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Driss Chahid, Larbi Boudad, Arnaud Lenoble, Michel Lamothe, Amel Chakroun, et al.. New lithostratigraphic and chronostratigraphic data for the fossil human skull-bearing eolianite of Rabat-Kebibat (Morocco).. Quaternaire, 2020, 31 (3), pp.249-261. 10.4000/quaternaire.14287 . halshs-03150251

**HAL Id: halshs-03150251**

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Submitted on 29 Sep 2021

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# NEW LITHOSTRATIGRAPHIC AND CHRONOSTRATIGRAPHIC DATA FOR THE FOSSIL HUMAN SKULL-BEARING EOLIANITE OF RABAT-KEBIBAT (MOROCCO)



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& Mohammed Abdeljalil EL HAJRAOUI<sup>6</sup>

## ABSTRACT

The Kebibat quarry locates on the coastal area of Rabat. It is also known as ‘‘The Rabat Human deposit’’ due to the presence of human cranial bones in the quarry deposit. These remains of Hominines are related to the archaic *Homo sapiens*.

The revision of the geological and geochronological context of Kebibat and its surroundings allowed clarifying the morpho-litho-stratigraphic aspects of the different formations that constitute it, as well as their evolution during the Middle-Upper Pleistocene. The sedimentary unit that fossilized the human remains corresponds to a dune deposit (eolianite), which is part of a high-resolution sedimentary sequence (parasequence). Luminescence and U-Th dating indicate that this sequence was deposited between the end of the marine isotopic stage 7 (MIS 7) until the end of MIS 6.

**Keywords:** Paleo-shorelines, Pleistocene, human remains, IRSL dating, Morocco.

## RÉSUMÉ

NOUVELLES DONNÉES LITHOSTRATIGRAPHIQUES ET CHRONOSTRATIGRAPHIQUES DE L'ÉOLIANITE À CRÂNE HUMAIN FOSSILE DE RABAT-KEBIBAT (MAROC)

L'ancienne carrière Kébibat qui se situe sur le littoral de Rabat est surnommée le gisement de l'Homme de Rabat du fait des restes crâniens humains qu'elle a livrés. Ces restes d'homininés se rattachent à un *Homo sapiens* archaïque.

La révision du contexte géologique et géochronologique de ce site et de ses environs permet de préciser l'aspect morpho-litho-stratigraphique des différentes formations qui le constituent, ainsi que leur évolution au cours du Pléistocène moyen et supérieur. Les restes humains sont fossilisés à l'intérieur d'une unité formée d'une calcarénite éolienne, elle-même située sur une séquence sédimentaire de haute résolution (paraséquence). La chronologie déduite des analyses de luminescence et de l'U-Th suggère que la séquence s'est mise en place à partir de la fin du stade isotopique marin 7 (SIM 7) jusqu'à la fin du SIM 6.

**Mots-clés :** Paléo-rivages, Pléistocène, restes humains, datation IRSL, Maroc.

## 1 - INTRODUCTION

The coastal area of Rabat-Temara (northwest Morocco) is a region known for its numerous archaeological sites (fig. 1), and a key area to a better understanding of the prehistoric lifestyle habits during the Middle Stone Age (MSA) in northwest Africa (Nespoulet *et al.*, 2008; Bouzouggar & Barton 2012; Stoetzel *et al.*, 2014; Campmas *et al.*, 2015, 2016; Chakroun *et al.*, 2017).

The archaeological and the paleontological record in the prehistoric sites of the Rabat-Temara area confirmed their occupation by human groups since the Middle Paleolithic until the Neolithic Age (Nespoulet *et al.*, 2008; Barton *et al.*, 2009; Michel *et al.*, 2009; Campmas, 2012; El Hajraoui & Nespoulet, 2017).

The presence of prehistoric groups on the Rabat-Temara coastline is documented by an archeo-sedimentary filling of the coastal caves (e.g. the caves

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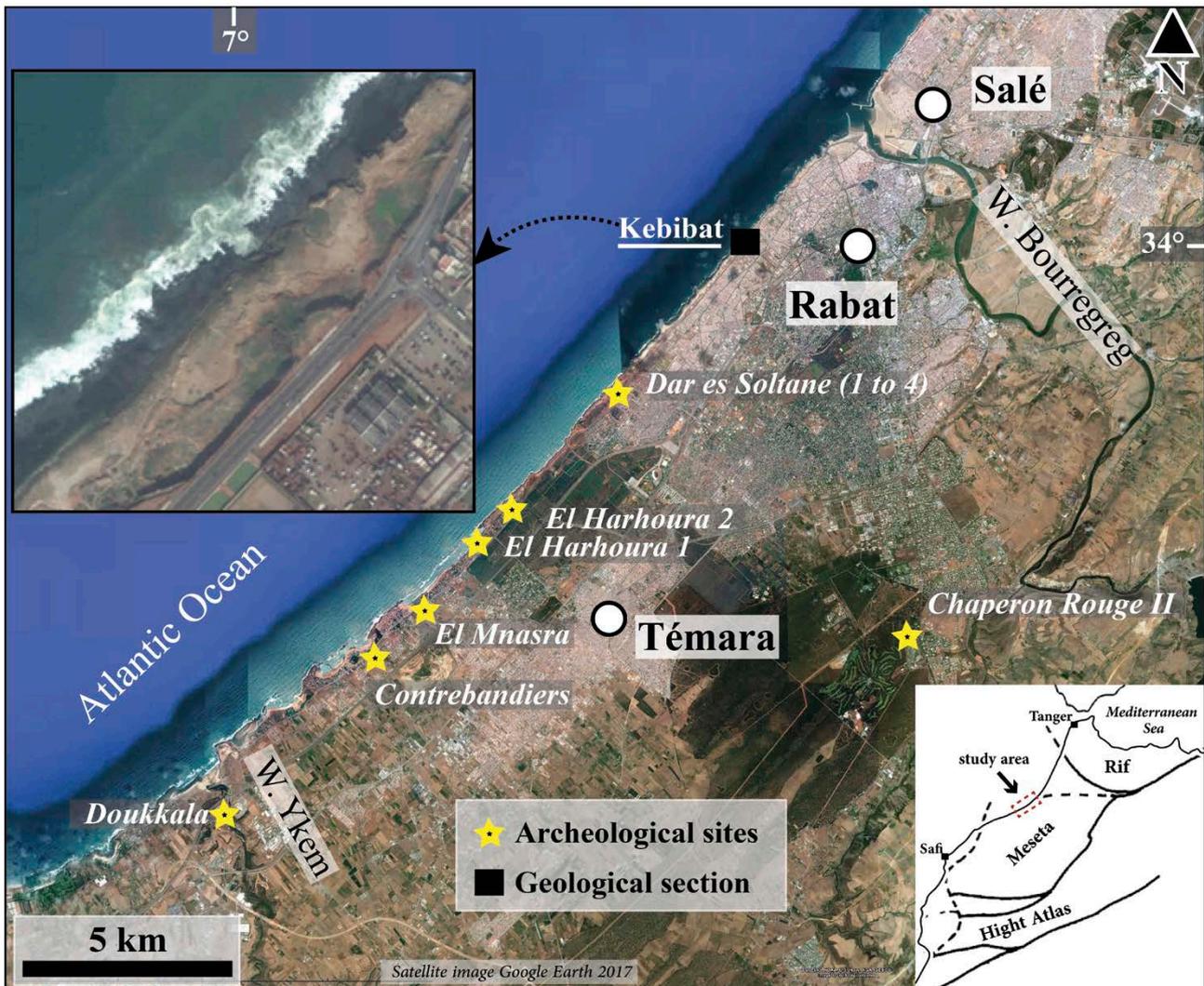


Fig. 1: Archaeological sites and the Kébibat section in the Rabat-Témara area (Morocco).

Fig. 1 : Sites archéologiques et la coupe de Kébibat dans la région de Rabat-Témara (Maroc).

of Dar es Soltane, El Harhoura 2, El Mnasra, and Contrebandiers). This outstanding filling upholds the good conservation of stone tools, bone remains, as well as ornaments, particularly in the form of perforated shells (El Hajraoui, 1994; Bouzouggar, 1997; El Hajaroui & Debénath, 2012; Boudad *et al.*, 2012, 2017; Nespoulet & El Hajaroui, 2015; Chakroun *et al.*, 2017).

