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Human Palaeontology and Prehistory

## Intentional cut marks on bovid from the Quranwala zone, 2.6 Ma, Siwalik Frontal Range, northwestern India



### *Traces de boucheries intentionnelles sur des bovidés de la zone Quranwala, 2,6 Ma, chaîne frontale de Siwaliks, Inde du Nord-Ouest*

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## ABSTRACT

The Indo-French research program 'Siwaliks' has been surveying the Late Pliocene Formation of the Chandigarh anticline (NW India) since 2008. These sub-Himalayan floodplain deposits are known for their Tertiary-Quaternary transitional fauna, especially those from the Quranwala zone in the Masol Formation, whose basal member is approximately 130 meters below the Gauss/Matuyama paleomagnetic reversal (2.588 Ma). About 1500 fossils have been collected in the inlier of Masol, most often on recently eroded outcrops, and sometimes in association with stone tools (choppers, flakes). Many bones were covered by a variety of marks (animal, bioerosion and tectonics) and among these traces a few were intentional cut marks. Different methods have been applied in Paris (France) to describe their topography on a micron scale, using the 3D Digital Video Microscope Hirox, and completed with binocular microscopy at the Center for Research and Restoration of Museums of France (C2RMF), and X-ray microtomography with the AST-RX platform, at the National Museum of Natural History, Paris. Experiments with quartzite cobbles collected near the fossils were carried out in India and in France. The mineralization of the traces is identical to the bone tissue, and comparison with our experimental cut marks confirms that the profiles are typical of the sharp edge of a flake or cobble in quartzite; their size and spatial organization testify to energetic and intentional gestures from an agile wrist acting with precision, and to a good knowledge of the bovid anatomy.

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## R É S U M É

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Le programme de recherche franco-indien « Siwaliks » explore le Pliocène final de l'anticlinal de Chandigarh (Nord-Ouest de l'Inde) depuis 2008. Ces dépôts de plaines d'inondation sous-himalayennes sont connus pour leur faune de transition plio/quatenaire, notamment celle de la zone Quranwala située dans la formation Masol, qui débute environ 130 m au-dessous de l'inversion paléomagnétique Gauss/Matuyama (2,588 Ma). Près de 1500 fossiles ont été recueillis dans la boutonnière géologique de Masol, rarement en stratigraphie, le plus souvent sur les affleurements en cours d'érosion et, dans ce cas, parfois en association avec de l'industrie lithique (choppers, éclats). Parmi les fossiles, certains présentent plusieurs types de marques (animal, bioérosion et tectonique), mais sur trois os de bovidés, celles-ci évoquent fortement des marques anthropiques intentionnelles. Différentes méthodes ont été appliquées pour décrire leur topographie en France, à Paris, avec la vidéo digitale microscopique 3D Hirox complétée par la microscopie binoculaire au C2RMF (palais du Louvre), ainsi qu'avec la microtomographie infra-millimétrique à rayons X de la plateforme AST-RX du Muséum national d'histoire naturelle. Des expérimentations ont été réalisées en Inde et en France avec des quartzites collectés près des fossiles. La minéralisation des marques est identique à celle du tissu osseux, et la comparaison avec les traces de boucherie expérimentales montre que leurs profils sont typiques d'un tranchant intentionnel. Leur taille, leur trajet et leur organisation spatiale témoignent d'une gestuelle intentionnelle et énergique agissant avec précision, en particulier celle d'un poignet agile accompagné d'un regard qui connaissait l'anatomie du bovidé décharné.

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## 1. Introduction

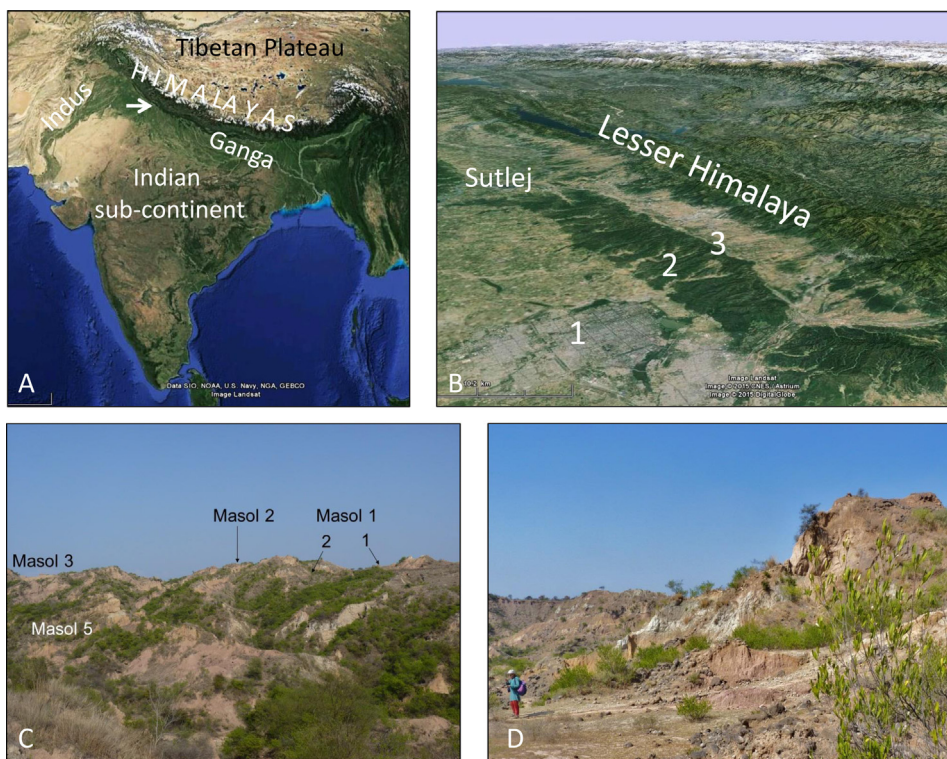
Given the current state of knowledge, the oldest known traces of lithic activity visible on bone are from the Afar depression in Ethiopia (Middle Awash Valley). Deep incisions have been described on two bones from Dikika, a basal member of the Hadar Formation from the Middle Pliocene, dating to 3.39 Ma (McPherron et al., 2010, 2011). Taphonomists have attempted to attribute them to crocodile teeth and weathering (Domínguez-Rodrigo et al., 2010, 2012) due to the lack of tools and the predominant paradigm wherein *Homo* is considered the only genus of Homininae able to create sophisticated operational sequences. Nevertheless, the recent discovery of a debitage workshop in stratigraphy dated to 3.3 Ma at Lomekwi 3 (West Turkana, Kenya) (Harmand et al., 2015) and recent experimental procedures to test the Dikika cut marks (Thompson et al., 2015), confirm such abilities far before the Tertiary–Quaternary boundary (2.58 Ma). Before the Dikika and Lomekwi 3 finds, the oldest cut marks associated to lithic industry in situ were found at Kada Gona (Ethiopia), and dated to the early Lower Pleistocene (2.53 Ma) (Semaw, 2000; Semaw et al., 2003), other cut marks were found near Kada Gona at Bouri (2.5 Ma) but without stone tools (de Heinzelin et al., 1999). In West Turkana (Kenya), lithic industries are associated with the *Homo* genus between 2.5 Ma and 2.34 Ma (Prat et al., 2005; Roche et al., 1999, 2003). They are contemporary with Asian tools recently dated to 2.48 Ma in Longgupo, Southwest China (Han et al., 2015), and a similar age has been envisaged for tools from Renzidong, Southeast China (Hou and Zhao, 2010; Jin et al., 2000; Zhang et al., 2000). Tools collected in Hadar (Ethiopia), are dated to 2.3 Ma and associated with *Homo* (Kimbel et al., 1996) and in the Upper Indus Basin at Riwayat (Pakistan) artifacts were found in a conglomer-

ate folded between 2.1 and 1.9 Ma; the polarity measured is positive. This polarity corresponds either to the upper limit of the Reunion Subchron, nearly 2.14–2.15 Ma ago (Dennell et al., 1988), or to the upper limit of the Gauss Chron, possibly close to 2.58 Ma (Dennell, 1998). Traces of butchery activities and lithic tools in association with *Homo* genus are then visible in Eurasia in South Europe (Dmanissi, Georgia) c.a. 1.9 Ma (de Lumley and Lordkipadnize, 2006).

