), mostly of the groups larger than medium gravel (25% of the total weight) (plate 11: fig. 412). The stones are mostly chert (12%), though mudstone, limestone and silicified chalk is relatively frequently present (plate 160: fig. 409). The clasts are more angular than in the previous unit; discs and spheres are the dominant group (plate 160: fig. 411). The matrix is composed of silty sand.

Gravel unit EZF1 is constituted of 50% of stones (plate 161: fig. 412). There is a high occurrence of sandstone (23%) and chert (13%) (plate 160: fig. 409). The lithological distribution is similar to that in EZF3. Overall, the stones are smaller than in EZF3, namely on average measuring 1.6 x 1.2 x 0.7 cm. The matrix, which is 50% of the sample weight (plate 161: fig. 412), is sandy silt (plate 163: fig. 419).

The particle size analysis indicates that sample EZF4 stands out for its larger number percentage of fine clay particles (plate 163: fig. 420).

B. Interpretation

Although EZE and EZF are located along the same exposure, some lateral variation is observed. Unit EZF7 represents the same channel as in EZE4, identifiable by its relatively rounded stones, its similar lithological composition and also silty sand matrix. At some time, the channel was abandoned though this location was still within the reach of overbank deposits. EZF6 is similar to EZE3, though EZF6 contains more stones. Subsequently, unlike in EZE3, the channel returned to this location (EZF5). However, soon after, it left this location again and some more overbank sediments were deposited. Once more, the channel returned (EZF3) to the former location and subsequently left this location. Unit EZF2 contains a larger input of colluvial fractions, added to overbank deposits. This is suggested by the increased angularity of the clasts. Once more, the channel reached this location (EZF1) and deposited its bedload, abandoning the channel. Some time elapsed since the deposition of EZF1 as is evident by the soil formation on its surface. A relatively high organic matter content in EZF1 indicates that an A-horizon developed. The magnetic susceptibility peak in EZF4 with combined evidence of a high fine clay percentage indicates that EZF4 is an incipient B_t-horizon. Additionally, the pH test indicated some translocation of calcium carbonate from EZF1 to lower units, especially to unit EZF5.

VII.2.4.7. EZG (plate 165: fig. 422 and plate 166: fig. 424)

A. Results

A slightly higher organic matter content is observed in EZG1 (4.8%), however still relatively low (plate 165: fig. 423). Throughout the section the mass specific magnetic susceptibility is remarkably high, with values up to 8.2 $\mu m^3 \, kg^{-1}$ in EZG2 (plate 166: fig. 425). The pH in EZG1 is 8.3, 8.2 in EZG2 and 8.6 in EZG3 (plate 167: fig. 427).

90% of gravel unit EZG3 consists of stones (plate 168: fig. 431). Some grading is observed within the unit, consisting of 8 couplets. Moreover, sample EZG3 is poorly sorted as stones range between all sizes, apart from an absence of stones between 8 and 5.6 mm. The stones consist mostly of sandstone (about 30%), though diabase (about 8%) is also often present (palte 167: fig. 428). Discs and spheres are the dominant stone shapes (plate 167: fig. 429). 70% of the clasts is rounded and sub-rounded (plate 168: fig. 430). The matrix, which is 10% of the sample weight, is composed of coarse sand (plate 168: fig. 432).

Gravel unit EZG2 also contains about 90% of its sample weight stones (plate 168: fig. 431), similar to the previous layer. Moreover, this layer almost has a similar lithological distribution as EZG3, however, neither basalt nor gabbro have been retrieved in EZG2 (plate 167: fig. 428). It contains slightly fewer discs and more blades than in the previous unit (plate 167: fig. 429). The matrix, which is 10% of the sample weight (plate 168: fig. 431), is composed of coarse sand (plate 168: fig. 433), similar as the matrix of the previous layer. The major difference between EZG3 and EZG2 is that the clasts are larger in EZG2. Moreover, unit EZG2 is more massive.

Unit EZG1 contains a much smaller weight proportion of stones than in the previous units (EZG3 and EZG2), only 51% of the sample weight compared to 90% in the previous units (plate 168: fig. 431). The stones in EZG1 consist predominantly of sandstone as attested in EZG3 and EZG2 (plate 167: fig. 428). Spheres and discs are again most occurring (plate 167: fig. 429). Overall, the stones are smaller, with an average size of 2.1 x 1.5 x 1 cm. The matrix, which is 40% of the sample weight (plate 168: fig. 431), is composed of silty sand (plate 169: fig. 434), with a peak in the medium and large sand volume.

The particle size analysis indicates that EZG2 and EZG3 have slightly higher numbers of clay particles than EZG1.

B. Interpretation

The high occurrence of rounded clasts indicates that the deposits in unit EZG3 represent bedload sediments of a former river channel, post-dating 1140 ± 20 AD. The grading, visible as 8 couplets, indicates that the velocity of the stream changed 8 times from high to lower. On the other hand, the massive structure of unit EZG2 was a result of a single flood event. After the flooding, the river left this location and deposited overbank sediments. Some incipient soil formation took place since then, according to the slightly higher organic matter in EZG1 (A-horizon formation), the high magnetic susceptibility of sample EZG2 (incipient B_t-horizon formation) and also the increase in alkalinity depending on depth (downward movement of calcium carbonate).

VII.2.4.8. EZH (plate 170: fig. 436 and plate 169: fig. 435)

A. Results

The loss-on-ignition test indicates higher organic matter levels in EZH1 (7.2%) and in EZH3 (7.7%) (plate 171: fig. 437). However, also worth noting is that the high organic matter content in EZH3 may be misleading as it could be the result of the occurrence of vegetation on the collapsed terrace. As in EZG, the mass specific magnetic susceptibility is relatively high compared to the other sections, levels going up to 5.23 $\mu m^3\, kg^{-1}$ (plate 171: fig. 438). Samples EZH1 and EZH2 have the highest susceptibility degree. EZH1 has a relatively low pH value (plate 172: fig. 440). However, higher values were found in the other layers.

Gravel EZH4 contains 80% stones (plate 173: fig. 444). The stones range from all sizes, with especially a large weight proportion of small stones between 8 and 5.6 mm. An average stone measures 2.4 x 1.7 x 1.2 cm. Most of the stones are sandstone (40%), though chert, chalk and limestone are also often present (plate 172: fig. 441). 75% of the stones is rounded or sub-rounded (platc 173: fig. 443). Spheres, discs and rods are about equally present, though discs and rods are also frequently occurring (plate 172: fig. 442). The matrix, which is 20% of the sample weight (plate 173: fig. 444), is composed of coarse sand (plate 173: fig. 445).

Unit EZH3 is composed of only 33% of stones, with again a large proportion of very large stones (plate 173: fig. 444). An average stone is smaller than in the previous unit and measures 1.4 x 1 x 0.6 cm. This unit contains fewer sandstones and cherts than in EZH4, though more silicified chalks and diabase stones (plate 172: fig. 441). Discs are the dominant shape group in this layer (plate 172: fig. 442). The matrix, which is 67% of the sample weight (plate 173: fig. 444), consists of sandy silt (plate

174: fig. 446), though it is relatively poorly sorted, ranging between clay and coarse sand.

Gravel unit EZH2 is constituted of a large weight proportion of stones (79%) of all sizes, except for an absence of clasts between 8 and 5.6 mm (similar to EZG2) (plate 173: fig. 444). The stones have again a similar size as in EZH4 and measure on average 2.5 x 1.8 x 1.2 cm. The matrix, which is 21% of the sample weight, is composed of medium sand (plate 174: fig. 447).

Unit EZH1 contains a much smaller weight proportion of stones, only 47% of the total sample weight (plate 173: fig. 444). Again, there is an absence of stones between 8 and 5.6 mm. The average clast is much smaller than in the previous layer, only measuring about 1.6 x 1.1 x 0.8 cm. Unit EZH1 has a similar lithological distribution as EZH2, though contains more diabase (plate 172: fig. 441). Within this unit, the stones are more angular than in the previous layer (plate 173: fig. 443). The clasts consist mostly of discs (32%), though spheres are also relatively often present (25%) (plate 172: fig. 442). The matrix, which is 53% of the sample weight (plate 173: fig. 444), is composed of sandy silt (plate 174: fig. 448).

EZH2, EZH3 and EZH4 have a similar number of clay particles. However, EZH1 stands out in that it has a slightly smaller proportion of very fine clays, but a wider range of slightly larger clays (plate 174: fig. 449).

B. Interpretation

EZG and EZH probably represent paired terraces. Most units of the section represent channel sediments, possibly deposited sometime after 1140 ± 20 AD. However, it is unlikely that 3 m of bedload were deposited at once, as some grading has been observed, which suggests at least two events with only little time in between, lacking any evidence of soil formation. At first, the velocity of the channel was relatively high, but reduced later on as is indicated by the fining upward sequence. Subsequently, the velocity of the stream increased again. Finally, the river changed its location and overbank sediments were deposited. Some incipient soil formation is identified on the present day soil surface. The high organic matter content in EZH1 indicates the formation of an A-horizon. Moreover, the pH test indicates that the units below EZH1 are more alkaline, probably a result of calcium carbonate translocation. Moreover, the particle size analysis indicates that clay has illuviated in EZH2, EZH3 and EZH4.

VII.2.5. Xeropotamos

VII.2.5.1. XA (plate 177: fig. 452; plate 176: fig. 451)

A. Results

The loss-on-ignition test indicates that XA1 and XA2 have a relatively high organic matter content, respectively 5.3% and 5.9% (plate 177: fig. 453). The mass specific magnetic susceptibility test shows relatively high values in XA1 and XA2 (plate 178: fig. 454). Values of frequency dependent susceptibility of about 15% suggest the occurrence of superparamagnetic grains in XA4 (plate 178: fig. 455). The pH test indicates that XA1 has a pH value of 8.8, XA2 a value of 9.1, XA3 a value of 8.8 and XA4 8.5 (plate 178: fig. 456).

Gravel unit XA4 contains for 94% of the sample weight stones (plate 180: fig. 460), mostly sandstones (40%), but also cherts, chalks and limestones (plate 179: fig. 457). Medium gravels, coarse gravels and cobbles are especially often present. An average stone measures 2.4 x 1.7 x 1.1 cm. 75% of the clasts are rounded to sub-rounded (plate 179: fig. 459). Spheres, discs and rods are about equally present, blades less frequently (plate 179: fig. 458). The matrix, which is 6% of the sample weight (plate 180: fig. 460), is poorly sorted with particles of all sizes between the clay and coarse sand fraction (plate 180: fig. 461). Hence, the matrix is silty sand.

Gravel unit XA3 is composed of less weight of stones (only 77%) than the previous unit (plate 180: fig. 460). Especially stones between medium gravel and cobbles are often present. An average stone measures 1.4 x 1.2 x 0.9 cm, which is smaller than in the previous unit. Moreover, limestone is less present than in the previous unit, though igneous stones as diabase and basalt occur more frequently (plate 179: fig. 457). The stones are similarly rounded as in the previous unit (plate 179: fig. 459). The matrix, which is 23% of the sample weight (plate 180: fig. 460), consists also of silty sand, though is coarser than in the previous unit (plate 180: fig. 462).

Unit XA2 is constituted of only 8% of stones, mainly fine gravel (plate 180: fig. 460). An average stone measures 0.6 x 0.4 x 0.3 cm, hence is much smaller than in the previous unit. There is a larger occurrence of limestone and less of sandstone than in the previous unit (plate 179: fig. 457). The stones are also more angular, with 70% of angular and sub-angular stones (plate 179: fig. 459). The matrix, which is 92% of the sample weight (plate 180: fig. 460), is composed of silty sand (plate 181: fig. 463), with a peak in the fine silt fraction and another peak in the fine sand fraction.

Gravel unit XA1 only consists of a small weight percentage of stones (22%) (plate 180: fig. 460). The unit is graded; three couplets are observable. The sample was retrieved in the smaller gravels. As a consequence, the weight percentage of the stones is relatively low. The matrix, which is 78% of the sample weight (plate 180: fig. 460), is composed of silty sand (plate 181: fig. 464).

No marked change was shown in the clay percentage throughout the section (plate 181: fig. 464).

B. Interpretation

At some time, a channel of the Xeropotamos with a relatively high velocity was situated at this location with (XA4), as evidenced by the bedload deposit. The occurrence of superparamagnetic grains in XA4 may be associated with human impact on the landscape, such as fire and burning. The velocity of the channel decreased in XA3. A sherd indicates that XA3 post-dates 432 ± 592 BC. Subsequently, the channel left this location and overbank sediments were deposited (XA2). Some incipient soil formation might have taken place on the surface of XA2, as attested by the higher organic matter content and magnetic susceptibility in this unit. Hence, a period of landscape stability might have taken place for some time. Subsequently, the river returned to this location and deposited one meter of bedload. The unit was not deposited at once, though over some time, as is attested by the observed grading, consisting of three couplets. Some incipient soil formation took place on XA1, as is identified by the higher organic matter content and higher mass specific magnetic susceptibility. However, more samples should be taken to thoroughly understand the degree of soil formation in the upper meter of the section. Finally, the section became exposed by present day river incision.

VII.2.5.2. XB (plate 182: fig. 466 and plate 183: fig. 468)

A. Results

XB1 has the highest organic matter content (5.7%) (plate 182: fig. 467). Moreover, this unit also has the highest magnetic susceptibility (plate 183: fig. 469). The susceptibility decreases from top to bottom. XB2 has a relatively high alkalinity of 8.9. XB3 has a lower pH value (8.3) (plate 184: fig. 471).

Gravel unit XB3 contains a large weight proportion of stones, mostly sandstones (55%) and limestones (25%) (plate 184: fig. 472). Igneous stones are present in very small amounts. 80% of the clasts are rounded (plate 185: fig. 474). Moreover, spheres and rods are most present (plate 185: fig. 473). An average stone measures 2.1 x 1.4 x 1 cm. The matrix consists of silty sand (plate 186: fig. 476).

Unit XB2 is composed of 44% of stones, ranging from fine to larger than coarse gravel (plate 185: fig. 475). An average stone is smaller than in the previous unit, measuring 1.3 x 0.9 x 1 cm. Limestone and sandstone are equally present as in the previous unit (plate 184: fig. 472). The clasts are more rounded than in the previous layer (60% compared to 80% in XB3) (plate 185: fig. 474). Additionally, spheres are most occurring (40%) and discs and rods are present in equal amounts (25%) (plate 185: fig. 473). The matrix, which is 56% of the sample weight (plate 185: fig. 475), consists of silty sand (plate 186: fig. 477).

Gravel XB1 contains a large weight proportion of stones, about 76% of the total sample weight (plate 185: fig. 475). There is a significant proportion of very large clasts (42% of the total sample weight), larger than coarse gravel. Other size groups of stones are about equally present in weight. An average stone measures 1.9 x 1.3 x 0.9 cm. The lithological distribution is similar to the previous units, with a considerable quantity of sandstone and limestone (plate 184: fig. 472). A similar amount of rounded and sub-rounded clasts occur as observed in the previous unit (plate 185: fig. 474). The matrix, which is 24% of the sample weight (plate 185: fig. 475), is composed of clayey silt with a peak at 40 μm (coarse silt fraction) (plate 186: fig. 478). Additionally, some sand fractions are present in the unit.

The particle size analysis indicates the occurrence of more clay fractions in XB2 than in any other unit (plate 186: fig. 479).

B. Interpretation

This sequence represents deposits of a longitudinal bar, built by the present day river. A typical fining upward sequence can be observed. The bar was possibly created during a period of high discharge. Since then, some incipient soil formation took place on XB1. The higher organic matter content and higher magnetic susceptibility indicates that an A-horizon developed in XB1. XB2 may be an incipient B-horizon as evident from the number of clay particles and the possible higher calcium carbonate content (cf. higher pH).

VII.2.5.3. XC (plate 187: fig. 480 and plate 188: fig. 481)

A. Results

XC1 has a slightly higher organic matter content than the other units (plate 188: fig. 482). Moreover, XC2 shows a peak in mass specific magnetic susceptibility (plate 189: fig. 483). XC1 has a relatively low pH value of 8.2, while the subsequent units are more alkaline: XC2, XC3 and XC4 respectively 8.9, 8.8 and 8.9 (plate 189: fig. 485).

The imbricated gravel unit XC4 consists of 85% of stones varying in size, however lacking stones between 11.2 and 5.6 mm (plate 191: fig. 489). A large amount of clasts is larger than medium gravel. An average stone within the unit measures 1.9 x 1.2 x 0.8 cm. Lithological, the stones mostly consist of limestone, chert and silicified chalk (plate 190: fig. 486). 70% of the clasts is rounded and sub-rounded (plate 190: fig. 488). Spheres, discs, rods and blades are about equally present (plate 190: fig. 487). The matrix, which is 15% of the sample weight (plate 191: fig. 489), is composed of coarse sand (plate 191: fig. 490).

Unit XC3 contains a slightly smaller weight percentage of stones (62%) than in the previous unit (plate 191: fig. 489). The stones are much smaller than in the previous unit, with no clasts larger than medium gravel. There is a similar absence of clasts between 11.2 and 5.6 mm, as observed in the previous unit. An average stone measures 1.7 x 1.2 x 0.7 cm. Cherts are most occurring in this layer, though sandstones, silicified chalks and limestones are also present (plate 190: fig. 486). The clasts are more angular than in XC4, consisting of 55% of rounded and sub-rounded clasts (plate 190: fig. 488). The matrix, which is 42% of the sample weight (plate 191: fig. 489), is constituted of coarse sand (plate 191: fig. 491).

Gravel unit XC2 is composed of 92% of its sample weight of stones, with a significant proportion of stones larger than medium gravel (about 84% of the total weight of the sample) (plate 191: fig. 489). Again, there is a marked absence of stones between 11.2 and 5.6 mm. The matrix, which is 8% of the sample weight, consists of coarse sand, similar as in XC4 and XC3 (plate 192: fig. 492).

Unit XC1 consists of a much smaller proportion of stones. The unit has a similar lithological distribution as in the previous units, consisting mostly of sandstones, though also of a relatively large proportion of cherts. Limestones, chalks, silicified chalks, and diabase stones are present as well. The matrix is composed of clayey silt (plate 192: fig. 493).

The particle number percentage graph of XC2 stands out from the other graphs in that the clay is finer (plate 192: fig. 494).

B. Interpretation

The imbricated gravel unit XC4 with a W-ward orientation of the stones, represents the deposits of a former high energy river. At some time after a flood, the river changed the location of its channel. As a result, overbank sediments were deposited (XC3). The grading indicates that this unit was not deposited in one event, though over a few events. After a flood, the river changed its channel, returning to this location (XC2). Subsequently, it left this location again and clayey silt overbank sediments were deposited (XC1). Since the last deposition, some soil formation took place as observed in the formation of an A-horizon in XC1 (cf. higher organic matter content), in clay illuviation in XC2 (cf. high magnetic susceptibility and smaller clay fractions) and also in the translocation of calcium carbonate (cf. higher pH values in XC2, XC3 and XC4 than in XC1).

VII.2.5.4. XD (plate 193: fig. 495 and plate 194: fig. 496)

A. Results

Two peaks in organic matter content were found, one in XD1 and one in XD5 (plate 194: fig. 497). However, the values are still relatively low, respectively 3.3% and 3.7%. Moreover, a peak in magnetic susceptibility is observed in XD3 (plate 195: fig. 498). Additionally, the pH in XD1 is 9, in XD2 9.1, in XD3 8.9 and in XD4 8.8 (plate 195: fig. 500).

Gravel unit XD6 consists of 85% of stones, of which especially large clasts are mostly present in weight (61% of the total weight) (plate 197: fig. 504). The lithology of the stones is mostly limestone, though chert, chalk and sandstone are also occurring (plate 196: fig. 501). Clasts are mostly rounded and sub-rounded (70%) (plate 196: fig. 503). Discs are dominant (40%) but spheres also count for a large proportion (30%) (plate 196: fig. 502). Some grading was observed, though an average stone measures about 2.6 x 1.8 x 1.1 cm. The matrix, which is 15% of the sample weight (plate 197: fig. 504), is composed of coarse sand (plate 197: fig. 505).

Gravel unit XD5 also contains a large amount of stones (51%), mainly ranging from medium gravel to cobbles (plate 197: fig. 504). Discs are dominant (50%) but spheres are also present (28%) (plate 196: fig. 502). The stones are equally rounded as in the previous unit (plate 196: fig. 503). The matrix, which is 49% of the sample weight (plate 197: fig. 504), is composed of fine sand, with a volumetric peak in the coarse sand fraction, though containing fine and medium sand as well (plate 197: fig. 506).

Gravel unit XD4 is constituted of 77% of stones, especially very large stones (plate 197: fig. 504). About 62% of the total weight of the sample is larger than medium gravel. The lithological distribution of the sample is similar to the distribution of XD5, though there are slightly more cherts (plate 196: fig.501). The stones are slightly more angular than in unit XD5 (plate 196: fig. 503). The matrix, which is

23% of the sample weight (plate 197: fig. 504), is composed of coarse sand (plate 198: fig. 504).

Unit XD3 contains only 10% stones, mostly very small (plate 197: fig. 504). On average, a stone measures 0.9 x 0.6 x 0.4 cm. The stones have a similar lithology as in XD4 (plate 196: fig. 501), though are more angular (55% of the clasts is angular and sub-angular) (plate 196: fig. 503). The matrix, which is 90% of the sample weight (plate 197: fig. 504), is laminated, medium sand (palte 198: fig. 508).

Gravel unit XD2 contains more stones than the previous sample (97%) (plate 197: fig. 504). The clasts are mostly larger than medium gravel (92% of the total sample weight). The lithological distribution of the stones is similar to that of the previous units. However, unit XD2 contains a larger proportion of silicified chalks and limestones, and a smaller proportion of sandstones than unit XD3 (plate 196: fig. 501). The matrix, which is 3% of the sample weight (plate 197: fig. 504), is very coarse, showing a volumetric peak of coarse sand (fig. 509).

Unit XD1 only consists of a small weight proportion of stones (5%), mostly fine gravel (plate 197: fig. 504). On average a stone measures 1.1 x 0.8 x 0.4 cm. The matrix, which is 95% of the sample weight (plate 197: fig. 504), is composed of silty sand, with a volumetric peak in the fine sand fraction, though also in the clay and silt fractions (plate 198: fig. 510).

The particle size analysis indicates that more clay particles occur in XD2 and XD3 than in the other units (plate 199: fig. 511).

B. Interpretation

XD6 attests for several flood events at this location as is evidenced by the laminated layers of rounded gravel. The gravel deposit, post-dating 1730 ± 70 AD, is more massive and may be the result of a single flood. After the suggested flood event, the velocity decreased abruptly and over some time several laminated sand layers were deposited (XD2). Subsequently, the velocity of the stream increased again (XD2) though was still lower than in the previous river at this location, as is attested by the occurrence of smaller stones. Finally, the river moved away from this location and overbank sediments were deposited. Since then, only incipient soil formation took place. Incipient A-horizon formation is attested by the relatively high organic matter content in XD1 (compared to the other units). Moreover, the magnetic susceptibility test as well as the particle size analysis in XD3 may indicate that a B_t-horizon started to develop.

VII.2.5.5. XE (plate 199: fig. 512 and plate 200: fig. 513)

A. Results

The loss-on-ignition test indicates that XE1 has a relatively higher organic matter content (4.5%) compared to the other units (plate 200: fig. 514). Moreover, XE2 has a relatively higher mass specific susceptibility compared to XE3, XE4 and XE5 (plate 201: fig. 515). The pH test indicates an increasing alkalinity, from 8.5 in XE2 to 9 in XE4, according to depth (plate 201: fig. 517).

Gravel layer XE5 contains 68% (of the sample weight) stones (plate 203: fig. 521). They range between all sizes with a considerable proportion of stones larger than medium gravel. An average stone measures 1.9 x 1.3 x 0.9 cm. Sandstones, limestones, cherts and chalks are present in almost equal amounts (plate 202: fig. 518). Igneous clasts are rarer. 52% of the clasts is rounded and sub-rounded (plate 202: fig. 520). Spheres, rods, discs and blades are present in this order of quantity, with spheres mostly occurring (plate 202: fig. 519). The matrix, which is 32% of the sample weight (plate 203: fig. 521), is composed of coarse sand (plate 203: fig. 522).

Gravel XE4 consists of a larger weight proportion of stones (86% of the sample weight) than the previous unit (plate 203: fig. 521). A larger amount of clasts, larger than medium gravel is present (48%). The stones are larger than in the previous unit, measuring 3 x 2.2 x 1.5 cm, on average. XE4 has a similar lithological composition as XE5, though it contains more igneous stones (plate 202: fig. 518). Additionally, the clasts are about equally rounded as in the previous unit (plate 202: fig. 520). Spheres, discs, rods and blades are present in equal amounts as in XE5, containing most spheres (plate 202: fig. 519). The matrix, which is 14% of the sample weight (plate 203: fig. 521), consists of coarse sand as in the matrix of XE5 (plate 203: fig. 523).

Unit XE3 is composed of a smaller proportion of stones (41%), of which most stones are larger than medium gravel (plate 203: fig. 521). An average stone is much smaller than in XE4, measuring 1.3 x 0.9 x 0.6 cm. Cherts and chalks are most frequently present whereas sandstones, limestones and igneous stones occur in a smaller amount (plate 202: fig. 518). Spheres and discs are the dominant shape while rods and blades occur less frequently (plate 202: fig. 519). The stones are slightly rounder than in the previous units, consisting of about 58% of rounded and sub-rounded stones (plate 202: fig. 520). The matrix, which is 59% of the sample weight (plate 203: fig. 521), is constituted of silty sand, with a peak within the volume of fine sand and also a large proportion of silt and clay particles (plate 204: fig. 524).

Gravel unit XE2 contains 68% in weight of stones, thus more stones than in the previous unit (plate 203: fig. 521). Additionally, they are also larger than in the previous unit, with an average size of 2 x 1.4 x 0.9 cm. The stones mainly consist of chert and sandstone (plate 202: fig. 518). Compared to the previous unit, there is an occurrence of almost 10% more sandstone. 70% of the clasts are rounded and sub-rounded, thus rounder than in the previous unit (plate 202: fig. 520). Spheres and discs are the dominant shapes while rods and blades occur less frequently (plate 202: fig. 519). The matrix, which is 32% of the sample weight (plate 203: fig. 521), is composed of poorly sorted silty sand, with a particle size ranging between fine clay and coarse sand, and a peak at the fine sand fraction (plate 204: fig. 525).

Unit XE1 contains fewer stones. An average stone measures 1.9 x 1.3 x 0.9 cm. The clasts mostly consist of chert (40%) whereas sandstone, diabase and limestone occur less frequently (plate 202: fig. 518). Overall, the stones are equally rounded as in the previous unit (plate 202: fig. 520). The matrix, which consists of a large proportion of the total sample weight, is composed of sandy silt.

All samples contain a similar number percentage of clay fractions, except XE5 with a higher percentage of coarser clay fractions (plate 204: fig. 526).

B. Interpretation

The units XE5 and XE4 represent channel deposits of the former Ezousas. XE5 and XE4 each show a fining upward sequence, indicative of a high stream velocity followed by a lower velocity. After the flood which resulted in the deposition of the graded bedload deposit XE4, the river changed its location for a while and a thin layer of overbank sediments were deposited (XE3). However, in another flood event shortly after, a thin gravel layer was deposited (XE2). Subsequently, the channel remained away from this location, though was still in the proximity as overbank sediments were deposited. The loss-on-ignition test indicates incipient A-horizon formation in XE1 (cf. high organic matter), possible B_t-horizon formation in XE2 (cf. higher magnetic susceptibility) and also the downward movement of calcium carbonate (cf. increasing alkalinity over depth).

