Quaternary International xxx (2017) 1–14

Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

Chronology and formation processes of the Middle to Upper Palaeolithic deposits of Ifri n'Ammar using multi-method luminescence dating and micromorphology

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ARTICLE INFO

Article history:
Received 30 November 2016
Received in revised form
20 October 2017
Accepted 31 October 2017
Available online xxx

ABSTRACT

The existence of an early Upper Palaeolithic culture at the transition from the Middle Palaeolithic to the Upper Palaeolithic in North African cave sites is currently under debate. We studied Ifri n'Ammar in North-East Morocco, which is one of the oldest settlement sites of anatomically modern humans (AMH) in the Maghreb and contains several sediment layers which are attributed to Middle and Upper Palaeolithic occupations. In order to investigate processes of sediment accumulation and postdepositional alteration, we studied thin sections from these levels. According to micromorphological analysis, aeolian input considerably contributed to sediment accumulation and postdepositional mixing by bioturbation occurred. We compared multiple and single-grain quartz and multiple-grain feldspar luminescence dating of three samples from corresponding sediment layers to achieve a comprehensive chronology. The single-grain dose distributions scatter strongly and the source of the scatter is unclear. We used an arithmetic mean to calculate the equivalent doses. Archaeological evidence and age control from radiocarbon dating was essential to interpret the data. Quartz and feldspar multiple-grain luminescence ages are between 15 and 80 ka. The central part of the profile shows an intermediate accumulation, which lacks specified lithic artefacts. This supports the idea of an occupational gap between Middle and Upper Palaeolithic layers.

1. Introduction

Ifri n'Ammar in North-East Morocco is one of the oldest settlement sites of anatomically modern humans (AMH) in North Africa. The site is of special importance for the Middle and Upper Palaeolithic occupation levels that are preserved in the sediment sequence (cf. Linstädter et al., 2012). Dating the end of the Middle Palaeolithic in the region is rare in most sites because of the lack of corresponding inventories. An example for this is the El Harhoura 2 site, where ages of ~30 ka have been reported (Debenath et al., 1986) for artefacts that have been ambiguously associated with either the Middle Palaeolithic or the Upper Palaeolithic (Nespoulet et al., 2008). More recent optically stimulated luminescence (OSL) chronologies date to around 55 ka for deposits that have been correlated with the late Middle Palaeolithic (Jacobs et al., 2012); similar to most other sites in North-West Africa (cf. Linstädter et al., 2012, Table 2).

A well-defined Upper Palaeolithic techno-complex starts with the Iberomaurusian that is widely distributed from Tunisia to Morocco (Linstädter et al., 2012). It has been separated by sedimentological criteria into an early and a late phase. Occupations of the Late Iberomaurusian are easy to identify, because they occur in greyish sediments called "escargotière". High proportions of gastropod shell fragments characterise these sediments (Nami and Moser, 2010).

Only very few sites in the Mahgreb display a complete sequence of Middle Palaeolithic occupation that is superimposed by Iberomaurusian layers. These sites are Taforalt, Contrebandiers and Ifri n'Ammar, which all have the same lithic assemblage (Barton et al., 2013, 2015; 2016; Bartz et al., 2015; Bouzouggar et al., 2007;

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https://doi.org/10.1016/j.quaint.2017.10.043
1040-6182/

Mikdad et al., 2002; Nami and Moser, 2010; Roche and Texier, 1976). The transition from the Middle Palaeolithic to the Upper Palaeolithic has generated a change in the lithic industry, which is a major cultural development (Barton et al., 2015; Lubell, 2001).

Ifri n'Ammar has been extensively excavated since 1997 (Fig. S1), yielding a sequence of Middle to Upper Palaeolithic layers which is more than 6 m thick. In the lower part of this sequence, several layers, attributed to the Middle Palaeolithic, are exposed. The sequence has previously been dated by radiocarbon (charcoal) and thermoluminescence dating (TL) of heated artefacts (Mikdad et al., 2002; Moser, 2003; Richter et al., 2010). Following these chronologies, the weighted average of nine TL ages from the Middle Palaeolithic layer "Lower OS" is 130 ± 8 ka and 83 ± 6 ka (n = 10) for layer "Upper OS" (Richter et al., 2010). The TL ages are significantly older than the radiocarbon ages of charcoal from layer "Upper OS", which have been dated between 40 and 50 ka BP (Mikdad et al., 2002; Moser, 2003). The overlying deposits of the Late Iberomaurusian are dated between 10 and 14 ka BP (Linstädter et al., 2012; Moser, 2003). According to these radiocarbon and TL ages of Mikdad et al. (2002), Moser (2003) and Richter et al. (2010) there is a temporal gap between Middle Palaeolithic and Late Iberomaurusian deposits of several ten thousand years. Nami and Moser (2010) have assumed that a lack of sedimentation, presumably caused by a hyperarid climate that promotes deflation, is responsible for the temporal gap. Another explanation is that the sediment package of about 30 cm thickness, which separates the Middle Palaeolithic and the Late Iberomaurusian deposits, has not yet been dated (Nami and Moser, 2010).

