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*Highlights (for review)

Highlights

1. We studied seed remains from the Epipalaeolithic-Neolithic site of Ifri Oudadane, Morocco.

2. Lentil, wheat, barley and pea are identified in Early Neolithic levels.

3. A lentil is dated to *c*. 7600 BP, the earliest date for a crop in northern Africa.

4. Wild plants are abundant in both the Epipalaeolithic and the Neolithic levels.

5. Wild plants were probably used as food, for fodder and for basketry.

Title

The origins of agriculture in North-West Africa: macro-botanical remains from Epipalaeolithic and Early Neolithic levels of Ifri Oudadane (Morocco)

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Abstract

This research aims to shed light on the early stages of agricultural development in Northern Africa through the analysis of the rich macro-botanical assemblages obtained from Ifri Oudadane, an Epipalaeolithic-Early Neolithic site from North-East Morocco. Results indicate the presence of domesticated plants, cereals (*Hordeum vulgare*, *Triticum monococcum/dicoccum*, *Triticum durum* and *Triticum aestivum/durum*) and pulses (*Lens culinaris* and *Pisum sativum*) in the Early Neolithic. One lentil has been dated to 7611 ± 37 cal BP representing the oldest direct date of a domesticated plant seed in Morocco and, by extension, in North Africa. Similarities in both radiocarbon dates and crop assemblages from Early Neolithic sites in Northern Morocco and the Iberian Peninsula suggest a simultaneous East to West maritime spread of agriculture along the shores of the Western Mediterranean. Wild plants were abundantly collected in both the Epipalaeolithic and the Early Neolithic periods pointing to the important role of these resources during the two periods. In addition to fruits and seeds that could have been consumed by both humans and domesticated animals, fragments of esparto grass *(Stipa tenacissima*) rhizomes have been identified. This is a western Mediterranean native plant that may have been used as a source of fibers for basketry.

1 Introduction

The origin and spread of agriculture and the transition from hunter-gatherer economies to farming have been crucially important archaeological research topics in recent years. A relatively comprehensive understanding has been achieved for several regions of the world, such as the Near East and Europe (Zohary et al., 2012); however, research in certain key regions is vastly underexplored. One of these is North Africa, a potentially critical zone with implications for surrounding areas including the Mediterranean, Europe and the Sahara.

Most of the available literature on the topic suggests that agriculture was introduced into North Africa during the Neolithic by Near Eastern and Mediterranean farmers. However, archaeobotanical data about this process is still very limited. Along the entire southern Mediterranean shore, from Libya to Morocco, only one site (Kaf Taht el-Ghar) has provided domesticated plant remains. Located on the northern coast of Morocco, Kaf Taht el-Ghar was occupied from the Epipalaeolithic to the Bronze Age (Ballouche and Marinval, 2003). The crop assemblage includes einkorn (*Triticum monococcum*), emmer (*Triticum dicoccum*), naked wheat (*Triticum aestivum/durum*), naked barley (*Hordeum vulgare* var. *nudum*) and broad bean (*Vicia faba*). A grain of the latter was dated to 7286 ± 85 cal BP [Ly-971 OXA]. Since data from plant macro-remains is absent for the whole region, it has been assumed that agriculture in North Africa was poorly developed during the Neolithic. In fact, nomadic pastoralism was supposed to dominate the economy at the time (Barker, 2002, 2006; Garcea, 2004; Marshall and Hildebrand, 2002; Roubet, 1979).

A significant proportion of Neolithic sites in North Africa were excavated during the first part of the 20^{th} century and with few accurately dated. Less than half a dozen have yielded clear evidence for farming in the form of reliably identified bones of domesticated animals or seeds and other residues of domesticated plants (Barker, 2002). As a result, throughout the critical millennia of the assumed transition from foraging to farming, the subsistence activities of North African Epipalaeolithic and Neolithic groups have been indirectly inferred from the presence of pottery and stone tools.

In this paper, we focus on a single site, Ifri Oudadane (Morocco) whilst simultaneously incorporating current archaeobotanical data from North Africa (Libya, Tunisia, Algeria and Morocco). This is a vast territory where several geographical regions have been suggested as likely foci from which agriculture was introduced into nearby areas. In Libya, agriculture was presumably introduced from Egypt and the Nile Valley (Garcea, 2004; Pelling, 2008); but in Tunisia, Algeria and Morocco several hypotheses have been put forward. Most of the studies agree with an East to West Neolithic spread consistent with a model involving maritime pioneers (Linstädter, 2008; Linstädter et al., 2012; Oliveira et al., 2011; Zilhâ o, 2001). The arrival of farming to the southern shore of the Mediterranean evidences a degree of delay when compared with the European side (Davison et al., 2006; Zeder, 2008). Unfortuntely, this issue may well be a consequence of an inadequate archaeological record for this specific region. Additionally, the adoption of Neolithic innovations by local hunter-gatherer groups, the potential domestication of cattle in North Africa and the presence of pottery in Epipalaeolithic sites of the Sahara add complexity to the discussion (Garcea, 2004; Linstädter, 2008). Furthermore, Camps (1974) suggested that the transmission of some Neolithic traits arrived from Italy and Sicily to Tunisia and from there to the rest of North Africa.

In the case of Morocco, three main hypotheses have been proposed regarding the beginning of the Neolithic. The first states that agriculture together with the whole Neolithic package arrived initially to the Iberian Peninsula, and from there it moved south through the Gibraltar Strait (Zilhâ o, in press). The second advocates the transfer of some traits related to pottery, flints and bone tools from North Africa to the Iberian Peninsula (Cortés-Sánchez et al., 2012; Manen et al., 2007; Marchand and Manen, 2010). The third suggests that the Neolithic package was spread by seafarers who synchronously arrived to both the northern and southern Mediterranean shores (Gilman, 1974; Linstädter et al., 2012).

This paper attempts to address the following questions: when was agriculture first practiced in this region? What plants were cultivated by the first farmers? What was the role of wild gathered plants in the transition between the Epipalaeolithic and the Neolithic? We present the results of archaeobotanical research from Ifri Oudadane, a recently excavated site on the northern coast of Morocco (Figure 1) that was occupied during the transition from the Epipalaeolithic to the Neolithic. The site demonstrates excellent preservation of plant macro-remains, allowing us to investigate human plant uses during both periods.

1.1 The site of Ifri Oudadane

The site is a rock shelter approximately 5 m high and 15 m wide located in a coastal marble cliff about 50 m above the present shore line (Figure 2). Present-day climate is Mediterranean with hot summers and mild winters, and with a wet season between autumn and spring. The potential flora of the area belongs to a maquia-forest type made of small trees such as pines (*Pinus halepensis*), junipers (*Juniperus* sp.), Holm oaks (*Quercus ilex*) and wild olive (*Olea europaea*) among others but human activities are responsible for deforestation and depletion of natural resources around the site (Figure 2). The site of Ifri Oudadane was discovered recently during road works in the area and it has been excavated since 2006 by a Moroccan-German team ("Eastern Rif" project) which includes the participation of the *Institut National des Sciences de l'Archéologie et du Patrimoine du Maroc* (INSAP), the *Kommission für die Archäologie Außereuropäischer Kulturen des Deutschen Archäologischen Instituts* (KAAK) and the University of Cologne (Jebb, 2008; Linstädter, 2004, 2010; Mikdad et al., 2000; Moser, 2003; Nami, 2008; Nami and Moser, 2010). The archaeobotanical study is part of a larger project on the origins of agriculture in the Western Mediterranean region, led by Dr. Leonor Peña-Chocarro and funded by the European Research Council through an Advanced Grant.