VII.2.5.6. XF (plate 205: fig. 527 and plate 206: fig. 528)

A. Results

The loss-on-ignition test indicates a peak in organic matter content in unit XF1 (4.6%) and in XF3 (5%) (plate 206: fig. 529). Additionally, a peak in mass specific susceptibility is observed in XF2 (1.285 $\mu m^3\ kg^{-1}$) and an even higher peak in XF4 (2.71 $\mu m^3\ kg^{-1}$) (plate 207: fig. 530). The pH test shows a value of 8.8 in XF1, a higher alkalinity of 9.1 in XF2 and subsequent decreased alkalinity from XF3 to XF4, respectively from 8.8 to 8.5 (plate 207: fig. 532).

Layer XF4 is only composed of 13% stones in weight (plate 208: fig. 533). The largest stone measures 1 x 0.7 x 0.3 cm. The matrix, which is 87% of the sample weight, consists of sandy silt, though also contains a lot of clay fractions. Peaks in the volume percentage occur at the fine silt and coarse silt fraction (plate 208: fig. 534).

Layer XF3 contains a very small proportion of stones, only 3% of the total weight (plate 208: fig. 533). The largest stone within the unit measures 2.2 x 0.9 x 0.4 cm. The matrix, which is 97% of the sample weight, is finer than in the previous layer and contains a smaller volume percentage of sand fractions. Consequently, this is clayey silt (plate 208: fig. 535).

Gravel unit XF2 consists of 95% weight of stones. The stones are mainly larger than medium gravel (plate 208: fig. 533). Sandstones, limestones and chalks occur in equal amounts within the unit (each 20%). Spheres and rods are mostly present while blades and discs occur less frequently. Rounded and sub-rounded clasts are dominant (60%). An average stone measures 2.3 x 1.5 x 1 cm. The matrix, which is 5% of the sample weight, is composed of coarse sand (plate 209: fig. 536).

Unit XF1 only contains 1% weight stones (plate 208: fig. 533). The other 99% of the weight consists of matrix, being silty sand (plate 209: fig. 537).

The particle size analysis indicates the occurrence of more clay particles in XF2 than in the other units (plate 209: fig. 538).

B. Interpretation

Layer XF4 and XF3 are the remains of overbank deposits as indicated by a lack of clasts. After the sediments were deposited, a period of landscape stability took place and incipient soil formation occurred as is evidenced by incipient A-horizon formation (cf. high organic matter content and magnetic susceptibility high in XF4 and XF3). Subsequently, a period of deposition took place as a result of the occurrence of an aggrading river bed of the former Xeropotamos at this location. It was a bedload dominated river with a relatively high velocity (cf. relatively large clasts). At some time, the river channel changed its course and overbank sediments reached this location. It is suggested that some soil formation took place on the present day soil as indicated by a higher organic matter content in XF1 (incipient A-horizon) and also possible clay illuviation in XF2 (cf. higher magnetic susceptibility and occurrence of more clay particles). However, the sampling procedure should be refined for better understanding of the soil formation.

VIII. Alluviation and sedimentation

VIII.1. Chronology of alluviation

Although the chronological base is less ample than I would have liked (see chapter VI), it is adequate to attempt to place the alluvial units in a tentative scheme.

VIII.1.1. Alluvium from or post-dating the prehistoric period

Prehistoric alluviation, consisting of streamflood deposits, may have taken place along the Agriokalamos as is suggested by the occurrence of two sherds in the deposits and several palaeosols on top. However, the OSL-dates on the sediments do not confirm this and indicate dates too old to contain any sherds. Hence, further chronological research is necessary.

Moreover, 50 cm of early Prehistoric streamflood deposits have been attested at the alluvial fan of Souskiou along the Dhiarizzos ante-dating 13.1 ± 6.5 ka BP. Furthermore, almost 2 meters of alluvium have been deposited at this location sometime between 13.1 ± 6.5 ka BP and 3.8 ± 1.1 ka BP.

VIII.1.2. Alluvium from or post-dating the Iron Age

Moreover, along the Xeropotamos at section XA there is evidence of 1.15 m of sediments deposited around or after 432 ± 592 BC, consisting of streamflood deposits.

VIII.1.3. Hellenistic and Roman alluvium

Along the Ezousas at section EZA, between 160 ± 160 BC and 300 AD, 2 meters of streamflood sediments were deposited. Subsequently, the landscape was stable. More streamflood sediments were deposited about 1.64 ± 0.15 ka BP.

Furthermore, at the alluvial fan of TA and TB along the Stavros-tis-Psokas, about 1 m of debris flow was deposited sometime after 300 ± 65.5 AD.

VIII.1.4. Alluvium from or post-dating the Byzantine period

At section MB along the Dhiarizzos, sometime after 800 AD about 1.5 m of streamflood sediments were deposited.

Additionally at Kithasi, along the Dhiarizzos as well, 3.30 m of streamflood sediments were deposited sometime after 894 ± 250 AD.

At section TA and TB, along the Stavros-tis-Psokas, about 2.5 m of sediments were deposited sometime after ± 753 AD, mostly consisting of debris flow.

Along the Ezousas, at section EZD, sometime after 868 ± 559 AD, 2.1 m of streamflood sediments were deposited.

VIII.1.5. Alluvium from or post-dating the Frankish period

Sometime after 1140 ± 60 AD, 1 m of sediments were deposited at PR1 along the Dhiarizzos, consisting of a mix of debris flow and streamflood deposits. However, through a soil formation study (cf. IX.2.5), it is suggested that the 1 m of sediments were deposited quite some time later than 1140 ± 60 AD.

Moreover, 2 meters of streamflood sediments were deposited after 1320 ± 60 AD at MA along the Dhiarizzos.

Sometime after 1221 ± 52.5 AD, 1.1 m of debris flow was deposited at EZD along the Ezousas. However, in a study on the degree of soil formation (cf. IX.2.5), it is suggested that the 1.1 m of sediments were probably deposited some time later than 1221 ± 52.5 AD.

Sometime after 1140 ± 20 AD, about 2.6 m of streamflood sediments were deposited at EZG along the Ezousas.

VIII.1.6. Alluvium from or post-dating the Venetian period

Sometime after ± 1560 AD, at KOL1 along the Dhiarizzos, 3.1 m of streamflood sediments were deposited.

VIII.1.7. Alluvium from or post-dating the Ottoman period

Sometime after 1730 ± 70 AD, 2.8 m of streamflood sediments were deposited at XD, along the Xeropotamos.

VIII.1.8. Conclusion

Supposedly, the shortage of Prehistoric alluviation in large measure reflects the inherently episodic nature of environmental processes. Major erosion cycles from the more distant past have removed (destroyed or displaced) the very sediments upon which we depend for the stratigraphic record of geomorphologic history. Hence, I would like to pose that there is no reason to assume that landscape change through sedimentation is exclusively post-Roman.

VIII.2. Provenance

In the following section, I will try to identify the provenance of the alluvial sediments. In this way, it may be possible to identify the erosion source. Consequently, a better insight will be gained into the causality of the erosion. In this chapter the data of chapter VII will be used.

VIII.2.1. Stavros-tis-Psokas (lithological map see plate 211: fig. 540)

VIII.2.1.1. TA and TB

The stones of TA and TB (plate 21: fig. 39) mostly consist of chalks, deriving from the Lefkara formation, located north of the section at the headwater of the Argakin Pyroia stream. Cherts, limestones and shales, present in small quantities probably also derive from the Lefkara formation north of the section. The small number of sandstones present in the sections derive from the Kannaviou formation, just to the north. The uppermost unit contains a larger variety of stones, with a marked content of igneous clasts (basalt, diabase and (micro-) gabbro), unlike the other units. The basalt may derive from the Northeast or Northwest. However, diabase does not outcrop locally and may have been transported along the Stavros-tis-Psokas from the East. However, it was suggested earlier that the uppermost unit was rather colluvial than alluvial in origin. This may be the result of the human transportation of stones from the river bed for human use.

VIII.2.2. Agriokalamos (lithological map cf. plate 212: fig. 541)

VIII.2.2.1. KAGB

The largest group of stones in section KAGB (plate 37: fig. 77), derives from the Lefkara formation (chalks, silicified chalks, shales and limestones), which is located in the headwaters of the Agriokalamos, several km East of the section. Cherts, which are often present, may derive from the Mamonia formation chert outcrop. The relatively large proportion of sandstones and the small amount of calcarenite present in the section, probably derive from the local marine terrace unit. Additionally, some basalt stones also occur and derive from a small, very localised outcrop along the easternmost branch of the river, where the road to Tala crosses the river.

VIII.2.2.2. KAGC

KAGC mostly consists of stones (plate 44: fig. 97) deriving from the Lefkara formation: a large proportion of silicified chalks, some chalks, limestones and cherts. Additionally, the sandstones derive from the local marine terrace. Furthermore, the small amount of serpentinites in some units originates from the serpentinite outcrop Southwest of Tala. Additionally, the basalt only present in KAGC3, derives from a very localised outcrop, along the easternmost branch of the river, where the road to Tala crosses the river. In KAGC9, mainly rip-up clasts occur. They were ripped up from a local depression, possibly an abandoned meander of the Agriokalamos.

VIII.2.2.3. KAGD

KAGD contains a large proportion of stones (plate 51: fig. 117) deriving from the Lefkara formation, mainly silicified chalks, though also chalks, limestones and cherts. However, in KAGD14 and KAGD16, rip-up clasts dominate. They derive from a local depression in the river valley and were transported only over a short distance. Sandstones and cherts are present and probably derive from the local marine terrace. Furthermore, the serpentinite clasts derive from the serpentinite outcrops Southwest of Tala.

VIII.2.2.4. Conclusion and discussion provenance of Agriokalamos clasts

The lithological distribution of the clasts reflects the lithology of the drainage. Of notice is that the source of the basalt clasts within the section can be located relatively precisely, along the easternmost branch of the river, where the road to Tala crosses the river. However, basalt clasts represent only a small proportion of the eroded and thus alluviated sediments. Hence, the rather restricted occurrence of stones from this source indicates that their presence is not necessarily related to large-scale erosion on that spot.

VIII.2.3. Dhiarizzos (cf. lithological map plate 210: fig. 539 and especially the more detailed lithological map of the Polis-Paphos area – Geological Survey Department Cyprus).

VIII.2.3.1. KOL1

The lithological distribution of the clasts of KOL1 (plate 59: fig. 142) approximately reflects the proportions in outcropping geology along the Dhiarizzos. Limestones, chalks and silicified chalks all provenance from the Pakhna or Lefkara formation. Their abundance in the KOL1 samples reflects the dominant outcropping Pakhna and Lefkara formation along the Dhiarizzos river, especially in the lower portion of the drainage. Furthermore, the frequent occurrence of sandstones also reflects the frequent outcrops of Mamonia formation in the lower portion of the drainage, especially between Souskiou and Kithasi. The incidence of some cherts in the KOL1 samples may derive from chert outcrops between Souskiou and Ayios Yeoryios. The occurrence of some intrusive stones, such as diabase, suggests a source in the Troodos hills.

VIII.2.3.2. KOL2

In the KOL2 samples (plate 65: fig. 157), limestones, chalks and silicified chalks from the Pakhna or Lefkara formation are most present. Moreover, sandstones occur frequently in the KOL2 fluvial deposits and derive from the Mamonia complex outcropping in the lower reaches of the drainage. Cherts, which outcrop between Souskiou and Ayios Yeoryios, are also present. The small quantity of basalt, gabbro and diabase clasts probably derive from the Troodos Mountains. However, basalt outcrops also more locally in the lower reaches of the Dhiarizzos drainage. Gabbro and diabase on the other hand only occur in the Troodos Mountains.

VIII.2.3.3. SOA and SOB

The abundance of chalks and silicified chalks in the sample can be linked with the headwater of the Fonias stream (the side stream of the Dhiarizzos building the alluvial fan), which is located to the East in the Lefkara and Pakhna formation (cf. plate 73: fig. 176 and plate 80: fig. 195). Moreover, the cherts have a more local source, just at the edges of the Mamonia formation to the East. Additionally, the occurrence of sandstones may indicate a local source to the Northeast of the fan and part of the Mamonia outcrop. The dark shales also derive from the Mamonia outcrop, located just to the east of the alluvial fan of Souskiou. We may say that the lithological distribution of the SOA and SOB sediments samples suggests that all sediments from sections SOA and SOB have a source in the East, indicating they are exclusively fan deposits.

VIII.2.3.4. SOC and SOD

Although SOC and SOD are only located about 10 meters W-ward of SOA and SOB (see VIII.2.3.3.), the lithological distribution of the samples is different, with SOC and SOD containing a larger variety of lithologies (cf. plate 84: fig. 206 and plate 89: fig. 221). Moreover, the occurrence of gabbro and diabase indicates that SOC and SOD are alluvial deposits from a former channel of the Dhiarizzos. This is because these lithologies only occur in the Troodos Mountains, where the headwaters of the Dhiarizzos are located. However, the cherts probably derive from rather local outcrops between Souskiou and Kithasi. Additionally, the frequently occurring chalks, silicified chalks and limestones originate from Pakhna or Lefkara formation, which outcrops along most of the lower reaches of the Dhiarizzos drainage. The sandstones, which are also frequently present, may derive from a local source, just north of Souskiou. The mudstones and shales rarely present in section SOC and

SOD, derive from the Mamonia formation, which outcrops at several places between Souskiou and Kithasi.

VIII.2.3.5. PH

The group of clasts deriving from the Pakhna formation is most present: silicified chalks, chalks and limestones (plate 95: fig. 237). Pakhna formation outcrops just East of the section, though also along most of the lower reaches of the Dhiarizzos drainage. Furthermore, cherts are present in large quantities and possibly derive from the abundant chert outcrops in the Mamonia complex north of the section. Sandstones also may derive from the Mamonia complex north of the section. Moreover, far-travelled diabase and gabbro, originating from the Troodos Mountains, is present in minor quantities. The small group of basalt stones probably derives from the local outcrop on the western bank of the Dhiarizzos, north of Phasoula as is indicated by their angular shape.

VIII.2.3.6. PR1

Silicified chalks, chalks and limestones are the main lithological groups present in the section and most likely derive from the Lefkara formation (plate 101: fig. 253). The cherts may originate from the Lefkara formation as well, though they could also derive from the Mamonia chert unit outcrop, just north of this section on the other side of the Dhiarizzos. Moreover, sandstones frequently occur in the PR1 sediments and may derive from a local Mamonia outcrop. The diabase stones, mainly present in the lowermost unit, probably derive from the Troodos Mountains, considering the roundness of the clasts. Furthermore, the occurrence of gabbro clasts throughout the section also indicates a source in the Troodos Mountains. Hence, on one hand, a large proportion of local clasts is present in the deposits. However, the occurrence of gabbro in all units and diabase in some units (PR1.6 and PR1.1) suggests long distance transport of clasts.

VIII.2.3.7. MA and MB

MA contains almost exclusively silicified chalks (plate 108: fig. 271), which were supplied by a small unnamed stream coming from the Southeast, having its source in the Pakhna formation area. A few cherts were also supplied from the Southeast. The occurrence of some sandstones may indicate a source in the north, which supports the fact that section MA represents floodplain deposits of a former channel of the Dhiarizzos.

Section MB has an almost similar lithological composition as MA, except for an absence of sandstones and the occurrence of a few shales (cf. plate 113: fig. 284).

The slight lithological difference between MA and MB seems to confirm the different depositional environment of both sections. Whereas the units in MB represent fan deposits, section MA clearly contains floodplain deposits. The sandstones in MA could only have been supplied from the north, while section MB exclusively contains clasts outcropping in the SE. However, the stream represented in section MA was supplied with an abundance of silicified chalks from the Pakhna formation in the SE.

VIII.2.3.8. KIS1

The almost exclusive occurrence of silicified chalks and chalks within this section (plate 122: fig. 308), suggests a local erosional source situated in the Pakhna or Terra formation. An absence of any stones deriving from the Troodos Mountains points to an exclusively local sediment supply. The rarely occurring shales also derive from the Terra formation. Additionally, the occurrence of sandstone in KIS1.1 indicates a local source from the west, where Mamonia formation outcrops.

VIII.2.3.9. Conclusion and discussion on provenance of Dhiarizzos sediments

It is easily recognisable that most sections represent former channels of the Dhiarizzos as clasts of the several lithological formations the river passes through today, have been identified in the deposits. However, most of the investigated sections only contain a small proportion of far-travelled igneous stones. On comparison with the Pleistocene sediments along this river, it is worth noting that the far-travelled Troodos clasts were much more frequent in the alluvial deposits (Poole & Robertson 1998: fig. 21). This reduced amount of igneous stones (deriving from the Troodos) in Holocene deposits, may indicate different geological processes at work. Maybe, there was an absence of erosion in the Troodos Mountains. Furthermore, the local supply may have been so large that it was directly deposited. Hence, it may be suggested that the lower reaches of the Dhiarizzos have known extensive erosion during the Holocene period while the Troodos Mountains were relatively stable. Especially where tributaries from the East joined the Dhiarizzos, large supplies of Pakhna and Lefkara formation clasts took place. This is observed in section MA, representing bedload deposits of a former Dhiarizzos channel. Additionally, this great influx of sediments deriving from the Pakhna formation was also observed at KIS1, where just north of the section a tributary joins the Dhiarizzos.

On the other hand, the fan sediments in section SOA/SOB and MB are clearly discernible from the former Dhiarizzos deposits through the absence of igneous stones deriving from the Troodos.

VIII.2.4. Ezousas (lithological map cf. plate 210: fig. 539 and especially the more detailed geological map of the Polis-Paphos area – Geological Survey Department Cyprus)

VIII.2.4.1. EZA

Throughout this section, the group of clasts originating from the Pakhna or Lefkara formation – chalk, silicified chalk and limestone- is mostly represented (cf. plate 130: fig. 327). Cherts are more present in the lowermost units while less in the upper 4 units. They probably derive from the local Mamonia formation chert outcrops, just north of this section. The relatively rounded sandstones suggest they might have been transported over some distance, thus may derive from the Pakhna/Lefkara formation somewhere in the Troodos foothills. Serpentinites, occurring only in the upper units, eroded from a local source, just north of this section. Their occurrence from EZA4 on might indicate the increased incidence of local erosion. This was also suggested by the increased angularity of the clasts in the uppermost units (see VII.2.4.1). Additionally, a far-travelling component occurs also throughout the section and is marked by the occurrence of rounded diabase and (micro-) gabbro stones. Most basalt stones may derive from local outcrops as is suggested by their angularity.

VIII.2.4.2. EZB

EZB has a similar lithological composition as EZA (cf. plate 138: fig. 350). The group of stones deriving from the Pakhna or Lefkara formation (chalks, silicified chalks and limestones) is most present. Sandstones and cherts from the Mamonia formation just to the north of the section are frequently present. The locally occurring serpentinite is only present in small quantities in the upper three units (similar as in EZA). Moreover, the small amount of shales probably derives from the Terra formation in the North. Additionally, far-travelled diabase from the Troodos Mountains is present in the upper three units. Furthermore, some far-travelled (micro-) gabbro is also present in EZB1.

VIII.2.4.3. EZC

A large proportion of stones from the Pakhna or the Lefkara formation (silicified chalks, limestones and chalks) has been observed (plate 142: fig. 365). Pakhna and Lefkara formation outcrop along a major part of the river between Episkopi and Ayios Dhimitrianos. The sandstones, cherts and basalt stones may derive from more local Mamonia outcrops. Furthermore, the relatively large proportion of mudstones has a local origin as well. Diabase and (micro-) gabbro on the other hand, have been transported over a long distance as they derive from the Troodos Mountains.

VIII.2.4.4. EZD

A dominant proportion of sandstones has been observed within this section (cf. plate 149: fig. 382). They probably derive from a Mamonia outcrop to the East. Cherts, occurring in smaller quantities, possibly also derive from the Mamonia outcrop to the East. The Lefkara formation component (chalks, silicified chalks and limestones) is also frequently present. They probably originate from a source to the East. The basalt, which is increasingly present in the uppermost layers, also has a source in the East. Hence, EZD only contains local sediments with a source East of the section.

VIII.2.4.5. EZE and EZF

The Pakhna or Lefkara formation group of clasts (limestones, chalks, silicified chalks and shales) is frequently present and originates from the North (cf. plate 154: fig. 395 and plate 160: fig. 409). Moreover, the sandstones and cherts may also derive from the North, where Mamonia formation outcrops. The serpentinite present in some units derives from serpentinite outcrops, located just north of the section. The basalt, present in small quantities in most units, is a very local component as it outcrops just to the East of the section. The occurrence of diabase indicates long-distance transport of these clasts, originating in the Troodos mountains.

VIII.2.4.6. EZG (plate 213: fig. 542)

The stones in section EZG consist mostly of sandstone, having a local origin in the Kannaviou formation (cf. plate 167: fig. 428). Limestones, silicified chalks, cherts and calcarenites from the Lefkara formation are also present in the section. The Lefkara formation outcrops only to the East in the direction of the village Asproyia. The geological map indicates that many landslides took place within this area. Basalt, present in small quantities only in unit EZG3, originates locally as this section is located within the Pillow Lava area. Diabase travelled at least 1 km from its source and occurs frequently throughout the section. Gabbro, possibly micro-gabbro, which is present in small quantities in EZG3, derived from the same diabase area. It is highly unlikely that the gabbro clasts derived from the Troodos plutonic core.

VIII.2.4.7. EZH (plate 213: fig. 542)

Section EZH has a similar lithological composition as EZG (plate 173: fig. 443). Sandstones are the dominant stones present, deriving from the local Kannaviou formation. However, sandstones occur less frequently in the upper units. Additionally, limestones, silicified chalks, chalks, cherts and calcarenites from the Lefkara formation outcropping near the village Asproyia, are often present. Furthermore, basalt, which is only present in small quantities, has a local origin, as section EZH is located within the Pillow Lava area. Moreover, a relatively large quantity of diabase stones and a small group of (micro-) gabbro stones, derive from the diabase area, at least 1 km to the North.

VIII.2.4.8. Conclusion and discussion provenance of the Ezousas clasts

Most sections in the lower portion of the Ezousas drainage contain a large proportion of relatively local stones. However, most sections also contain a very small proportion of igneous stones, indicative of long-distance fluvial transport. On comparison with the Pleistocene sediments (Poole & Robertson 1998: fig. 21), it is noteworthy to point to the different lithological composition of the fluvial deposits. In general, the Pleistocene alluvial deposits of the Ezousas seem to contain a larger proportion of igneous stones than the Holocene deposits. This lithological change between Pleistocene and Holocene deposits, is probably related to different geological processes at work in the Pleistocene than in the Holocene. However, as expected, the sections EZG and EZH, North of Kannaviou contain a larger proportion of igneous stones as a result of their location.

Furthermore, of importance is that it was possible to locate exactly the erosion source of some deposits. These are important data, which should be connected with archaeological survey data. For example, the relatively abundant occurrence of Lefkara formation clasts in sections EZG and EZH could only derive from the outcrops in the East around Asproyia (cf. plate 213: fig. 542). Also in EZA and EZB, one of the erosional sources is known. The serpentinite, only present in the units deposited between 160 ± 160 BC and 510 AD, points to local erosion somewhere between the area of Marathounda to Ayia Marinoudha and the Ezousas. Moreover, the occurrence of basalt in EZE and EZF could be related with erosion of basalt of the Mamonia formation just to the East of the section.

VIII.2.5. Xeropotamos (geological map cf. plate 210: fig. 539 and especially the more detailed geological map of the Polis-Paphos area – Geological Survey Department Cyprus)

VIII.2.5.1. XA

Clasts from the Lefkara formation are most present within this section (plate 179: fig. 457). They consist of limestones, silicified chalks, chalks and shales. Sandstones and cherts, originating from Mamonia outcrops are also frequently present. The shales, which are present in small amounts, derive from the Terra formation. Moreover, the occurrence of diabase and (micro-) gabbro clearly indicates the long distance transport of the Xeropotamos. However, they represent a minority of the clasts.

VIII.2.5.2. XB

The clasts within this section consist mostly of sandstones, probably deriving from Mamonia outcrops (plate 184: fig. 472). Additionally, the relatively small number of cherts possibly originates from Mamonia outcrops as well. The large amount of limestones and the small amount of silicified chalks, both derive from the Lefkara formation. The serpentinite occurrence in XB3 could only be the result of erosion at a few possible places in the lower reach of the drainage. They probably derive from serpentinite outcrops around Kholetria though may also originate from outcrops around Ayios Nicolaos. The diabase and (micro-) gabbro have been transported a long way from their source in the Troodos Mountains. Basalt on the other hand, may derive from the outcrop near Kholetria or from the outcrop near Ayios Nicolaos.

VIII.2.5.3. XC

Sandstones and cherts deriving from Mamonia chert formation constitute the largest group of stones present (plate 190: fig. 486). These formations outcrop at several places along the Xeropotamos. Furthermore, clasts deriving from the Lefkara formation (limestones, chalks and silicified chalks) also represent a large group of stones. The Lefkara formation outcrops at several locations along the Xeropotamos. The small group of serpentinites present in the section most probably derives from serpentinite outcrops around Kholetria, though may also derive from outcrops in the neighbourhood of Ayios Nicolaos. The small number of basalt stones present in this unit, possibly derive from the outcrop near Kholetria though also may derive from the outcrop near Ayios Nicolaos. On the other hand, diabase and (micro-) gabbro stones in the section point to long distance transport of some clasts as they only have a source in the Troodos Mountains.

VIII.2.5.4. XD

The group of stones deriving from Mamonia outcrops (sandstones and cherts) is most present and may derive from several areas along the Xeropotamos (plate 196: fig. 501). Moreover, the group of stones from the Lefkara formation (limestones, chalks, silicified chalks and shales) occurs frequently throughout the section. The Lefkara formation also outcrops at several places along the Xeropotamos. Serpentinite and basalt occur in small numbers throughout the section and derive from specific localised sources along the Xeropotamos. The serpentinites most probably derive from serpentinite outcrops around Kholetria, though may also derive from outcrops in the neighbourhood of Ayios Nicolaos. The basalt stones possibly originate from the outcrop near Kholetria though may also derive from the outcrop near Ayios Nicolaos. Far-travelled diabase stones and (micro-) gabbro stones have been identified as well and have a source in the Troodos Mountains.

VIII.2.5.5. XE

Section XE has a similar lithological composition as section XD (plate 202: fig. 518), except for the occurrence of some calcarenite stones, deriving from the marine terrace deposits in unit XE2.

VIII.2.5.6. XF

Only XF2 contains a considerable proportion of clasts. The group of stones deriving from the Lefkara formation is most present, consisting of limestones, chalks and silicified chalks. Additionally, sandstones, possibly deriving from Mamonia outcrops are also well present. The small number of basalt stones may derive from the outcrop near Kholetria though may also derive from the outcrop near Ayios Nicolaos. Moreover, a relatively large proportion of far-travelled Troodos diabase stones is present.

VIII.2.5.7. Conclusion and discussion provenance of Xeropotamos sediments

The investigated sections along the Xeropotamos almost all have similar lithological distributions. This is probably a result of the fact that they are all located in the same neighbourhood at the mouth of this river. Hence, it is mostly impossible to discover precisely localised erosion sources. However, the restricted outcrops of some lithologies along the Xeropotamos may make it possible to identify the source of some of the erosion. More specifically, the occurrence of serpentinite and basalt stones points to erosion at the serpentinite and basalt outcrops around Kholetria or around Ayios Nicolaos. Far-travelled igneous stones are only present in small quantities in the sections, with exception of XF where more diabase is present than in the other sections. Overall, igneous stones are far less present in the Holocene alluvial deposits of the Xeropotamos than in the Pleistocene alluvial deposits (see Poole 1998: fig. 21).