From a paleoanthropological point of view, the human remains found in the archaeological sites are attributed to *Homo sapiens* (Debénath, 1975; Debénath, 1980; Oujaa and Hublin, 2012). Along with the human remains exhumed in a cave, context is added by other human remains found embedded in the rock that forms the structure of the caves. These last fossils were named in the old publications “*l’Homme de Rabat*” or “*l’Homme fossile de Rabat*” (Neuville and Ruhlmann, 1942; Lecoindre, 1952; Thoma and Vallois, 1977). Recently, after more than 70 years, a paleo-anthropological revision of this Rabat-Kébibat Man was carried out by using new technologies such as micro-computerized tomography, surface scanners, and (2D and 3D) geometrical morphometry (Oujaa *et al.*, 2017).

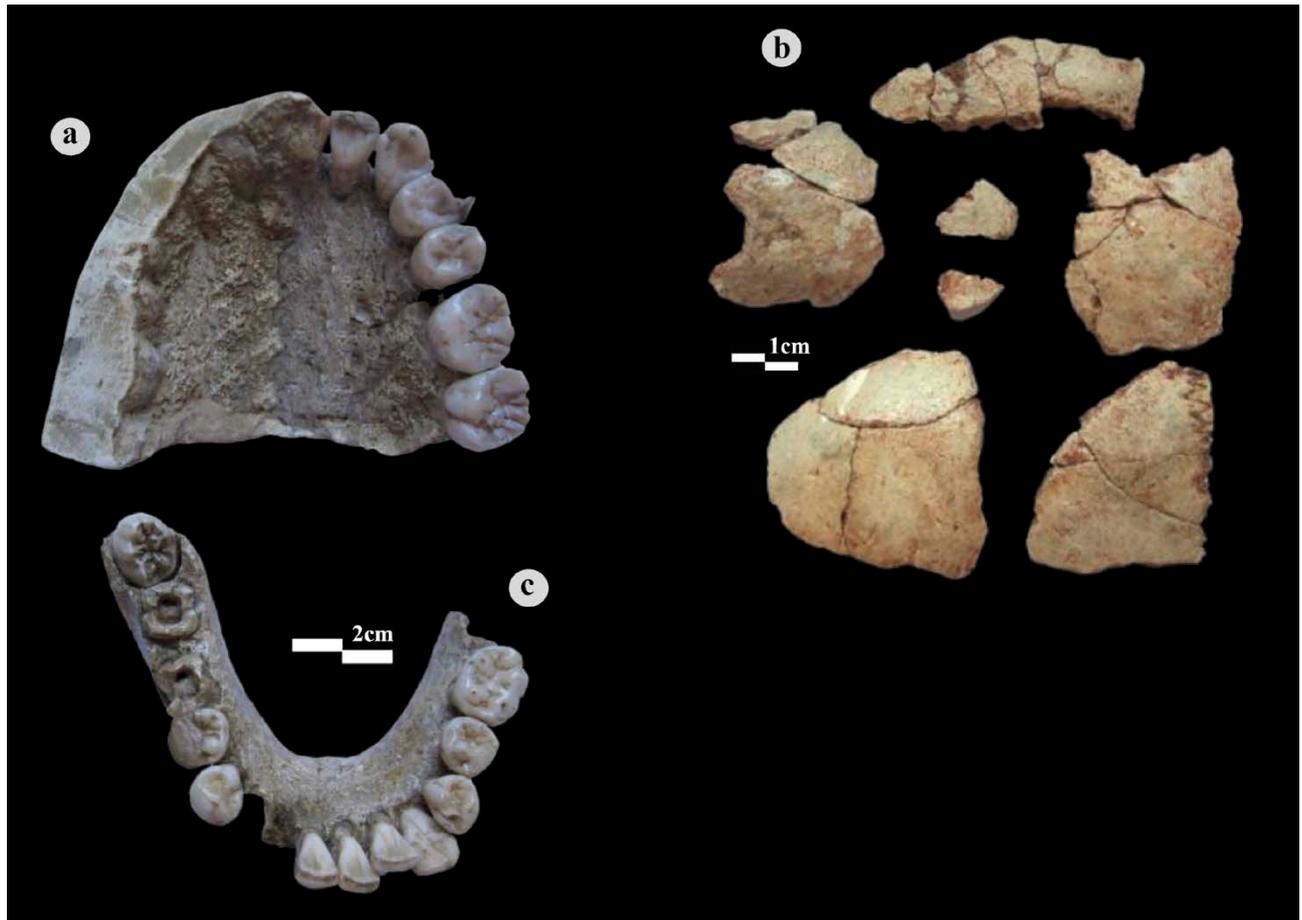
Here we report a new contextualization for the Kébibat quarry site (fig. 1) based on a new morpho-litho-stratigraphic and geochronological data of the section where the human remains were discovered.

## 2 - FOSSIL HOMINID OF RABAT-KEBIBAT

### 2.1 - FOSSIL REMAINS

The name of the site of Kébibat was added to the name of the human fossil remains of Rabat to avoid any confusions with the fossil remains found in the caves in Rabat (Oujaa *et al.*, 2017). The bone material of the Rabat-Kébibat human fossil is composed of twenty-seven fragments: the left part of the maxilla, the mandible, and 23 fragments of the cranial box (fig. 2). The results obtained through a new study concerning internal structures, previously inaccessible (Oujaa *et al.*, 2017), make it possible to position this fossil. Specific morphological characters entirely exclude the Rabat-Kébibat Man from modern human groups: absence of a real chin, robustness, and orientation of the mandibular corpus. In contrast, others are assimilated to derived characters such as the complexity of meningeal vascularization, the intensity of encephalic depressions linked to the development of the parietal reliefs of the second parietal convolution, absence of occipital torus, and regular convexity of the sagittal occipital curvature.

The man of Rabat-Kébibat thus fits perfectly into the mosaic pattern of evolution in the transition between ancient and modern *Homo sapiens* in North Africa,



**Fig. 2: Human remains collected by Marçais in Kebibat (photo A. Oujaa).**

a/ Maxillary. b/ Mandible. c/ Cranial fragments.

*Fig. 2 : Restes humains fossiles collectés par Marçais à Kébibat (photo A. Oujaa). a/ Maxillaire. b/ Mandibule. c/ Fragments de crâne.*

as recently demonstrated on the site of Jebel Irhoud (Hublin *et al.*, 2017).

Marçais collected these remains in 1933 during the exploitation of the quarry of Kebibat (fig. 3). The remains were well preserved and fossilized in the calcarenite at the front of the quarry (Marçais, 1934). The paleoanthropological study carried out by Boule (Boule *in* Marçais, 1934) indicates that these remains have archaic characters. Both the archaic aspect and the stratigraphical location of the remains suggest a probable Middle Pleistocene age (Marçais, 1934; Jaranoff, 1936; Choubert & Marçais, 1947).

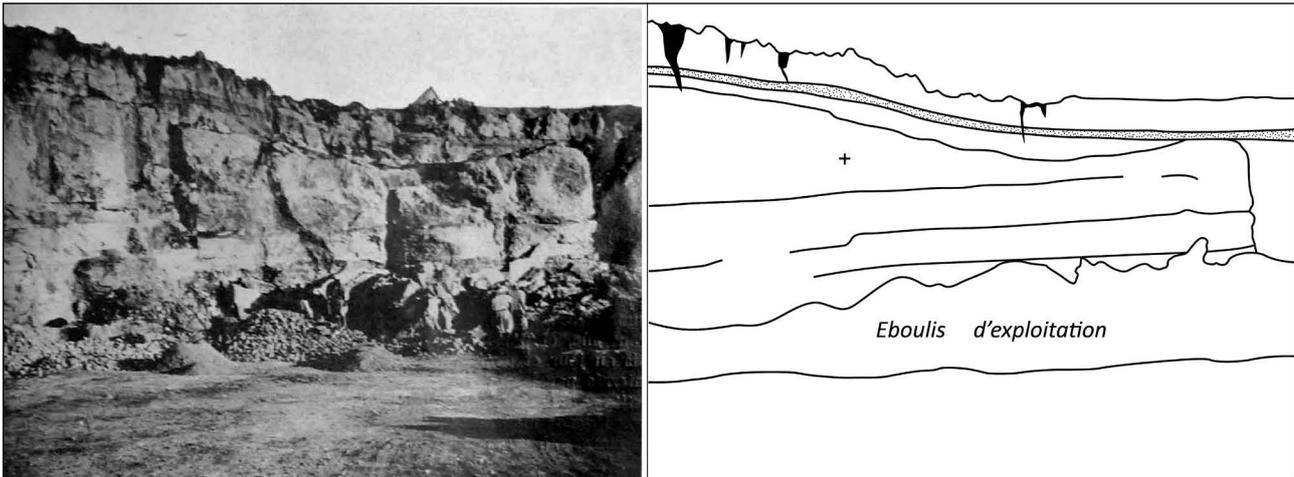
## 2.2 - RESEARCH HISTORY OF THE SITE

The site of Kebibat, also called Mifsud-Giudice (Lecointre, 1958), is a former rock quarry. It was opened in the Quaternary calcarenite deposit outcropping along the coast of Rabat. After the discovery of the human bones (see below), the site received particular attention in the study of the Rabat coastal formations. Jaranoff (1936) was the first author to describe it and to detail its general geological context. Besides, he used the discovered “archaic human” remains as an indicator of the antiquity of the formations of the quarry.