The stratigraphy of the cave is divided into two clear occupation periods (Linstädter and Kehl 2012). The deepest level covers the Epipalaeolithic period (Figure 3). It is a 100 cm thick layer where bone fragments of wild animals (e.g. *Ammothragus lervia*) and lithic tools were retrieved. Three radiocarbon dates on seeds of *Chamaerops humilis* from this period are available (table 2); the oldest dates to 9028 ± 41 cal BP (Beta-313468) while the youngest to 7632 ± 29 cal BP (Beta-316137). The upper part of the stratigraphy forms a 1.5 m thick deposit including ash lenses with significant amounts of charcoal. Pottery fragments and bones of domesticated animals are present indicating an Early Neolithic occupation. While Epipalaeolithic deposits are rather homogeneous and no traces of ash lenses are present, the Neolithic layers appear fairly heterogeneous. The concomitant decrease in C/N ratio indicates that, besides wood, grass and dung were incorporated into the sediments during the Neolithic period. Ovicaprine coprolites and calcite spherulites, as detected by micromorphological analysis, indicate the presence of domesticated animals in the shelter during the early Neolithic occupation. It is also likely that grasses and dung were also used for fuel (Linstädter and Kehl, 2012). Based on the radiocarbon dates, the Neolithic occupation can be divided into three archaeological sub-layers: the Early Neolithic A **(**ENA**),** a 20 cm thick deposit containing material (bone fragments of domesticated ovicaprines) attributed to the early Neolithic. Two radiocarbon dates are available covering a time span between 7.6 and 7.3 ka cal BP. The Early Neolithic B (ENB) is the major occupation phase with ten radiocarbon dates ranging between 7.1 and 6.7 ka cal BP obtained. This part of the stratigraphy yielded the richest Early Neolithic assemblage including retouched blades, impressed pottery and bone fragments of domesticated species. The Early Neolithic C (ENC) is the last unit of the deposit. It contains very few artifacts with dates ranging from 6.6 to 6.4 ka cal BP (Linstädter and Kehl, 2012).

Although rates of sedimentation increased from the Epipalaeolithic to the Neolithic, suggesting that activities were progressively frequent inside the cave (Linstädter and Kehl, 2012), it is likely that the site was seasonally occupied. Unfortunately, the analysis of faunal remains, snails and shells has not been yet completed. However, preliminary data indicates that the Epipalaeolithic groups of Ifri Oudadane were foragers whose diet had a high marine component of fish and marine mollusks.

Foraging continued during the Neolithic and included intensive exploitation of marine resources. No evidence of gradual adoption of Neolithic innovations (pottery, domesticated plants and animals) was detected and food production was still a secondary subsistence strategy (Linstädter and Kehl, 2012). In fact, preliminary results from the excavations carried out in 2006 and 2007 (Linstädter, 2010) indicate that the percentage of domesticated animals is not more than ten percent of the total faunal remains. It is true that the location of the site and the archaeological remains recovered suggest that Ifri Oudadane was mostly used for the processing and consumption of marine resources. The site could have been part of a far more complex settlement which may have included the nearby Oued Kert, an area of permanent water and abundant raw material for producing lithic tools and pottery. Indeed, analysis of the ceramic fragments of Ifri Oudadane point to a local origin of the clay (Linstädter and Müller-Sigmund 2012). Unfortunately, no other sites have been found in the area probably due to the enormous rates of erosion caused by the dynamic Oued Kert River and the heavy grazing of livestock.

Four excavation campaigns were undertaken in 2006, 2007, 2010 and 2011. During the 2006 and 2007 seasons, the sediment was dry sieved and few macro remains were retrieved. However, in 2010 and 2011 the totality of the sediment was floated and a rich assemblage of cultivated and wild plant remains was recovered. The data presented in this paper derived from the 2010 season.

1.2 Palaeoenvironmental data

Pollen and charcoal analyses (Zapata et al., in prep) were undertaken with the pollen diagram showing a high percentage of trees (60-72%) during the Epipalaeolithic indicating the establishment of evergreen sclerophyllous oak and riparian forests in the area around the site. The shrub vegetation (21-31%) is a good representation of the xerothermophilous maquia and was mainly composed of *Olea europaea* and *Pistacia lentiscus* as well as *Myrtus communis*, *Phillyrea* sp., *Rhamnus alaternus*-type, *Cistus*-type, *Erica arborea*-type and *Genista*-type. Among the herbs (4.2-8.3%), only Poaceae and *Ruscus aculeatus* showed significant values. Anthropogenic types were scarcely represented (<1.3%), while pastoral indicators and coprophilous fungi accounted for less that 1%. During this period the main wood fuels used were *Olea* (27%), *Pistacia* (26%) and *Salix* (25%). *Juniperus* (12%) and *Alnus* (8%) were well represented while other types of wood were minor (< 1%) (*Ficus*, Leguminosae, *Pinus*, Rosaceae).

A general decrease in arboreal pollen (30.1-38.2% ENA, 19.4-33.2% ENB) occurred during the Early Neolithic A and B. Riparian forests declined progressively while *Tamarix* increased. Among the shrubs (24.5-32.3%), *Olea europaea* and *Pistacia lentiscus* continued to be relatively abundant while other elements of the xerothermophilous maquia were also present. Anthropogenic types and Poaceae showed substantial values, as do pastoral indicators and coprophilous fungi. *Cerealia* pollen was attested in all samples from the Early Neolithic A (4.5-7.2%) and Early Neolithic B levels (3.6-8.1%) suggesting that cereal fields were relatively near to Ifri Oudadane.

During the Early Neolithic A, *Salix* disappeared from the charcoal assemblages, *Pistacia* decreased slightly and *Juniperus* (24%), *Alnus* (25%) and *Olea* (26%) appeared as the main taxa used. The Early Neolithic B witnessed the disappearance of *Alnus* and the decline of *Olea* (6,9%). In contrast, *Pistacia* became a very important species (44.1%) and *Juniperus* (23.4%) continued to be used.

