doi:10.1038/nature22335

This file contains additional information about the excavation methods, geology, fauna, lithics and considerations on the chronometric dating of the site.

Excavation Methods (SPM)

The site was excavated closely following existing protocols[1–6]. Layers were defined first on lithological criteria and second on archaeological criteria. Our stratigraphy (Layers 1-7) was determined independently of the previous excavations (Tixier's[7] Layers 1-22). All finds were recorded by layer and 3D coordinates (using an arbitrary grid established for the excavation) measured with Leica total stations (5" accuracy) using data collectors with self-authored software (EDM-Mobile). Lithics and all fauna > 25 mm were provenienced and given unique identifiers. Complete bones, identifiable teeth, and human remains < 25 mm (but larger than microfauna) were also given coordinates and IDs. Natural stones > 10 cm were recorded with a single coordinate, and stones > 20 cm were measured with multiple coordinates to describe their volume and orientation. The sediment, excluding recorded stones and artefacts, was collected by 7 litre bucket and dry screened on-site through 5 mm meshes. Buckets have unique IDs and their coordinate were measured in the centre of the area worked at the completion of the bucket. The volume was recorded for each bucket. Large (> 25 mm) objects in the buckets were given IDs and assigned the coordinates of the bucket. All samples and features were provenienced as well. Digital photographs documenting the excavation were recorded daily, and final sections were documented through a combination of digital photography (sometimes with rectification), drawing, and total station measures. Additional measures were required for the hominin fossils. For the partial skull, a structured light surface scan was made with a Breuckmann triTOS-HE (see also[8,9] for additional technical details). We merged 64 scans each with a lateral resolution of 0.45 mm and a feature accuracy (the difference of the measured positions of index marks towards target values) of 0.068 mm using Optocat 4.01 and GeoMagic to fill holes. We next made a silicone mould of the same fossil area using Silastic 3483 Base and Silastic Thixo Additive (both of Dow Corning). Prior to the mould we applied Paraloid B72 in a 10% solution of Acetone. We also applied modelling clay to stabilize the fossil and fill cracks. The final, painted, cast in high quality resin and fiberglass is housed at the Institut National des Sciences de l'Archéologie et du Patrimoine in Rabat, Morocco. Finally, the fossils were excavated with fine tools, documented with additional photographs, and removed. The partial skull was removed as a plastered block. This block contained the pyramidal shaped rock beside it. In the course of excavating this rock for plastering and removal, we discovered the mandible wrapped around the rock. It was removed separately, as was the hominin femur.

Geology (MR and JPR)

The Jebel Irhoud hill has been deeply karstified and mineralized over time. During the last century, mining activity to recover baryte and associated copper and silver frequently cut into cavities filled with Pleistocene sediments. One of these, the site Jebel Irhoud, yielded human fossils and was properly excavated in the late 1960's after the remaining roof had been blasted away. New excavations were initiated in 2004 on the section that remained from the late 1960s excavations.

The karst containing the site developed along a fracture zone oriented SE-NW with a slope towards the southeast (see Figure 1). The cavity's history can be partly deciphered using photos and text archives provided by former excavators and by observations and analyses of what remains of the site itself. Several stages characterize its history. In a first stage, the cavity was part of an internal karst with no connection to outside. At the base of the sequence are cubical blocks of roof fall covered with several layers of speleothems. In a second stage, sediments were brought into the cavity, in part through water transport, and partially filled the spaces between these blocks. These deposits contain no archaeological material and are represented in our excavation by Layer B (see Figure 2). In a third stage, the cavity opened by roof collapse in its southern part and eventually became an open cave in the central portion where the excavations took place (again - this roof was then totally removed in the 1950s/60s leaving the completely open cavity seen today). In a fourth stage, the area around the entrance was visited by animals and humans; artefacts, bones and charcoals were deposited in the cave within sediments characterized by their heterogeneity in size and poor sorting, building a large debris fan which submerged the inside topography (Layers 1-7, see Figure 2). Then, in a last stage, the cavity quickly filled with similar materials with some local deformations observable and the site was completely sealed again.