The archeozoological assemblages of crocodiles, *Homo* genus, marks on bones and lithic industries are a recurring debate (Braun et al., 2010; Westaway et al., 2011). Detailed arguments are essential when confusion is possible between marks of the Oldowayan industry and those of crocodile teeth (Njau and Blumenshine, 2006). The distinction between these two marks benefits from advances in sub-millimeter imaging (e.g. Bello and Soligo, 2008; Bello et al., 2009) and experimental protocols (e.g. Milan et al., 2010; Baquedano et al., 2012; Drumheller and Brochu, 2014).

## 2. The context

The bones with cut marks were recorded between 2009 and 2011, in the Masol Formation of the Siwalik Frontal Range, to the north of Chandigarh, N 30° 50' E 76° 50' (Fig. 1) during the research program 'Siwaliks' (Coppens, 2016; Dambricourt Malassé, 2016; Dambricourt Malassé et al., 2016). This sector is an inlier of 80 to 100 hectares dug into the summit axis of an anticline formed by floodplain deposits, with a thick fossiliferous sequence of 60 meters, beginning approximately 130 meters below the Gauss/Matuyama paleomagnetic reversal. The fossiliferous layers, called the 'Quranwala zone', were identified in the 1960s during the geological mapping of the Chandigarh anticline (Sahni and Khan, 1964, 1968); stratigraphically



**Fig. 1.** Location of Masol. A. In the sub-Himalayan foothills (arrow). B. Precisely in the Siwalik Frontal Range, 1: Chandigarh, 2: Patiali Rao River, 3: Masol village. C. View towards the northeast, the dome of the anticline with three paleonto-archeological localities (Masol 1 and two sub-localities 1 and 2, Masol 2 and Masol 3) and the watershed of the Pichhli Choe with one locality (Masol 5). D. Masol 1, sub-locality 1, where the tibia shaft with cut marks was collected in 2009.

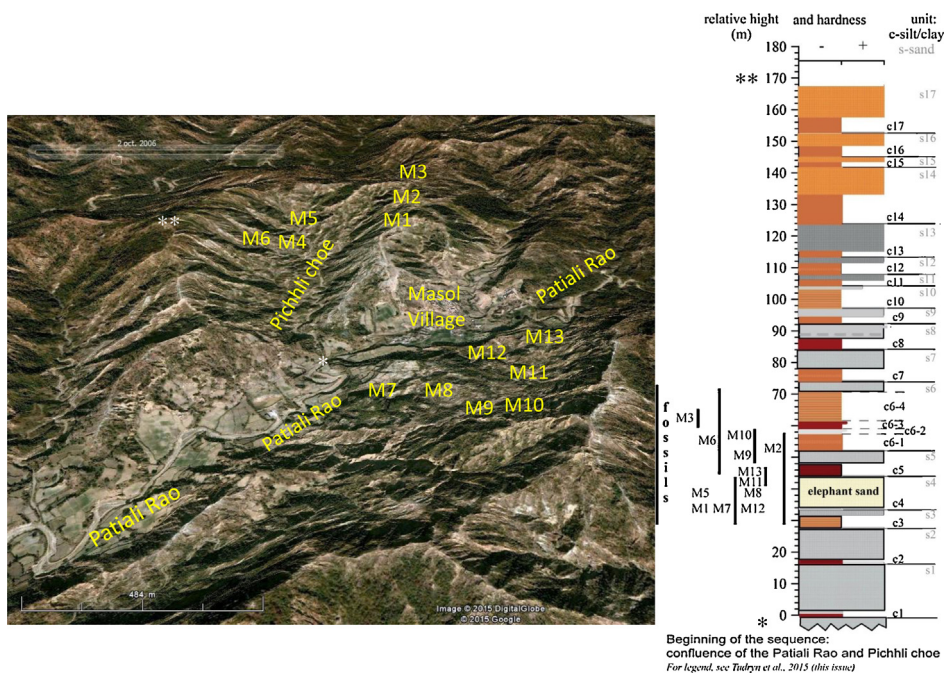
**Fig. 1.** Localisation du site de Masol. A. Dans les piémonts himalayens (flèche). B. Précisément dans la chaîne frontale des Siwaliks, 1 : Chandigarh, 2 : le Patiali Rao, 3 : le village de Masol. C. Vue vers le nord-est, le dôme de l'anticlinal avec trois localités paléonto-archéologiques (Masol 1 avec deux sous-localités 1 et 2, Masol 2 et Masol 3) et bassin versant du Pichhli Choe avec une localité (Masol 5). D. Le site Masol 1, sous-localité 1, où le fût tibial aux traces de découpes a été collecté en 2009.

A and B. Map data ©Google Earth. C and D. Photo A. Dambricourt Malassé.

they correspond to the end of the Tatrot (Upper Pliocene). The borderline with the Pleistocene was the subject of debate among paleontologists and geologists on the basis of the faunal assemblages, lithological variations and the conditions of fossilization. According to [Sahni and Khan \(1964\)](#), the limit was a conglomeratic sandstone beyond which Early Pleistocene fossils represented 20% of the collections and appear only in pockets 4 feet thick ([Sahni and Khan, 1968](#)). Fossils of the Tatrot are highly mineralized, which is not the case in specimens collected in these pockets. Later, in the 1990s, the Tertiary-Quaternary boundary was firmly located through paleomagnetism ([Ranga Rao, 1993](#); [Ranga Rao et al., 1995](#)), and the late Pliocene age of the Quranwala zone was confirmed. Now this fossiliferous zone is a reference site for paleontological studies of the Tertiary-Quaternary transitional fauna. There is no longer any doubt about their age and stratigraphic position ([Chapon Sao et al., 2016a, 2016b](#)). The inlier is totally isolated from other fossiliferous sectors, and there is no natural communication between them; any fossil collected around the village of Masol can only have come from the Quranwala zone. We prospected the inlier over 50 hectares between the lower and upper limits of the fossiliferous deposits, and identified 12 paleonto-archeological localities on the outcrops

([Fig. 2](#)). We found again the descriptions of Sahni and Khan and initiated a comprehensive study to further clarify the lithostratigraphical origins of fossils and stone tools.

Geological surveys and stratigraphic correlations were performed for the 12 localities ([Abdessadok et al., 2016](#); [Chapon Sao et al., 2016b](#); [Gargani et al., 2016](#); [Tudryn et al., 2016](#)), the paleomagnetism was verified ([Chapon Sao et al., 2016a](#)), the determination of the taxa ([Moigne et al., 2016](#)), and the lithic industry collected on the outcrops near the fossils were described in detail ([Gaillard et al., 2016](#)). The synthetic log of the sequence was reconstituted with an indication of each paleonto-archeological locality ([Chapon Sao et al., 2016b](#)) ([Fig. 2](#)). The context and the erosion are very specific, linked to the Tibetan plateau uplift and to the monsoon. The main direction of the layers is vertical: the gravity activates the erosion and unearths the fossils and the quartzite cobbles when monsoon, waterfalls and torrents dragged the sediments. The richest sector is visible in the small watershed of a seasonal torrent called Pichhli Choe ([Fig. 2](#)). Fossils were sometimes collected in situ from the silts but most were on the recent slopes covering the outcrops, or directly on the outcrops. The Pichhli Choe is the main factor in the incision of the dome, and therefore it is to commonplace to collect fossils and sometimes pieces



**Fig. 2.** The paleo-archaeological localities in their geomorphological context: the dome of the anticline (M1, M2, M3), the watershed of Pichhli Choe (M4, M5, M6), the Patiali Rao, the village of Masol and the silty plateau with M7 to M13, \* and \*\*, the bottom and the top of the stratigraphic log; C: stratigraphic log (Chapon Sao et al., 2016b; Tudryn et al., 2016). The general log indicates the lithostratigraphic position of each paleo-archaeological locality of Masol (M1 to M13). The sequence of Masol Formation is an alternation of silt and sandstone identified on the field as unit c (silt) and unit s (sandstone). Each unit is defined by a number. The fossil bones have been recorded from the base of the Quranwala zone (silt c3) to the silts c7, whereas the log begins with the bed of the Pichhli Choe at the confluence with the Patiali Rao with the unit c1 devoid of fossil. Above the unit c7, the layers are devoid of fossils until s13, then they appear again but more rarely towards the Gauss/Matuyama magnetic reversal situated between c13 and s17.