VIII.2.6. Discussion and conclusion

We may say that the lithological distribution of the samples indicates that the West Cypriot Pleistocene alluvial deposits were different than the Holocene alluvial deposits. However, this observation was especially noticeable in the major river valleys of Western Cyprus. Hence, it is can be posed that different geological, alluvial or causal factors took place during the Pleistocene compared to during the Holocene. As a matter of fact, several reasons for this marked difference can be posed.

A first possible explanation could be that the Pleistocene was marked by different, more extreme climatic conditions than the Holocene. Poole & Robertson (1998) suggest that the Pleistocene climate was periodically more humid during the interglacials which favoured erosion (Poole & Robertson 1998: 564). A larger water supply for the river might have transported stones over a larger distance in a shorter period.

A second explanation may be that the Troodos Mountains were uplifted and unroofed by consequent erosion during the Pleistocene. Indeed, Poole & Robertson (1998) suggest that the Early to Middle Pleistocene alluvial deposits were mainly the result of a high rate of tectonic uplift during that period. The early Middle Pleistocene deposits were due to the combined cause of a high glacio-eustatic sea level, followed by surface uplift. Moreover, the fluvial deposits from between 219-184 ka BP and those from between 141-116 ka BP, resulted from high sea levels, followed by further uplift and river downcutting. Hence, the Pleistocene period was marked by severe tectonic uplift centred on the Troodos. Consequently, this triggered erosion of the Troodos Massif and resulted in the high incidence of igneous stones in the Pleistocene alluvial deposits.

A third possible cause for the different lithological composition of the Holocene alluvial sediments compared to the Pleistocene sediments, might be attributed to human impact on the landscape. Humans first appear in the Cypriot archaeological record at the start of the Holocene. They introduced the Neolithic package to the island and since then continued to depend on farming and herding for subsistence. In general, for these activities humans probably preferred the lowlands and avoided the mountain areas. Hence, the increased proportion of sedimentary stones and decreased proportion of Troodos derived igneous stones in the Holocene alluvial sediments might reflect the human preference for the lower portion of the drainage.

Furthermore, this provenance study successfully identified the exact erosional source in some cases. In order to gain deeper insight into the human factor in causing alluviation, it is necessary to investigate the site evidence for the period under consideration in greater detail at the identified erosional source.

In this way, some interesting direct correlations are visible between human use of the landscape and erosion. Indeed, the frequently occurring chalks, silicified chalks and limestones in the alluvial deposits in section EZG, could only provenance from one specific Lefkara formation source to the East around Asproyia and Pano Panayia.

Interestingly, in chapter III.2.3 and chapter V.2.2, it has been mentioned that at Asproyia-*Ayios Sozondas* (cf. location indicated on map of plate 213: fig. 542) a Medieval mining and smelting site was discovered, consisting of 24 adits in the pillow lava and 2,000 square meters of slag heaps. The occurrence of slag heaps suggests the use of fuel wood and consequent deforestation of the area. Hence, the marked synchronicity between erosion in that particular area sometime after 1140 ± 20 AD and the Medieval mining and smelting activities seems to indicate human impact on the landscape. However, this erosion might have been triggered by specific climatic conditions.

Furthermore, also in EZA and EZB, one of the erosional sources is located relatively precisely. The serpentinite, only present in the units deposited after the units dated between 160 ± 160 BC and 510 AD, points to local erosion which took place West of the Ezousas on the serpentinite outcrops. In this context, of mention is the large settlement site of Ayia Varvara-*Pavoules* (cf. V.2.2.2.B), located in the neighbourhood of serpentinite outcrops, with evidence of Late Roman, Early Byzantine and Medieval activity.

Moreover, the large proportion of Lefkara formation stones in section PR1 suggests a source in the East. Indeed, erosion might have taken place sometime after 1200 AD as the Prastio Ayios Savvas monastery was founded ca. 1120 AD upslope in the east. It is suggested that the activity at the monastery increased in the 15^{th} century AD and reached its height in the 16^{th} century AD (Rupp 2000).

VIII.3. River morphology

The river morphology has implications for the preservation of the archaeological record in alluvial contexts. This is why it is necessary to try to identify the former river environment of the Western Cypriot rivers. Furthermore, the river morphology also had an impact on the decision making of former Cypriot humans. Stone bridges were probably only constructed in stable areas and mills and aqueducts were only built where water was available.

VIII.3.1. Morphology and velocity

However, differentiation between ancient meandering and braided environments is not a simple task. The most easily discernible criterion to differentiate is that braided river deposits show a greater proportion of channel fills relative to lateral accretion deposits, while meandering rivers show a larger proportion of lateral accretion deposits. Furthermore, meandering river deposits commonly show a greater contrast in grain size between channel fill and channel bar deposits. Moreover, meandering rivers also have a larger palaeo-current variability. Additionally, the bedding type is also a useful criterion to discern between river morphologies. Epsilon cross-bedding is often associated with deposition in a meandering single channel system ; plane bedding is often associated with the deposition in a low-sinuosity single channel stream with large tabular lateral or medial bars and trough cross-bedding with colluvial lenses is typical for multi-channel rivers (Rust & Koster 1984: 53-69). However, for the here studied Western Cypriot fluvial sediments, the best-documented criterion was the proportion of channel fills relative to lateral accretion deposits and mostly the only visible criterion.

Some idea of the magnitude of the flows can be gained from the application of equations, which attempt to relate a given particle to the velocity that would be required to transport the specified particle size. Therefore, the following equation will be applied:

$$Vb = 0.64\ D^{0.44}$$

V_b is the mean velocity at a distance from the bed determined by the particle size in ft/s. D is the particle size in mm. A conversion factor of 1.4 may be applied to correct Vb to the mean flow velocity if, as seems reasonable to assume in this case, the flow depth is several times the particle diameter (Gomez 1987: 354).

We may say that the Stavros-tis-Psokas was certainly since Venetian times, a low sinuosity, meandering stream as it appears today. The Venetian bridge (cf. cover fig.) also corroborates this and suggests that the river was perceived as relatively stable. However, in recent times the river was rather unstable and the channel under the bridge was abandoned. As a matter of fact, a 70 years old man of the village of Simou narrated that in his lifetime, the river had changed its course three times at this specific locality Sarama-*Skarphos*. First, the river flowed under the Venetian Skarphos bridge. Subsequently, the river channel moved several meters to the North. In 1962, after a severe storm, the river channel left its course again and moved to a more southerly location, just adjacent to Skarphos bridge.
The velocity equation suggests that a mean velocity of approximately 2.7 m/s would be required to transport the average size of particles in pit 8, unit 5. However, some very large stones suggest that a velocity of about 2.9 m/s was required to move these stones. The size of the clasts in layer 3 of the same pit, indicates that the velocity was slightly higher, being about 3 m/s.

Furthermore, it is suggested that also the Agriokalamos was a meandering river as is indicated by the occurrence of a large quantity of fine grained overbank deposits. Furthermore, the rip-up clasts in KAGB and KAGD suggest the occurrence of an undeep oxbow lake in the neighbourhood, indicative of an abandoned meander, a common feature for meandering rivers. The velocity for an average stone of KAGB11 would have been about 3 m/s and up to 3.2 m/s for the largest stones.

The Dhiarizzos, on the other hand was probably, as it appears today, a braided river. Its Holocene fluvial sequence is marked by an abundance of coarse deposits, typical for braided streams.

The KOL1 section in the coastal lowlands, indicates that sometime after ± 1560 AD, the Dhiarizzos first (KOL1.4) had a mean velocity of 2.5 m/s, even up to 3.4 m/s as is indicated by the largest stones. Subsequently the size of the stones in KOL1.3 and KOL1.4, indicates that the velocity increased. An average stone in these units needed a velocity of 2.9 m/s to be transported; the largest stones even a velocity up to 3.1 m/s and 3.5 m/s.

Additionally, at the undated section of KOL2, situated in the coastal lowlands as well, a high velocity was identified, consisting of 3.2 m/s in the bottom layer (KOL2.4) to transport the average stone and of 4.7 m/s to transport the largest stones. However, the average stone size in KOL2.3, suggests that the velocity decreased to 3.2 m/s to transport an average stone and 4.7 m/s to transport the largest stones. Subsequently, in KOL2.2, the velocity increased slightly again to 3 m/s for an average stone and up to 4.2 m/s to move the largest stones in this bed.

Moreover, at the PH site, the velocity was probably around 3 m/s to transport an average stone, and may have been up to 3.9 m/s as is indicated by some larger stones. Furthermore, velocity calculations at the MA site near Prastio, indicate a mean velocity of 2.7 m/s for an average stone and a velocity of 3.6 m/s for a large stone within the unit MA3, post-dating 1320 ± 60 AD. An average stone in MA1 is slightly larger than in MA3 and indicates a slightly higher velocity, being about 3.2 m/s for an average stone and 3.4 m/s for a large stone.

Finally, at Kithasi, the velocity was probably relatively low in KIS1.7, being only about 2.2 m/s. KIS1.4 deposited sometime after 894 ± 250 AD, indicates that the velocity was about 2.9 m/s (to transport an average stone) or even up to 4.3 m/s (to transport the large stones). KIS1.2 had a similar mean velocity as KIS1.4, though contains less large stones.

Furthermore, the Ezousas, today a braided river, was supposedly in the past a braided river as well, marked by a large proportion of coarse alluvial deposits. The Ezousas channel represented by EZA12 with a deposition date between 160 ± 160 BC and 200 AD, had a mean velocity of 2.8 m/s for an average stone size and even up to 3.7m/s to transport the largest stones within the channel. The channel in EZB4 probably has a similar date as the channel in EZA12. However, a slightly higher velocity was attested, measuring about 3.4 m/s in order to transport an average sized stone and up to 4.1 m/s in order to transport the largest stones present within the channel deposits. Channel deposit EZB1 is probably much more recent and has a slightly lower velocity than the previous channel at this location, measuring about 3.1 m/s to transport an average stone, and up to 3.6 m/s to transport the largest stones.

The velocity of the channel in EZC3 probably was about 3.1 m/s in order to transport an average stone present in the unit and up to 3.4 m/s to transport the largest stones.

EZE4 and EZF7 represent the same channel. However, the average sampled stone of EZE4 is much smaller than the one in EZE7. However, this difference in average size is probably due to unrepresentative sampling. It is suggested that the average measurement of the EZF7 sample is most representative, for which a mean velocity of 3.2 m/s was measured. In order to transport the larger stones a velocity of up to 4.3 m/s is even suggested. Channel deposits in EZE2 suggest a velocity of 2.7 m/s for the average stone and a velocity of up to 3.2 m/s to transport the largest stones.

For the channel deposits EZF5 and EZF3 a mean velocity of 3.2 m/s is suggested and up to respectively 4.1 m/s and 3.5 m/s in order to transport the largest clasts in EZF5 and EZF3. In EZF1, the velocity dropped to 2.5 m/s for transporting average sized stones and 3.6 m/s to transport large stones.

Sometime around or after 1140 ± 20 AD, the Ezousas channel, represented in section EZG, had a mean velocity of about 3.1 m/s and possibly even up to 4 m/s. Section EZH indicates similar velocities and may be synchronous with section EZG.

Along the Xeropotamos, section XB represents a longitudinal bar deposit, a typical feature of a braided river. For the more remote past, it is suggested the Xeropotamos was a braided river as well, as is marked by the large proportion of coarse-grained alluvial deposits.

Velocity calculations at section XA indicate that sometime around or after 432 ± 592 BC, the channel had a velocity of about 3.1 m/s (XA4). Furthermore, the calculations indicate that the velocity in the channel represented by unit XA1 was lower than the one represented by unit XA4 (though the sample was retrieved in a zone with relatively small clasts and may not be representative for the deposit). It is suggested that the channel represented by unit XA1 had a minimum velocity of 2.1 m/s.

Furthermore, the velocity of the channel represented in XC4 was probably about 2.8 m/s. The channel represented in unit XC2 had a slightly higher velocity of about 3.2 m/s and even up to 4.4 m/s according to the largest clasts.

Unit XD6 of section XD, represents the remains of several flood events. The velocity calculation indicates that the river had a mean velocity of 3.1 m/s, and maybe up to 4.4 m/s. The gravel deposit XD4, post-dating 1730 ± 70 AD, indicate that the river had a similar velocity of 3.1 m/s. However, the largest stones within this unit are smaller than the largest stones of XD6, indicating the maximal velocity was 3.4 m/s in the channel represented by XD4. Furthermore, the channel represented by the deposits XD2 probably had a slightly lower mean velocity of about 2.8 m/s.

Additionally, velocity calculations in section XE, indicate that the channel represented in unit XE5 had a mean velocity of 2.7 m/s and even up to 3.7 m/s (to transport the largest stones present in this unit). The velocity increased in XE4, calculated at 3.4 m/s for the average stones and may have been up to 4.2 m/s.

Velocity calculations for section XF, indicated a mean velocity of 2.9 m/s for the channel represented in XF2. However, the velocity might have been up to 3.3 m/s in order to transport the largest stones.

The Water Development Department provided flow data on the investigated rivers from the sixties until nowadays. Leafing through the data, it became clear that a comparison between the present day velocity and the ancient velocity is impossible, as the flow of the Western Cypriot rivers varies from day to day, with almost no flow during the summer months and peak flows in the winter months.

VIII.3.2. Implications of the former river morphology for the preservation of the archaeological record

Vita-Finzi (1969) refers to the Younger Fill as predominantly consisting of stratified sands and silts. The Western Cyprus Geo-Archaeological Project, rarely came across these types of deposits. This is probably a result of the fact that the rivers on Cyprus had a different morphology than those investigated by Vita-Finzi. Indeed, most investigated sections are located along the three major rivers -Dhiarizzos, Ezousas and Xeropotamos-, coming straight out of the Troodos mountains. It has been suggested above that they had a braided morphology in the past as well as nowadays. Fine-grained sediments are minor constituents of the depositional record in braided streams because periodic high flows tend to keep silt and clay in suspension and transport it through the system without allowing it to accumulate. Moreover, braided streams develop in areas where an overabundance of coarse sediment is available (Waters 1992: 123-126). As a matter of fact, the dynamic processes associated with braided rivers, especially the periodic high-energy flows create a setting that is not conducive to the preservation of archaeological sites. During episodes of flooding, most sites situated on the bars and banks of a braided river are destroyed. Artefacts, hearthstones, charcoal and other remains are swept from the surface of these sites and transported into a secondary context. Artefacts and other archaeological debris are rolled and behave like natural sediment particles as they become incorporated into the active channel sediments. These artefacts reworked by the river are referred to as "arteclasts". However unusual, primary archaeological contexts may be preserved in a braided stream environment.

However, the Agriokalamos and Stavros-tis-Psokas sediments resemble more Vita-Finzi's descriptions of the Younger Fill. It is suggested that the Agriokalamos and Stavros-tis-Psokas were meandering rivers, as they appear nowadays as well. Within meandering river environments, sites have better preservation chances. However, artefacts incorportated in lateral accretion deposits generally occur in secondary contexts. Relatively undisturbed archaeological sites are likely to occur in the vertical accretion sediments of the floodplain. Archaeological material can become incorporated into the floodplain sediments of the meandering river when occupation takes place on the lowlands adjacent to an active river channel during a period of stability. Good site preservation is likely to occur if after abandonment the site was inundated and buried. However, also in a meandering context, archaeological preservation depends on the energy level associated with the deposition of sediments.

IX. Stability and soil formation

The soil archive provides information on several issues. First, it informs about landscape stability, its occurrence and duration. As a matter of fact, a soil can only develop in the floodplain when there is an absence of alluviation. Moreover, soil formation makes it possible to identify the palaeo-environment (e.g. climate and vegetation cover).

In chapter VII, soil formation in the investigated sections was recognised through the combination of several laboratory results. A high organic matter content suggests an A-horizon. A mass specific magnetic susceptibility peak indicates the occurrence of a B_t-horizon as well as an A-horizon. The pH value may give an indication of the calcium carbonate translocation. Moreover, the particle size analysis shows the quantity of clay fractions present in the sample and can thus identify the illuviation of clay. In this chapter, the interpretations of the sediment analysis (cf. chapter VII) will be used in order to gain further understanding of the Western Cypriot landscape evolution.[18]

IX.1. Soil formation classification

Van Andel (1998) described a typical, mature Mediterranean soil. The profile displays an upper dark, organic A-horizon, grading to a pale leached E-horizon. Underneath the E-horizon, solutes carried down by winter rains precipitated Fe and Mn oxides and hydroxides and deposited illuvial clay in a yellow-brown to red B_t-horizon. Additionally, dissolved $CaCO_3$ is precipitated low in the B_t-horizon, which is named B_k-horizon. If the amount of carbonate exceeds 50%, the B_k- becomes a K-horizon. The soil profile ends with the only slightly altered substrate, the C-horizon (van Andel 1998: 363-364).

[18] In retrospect, micromorphology would have been relevant for better understanding of the complex soil formation processes. However, there was no time to acquire and apply those skills.

However, a mature soil is seldom attested within alluvial contexts, as interruption by burial is a common phenomenon. On one hand, polycyclic profiles occur frequently in the Western Cypriot river valleys. This so called *polysequum profile* consists of soil formation on a thin fresh deposit on an existing soil, in such a way that both, old and new material, are involved in the soil processes. On the other hand, the observed floodplains were relatively unstable during the Holocene. As a result, the palaeosols only had little time to develop. Consequently, in most of the recognised palaeosols, only incipient soil formation could take place.

The occurrence of soil formation in the floodplain is proof for landscape stability at the given location. In the floodplain, this stability consists of the lack of sedimentation. As a consequence, the degree of soil formation depends partially on the time of exposure and stability, though also on other factors such as climate and vegetation.

On one hand, the degree of soil formation is partially an indicator of the duration of the stability. It has been observed that Mediterranean calcareous soils show with increasing age the following maturation processes. An age-related increase in clay content takes place in the B_t-horizons. This increasing maturity of B_t-horizons is noticeable by changes in colour, structure and abundance and thickness of clay films. Maturation intensifies the Munsell colour hue from 10YR to 2.5 YR or even 10R as a result of the precipitation of Fe oxides. Structurally, the B_t-horizon is composed of units called peds that range from small granular aggregates to ever-larger blocks and prisms. Moreover, the B_k/K-horizon matures through a series of stages defined by the morphology of precipitated $CaCO_3$ (calcrete) (van Andel 1998: 367-368).

On the other hand, the type and degree of soil formation is also a result of environmental factors. As a matter of fact, palaeosols are palaeo-climatic archives. However, the integrity, accuracy and retrieval of the palaeo-climatic information depend on the degree of development and preservation of diagnostic, soil-formed properties and whether the properties can be interpreted via modern-day analogues.

Cypriot alluvial palaeosols are not straightforward interpretable to climatic conditions as they are only poorly developed. In chapter II.1.4 some climatic driven processes were mentioned, such as the precipitation of calcium carbonate and the supply and breakdown of organic matter. Obviously, climatic changes have a short-term impact on the precipitation of calcium carbonates in the soil. Low precipitation during a period of only 50 years can already lead to the development of caliche. This is because precipitation translocates calcium carbonate from the surface horizon to an accumulation layer at some depth. On moisture deficit, calcium carbonate is reprecipitated (Driessen & Dudal 1991: 221). Temperature also affects the $CaCO_3$ equilibria. CO_2 is less soluble in warm water than in cold water, thus the $CaCO_3$ solubility decreases with rising temperature. As a consequence, the position of the $CaCO_3$ bearing horizon is related to the depth of leaching, which is related to climate (Birkeland 1999: 127-129). Furthermore, Nakos described the relation between soils and bio-climatic zones in Greece and found that the A-horizon in the zone with a Mediterranean climate is about 1.3 pH units more alkaline than A-horizons in the Mountainous zone (Nakos 1984: 104). Moreover, the organic matter content of the A-horizon doubles almost corresponding to a drop in mean annual temperature of about 10 °C. This is probably due to a lower rate of litter decomposition (Nakos 1984: 118). Another climatic indicator is that clay illuviation only takes place on humid and sub-humid soils in the Mediterranean basin.

The Western Cyprus Geo-archaeological Project identified several palaeosols and present day soils on the alluvial deposits, of which most were only identifiable through laboratory analysis as a result of their immaturity.

IX.2. Soils on alluvial deposits developing at present

In order to gain understanding of the duration of soil formation and thus the duration of landscape stability at this location, it is useful to gain understanding of soils formed on the present day exposed alluvial sediments.

IX.2.1. Stavros-tis-Psokas

IX.2.1.1. TA and TB (plate 214: fig. 543)

The soil on TA8 and TB1 (present day surface) started to develop sometime after ± 753 AD. Hence, the soil could form at longest for about 1247 years. Indeed, it is observed that this soil has a relatively high maturity, which suggests that a long time has passed since the last unit was deposited. The A-horizon has an organic matter content between, 6.6 and 8.2%. Clay was illuviated to a depth between 0.72 and 2.48 m. Moreover, calcium carbonate has been translocated to a depth between 1.35 m and 2.85 m. The great depth of the soil may be related to specific climatic conditions under which the B_k-horizon developed. The deep calcium carbonate translocation may be the result of some periods of high precipitation and relatively cold temperatures (Birkeland 1999: 128). Furthermore, the relatively deep clay leaching also indicates that this soil has developed for some time yet.

IX.2.2. Dhiarizzos

IX.2.2.1. KOL1 (plate 215: fig. 545)

Moreover, the soil developed on the surface of KOL1 is younger than 440 years old. An incipient A-horizon has formed, having an organic matter content of about 3.2 %. At a depth between 1 and 2.20 m clay has illuviated. Additionally, calcium carbonate has been translocated to a depth between 2.20 and 3 m. The parent material of most part of the soil consists of gravel and sand. This is probably why the soil formation is so deep in relation to the only short period under which the soil could develop.

IX.2.2.2. SOA

Incipient soil formation is observed on the present day alluvial fan surface. Only an A-horizon could develop containing about 5.5% organic matter, which suggests that soil formation only started recently. As a consequence of this immature soil on the present day surface of the alluvial fan of SOA, it is suggested that the last 2 meters of the alluvial fan were deposited only fairly recently.

IX.2.2.3. SOC

The soil formed on SOC1 is rather undeep which supports the recent date of deposition of the sediments. A slightly higher organic matter content in the surface layer suggests that an A-horizon started to develop. Moreover, the exceptional high pH degree within the upper units is probably the result of present day ploughing and cultivation. Hence, this all suggests that units SOC1 and SOC2 were deposited fairly recently.

IX.2.2.4. PR1 (plate 214: fig. 544)

PR1.1 only has a slightly higher organic matter content indicative of soil formation (4.9%). Hence, we may conclude soil formation on this surface took place only recently. Consequently, the units PR1.1 to PR1.4 were deposited relatively recently. As a matter of fact, the sherds occurring in the section suggest a date sometime after ± 1140 AD, thus a period of less than 860 year that soil formation could take place.

IX.2.2.5. MA (plate 216: fig. 546)

The present soil on the surface of MA could only develop over a period less than 740 years as the deposition of the sediments (on which the soil formed) took place sometime after 1320 ± 60 AD. However, some clay illuviation has been observed to a depth of approximately 1.2 m. Thus an incipient B_t- horizon has been formed. Furthermore, calcium carbonate has been translocated to a depth of approximately 1.5 m. The organic matter content of the A-horizon is relatively low, only about 2.5%. This is probably a result of the gravelly and sandy parent material.

IX.2.2.6. MB (plate 216: fig. 547)

The soil formed on the surface of MB developed sometime after ± 800 AD, thus could develop over a period of less than 1200 years. That some time has passed since the soil formation started is suggested not only by the A-horizon formation, but also by the occurrence of an incipient B_t- and B_k-horizon at a depth between 0.8 and 1.5 m. Hence, it is suggested that the sediments on which the soil developed were deposited around or shortly after ± 800 AD.

IX.2.2.7. KIS1 (plate 217: fig. 548)

The soil developed on KIS1 consists of an A-horizon with an organic matter content of about 6.3% and an incipient B_k- and B_t- horizon at a depth of 1.20 m. The relatively deep soil is probably partially a result of the fact that a large proportion of the parent material consists of gravel. The soil formation post-dates 894 ± 250 AD, thus could only develop for about 1350 years at longest. The degree of soil formation supports a considerable period of soil development. Consequently, it could be that the upper 2.5 m of the section were deposited sometime shortly after 894 ± 250 AD.

IX.2.3. Ezousas

IX.2.3.1. EZA

Some soil formation took place on EZA0 as an incipient B_t-horizon could develop on EZA2. However, when the upper unit (EZA0) was partially removed, further soil formation took place and a new B_t-horizon developed in EZA4. Both B_t-horizons show a marked redness probably as a result of periodic water saturation. Most red soils in the Mediterranean are considered to be typically old. However, the soils formed on EZA1 and EZA0 are certainly young. Birkeland mentions that he also observed a red colour in some young Mediterranean soils, which have not significantly undergone climate change. Though in these young soils, the red colour is restricted to the B_t-horizon (Birkeland 1999: 221). This is also the case here.

IX.2.3.2. EZC (plate 217: fig. 549)

The soil formed on the present day surface is marked by a relatively high organic matter content (11%). Furthermore, some carbonate translocation and clay illuviation took place. The clay illuviated to a depth between 0.5 and 1.30 m. Furthermore, the possible incipient B_k-horizon is located at a depth between 1.3 and 1.55 m.

IX.2.3.3. EZD (plate 218: fig. 550)

The soil formed on the present day surface started to develop sometime after 1221 ± 52.5 AD and contains only little signs of soil formation. The uppermost unit has an organic matter content of 5.7%, suggesting A-horizon formation. The relatively high pH in the uppermost layers is probably a result of present day farming and ploughing on this surface. The small degree of soil formation suggests that the sediments on which the soil has formed, were deposited relatively recently, probably quite sometime later than the date of the youngest sherd (1221 ± 52.5 AD).

IX.2.3.4. EZE (plate 218: fig. 551)

The soil formation on the surface of EZE consists of an A-horizon containing about 6.4% of organic matter. Furthermore, some clay illuviation took place to a depth between 0.55 m and 1.5 m. As a consequence of the degree of soil formation, we may say that some time has passed since the deposition of the sediments on which this soil has developed. On comparison to the soil developed on KOL1, it is possible to suggest that the soil on EZE developed over more than 400 years.

IX.2.3.5. EZF (plate 218: fig. 552)

The soil on the surface of EZF is similar to the one on EZE. It consists of an A-horizon with a relatively high organic matter content of about 7.3%. Furthermore, some clay was illuviated to a depth between 0.80 m and 1 m. Also some carbonate translocation has been observed, thus an incipient B_k-horizon formed at a depth between 1 and 1.20 m. Hence, this soil is relatively well-developed and suggests that the sediments on which the soil formation took place, have been deposited for some time yet. On comparison with the soil developed on KOL1, it is possible to suggest that the soil on EZF developed for more than 400 years.

IX.2.3.6. EZG (plate 219: fig. 553)

The soil on EZG only could develop over a period of less than ± 860 years. However, some evidence of soil formation has been attested. The A-horizon has an organic matter content of about 4.8%. Furthermore, clay illuviated to a depth of about 1 m and an incipient B_t-horizon has been formed. Additionally, carbonate was translocated to a depth of about 2 m. Hence, the soil on EZG suggests that some time elapsed since the soil formation started.

IX.2.3.7. EZH (plate 220: fig. 555)

The soil developed on EZH consists of an A-horizon with an organic matter content of about 7.2%. Furthermore, clay illuviation has been attested at a depth of approximately 1 m. Additionally, evidence of carbonate translocation has been attested at a depth of about 2.5 m. Hence, the soil formed on EZH is very similar to the one developed on EZG.