Neuville and Ruhlmann detailed the geology and the malacology related to this site (Neuville & Ruhlmann, 1942). They clarified the general morphology of the site, focusing on the layout of the several observed

geological layers within the different outcrops. This study of marine species allows correlations between Rabat paleo-shorelines and those of Casablanca. The dune called *La grande dune* or *Dune à Homo* containing the human skull is attributed to the Post-Tyrrhenian (Neuville & Ruhlmann, 1942). However, based on a local lateral correlation between sedimentary layers between Kebibat and Bouregreg wadi, an age of Ante-Tyrrhenian was given to this dune (Choubert & Marçais, 1947).

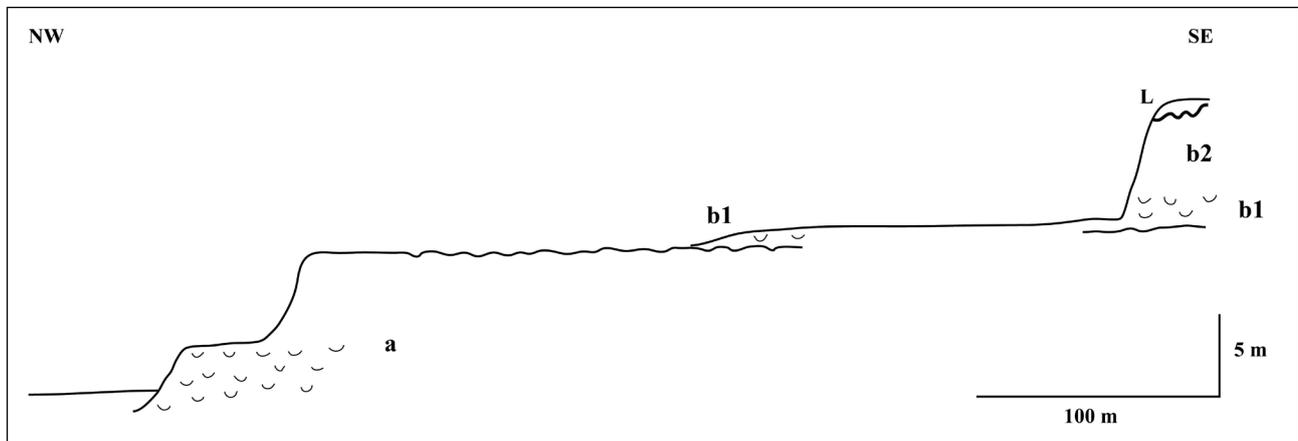
Later, in its synthesis dedicated to the geological context of the human remains of Kebibat, Lecointre (1958) criticized Neuville and Ruhlmann’s subdivision favoring Jaranoff’s stratigraphic analysis. In this publication, Lecointre attributed the skull remains to Tyrrhenian, based on the study of the shell layer at the bottom of the dune (b1 in Gigout stratigraphy) (fig. 4) and by comparison with the Casablanca sections. The last version of the study of this famous site even bears credible and relevant elements in the interpretation of the sedimentary deposits, which form all the geological formations of the Kebibat quarry (Gigout, 1960). Gigout understood the dynamic of the paleo-shorelines and their records, avoiding the confusion by Neuville and Ruhlmann, who attributed two different ages to the same sedimentary layer. Gigout named “*épisode de Kébibat*” the paleo-shoreline, including the dune with human fossil (Gigout, 1960); he considered this sea-level marker as equivalent to the Rabatian of Choubert (Choubert &



**Fig. 3: Kebibat quarry**

(A) On the left: a picture of the quarry of Kebibat in February 1933 (Marçais, 1934). (B) On the right: a schematic drawing with a cross pointing out the location of the human remains (Lecointre, 1958). Les personnages au pied de la coupe, sur la droite, donnent l'échelle.

Fig. 3 : La carrière de Kébibat. (A) À gauche, photographie de la carrière en février 1933 (Marçais, 1934). (B) À droite, dessin schématique, la croix indique la position des fossiles humains (Lecointre, 1958). Peoples at the foot of the profile, on the right, give the scale.



**Fig. 4: The geological section at Kebibat quarry from Gigout (1960), redrawn.**

a: Lower formation (probably anfatian). b1: Kebibat marine episode. b2: Kebibat dune episode. l: Soltanian red silts.

Fig. 4 : Coupe géologique de la carrière de Kébibat, redessinée à partir de Gigout (1960). a : Formation inférieure (probablement d'âge Anfatien). b1 : Episode marin de Kébibat. b2 : Episode dunaire de Kébibat. l : Limons rouges soltaniens.

Faure-Muret, 1959; Choubert, 1962). This term of the regional stratigraphy designating the marine formations built during MIS 7 (e.g., Plaziat *et al.*, 2008). The local correlation between Marie Feuillet quarry (the section eponym of Rabatian) and the Kebibat quarry is a stratigraphic problem. In summary, for Gigout, the dune (b2) is post-Rabatian (fig. 4), whereas for Choubert, it is a post-Anfatian dune (e.g. Choubert, 1962; Lecointre, 1963). The Anfatian is referring to the marine formation deposited during MIS 11 (e.g. Plaziat *et al.*, 2008).

For many years, the chronological interpretation of the Quaternary coastal formations in Rabat was based essentially on the malacological content, the altitude of the marine terraces, and sometimes their lithology (e.g. Bourcart, 1943; Lecointre, 1952; 1958; Gigout, 1960; Beaudet, 1969). These methods had their limitations given the repetitive nature of the coastal lithofacies and their similar biostratigraphy, except for specific beaches like that of MIS 5 (Chakroun *et al.*, 2017) and the use of elevation as a criterion is challenging, especially in the presence of tectonic activity (Morel, 1987; Chabli *et al.*, 2014). In summary, the geologic research in the Kebibat quarry needed more investigation in order to

resolve the local and regional correlations of the Rabat Quaternary paleo-shorelines.

Absolute chronology could be a critical tool to confirm or reject field observations. The first attempt to date the coastal formations of this region was made by Stearns and Thurber (1965). In the Kebibat section, their publication indicated that the age of the shell layer below the dune with skull remains is more than 200 ka. This age, at least, confirmed the antiquity of these remains in agreement with the Gigout hypothesis (Gigout, 1960).

### 3 - MORPHO-STRATIGRAPHY OF THE COASTAL FORMATIONS OF RABAT

The coastal zone of Rabat-Temara corresponds to a Miocene, Pliocene, and Quaternary stratigraphic sequence, which overlays a Paleozoic substratum. The geomorphology of this region displays a pattern of coastal ridges, generally composed of marine and eolian calcarenites (Gigout, 1960; Beaudet, 1969; Stearns, 1978; Akil, 1985; Chahid *et al.*, 2016; Chahid, 2017). These coastal ridges are sub-parallel to the present shoreline,

whose local relief may reach about ten meters on the recent cliff to about 150 m at a distance of 11 km inland.

In the coastal area, the first ridge (R1) is cut into a fresh-cliff, and the second ridge (R2) displays a dead cliff. Those ridges are separated by a furrow locally called "Oulja". The prehistoric caves of Temara were dug into the second dead cliff. Recent studies showed that the previous ridges were formed by the interlocking and superimposition of three paleo-shorelines ranging from the Middle Pleistocene to the Upper Pleistocene (Chahid *et al.*, 2016, 2017; Chakroun *et al.*, 2017). Each paleo-shoreline is related to a sedimentary sequence (S1, S2, and S3) or parasequence of coastal deposits and reflects a progradation of the tidal prism in a regressive system (fig. 5). Available chronological results based on absolute ages confirm that the age of the three sequences ranges between MIS 11 and MIS 5 (Chahid, 2017; Chahid *et al.*, 2017). In this paper, only the sedimentary sequence 2 (S2) of Kebibat will be detailed since it contains the fossilized human remains.