**Fig. 2.** Les localités paléonto-archéologiques dans leur contexte géomorphologique : le dôme de l'anticlinal (M1, M2, M3), le versant du Pichhli Choe (M4, M5, M6), le Patiali Rao, le village de Masol et le plateau où se concentrent les localités de M7 à M13, \* et \*\* la base et le sommet du log stratigraphique synthétique ; C : log stratigraphique synthétique (Chapon Sao et al., 2016b ; Tudryn et al., 2016). Le log général indique la position lithostratigraphique de chaque localité paléonto-archéologique de Masol (M1 à M13). La séquence de la formation Masol est une alternance de limon et de grès identifiés sur le terrain comme unité c (limon) et unité s (grès). Chaque unité est définie par un numéro. Les os fossilisés ont été collectés depuis la base de la zone Quranwala, du limon c3 au limon c7, alors que le log commence au lit du Pichhli Choe à la confluence avec le Patiali Rao avec l'unité c1 dépourvue de fossiles. Au-dessus de l'unité c7, les couches sont de nouveau dépourvues de fossiles jusqu'à s13, puis ils réapparaissent mais plus rarement en s'approchant de l'inversion magnétique Gauss/Matuyama située entre s13 et s17.

from the lithic industry in its small terraces. If fossils bear cut marks, they will be collected statistically in the areas of greater accumulation, at the foot of the outcrops or at the bottom of the slopes, as well as in the terraces of the Pichhli Choe.

Associating the stone tools with the fossils is not easy, due to the circumstances of their collection on the surface, nevertheless, it is worth paying attention to some artifacts which were alongside one bone and totally isolated (Masol 3), or in the immediate perimeter of a fossil-bearing cut marks (Masol 1, Masol 13) (see more in Chapon Sao et al., 2016b). As we will see, these cut marks cannot be confused with animal teeth present in the faunal assemblage (crocodilians, *Crocota*, *Panthera*) or visible only on bones (the rodent *Rhyzomis*). The sediments of the Quranwala zone which provided the cut marks are more than 100 meters below the Gauss/Matuyama paleomagnetic reversal (2.58 Ma). These layers are only 70–100 ka older than the lithic industries and faunal assemblage of Longgupo in South West China (Han et al., 2015), located exactly at the same latitude (N 30° 50'), 3100 km towards the East. The discovery of intentional cut marks in the sub-Himalayan floodplains during the late Pliocene is thus credible. Their

study nonetheless needed exhaustive investigation using multiple methods. Their size, profiles and trajectories had to be measured on an infra-millimeter scale and their characteristics compared to the experimental cut marks made by the quartzite cobbles of Masol. We present all the experiments carried out in India and in France. Comparison was then possible with the experiments demonstrating their lithic and intentional origin. The conclusion allows granting of the interest to the tools collected in the same erosional context than the fossils (Gaillard et al., 2016). All justify the fieldwork efforts in seeking hominin fossils and tools within stratigraphy (Dambricourt Malassé, 2016; Dambricourt Malassé et al., 2016).

### 3. Materials and method

Four methods were used:

- taphonomy;
- experiment;
- description of the fossilized marks;
- comparison with experimental marks for each bovid bone.

For this reason we present the experiment before describing the fossilized cut marks.

### 3.1. The results of taphonomy

Fossils were collected in sandstone concretions and extracted without damage to the cortical bone, or preserved in sandy crusts, which did not allow extraction without fracturing them, others were protruding from silts or sandstones with good preservation of the bones (including a large carapace of *Colossochelys*). A total of 1469 fossils have been studied with attention to the different types of traces, chemical and also physical, due to the tectonics. Cracking is frequent, alterations of chemical origin are visible on the dermal plates of turtles and trampling marks are sometimes observed. Green fractures are also relatively frequent and animal marks have been identified, taking into account species on the fauna list such as *Crocodylus*, *Gavialis* and rare carnivores (5 fossils with 4 *Hyena* and 1 *Panthera*) (Moigne et al., 2016). Sahni and Khan (1968) have noted the exceptional occurrence of carnivores (4 molars) and the absence of large felids, seeking an explanation for the absence of terrestrial predators. Among the different sorts of marks, a few could not be confused with animal or physicochemical alterations. In contrast, these incisions looked like microgrooves made by the sharp edge of a stone, probably quartzite cobbles, as this lithic material is frequent on the outcrops and sometimes visible in the stratigraphy of the Masol Formation.

### 3.2. The specimens and the method

The material consists of three bovid fossils from three different localities of the Quranwala zone. They belong to the transitional faunal assemblage from Tatrot (late Pliocene, see more in Moigne et al., 2016). The lithostratigraphic context has been described in detail (Chapon Sao et al., 2016b), we summarize it for each fossil:

- Masol 1, R10084, a distal tibia shaft;
- Masol choe R10286, a distal metacarpal (*Leptobos* size);
- Masol 13 R10298, a large splinter.

The description and measurements of the marks were made in 2014 in Paris, France:

- at the Center for Research and Restoration of Museums of France in the Louvre Palace (C2RMF) using the 3D Digital Video Microscope Hirox, and a binocular microscope;
- by microtomography at the X-Ray Tomography Scientific Access Platform (AST-RX) of the National Museum of Natural History.

The comparison with animal marks was made in Paris using the 'Henri Martin collection' (Hyaenidae, Canidae, Ursidae) stored at the Department of Comparative Anatomy and Archeozoology of the Institute of Human Paleontology, Paris, (Dambricourt Malassé). This study benefits from many years of experience in taphonomy devoted to tens of thousands of fossils (Moigne), from la Caune de l'Arago, Terra-Amata, Orgnac 3 and Cagny

l'Épinette in France (Moigne and Barsky, 1999; Moigne et al., 2005; Rivals et al., 2002, 2006; Sam and Moigne, 2011), from Zafarraya in Spain (Barroso Ruiz et al., 2003, 2014), the Sangiran dome and Song Terus in South East Asia (Bouteaux and Moigne, 2010; Bouteaux et al., 2007, 2009; Moigne et al., 2004), from Yunxian in China on Mainland Asia (Echassoux et al., 2008) and from South Korea (Moigne et al., 2011).

### 3.3. Experiment

We conducted two experiments, one in India (Moigne and Gaillard), the second in France (Dambricourt Malassé). In India, bovines provide milk but not meat. It was not possible to use their carcasses, which are fairly common around the village of Masol, however, the disarticulated skeleton of a large wild cervid was found on a prospected locality along a ravine gullied by a seasonal waterfall. The bones had no remaining fascia (or periosteum): they were intact, buried in mud, and no traces of carnivore activity were observed.