IX.2.4. Xeropotamos

IX.2.4.1. XB (plate 219: fig. 554)

The soil developed on XB consists of an A-horizon having an organic matter content of about 5.7%. Furthermore, an incipient B_t- and B_k-horizon has developed at a depth between 0.55 and 0.75 m. Although this soil formed on gravelly parent material, soil formation was not particularly to a great depth. As a consequence, it is suggested that the soil started to develop only relatively recently.

IX.2.4.2. XC (plate 221: fig. 556)

The soil on the surface of XC consists of an A-horizon, having an organic matter content of approximately 5.3%. Furthermore, leaching of clay took place to a depth between 0.7 and 1.3 m. Additionally, calcium carbonate has been translocated to a depth between 0.7 and 1.8 m. This soil is relatively deep, though this might be partially a result of gravel parent material. This soil is relatively well developed and suggests that some time elapsed since the deposition of XC. The degree of soil formation is comparable to the degree of soil formation of KOL1, thus probably about 400 years old.

IX.2.4.3. XD (plate 221: fig. 557)

On the surface of XD1, soil formation could take place for about 270 years at longest. The topsoil contains an organic matter content of about 3.3 %, which indicates incipient A-horizon formation. Moreover, some evidence of clay illuviation is attested at a depth of almost 1 m. No clear evidence is found of calcium carbonate translocation in the section. It should be mentioned that a large proportion of the parent material of the soil consists of gravel and sand. This is probably also the reason for the relatively deep soil leaching, considering the relatively short period of soil development.

IX. 2.4.4. XE (plate 222: fig. 558)

The soil formed on the surface of section XE is quite developed. The A-horizon contains an organic matter content of approximately 4.5%. Furthermore, some clay illuviation took place at a depth of about 0.7 m. Additionally, calcium carbonate precipitated to a depth of about between 0.76 and 1.4 m. As a consequence, it is suggested that some time elapsed since the sediments were deposited.

IX.2.4.5. XF (plate 222: fig. 559)

The soil on the surface of section XF is also quite well developed. The A-horizon has an organic matter content of about 4.6%. Furthermore, clay and calcium carbonate illuviated to a depth between 1 m and 2.5 m. Hence, it is suggested that some time elapsed since the sediments were deposited.

IX.2.5. Conclusion

This study of the present day surface soils on alluvial sediments is useful for the interpretation of the palaeosols (cf. next section). Furthermore, the degree of soil formation gives some indications as to how long the soil formation is under way and consequently when the alluvial sediments were deposited. This is especially useful for alluvial sections without artefacts, but also for all sections dated by a *terminus post quem*. Hence, the degree of soil formation provides additional chronological indications.

As a conclusion, we may say that the soil on KOL1 is probably approximately 440 years old and that the 2.8 m of sediments were probably deposited shortly after the date of the youngest sherd in the section. Furthermore, the soil on SOA only recently started to develop, which implies that the upper 2 m of the fan were relatively recently deposited. Additionally, the immature soil on SOC supports a rather recent date for this deposit. The soil on PR1 was also rather immature and suggests that the soil probably started to develop much later than the date of the youngest sherd in the deposit. Consequently, it is supposed that the upper m of the deposits post-dates quite some time 1140 ± 60 AD. Moreover, the soil developed on MA corroborates a formation period of approximately 680 years. It is thus suggested that the sediments were deposited only shortly after the date of the youngest sherd in the deposit. Also the soil on MB, suggests that quite some time elapsed since the soil started to develop, possibly shortly after 800 AD. The soil developed on the surface of KIS1 also suggests a relatively long period of landscape stability since the last 2.4 m of sediments were deposited. The degree of soil formation might corroborate a date shortly after 894 ± 250 AD for the start of soil development at this location. Furthermore, the soil on the surface of EZA suggests that only a short period elapsed since it started to develop. The soil on EZC is probably under development of some time as the soil formation is relatively deep. Moreover, the small degree of soil formation on EZD suggests that the sediments on which the soil formed, were deposited relatively recently, probably quite sometime later than the date of the youngest sherd (1221 ± 52.5 AD). The soil on EZE indicates that some time passed since the deposition of the sediments, probably more than 400 years. The same is suggested for the similar soil in EZF. The soils on EZG and EZH are similar and both suggest a degree of soil formation which could corroborate that the sediments on which the soil has formed were deposited sometime around ± 1140 AD. Furthermore, the immature soil on XB suggests a young date for the deposition of the sediments. The degree of soil formation on XC indicates that it may be a few hundred years old. The soil formed on XD, corroborates that the sediment was deposited about ± 1730 AD as quite some soil development took place. Additionally, the soil formation on sections XE and XF suggests also that some time elapsed since the sediments were deposited, probably a few hundred years.

IX.3. Palaeosols

IX.3.1. Palaeosols along the Stavros-tis-Psokas

IX.3.1.1. TA and TB (plate 223: fig. 560)

Soil formation in TB5/TA3 took place sometime after 300 ± 65.5 AD and was halted by a new phase of deposition which took place sometime after ± 753 AD. Thus, soil formation might have taken place over about 400 years, though this period might have been shorter as well as longer. The A-horizon is marked by a high organic matter content of about 9.7%. Moreover, an incipient B_t-horizon formed at a depth of about 0.34 m, thus relatively thin. Carbonate translocation has not been observed. The shallow depth of leaching suggests a relatively dry climate. Moreover, a lack of calcium carbonate translocation might be the result of a warm climate as $CaCO_3$ is less soluble in warm water. Hence, it is supposed that the climate was dry and warm at the time of the soil formation. This may corroborate the evidence from chapter II.1.2, which suggests that between 1700 and 1100 BP a dry climate established in the Eastern Mediterranean region.

IX.3.2. Palaeosols along the Agriokalamos

IX.3.2.1. KAGB14 (plate 223: fig. 561)

KAGB14 is a truncated soil, lacking its A-horizon. However, the B_t-horizon is preserved. As a consequence of the obliteration, little can be said about its development and conditions under which it was formed.

IX.3.2.2. KAGB8 (plate 223: fig.562)

The soil on KAGB8 is quite well developed. It has an A-horizon containing a relatively high organic matter content of 7.8%. Furthermore, a B_t- and B_k-horizon developed at a depth between 0.50 m and 1.40 m. The B_t-horizon is rubified (red colour), suggesting periodic water saturation.

IX.3.2.3. KAGB6 (plate 224: fig. 563)

The soil on KAGB6 is blurred by earlier soil development, though an A-horizon can clearly be discerned with a high organic matter content of about 10%. As a consequence of the blurred evidence it is difficult to undertake any further environmental interpretations.

IX.3.2.4. KAGC10 (plate 224: fig. 566)

The soil on KAGC10 is rather thin. The A-horizon has an organic matter content of about 3.2%. Furthermore, leaching of clay took place to a depth between 0.20 and 0.60 m. Additionally, calcium carbonate was translocated to a depth between 0.20 and 0.35 m. The high pH of the A-horizon suggests that the soil probably formed under a dry climate. The shallow depth of soil formation and the low organic matter content of the A-horizon also support that a dry climate prevailed.

IX.3.2.5. KAGC7 (plate 224: fig. 564)

The soil formed on KAGC7 is very immature. The only soil development that could take place, is the formation of an A-horizon, consisting of an organic matter content of about 4%. Hence, the time of exposure was probably rather short as it is known that A-horizons form quickly.

IX.3.2.6. KAGC3 (plate 224: fig. 565)

The soil developed on KAGC3 is rather thin. The A-horizon is marked by a relatively high organic matter content of approximately 3.8%. Additionally, clay and calcium carbonate were leached to a depth of 0.4 m. Hence, the observed soil formation is rather thin, which suggests a dry environment. Furthermore, the relatively high pH value of the soil also suggests a dry climate. Moreover, the relatively low organic matter content of the A-horizon might suggest that the vegetation was not very dense on the surface.

IX.3.2.7. KAGD15 (plate 225: fig. 567)

The soil formed on KAGD15 consists of an A-horizon with 7.9% organic matter. Furthermore, calcium carbonate precipitated at a depth of about 1 m. No clay illuviation has been identified. As a consequence of this lack of clay illuviation, we may suppose that the soil developed only over a relatively short period or that the soil developed under dry conditions. However the latter was probably not the case as the incipient Bk-horizon is located too low down the section to be formed under dry conditions.

IX.3.2.8. KAGD12 (plate 225: fig. 568)

The soil developed on KAGD12 has an A-horizon consisting of about 8.1% organic matter, an incipient B_t-horizon at a depth between 0.36 and 0.47 m and an incipient B_k-horizon at a depth between 0.26 and 0.47 m. Hence, the soil formation is relatively thin, suggesting relatively dry climatic conditions.

IX.3.2.9. KAGD8 (plate 225: fig. 569)

The soil formed on the surface of KAGD8 consists of an A-horizon with an organic matter content of 7.4%. Furthermore, clay leached to a depth between 0.27 and 0.65 m and formed a B_t-horizon with a typical red colour and prismatic peds. Hence, this soil could have developed over quite some time. However, the rather restricted depth of the soil may be related to specific climatic conditions, such as relatively dry conditions.

IX.3.2.10. KAGD5 (plate 225: fig. 570)

The soil shaped on KAGD5 only consists of an A-horizon with a relatively high organic matter content of 9.1%. This surface was exposed only for a short time before deposition continued as A-horizons form relatively rapidly.

IX.3.3. Palaeosols along the Dhiarizzos

IX.3.3.1. SOA2 (plate 226: fig. 571)

The soil formed on SOA2 is very immature. The surface of SOA2 was probably only extant for a short period as only an A-horizon could develop. The A-horizon contains 5% organic matter.

IX.3.3.2. SOA10

The soil developed on the surface of SOA10 consists of an A-horizon with an organic matter content of approximately 6%. Furthermore, an incipient B_k-horizon has been observed at a depth between 0.50 and 0.53 m. No evidence of clay leaching has been attested.

IX.3.3.3. SOA12 (plate 226: fig. 572)

The soil formation on the surface of SOA12 is rather immature. Only an A-horizon could be discerned, consisting of 6% organic matter. Obviously, at this location the landscape was stable only for a relatively short period.

IX.3.3.4. SOA14 (plate 226: fig. 573)

The soil developed on SOA14 is rather immature as it only contains an A-horizon with an organic matter content of 6%. Hence, the soil could develop only for a short period, which implies that soon after more sediments were deposited.

IX.3.3.5. SOC3 (plate 226: fig. 574)

The soil developed on SOC3 consists of an A-horizon with an organic matter content of approximately 6.6%. Furthermore, clay was illuviated to a depth between 0.30 and 1.55 m. Additionally, calcium carbonate was translocated to about the same depth as the clay. Hence, there is evidence of an incipient B_{tk}-horizon. It is supposed that some time elapsed before the recent sediments SOC2 and SOC1 (cf. IX.2.2.3) were deposited.

IX.3.3.6. PR1.5 (plate 227: fig. 575)

The soil formed on PR1.5 is composed of an A-horizon with an organic matter content of about 6.5%. Furthermore, clay was illuviated to a depth between 0.80 and 1.10 m. Additionally, evidence was found that calcium carbonate was translocated to about the same depth. Hence, the landscape was stable for a considerable time at this location. On extrapolation of the evidence retrieved in IX.2.2.4 it is suggested that this soil developed shortly after ± 1140 AD.

IX.3.3.7. KIS1.6 (plate 227: fig.576)

The soil developed on KIS1.6 consists of an A-horizon with an organic matter content of 4.6% and an incipient B_t-horizon at a depth between 0.5 and 0.9 m. Some carbonate leaching might have taken place as well, though the pH could not be tested for all units. Hence, this soil is also relatively well-developed and suggests some time of exposure before renewed deposition started. Based on the evidence of IX.2.2.7 it could be extrapolated that the end date of the soil development was about 894 ± 250 AD. The soil development suggests that the soil KIS1.6 developed over quite some time, probably over more than a few centuries.

IX.3.4. Palaeosols along the Ezousas

IX.3.4.1. EZA8 (plate 227: fig. 577)

The soil formed on EZA8 developed sometime between 160 ± 160 BC and 510 AD, thus a period of 830 years at longest, though probably much shorter. This soil formed on the surface of EZA8 is relatively shallow, only about 70 cm deep. The A_h-horizon contains a large proportion of organic matter (7%), suggesting the occurrence of abundant vegetation on the surface at that time. The calcium carbonate as well as the clay illuviation horizon is rather thin compared to the soils formed on KOL1 and XD. The shallow leaching and illuviation could be a result of the absence of rain and/or the incidence of higher temperatures. Hence, the soil formed in EZA8 is quite different from those formed under present day conditions. In chapter II.1.2 it was mentioned that the period between 1700 and 1100 BP was marked by a significantly drier climate. The here presented soil could corroborate this.

IX.3.4.2 EZA4 (plate 228: fig. 578)

The soil on EZA4 post-dates 1.64 ± 0.15 ka BP and it is unknown how long it could develop before renewed deposition continued. Hence, through investigating the degree of soil formation, it may be possible to estimate the exposure time. The A-horizon has a relatively high organic matter content of about 7%. Calcium carbonate translocation took place and an incipient B_k-horizon formed. Leaching was deeper than observed in the soil on EZA8, about 90 cm deep. Hence, the evidence suggests wetter conditions prevailed than attested for the soil on EZA8.

IX.3.4.3. EZD3 (plate 228: fig. 579)

The soil developed on EZD3 consists of an A-horizon with an organic matter content of about 15% and an incipient B_t-horizon at a depth between 1.4 and 2.1 m. Additionally, an incipient carbonate enrichment horizon developed at a similar depth.

The relatively deep leaching suggests wet and warm climatic conditions under which this soil formed. Furthermore, the high organic matter content of the A-horizon suggests lush vegetation. This soil formed sometime after 868 ± 559 AD. In chapter II.1.2 it was indicated that the climate between 1100 BP and 700 BP was moist and warm. It is suggested that the soil on EZD3 developed during that period.

IX.3.5. Palaeosol along the Xeropotamos

IX.3.5.1. XA2 (plate 228: fig. 580)

The soil formed on the surface of XA2 is rather immature as only an A-horizon could develop with an organic matter content of 5.9%. Hence, the soil formation took place only for a short period.

IX.3.6. Discussion and conclusion

The palaeosols delivered information on the duration of the landscape stability. Through extrapolation with the evidence presented in IX.2 it is possible to estimate a deposition date for undated deposits. As a matter of fact, the slight development of the soil on KAGC7 suggests that only a short period of landscape stability took place at this location. Furthermore, the same was suggested for KAGD15, KAGD5, SOA2, SOA10, SOA12 and SOA14. On the other hand, the development of prismatic peds in the B_t-horizon of the soil formed on KAGD8 suggests a relatively long period of landscape stability at this location. Furthermore, the relatively well-developed soils on SOC3, PR1.5 and KIS1.6 suggest that a relatively long period of landscape stability took place at these locations.

On the other hand, the palaeosols also delivered palaeo-environmental information. It is suggested that the soil on TB5/TA3 developed under dry and warm conditions sometime past 300 ± 65.5 AD.
Furthermore, the palaeosols on KAGC3, KAGC10, KAGD12, KAGD8 suggests rather dry climatic conditions as evidenced by shallow leaching.

The soil on EZA8 suggests dry and warm climatic conditions sometime after 160 ± 160 BC and 1.64 ± 0.15 ka BP, while the soil on EZA4 suggests wetter conditions sometime after 1.64 ± 0.15 ka BP. Additionally, the soil developed on EZD3 suggests warm and wet climatic conditions sometime past 868 ± 559 AD.

Although further research is necessary for more profound understanding of the climatic conditions under which the soils developed, some hypotheses have been posed which should be further tested. Obviously, the degree of soil formation provides important chronological information.

PART 4: Integration of the fieldwork with previous studies

X. Evaluating causality of the landscape changes

Understanding the causality of landscape changes is complex because there are several interdependent variables. It is tempting to ask simple questions to find simple answers, such as was the alluviation anthropogenic or is the alluviation a result of climatic change? However, these questions are based on the presumption that one of the variables (humans or climate) was constant. This is impossible because they are interdependent.

> "The question however as to whether the alluviation was caused by human activity or climatic change is misleading, since all human activities take place within a climatic context and moreover it is climatic events – like rainfall- which transport the sediment that results in alluviation. The question should be rephrased as: is it possible to detect the relative importance of climatic change or human impact during a particular period of the past in the alluvial record ?" (Brown 1997 : 251)

Consequently, to gain a profound understanding of the causes of landscape changes we have to investigate several variables and be aware of their possible interdependence. In this study, the variables climate, sea-level, tectonics and humans were investigated in part II.

This interdepence of the variables makes it difficult to disentangle the causality. However, several clues can be used to understand the relative impact of humans, climate, sea-level and tectonic history on the alluvial sequence.

- Climatic impact on the fluvial system should be detectable over large areas because climate is regional. As a result, similar fluvial events all-over the Mediterranean may indicate a climatic cause. Vita-Finzi (1969) also used this reasoning to explain the Older and Younger Fill because he believed these deposits were synchronous all-over the Mediterranean. The subsequent critiques on Vita-Finzi's study were not related to this reasoning but to the chronology of the detected alluvial events which was not refined enough to use this criterium. Indeed, the useability of this criterium falls with the lack of profoundly dated alluvial studies in other regions. Consequently, the more alluvial chronologies exist for the Mediterranean region, the better the factor climate will be understood in the deposition of the sediments. This criterium to recognise climatic caused alluviation, will be applied in section X.2 where the fluvial sequences of several areas of the Mediterranean will be compared with the evidence from Cyprus.

- Another valuable clue in evaluating the causes of alluviation is through the correlation of the settlement history and economy of the drainage with alluvial events. Some alluvial events may be so synchronously tied with the known settlement history that they may indicate some kind of human related impact on the landscape. Severe erosion might have taken place in periods of rapid cultural expansion as well as in periods of cultural collapse (van Andel 1986) (plate 2: fig. 2). Hence, it is opportune to opt for a well-surveyed drainage to undertake fluvial research. Van Andel and his team in Greece were the first to explore in depth the correlation between the settlement history and the alluvial sequence to understand its causal relation (Van Andel 1986). Later critiques on this study were not related to the use of this criterium but to the absence of any scope for climatic interpretations.
- To add to the shortcomings of the work of van Andel (see above), a similar correlation between the alluvial history and any other variable ideally should be investigated (see also Frederick 2001: 61-62). The combination of some particular changes in several variables might have triggered a change in river behaviour. Thus, besides understanding the settlement history and economy, a combined additional knowledge of metallurgical impact, sea-level change, climatic changes and tectonic events seems necessary. As a matter of fact, this was the aim of the first part of the study. In the following chapter the hypothesis based on published literature (cf. also plate 4: fig. 5) will be tested against the fieldwork evidence (X.1). As a result, a more differentiated picture can be gained of the relative impact of several variables on the fluvial sequence (X.2).

X.1. The landscape development hypothesis for Cyprus based on a literature study tested against the geo-archaeological fieldwork evidence

A comparison is undertaken in this chapter between the hypothesis based on a literature study in chapter IV and the fieldwork data summarised in chapter VIII.1.

The study of literature suggests that the Neolithic, Middle-Late Chalcolithic and Late Bronze Age period were probably marked by alluviation (cf. hypothesis p. 80). Some possible Prehistoric alluvium is discovered along the Agriokalamos, though the sections need further chronological understanding. Additionally, along the Dhiarizzos at the alluvial fan of Souskiou, some alluvium has been attested ante-dating 13.1 ± 6.5 ka BP. Furthermore, between 13.1 ± 6.5 ka BP and 3.8 ± 1.1 ka BP, 2 meters of sediment were deposited at the same location. Hence, it is possible that alluvium has been detected from the Neolithic, Chalcolithic and Bronze Age. However, the evidence is not extensive. The scarcity of prehistoric alluvium may be the result of the inherently episodic nature of environmental processes. Later erosion cycles might have destroyed or displaced Prehistoric sediments. Furthermore, the use of sherds to date alluvial sections inherently favours the identification of later alluviation and discriminates against sediments with a lack of artefacts.

Additionally, the sherd from section XA is very imprecisely dated and may be older than the Iron Age as is indicated by an average date. Hence, it is possible that there is a lack of Iron Age alluvium. This is not very surprising, as the literature study (cf. hypothesis p. 80) does not particularly indicate that this period was marked by a combination of several factors favouring alluviation.

Furthermore, evidence of Hellenistic and Roman alluvium was less widespread attested than expected. While the hypothesis (p. 81) suggests that several factors would have favoured alluviation, specific alluvium evidence only has been attested at two locations in Western Cyprus. The Late Hellenistic and most of the Roman period featured a moist climate, which suggests increased overbank flooding. The Late Roman period was marked by severe drought, which might have reduced the vegetation cover and resulted in debris flow. Furthermore, a sea-level rise, increased tectonism and large-scale copper exploitation, all favoured a mode of alluviation in the river valley. The investigated sections TA and TB along the Stavros-tis-Psokas, where more than 1 meter of sediment was deposited sometime after 300 ± 65.5 AD, could be correlated with intensive mining and smelting activities in the area during the Roman period (see more detailed in chapter XI.3). Nevertheless, other factors such as the increased tectonism, the drier climate and the sea-level rise might have favoured erosion as well. Additionally, it was indicated that alluviation started sometime after 160 ± 160 BC and continued to sometime before 300 AD at sections EZA and EZB along the Ezousas. Then, a period of landscape stability took place. Alluviation started again about 1.64 ± 0.15 ka BP. Subsequently, the landscape was stable. Correlation with the settlement evidence indicates that the alluviation could have been partially caused by farming and land exploitation activities in the neighbourhood of the settlement Agia-Varvara-*Pavoules* (see chapter XI.3).

From the Byzantine period onwards, increased alluviation has been observed in the major river valleys of Western Cyprus. The 8^{th} and 9^{th} Century AD might have been periods of extensive erosion on Cyprus. Although, this is not suggested by the hypothesis based on the combination of several variables (chapter IV, p. 81), it has been mentioned above (chapter II.1.2) that the climate was relatively dry in the Byzantine period. In the long run, this dry climate might have led to increased deposition in the river valleys. Especially around 800 AD a severe drought occurred (see chapter II.1.2.). It is noteworthy that most sherds in the investigated alluvial sections date from that period. Furthermore, human impact on the landscape ought not to be underestimated. It was mentioned in the study of literature that mining (chapter III.2.2) and farming might have had considerable impact on the landscape (chapter III.1.10).

Furthermore, alluvium probably dating to the Fankish period is extensive. This corroborates the hypothesis based on the literature study (cf. chapter IV). Indeed, the

Frankish period was marked by a warm and wet period. Moreover, several earthquakes took place during that period, which might have triggered landslides. Additionally, new crops allowed two growing seasons in comparison with only one growing season previously. Furthermore, some evidence of Medieval mining and smelting activities in the headwaters of the main rivers was discovered, suggesting deforestation. Indeed, in chapter VIII.2 it was concluded that the alluvial deposits in section EZG could be correlated with erosion upslope at the Medieval mining and smelting site of Asproyia-*Ayias Sozondas*. All these factors, combined with an increased population density in this area, might have triggered erosion.

Some evidence was discovered of possible Venetian and Ottoman alluvium. The hypothesis based on the literature study suggests that this period featured more intensive precipitation and extreme temperatures. Consequently, thick gravel units were deposited in the floodplain. Additionally, some earthquake effects might have been aggravated by this extreme climate. As an example, section KOL1 represents the evidence of a devastating flood event after which more than 2 meters of coarse gravels were deposited. Hence, section KOL1 might be the result of an extreme rainfall event.

As a conclusion, we may say that the hypothesis matches the fieldwork results in its broad outlines. The lack of earlier alluvium in large measure might reflect the episodic nature of the alluvial processes that took place in Western Cyprus. Recent major cycles of erosion may have destroyed or displaced the Prehistoric evidence.
The find of Prehistoric, Hellenistic and Roman alluvium at certain locations suggests that it might have been more extensive and could have been destroyed or displaced by later river action. Moreover, the evidence of possible Frankish alluvium is extensive and corroborates the hypothesis. Additionally, the possible Venetian and Ottoman alluvium is less extensive than presumed, though testifies for some expected extreme floods.

X.2. A comparison with alluvial sequences from other Mediterranean river valleys

It is very difficult to compare the Cypriot alluvial sequence with those of other parts of the Mediterranean region. On one hand, the Western Cypriot alluvial chronological framework as we presently have it, is less tight than needed for this kind of correlation. However, in chapter VI some chronological insight was gained. Moreover, in that chapter it has been proven that the luminescence method is a powerful tool to date the Cypriot alluvial sequence. Hence, the possibility is there to date the Cypriot alluvial sequence; it is now only a matter of funding to reach a greater dating precision. On the other hand, although several alluvial studies were accomplished in the Mediterranean region, the chronology of most of these studies is not exactly pinpointed as well. As a result, the following comparative study is only tentative and preliminary. Unless we possess over precise alluvial chronologies, all comparisons are only tentative and patterns may be missed out due to dating imprecisions. As a matter of fact, there is a severe lack of absolutely dated alluvial sequences from the Mediterranean region. Hence, an attempt to perform a similar comparative study as Macklin undertook for the UK (Macklin1993), resulted in extreme problems as most Mediterranean alluvial units are imprecisely dated through the use of a *terminus post quem* and/or *terminus ante quem*. So, we often neither know when alluviation started, nor when it finished.

The following studies were used for this comparison:

Turkey	
Küçük Menderes	Eisma 1964
Carşamba	Roberts 1982
Ibrala fan	Roberts 1995
Sakarya	Marsh 1999
Kazane Höyuk	Rosen 1997
Euphrates/Kurban Höyuk	Wilkinson 1999
Titris Huyuk	Wilkinson 1999
Israel	
Ain el Gudeirat	Bruins 1990
Nahal Lachish	Rosen 1986
Qadesh Barnea	Goldberg 1984

Crete	
Omalos	Maas etal.1998
Italy	
Bradano, Basento, Cavone	Brückner 1990
Bradano, Basento, Cavone	Abbott et al 1995
Cacchiavia	Brückner 1990
Bifferno Valley	Barker et.al; 1995
Feccia, Farma, Rosia	Hunt et.al. 1992
Greece	
Charaka, Hagia Photini, Thimari	Brückner 1990
Southern Argolid	Van Andel 1990
Argive plain	Van Andel 1990
Peneios Plain -Thessaly	Van Andel 1990
Paximadhi peninsula (S-Euboia)	De Dapper 2000
Syria	
Khabur	Courty 1994
Euphrates river/ Jeralbus-Tahtani	Peltenburg *et al.* 1996
Euphrates/ Tell Sweyhat	Wilkinson 1999
Balikh/ Kazane Huyuk	Rosen 1997
Tunisia	
Regional survey	Jean-Louis Ballais 1995

Table 4: The used studies for a comparison between alluvial chronologies from several parts of the Mediterranean. cf. plates 229-231.