Macrofacies

The principal points of the sedimentary sequence are as follows:

Speleothems. These are present at the base of the sequence in the southeast and the northwest of the cavity. They attest to a period when the cavity was part of a wet karstic system without sedimentary connections to the exterior. However, there are not yet speleothems in direct contact with the sediments excavated by our project.

Boulders. This represents a phase during which the cavity probably opened to the surface through a collapse of the roof. The roof collapse itself consists of blocks in a range of sizes and was concentrated on the centre and southeast portion of the cavity.

Poorly stratified deposits. Most of the sedimentary deposit is poorly stratified with some rare stony lenses. The grain size is generally large and fits with waves of deposition from a debris cone.

Clasts are organised according to the slope of the deposits. In some rare cases, the deposit fits with debris flow. These deposits are thin and where the clast orientation can be measured it is sloped and shows some indications of plastic deformation.

Multiples charcoal lenses were observed at the bottom of Layer 7, directly on huge underlying blocks and in positively graded sediment at the top of inter-block filling. Numerous flint flakes have been heated, some apparently after being retouched.

The sedimentation is that of a rock talus slope fed by debris flow sometimes matrix supported but more often clast supported. The orientation of these deposits is sometimes planar but more often isotropic.

Microfacies

Microscopic observations were performed on 25 large thin sections cut in 14 oriented block samples extracted from Layers 1 to 7.

All samples are matrix supported and composed of poorly sorted predominantly schisteous clasts inserted in a red-brown sandy-silty matrix partly derived from eroded soils outside of the cavity. The c/f-related[10] distribution is of dense porphyritic type. Main sedimentary structures consist of millimetre size decantation which are indicators of run-off transport. Their good preservation demonstrates that post-depositional processes have not intensively destroyed the depositional organization, and they are frequently covered by cave wall lithoclasts (Extended Figure 2a).

Sedimentary microfacies do not change significantly from the bottom to the top of the sequence, and this indicates that relatively permanent aggradation processes took place during its accumulation. However, seven parameters show different states from bottom to the top of the sequence (SI Table 1):

- Materials show a progressive change from a granular microstructure (Layer 7) to an angular polyedric one (Layer 1) with a correlated increase of red-brown matrix from the base of Layer 4 upwards. The birefringence mode of the matrix is of stipple-speckled b-fabric.
- Elongated clasts in the base of Layer 4 are preferentially oriented according to the unit dip (Extended Figure 2b).
- Run-off deposits appear within Layers 7 and 6 and at the top of Layer 4. They are particularly well developed at the bottom of Layer 6 (Extended Figure 2c).
- Bone microfragments generally of angular morphology are characteristic of Layers 6 and 7. They are not abundant (< 5 %) (Extended Figure 2d). Phosphatic nodules are mainly concentrated in the bottom of Layer 7 and evoke small animal coprolites.
- In the bottom part of Layer 7, micro-charcoal concentrations are locally associated with soil aggregates, bone fragments and heated lithoclasts. The densest concentration lies at the very bottom of Layer 7 (Extended Figure 2e). The very top of Layer 7 shows a micro-organization of a trampled surface (Extended Figure 2f).

The spatially constrained accumulations of black material consist of wood charcoal with classic vesicular structure, but other black undetermined particles can partly be weathered schisteous material. Some of these were deposited in a plastic form, as testified by black coatings in a biogallery (Extended Figure 3b) or micro-beds mixed in the matrix (Extended Figure 3c). In some micro-organizations (named ‘structures’), black particles are concentrated in beds and look like carbon products issued from a fire-place (Extended Figure 3d and e). In other layers, no charcoal beds were observed.

Table 1. Summary of thin-section results.