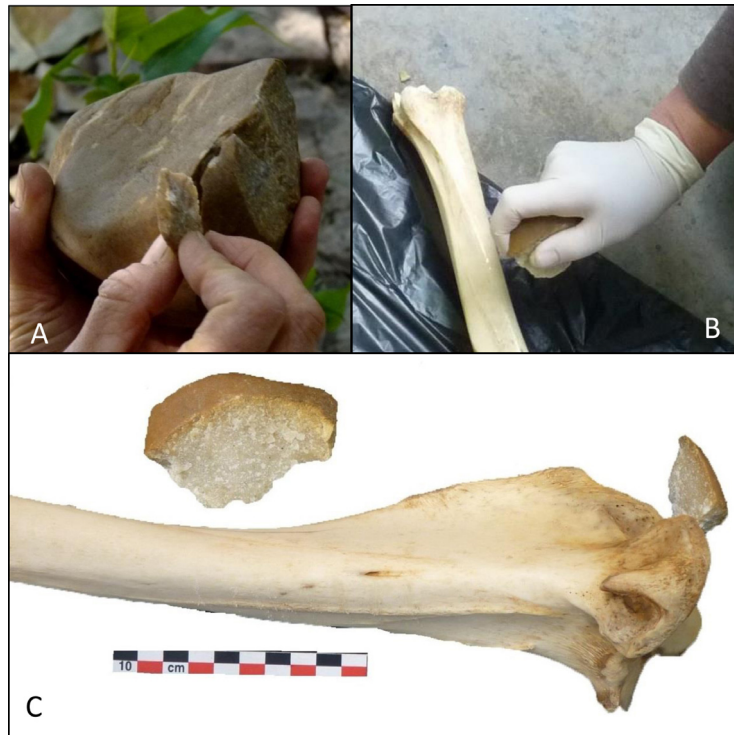
This was an interesting material for comparison with the fossils collected in the sector. We followed the experimental protocol using quartzite cobbles from this area. The quartzite flakes were obtained by percussion on anvil (Gaillard) and the cut marks were made on a rib and a tibia (Moigne), specifically on the crests of insertion and cortical surfaces (Fig. 3). They were photographed one year later, after being stored in the collection.

In France, it is possible to conduct this type of experimental protocol on an animal sold for butchery, making it possible to take into account the leather, muscles and tendons. An experiment was conducted on the foot of a *Sus scrofa domesticus* with a quartzite cobble collected near the fossils. In all cases, the fracturing necessitated very powerful energy because of the level of hardness of the cobbles. The use of an anvil and hammer was necessary and the fracturing efficient only after several particularly violent impacts. One of the cobbles was split at one extremity (India), the second along its greatest axis (France), the two types of chopper are present at Masol (Gaillard et al., 2016). Then, the production of flakes was easy.

The traces on the cervid's dry bones were made with flakes; they show several types of incision, microgrooves and scrapings (Fig. 4). The flake made:

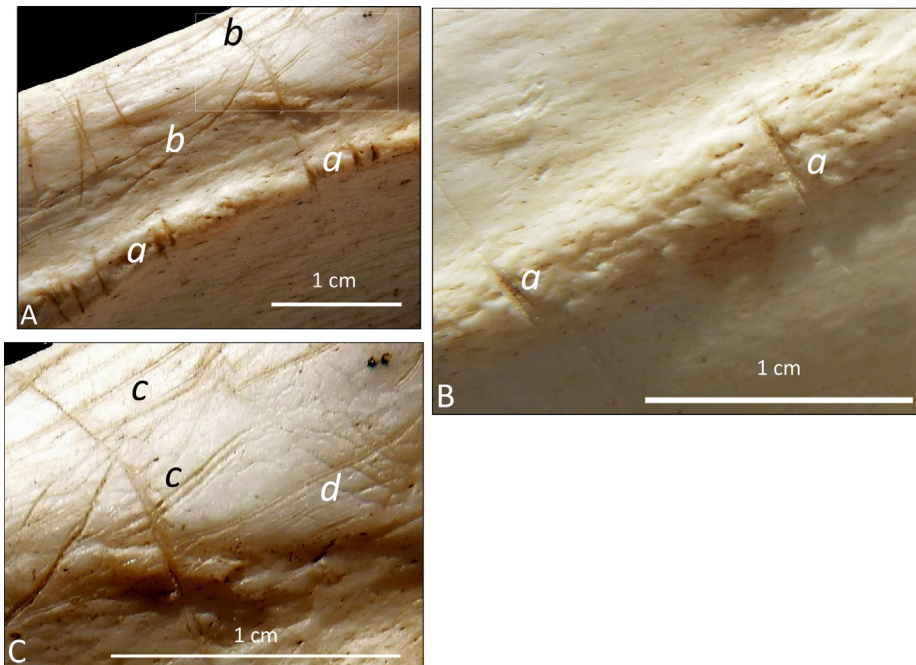
- type *a* on the crest of insertion: a deep trace where the pressure was the highest with two microgrooves at the start of the cut (Fig. 4A and B);
- type *b* on the cortical surface: two parallel microgrooves (traces *c*) when the edge of the flake is in the direction of the movement (Fig. 4A and C), and several parallel microgrooves (traces *d*) when the cutting edge is perpendicular to the direction of the movement (Fig. 4C).

The results on the fresh bone of *Sus scrofa domesticus* are particularly interesting. The thick and resistant leather was cut with the longest natural edge of the chopper. After the resistance of the leather, cutting was fast and easy; after cleaning the bone, parallel incisions appeared in the periosteum and on the bone (Fig. 5). The traces



**Fig. 3.** A. Manufacture of flakes in quartzite. B. Experimental incisions on a tibia of wild deer with one of these flakes. C. Materials for experimentation in India.

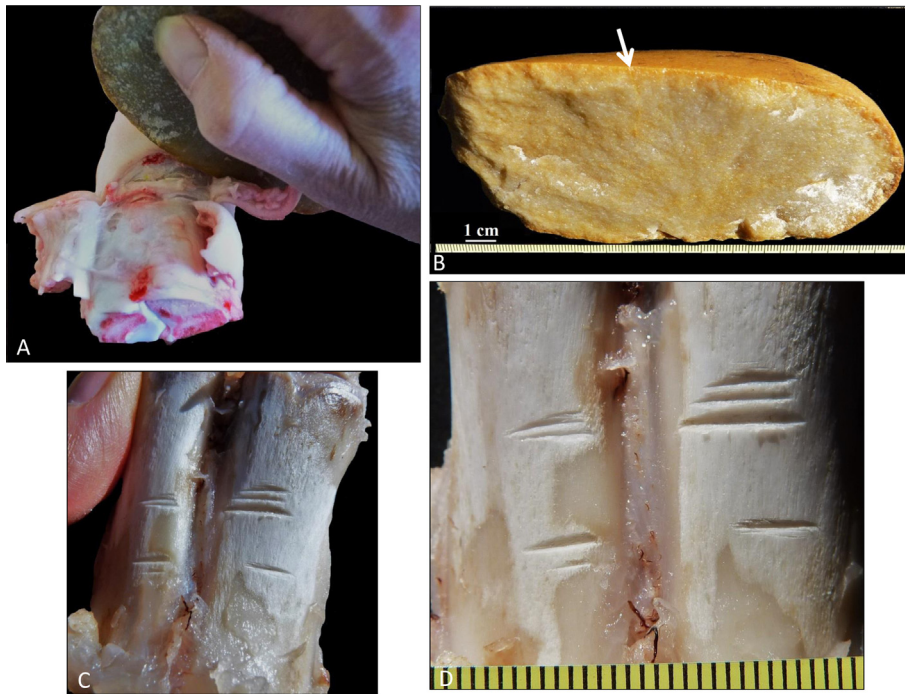
**Fig. 3.** A. Fabrication d'éclats en quartzite. B. Incisions d'un tibia de cervidé sauvage avec un de ces éclats. C. Les matériaux de l'expérimentation en Inde. Photo A. Dambricourt Malassé.