Finally, a general increase in shrub percentages (max. values *c*. 47%), suggests that the establishment of a xerothermophilous maquia at the expense of some local arboreal elements occurred during the Early Neolithic C. Riparian taxa such as *Alnus* or *Fraxinus* disappeared following drier conditions and increasing anthropogenic pressure. The herbaceous component was dominated by grass pollen and taxa related to human activities. There is, however, a small decline in coprophilous fungi and *Cerealia*-type percentages with respect to the previous phases. Fuel use during the Early Neolithic C follows the pattern observed in earliest levels. The use of *Juniperus* (36%) increased while *Pistacia* (39%) slightly decreased. *Olea* (8.4%) and *Pinus* (5.4%) continued to be collected.

2 Material and methods

All sediment, amounting to some 2,322 litres, from the excavation carried out in 2010 underwent water flotation. This corresponds to 160 samples collected from the Epipalaeolithic (46 samples from 691 litres) and Neolithic (114 samples from 1,631 litres) contexts. The flots were divided into 4 fractions using a sieve column of 4 mm, 2 mm, 1 mm and 0.5 mm. Due to the high density of charcoal fragments in the samples and because most of the domesticated plants were recovered in the 2 mm fraction, the 1 mm and 0.5 mm fractions were split in order to assist the work. Only a quarter of the 1 mm fraction and an eighth of the 0.5 mm fraction were analyzed. Figures in table 1 show the estimated number of seeds after calculation of the total number of remains in each sample. Botanical nomenclature for crops follows traditional binomial classification (see Zohary et al., 2012 for their modern grouping on the basis of cytogenetic and molecular affinities) while for the wild plants we used Charco (2001) and Fennane et al. (2007).

3 Results

A total of 8,002 macro-botanical remains were recovered. Most of them came from the Neolithic levels (7,260) although the Epipalaeolithic layers also contained abundant remains (742). The density of seeds per sediment litre was higher in the Neolithic (4.45 findings per litre) than in the Epipalaeolithic (1.07 findings per litre). Both cultivated and wild plants were identified among the macroremains. The Neolithic layers yielded only domesticated plants whereas wild plants were abundant in both the Epipalaeolithic and the Neolithic levels. A summary of the results is shown in table 1 while a complete table with full results is provided in the on-line supplementary material 1. Figure 4 shows images of the most common and important species.

3.1 Domesticated plants

Barley (*Hordeum vulgare*), hulled wheat (*Triticum monococcum/dicoccum*), free-threshing wheat (*T. aestivum/durum*) and hard wheat (*T. durum*) were identified in the Neolithic levels. For barley, it has not been possible to distinguish between hulled or naked types because diagnostic features were not preserved. In addition, two domesticated pulses, pea (*Pisum sativum*) and lentil (*Lens culinaris*) were also found. The identification of the lentil is problematic due to the presence of three native wild lentils in the modern flora of Morocco: *Lens nigricans*, *L. ervoides* and *L. lamottei* (Fennane et al., 2007). *L. nigricans* and *L. ervoides* produce seeds smaller (maximum longitude 2.5 mm) than domesticated lentils. In addition, some studies suggest that *L. nigricans* is not native to the Western Mediterranean and that it could have been dispersed by humans in the past (Fuller et al., 2012; Ladizinsky et al., 1983). Conversely, seeds of *L.lamottei* are completely circular while domesticated lentils are more ellipsoidal in shape. The archaeological lentil from Ifri Oudadane is 3.2 mm long and has an ellipsoid shape (see Figure 4) which suggests that it belongs to the *Lens culinaris* group. A further interesting issue relates to the absence of wild lentils in the Epipalaeolithic. In fact, lentils have only been identified in the Neolithic period suggesting that this species was indeed a new crop and not a wild local plant gathered by the inhabitants of Ifri Oudadane.

The number of domesticated plants is small (61), and only a few seeds of each taxa have been identified, barley being the most abundant (see table 1). For some taxa such as the group of hulled wheats, pea and lentil only one seed was recovered. In order to confirm the antiquity of the domesticated plant remains nine seeds were radiocarbon dated. Table 2 shows a complete list with the results. Dates range from 7611 ± 37 cal BP (Beta-295779) to 6370 ± 39 cal BP (Beta-295772) confirming the presence of domesticated plants in the Early Neolithic phase of Ifri Oudadane. The oldest date comes from a pulse while cereals were only retrieved from the upper part of the Early Neolithic A. Yet, these were dated to the Early Neolithic B suggesting that some of them are intrusions from the upper level as a result of site formation processes. Nonetheless, there is no evidence of mixing or re-worked layers.

3.2 Wild plants

The number of macroremains from wild plants is extremely large (7,243) with particular emphases in the Neolithic levels. Until recently, most of these plants were gathered for various uses in rural communities of the Western Mediterranean suggesting that the species identified at Ifri Oudadane were probably the result of gathering activities.

Seeds from the mastic tree (*Pistacia lentiscus*) were the most abundant and frequent plant remains. During the recent past, its fruits have been used as a source of oil for cooking and lighting in both Southern Spain and Northern Africa (Rivera-Núñez and Obón-de-Castro, 1991; Torres-Montes, 2004). In addition, leaves have been commonly used as food for livestock (Zapata et al., 2003).

Wild legumes (*Lathyrus* sp./ *Vicia* sp.) were also abundant throughout the stratigraphy pointing to a likely collection from the wild. Rich in proteins, the seeds from wild legumes have been extensively collected for food in the Western Mediterranean (Rivera-Núñez and Obón-de-Castro, 1991; Tardío et al., 2006).

The dwarf palm (*Chamaerops humilis*) was a common species through the whole sequence. Three seeds from the Epipalaeolithic were directly dated (see table 2). Native to the Western Mediterranean (Charco, 2001), this palm produces a type of date that was consumed in Northern Africa and Southern Spain despite the astringent taste of their fruits (Rivera-Núñez and Obón-de-Castro, 1991; Torres-Montes, 2004).

Seeds from Juniper (*Juniperus phoenicea*) were abundant but they were only collected from the Early Neolithic B and C layers. In Tunisia and Turkey, the juniper fruits are still consumed after boiling and crushing them (Rivera-Núñez and Obón-de-Castro, 1991; Semiz et al., 2007).

Other wild plants likely collected for food are wild olive (*Olea europaea*), acorns (*Quercus* sp.) and yew (*Taxus baccata*), which are not numerous. Despite the toxicity of its wood, the yew produces a sweet aril around the seed that is edible (Rivera-Núñez and Obón-de-Castro, 1991; Tardío et al., 2006). Most of these species are also commonly used as fodder or grazed by domesticated animals (Badal and Martí, 2011; Zapata et al., 2003).

Fragments of the aerial rhizome of esparto or alfa grass (*Stipa tenacissima*) were the second most frequent macroremain. The leaves of this economically important grass are still extensively used for producing ropes, baskets, bags, clothes, nets, and so on in Northern Africa (Louis and Despois, 1986) and Spain (Alfaro-Giner, 1984; Sánchez-Sanz, 1982).

Additionally, in the Neolithic levels, a group of arable weeds were identified. Seeds belonging to this group are commonly grown in crop fields and they were probably introduced into the cave accidentally as part of the harvest. A further possibility relates to their inclusion in droppings from domesticated animals, either as a result of grazing or as part of fodder. In any case, they are represented by a limited number of remains *Chenopodium murale*, Malvaceae and *Plantago* sp. being the most frequent species.