Macroscopy				Microscopy						
Thin section n°	**Field units**	**Layer**	**Number of sub-units**	**Micro-structure**	**Brown-red matrix**	**Preferential orientation of elongated clasts**	**Run-off structures**	**Bone fragments**	**Phosphatic nodules**	**Micro-charcoals**
601T	1	1		AB	xxx					x
601B	1	1		AB	xxx					
602	1	1/2		AB	xxx					
603	4	3		AB-G	xx		x			
604T	4	3/4		AB-G	xx	x	xx	x	x	
604B	4	4		AB-G	xx	xx				
605T	4	4		AB-G	xxx	x	x			
605B	4	4		AB-G	xxx	x	x			
606T	4	4		AB-G	xxx	x	x			
606B	4	4		AB-G	xxx	xx	x			
607T	4	4		AB-G	xx					
607B	4	4		AB-G	xx					
608T	4	4		AB-G	xx	x				
608M	4	4	2	G	x	xx	x			
608B	4	4/5	2	G	x	x	xx			
609T	7	6		G	x	x	x	xx		
609B	7	6		G	x	x	x	xxx	x	
712T	7	6		G	x		xxx	xx		
712M	7	6/7		G	xx		x	xx		xx
712B	7	7		G	x		x	xx		xx
713	7	7		G	x		xx	xx		xx
714T	7	7		G	x		x	xx		xx
714B	7	7		G	x		x	xx	x	xx
716	7	7		G	x	xx		xx	x	xx
717	7	7	3	G	x		x	x		xx

T : top, M : middle, B : base

microstructure : AB : angular blocky ; G : granular ; AB-G : intermediate

abundance / intensity : x : weak, xx : medium, xxx : strong

Fauna (TS, FA and DG)

The Jebel Irhoud provenienced faunal assemblage derives primarily from Layer 4 and below, with the densest faunal accumulation in Layer 7. The species identified in the current sample (SI Table 2) closely follow those documented by Thomas[11], Amani[12], and Amani and Geraads[13] from the earlier samples. However, we have identified fewer bovid taxa other than gazelles (*Gazella* sp.), likely because our sample is smaller. Gazelles dominate the assemblage, and three species can be identified in the provenienced material (based on horncores): *G. atlantica*, *G. cuvieri*, and *G. tingitana*, which were also identified by Amani and Geraads[13]. Alcelaphins (tribe Alcelaphini: wildebeest, hartebeest and relatives) are also present. In the much larger Ennouchi sample, blue wildebeest (*Connochaetes taurinus*) and possibly *Damaliscus* sp. (potentially topi) and *Rabaticeras arambourgi* were identified[13], but none were recorded in the sample studied by Thomas[11]. Hartebeest (*Alcelaphus* sp.) have been documented in younger Late Pleistocene assemblages[14]. The presence of *Rabaticeras* would be the most recent occurrence of this genus and would postdate the appearance at 600 ka of its likely descendant, *Alcelaphus*[15,16]. Currently the alcelaphins are best represented by dental remains; at least two sizes appear to be present, but horncores are necessary for more precise species designations. Zebras (*Equus* sp.) and large bovins (potentially aurochs, *Bos primigenius*[17]) were found in this study as well as in the previously analyzed samples. We have confirmed the presence of eland (*Taurotragus*) at the site (but from the initial, out of context, cleanings)[11, 13], and unlike the earlier excavations, no addax or oryx (*Addax* or *Oryx*) teeth or horncores have been identified. We note the absence of Eurasian cervids and suids. These are found in Late Pleistocene North African sites[18], and their absence at Jebel Irhoud in the smaller, recently excavated, and well provenienced sample, the larger out of context, site cleaning sample, and the earlier Ennouchi and Tixier samples supports the conclusion that the material accumulated during the Middle Pleistocene.