**Fig. 4.** A. Different types of traces made by a sharp edge in quartzite, *a* on a crest of insertion, *b* on the cortical surface. B. Two traces from type *a*. C. Magnification of the inset from picture A showing on the cortical surface two parallel microgrooves *c* and multi-parallel microgrooves *d*.

**Fig. 4.** A. Différents types de traces de tranchant en quartzite, « *a* » sur une crête d'insertion, « *b* » sur la surface corticale. B. Grossissement de traces de type « *a* ». C. Grossissement de l'encart de la photo A montrant sur la surface corticale deux sillons parallèles *c* et une série de microsillons parallèles.

Photo A. Dambricourt Malassé.



**Fig. 5.** A. Cut marks made on the metapodes of *Sus scrofa domestica* by the sharp edge of a cobble in quartzite (arrow). B. The cutting edge of the cobble. C and D. Cut marks after cleaning, scale: space between two lines = 1 mm.

**Fig. 5.** A. Découpe des métapodes de *Sus scrofa domestica* avec le tranchant d'un quartzite. B. Le tranchant du quartzite (flèche). C et D. Les traces de découpe après nettoyage, échelle : espace entre deux traits = 1 mm.

Photo A. Dambricourt Malassé.

were photographed and then compared with the different images of the fossilized marks.

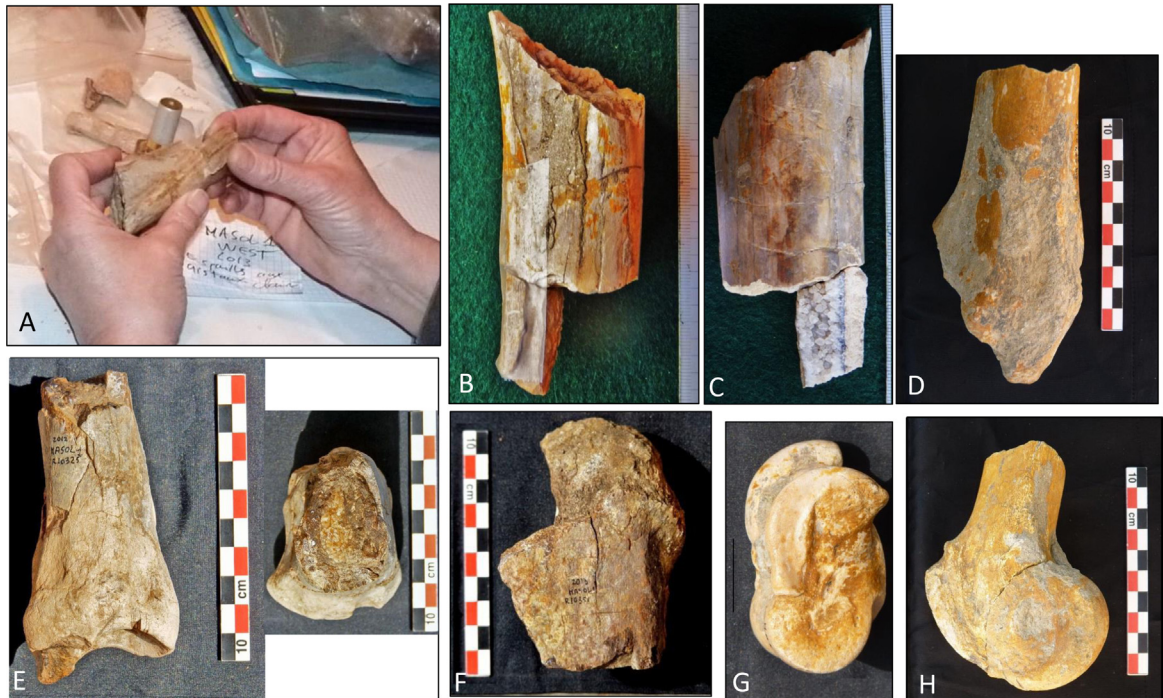
### 3.4. Analysis of the traces

#### 3.4.1. Masol 1 R10084, bovid tibia shaft recovered in March 2009

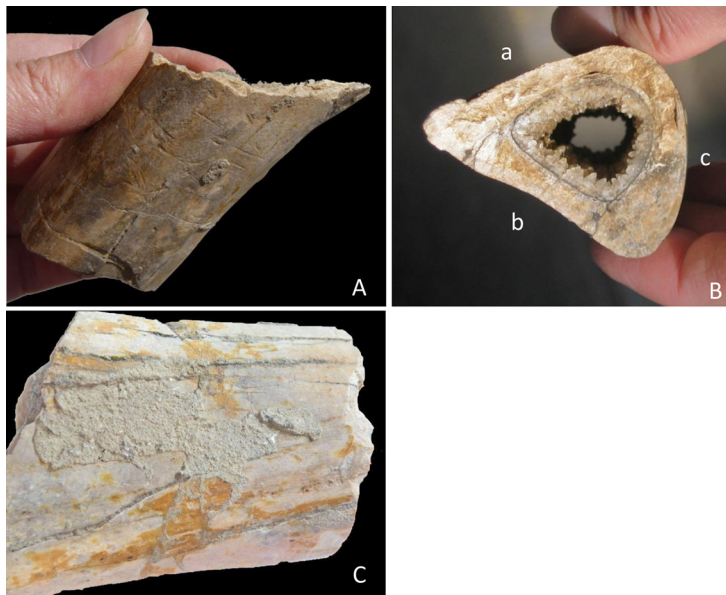
**3.4.1.1. Location and lithostratigraphic context.** Masol 1 is located at the top of the anticline and on its western flank, which borders the Pichhli Choe (Fig. 1C, D and 2). The locality, which is 150 meters long, is divided into sub-localities around the eponymous site at the summit of the dome: Masol 1 South, Masol 1 North, Masol 1 West and Masol 1 East. Masol 1 West is on the western slope. Lithostratigraphic analyses have shown that silts and sandstones belong to the oldest layers of the Quranwala zone (Abdessadok et al., 2016; Chapon Sao et al., 2016b; Gargani et al., 2016; Tudryn et al., 2016). The tibia shaft R10084 was collected in 2009 at Masol 1 during a survey planned to verify the stratigraphic origin of the first chopper recovered in 2008 (Dambricourt Malassé et al., 2016). The diaphysis was mixed with silts and sandstones dismantled by the current erosion of a small cliff, these sediments corresponded to silts c3, c4 and sandstones s3, s4 of the general log (Fig. 2). This sub-locality is visible 30 meters beyond the redeposited silts and sandstones containing the first chopper (Fig. 1C and D). The local origin of the shaft was reinforced, four years later (2013), by the collection of a splinter whose mineralized edges connected with the shaft

(Fig. 6A, B, C). Its mineralization, the yellow color of the cortical bone, the thin crusts of micaceous sand and its natural fracturing match other fossils collected at Masol 1, either in the c3 yellow silts, on the slopes of their dismantling mixed with that of the s3 micaceous sandstone which cover them in the stratigraphy (Figs. 2 and 6). The medullar cavity of the shaft is lined with calcite crystals (Figs. 6D and 7B) like other fossils from Masol 1 (Moigne et al., 2016). Ultimately, the bovid bone originates from the limit between the upper part of the c3 yellow silts and the base of the s3 silty micaceous sandstone (Chapon Sao et al., 2016b).