4 Discussion

4.1 The origins of agriculture in Northern Africa. The evidence from Morocco

The recording of domesticated cereals and pulses from the Early Neolithic levels of Ifri Oudadane and the direct dating of nine of these seeds has provided the most complete and well dated assemblage of domesticated plants from the region. Based on the radiocarbon dataset available (Table 2), the Early Neolithic sequence of Ifri Oudadane starts in the middle of the 8th millennium BP. The oldest date, 7611 ± 37 cal BP (Beta-295779), currently represents the earliest evidence of a Neolithic crop from Northern Africa, being slightly earlier than the date from Kaf Taht El-Ghar (Ballouche and Marinval, 2003). The date comes from a charred lentil (*L. culinaris*) located at the bottom of the Neolithic sequence. Cereals appeared later, as demonstrated by the date obtained from a wheat grain (*Triticum* sp.), 7063 ± 73 cal BP (Beta-318608). Further dates were carried out on barley (*Hordeum vulgare*), pea (*Pisum sativum*) and free threshing wheat (*Triticum aestivum/durum*) seeds and they range between 6823 ± 54 cal BP (Beta-295773) and 6370 ± 39 cal BP (Beta-295772) (see table 2).

The early date obtained from the Ifri Oudadane lentil places agriculture some 300 years earlier than in Kaf Taht El-Ghar and *c*. 100 years before than the earliest dates from the site of Mas d'Is in the Valencia area, 7505 ± 46 cal BP (Beta-166727) (Bernabeu-Aubán et al., 2003), which signals the arrival of agriculture into the Iberian Peninsula and the Western Mediterranean. However, all these radiocarbon dates overlap on the calibration curve and can be considered roughly contemporaneous. The presence of cereals at Ifri Oudadane is only recorded by the end of the 8th millennium BP. The archaeobotanical record from the lower part of the Neolithic sequence does not include cereals but this lack of evidence has potential explanations. The seasonal occupation of the cave as well as its main use for the exploitation of marine resources may explain the absence of cereals from the earliest Neolithic level. In fact, the presence of *Cerealia* pollen throughout the Early Neolithic A sequence suggests that cereals could have been cultivated in fields near the cave since the earliest levels.

In Kaf Taht El-Ghar, *Cerealia* pollen, charred cereal grains and domesticated ovicaprids, pigs and cattle have been recovered from the same level confirming the presence of domesticated plants and animals from the Early Neolithic. No other contemporaneous sites from Morocco have yielded domesticated plant remains, although no systematic sampling and recovery has been reported. This delay in the application of these vital recovery techniques has certainly influenced research into early agriculture. Clearly, the absence of plant remains is more a methodological problem than an empirical lack of data. The experience from Ifri Oudadane supports this hypothesis. Current research in two other Neolithic sites from the same region is providing data that may complete this picture.

So far, these data suggest that the Ifri Oudadane plant remains are the oldest cultivated plant remains not only from North of Africa but also, most likely, from the entire African continent. Egypt, being closer to the place where cultivated plants were domesticated, has evidence of wheat and barley grains from a Neolithic context at the Fayum dated back to c.5.6-5.3 ka cal BP (Wendrich et al., 2010). In Libya, the oldest crop remains come from Garamantian sites and do not appear to be older than the third millennium BP (Pelling, 2008; Van der Veen, 1995). In contrast, the Algerian Early Neolithic site of Capéletti (7387 ± 242 cal BP [1 Alg. 37] to 4947 ± 292 cal BP [11 Alg. 30]) has provided abundant plant remains, but with no trace of domesticated cereal. The archaeobotanical evidence suggests the exploitation of wild species, such as acorn (*Quercus ilex*), wild pulse (*Vicia* sp.), wild grape (*Vitis vinifera*), maritime pine (*Pinus pinaster*) and yew (*Taxus baccata*) (Roubet, 1979).

The spread of agriculture across the northern Mediterranean shore has been widely studied and there is a better understanding of the Neolithization process in the area (Zohary et al., 2012). Several sites have yielded assemblages of cultivated plant remains which in most cases have been accurately dated. Figure 1 shows approximate dates for the regions discussed in this paper.

Around 10.0 ka BP cultivated plant remains appeared in Cyprus; *c*. 9.0-8.5 ka BP in Greece; between 8.0-7.5 ka BP in Italy; and between 7.7-7.2 ka BP in the Iberian Peninsula (Peña-Chocarro and Zapata, 2010; Zapata et al., 2004, Zohary et al., 2012). In Spain, several sites in the Andalusia region, facing the Moroccan coast, have yielded domesticated plants dated to *ca* 7.3 ka BP (Martínez-Fernández et al., 2010; Pérez-Jordà et al., 2011).

Comparison between dates carried out on seeds from northern Africa (Ifri Oudadane and Kaf Taht El-Ghar) and the Iberian Peninsula attributed to the middle-late 8th millennium BP supports the hypothesis that the spread of agriculture on both sides of the Western Mediterranean coasts could have been a more or less simultaneous process.

Likewise, the range of plants cultivated in the Iberian Peninsula and in north-western African is similar (Table 3). In fact, Moroccan samples have yielded emmer (*Triticum dicoccum*), naked barley (*Hordeum vulgare* var. *vulgare*), free threshing wheat (*Triticum aestivum/ durum*) and broad bean (*Vicia faba*) at Kaf Taht El-Ghar (Ballouche and Marinval, 2003); at Ifri Oudadane the plant remain assemblage includes durum wheat (*Triticum durum*), lentil (*Lens culinaris*) and pea (*Pisum sativum*). This variety of cultivated plants comprises most of the species identified in Early Neolithic sites in the Iberian Peninsula (Peña-Chocarro and Zapata, 2010, Zapata et al., 2004). No African crops, such as sorghum *(Sorghum bicolor*) or pearl millet (*Pennisetum glaucum*), have been identified. In contrast, the domesticated plants identified in western Mediterranean Neolithic sites come from the Near East (Peña-Chocarro and Zapata, 2010; Zapata et al., 2004; Zohary et al., 2012), indicating that the Neolithic package had an eastern Mediterranean origin.

4.2 The gathering of wild plants: food and basketry

In addition to domesticated plants, a wide set of wild species likely gathered for various uses, has been identified. Apart from juniper (*Juniperus phoenicea*), only present in the Early Neolithic B and C layers, all the remaining species were recorded in both Epipalaeolithic and Neolithic levels. The high numbers of wild plants in the Neolithic deposits contrast to the scarcity of remains in the Palaeolithic. This is particularly striking as the volume of soil processed (1,631 litres) during the Neolithic was only 2.3 times higher than the sediment taken from the Epipalaeolithic (691 litres). Hence, it is surprising that the Neolithic remains were almost 10 times more abundant (no. 6,478) than those from the Epipalaeolithic (no. 645) assemblage. Densities of charred seeds in the samples (number of seeds per litre of sediment) are also higher in the Neolithic (4.45) than in the Epipalaeolithic (1.07) (see table 1). The highest density is found in the Early Neolithic B sub-layer (5.48 seeds per litre) which is the main and richest archaeological deposit within the stratigraphy of the cave.