Most of the carnivores that are present consist of felids and canids, and are known from other Middle Pleistocene assemblages from the larger region[19,20]. In addition to fox remains (*Vulpes* sp.), there are multiple specimens of larger canids, which were recognized in the material from the earlier excavations and from other Pleistocene sites of the region. These may be from large jackals (*Canis aureus*) or from a form more closely related to wolves (*Canis lupaster*)[18]; further work on the assemblage will help clarify this. Lions (*Panthera leo*) and especially leopards (*Panthera pardus*) have been identified in all the excavation campaigns (however, our lion specimen is from out of context cleanings), but we add here small (*Felis silvestris*) and medium-sized (*Caracal caracal*) felids. Both of these taxa are present in North Africa today and have been found in the Late Pleistocene and Holocene assemblages of Haua Fteah[21] and El Harhoura 1[22], so their presence is not unexpected. Hyena coprolites are found throughout the sequence; however, despite their consistent presence, there is not a strong signature of carnivore activity on the bones. Unfortunately, our ability to identify surface modifications is limited by the encrustations on the bones, but breakage patterns and carnivore scalloping would be more clearly identifiable. Only one carnivore-chewed bone was identified, a gazelle rib from Layer 6, while probable cut-marks were seen on small bovid (gazelle) remains from Layers 4 (1 rib), 6 (1 rib) and 7 (1 astragalus, 1 distal humerus, and 1 long bone fragment) and scraping marks on 2 larger bovid remains from Layer 7 (1 rib and 1 tibia). Following the methods established by Villa and Mahieu[23], the majority of long bones exhibited breakage patterns indicating that they were broken while green or fresh (at least 61% in Layer 4, 69% in Layer 5, 54% in Layer 6, and 60% in Layer 7). A few percussion notches are present on the bones, supporting the possibility that these bones were broken open for marrow extraction. Further evidence of human impact on these assemblages is found in the relatively high abundance of burnt bones (5% in Layer 4, 25% in Layer 5, 19% in Layer 6, and 24% in Layer 7). Gazelles of all ages are present in the sample. The horncores of *G. atlantica* indicate that they were females. The *G. cuvieri* and *G. tingitana* horncores from Layer 4 are from males, and in Layer 7, one *G. cuvieri* horncore is from a male and the other is from a female. Alcelaphins seem to be biased towards juvenile individuals. The abundance of lithics, faunal remains, and evidence for fire indicate that humans were primarily responsible for accumulating the vertebrate remains. In addition to these vertebrate remains, ostrich eggshell fragments are preserved in Layers 4 through 7. These eggshell fragments appear to cluster with the bones, coprolites, and stone artefacts. They may have been collected by humans or hyenas, and further investigation into their breakage patterns needs to be completed before we can discriminate between these accumulating agents. Therefore, the possibility of a limited role for carnivores cannot be ruled out, and continuing excavations and analyses will further investigate these issues.

One notable find from Layer 6 is a long bone shaft fragment that was used as a retouchoir. These have been commonly described from Mousterian sites in France, but have only rarely been documented in Africa. A few examples are known from the Middle Stone Age sites of

Blombos Cave[24] and Ysterfontein 1, South Africa and the Aterian layers at Rhafas Cave and Taforalt, Morocco.

Table 2: Taxon table of provenienced fauna from Jebel Irhoud.

		Layer							
Scientific name	**Common name**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Grand Total**
Leporidae	Hares and rabbits					1	3	2	**6**
Hystrix cristata	Crested porcupine							3	**3**
Panthera pardus	Leopard							4	**4**
Caracal caracal	Caracal						1		**1**
Felis silvestris (*lybica* group)	African wild cat				1			2	**3**
Canis sp.	Canid				5				**5**
	Medium carnivore							4	**4**
Equus sp.	Equid				2	2	4	4	**12**
Bovini	Aurochs or buffalo						1	4	**5**
Alcelaphini	Hartebeest, wildebeest and allies				3	3	1	2	**9**
Gazella atlantica	Atlantic gazelle						1	2	**3**
Gazella cuvieri	Cuvier's gazelle				1			2	**3**
Gazella tingitana					1				**1**
Gazella sp.	Gazelle			2	28	21	20	33	**104**
	Small bovid				14	11	39	89	**153**
	Small-medium bovid				9	5	18	41	**73**
	Large-medium bovid				5	9	7	17	**38**
	Large bovid				4	3	5	6	**18**
Aves	Birds				1			4	**5**
	Tortoise		1		2			1	**4**
	Snake							6	**6**
	Terrestrial gastropods				1			5	**6**
	Freshwater bivalves	2	1		2		1		**6**
	Total	**2**	**2**	**2**	**79**	**55**	**101**	**231**	**472**

Lithics (SPM)