Evidence of Early Holocene alluvium is relatively scarce in most parts of the Mediterranean region (plate 229: fig. 581 and 582). However, in Turkey, the Carşamba (Roberts 1982) and Ibrala Fan (Roberts 1995) both contain evidence of 11th millennium BP sedimentation, maybe synchronous with the alluvium attested at the fan of Souskiou. Furthermore, the possible Early Prehistoric alluvium attested along the Agriokalamos is probably of a later date. Part of the exposure may predate the Chalcolithic period, though also evidence of post-Chalcolithic alluvium was possibly found. Supporting this evidence is the occurrence of alluvium in the Vasilikos Valley on Cyprus, ante- and post-dating the Aceramic Neolithic period (Gomez 1987: 356). In the Mediterranean, an increase in alluviation has been observed throughout the 3rd millennium BC (plate 230: fig. 584). More precisely, in Turkey, alluvium was found dating to about 2,900-2,500 BC near Kurban Höyük (Wilkinson 1999: 557) and alluvium from 2,500-2,400 BC near Titrish Höyük

(Wilkinson 1999: 557). Moreover, in Israel alluvium ranging from 3,500 to 2,000 BC was found in the neighbourhood of Tel Lachish (Rosen 1986: 55). Additionally, in the Argive plain of Greece, alluvium dated to about 2,500 BC was found (van Andel 1990). Furthermore, around 2,300 BC at several locations alluviation seems to have intensified, it is in the Southern Argolid (van Andel 1990), along the Euphrates at Tell Jerablus Tahtani (Peltenburg *et al.* 1996) and near Tell Sweyhat (Wilkinson 1999).

There is much less evidence of second millennium BC alluviation in the Mediterranean area as well as on Cyprus (plate 230: fig. 584). Subsequently, during the first millennium BC renewed aggradation might have taken place at the alluvial fan of Souskiou, however the dating is too imprecise to draw any comparative conclusions. Furthermore, towards the end of the first millennium BC and the beginning of the first millennium AD, renewed aggradation took place in the west Cypriot rivers. As a matter of fact, there is evidence from several drainages in the Mediterranean region, suggesting renewed aggradation took place in the course of the first millennium BC (plate 231: fig. 585). Most evidence derives from Turkey, Israel and Italy. The evidence from Turkey indicates that along the Küçük Menderes aggradation occurred between 400 and 100 BC (Eisma 1964). Moreover, around 700 BC renewed aggradation also occurred along the Sakarya stream (Marsh 1999). Additionally, around 500 BC aggradation started near Kazane Hoyuk as well (Rosen 1997). The evidence from Israel points to the incidence of alluviation between 100 BC and 300 AD near Ein el Gudeirat (Bruins 1990). Furthermore, in the neighbourhood of Nahal Lachish alluviation took place between 800 BC and 600 BC and again between 300 and 600 AD (Rosen 1986). Additionally, in the Qadesh Barnea region alluvium dating between 0 and 600 AD has been attested as well (Goldberg 1984). First millennium BC alluvium from Italy was discovered along the Bradano, Bassento and Cavone and was dated between 400 and 0 BC (Abbott & Valastro 1995). Moreover, along the Cacchiavia alluvium was found, dated between 800 BC and 200 AD (Brückner 1990). Furthermore, along the Bifferno Valley, evidence is retrieved on aggradation between 400 and 0 AD (Barker & Hunt 1995).

Hence, the database of first millennium BC Mediterranean alluvium is quite extensive and may have been partially triggered by specific climatic conditions.

Late alluvium occurs extensively in the Western Cypriot river valleys. Quite a lot of alluvium was found from or post-dating the Byzantine and Frankish period. Possible evidence of Venetian and Ottoman alluviation was identified as well in the Western Cypriot river valleys. Most geomorphological researchers in Mediterranean river valleys came across evidence of Medieval alluvium. As a matter of fact, alluvium from the 8th, 9th or 10th century AD has been attested in the Southern Argolid (van Andel 1990) and the Euboia region of Greece (De Dapper 2000). Moreover, in Tunisia a major alluviation phase took place between 700 and 1200 AD (Ballais 1995). Furthermore, Faugéres (in Delibrias 1978) mentions evidence of alluviation in Macedonia from the 9th century AD onward as well. Moreover, Dufaure (1976) has described alluvium at Olympia from between the 7th and 14th centuries. Stream aggradation also has been noted by Genre (1988) for central and northern Euboea around that time. All the above mentioned incidence of alluvium could have coincided with the possible Byzantine alluvium found along several drainages on Cyprus. Slightly later alluviation took place in Israel near Ein el Gudeirat (Israel) between 1200 and 1700 AD (Bruins 1990) and near Tell Lachish between 1200 and 1400 AD (Rosen 1986).

We may say that a better chronological precision for all Mediterranean alluvial studies is prerequisite to draw far-reaching conclusions. However, based upon the present evidence, it appears that the 3rd millennium BC was marked by alluviation in several areas of the Mediterranean. Furthermore, another period of aggradation increase took place in the 1st millennium BC. Moreover, the Medieval alluvium is most extensive in all river valleys of the Mediterranean. Hence, Vita-Finzi was certainly not wrong in recognising so much late alluvium throughout the Mediterranean.

X.3. Conclusion

The attested Neolithic alluviation on Cyprus is probably a result of the combination of a moist climate, a rising sea-level and the first Neolithic humans in an island environment. The correlation between alluvial deposition and Prehistoric human activity is especially marked in the studied sections at Souskiou (SOA and SOB), where Prehistoric Cypriots undertook quarrying activities in the fluvial deposits. Furthermore, the alluvium along the Agriokalamos near the Chalcolithic settlement of Lemba probably ante- and post-dates the Chalcolithic period. The evidence suggests that at first relatively swampy conditions prevailed in the river valley, thus moister than nowadays. This supports the suggested moist period evidence during the Middle Chalcolithic period. Additionally, the attested agricultural intensification from the Middle Chalcolithic on probably favoured further local alluviation. From the Late Chalcolithic onwards (around 2,500 BC), the onset of drier conditions near the site was identified through pollen analysis. Evidence of swampy conditions is lacking in the uppermost units.

The possible Iron Age, Hellenistic and Roman period alluviation can be correlated with extensive erosion in many parts of the Mediterranean during the first millennium BC, which suggests climatic factors operating in causing the alluviation. As a matter of fact, the first millennium BC was marked by relatively dry conditions, probably resulting in a reduction of vegetation and leading to sheet erosion and the deposition of debris flow in the river valleys. The subsequent moist Roman period might have triggered severe erosion. However, human impact on the landscape through farming and mining caused erosion as well (cf. XI.3).

Alluvium from or post-dating the Byzantine period was attested on Cyprus as well. The Byzantine period was significantly drier than the Roman period. A severe drought would have taken place around 800 AD. Noteworthy is that most sherds in the alluvial sections date from that period. Additionally, evidence from many parts of the Mediterranean region indicates that increased erosion took place about that time. This supra-regional synchronicity indicates the climate as an important factor in causing increased deposition of sediments in the Mediterranean river valleys. However, the human impact ought not to be underestimated in triggering erosion. More specific on Cyprus, section KIS1 along the Dhiarizzos contains evidence of human impact on the landscape through deforestation around that time. Furthermore, at section TA and TB along the Stavros-tis-Psokas deforestation as a result of mining and smelting was increased erosion in that area as well (see in more detail XI.3).

Furthermore, the possible more extensive Frankish alluviation on Cyprus was favoured by the warm and wet climate, which accelerated overbank deposition. Additionally, a major incidence of earthquakes possibly triggered landslides. Moreover, new crops allowing two growing seasons were increasingly produced during that period. Especially, areas near monasteries were extensively exploited and resulted in erosion (cf. section PR1). Furthermore, the deposition of alluvium in section EZG could be correlated with human caused erosion through deforestation in the form of smelting and mining operations. Hence, although the climate favoured overbank deposition, human impact on the landscape was also at least partially responsible for alluvial deposition during that period.

The relatively recent alluvium (Venetian and Ottoman) might correlate with the far more extreme climatic conditions during the Little Ice Age. As a result, flood events deposited thick layers of alluvium. Additionally, frequent earthquakes during this period might have caused landslides. Furthermore, human impact on the landscape was intensive as a consequence of the use of two growing seasons in farming practices.

As a conclusion we may say that further chonological research is necessary in order to gain deeper insight into the entangled factors causing erosion on Cyprus and in the Mediterranean in general.

XI. Implications for the archaeological record

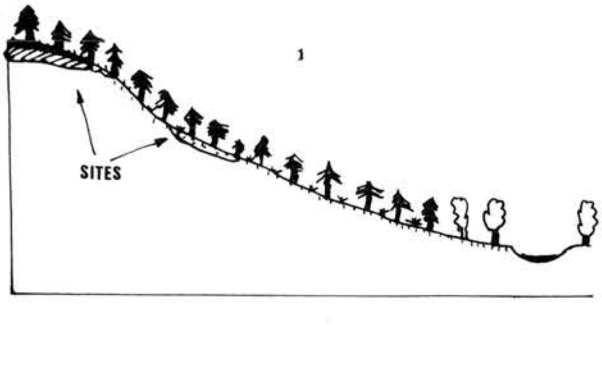
In this chapter the implications will be considered of the Western Cypriot alluvial data for the archaeological record. First, I will synthesise the landscape evolution in some regions and the implications for the archaeological sites. Seconly, I will detail the possibilities of alluvial research to understand Cypriot settlements in the landscape. Then, I will examine the impact of the environment on humans, more specific through erosion and siltation as indicated by the fluvial sequence. Furthermore, I will investigate the impact of humans on the environment.

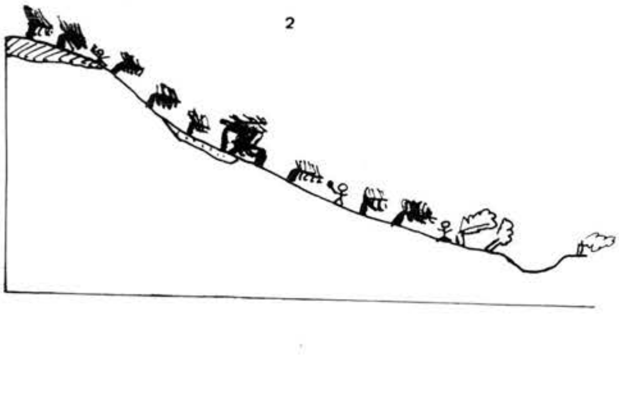
XI.1. An interpretative narrative of the history of some landscapes and archaeological sites

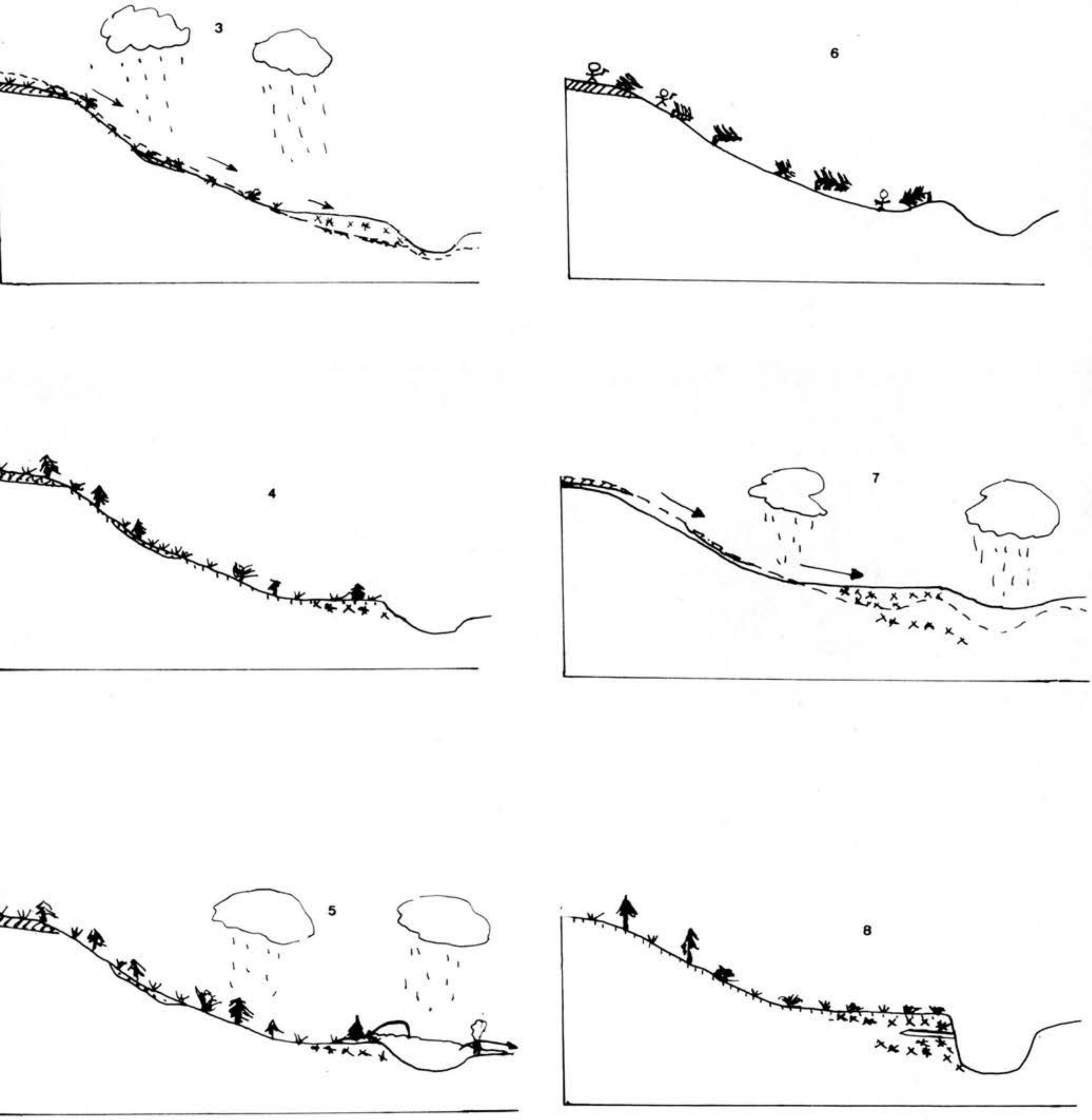
In order to treat the geomorphologic evidence from Western Cyprus systematically, the results were split up in several chapters and were sometimes not related to each other. In order to gain a better understanding of the complex history of the landscape and the archaeological sites in the landscape, it is necessary to synthesise the results of the most complex soil sections.

- The evolution of the landscape observed at sections TA and TB (scheme 2)

Sometime after 300 ± 65.5 AD (cf. VI.2.2.4) large-scale mining and smelting operations in the area reduced the vegetation (cf. III.2.3.1.) (scheme 2: from 1 to 2). Only about 400 m W of sections TA and TB, at Sarama-*Katavlaka* I, large-scale metallurgical production took place in the Late Roman period (cf. III.2.3.1). These metallurgical operations required a large amount of charcoal and consequently resulted in the deforestation of the area. During subsequent rainfall (scheme 2: 3), drastic erosion was initiated at the bare slopes and resulted in the deposition of 1 meter of sediments in the river valley (cf. VII.2.1.2. B). This extreme erosion destroyed archaeological sites: an unknown Chalcolithic site, the Bronze Age site Sarama-*Kamarin* and/or Sarama-*Adhioes*, the Iron Age site Sarama-*Paliokamina* and the Roman period site Sarama-*Paliokamina* (cf. VI.2.2.4.1). Subsequently, the landscape was relatively stable and a soil started to develop as a consequence of a regeneration of the vegetation and a relatively dry and warm climate (cf. IX.3.1.1) (scheme 2: 4). During a subsequent rainfall event, the Stavros-tis-Psokas river flooded the valley and about 40 cm of overbank sediments were deposited (cf. VII.2.1.2.B.) (scheme 2: 5). Then, sometime after ± 753 AD, probably about ± 800 AD (cf. VI.2.2.4.1.), marked landscape changes took place in the Stavros-tis-Psokas region. Pronounced erosion was initiated by the combination of mining and smelting activities in the region (cf. III.2.3.1.) and the occurrence of a prominent drought, both reducing the vegetation and making the land prone to erosion (scheme 2: 6). As a result, about 2.5 meters of debris and mudflow were deposited in the valley (scheme 2: 7) (cf. VII.2.1.2.B.). Again, several archaeological sites eroded upslope: an unknown Chalcolithic site, the Bronze Age site Sarama-*Kamarin* and/or Sarama-*Adhioes*, the Iron Age site Sarama-*Paliokamina* and the Roman period site Sarama-*Paliokamina*. Artefacts from these sites were redeposited in the river valley (cf. VI.2.2.4.1.). Since then, the river incised the alluvial fan deposits (cf. VII.2.1.2.B) and soil formation took place on the fan surface (cf. IX.2.1.1.) (scheme 2: 8).



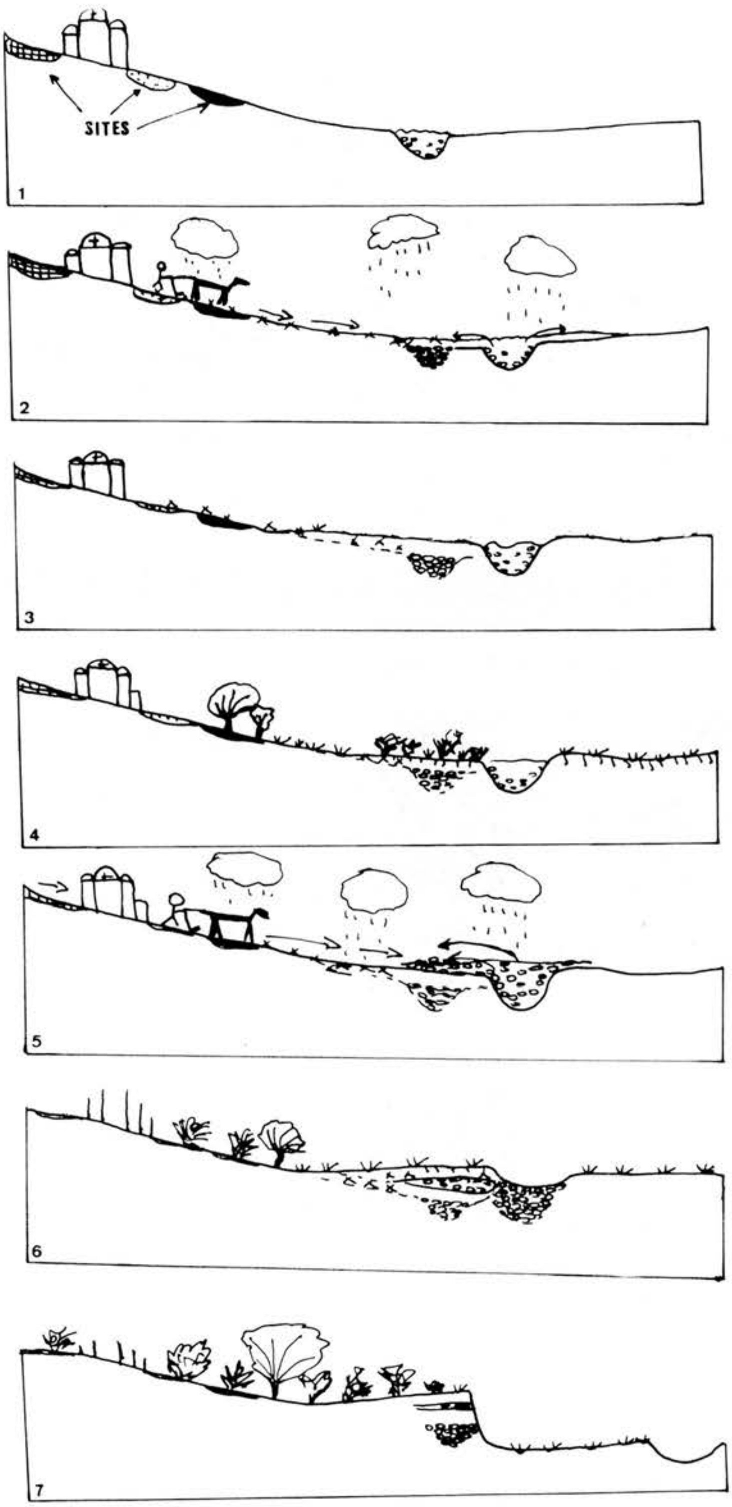




Scheme 2: The evolution of the landscape as observed at sections TA and Tb (x = eroded artefacts)

- The evolution of the landscape as observed at section PR1 (scheme 3)

During a warm and moist climate sometime after 1140 ± 60 AD (cf. VI.2.2.4.3C), a channel of the Dhiarizzos river passed at the location of section PR1 (scheme 3: 1). Subsequently, the river abandoned this location and left behind its bedload (scheme 3: 2). However, the river continued depositing overbank sediments at this location (cf. VII.2.2.7B) (scheme 3: 2, 3). Not only the moist climate, but also humans indirectly were responsible for the deposition of almost a meter of sediments in the river valley (cf. V.2.1.2B). Intensive land exploitation took place around the Prastio-*Ayios Savvas tis Karonis* monastery (upslope of section PR1), which reduced the natural vegetation and made the land prone to erosion (cf. V.2.1.2B and III.1.10). As a result, on rainfall large amounts of sediments were transported downslope. This erosion probably also affected archaeological sites, which were abundantly present within the landscape (cf. V.2.1.2B). Subsequently, the erosion halted for a considerable period (cf. IX.3.3.6) and a soil formed on the river terrace (scheme 3: 4). However, some time after, erosion renewed upslope (cf. VII.2.2.7B), as the soil was exposed through land exploitation around the Prastio-*Ayios Savvas tis Karonis* monastery (cf. V.2.1.2B) (scheme 3: 5). The erosion was probably initiated by wetter conditions as well. Subsequently, during a flood, the Dhiarizzos reached this location again and left shortly after (scheme 3: 5). More sediments were deposited in the river valley, consisting of a mix of overbank sediments and colluvial sediments (cf. VII.2.2.7B) (scheme 3: 6). More archaeological sites eroded during this period. Upslope, an unknown Byzantine site and an unknown Classical site (maybe related to the Iron Age sanctuary site at Prastio-*Ayios Savvas tis Karonis Monastery*) eroded (cf. VI.2.2.4.3C). Subsequently, the landscape was again stable in this area and an incipient soil developed (cf. IX.2.2.4). The erosion decreased in recent times as a consequence of the reduced activities at the Prastio-*Ayios Savvas* monastery (cf. V.2.1.2B). Recently, the river exposed section PR1 through incision (scheme 3: 7).



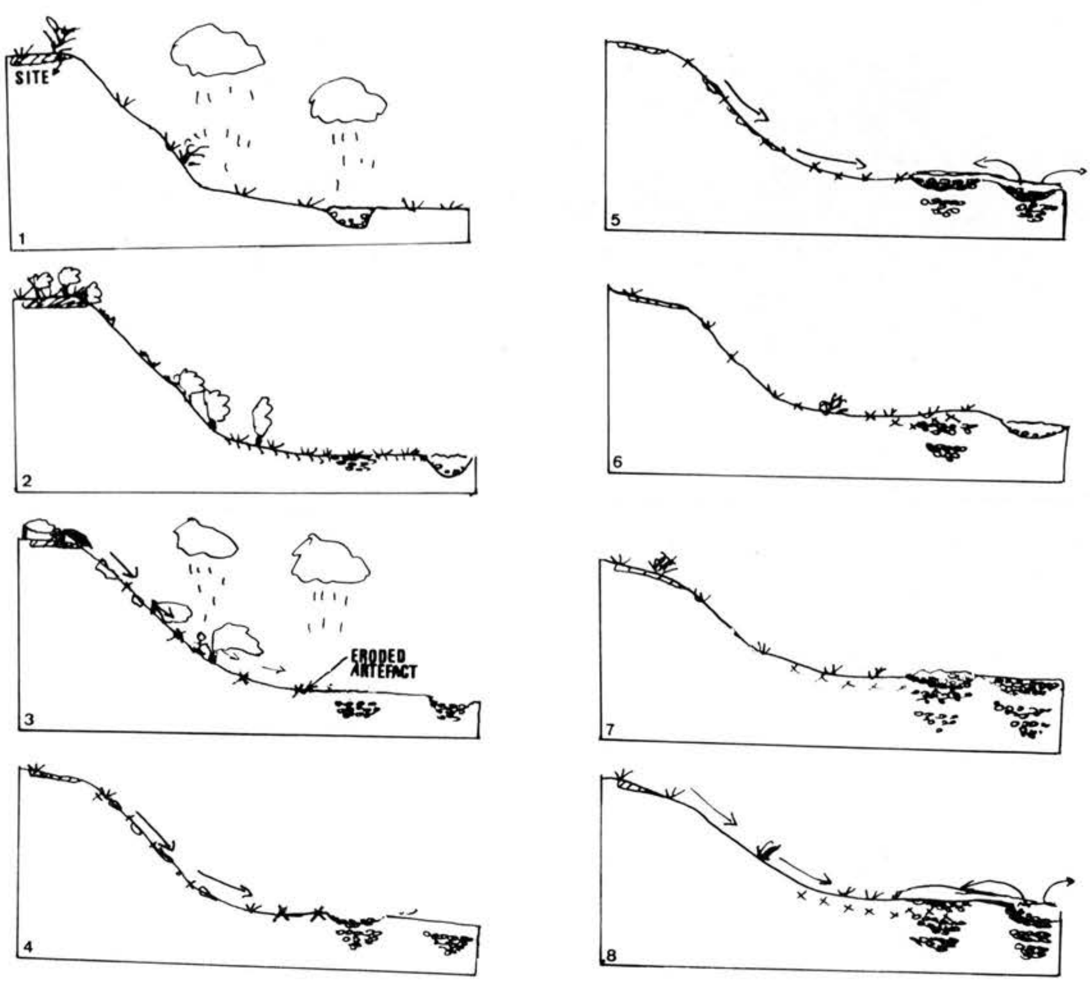
Scheme 3: The evolution of the landscape as observed at section PR1 (x = eroded artefact).

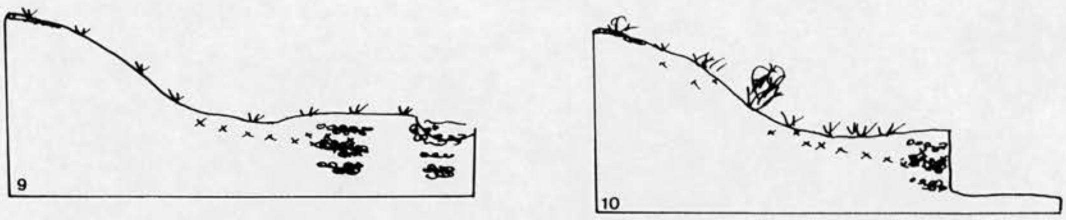
- The evolution of the landscape as observed at sections MA and MB

An aggrading unnamed gully with a source in the N moved 4 times there and back at the location of section MB. Sometime shortly after ± 800 AD (cf. IX.2.2.6) erosion increased in the area (cf. VII.2.2.8B). Several archaeological sites eroded, such as an unknown Roman and an unknown Byzantine site (cf. VI.2.2.4.3E). The increased erosion shortly after 800 AD was probably related to the reduction of the vegetation as a result of dry climatic conditions (cf. II.1.2). This reduction of the vegetation made the land prone to erosion when occasional rainfall took place. Since then, the landscape remained relatively stable at the location of section MB and a soil developed (cf. IX.2.2.6). However, a channel of the Dhiarizzos river incised the alluvial fan (section MB). Sometime after 1320 ± 60 AD (cf. VI.2.2.4.3D) the Dhiarizzos river aggraded and about 1 meter of coarse grained sediments were deposited after a flood. Soon after, another flood occurred and again more than 1 meter of coarse grained sediments were deposited (cf. VII.2.2.8B). Bedrock was exposed upslope and was supplied to the river (cf. VIII.2.3.7). This was probably partially caused by intensive land exploitation on the estate of the Prastio-*Ayios Savvas tis Karonis* monastery. Through this erosion, several sites eroded, such as an unknown Byzantine and Roman site (cf. VI.2.2.4.3D).