These numbers may suggest that the role of wild plants did not decline with the arrival of agriculture, and that, on the contrary, their importance within the economy of the inhabitants of Ifri Oudadane may have even increased.

In terms of nutrition, the wild species identified at Ifri Oudadane are able to supply most of the basic nutrients needed for human development (table 4). Dates of the dwarf palm (*Chamaerops humilis*), rose hips (Rosaceae), wild legumes (*Lathyrus*/*Vicia* sp.) and acorns (*Quercus* sp.) are rich in carbohydrates or sugars; wild legumes (*Lathyrus*/*Vicia* sp.) provide proteins; and the seeds of the mastic tree (*Pistacia lentiscus*), wild olives (*Olea europaea*) and acorns contain high levels of lipids or fats.

Most of these taxa are recorded in other Epipalaeolithic and Neolithic sites from North Africa (Ballouche and Marinval, 2003; Barker et al., 2010; Roubet, 1979) and the Iberian Peninsula (Aura et al., 2005; Buxó, 1997; Pérez-Jordà et al., 2011) suggesting that these species were common food resources for both hunter-gatherers and farmers living in proximity to the Mediterranean forests. The similar spectrum of collected wild plants and comparable species proportions identified during the Epipalaeolithic and the Neolithic indicates that the cave inhabitants in both periods may have been local groups who continued plant gathering and added domesticated plants as a complementary resource to the broad spectrum of wild food species. Alternatively, bearing in mind that a similar environment characterized both the coastal Moroccan region and other areas of the Mediterranean, newcomers may have made use of those resources they were more familiar with based on previous experience in other Mediterranean environments.

In terms of seasonality, most of the plants identified in Ifri Oudadane produce fruits that ripen in autumn (Charco, 2001), with the exception of, wild legumes which ripen earlier, at the end of spring or beginnings of summer (table 4). Therefore, during the autumn, when most of these fruits were ready for harvesting, wild plants may have played a significant role in human subsistence. Besides, some food plants yield seeds, such as acorns and juniper berries, which could be stored for later use during the winter. This has been a common practice in traditional Mediterranean communities until recently (Pereira-Sieso, 2010; Semiz et al., 2007).

Among the species identified, mastic tree seeds were abundantly found (5,842). Due to their high fat content, these fruits have traditionally been employed to produce oil for consumption and lighting (Torres-Montes, 2004). Fats are a primary source of energy for hunter-gatherers and in some contemporary forager groups they are considered the most valuable source of food (Hayden, 1981; Kelly, 1995).

Oil seed extraction involves heating whole fruits (Rivera-Núñez and Obón-de-Castro, 1991; Torres-Montes, 2004) after which the waste (seeds and whole fruits) is usually discarded by throwing these residues into the fire. The high numbers of charred seeds retrieved, some with parts of the flesh still preserved (figure 5) may point to similar practices by the inhabitants of Ifri Oudadane. Since wood charcoal from the mastic tree was identified in the same samples (Zapata et al., in prep) it is also likely that some seeds were unintentionally charred as part of the fuel used in the cave. The mastic tree is also a common foodstuff for domesticated animals in the region (Zapata et al., 2003) and it cannot be ruled out that it was used as fodder during the Neolithic. Data from pollen and wood charcoal suggests, in fact, the use of the cave for penning flocks (Zapata et al., in prep).

Another important wild species is esparto or alfa grass (*Stipa tenacissima*). Remains of charred rhizome (aerial roots) fragments were extremely common through the whole sequence with particular emphases during the Early Neolithic B. Nowadays the leaves are extracted directly from the ground using a wooden stick, leaving both stems and rhizomes in the soil (Rivera-Núñez and Obón-de-Castro, 1991; Sánchez-Sanz, 1982). The considerable numbers of rhizome fragments may be related to the collecting of whole plants by uprooting with the aim of processing them in the cave later. After selecting the leaves, rhizome were probably thrown into the fire. According to ethnographic sources, esparto rhizomes have not been commonly used for fodder or fuel (Rivera-Núñez and Obón-de-Castro, 1991). Its presence may thus indicate plant processing for fibre working.

Esparto grass has been recorded in Neolithic and Bronze Age sites from Spain (Buxó, 2010). In the 19th century, several corpses, wrapped up in esparto grass shrouds, were discovered in the Neolithic cave of Los Murciélagos (Albuñol, Granada) (Alfaro-Giner, 1980; Cacho-Quesada et al., 1996). Shoes, small bags and baskets were also found suggesting an intensive use of this plant at least since the Neolithic. Remains from Ifri Oudadane come also from the Epipalaeolithic deposit pointing, perhaps, to a possible use of this species for basketry. This would fit with evidence of textile technologies for producing cordage, baskets and cloth dating back to the Upper Palaeolithic (Soffer et al., 2000).

5 Conclusions

The research carried out at Ifri Oudadane is an important step towards a better understanding of the Neolithic transition in North Africa. From a methodological point of view, this work highlights the need to collect and process by flotation as much sediment as possible in order to obtain a representative assemblage of plant remains. In fact, the absence of domesticated plants in North African Neolithic sites has been traditionally interpreted as the result of a pastoral economy. This research shows that the failure to apply proper recovery techniques can result in the near absence of plant remains.

More importantly, results from Ifri Oudadane have shed light on the spread of agriculture to Morocco, and by extension, to North Africa, providing data that indicates an early arrival of the Neolithic crop assemblage to this region. The similarity in radiocarbon dates on domesticated plant species from Neolithic sites in Morocco and the Iberian Peninsula suggests a more or less synchronous spread of agriculture along both shores of the Western Mediterranean. Furthermore, gathering of wild food plants has been well attested while there is tentative evidence of intensive use of esparto grass, maybe related to plaiting and basketry. Within the seed assemblage, domesticated species are represented by a reduced number of seeds which may indicate the significance of foraging activities at the beginning of the Neolithic. It should be borne in mind, however, that the site was seasonally occupied in order to maximize the use of some wild resources and, therefore, cultivated plants might have played a marginal role in the subsistence system developed during the period the cave was occupied.

Data from Ifri Oudadane starts to fill in the many gaps in our understanding of the origins of agriculture in North Africa and provides interesting insights into the important role of wild species at the beginning of food production in Morocco.

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Caption tables

Table 1. List of macro-botanical remains collected from archaeological levels at Ifri Oudadane.

Table 2. AMS dates on macro-botanical remains from Ifri Oudadane. Calibrated with CalPal2007_HULU (Weninger et al., 2007).

Table 3. Presence/ absence of crops in the most important Early Neolithic sites in Morocco and the Iberian Peninsula. According to Ballouche and Marinval (2003); Buxó (1997); Peña-Chocarro and Zapata (2010); Pérez-Jordá et al. (2011); Zapata et al. (2004).