The Jebel Irhoud analyzed lithic assemblage consists of 320 artefacts across 4 layers (pieces greater than 25mm in maximum dimension: Layer 4 N=14, Layer 5 N=49, Layer 6 N=122 and Layer 7 N=135). Layer 7 corresponds to Layer 18 (unknown size cut-off: N=217) of the Tixier excavations (see main text, Fig. 2) and was previously published[7]. In his publication, Tixier emphasizes the following points: the raw materials consists mainly of flint, quartzite and quartz but most of the retouched tools are on flint; the assemblage has a high percentage of retouched tools relative to the amount of debris; there are very few cores; a quarter of the retouched artefacts are on Levallois blanks; the retouched blanks are rarely laminar; there is no Quina retouch, there is very little bifacial retouch; scrapers are the most common tool, many of which are déjeté; unretouched Levallois blanks exist as well; there are no end-scrapers no pedunculated pieces, and there are no bifacial foliates. In a European Middle Paleolithic framework, Tixier would classify the assemblage as a Levallois Mousterian rich in scrapers (or Typical Mousterian rich in scrapers). Note that while Tixier reports only on his Layer 18, he states that the same assemblage characteristics are true for the other layers.

This finding is additionally supported by Balout[25] and Sileh[26]. Balout looked at 400 artifacts coming from the site prior to the Tixier excavations. He concluded that there was no evidence of Aterian, and that the industry can best be described as a very typical Mousterian with Levallois technology and scrapers. Sileh looked at an additional 1600 artifacts (thought lost or exported and previously unreported) coming from Ennouchi's and Tixier's work at the site. He agrees with what was previously reported by Balout and by Tixier calling it a Levallois Mousterian rich in scrapers.

All of these previous observations hold for the newly excavated assemblage. In terms of raw materials, the complete assemblage is characterized primarily by flint/chert (64%) and by silicified limestone (26%, what Tixier called quartzite). Of the retouched artefacts, 87% are on flint/chert. There are only 2.5 flakes (with platforms) for each retouched tool (with a platform). Only 2 cores have been recovered. They are both on silicified limestone. One from Layer 4 can be classified as Levallois. The other, a core fragment from Layer 7, can be classified as discoidal. Of the retouched artefacts, 27% are made on Levallois blanks. Of the unretouched artefacts, 22% are Levallois. Only two blanks (retouched or not) could be classified as coming from a blade technology, 28 artefacts have a blade form, and the length:width ratio for the complete, unretouched flakes is 1.52. Platforms are mostly plain (61%) followed by dihedral (18%), faceted (15%) and cortical (4%). Tixier reported numbers of 46%, 14%, 25% and 6% respectively for Layer 18 (numbers recalculated to exclude removed platforms and non-recognizable platforms from the totals achieve comparability). Of the retouched artefacts, 79% are scrapers. Of the scrapers, simple (39%) and convergent (36% including Mousterian points and déjeté scrapers) forms dominate. Déjeté scrapers are 7% of the scrapers (Tixier reported 19% for his Layer 18, we have 15% for Layer 7). The frequency of double scrapers is 13%, and transverse forms are rare (4%). There are no Upper

Paleolithic retouched types and no pedunculated artefacts. There are 4 truncated-facetted artefacts. Like Tixier, we find no clear differences or trends in the assemblages of Layers 4, 5, 6, and 7, though small sample sizes make comparisons difficult. Also like Tixier, in a European framework, these assemblages would be characterized as Levallois Mousterian. One difference between our assemblage and that of Tixier, is that our percentage of scrapers (essential count) is high enough that it would be classified as Ferrassie type Mousterian. This is true as well when considering just Layer 7 (75%). However, as others have suggested already, despite the historical tradition of using the term Mousterian to describe North Africa assemblages, we prefer to place the Jebel Irhoud assemblages in an African framework. In this case, this means the Middle Stone Age. Like Tixier, Balout and Sileh, we find absolutely no trace of the Aterian facies of the Middle Stone Age in the assemblages from Jebel Irhoud.