- The evolution of the landscape as observed at section KIS1 (scheme 4)

During a rainfall event, a channel of the Dhiarizzos river passed through this location (scheme 4: 1). Sometime after, it changed location and left behind its bedload (cf. VII.2.2.9B). Subsequently, over the next centuries, the landscape remained stable in this area (cf. IX.3.3.7) (scheme 4: 2). Sometime after 894 ± 250 AD, about 10 cm of colluvium ended up downslope in the river valley (scheme 4: 3). This upslope erosion was possibly caused by human exploitation of the landscape, more precisely by deforestation, probably related to the habitation at Kithasi-*Old Village* (cf. VII.2.2.9B). Moreover, the climate was probably also relatively dry at that time which had a negative impact on vegetation growth. Rocks became exposed in several areas. During rare rainfall events a large amount of rocks eroded and ended up in the river, which was again located at section KIS1 (scheme 4: 4). Then, the river changed and left its bedload (scheme 4: 5). Subsequently, overbank sediments with a large colluvial fraction were deposited (scheme 4: 6). The above mentioned erosion affected archaeological sites in the neighbourhood, such as an unknown Iron Age site and the Byzantine site at Kithasi-*Old Village* (cf. V.2.1.2B). Subsequently, the channel returned to the location of KIS1 (scheme 4: 7) and finally left it (scheme 4: 8). Then, about 50 cm of sediments were deposited, consisting of a mix of alluvium and colluvium, which indicates that a large local influx of sediments took place (cf. VII.2.2.9B) (scheme 4: 8). At that time, the floodplain was more than 3 meters higher than nowadays (cf. plate 119: fig. 302). Shortly after 894 ± 250 AD, the landscape was stable at this location and a soil developed. In recent times, the Dhiarizzos exposed section KIS1 through incision (scheme 4: 10).

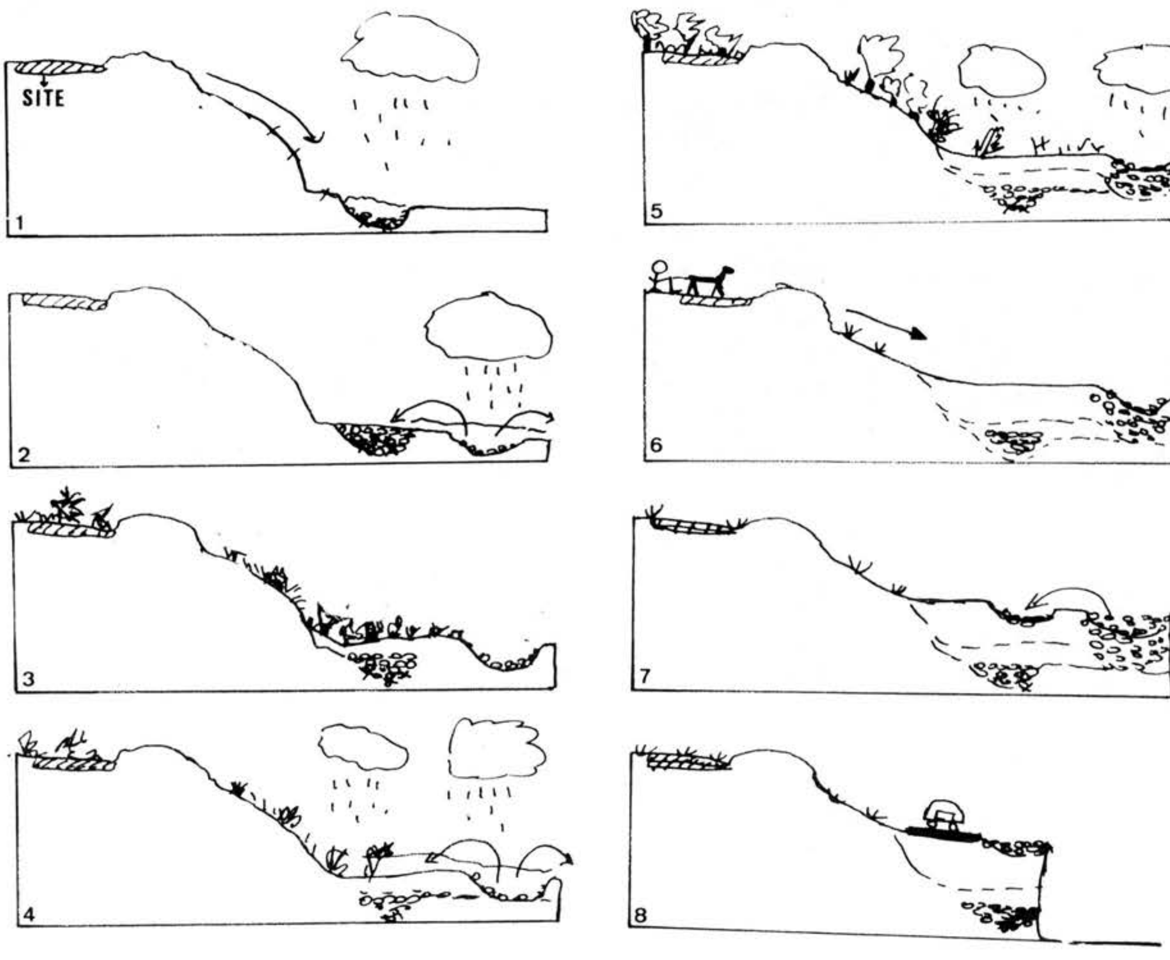




Scheme 4: The evolution of the lanscape as observed at section KIS1 (x = eroded artefact)

- The evolution of the landscape as observed at section EZA (scheme 5)

During a wet interval sometime between 160 ± 160 BC and 300 AD (cf. VI.2.2.4.3A and VI.2.2.3.3), the channel of the Dhiarizzos was situated at the location of section EZA, slightly higher than the present day channel (scheme 5: 1). Several archaeological sites eroded at that time (cf. VI.2.2.4.3A). However, the eroded sites are not identifiable. After this flood, the river changed location and overbank sediments were deposited (cf. VII.2.4.1B) (scheme 5: 2). Subsequently, the climate probably became significantly drier (cf. IX.3.4.1) (scheme 5: 3). As a result, the landscape was stable at this location. Only an undeep soil could develop through the absence of rain and/or the incidence of higher temperatures. Sometime between 210 and 510 AD, a moister interval followed and renewed deposition of overbank sediments took place (cf. VII.2.4.1B) (scheme 5: 4). Through a lack of vegetation after the previous dry period, the river received a large input of sediments when rainfall took place. Almost a meter of overbank sediments were deposited in the river valley. Subsequently, the landscape was stable at this location and another soil developed (cf. VII.2.4.1B and IX.3.4.2) (scheme 5: 5). Relatively wet conditions prevailed and lush vegetation established. However, sometime after, more deposition of sediments took place at this location (cf. VII.2.4.1B) (scheme 5: 6). The sediments are largely colluvial, suggesting local erosion upslope. This erosion was partially a result of the human exploitation of the area during the Byzantine period. A large Byzantine settlement was inhabited at Ayia Varvara-*Ambeloudhin*, just North of the investigated section (cf. V.2.2.2B and plate 126: fig. 320). Subsequently, after a flood during a wet interval, bedload sediments of the Dhiarizzos river were deposited (scheme 5: 7). Since then, a soil developed. However, the upper sediments were removed during the construction of the road. Though soil formation continued. Recently, the Dhiarizzos exposed section EZA through river incision (cf. VII.2.4.1B).



Scheme 5: The evolution of the landscape as indicated by section EZA (x = eroded artefact)

- The evolution of the landscape as indicated by section EZD

Sometime after 868 ± 559 AD or 369 ± 5.5 AD, a gully formed during a rainfall event. Only little vegetation was growing in the area at that time as about 2 meters of sediment were deposited (cf. VII.2.4.4), indicating that the area was prone to erosion. The erosion affected several archaeological sites in the area (cf. VI.2.2.4.3B). Several artefacts were redeposited in the valley in secondary context. However, it is unknown which sites exactly eroded as on one hand the dating precision of one sherd is relatively imprecise and on the other hand no Roman site is known near the gully's source where the Roman sherd could derive from. However, it is known that the area was intensively occupied during the Roman period (cf. V.2.2.2B). Subsequently, during a warm and moist period, lush vegetation could establish and a soil formed at this location. Quite sometime after 1221 ± 52 AD (cf. IX.2.3.3), erosion took place in the area. More than 1 meter of sediments was deposited in the river valley. This recent erosion affected an unknown Frankish site.

XI.2. Cypriot settlements in the landscape

Absences or gaps in occupation at a specific locality or in a region may be the result of erosion as well as of cultural processes. Only when the alluvial history of deposition, erosion and stability is reconstructed and their effects on both the spatial and temporal aspects of the archaeological record recognised, are meaningful reconstructions of human behaviour possible. Consequently, alluvial research offers a better understanding of settlement and site patterns. Hence, it is imperative to gain understanding of the geological processes imposed on the archaeological record. Ideally, a geo-archaeological survey should be conducted in association with an archaeological survey. This is because on one hand, archaeological sites have been affected by erosion and on the other hand, meters of alluvium might have covered archaeological sites.

The Canadian Palaepaphos Survey team undertook extensive archaeological survey along the Dhiarizzos, Xeropotamos and Ezousas drainages (Rupp 1981, Rupp 1984, Rupp 1986, Rupp 1993, Rupp *et al.* 1992). Armed with the data from the above presented geo-archaeological survey, we can value the following statements resulting from their research: "Most of the sites are located in zone II *(it is between 101 and 200 meters)* on higher ground overlooking watercourses and accessible to both the river flood plains and relatively flat land of the surrounding rolling plateau" (Rupp 1981: 254). "In general Cypriotes of all cultural periods did not live in these river floodplains or adjacent terraces, but appeared to have preferred mid-slopes" (pers. comm. Rupp 1999). As a matter of fact, as evidenced by the abundant occurrence of Medieval alluvial deposits in the Cypriot valleys, valley floors and terraces will be devoid of any sites older than a few centuries. Hence, the above statements might imply that either there were strong constraints against settlement/sites on the valley floors in antiquity (see further in XI.2) or that the archaeological evidence is obscured or missing. In either case, this constitutes an important area of inquiry.

As a matter of fact, sites might have been covered by alluvium. However, the chances in river valleys of Western Cyprus are relatively rare as the major rivers are marked by a braided morphology, which is not conducive to the preservation of archaeological sites. In general, there is only little evidence on Cyprus of buried sites under alluvium. However, Gomez reported the find of two Aceramic Neolithic fire pits *in situ* on investigating the alluvial fill of the Vasilikos Valley (South Cyprus) (Gomez 1987: 356). Furthermore, a possible example of a site buried by alluvial sediments was encountered in the Western Cyprus Geo-archaeological Survey and is located in the alluvial fan of Souskiou along the Dhiarizzos river. It concerns a possible quarry site covered under 5 meters of sediment. Several lithic artefacts were retrieved from the lower units of the fan. Dr. Carole McCartney identified some tested cores, and suggested that the gravel bed may represent a quarry area (see chapter VI.1.2.). These cores would have been discarded due to the inferior quality of the raw material. Moreover, core reduction debris was also identified which seems to confirm this evidence. The diagnostic lithic artefacts suggest an Early Prehistoric date. Clearly, the sample was rather small and further investigation is necessary. However, OSL-dates on the sediment just above this unit provided a date of 13.1 ± 6.5 ka BP, which indicates that this sediment was deposited between 17,600 and 4,600 BC (see chapter VI.2.3.3.2). Although this date is relatively imprecise due to some difficulties in dating alluvial sediments, it seems to confirm the Prehistoric date for the quarry site and its possibility to be located *in situ*. It has often before been suggested that the raw material for lithic artefacts was recovered from river beds on Cyprus. However, this is the first archaeological site which seems to confirm this hypothesis. The lack of such archaeological finds is probably partly due to a lack of substantial architectural remains at these places as well as to the fact that these sites are mainly located in the unstable fluvial environment and are either covered by meters of alluvium or eroded by river incision.

There is even more evidence that the river terraces or fluvial deposits had an important function for the former Cypriotes. Neutron activation analysis indicated that clay for pottery production was retrieved from alluvium of the Upper Ezousas valley and from the present-day coastal plain (Rupp *et al.* 1986: 40). Although such a site has not been discovered until now, this evidence certainly indicates that the floodplain and adjacent terraces constituted active parts of the human landscape. Indeed, the evidence is biased through the complex fluvial processes, which destroyed or buried part of the evidence of most former human activities within the floodplain.

Moreover, the alluvial research also indicates that many sites eroded. Hence, the interpretation of settlement patterns might be distorted by this loss. As a matter of fact, the dates of the 76 sherds found off-site in alluvial sediments indicate that archaeological sites of all periods have been affected by erosion, as sherds of all periods occur in the alluvial sediments[19].

Artefacts occurring in alluvial sediments are often the ultimate evidence of sites lost by erosion. As an example, in a 2 m deep section at Prastio along the Dhiarizzos river, 4 pieces of pottery were retrieved. The 2 meters of alluvial sediments themselves indicate quite a lot of erosion upslope. The dates of the sherds occurring in the section indicate that a site was eroding upslope. More specific, at the bottom of the section, a sherd dated to 1,200 AD. In the middle of the section, a sherd dated to 1,084 ± 16 AD and at the top a sherd of approximately 720 AD and one dating to 467 ± 17 BC was found. Hence, an inverted stratigraphy is observed, as the oldest sherd is located in the youngest sediment. This is due to the erosion of a site sometime around or after 1140 AD. The inverted stratigraphy suggests severe erosion of a Byzantine site, with the disappearance of several archaeological strata from 1140 AD until the lower strata dating to 720 AD. The erosion also affected a Cypro-Classical site in the neighbourhood. The "Western Cyprus Project" team undertook right at the erosional source for these fluvial deposits, investigation of a Chalcolithic settlement (Prastio-*Ayios Savvas tis Karonis Monastery*) (Rupp *et al.*1993; Rupp *et al.* 1994). If they had been aware of this alluvial evidence, they probably would not have selected this site for solving the specific queries as mentioned in the excavation aims. Moreover, they probably would not have spent so many hours in the field looking for a Prehistoric site *in situ* at this location. Indeed, Rupp had to admit "after two field seasons of excavation at Prastio-Agios Savvas on

[19] GIS and erosion modelling also have great potential to reconstruct the former landscape.

three of these land plots it appears that what was at first thought to be the surface scatter from one small settlement is actually the downslope erosional remains from two separate small settlements" (Rupp *et al.* 1994: 318). And he continues "the trenches revealed a series of erosional gullies running from South to North downslope toward the Monastery" (Rupp 1994: 318). This all indicates that an archaeological survey should actually be conducted hand in hand with a geo-archaeological survey to achieve a better understanding of the preservation chances of sites and the interpretation of surface scatters. Although this was probably not what the excavator was hoping for, his research showed how drastically the landscape changed in relatively recent times and how careful we have to be in interpreting survey data, especially Prehistoric scatters.

Another example of major erosion, which affected several archaeological sites, has been attested along the Stavros-tis-Psokas. At Sarama-*Kamarin* at the junction of the Stavros-tis-Psokas with the Argakin Pyroia, an abundance of artefacts were retrieved within a 4 meters deep alluvial fan deposit. At this location about 1 meter of sediments were deposited sometime after 300 ± 65.5 AD. Within the sediments, there is evidence that several upslope archaeological sites had been eroded. More specifically, there is extensive evidence of the erosion of Neolithic, Chalcolithic, Late Bronze Age and Cypro-Archaic site evidence lost within these units. Shortly after, some landscape stability took place. Sometime after approximately 753 AD, erosion started again and more than 2.5 meters of mudflow were deposited. Within the mudflow, the occurrence of many sherds indicates the erosion of a Neolithic, Chalcolithic, Bronze Age, Cypro-Archaic, Roman and Early Byzantine site. Moreover, this evidence suggests that the landscape changed profoundly since Prehistoric times and sites located upslope have been severely eroded in this area. Additionally, it was hoped that this section could also answer the problem raised in chapter V.1.1.2 where it was questioned whether both Early/Middle Cypriot artefact scatters on either side of the gully the Argakin Pyroia represent a single site or two separate sites. Thus the more specific question is whether the Argakin Pyroia gully was as deep as it appears nowadays. At this location, the geomorphological investigations indicate that the Stavros-tis-Psokas was located at a much higher elevation around 300 AD, thus that the base level of the Argakin Pyroia was considerably higher and consequently the Argakin Pyroia less deeply incised. Hence, by extrapolation it is possible to conclude that the Argakin Pyroia was probably less deeply incised about the Early/Middle Cypriot period. This might imply that the artefact scatters on both sides of the river might belong to a single site.

As a conclusion, we may say that site visibility at the modern surface is neither a reliable, nor a complete indication of what might still be present in the archaeological record. A geo-archaeological survey is imperative to gain understanding of the landscape changes, site preservation and settlement patterns.

XI.3. Impact of the environment on humans

Alluvial research can improve our understanding of the impact of the environment on humans. River deposits not only contain climatic information but also the direct evidence of floods, swampy conditions and siltation.

Reactions to environmental fluctuations, especially unfavourable ones, vary. In some cases a long sequence of environmental stress may exacerbate internal stresses and lead to the abandonment of settlements. In others, the same environmental stress may result in the reorganisation of social institutions, or in technological advances.

Fluvial systems had impact on humans, human behaviour and human genetics. This was indicated in chapter III.3 through a study on malaria, thalassemia and the connection with rivers. Malaria is caused by a parasite living in malaria mosquitoes and is transmitted through mosquito bites. Thalassemia is a genetic adaptation, rendering people less susceptible to the malaria parasite. The malaria mosquitoes breed in stagnant pools and swamps. Drying river beds are also often mentioned among the favourite breeding places for the mosquitoes. A correlation between the incidence of thalassemia and swampy conditions in the adjacent river has been attested at the archaeological site of Khirokitia (see chapter III.3). Additionally, prevalence of thalassemia has been discovered at the Chalcolithic site of Lemba-*Lakkous* (see chapter III.3.). The geomorphological investigations along the Agriokalamos river near the site of Lemba, indicated that swampy conditions prevailed. Of importance in this discussion is the occurrence of rip-up clasts in the bedload deposit unit 9 of section KAGC and KAGD (chapter VI9.4.3.1). Rip-up clasts are laminated mudstones, deriving from a local lake, possibly an abandoned meander of the former river, ripped up by river action and rolled through transport. They certainly indicate that swampy conditions prevailed which were favourable for mosquito breeding. As to the timing of these deposits some problems were confronted. Initially, 2 Prehistoric sherds in the deposits and the occurrence of several palaeosols above, indicated a possible Prehistoric date for the deposits. To gain better insight into the deposition date of these sediments, 4 OSL-dates on the sequence were submitted. However, they gave dates too old to contain Prehistoric sherds, which may be due to incomplete resetting of the sediment. Hence, further dating is necessary to establish the correlation between swampy conditions in the river valley and the incidence of thalassemia in the Chalcolithic settlement of Lemba-*Lakkous*. Furthermore, at the Chalcolithic site of Kissonerga-*Mosphilia*, only a few km from Lemba, the incidence of thalassemia has also been attested (see also III.3). Moreover, the molluscan evidence there also indicates the occurrence of swamps. More specific, the freshwater moluscs show that when Kissonerga was occupied, the Skotinos stream was a permanent water source, flanked by marsh and/or reed beds (Ridout-Sharpe 1998: 228). Hence, also at the site of Kissonerga-*Mosphilia*, a correlation is observable between the incidence of thalassemia and swamps. We may say, malaria was one of the problems coastal people endured as a result of the occurrence of swampy, marshy rivers. Moreover, thalassemia was a genetic adaptation to this problem, rendering people less susceptible to the malaria parasite. Hence, the fluvial system did have an indirect impact on both the Cypriot people's genes and behaviour. As a matter of fact, in chapter III.3.2 it has been discussed that at present a large proportion of the Cypriot population is a carrier and potential donor of the thalassemia gene. Couples, of which both partners are carriers, are advised not to have children. However, the high incidence of children mortality related to thalassemia on the Prehistoric sites suggests that Prehistoric groups probably did not receive any such advice.

Another problem caused by rivers is the siltation of harbours. Apart from the fact that siltation of harbours causes malaria, it can cause the decline of an important harbour town. Leonard *et al.* (1998) found evidence of harbour siltation at the harbour of Nea Paphos (Western Cyprus). Geomorphological investigations at this harbour site suggest that following a sea-level rise, the natural embayment of Paphos harbour was created. A sandy shoreline bordered most of the natural embayment. However, in the the East of the embayment, a muddy sandy stream-delta developed. The waves and longshore current probably swept the shallow marine environment and acted as a natural flushing system. Subsequently, sometime in the late 4th century BC a breakwater was built. This disturbed the natural flushing system and the harbour gradually filled with silt. Probably during Roman times, channels were cut through the breakwater to restore this flushing system. Though, the harbour still became increasingly shallow also due to a seaward prograding shoreline. This is probably a reason why Paphos declined in Medieval times. In 1806 Ali Bey mentioned that the harbour of Paphos was small and blocked with sand, so that only the smallest boats could enter. Hence, alluviation can clearly be linked with the decline of the city of Paphos in Western Cyprus (Leonard *et al.* 1998).

Rivers not only had impact on the prosperity and decline of harbour towns, though in general, rivers might have had an impact on the settlement pattern. This will be indicated through a study to the lack of tells on Cyprus. Indeed, it has often been mentioned as a curiosity that there is a suspicious absence of tell-sites on Cyprus, unlike in all surrounding areas of the mainland. It has been suggested that sites were not as long-lived as in the mainland due to settlement fission and settlement relocation. However, it can be questioned whether there is an environmental rationale behind the absence of tells. What struck me on leafing through some geo-archaeological studies on tell-sites is that tells are located in the floodplain and that they sometimes contain in between anthropological strata evidence of flood events (alluvial sedimentation). As a matter of fact, Marsh reported on geomorphological research at the tell site, identified as Gordion, located on the floodplain of the Sakarya River in Central Turkey. He found evidence that the Sakarya river brought important changes upon Gordion over nearly three millennia through extensive burial, lateral cutting of meanders and downward erosion onto structures after the river shifted to the west side of the mound (Marsh 1999: 163-174). Moreover, van Andel and his team also suggested that the first occupation on the location of the Platia Magoula Zarkou in Thessaly took place in the floodplain during a phase of aggradation. Although since the Middle Neolithic, the human accumulation rate overtook natural sedimentation, flood deposits were possibly regularly intercalated within the anthropogenic layers, but all thin ones were destroyed by the occupation of the site. Van Andel and his team therefore conclude that it is not possible to estimate the frequency of local flooding. Additionally, investigations by the Oguchi's indicate that Mid-Holocene flood events are often incorporated in Syrian tell sites (Oguchi 1998: 307-315). Hence, it seems that tells developed in broad alluvial plains shaped by rivers with relatively low gradients and were flooded only occasionally, especially more in the beginning of their formation. The geographical situation in Western Cyprus is different than on the mainland as the rivers are relatively short as a consequence of the insularity of Cyprus. Hence, the rivers have their source in the almost 2000 m high Troodos Mountains and end shortly after in the sea. As a result, they have a steep gradient and a braided morphology. This is not conducive for long-term occupation in the floodplain as well as for site preservation. Floods can be severe within the floodplain and can drown humans. A farmer told a story about a flash flood, which took place in the Dhiarizzos when he lived in the then occupied settlement of Souskiou located on an alluvial fan at the edges of the floodplain. The water must have had a considerable velocity as the river carried a woman away over quite some distance while people tried to save her with sticks from the alluvial fan. Hence, this indicates that it would be unfortunate to build a settlement in a Western Cypriot floodplain, as it is a risky environment, even if the settlement would have been artificially heightened. If we were to doubt the erosive power of the Cypriot rivers, Christodoulou convincingly drew attention to this. "The steep gradients (*of the rivers*) lead also to great erosive power and exceptional floods frequently wash dams away or breach them. The Kouklia reservoir in 1949 was breached at twenty places and the repairs cost £15,000"..."The expectations of life of the reservoirs have been calculated. The time of complete sedimentation ranges from 7 years (Kophinou) to 87 years (Lythrodhonda) in the case of the reservoirs built since 1944; the Kouklia reservoir will take 276 years. " (Christodoulou 1959: 115). Moreover, if seasonal settlements took place within the floodplain of the major rivers, most evidence has been swept away by flash floods anyway. Hence, it is suggested that a different fluvial environment from the mainland, resulted in different human behaviour and adaptations.

The Cypriot rivers not only had the power to sweep away humans and archaeological evidence, though also might have destroyed the sugar cane crops. Sugar cane was a highly valued crop during the Frankish period. Sugar cropping was probably imported to Cyprus before 1191. The diffusion of sugar cane to the Mediterranean around that time was probably favoured by climatic conditions different from the present day ones, consisting of temperatures about 1 to 2 degrees C warmer than nowadays and a greater humidity. The Cypriot sugar industry expanded in the 14th century and flourished in the 15th. The end of the sugar industry in Cyprus came in a brief period of thirty years, at approximately 1570 to 1600 AD. The sugar industry could develop in only a few areas, mostly in the coastal plains. Three main centres of cane sugar cultivation on Cyprus are located within the Western Cyprus Geo-Archaeological survey area: the plantations of Kouklia, Akhelia and Emba/Lemba (von Wartburg 2001: 306). Water was a prime need for successful sugar production, both for the irrigation of the plantations and for the refining process. This is probably also why the main centres are located in the Western Cypriot Lowlands. As a matter of fact, it has been mentioned above (chapter II.1.3) that the Western Cyprus Geo-Archaeological Survey area is marked by the highest rainfall level compared to the rest of Cyprus. Some evidence was found that irrigation was used in some of the cane fields (von Wartburg 2001: 315). In chapter V.2.1.2B it was mentioned that 200 m away from the investigated soil sections KOL1 and KOL2 at the locality Kouklia-*Stavros* a 14th to beginning 16th Century sugar production site was found. Hence, all this evidence indicates that the surrounding fields were intensively used as sugar plantations. Indeed, this is attested by several ancient travellers such as Jodokus von Meggen and Jan Kootwyk who recorded "well-watered fields abound in grain, cotton and sugar" at Kouklia (von Wartburg 2001: 328). There are several hypotheses as to why the sugar industry disappeared after 1,600 AD. Some researchers linked the fall of the Mediterranean sugar industry with climatic change (Galloway 1989: 25). In chapter II it has been mentioned that around 1,550 AD cold and wet conditions prevailed throughout the Mediterranean, which were associated with alternating seasons of drought and flooding. As a result of the location of the sugar cane fields in the Mediterranean, flooding and consequent sediment deposition probably took place periodically or episodically. Whilst siltation was advantageous because it increases the soil's fertility, the deposition of large gravels caused great losses. Of importance in this discussion is the investigated geomorphological section KOL1. KOL1 represents the remains of a high velocity river channel choked by its own bedload after a flood sometime after ± 1560 AD. More than 2 meters of gravels were deposited and the river changed location. Subsequently, continued flooding of the new channel deposited almost a meter of overbank deposits at the location of KOL1. Hence, we can question the causal relation between the deposition of more than 2 meters of gravel alluvium in the coastal plain and the fall of the sugar industry at the nearby location of Kouklia-*Stavros*. If environmental factors were not the main reason, the evidence indicates that losses in the sugar cane crops certainly took place. Moreover, this damage might have been the last straw for the sugar industry at Kouklia, which was already under pressure by the low prices of the South American sugar.

As a conclusion, we may say the Western Cypriot rivers had direct and indirect impact on humans, human behaviour and even human genetics. Although rivers were a positively valued factor in settlement location and land exploitation, they could also cause problems. Siltation and alluviation had impact on the decline of harbour towns, on the decline of the sugar industry and indirectly changed human genes and social behaviour.