At Taforalt, Barton et al. (2013) did not observe such a major hiatus in the sediment sequence. Instead, a small gap of about 1900–3800 years has been reported between the Middle Palaeolithic and the Iberomaurusian levels, based on two radiocarbon ages of ~21.8 and 24.4 ka cal BP at a 2σ uncertainty (Barton et al., 2013). It is important to note that the modern excavation at Taforalt is limited to small vertical slots in the ancient profiles. These slots are from distant areas of the cave with different sedimentation cycles and have been merged to a synthetic stratigraphy. Lithic artefacts are rare and not present in every level that has been dated and the artefacts do not show significant morphological features (Barton et al., 2013). A new slot, located near the entrance area of the cave, dates the final part of the Middle Palaeolithic with three different methods (TL, OSL, ^{14}C) from about 28 ka (TL) to 37 ka (OSL) and 29 ka (^{14}C) (Barton et al., 2016). These data suggest an end of the Middle Palaeolithic at about 30 ka. Above this level, scattered unspecified lithics have been found. OSL dating resulted in age estimates between 25 and 28 ka. On top, the Iberomaurusian has been attested and dated by OSL to ~19 ka (Barton et al., 2016).

At Contrebandiers, the situation is different, because Iberomaurusian layers have only been found in a small portion of sector IV of the excavation. The chronology concentrates on Middle Palaeolithic layers and yielded OSL ages of >90 ka (Jacobs et al., 2011) which prevents a closer discussion on the timing of a depositional hiatus between Middle Palaeolithic and Upper Palaeolithic deposits. Aldeias et al. (2014) have considered sediment erosion responsible for the limited extent of Iberomaurusian layers.

In general, the transition from the Middle Palaeolithic to the Upper Palaeolithic in North Africa is highly debated, because of the paucity of data. Numerical dating is requested especially because lithic artefacts are rare and in most cases unspecified. The use of radiocarbon dating can also be problematic because of a lack of well-preserved organic material, contamination with younger carbon (Wrinn and Rink, 2003) or dating of bulk sample material (Bouzouggar et al., 2008).

In this study we applied luminescence dating of sediments and micromorphological analysis to investigate the depositional history of Ifri n'Ammar at the transition from Middle to Upper Palaeolithic deposits. The profiles of the old excavation that have been published in Nami and Moser (2010) were not available anymore; instead we sampled a profile that was exposed by the new excavation, which started in 2009. This new profile may document the Middle to Upper Palaeolithic transition at a high resolution, because a thick package of slightly reddish silty to sandy deposits is intercalated between the Middle and Upper Palaeolithic layers. This package shows similar sediment features compared to the sandy Middle Palaeolithic layers and is named "couche rouge". The individual units of the new profile cannot be directly linked to the profiles described in Moser (2003) and Nami and Moser (2010), but the lower boundary of the shell-rich and dark coloured "escargotière" on top of the "couche rouge" is clearly visible. A detailed sedimentological study of profiles exposed in the old excavations was conducted by Reisch (2010), but for the new profile, very limited information on the sediment nature is available, which also holds true for other deposits of the "couche rouge" in Morocco such as Ifri el Baroud (Nami, 2007) or Taforalt (Barton et al., 2015). We therefore took a series of thin sections in order to study the sediment composition as well as the processes of sediment accumulation and postdepositional alteration. With the micromorphological study we also intended to provide seminal data for evaluating the luminescence age estimates, because archaeological sequences are often stratigraphically complex and therefore challenging to date. Post-depositional mixing, temporally varying sediment inputs by roof spall, insufficient bleaching prior to burial and dose rate heterogeneity may have affected the sediments, which might have an effect on the spread of the luminescence data. According to Jacobs and Roberts (2007), the shape of the equivalent dose (D_e) distribution can give information about the source of the scatter. To account for this, single-grain dating has been the method of choice for dating cave sediments for years (e.g. Arnold et al., 2013; Demuro et al., 2014; Doerschner et al., 2016; Feathers et al., 2010; Jacobs et al., 2012; Tribolo et al., 2010). Furthermore, some statistical analysis models require the use of single-grain data sets instead of multiple-grain data (Galbraith and Roberts, 2012). On the contrary, Guérin et al. (2015a) and Thomsen et al. (2016) have documented the good applicability of multiple-grain dating in cave environments. Moreover, these studies have shown that single-grain dating in combination with sophisticated statistical models to calculate an equivalent dose resulted in severe age underestimation, which would have remained undiscovered without a comparison of different luminescence dating techniques using quartz and potassium feldspar plus a crosscheck with radiocarbon dating.

We applied different approaches to date the cave deposits from Ifri n'Ammar and compared single-grain and multiple-grain quartz dating with multiple-grain feldspar dating for an internal cross-check of the different methods. The upper part of the sequence contains artefacts that have been tentatively attributed to an Upper Palaeolithic-Early Iberomaurusian occupation which is widespread in the Maghreb and has been dated at several sites between 16 and 20 ka cal BP (Linstädter et al., 2012). A solid chronology based on numerical dating is especially important because we collected one sample from a layer below the Upper Palaeolithic unit that lacks distinct lithic artefacts. This sample most likely represents the transitional zone between the Middle and the Upper Palaeolithic occupation. The aim of our study was to provide a robust chronology based on OSL dating of sediments by using multiple optical dating techniques to better understand occupational processes at the Middle to Upper Palaeolithic transition at Ifri n'Ammar.

Please cite this article in press as: Klasen, N., et al., Chronology and formation processes of the Middle to Upper Palaeolithic deposits of Ifri n'Ammar using multi-method luminescence dating and micromorphology, Quaternary International (2017), https://doi.org/10.1016/j.quaint.2017.10.043