#### 4 - METHODS

The geological contextualization of Rabat-Kebibat's site is based on a morpho-lithostratigraphic and petrographic approach. In the field, a macroscopic description of the sedimentary facies was carried out to reconstitute the geometry of the sedimentary bodies and determine the relation of the different stratigraphic units. This study was completed in the laboratory by microscopic analysis. Several oriented samples were taken for the confection of thin sections for the petrographic study.

Infrared Stimulated Luminescence (IRSL, Hütt *et al.*, 1988) dating was performed at the LUX Laboratory at the University of Quebec in Montréal (UQAM) on K-feldspar. Due to the expected large (> 200 Gy) equivalent doses, quartz was not measured.

In the course of his PhD work, Chahid (2017) carried out a luminescence dating program involving six samples collected in six lithostratigraphic units, from two quarries in the Rabat-Temara area (Chahid, 2017). The full dating

program shall be published in a methodological journal in due course. For this study, the sample was taken about 460 m SW of the Kebibat historical section of the quarry, where the fossil was found initially in the same lithostratigraphic unit. Feldspar and quartz were extracted from the sample, a bioclasts-rich calcarenite with quartz as the primary silicate with minor K-feldspar (see petrography section). The sample was collected as a cemented block and brought into the laboratory where the grain size fraction 150-300  $\mu\text{m}$  (feldspar and quartz) was extracted from the carbonate matrix/cement following extended HCl leaching and density separation. In the case of the selected sample, preliminary results from micro-aliquots (five grains) showed relatively large scatter. We chose to gently break down the largest grains before mounting 2 mm diameter multi-grains aliquots. This allowed increased reproducibility, as shown below, while limiting laboratory beta dose attenuation.

The luminescence measurements were carried out on a Lexsyg SMART reader (Richter *et al.*, 2015) using an infrared LED array of ca  $850 \pm 20$  nm, at a power of  $300 \text{ mW/cm}^2$ . Detection was centered at 410 nm using a set of Schott-BG 39 (3 mm) and AHF-BrightLine HC 414/46-Interference (3.5 mm) filters. The irradiation unit in the SMART reader delivered a laboratory beta-dose rate of ca  $0.133 \text{ Gy/s}$ . The measurement protocol chosen was similar to that of Buylaert *et al.* (2009) as the aliquots were first preheated at  $250^\circ\text{C}/60\text{s}$  (heating rate:  $5 \text{ K/s}$ ), IR stimulated at  $50^\circ\text{C}$  ( $\text{IR}_{50}$ ), and then at  $225^\circ\text{C}$  ( $\text{pIRIR}_{225}$ ), each for 100 s. The aliquots were then heated to  $320^\circ\text{C}$  to reduce the effect of residual signals being carried over to the test dose ( $T_n$  or  $T_x$ ), herein of 107 Gy. Dose and test dose were measured using the same preheat (Lamothe, 2004). We only report here the results obtained for the  $\text{IR}_{50}$  signal as the age calculated from  $\text{pIRIR}_{225}$  was found to be twice as high as the fading-corrected  $\text{IR}_{50}$  age, an overestimation presumably resulting from partial bleaching. The natural signal  $\text{Ln}/T_n$  was then interpolated on the laboratory exponential dose-response curve and an equivalent dose evaluated. The sample equivalent dose was calculated using the Central Age Model (Galbraith *et al.*, 1999). A typical growth curve is shown in figure 6A. On the radial plot shown in figure 6B, the strong grouping

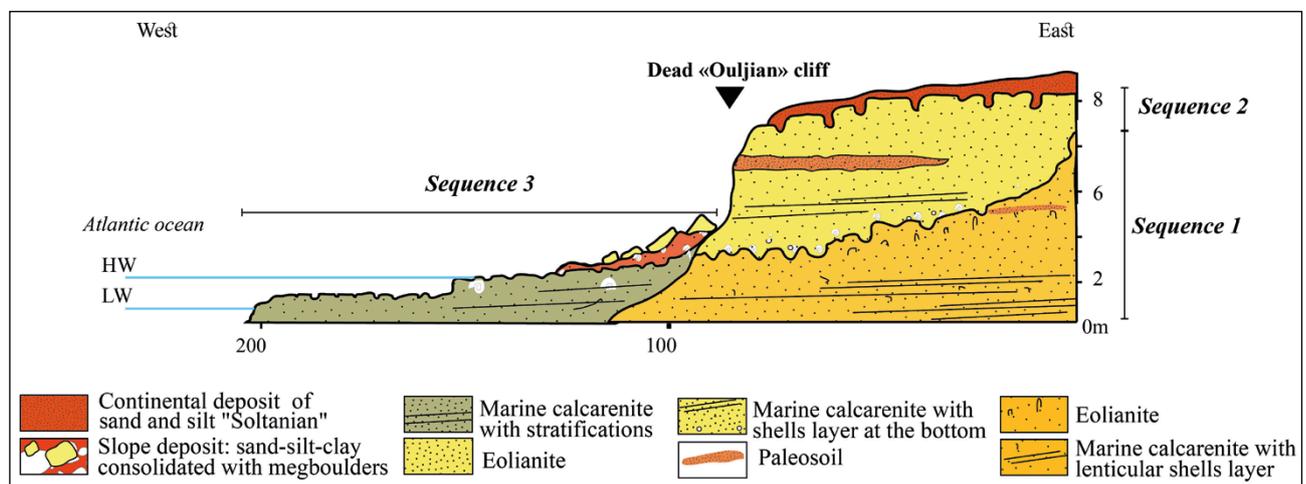


Fig. 5: Synthetic section of the second coastal ridge in Rabat (Chahid *et al.*, 2017, modified).

Fig. 5 : Coupe synthétique du deuxième cordon littoral à Rabat (Chahid *et al.*, 2017, modifié).

## 5 - RESULTS

## 5.1 - MORPHO-LITHO-STRATIGRAPHY AND PETROGRAPHY

The human remains were found in Kebibat in the second ridge, in S2 (figs. 5 & 7). Locally, this sequence has the most significant thickness compared to other sections along the Rabat Temara coastline. The elevation of the base of the S2 increases from 3 m to 4 m (m a.s.l.) on the current cliff and rises to 5 m to 6 m on the quarry front at about 100 m towards the southeast of the quarry where the maximum thickness of S2 is 7 m (fig. 7).

The map (fig. 7) shows the main geological features of the quarry. The floor and the current cliff reveal the oldest sequence (S1). On the eastern side on the front of the quarry, S2 is observed. Also, locally on the floor of the quarry, it is possible to find some remains of the basal unit related to S2. Facing the Atlantic Ocean, the last sequence (S3) is incised into the previous sequences. The suture line between S3 and the older sequences marks the ‘‘Ouljian’’ paleo-shoreline (MIS 5e) (Chahid *et al.*, 2016). During the Holocene, sea-level rise eroded the older geological formations, in particular, the dune part of S3, which forms the outer ridge, and a foreshore took place (fig. 7). This ridge is currently observable in small outcrops in Rabat, but they are also present on the coast of Temara in the south of Rabat. Despite the general similarity between these three sequences, each one has some particularities. Based on its heterogeneous lithology, S2 was divided into four units, formed from the bottom to the top as follow (figs. 8 & 9):

**Unit 1**, is separated from the lower sequence by an erosive surface (lapiaz). The base of this unit comprises a few centimeters thick, coarse lumachel with well-preserved and fragmented shells. Pebbles and gravels characterize the base that forms an almost twenty centimeter thick layer slightly inclined towards the ocean.

A deposit of shell-rich marine sand covers this lumachel layer with flat bedding. Locally whole and broken seashells were observed. The thickness of this sandy layer is important and can reach 3 m. It is an intertidal to supralittoral marine calcarenite (Reineck & Singh 1975; Strasser *et al.*, 1992; Frebourg *et al.*, 2008).