XI.4. Impact of humans on the environment

Alluvial research can improve our understanding of human impact on the Cypriot landscape throughout time. Alluviation, the deposition of sediments in the river valleys, can be the result of human impact on the landscape. However, it is not always straightforward to interpret the causality of the deposition of the sediments, as many other factors such as climatic changes, sea-level changes and earthquakes, might have triggered erosion as well and consequently deposition in the river valleys (see chapter X).

First of all, a marked difference between Pleistocene and Holocene deposits was observed in the geo-archaeological survey, suggesting human impact on the landscape during the Holocene period (see also chapter VIII.2.6). As a matter of fact, an increased proportion of sedimentary stones and a decreased proportion of igneous stones occurred in the Holocene alluvial deposits in comparison to Pleistocene alluvial deposits. Humans first appear in the Cypriot archaeological record at the start of the Holocene. As they introduced the Neolithic package to the island, they depended on farming and herding for subsistence. In general, for these activities they probably preferred the lowlands and foothills, though avoided mountainous areas. Hence, the change in sediment sources might reflect the more and more local influx of sediments as a result of local land exploitation.

Moreover, through lithological provenancing of the alluvial sediments from section EZG along the Ezousas, it was possible to connect this alluvial deposition with only one source of erosion (see chapter VIII.2.6). More specifically, the frequently occurring chalks, silicified chalks and limestones in the alluvial deposits in section EZG, could only provenance from one specific Lefkara formation source to the East around Asproyia and Pano Panayia. Interestingly, at the location Asproyia-*Ayios Sozondas* a Medieval mining and smelting site was discovered, consisting of 24 adits in the pillow lava and 2,000 square meters of slag heaps. Hence, the marked correlation between erosion in that particular area sometime after 1140 ± 20 AD and the Medieval mining and smelting activities, suggesting deforestation, seems to indicate human impact on the landscape, though might have been triggered by specific climatic conditions.

Additionally, the large proportion of Lefkara formation stones in section PR1 along the Dhiarizzos suggests that erosion took place East of the section, sometime after 1140 ± 60 AD (see also chapter VIII.2.6). Indeed, only a few hundred meters upslope ca. 1120 AD, the Ayios Savvas-tis-Karonis monastery was founded. It has been mentioned above (chapter III.1.10) that estates and monasteries were involved in mass production. It is suggested that the activity at the monastery increased in the 15^{th} century AD and reached its height in the 16^{th} century AD. Thus, the erosion attested at this location is probably a result of agricultural activities on the slopes in the neighbourhood of the monastery. Archaeological investigations undertaken upslope in order to find a Chalcolithic site, found evidence of a dendritic network of deep, narrow gullies and minor, shallow rills in the underlying chalk. Hence, erosion first stripped the overlying soil and subsoil horizons lying on the bedrock. This was probably followed by an episode, which cut the gullies and rills into the bedrock. Subsequently, the gullies were filled with sediments and artefacts (Rupp *et al.* 2000: 201). As a result of the erosion upslope, more than 2 meters of sediment finally ended up in the river valley sometime after 1200 AD. However, it is suggested that 2 periods of sediment deposition were separated by a period of landscape stability (VII.2.2.7.B). In chapter XI.3, it has been suggested that erosion during that period in general might have been favoured by the prevailing moist climate (see II.1.2 and XII.3).

Also in soil section EZA and EZB, one of the erosional sources has been located relatively accurate and can be connected with human activity. The serpentinite, only present in the upper units post-dating 1.64 ± 0.15 ka BP (210 - 510 AD), points to local erosion in the serpentinite outcrop area West of the Ezousas. It is striking that in the neighbourhood of the serpeninite outcrops at the location of Ayia Varvara-*Pavoules*, a large settlement was discovered. At this location Late Roman, Early Byzantine and Medieval activity took place (Rupp 1984: 150). Hence, the erosion might be partially caused by land exploitation in the surroundings of the settlement.

Furthermore, more evidence of human impact on the landscape was discovered in section KIS1.5 (see also VII.2.2.9B). The occurrence of superparamagnetic minerals in KIS1.5 suggests human impact on the landscape, possibly related to fire and burning activities, maybe related to depletion of the forests. The unit above this thin layer possibly indicates the consequences of these activities. This is, sometime after 894 ± 250 AD, erosion upslope led to the deposition of an alluvial layer containing lots of sherds.

Additionally, at section TA and TB along the Stavros-tis-Psokas, evidence was found of two major phases of erosion. While the first erosional phase took place sometime after 300 ± 65.5 AD, the second erosional phase occurred sometime after ± 753 AD. In chapter III.2.3 it was mentioned that substantial evidence was found of Roman and Byzantine metallurgical activities within the Stavros-tis-Psokas drainage in the neighbourhood of the investigated sections. Late Roman slag heaps were found at Trimithousa-*Paravoulena*, Sarama-*Katavlaka I* and Philousa-*Leyirin*. They suggest that an increased metallurgical activity took place in the area during that period. Also several Byzantine sites were found having a typical association with slag. The possible temporal correlation with the increased mining and smelting activities in the area and the increased erosion during these periods seems to suggest a causal relation.

Hence, anthropogenic induced erosion is not only a recent problem on Cyprus, but probably took place in the Late Roman, Byzantine and Frankish period as well, as is suggested by the above geomorphological case-studies. Mining/smelting activities and farming/herding were probably the main causes for anthropogenic erosion. Through this erosion at the given localities, not only the landscape, but also the archaeological record was partially destroyed.

XI.5. Conclusion

This chapter indicates the importance, possibilities and necessity of alluvial research on Cyprus. Alluvial research can offer landscape reconstructions, improves our understanding of settlement and site patterns, improves our understanding of human impact on the landscape and opposite of the impact of the environment on humans.

General conclusion

Only little attention was given to the geo-archaeological sub-discipline on Cyprus. Since Vita-Finzi's pioneering work « *The Mediterranean Valleys* » (1969) in which he presented a landscape evolution model for the whole of the Mediterranean region, only limited progress was made on Cyprus. Archaeologists paid lip service to alluvial research on Cyprus. Actually, new interest on the alluvial sediments has resumed while the last pieces of evidence of previous landscapes are being destroyed by major land development. Alluvial research can offer a variety of information for archaeologists on Cyprus. First, it can deliver information on site locations. Secondly, in order to understand the settlement patterns on Cyprus, it is imperative to acknowledge the limitations geologic processes impose on the archaeological record. More specifically, some sites have been destroyed by channel activity, while others have been covered by sediments. Finally, alluvial research will make it possible to create landscape reconstructions and will broaden the scope from the site-oriented archaeology towards a better understanding of the past. Humans lived in a world of many locations. Hence, restricting our insight into Cypriot people in the past to discrete archaeological sites, unnecessarily narrows our understanding of their way of life. Eventually, when the Mediterranean alluvial research reaches the same standards as in the USA, deeper insight will be gained into climatic and anthropogenic impact on the landscape.

On the one hand, the following variables were investigated in order to obtain understanding of the impact of natural factors on the fluvial history: climate, sea level and tectonic activity.

Although little palaeo-climatic evidence was retrieved on Cyprus itself, added evidence from surrounding countries indicates that the two-tiered Vita-Finzi model for landscape evolution, consisting of an Older and Younger Fill is too simplistic and needs to be more elaborated. Vita-Finzi assigned the Older Fill to Pleistocene climatic conditions and the Younger Fill due to the Little Ice Age. However, climatic fluctuations during the first half of the Holocence were far more extreme compared to the Little Ice Age fluctuation. The climate in the Eastern Mediterranean has alternated between humid and dry periods since the last glacial.

Furthermore, sea-level research indicates that the main post-glacial sea-level rise probably occurred between 15,000 and 11,000 BP. The sea level probably continued to rise until about 5,000 BP. This rising sea level might have favoured aggradation in the Cypriot rivers. Subsequently, a sea level fall between 5,000 and 3,500 BP might have promoted incision. Moreover, a rapid sea level increase from 1,000 until 0 BC might have favoured aggradation again. Since 0 BC, the sea level was approximately similar to what it is today.

Research suggests that the island has known considerable tectonic uplift first during the Late Pliocene-Early Pleistocene. During the Early and Middle Pleistocene particularly rapid uplift took place, centred on the Troodos. From the Late Pleistocene onwards, uplift of the island seems to have been reduced. This uplift had a severe impact on the rivers. It resulted in the present day radial drainage pattern and was the dominant factor in causing the deposition of Early and Middle Pleistocene Fanglomerate units. However, the uplift decreased since the Late Pleistocene. Hence, alluvial deposits in Western Cyprus are presumably not primarily a result of uplift centred on the Troodos. However, tectonic activity in general probably had an impact on the Holocene alluvial history of Cyprus, mainly by causing landslides. The Cypriot recorded Holocene tectonic history is far from complete. Especially the 4th century AD is known as a period of unusually high seismic activity in the Eastern Mediterranean.

On the other hand, the impact of humans on the fluvial history was investigated through a study of literature on the subsistence economy and metallurgy.

The archaeobotanical, faunal and literary evidence make it possible to estimate what effect food provision had on the environment. Research on the subsistence economy indicates that the following periods were crucial for the environment as a consequence of expanded clearance for cultivation and herding. The landnam of the

Aceramic Neolithic period was probably a crucial period. Furthermore, the agro-pastoral intensification of the Middle Chalcolithic might have led to increased, localised deforestation and land exploitation. Additionally, the introduction of the ox-drawn plough complex in the Early Bronze Age opened new lands and consequently might have caused expanded erosion. The incidence of an increased production in the Late Bronze Age might have resulted in erosion as well. Finally, the increased production in the Frankish and Venetian period by the use of new crops allowing two growing seasons might have been a crucial period of erosion.

The metallurgical activities had a severe impact on the Cypriot forests. Based on all slags discovered on Cyprus, it has been estimated that the island would have been deforested 16 times approximately. However, numeric data about slagheaps in order to estimate the actual production for each region and period on Cyprus are not available. This necessitated the investigation of the metallurgical history. In spite of all available archaeological and historical evidence, we still seem to lack the necessary evidence to understand the exact impact of metallurgy on the Cypriot environment. Most extensive mining sites were reused more recently. As a result, former evidence has disappeared and accordingly only small mining sites were preserved. Hence, the archaeology of mining and smelting sites seems to suggest rather small-scale activities. The historical evidence seems to point to more large-scale operations and organised activities, especially during Roman times but also during the Bronze Age. According to the ancient literature and correspondence Cyprus was famous for its copper. As a consequence, the importance of metallurgy on the Cypriot economy must have had a strong impact on the environment, especially during the above-mentioned periods.

The several variables that supposedly affected the Cypriot alluvial sequence were assembled as to build a landscape evolution model that can be compared with the alluvial sequence. It is suggested that the following periods were marked by a combination of factors possibly favouring alluviation: the Neolithic period, the Middle and beginning of the Late Chalcolithic period, the Late Bronze Age, the Late Hellenistic and Roman period, the Frankish and Venetian period.

The impact of the fluvial history on humans was addressed through a study of literature on the prevalence of malaria and thalassemia, which indirectly indicates the occurrence of swamps. Malaria was one of the problems coastal people endured when rivers silted up. The malaria parasite was probably endemic in Cyprus by the Neolithic period and is attested throughout the island's history. Malaria incidence has profoundly influenced the genetic structure of human populations on Cyprus, by causing the genetic adaptation of thalassemia. Malaria also had a major impact on human behaviour as the population had to avoid the coastal areas.

In order to test the landscape development hypothesis based on literature research, geomorphologic fieldwork was undertaken along several streams of Western Cyprus: the Stavros-tis-Psokas, Agriokalamos, Dhiarizzos, Ezousas and Xeropotamos. About 30 fluvial sections were recorded and about 300 sediment samples were taken for further laboratory investigations, consisting of loss-on-ignition, magnetic susceptibility, pH, lithological identification, clast shape analysis and particle size analysis.

Several problems initially hampered the dating of the alluvial deposits. Morphological mapping difficulties were faced as a result of severe landscape destruction. River terraces were often bulldozed and made mapping impossible. Secondly, organic material for ^{14}C dating was retrieved only in the upper, recent layers of the sediment sequences. Sherds were often rolled by river action. Only three sherds could be dated by typology. Furthermore, lithic artefacts were even more difficult to date. Hence, other means were needed to date the alluvial sequence. The luminescence dating method proved to be a powerful tool for establishing a preliminary alluvial chronology on Western Cyprus. A simple application on about 80 sherds provided an approximate chronology for quite a lot of soil sections. This dating application was especially useful for late deposits. Since the date of the sherds can only be used as *terminus post quem* for the deposition of the sediment, the later the sherd, the smaller the risk for interpretation errors. Consequently, the method of using roughly dated sherds to receive a first chronological insight into the time of sedimentation is obviously more successful with younger deposits. The possible older deposits require different techniques to corroborate their antiquity. Moreover, dating alluvial sequences through dating the artefacts in them, inherently discriminates the sediments lacking artefacts. The optically stimulated luminescence (OSL) dating method on 8 sediments was addressed to date some possible older sediments. The OSL-method appears to be a promising technique to develop a chronological framework for the fluvial deposits on Cyprus. In most cases, the quartz SAR method produces results consistent with the field evidence and completes the information available. Although the dating precision using the conventional OSL-SAR procedures is rather limited, due to incomplete bleaching in fluvial contexts, a new small-aliquot SAR procedure may overcome these limitations in future work.

Evidence was found of alluvium from or post-dating the Prehistoric period, the Iron Age, the Hellenistic and Roman period, the Byzantine, the Frankish and Ottoman period. The alluviation evidence from recent periods is far more extensive than from more remote periods. This supposedly reflects the inherently episodic nature of environmental processes. Major erosion cycles from the more distant past may have removed (destroyed or displaced) previous erosion.

The lithological distribution of the investigated alluvial samples indicates that the West Cypriot Pleistocene alluvial deposits were different from the Holocene alluvial deposits. The latter contain a smaller proportion of far-travelled stones. This observation was especially noticeable in the major river valleys of Western Cyprus. Several reasons for this marked difference were given. A first possible explanation may be that the Pleistocene was marked by different, more extreme climatic conditions than the Holocene. A larger water supply for the river might have transported stones over a larger distance in shorter periods. A second explanation may be that uplift and consequent unroofing of the Troodos resulted in a larger supply of igneous stones in the Pleistocene deposits. A third possible cause for the different lithological composition of the Holocene alluvial sediments compared to the Pleistocene sediments, might be attributed to human impact on the landscape; a result of the human preference for the lower portion of the drainage.

Through lithological provenancing it was possible to discover some direct correlations between human use of the landscape and erosion. The deposition of more than 2 meters of alluvial deposits along the Ezousas near Kannaviou (EZG) could be correlated with erosion at the Medieval mining and smelting site at Asproyia-*Ayios Sozondas*. Furthermore, deposits near Ayia Varvara (EZA) could be correlated with activities of the large Late Roman, Early Byzantine and Medieval settlement at Ayia Varvara – *Pavoules*. Moreover, the lithological composition of the fluvial deposits near Prastio (PR1) could be correlated with the activities at the Medieval monastery at Prastio Ayios Savvas tis Karonis.

Vita-Finzi referred to the Younger Fill as predominantly consisting of stratified sands and silts. However, the Western Cyprus Geo-Archaeological Survey, rarely came across these types of deposits. This is a result of the fact that the major rivers on Cyprus had a braided morphology (as nowadays as well). Fine-grained sediments are minor constituents of the depositional record in braided streams. The river morphology has implications for the preservation of the archaeological record. The dynamic processes associated with braided rivers, create a setting not conducive to the preservation of archaeological sites. However, the Agriokalamos and Stavros-tis-Psokas sediments resemble more Vita-Finzi's descriptions of the Younger Fill. It is suggested that the Agriokalamos and Stavros-tis-Psokas were meandering rivers, as they appear nowadays as well. Within meandering river environments, sites have better preservation chances.

The study of the soil archive on top of and intercalated within alluvial deposits makes it possible to draw conclusions about landscape stability, its occurrence and duration. Moreover, soil formation makes it possible to identify the palaeo-environment (e.g. climate and vegetation cover). The study of present day surface soils on alluvial sediments is useful for the interpretation of the palaeosols. Furthermore the degree of soil formation gives some indications as to when the alluvial sediments were deposited. This is especially useful for alluvial sections without artefacts, but also for all sections dated by a *terminus post quem*. The palaeosols delivered information on the duration of the landscape stability. Through extrapolation with the evidence of recent soil development, it is possible to estimate a deposition date for undated deposits. The palaeosols also delivered palaeo-environmental information. It is suggested that the soil on TB5/TA3 developed under dry and warm conditions sometime past 300 ± 65.5 AD. Furthermore, the palaeosols on KAGC3, KAGC10, KAGD12 and KAGD8 suggest rather dry climatic conditions. The soil on EZA8 suggests dry and warm climatic conditions sometime after 160 ± 160 BC and 1.64 ± 0.15 ka BP, while the later soil on EZA4 suggests more humid conditions sometime after 1.64 ± 0.15 ka BP. Additionally, the soil developed on EZD3 suggests warm and humid climatic conditions sometime past 868 ± 559 AD.

A comparison of the geomorphologic data with the hypothesis based on the study of literature of several variables and with the alluvial data from other Mediterranean regions results in the following conclusions about the causality of the landscape changes. The attested Neolithic alluvium on Cyprus is probably a result of the combination of a humid climate, a rising sea level and the first Neolithic humans in an island environment. Furthermore, the alluvium along the Agriokalamos near the Chalcolithic settlement of Lemba probably ante- and post-dates the Chalcolithic period. The evidence suggests that at first relatively swampy conditions prevailed in the river valley, thus moister than nowadays. Additionally, the attested agricultural intensification from the Middle Chalcolithic on, probably favoured further localised alluviation. The possible Iron Age, Hellenistic and Roman period alluviation can be correlated with extensive erosion in many parts of the Mediterranean during the first millennium BC, which suggests climatic factors operating in causing the alluviation. As a matter of fact, the first millennium BC was marked by relatively dry conditions, probably resulting in a reduction in the vegetation, leading to sheet erosion and the deposition of debris flow in the river valleys. The subsequent humid Roman period might have triggered severe erosion. However, human impact on the landscape through farming and mining caused erosion as well. Alluvium from or post-dating the Byzantine period was probably a result of severe droughts around 800 AD and the overall drier Byzantine period. Evidence from many parts of the Mediterranean region indicates that increased erosion took place about that time. This supra-regional synchronism indicates the climate as an important factor in causing increased deposition of sediments in the Mediterranean river valleys. However, the human impact should not be underestimated in triggering erosion during that period. Several Cypriot sediments from that period contain the evidence of human impact on the landscape, through deforestation, mining and smelting. Furthermore, the possible widespread Frankish alluviation on Cyprus was favoured by the warm and wet climate, which accelerated overbank deposition. Additionally, a major incidence of earthquakes possibly triggered landslides. Moreover, new crops allowing two growing seasons were increasingly produced during that period. Especially areas near monasteries were extensively exploited and resulted in erosion. Furthermore, the deposition of alluvium could also be correlated with human caused erosion through deforestation in the form of smelting and mining operations. Hence, although the climate favoured overbank deposition, human impact on the landscape was also at least partially responsible for alluvial deposition during that period. The relatively recent alluvium (Venetian and Ottoman) might correlate with the far more extreme climatic conditions during the Little Ice Age. As a result, flood events deposited thick layers of alluvium. Additionally, frequent earthquakes during this period might have caused landslides. Furthermore, human impact on the landscape was intensive as a consequence of the use of two growing seasons in farming practices. Although some preliminary conclusions, we may say that further chronological research is necessary in order to gain deeper insight into the entangled factors causing erosion on Cyprus and in the Mediterranean in general.

All this alluvial data have implications for the archaeological record. Alluvial research provides new insights for the understanding of Cypriot settlements in the landscape. The Western Cypriot alluvial data indicate that site visibility at the modern surface is neither a reliable, nor a complete indication of what might still be present in the archaeological record. Some sites were covered by alluvium, such as a possible Prehistoric quarry site in the investigated alluvial fan at Souskiou, while other sites might have been eroded, such as a Byzantine site at Prastio and sites of all periods at Sarama. Hence, the geo-archaeological survey in Western Cyprus is prerequisite to understand settlement patterns. Furthermore, alluvial research leads to a better understanding of the impact of the environment on humans. The Western Cypriot rivers had direct and indirect impact on humans, human behaviour and even human genetics. Although rivers were a positively valued factor in settlement location and land exploitation, they could also cause problems. Several case studies have been presented in this thesis which indicate that siltation and alluviation had impact on the decline of harbour towns, on the decline of the sugar industry and indirectly also changed human genes and social behaviour. Additionally, alluvial research also leads to a better understanding of the impact of humans on the environment. The alluvial evidence at several locations in Western Cyprus indicates that anthropogenic induced erosion is not only a recent problem on Cyprus, but probably took place in the Late Roman, Byzantine and Frankish period as well, as suggested by several case-studies. Mining/smelting activities and farming/herding were probably the main causes for anthropogenic erosion. Through this erosion at the given locations, not only the landscape, but also the archaeological record was partially destroyed.

This thesis indicates the importance, possibilities and necessity of alluvial research on Cyprus. Alluvial research can offer landscape reconstructions, enhances our understanding of settlement and site patterns, and improves our understanding of human impact on the landscape and opposite of the impact of the environment on humans.

- **Possible future research directions:**

Indeed, this thesis is a first attempt to make up the arrears of geo-archaeological survey in Western Cyprus. Hence, it is hoped that this research instigates further research. As a matter of fact, several suggestions and directions for future research are pointed out in the thesis.

1. First of all, the variables, which shaped and changed the landscape are not that well known on Cyprus.

   a) The climatic history of the island itself is only known by extrapolation from the mainland, which inherently causes some problems. Pollen analysis has rarely been applied on Cyprus. Although the alluvial sediments are mostly very alkaline, an attempt should be made to retrieve pollen from it. The rip-up clasts from the sections KAGC and KAGD along the Agriokalamos may contain a pollen archive, as they are organic rich.

   b) Furthermore, considering the large amount of fairly recent deposits, only little is known of climatic conditions in historical times. Grove and Contario clearly point out the possibilities the historical archives from the Venetian period contain to reconstruct the former climate of Crete. Only little is known of the Little Ice Age in the Eastern Mediterranean. It is suggested that for Cyprus, having a similar history as Crete, similar historical research should be undertaken on the Venetian archives in order to understand local climatic conditions.

   c) Moreover, the economy is not well known for all periods. Major gaps in the evidence are attested for the Iron Age, the Hellenistic and Roman period. More palaeobotanical, archaeozoological and historical research should be undertaken for these periods on Cyprus.

   d) Furthermore, in order to estimate the impact of the metallurgy on the landscape, major research progress should be made. Slag heaps in Western Cyprus should be measured and dated in order to estimate the needed fuel and consequent deforestation for metallic production during each period.

2. As a matter of fact, the dating provided in this thesis is preliminary and further research is necessary to establish an accurate landscape evolution model for Western Cyprus. This thesis indicates the possibilities of the luminescence method on Cyprus, though many more dates are necessary to establish a firm chronology. The new small-aliquot SAR procedure, applied in this thesis,

seems to be very promising to develop a chronological framework as it enhances the dating precision of conventional OSL-SAR procedures. However, dating problems are encountered at the alluvial sections along the Agriokalamos, where the OSL-dates suggest a Pleistocene date while sherds occurred in the sections. Hence, further chronological research is necessary at this location. A ^{14}C date should be retrieved from the humate fraction from a palaeosol A-horizon in these sections.

Not only the Cypriot alluvial chronology needs to be refined, but also all Mediterranean alluvial chronologies need to be dated more precisely before we can thoroughly understand the causality of the alluviation in the Mediterranean region. This thesis provided two new useful luminescence methods, which could be applied in other parts of the Mediterranean to date the alluvial sequence.

3. Additional techniques could expand the understanding of the Cypriot landscape evolution. Micromorphology could enhance our understanding of the complexity of the soil formation on Cypriot alluvial sediments. Moreover, aereal mapping may enable recognition of the spatial and temporal relationship of the bulldozed terraces. Furthermore, GIS and erosion modelling could result in landscape reconstructions.

Last but not least, I hope this thesis stressed the fact that ideally a geo-archaeological survey should be conducted in association with an archaeological survey as it enhances the interpretation of the settlement pattern.

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Appendix 1:

Optically Stimulated Luminescence dating of fluvial sediments from Western Cyprus

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Joel Q. Spencer and David C.W. Sanderson

*Scottish Universities Environmental Research Centre,
East Kilbride G75 OQF, Scotland, UK*

1. Introduction

This report presents results from an optically stimulated luminescence dating (OSL) study on fluvial sediments sampled from river terraces within selected valleys in Western Cyprus associated with archaeological settlement in these regions. Katleen Deckers, from the Department of Archaeology, University of Edinburgh, submitted sixteen fluvial sediment samples to the luminescence laboratories at SUERC. Of these sixteen, eight were chosen as priority samples for luminescence analysis. Deckers completed on-site field gamma dosimetry measurements and the samples were submitted with details concerning stratigraphic relationships, geographic location, depth of overburden, expected ages, and SUERC-TL (SUTL) laboratory numbers (Table 1).

Table 1. Sample details as received

Site Name	Stratigraphic Unit/Context	Sample #	SUTL Lab #	Latitude (°N)	Longitude (°E)	Altitude (m)	Field γ dose-rate ($mGya^{-1}$)	Expected Age (ka)
Souskiou	SOA2	SOA1	1327	34.7347	32.6013	80	0.577±0.044	~5-7?
	SOA10	SOA3	1329	34.7347	32.6013	80	0.636±0.047	~2.5?
Ezousas A	EZA9	EZA1	1332	34.756	32.5039	80	0.554±0.043	<2.16
	EZA5	EZA4	1335	34.756	32.5039	80	0.653±0.049	<2.16
Agriokalamos	KAGB15	KAGB1	1337	34.8151	32.4008	24	0.539±0.040	>>~10
	KAGB12	KAGB2	1338	34.8151	32.4008	24	0.569±0.041	>~10
	KAGB10	KAGB3	1339	34.8151	32.4008	24	0.490±0.036	<10
	KAGB6	KAGB5	1341	34.8151	32.4008	24	0.861±0.058	<~5.5

2. Sample preparation and luminescence measurement

Preparation and measurement procedures were carried out under safelight conditions to avoid bleaching the natural luminescence. The eight samples were carefully removed from the metal sampling tubes and the as-received moisture content measured by comparing wet mass with dry mass after weight stabilisation in a 50°C oven. A 20 g portion of dried sediment from each sample was removed to determine beta dose-rates using thick source beta counting (Sanderson, 1988) by comparison with known dose-rate standards and backgrounds in the same counting geometry. These portions were then placed in plastic petri dishes and made gas-tight with an araldite seal. The petri dishes were stored to allow radon gas build-up, and then counted on a high-resolution gamma spectrometry system with standards and backgrounds. In the meantime, 90-125 μm quartz grains were extracted from the remaining sediment from each sample. This procedure involved sieving to the desired grain size fraction, removal of carbonates with HCl, removal of plagioclase feldspars and etching of the surface of the quartz grains with 40% HF and removal of any heavy minerals by density separation techniques using a solution of sodium-polytungstate ($2.74\ g\ cm^{-3}$). The quartz grains were mounted onto stainless steel discs (~9.6 mm diameter and thickness of ~0.25 mm) coated with a layer of silicon grease. Sixteen discs were prepared from each sample, dispensing a circle of grains onto the centre of each disc with a diameter of about 5 mm.