**3.4.1.2. Description.** The specimen is a bovid tibia shaft, measuring between 7 and 8 centimeters long; the cortical bone is very well preserved. The shaft corresponds to the lower third of the tibia as can be seen from the lessening of the crest for the muscular insertions (Fig. 8). The size is similar to that of *Leptobos*. The incisions are distributed on the caudal and cranial faces and are of different types; none appear on the lateral side (Fig. 7C). Two sets of traces, A and B, are the most obvious. In 2011, group A was studied in India using the ProScope Mobile and its print analyzed with the SEM of the European Centre for Prehistoric Research at Tautavel (CERP) (Moigne). Two very fine microgrooves visible at the beginning of one trace looked similar to cut marks already identified in the international collections cited above. Since the stone tool's origin seemed authentic, three years later the Archaeological Survey of India authorized the "Society for Archaeological and



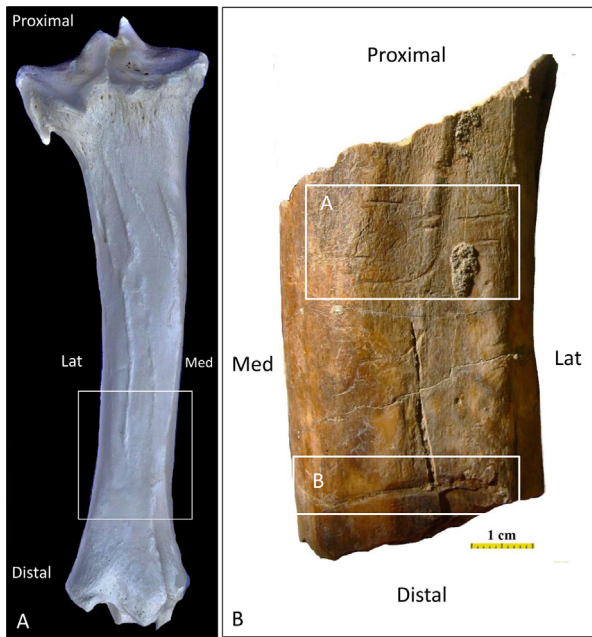
**Fig. 6.** A. Reassembly of the splinter on the tibia shaft Masol 1 R10084 (photo A.-M. Moigne). B and C. The shaft and the flake. D to G. Samples of the faunal assemblage from Masol 1 including the tibia shaft. E. View of a crystallized medullar cavity at Masol 1 (photos A. Dambricourt Malassé).  
**Fig. 6.** A. Remontage de l'esquille sur le fût tibial Masol 1 R10084 (photo A.-M. Moigne). B et C. Le fût et l'esquille. D à G. Des fossiles de Masol 1 associés au fût tibial (B et D). E. Cristallisation d'une cavité médullaire à Masol 1 (photos A. Dambricourt Malassé).



**Fig. 7.** The tibia shaft Masol 1 R10084. A. Caudal or plantar view. B. The medullar cavity with its crystallization, a: caudal face, b: lateral face, c: cranial face. C. The lateral face.  
**Fig. 7.** Le fût tibial Masol 1 R10084. A. Vue caudale ou plantaire. B. Vue sur la cavité médullaire avec sa cristallisation, a : face caudale, b : face latérale, c : face crâniale. C. Vue de la face latérale.

Pictures A and B, A. Dambricourt Malassé; picture C, A.-M. Moigne.

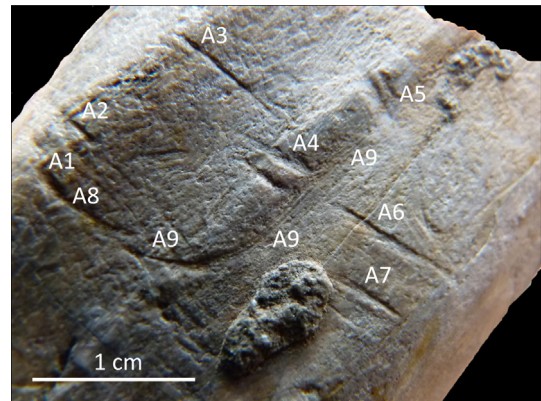




**Fig. 8.** A. Localization of the shaft R10084 on a bovid tibia (rectangle) (source: osteology site from the National Veterinary school of Alfort). B. Location of the two sets of marks analyzed on the caudal (plantar) face of the shaft R10084 (rectangles A and B) (B photo A. Dambricourt Malassé). **Fig. 8.** A. Localisation du fût R10084 sur un tibia de bovidé (rectangle) (source : ostéologie, site en ligne de l'École nationale vétérinaire d'Alfort). B. Localisation des deux ensembles de traces analysées sur la face caudale (plantaire) du fût R10084 (rectangles A et B) (B photo A. Dambricourt Malassé).

Anthropological Research” to analyze the original bones in France. In 2014 the original marks A and B were filmed by Thomas Calligaro with the 3D Digital Video Microscope Hirox at the Center for Research and Restoration of the Museums of France (C2RMF), Le Louvre Palace, in order to measure the microgrooves at the sub-millimeter scale and to analyze their mineralization. They were also viewed and photographed with a binocular microscope. All the data converged to the same conclusion and confirmed the hypothesis formulated in 2009, whereby these mineralized incisions correspond to an intentional butchery activity carried out by a sharp edge on quartzite.

**3.4.1.3. Demonstration.** Set A is at the proximal part of the shaft and on its caudal face as well as the curved edge which rises to the medial face (Fig. 9). This area surrounds the crest for the ligament insertions which developed along the great axis of the bone. On the curved edge there are three parallel deep cuts, two close together (A1 and A2). The third (A3) is isolated, and continues for 6 mm on the caudal face towards the crest of insertion, shallower and thinner. There are then four notches on this crest, two parallel sets of two, short and wide (A4: 4 mm and 6 mm long; A5: both 2 mm long). The sets of A4 and A5 are separated by 6 mm. In continuation of A4, under the crest and after a gap of 2 mm, a finer and longer incision is seen, following the same parallel (A6,  $l=8$  mm). On its left there is a finer and shorter incision near a sandy crust, still on the same parallel (A7,



**Fig. 9.** Tibia shaft Masol 1 R10084, legend of the traces from the group A, caudal face.

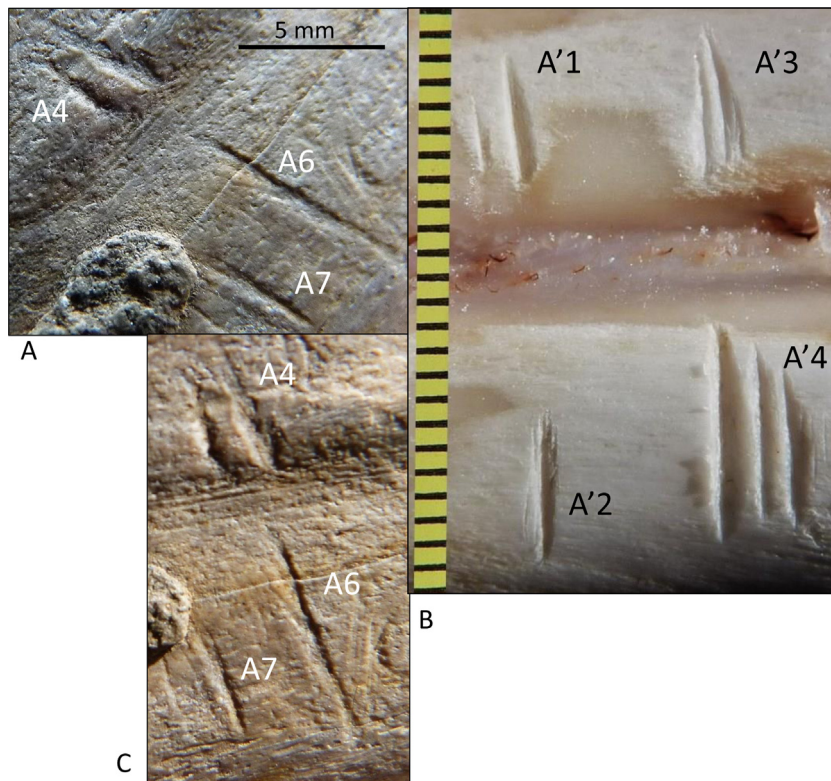
**Fig. 9.** Fût tibial Masol 1 R10084, légende des traces du groupe A, face caudale.

Photo A. Dambricourt Malassé.