**Unit 2**, the contact between this unit and the underlying unit is diffuse. This unit corresponds to a massive calcarenite in which the human remains were discovered. The presence of helix shells, centimetric fragments of bones, and some rare fragments of ostrich eggs confirm its continental character related to a dune calcarenite (eolianite) (Reineck & Singh 1975; Mckee, 1979; Bridge & Demicco, 2008; Frebourg *et al.*, 2008).

Based on the stratigraphy of this sequence in the Kebibat quarry and other quarries in Rabat (Chahid, 2017), it was found that this dune unit (unit 2) is subdivided into two units (unit 2 and unit 4) by a palaeosol (unit 3). The latter is laterally discontinuous in lenticular form. This palaeosol is associated with decarbonization structures and abundant rhizoliths at the top of unit 2.

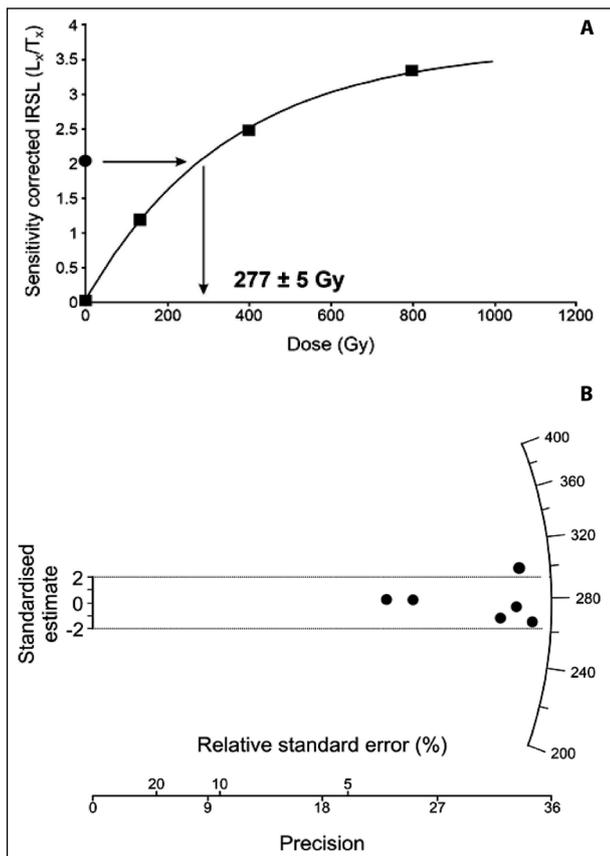


Fig. 6: Measurement of the equivalent dose.

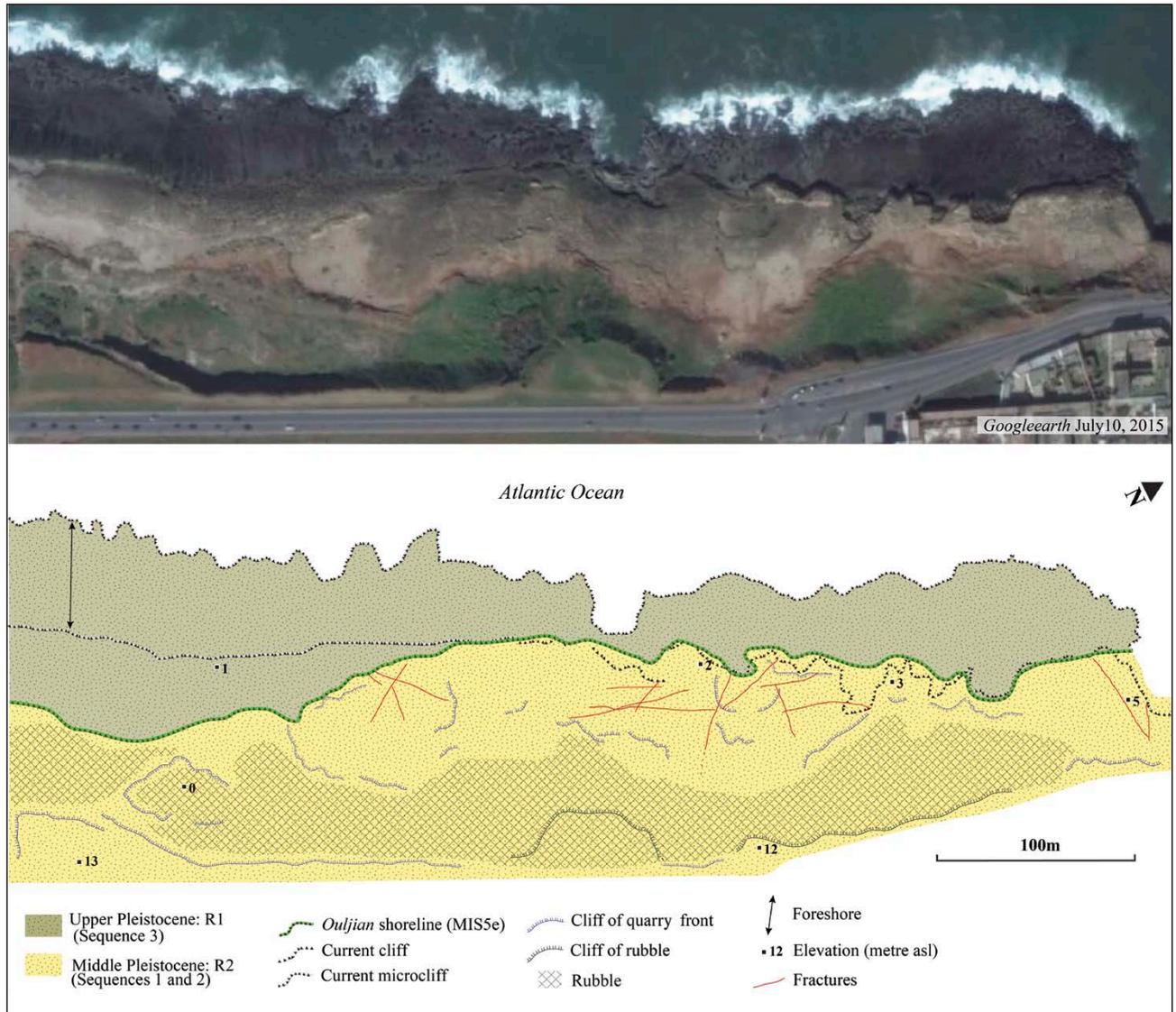
(A) Fading-corrected SAR dose-response curve for the mean of six multi-grains aliquots. (B) The equivalent doses for the six aliquots on a radial plot (Galbraith *et al.* 1999) with the reference value centered on  $277 \pm 5$  Gy.

Fig. 6 : Mesure de la dose équivalente.

(A) Courbe dose-réponse SAR corrigée pour le fading pour la moyenne de six aliquotes multigrains. (B) Doses équivalentes pour les six aliquotes sur une courbe radiale (Galbraith *et al.* 1999) avec la valeur de référence centrée sur  $277 \pm 5$  Gy.

of the aliquots around the central value is an indication of high reproducibility, with an overdispersion of ca 5%.

Each aliquot was tested for anomalous fading using the protocol of Auclair *et al.* (2003) and storage periods up to 100 hours. The ages were then corrected for anomalous fading using the DRC correction of Lamothe *et al.* (2003). The obtained paleodose was divided by the sample dose-rate calculated from the abundance of the radioactive elements using the DRAC software (Durcan *et al.*, 2015). The abundance of the individual radio-emitters (U, Th, and K(Rb)) was obtained through high-resolution gamma-ray spectrometry. To ensure precision and reliability as well as radon equilibrium, the samples were sealed in wax and stored for 21 days before measurement. We are here postulating that carbonate diagenesis was almost penecontemporaneous, the cement proportion of ca 15% being reached a few thousand years following the burial of the human remains. We thus used the *in situ* water content of  $2 \pm 1\%$  for the calculation of the dose-rate. A beta-dose rate of  $1.02 (\pm 0.09)$ ; mean grain-size of  $265 \pm 25 \mu\text{m}$  Gy/ka was added to account for the internal K concentration of the feldspar grains. As the surface of the grains was not etched during preparation, a small external alpha dose of  $0.05 (\pm 0.01)$  Gy/ka was also included in the dose-rate calculation.