Table 4. Nutrition and ripening season of the most abundant edible plants identified in Ifri Oudadane (g/100g). Data for *Juniperus phoenicea*, *Pistacia lentiscus and* Rosaceae (Debussche et al., 1987); for *Lathyrus*/*Vicia* values are taken from *Lens culinaris* (Urbano et al., 2007); for *Quercus* sp. values are taken from *Quercus ilex* (Gonçalves and Graça, 1963); for *Chamaerops humilis* values are taken from *Phoenix dactylifera* (Al-Farsi et al., 2005); for *Olea europaea* data from http://nutritiondata.self.com/facts/fruits-and-fruit-juices/7338/2.

Caption figures

Figure 1. Location of sites mentioned in the text and dates for the spread of agriculture in the Western Mediterranean.

Figure 2. The rock shelter and excavation of Ifri Oudadane.

Figure 3. Stratigraphy of the section CE of Ifri Oudadane.

Figure 4. Macro-plant remains from Ifri Oudadane: a. *Hordeum vulgare*, barley, b. *Lens culinaris*, lentil, c. *Triticum aestivum*/*durum*, free-threshing wheat, d. *Triticum durum*, hard wheat, e. *Pisum sativum*, pea, f. *Stipa tenacissima*, esparto grass, g. *Juniperus phoenicea*, juniper, h. *Olea europaea*, wild olive, i. *Chamaerops humilis*, dwarf palm, j. *Lathryus*/ *Vicia* sp., wild pulse, k. *Pistacia lentiscus*, mastic tree l. *Quercus* sp., acorn. Scale bar is one millimeter.

Figure 5. *Pistacia lentiscus* seeds.

Caption supplementary material

Supplementary material 1. Complete list of macro-botanical remains collected from archaeological levels at Ifri Oudadane.

Table 1

Archaeological level	Epipalaeolithic	Early Neolithic A	Early Neolithic B	Early Neolithic C	total
Number of samples	46	25	74	15	160
Volume sediment, in litres	691	378	1091	162	2322
Cultivated plants					
Triticum monococcum/dicoccum, seed (einkorn/ emmer)			1		1
Triticum durum, rachis segment (hard wheat)			1		1
Triticum aestivum/durum, seed (free threshing wheat)			6	1	7
Triticum sp., seed (indeterminated wheat)		1	8		9
Hordeum vulgare, seed (barley)			29	2	31
Cereal indeterminated			8	2	10
Lens culinaris (lentil)		1			1
Pisum sativum (pea)			1		1
Wild plants					
Chamaerops humilis (dwarf fan palm)	53	20	65	4	142
cf. Cistaceae capsule		1			1
Fabaceae	14	2	19	9	44
Juniperus phoeniceae (juniper)			27	6	33
Lathyrus/ Vicia sp. (wild pulse)	13	4	16	16	49
Myrtus communis (myrtle)		1			1
Olea europaea (wild olive)	6		4		10
Pistacia lentiscus (mastic tree)	469	570	4701	102	5842
Poaceae type *Festuca arundinaceae*	19	65	61	2	147
Quercus sp., cupule (acorn)	2	3	4		9
Quercus sp., cotyledon (acorn)	1				1
Rosaceae, fruit fragment			2		2
Rosaceae, seed			4		4
cf. *Ruscus* sp.	4	1	1		6
Solanaceae			1		1
Stipa tenacissima, rhizome (esparto grass)	61	149	491	125	826
Taxus baccata (yew)	1		1		2
Withania sp.	2	1			3
Weeds					
Aizoon hispanicum			2		2
cf. *Asperula/Galium* sp.			1		1
Asteraceae			6	4	10
Centaurea			1		1
Chenopodium cf. *album*		8	13		21
Chenopodium murale		4	50		54
Cleome sp.			1	1	2
Emex spinosa				1	1
Fumaria sp.			1		1
Galium sp.		1	5		6
Geraniaceae			8		8
Lamiaceae			5		5
Malvaceae		4	6	1	11
Phalaris sp.			1		1
Plantago sp.		12		2	14
Polygonum sp.			1		1
Portulaca oleraceae			2		2
Scorpiurus muricatus			1	1	2
Small seeded legume	8		16	1	25
Indeterminated fruit		1	3		4
Indeterminated fruit fragment		1			1
Indeterminated seed	3	2	102	2	109
Indeterminated fragment	86	124	306	20	536
Total	742	976	5982	302	8002
Seed density per liter	1.07	2.58	5.48	1.86	3.44
Cultivated seed density per litre	0	0.005	0.049	0.03	0.026

Table 2

material	common name	ref. Laboratory	submission reference	conventional age BP	Cal BP	Cal BC	Archaeological levels
Chamaerops humilis	dwarf palm	Beta-313468	ERCIODPOS989	8080+-40	9028 ±41	7078 ± 41	Epipalaeolithic
Chamaerops humilis	dwarf palm	Beta-313467	ERCIODPOS945	7150+-40	7979 ± 25	6029 ± 25	Epipalaeolithic
Chamaerops humilis	dwarf palm	Beta-316137	ERCIODPOS890	6780+-40	7632 ± 29	5682 ± 29	Epipalaeolithic
Lens culinaris	lentil	Beta 295779	ERCIODPOS860	6740+-50	7611 ± 37	5661 ± 37	Early Neolithic A
Triticum sp.	wheat	Beta-318608	ERCIDOPOS835	6140+-30	7063 ± 73	5113 ± 73	Early Neolithic A
Hordeum vulgare	barley	Beta 295773	ERCIODPOS520	5980+-40	6823 ± 54	4873 ± 54	Early Neolithic B
Hordeum vulgare	barely	Beta 295774	ERCIODPOS537	5980+-40	6823 ± 54	4873 ± 54	Early Neolithic B
Pisum sativum	pea	Beta 295778	ERCIODPOS766	5930+-40	6758 ± 54	4808 ± 54	Early Neolithic B
Triticum aestivum/durum	free thresing wheat	Beta 295775	ERCIODPOS635	5910+-40	6735 ± 45	4785 ± 45	Early Neolithic B
Triticum aestivum/durum	free thresing wheat	Beta 295776	ERCIODPOS678	5900+-40	6727 ± 44	4777 ± 44	Early Neolithic B
Hordeum vulgare	barley	Beta 295777	ERCIODPOS764	5670+-40	6458 ± 38	4508 ± 38	Early Neolithic B
Triticum aestivum/durum	free thresing wheat	Beta 295772	ERCIODPOS487	5590+-40	6370 ± 39	4420 ± 39	Early Neolithic C