OSL measurements were carried out using a Risø TL/OSL-DA-15 automated system. Luminescence from the quartz grains was stimulated using blue diodes (470 Δ 20 nm) with detection in the ultraviolet defined by two Hoya U340 filters. A single aliquot regenerative-dose (SAR) protocol (Murray and Wintle, 2000; Sanderson *et al.*, 2001) was used to determine the equivalent dose (D_e) on each disc measured. In the SAR method, each natural or regenerated OSL signal was corrected for changes in sensitivity using the luminescence response to a subsequent test dose. Each measurement cycle comprised a regeneration dose (zero for natural), a sample preheat for 30 s, optical stimulation for 100 s (sample temperature of 125°C), a constant test-dose, a test-dose preheat of 160 °C for 30 s and a final optical stimulation for 100 s at 125 °C. The sample preheat was 250°C for the first set of 4 discs, and for each set of 4 thereafter the preheat was increased by 10°C. This was carried out to enable monitoring of stability of D_e over 250, 260, 270 and 280°C preheats. The net-natural and net-regenerated OSL was derived by integrating the OSL signal over the first few channels of data (typically integrals varying between 0.5 and 5 s) and subtracting a background from the last part of the stimulation curve (80-100 s); the net-test-dose response was derived by subtracting the background from the preceding natural and regenerative OSL signals. Several such measurement cycles were carried out at different regeneration doses to enable construction of a growth curve. The growth curves were plotted using the net-regenerated data divided by the subsequent response to the net-test-dose. The growth curve data were fitted with a linear or single saturating exponential function and the D_e was estimated by interpolation with the net-natural sensitivity-corrected luminescence level. The distribution in D_e values was examined using weighted histogram plots (Duller *et al.*, 2000).

3. Results and discussion

The results of dosimetry measurements are shown in Table 2. Gamma and beta dose-rate estimates from laboratory gamma spectrometry were broadly consistent with dose-rate estimates based on field measurements and TSBC. They did not appear to add significant information and have not therefore been included in the final assessment of environmental dose-rates.

Table 2. Dosimetric measurements

SUTL Lab #	Field γ dose-rate ($mGya^{-1}$)	Dry TSBC[a] ($mGya^{-1}$)	$W_{in\text{-}situ}$[b]	Cosmic[c] ($mGya^{-1}$)	Total[d] ($mGya^{-1}$)
1327	0.577±0.044	0.847±0.062	0.32	0.097±0.010	1.22±0.08
1329	0.636±0.047	0.750±0.084	0.083	0.124±0.012	1.40±0.11
1332	0.554±0.043	1.038±0.066	0.16	0.154±0.015	1.50±0.11
1335	0.653±0.049	1.061±0.082	0.12	0.169±0.017	1.66±0.12
1337	0.539±0.040	0.709±0.071	0.19	0.101±0.010	1.16±0.08
1338	0.569±0.041	0.811±0.085	0.34	0.116±0.012	1.20±0.08
1339	0.490±0.036	0.737±0.106	0.16	0.131±0.013	1.18±0.11
1341	0.861±0.058	1.032±0.061	0.15	0.148±0.015	1.80±0.11

Notes: [a]Thick source beta counting
[b]Estimated fractional water content (mass moisture/dry mass) as received. Uncertainty taken as ±10%.
[c]Calculated cosmic ray dose-rates. For details see Table A1 in Appendix A.
[d]Total dose-rate from beta, gamma and cosmic components. Beta dose-rates from TSBC attenuated for moisture content, grain size and acid etch.

Weighted histogram plots representing the distribution in D_e values for each sample are shown in Appendix B (Figures B1 to B8). It is clear from these plots that all the samples have a wide distribution in D_e values, which is reflected in the large uncertainty in weighted mean results in Table 3. Therefore the errors on the OSL ages are correspondingly large. However, we see that with comparison with Table 1, 5 out of the 8 OSL ages are broadly concordant with expected ages. The OSL results for

SUTL1339 and SUTL1341 indicate Pleistocene ages and it is very unlikely these samples are associated with Holocene or younger deposits. The reason for the wide distribution in D_e results is most likely to be due to a combination of varying or insufficient solar bleaching at deposition and mixing processes leading to co-deposition of well-zeroed and unbleached grains. These are recognised problems for the dating of fluvial sediments using OSL techniques.

Table 3. Summary of OSL dating results from 90-125 μm quartz extracted from sediment matrices

SUTL Lab #	N^a	Weighted mean D_e (Gy)	Total dose-rate ($mGya^{-1}$)	Age (ka)
1327	16	16.0±7.91	1.22±0.08	13.1±6.5
1329	16	5.38±1.51	1.40±0.11	3.8±1.1
1332	15	4.25±1.68	1.50±0.11	2.8±1.1
1335	16	3.77±2.30	1.66±0.12	2.3±1.4
1337	7	77.1±13.3	1.16±0.08	66.5±12.4
1338	7	89.3±14.7	1.20±0.08	74.4±13.2
1339	11	65.5±10.7	1.18±0.11	55.5±10.4
1341	16	63.4±25.9	1.80±0.11	35.2±14.6

Notes: [a]Number of SAR D_e results used to calculate final ages

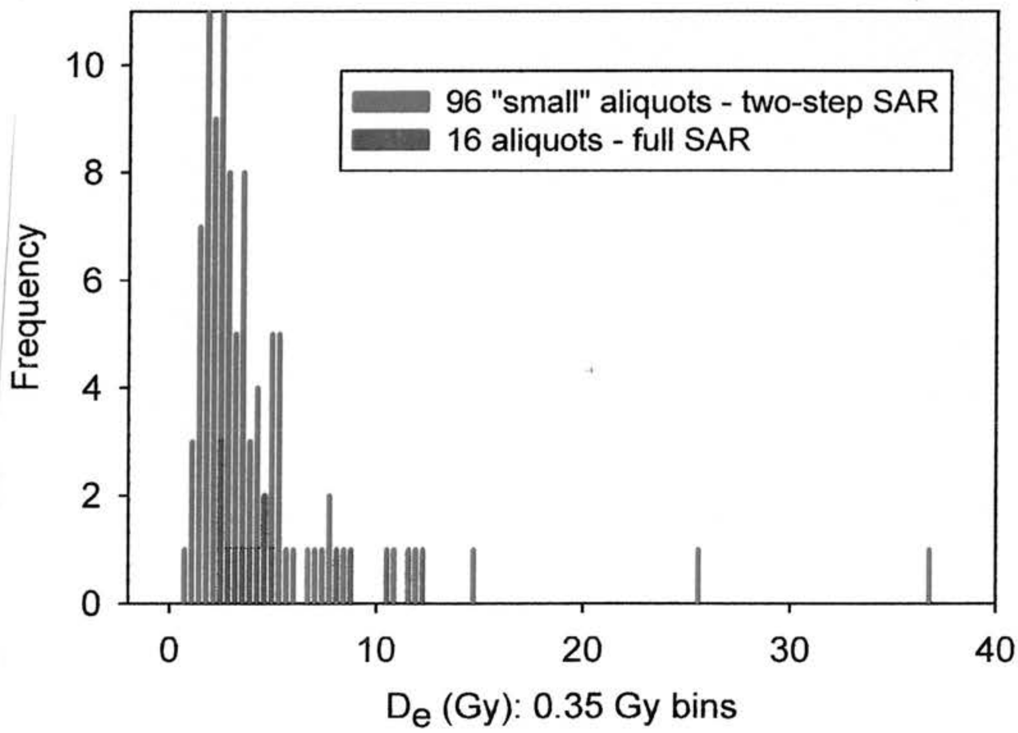

Figure 1. Histogram of SAR equivalent doses (D_e) for sample SUTL1335 showing full SAR runs on 16 aliquots and a shortened two-step SAR on 96 small aliquots.

We decided to look at one of the samples in more detail to determine if it was possible to separate bleached and unbleached components in the OSL data. In a similar manner to Olley *et al.* (1998) we dispensed 96 small aliquots (~100-200 grains) of quartz from sample SUTL1335. We measured these aliquots using a shortened 'two-step' SAR approach. This involved only one regeneration dose of 3.5 Gy, in an attempt to match the natural OSL level from those discs that we would expect to give us more or less the correct (unbleached) D_e.

Our approach differs from Olley *et al.* (1998) firstly because with the use of SAR we can correct for luminescence sensitivity changes, and secondly we believe the mode of the distribution may designate the actual burial dose rather than the 5% position in the distribution. The 96 small aliquot data in Figure 1 clearly shows a significant mode at about 3 Gy, which is distinct from a few scattered points tailing to higher D_e values. This confirms that with the use of small-aliquots we can discriminate between aliquots containing different proportions of bleached and unbleached grains.

This result not only provides clear evidence to support the interpretation of the conventional SAR results being scattered due to variable solar bleaching and environmental mixing processes, but they also suggest that the major low-dose mode of the small-aliquot distribution provides a means of estimating the depositional age for the bulk sediment. From the full SAR growth curves for SUTL1335 it is clear that the mode of the distribution in Figure 1 for the 96 aliquots falls within the linear dose region. We can therefore use a simple linear extrapolation to calculate D_e values. The modal D_e is 2.72±0.14 Gy, corresponding to an OSL age of 1.64±0.15 ka.

In summary: the OSL method does appear to produce a promising technique for development of a chronological framework for these fluvial sediments. The quartz SAR method produces results which are consistent with field evidence and which add to the information previously available. Dating precision using conventional OSL-SAR procedures is limited by mixing processes in these depositional environments but it appears that a new small-aliquot SAR procedure may be able to overcome these limitations in future work.

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Appendix A. Cosmic ray dose-rates

Table A1. Cosmic ray dose-rates calculated according to Prescott and Hutton (1994)

Sample name	SUTL #	Depth of deposit[a] (cm)	Density[b] ($g\ cm^{-3}$)	Mass per unit area ($g\ cm^{-2}$)	D_0[c] ($mGya^{-1}$)	Latitude (°N)	Longitude (°E)	Altitude, h (m)	Geomagnetic latitude (°N)	F[d]	J[d]	H[d] (m)	D ($mGya^{-1}$)	σ_D (10%) ($mGya^{-1}$)
Souskiou A1	1327	600	2	1200	0.09703	34.7347	32.6013	80	31.62	0.27	0.72	4150	0.09742	0.00974
Souskiou A3	1339	400	2	800	0.12309	34.7347	32.6013	80	31.62	0.27	0.72	4150	0.12358	0.01236
Ezousas A1	1332	230	2	460	0.15310	34.756	32.5039	80	31.66	0.27	0.72	4150	0.15371	0.01537
Ezousas A4	1335	160	2	320	0.16818	34.756	32.5039	80	31.66	0.27	0.72	4150	0.16885	0.01689
KAGB1	1337	560	2	1120	0.10159	34.8151	32.4008	24	31.74	0.27	0.72	4150	0.10100	0.01010
KAGB2	1338	440	2	880	0.11718	34.8151	32.4008	24	31.74	0.27	0.72	4150	0.11649	0.01165
KAGB3	1339	345	2	690	0.13188	34.8151	32.4008	24	31.74	0.27	0.72	4150	0.13111	0.01311
KAGB5	1341	250	2	500	0.14911	34.8151	32.4008	24	31.74	0.27	0.72	4150	0.14824	0.01482

Notes: [a]Estimated depth below ground level during sample burial period

[b]Estimated wet density of sediment samples

[c]Dose-rate due to cosmic rays at the sampling depth at sea-level and 55° geomagnetic latitude

[d]Parameters in the expression $D = D_0[F + J \exp(h/H)]$ for finding the cosmic ray dose-rate as a function of altitude and geomagnetic latitude

Appendix B. Weighted histogram (after Duller *et al.*, 2000) representing the distribution in measured D_e values for N repeats. Mean values are weighted mean and standard deviation in seconds of beta dose.

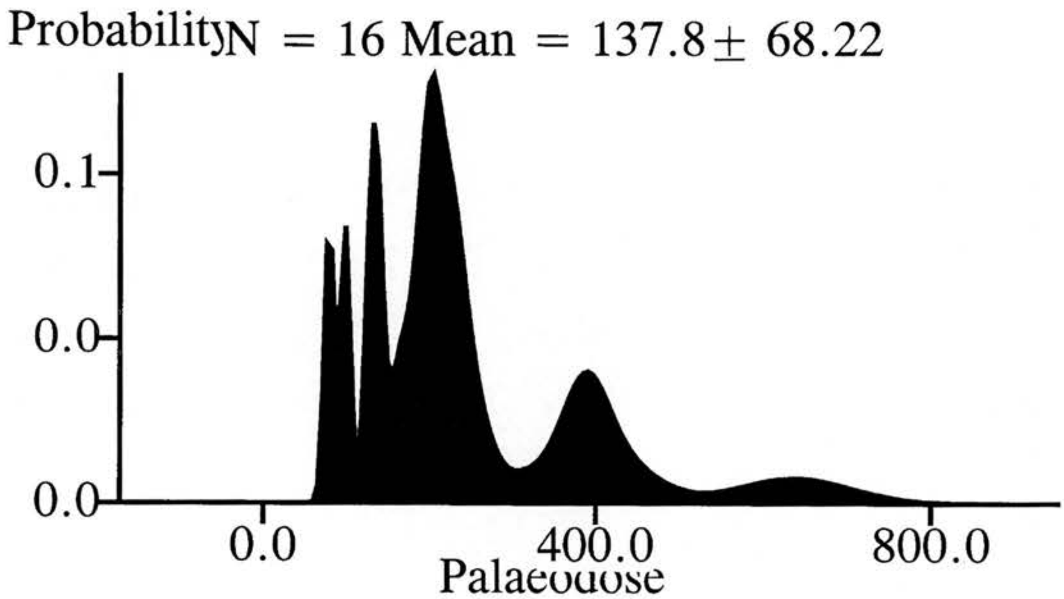

Figure B1. SUTL1327.

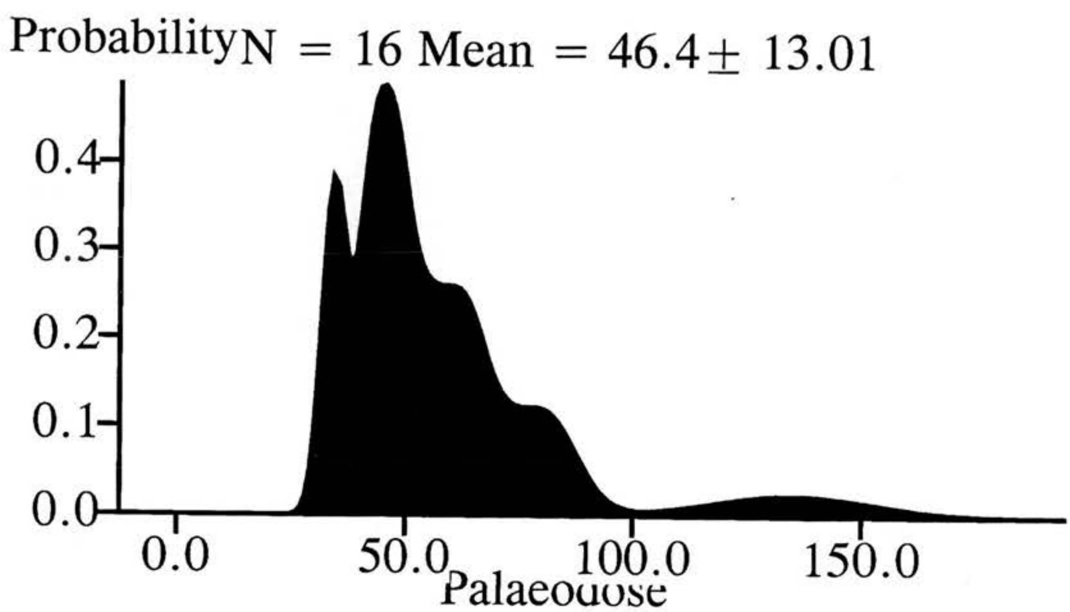

Figure B2. SUTL1329

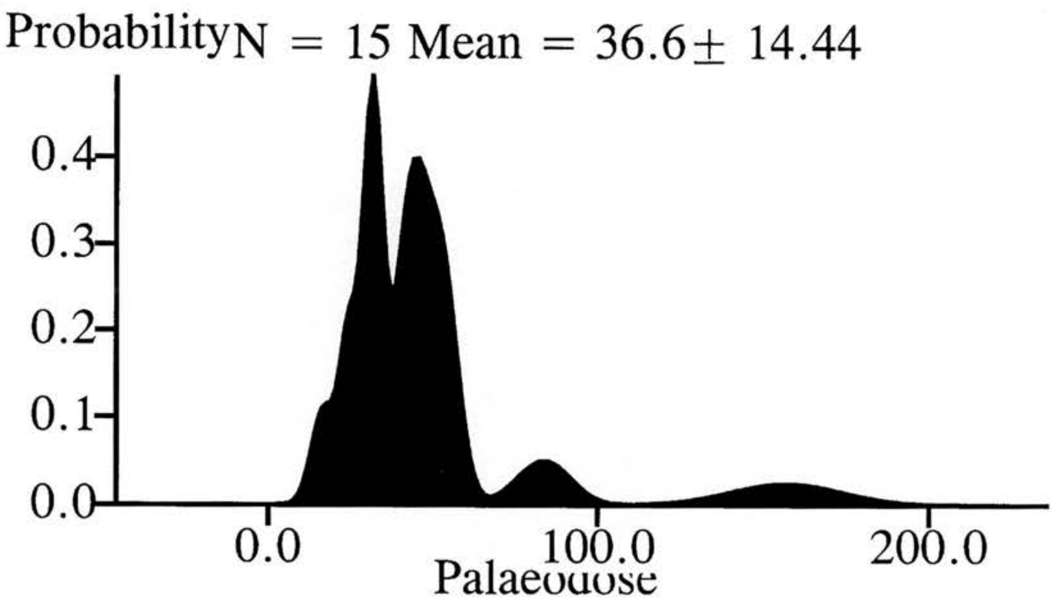

Figure B3. SUTL1332

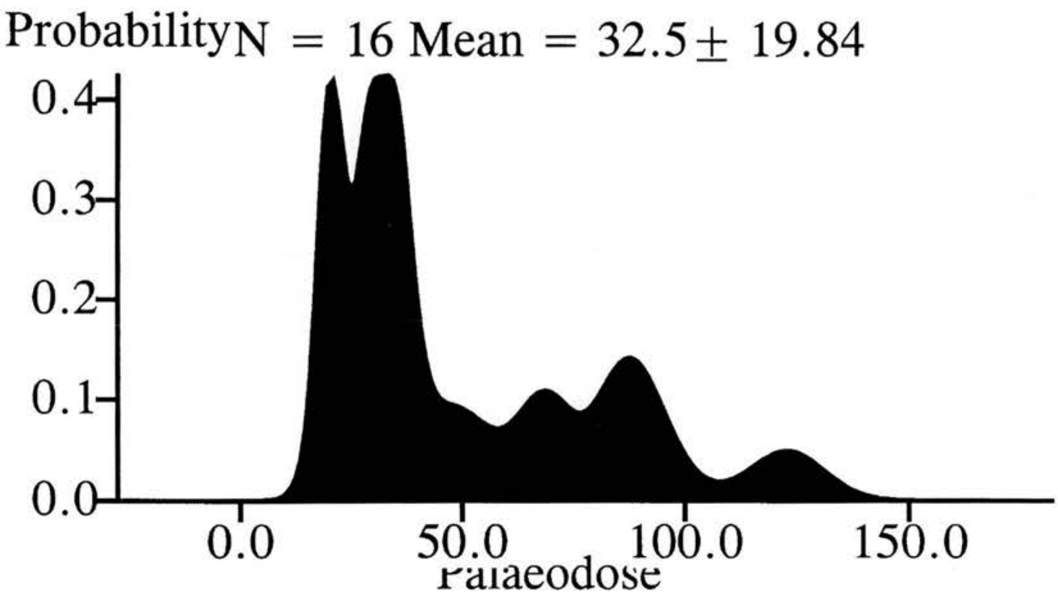

Figure B4. SUTL1335

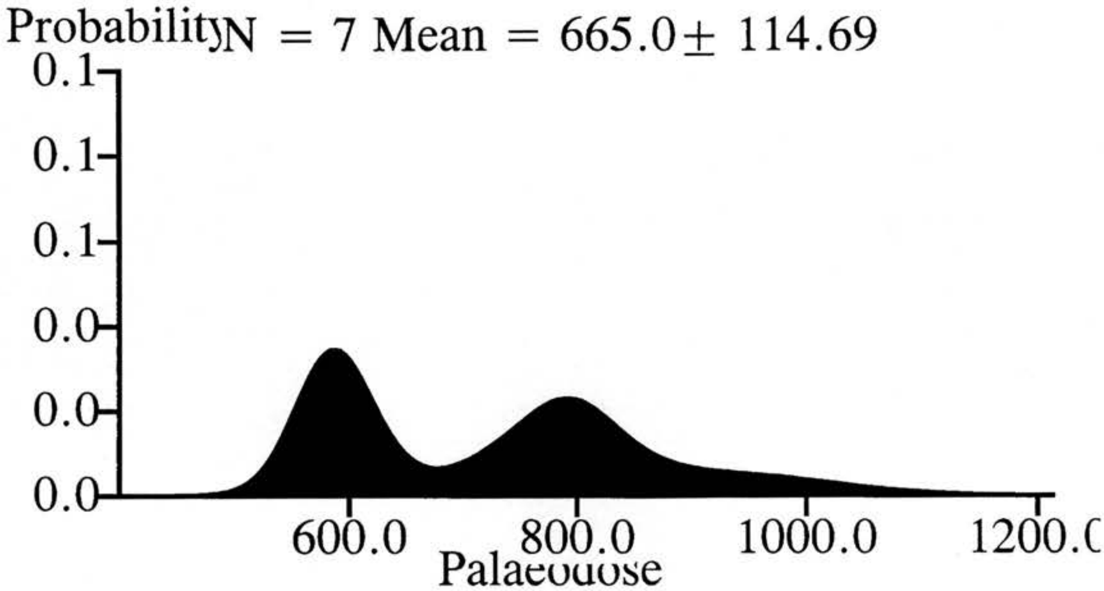

Figure B5. SUTL1337

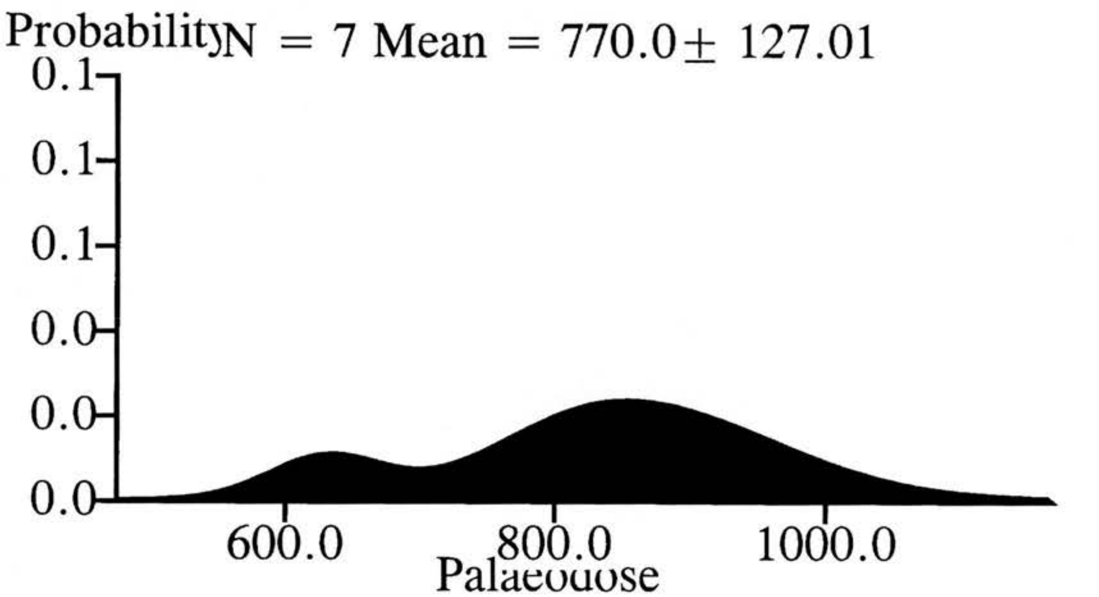

Figure B6. SUTL1338

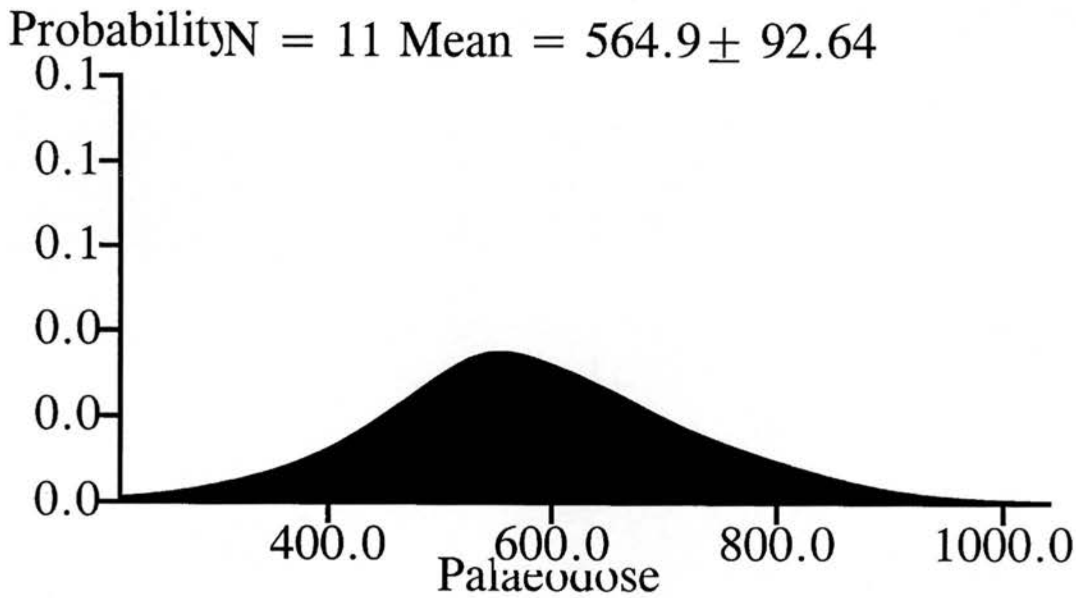

Figure B7. SUTL1339

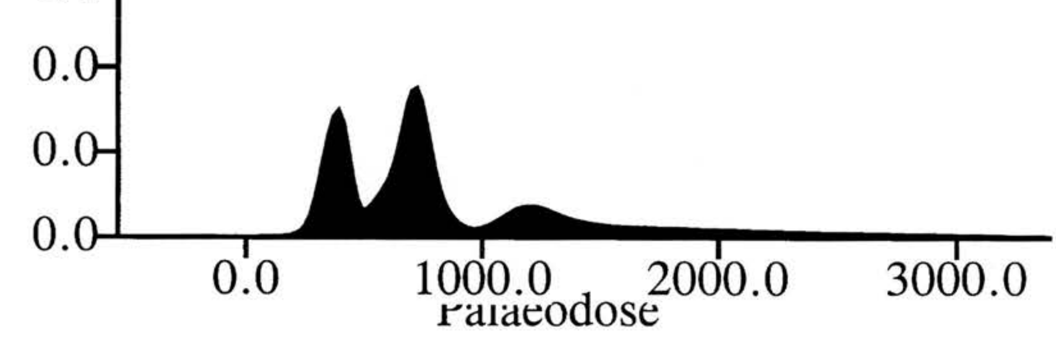

Figure B8. SUTL1341