**Fig. 7: Geological map of the Kebibat quarry.**

*Fig. 7 : Carte géologique de la carrière de Kébibat.*

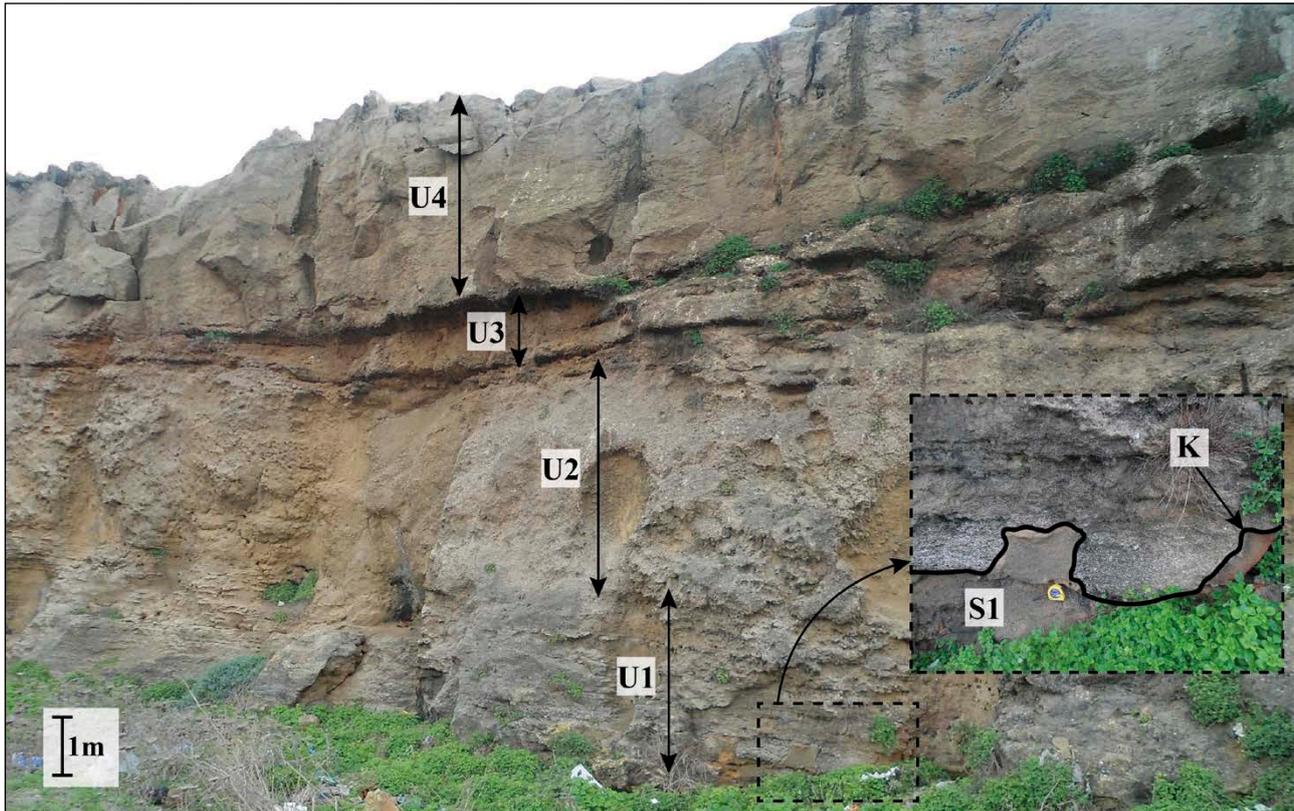
**Unit 3**, consists of a weakly lithified fine to medium-grained reddish sandy deposit. It is less consolidated than calcarenites and contains small helix shells and locally, rhizoliths, and some small bone fragments. This unit has a thickness generally less than 1 m with a discontinuous lateral layout. Considering all of its features, unit 3 is interpreted as a palaeosol. During the Quaternary period, this type of palaeosol is frequent and generally associated with eolianite in Morocco as in other localities in the world (e.g., Alouane & Aberkan, 1998; Nawratil De Bono, 2005; Assal *et al.*, 2020).

**Unit 4**, the passage from units 3 to 4 is abrupt, with generally a plane and sub-horizontal contact. This unit is a massive eolianite, with an average thickness of about 1.5 m. Many small continental gastropods and rhizolites are locally observed. This unit was formed by the consolidation of a coastal dune sedimentary deposit. Restrictedly, on its weathered (“lapiaz”) surface, there is a centimetric-thick calcrete. In addition to the lapiaz, the surface of unit 4 is sprinkled with voids corresponding to dissolution vug wells, which all have a reddish silt-clay sand filling.

Considering the history of the Kebibat quarry, the authors (e.g., Marçais, 1934; Lecointre, 1958) indicate that after the discovery of human remains, the mining of rocks continued, which implies that the forehead has receded and that the exact location does not exist anymore. On the quarry floor, remains of the lumachel (unit 1) of S2 are observed. Tracing this unit and the underlying S1 on the floor of the quarry up to the current front of the quarry is evidence that this is the same sequence that contained the human remains. Thus, the current section is the lateral equivalent of the old one.

Micromorphology was used as a tool to highlight the microscopic characteristics of the host rock of the human remains and clarify the fossilization conditions and further details on the diagenesis zone of this rock.

The microscopic features of the facies constituting the different units of the S2 reveal, first of all, the similarity in terms of constitutions (mineral grains and other debris) observed in the marine and dune facies (figs. 10 & 11). Bioclasts are the most abundant and composed mainly of debris of mollusks, bivalves, sea urchins, algae and foraminifera. However, the silico-clastic grains are,



**Fig. 8:** East front of the Kebibat quarry showing the units of sequence 2.

U: Unit. S1: Sequence 1. K: Karstification surface.

*Fig. 8 : Front de taille de la carrière de Kéibat montrant les unités de la séquence 2. U : Unité. S1 : Séquence 1. K : Surface de karstification.*

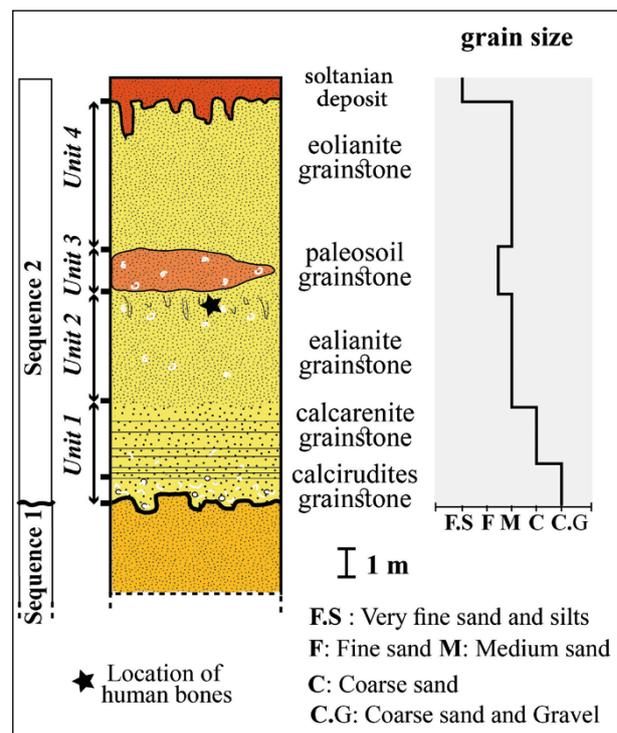
for the most part, composed of quartz, to which are added feldspars and rare glauconite minerals, as well as intraclasts and extraclasts except that the dune facies also contains fragments of continental gastropod shells and a large amount of silico-clastic grains.

The micromorphological observation of the palaeosol reflects the composition of marine and dune calcarenites already observed. Most bioclast fragments have lost their internal structure due to a very intense dissolution. It should be noted that thin red-brown coverings lining the wall of some voids reflect pedogenetic features (Alouane & Aberkan, 1998; El Graoui, 1994).

The abundance of bioclasts promotes the rapid cementation of calcarenites in this sequence (Pursler, 1980; Gardner & McLaren, 1993). Marine deposits have lithification in the supratidal to intertidal marine environment in the vadose zone rather than in the phreatic zone. The dune deposits have a diagenetic evolution in the vadose zone with the presence of meteoric waters circulation and temporarily in the continental phreatic zone. The cementation of the marine and the dune facies demonstrates a diversity of the cement forms, commonly: palissadic, epitaxial and irregular mosaic.