$l=4$  mm). Finally, 6 incisions run parallel on a small surface 2.5 cm long and 1.3 cm wide. The comparison with the experimental cut marks made with the quartzite cobble on the *Sus scrofa domesticus* shows a remarkable similarity: A3 with A'3, A4 with A'1, especially the extremity with the secondary microgrooves that form barbs: A6 with A'4 and A7 with A'2 (Fig. 10). The notches A1, A2 and A5 (Fig. 9) are similar to the experimental traces a (Fig. 4A and B).

There are two long traces, which follow each other, A8 and A9. The first, A8, is 8 mm long, and starts on the curved edge of the bone at A1, before continuing towards the caudal face, making a curve towards the crest of insertion, but it becomes thinner and is interrupted (Figs. 9 and 11A). In A3, the pressure was highest on the curved edge and decreased towards the crest of insertion, but following a curve as if to join it. If the movement had extended, the trajectory would pass above the crest. The second trace, A9, accomplishes this movement, passing below the crest and the two A4 notches. It starts 1 mm above the interruption of A8, barely sliding on the side towards the distal extremity of the shaft. The trajectory is 3 mm above the crest of insertion and is more curved in its direction, the trajectory cuts it, before finishing straight against its lower edge for more than 1 cm (Fig. 9). In detail, the trace begins with a thin notch, then it marks a depression and a broadening on the crest where it curves to continue its trajectory below this line in two parallel, perfectly straight microgrooves; the longest measures 120 mm. The pressure becomes maximal at the curvature of the trajectory, and then it decreases. In summary, marks A8 and A9 both appear to belong to the same movement beginning on the curved edge of the bone with A1, curving in the direction of the crest of insertion, interrupted, and then slightly changed relative to the curve in order to follow the long axis of the bone, but under the crest after cutting the insertions of the muscular fascia. It is maintained without change, true and straight below the crest where the fascia continues to cover the cortical bone.

The 3D Digital Video Microscopy shows two microgrooves under the crest rather than a series of parallel striations as would suggest the trabecular bone



**Fig. 10.** Comparison of fossilized and experimental. A and C. The tibia shaft Masol 1 R10084 with the A4, A6 and A7. B. Experimental cut marks on *Sus scrofa domesticus* A'1, A'2, A'3 and A'4.

**Fig. 10.** Comparaison de marques fossilisées et expérimentales. A et C. Le fût tibial Masol 1 R10084 avec A4, A6 et A7 de Masol 1. Traces expérimentales sur les métapodes de *Sus scrofa domesticus* A'1, A'2, A'3 et A'4.

Photo A. Dambricourt Malassé.

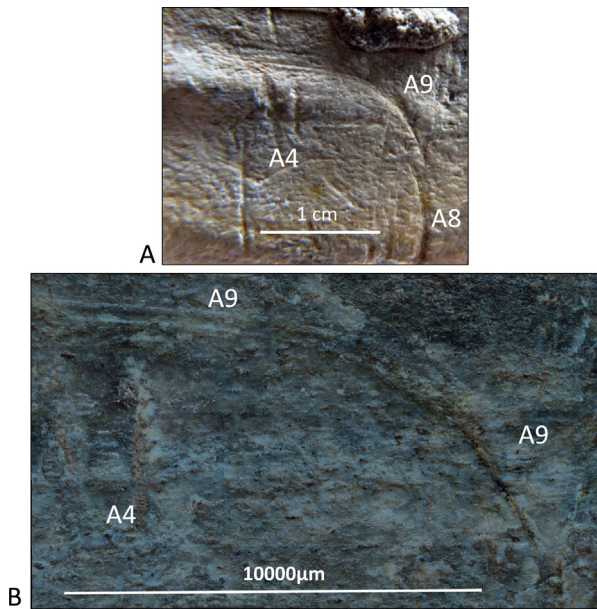
(Figs. 11B and 12). The width of one groove is of the order of 300  $\mu\text{m}$ . These two microgrooves match the profile of an incision made by the cutting edge of a flake in quartzite, as shown by the experimental traces c (Fig. 4C). 3D microscopy allows the mineralization of all the traces to be seen, similar to the bone tissue (Figs. 11B and 12) that emphatically cannot be any type of recent trace made by shepherds (e.g. whetstone, cutting support).

Their microtopography and spatial organization have nothing in common with the patterns created by a crocodile jaw, teeth alignment, multiple grooves with discontinuous trajectory, or continuous but undulating (Baquedano et al., 2012). All these traces show a spatial distribution according to the insertions for the ligaments of the metatarsal muscles. Such precision located and ordered around the crest and the curved edge of the bone, coincides with a precise detachment of fascia, and therefore a movement necessarily coordinated with the eyes, which would have been impossible with the jaw of a carnivore. Variations in depth correspond to variations in the pressure of a quartzite cutting edge, depending on the strength of the fascia with the periosteum. They match precise gestures coordinated visually and made with intention. In summary, all the A traces, because of the details of their profiles, correspond to a cut using a sharp edge of quartzite, and their trajectories and locations reflect a thoughtful focus on an anatomical part where the ligament attachments of the foot are the most

developed. This corpus of observations strongly suggests intentional gestures typical of butchery activity.

The second set of marks, B, was the subject of an investigation using the 3D Digital Video Microscope Hirox (Fig. 13A). They comprise two traces beginning on the cranial surface towards the caudal face starting from the same notch (Fig. 13A). The first, B1, is short (13 mm), thick at the start but the trajectory continues more finely before stopping on the cranial side of the tibia; this trace is altered, and the microgrooves are not easily distinguishable (Fig. 14).

In contrast, the second trace, B2, is very long; it covers all the caudal and medial surfaces by following the contour of the tibia (Fig. 15). It starts on the first notch, forming two parallel microgrooves which stop 10 mm away; the trace starts again but higher with a change in direction becoming parallel to B1. The 3 D Digital Video Microscope Hirox shows a V-shaped profile (Fig. 15C). The path continues for 6 cm, following the curvature of the bone (Fig. 16A), before it is altered by a sort of gutter that extends to the outbreak of the cortical bone in the distal limit of the shaft. The two microgrooves were identified with the 3D microscope Hirox (Fig. 16B and C), special attention was paid to verify their mineralization identical to the bone (Fig. 16D). The two grooves suffered the same diagenesis as all of the bony tissue. This profile does not correspond to marks made by a crocodile tooth, as multiple grooves do not appear.



**Fig. 11.** 3D Digital Video Microscope Hirox showing (A) the fossilization of the marks from the tibia shaft Masol 1 R10084: A4, A8 and A9 (photo A. Dambricourt Malassé), (B) A9 with two parallel microgrooves above A4 (photo T. Calligaro, C2RMF).

**Fig. 11.** Vidéo digitale microscopique 3D Hirox montrant (A) la fossilisation des marques du fût tibial Masol 1 R10084 : A4, A8 et A9 (photo A. Dambricourt Malassé), (B) A9 avec deux microsillons parallèles au-dessus d'A4 (photo T. Calligaro, C2RMF).

The two traces, B1 and B2, do not match the marks left by carnivores such as those known at Masol (Hyaenidae, Felidae), which are usually more numerous and of different types and trajectories. On the other hand, there are the characteristics of the A1–A9 set (a notch at the beginning of the movement, two typical parallel incisions), typical of a quartzite cutting edge, an interruption, a recovery very slightly above and to the side of the previous trajectory, and a readjustment of the direction in a single trait. The trace is always formed by two microgrooves. This type of trajectory interrupted with an angular resumption of the movement is visible on a photography by Giacobini (Fig. 9a in [Vercoutère et al., 2014](#), p. 268). This reveals the gesture of a skilled wrist. Traces B1 and B2 can be interpreted as a first gesture quickly interrupted (B1), which takes up its work again at the same point of the aponeurosis attachment (B2), but shifting it in order to avoid an area which would resist a first gesture. As is Set A, Set B is compatible with gesture of an agile, fast and powerful wrist detaching the fascia using a quartzite cutting edge.