Table 3

	Morocco		Iberian Peninsula						
	Ifri Oudadane	Kaf Taht el-Ghar	Castillejos	Mármoles	Murciélagos de Zuheros	Mas d'Is	Cova de L'Or	Can Sadurní	Cendres
Cal BP radiocarbon dates	7611 ± 37 7063 ± 73	7286 ± 85	7238 ± 47	7098 ± 60	7078 ± 156 7058 ±159	7505 ± 46 7505 ± 46	7387 ±39 7268 ±48	7347 ± 54	7401 ± 80
Site type	rock shelter	rock shelter	village	rock shelter	rock shelter	village	rock shelter	rock shelter	rock shelter
Triticum monococcum (einkorn)	x*		x	x		x	x	x	x
Triticum dicoccum (emmer)	x*	x		x	x		x	x	x
Triticum durum (hard wheat)	x				x				
Triticum aestivum/durum (free threshing wheat)	x	x	x	x	x	x	x	x	x
Hordeum vulgare (barley)	x	x	x	x	x	x	x	x	x
Vicia faba (broad bean)		x	x	x					x
Vicia ervilia (bitter vetch)				x					
Lens culinaris (lentil)	x				x				x
Pisum sativum (pea)	x		x	x	x				x
Lathyrus saitvus/cicera (grass pea)				x					x
Linum usitatissimum (flax)			x						
* The taxa identified in Ifri Oudadane is *T. monococcum/dicoccum*.									

Table4

	Common name	**Nutritional value**			**Ripening season**
		Carbohydrates	*Lipids*	*Protein*	
Chamaerops humilis	dwarf palm	80	1	2	autumn
Juniperus phoenicea	juniper	18	4	5	autumn
Lathyrus sp., *Vicia* sp.	wild pulse	58	2	26	summer
Olea europaea	wild olive	5	20	1	autumn
Pistacia lentiscus	pistachio	7	50	5	autumn
Quercus sp.	acorn	53	10	3	autumn
Rosaceae	rose hip	31	1	3	autumn

Figure 1
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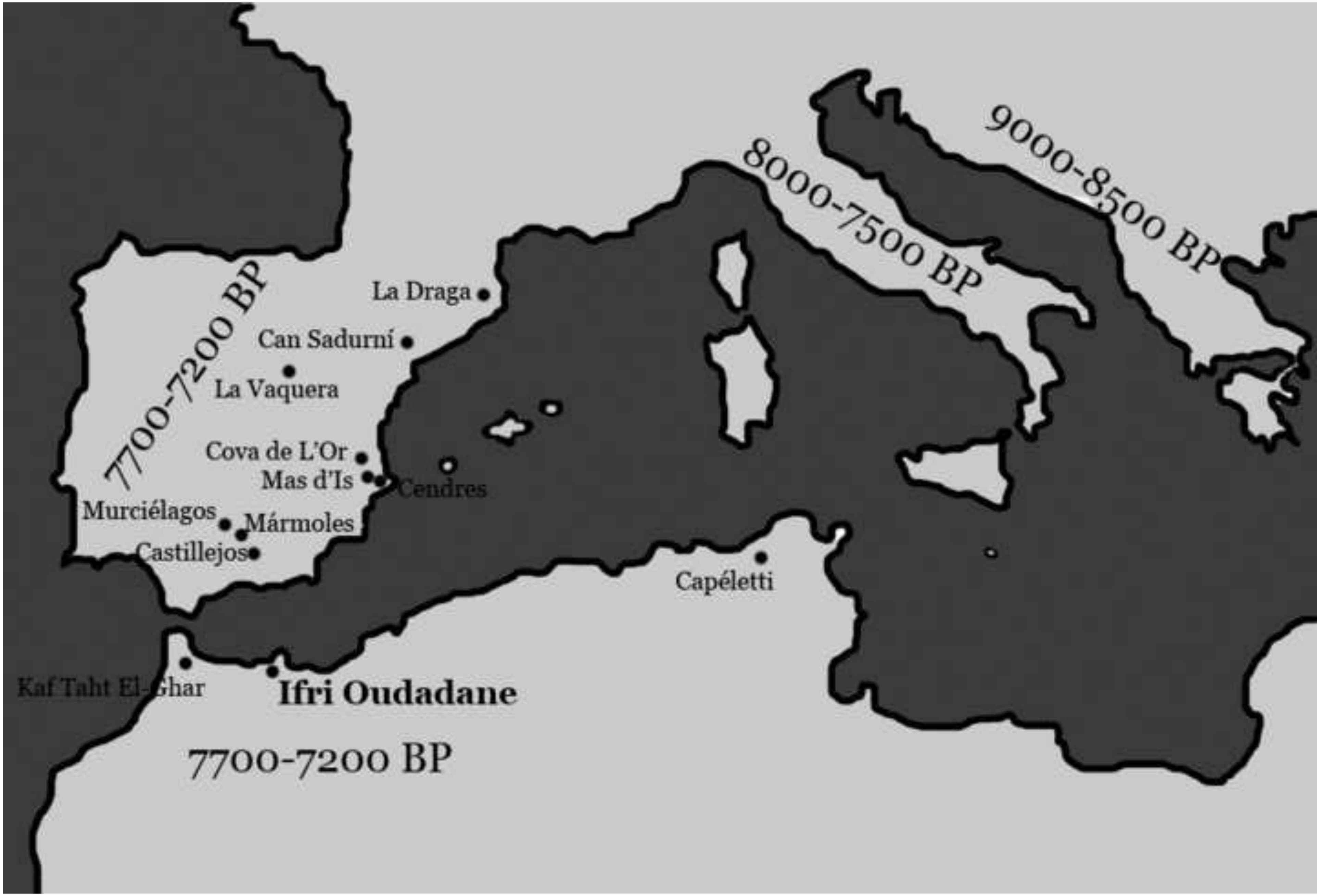

Figure 2
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Figure 2 for print
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Figure 3