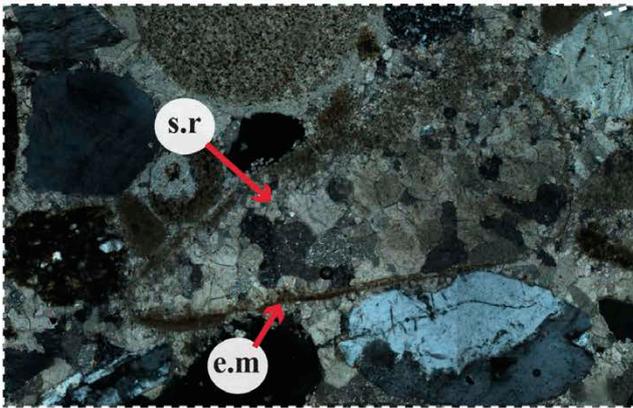
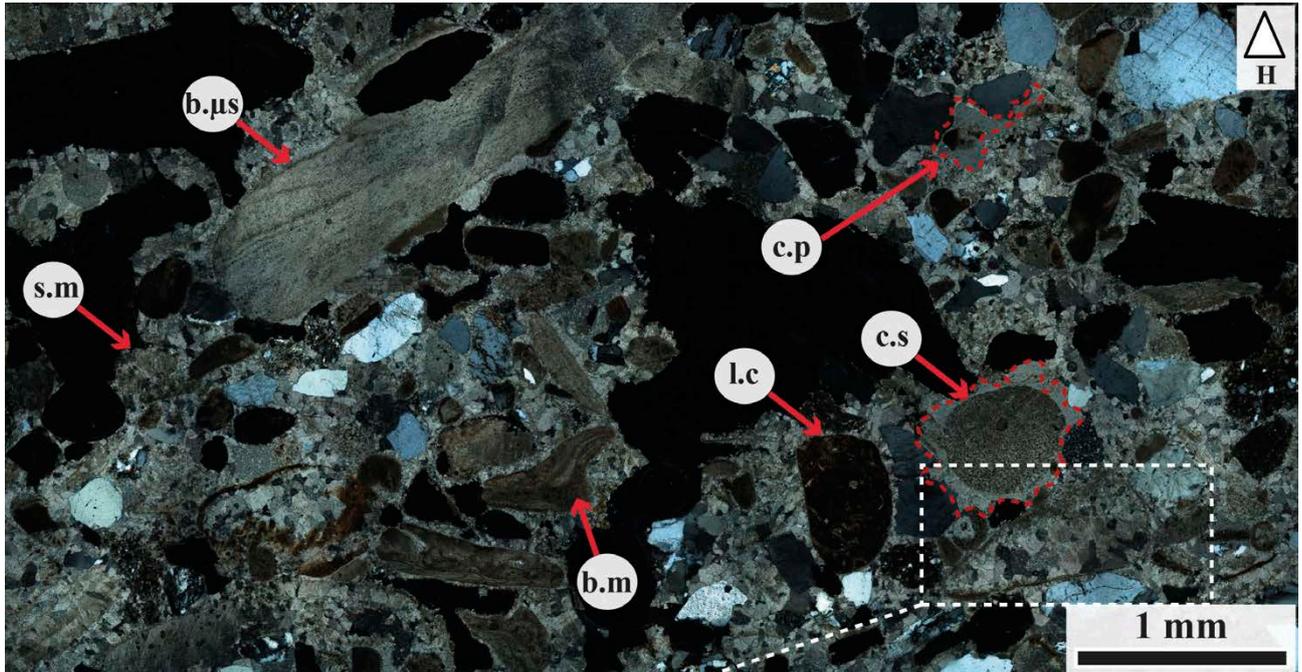
The fragments of bioclasts constituting the dunes and marine facies are mineralogically unstable (calcite, aragonite). However, bone tissue composed of calcium phosphate is more resistant to recrystallization. Two parameters, therefore, play in favor of rapid lithification and, consequently, the preservation of human bones (Lucas *et al.*, 1976; Maurer *et al.*, 2014; López-Costas *et al.*, 2016). The first parameter corresponds to the good conservation of the Kebibat's human remains. Hominid

bones did not record any trace of predation (Oujaa *et al.*, 2017). The second parameter is related to the dissolution due to the circulation of meteoric water, which has increased the secondary porosity, especially in the form of vacuolar porosity (thin section observation: fig. 11).



**Fig. 9:** Lithostratigraphic log of the Rabat-Kebibat human fossil deposit.

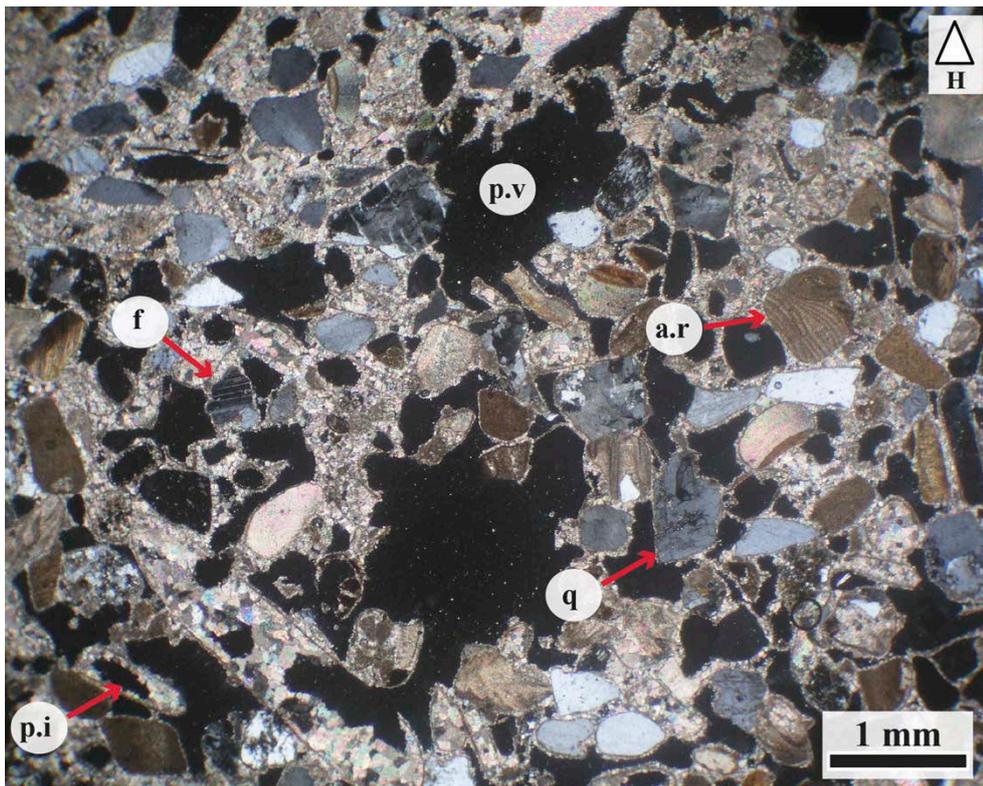
*Fig. 9 : Contexte lithostratigraphique dans lequel ont été retrouvés les fossiles humains de Rabat-Kéibat.*



**Fig. 10: Microfacies of marine deposit of sequence S2.**

b.µs: Microsparitised bioclast. c.s: Syntactic calcite. l.c: Carbonate lithoclast. e.m: Micritic envelope. s.r: Sparite of recrystallization. ep: Epigenesis of quartz in calcite. c.p: Poecilitic calcite. s.m: Cement in mosaic.

*Fig. 10 : Microfaciès des dépôts marins de la séquence S2. b.µs : Bioclastes microsparitisés . c.s : Calcite syntaxique. l.c : Lithoclaste carbonaté. e.m : Enveloppe micritique. s.r : Sparite de recrystallisation. ep : Épigénèse du quartz en calcite. c.p : Calcite poecilitique. s.m : Ciment en mosaïque.*



**Fig. 11: Thin section of unit 2 in polarised light.**

a.r: Red algae. f: Feldspar. p.i.: Intragranular porosity. p.v: Vacuolar porosity. q: Quartz.

*Fig. 11 : Lame mince de l'unité 2 en lumière polarisée. a.r : algue rouge. F : Feldspath. p.i. : Porosité intragranulaire. p.v : Porosité vacuolaire. Q : Quartz.*

Due to this second porosity, the presence of water increased, favoring probably the post-fossilization alteration and erosion of bones. We assume that the taphonomic study cases are delicate in such an open “system” and deserves more detailed investigations.