Given the now much greater antiquity of this assemblage, an Acheulean attribution has to be considered as well; however, we find no evidence (large cutting tools, bifacial thinning flakes, or handaxes) in support of this attribution. One difficulty in this regard is that artefacts like handaxes can occur in relatively low frequencies meaning that large sample sizes are needed to reliably detect their presence. Our excavated sample is small, but as noted above, the larger previously studied collections from the site also make no mention of Acheulean elements. Finally, it is important to note that despite the size of the combined assemblages in terms of raw numbers, they represent a sample drawn from nearly a complete excavation of what was once a very large site. All that remains of Jebel Irhoud is an approximately 1.5 m^3 block of sediment. When this is excavated, we expect that we may add only an additional ~150 lithic artifacts (>2.5cm) to the ~2500 already known from the site. Thus we do not expect that additional excavation will greatly alter the consistent view that multiple studies have had based on various larger samples coming from very nearly the entire site.

Considerations of association and chronometric dating approaches (DR and PF)

The chronometric methods of TL and ESR are generally regarded as independent dating methods[27,28]. Because of the shared γ-dosimetry, we here consider these methods as quasi-independent and argue that the ESR data is, therefore, supporting the TL data. Nevertheless, other independent age control would be desirable.

Neither macroscopically visible well crystallized secondary carbonates nor tephra were observed within the stratigraphy in order to allow for other independent chronometric dating by U-series or Ar/Ar, respectively. Within the area of excavation no suitable speleothems were observed on the boulders excavated (bottom of the section) which could, despite the presumed antiquity, have served for a maximum age determination of the sequence by U-series dating.

The sediments at Jebel Irhoud contain particles partially derived from outside the cave, which, in principle, allows for luminescence dating. However, given the heterogeneous bleaching of such a mix of sediment particles from in- as well as from outside of the cave, a single grain (SG) approach is required. Such is well established for quartz minerals, which can be dated by optically stimulated luminescence (OSL), but in addition to differences in age, palaeodose and bleaching of individual sediment particles, the high dose rates preclude application of SG-OSL. Based on an estimated γ+β-dose rate of ~3.5 mGy a^{-1} (Extended Data Table 2) and a general saturation limit of ~300 Gy, it is concluded that the limit of standard quartz OSL dating is likely below 100 ka at Jebel Irhoud.

The association of samples for which an age estimate is determined to an event which can be historically interpreted has to be shown; the dated event (last heating) should equal the target event (archaeological occupation)[29]. In this case, the unit of analysis (the events) is an individual layer. Within Layer 7, for instance, we found nearly all of the fossil hominins in association with heated flints and a Middle Stone Age assemblage. We presume that the Middle Stone Age human activity represented by the deposition of flints, their subsequent heating (likely incidentally directly from fires), and the deposition of the human fossils were linked in time, but we cannot establish this beyond the resolution of an individual stratigraphic deposit. The association of the flints and the hominins in a particular deposit is also based on the assumption that there has been no movement of artifacts (or bones) between layers. Surface analyses have been carried out on a sample of 200 lithics by macroscopic and microscopic examination (binocular loupe X25 and X40). No indication for temperature variations of heated lithics were found as well as very few impacts of post-depositional processes. Effects of mechanical alterations due to movements of the objects (impacts, blunt/dulled edges or ridges, friction) are absent on their surfaces, rare on the ridges, and scarce on the edges. Alterations related to flushing/desiccating cycles are also scarce. These indicators do not suggest an important redistribution of the objects or a significant influence of chemical processes. Additionally, the geological observations presented here and the taphonomic analysis of the faunal collections do not suggest major reworking or movement of materials.

One piece of evidence for a close association in time between the heating of an artifact and its use comes from an artifact (Irhoud-1662 from Layer 6) that was retouched after it was heated. The retouch overlaps a white patina formed as a result of heating[30], which is additionally confirmed by the presence of incipient potlids on the ventral face. The modification of this artifact took place after the artefact was heated, and therefore provides some evidence for an association of the heating event and the human occupation (otherwise the artefact would have been buried and inaccessible for subsequent retouch).

Whether the heating events at Jebel Irhoud were a result of human behavior or unlikely natural repeated fires in the cave does not alter the association of the ages with the fossils and artifacts at the resolution of a layer given that the sedimentology, the stratigraphy and the preservation of stones and bones do not provide evidence of a hiatus and thus exposure (or close surface exposure for the flints) of a duration long enough to be significant within the uncertainties of the method or to be significant for the dosimetry.

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