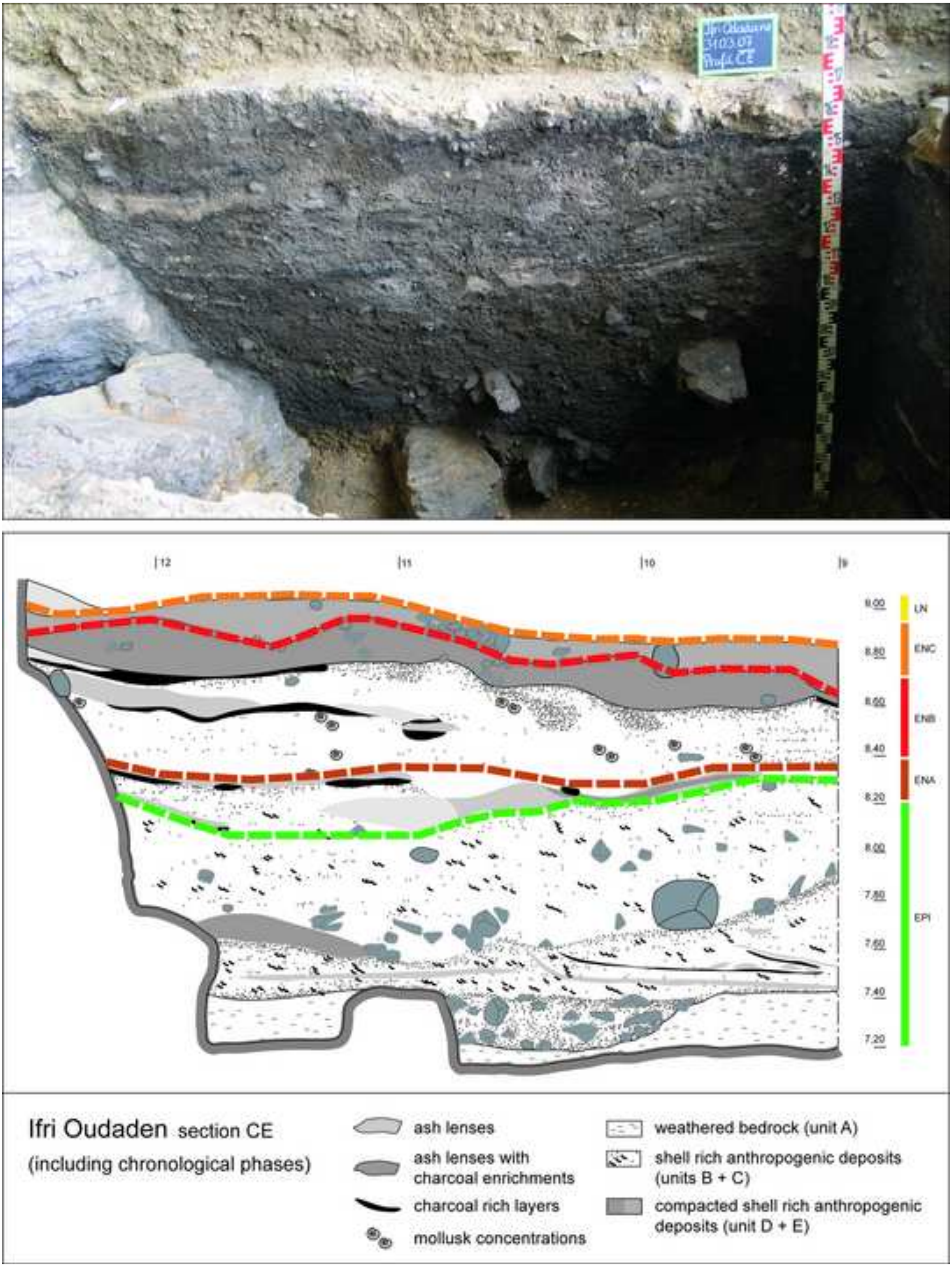
12
11
10
9
8.80
8.60
8.40
8.20
8.00
7.80
7.60
7.40
7.20
LN
ENC
ENB
ENA
EPI
Ifri Oudaden section CE
(including chronological phases)
ash lenses
ash lenses with charcoal enrichments
charcoal rich layers
mollusk concentrations
weathered bedrock (unit A)
shell rich anthropogenic deposits (units B + C)
compacted shell rich anthropogenic deposits (unit D + E)

Figure 3 for print

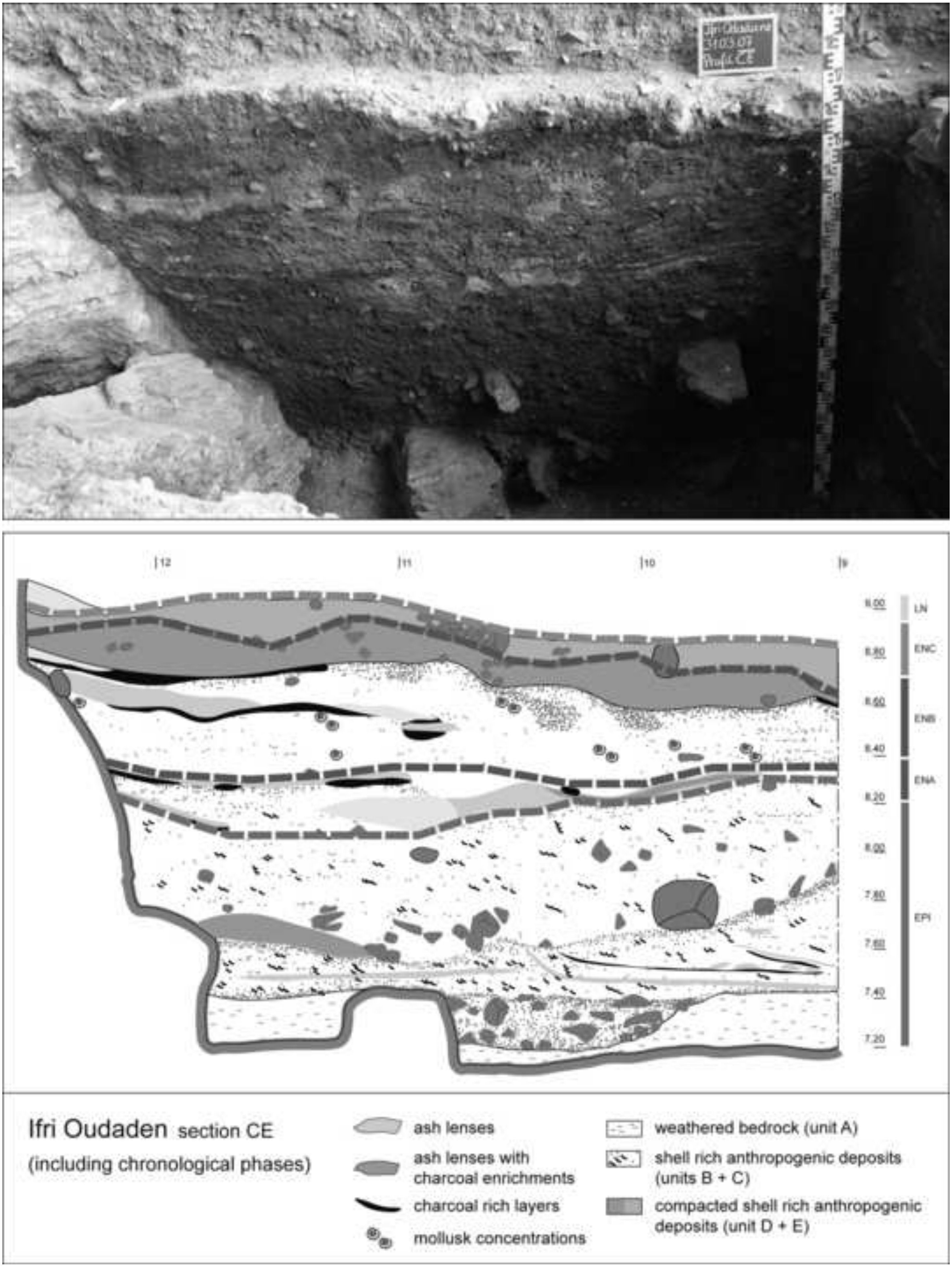

Figure 4

Figure 4 for print

Figure 5
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