The detailed lithological and petrographical data indicate that after the deposition of S1, a palaeo-platform (foreshore) and a paleo-cliff were formed above S1 by rising sea level. During the fall of the sea level, the regressive progradation deposits of S2 were accumulated by an evolution of a supratidal/intertidal marine environment towards a continental environment (coastal dune). This standard of coastal deposits evolution on the Atlantic margin was observed not only in Rabat, but also in northern Morocco (Alouane, 1986; Aboumaria *et al.*, 2009), in Kenitra (Palziat *et al.*, 2006), and towards the south in Casablanca and Agadir (e.g., Lefèvre *et al.*, 1994; Texier *et al.*, 2002; Weisrock *et al.*, 2012). In addition to the Moroccan Atlantic coasts, regressive coastal depositional sequences during the Pleistocene have been noted in several localities in the world (e.g., Davaud *et al.*, 1991; El Graoui, 1994; Brooke, 2001; Ridente & Trincardi, 2002).

## 5.2 - CHRONOLOGY

The available IRSL and OSL (Optically Stimulated Luminescence) data can constrain the age of the sedimentary unit that contained the human remains, as well as U-Th ages already performed on other units in the same sequence.

The sample from unit 2 of S2 (figs. 8 & 9) that delivered the human skull gave a fading corrected IR<sub>50</sub> age of 137 ± 7 ka (tab. 1).

The bottom of S2 corresponding to unit 1 and composed of a marine deposit, probably yields an age older than 200 ka based on a U-Th dating (Stearns & Thurber, 1965). Even if this age dates back to the sixties and maybe questionable in terms of precision, it probably allows us only to assume that this sequence was deposited during MIS 7.

Towards the south of the Kebibat quarry (approximately 1.4 km), the prehistoric cave Dar es Soltane 1 (e.g., Débenath, 1972) was excavated in a calcarenite belonging to the same sedimentary sequence as Kebibat (sequence 2) (Chahid *et al.*, 2017; Chahid, 2017). Two OSL ages were obtained from quartz extracted from the limestone in which is formed this cave. The first sample yields an age of 209 ± 30 ka at the base of sequence two, and the second sample yields an age of 156 ± 14 ka at the top of the sequence precisely at the dune deposit (Barton *et al.*, 2009).

All these geochronological elements are coherent with the proposal that the human skull remains found at Kebibat belong to a coastal dune formed during MIS 6 (fig. 12).

From a palaeoanthropological and geochronological point of view, Kebibat human remains are characterized by a more archaic morphology and are older than the other human remains found in the coastal caves of Temara (e.g., Jacobs *et al.*, 2011; Barton *et al.*, 2009; Oujaa *et al.*, 2017). Moreover, the comparison between the human skull's aspect of the Kebibat site and Jebel Irhoud site suggests that morphologically, in Jebel Irhoud, skulls are less archaic and relatively older with an age of 300 ka (Hublin *et al.*, 2017; Richter *et al.*, 2017).

Dose-rate data			Palaeodose data	
Radioactive elements abundance			Equivalent dose (Gy)	207 ± 4
	Uranium (ppm)	2.86 ± 0.04		
	Thorium (ppm)	0.54 ± 0.03		
	External K (%)	0.11 ± 0.01	g value (%/decade)	2.12 ± 0.14
Effective environmental dose-rate			DRC correction factor	0.82 ± 0.01
	Alpha (Gy/ka)	0.05 ± 0.01		
	Beta (Gy/ka)	0.42 ± 0.01		
	Gamma (Gy/ka)	0.37 ± 0.01		
	Cosmic (Gy/ka)	0.16 ± 0.02	Equivalent dose corrected for fading (Gy)	277 ± 5
Internal dose-rate				
	Beta (Gy/ka)	1.02 ± 0.09		
<b>Total dose-rate (Gy/ka)</b>		<b>2.03 ± 0.10</b>	<b>Age (ka)</b>	<b>137 ± 7</b>

Notes:

1. Internal dose using 12.5 ± 0.5 % potassium and 400 ± 100 ppm Rb (Huntley & Baril, 1997)
2. Grain-size 265 ± 25 µm (from laser grain-size analysis)
3. a value = 0.08 ± 0.02 (Kreutzer *et al.*, 2014)
4. g value is for a tc = 48 hours.

**Tab. 1: Luminescence dating dose-rate and palaeodose data.**

Tab. 1 : Datation par luminescence (dose annuelle et paléodose).

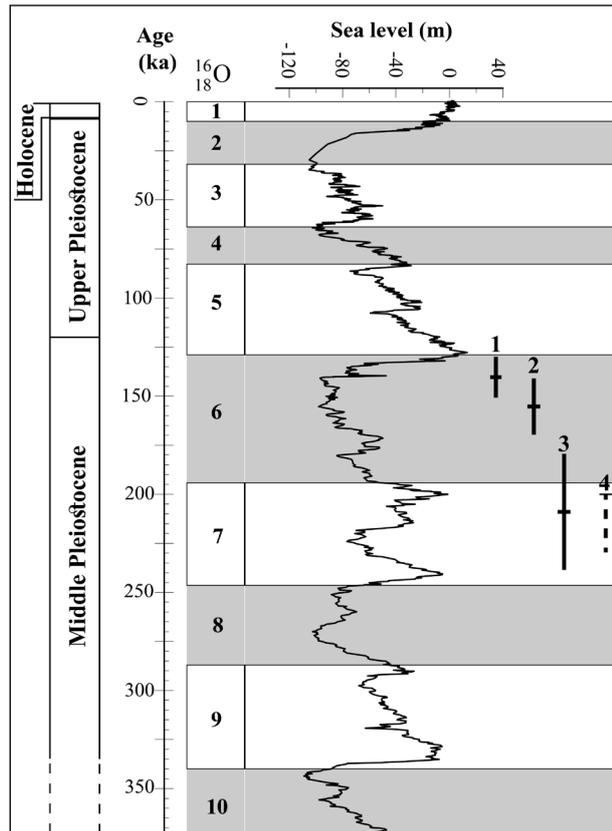


Fig. 12: Ages of sequence 2.

1: This work. 2 and 3: Barton *et al.*, 2009. 4: Stearns & Thurber (1965). The curve is modified after Rohling *et al.* (2009).

Fig. 12 : Les âges obtenus sur la séquence 2. 1 : cette recherche. 2 et 3 : Barton *et al.* (2009). 4 : Stearns & Thurber (1965). La courbe est modifiée d'après Rohling *et al.* (2009).

## 6 - CONCLUSION

The stratigraphic and chronological context of the archaic *Homo sapiens* of Rabat-Kebibat was detailed using available and new chronological data and lithological information. The lithological unit that delivered the fossil Human bone remains of the Rabat-Kebibat belongs to sequence 2, corresponding to a coastal-prism-regressive sedimentary deposit. S2 is formed at the base of a sedimentary stock of high beaches and overcomes a dune interspersed with a palaeosol. Given the lithological nature of the deposit, a bioclasts-rich eolianite, early cementation has favored the conservation of bones.

The chronological data resulting from our IRSL measurements and previous OSL and U-Th dating programs are critical components of our new analysis. Thus, the sequence which delivered the fossilized human remains was formed between the end of MIS 7 and probably the end of MIS 6, considering the age uncertainty includes the end of the penultimate glaciation.

This age is young with regard to the archaic characters exhibited by the Man of Kebibat. It is all the more so as older specimens show less archaic characters, as is the case of the subject of Jebel Irhoud, dated at 300,000 years before the present.

These chronological results thus contribute to the anthropological debate by supporting the hypothesis of a complex transition between ancient and recent forms

of *Homo sapiens* in North Africa, with recent characters carried by individuals dated earlier and ancient characters carried by more recent individuals.

This Kebibat chronology may thus contribute to the anthropological debate about the evolution of archaic *Homo sapiens*.

## ACKNOWLEDGMENT

This research was made possible by the support of the Moroccan French Mission El Harhoura-Temara under the administrative supervision of the *Institut National des Sciences de l'Archéologie et du Patrimoine* (Rabat, Morocco). D.C. is grateful to the scientific team of the Luminescence dating laboratory (LUX) at the *Université du Québec à Montréal* for supervision in the dating of the palaeo-shorelines of Rabat-Temara. We would like to thank the two anonymous reviewers for their comments and suggestions, which enabled us to improve the quality of this paper. This paper is dedicated to the memory of our dear friend and colleague Emilie Campmas.

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