The other sets are uncertain; on the caudal face, two deep striations are oblique to the great axis of the shaft and intersect a sinusoidal mark (Fig. 17A and B); fine and superficial striations occur, scattered on the cortical bone (Fig. 17C); a deep crescent-shaped cut in the medial edge is filled with sandstone and shows a thin primer at both ends which widens with distance between the two edges of the bone. This trace resembles the mark of a thick cutting edge (Fig. 17D).

**3.4.1.4. Discussion.** The Masol 1 locality comprises the highest percentage of fossils (nearly 400 specimens for a total of 1500) that matches its large extent on the dome (150 meters). Fossils from Masol 1 have been collected in four main sub-localities, and correspond to fauna assemblages that deserve special attention because of the choppers and flakes collected only in the fossil-bearing areas along this erosion forehead. This distribution of stone tools therefore presents a consistency that takes sense according to the cut marks of quartzite and two choppers collected in the immediate perimeter of the diaphysis.

The erosion of silts and sandstones outcrops, as well as the slopes of their dismantling, is permanent. The fauna associated with the tibia shaft includes the mandible of an antelope collected in 2015 in the c3 yellow silts under the s3 silty sandstones. Its two corpora were close to each other with excellent preservation of the cortical bone, as remarkable as that of the cut marked diaphysis. They show no trace of scavenging. Other fossils from the same sub-locality include, for example, three distal extremities of bovid long bones with their articular surface, a large vertebra, one broken mandible of *Hexaprotodon* and many dermal plates of turtles, including *Colossochelys*.

No bone is in anatomical connection, many are broken along the lines of natural fractures and some have been reassembled in the laboratory. They were recovered near the place of their exhumation in accordance with the speed of the erosion ([Gargani et al., 2016](#)). The fauna list of Masol 1 (Table 1) comprises a majority of herbivores (65 small and 36 large). Among the herbivores, the most frequent are the Bovidae (55 fossils) including *Hemibos* (15), *Sivacpra* (3), *Bubalus* (2) and *Duboisia* (1), then the Hippopotamidae (26) with *Hexaprotodon sivalensis* equally represented with the Elephantidae (25), including 12 *Stegodon insignis*, 16 Cervidae including, 7 *Cervus punjabiensis*, and 1 *Axis* like-cervid, 2 Suidae (*Sus brachygnathus*) and 1 Camelidae. Among other vertebrates, the Masol 1 collection provides the remains of fish and reptiles such as *Varanus*, turtles and a few crocodiles. Only one carnivore was collected (*Hyena*) ([Moigne et al., 2016](#)). These are scarce, with 1 *Panthera* at Masol 6 (hemi-mandible) and 5 *Hyena crocuta*: 1 from Masol 1, 2 from Masol 5, 1 from Masol 9 and 1 from the collections of the SAAR.

Among the reptiles, Masol 1 provided 9 *Varanus* and a large number of dermal plates of turtles, 40 of *Colossochelys* and 27 of *Geoclemys*. Masol 1 and Masol 2, which belongs to the same set of cliffs, provided 17 fossils of crocodylians, mainly plates and rare teeth (16 *Crocodylus punjabensis* and 1 *Gavialis*). Ultimately the two localities count 7 traces of carnivores and none of crocodylians, which are not scavengers. They swallow their small prey alive.

The sedimentary context of the bovid tibia shaft was silty sand deposited on silts. Its lithostratigraphic context attests to a condition of burial in calm water, whereas the taphonomic study reveals that the disarticulated carcasses were naturally accumulated. Since the bovid tibia was not far from its place of deposit in calm water, the tools used for the scavenging activity could therefore be found nearby if they were left in place. The environmental context is favorable for the conservation of the tools which made these traces. Two choppers have been collected in the perimeter

**Table 1**

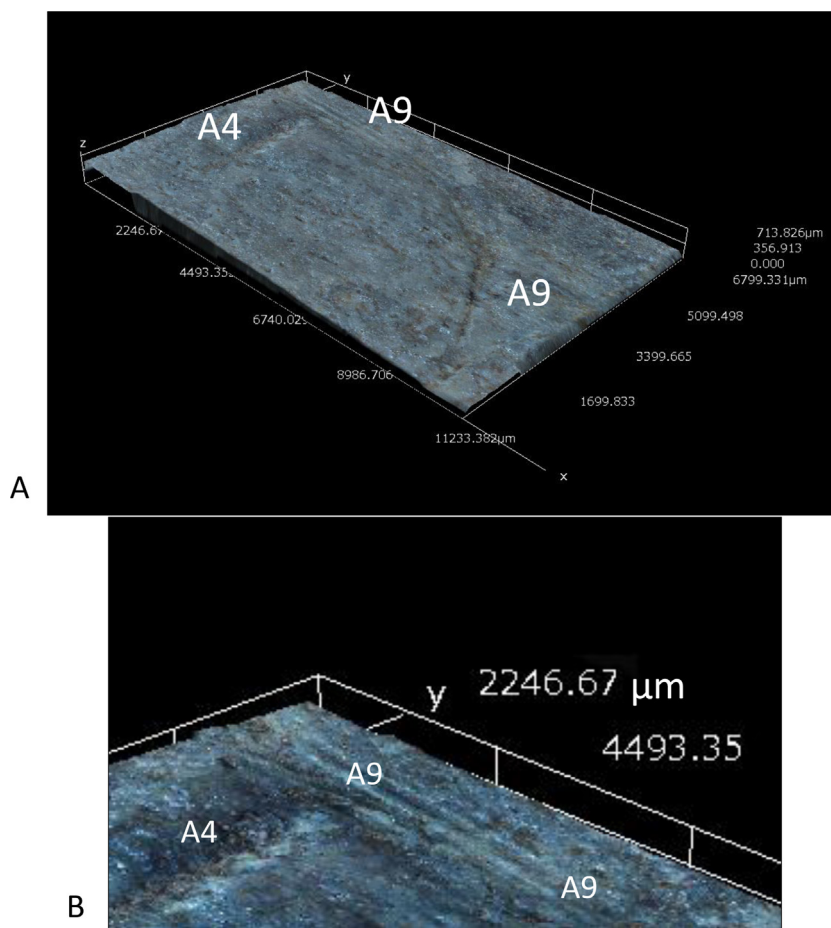
Faunal list of Masol localities. Masol A is the collection of the “Society for Archaeological and Anthropological Research”.

**Tableau 1**

Liste de la faune des différentes localités de Masol. Masol A est la collection de la « Society for Archaeological and Anthropological Research ».

	Masol 1	Masol 2	Masol 3	Masol 5	Masol 6	Masol 7	Masol 8	Masol 9	Masol 10	Masol 11	Masol 12	Masol 13	Masol A	Masol total
CARNIVORA	1			2	1			1					1	6
<i>Crocuta sp.</i>	1			2				1					1	5
<i>Panthera</i>					1									1
ELEPHANTIDAE	25	29	10	10	90	5	35	12		1	1	4	30	252
<i>Elephas planifrons</i>		5	2		1		4						4	16
<i>Stegodon insignis</i>	12	20			22	1	4					1	17	77
ANTHRACOTERIDAE				1										1
<i>Merycopotamus dissimilis</i>				1										1
HIPPOTAMIDAE	26	22	4	7	20		16	2				4	19	120
<i>Hexaprotodon sivalensis</i>	26	22	4	7	20		16	2				4	19	120
BOVIDAE	55	34	13	12	32	3	22	11			1	17	24	224
<i>Bubalus sp.</i>	2		2								1		4	9
<i>Duboisia sp.</i>	1	1	1											3
<i>Hemibos sp.</i>	15	14	3	2	14		12					1	10	8
<i>Hippotragus sp.</i>	6	5		1	4	1						1	3	21
<i>Sivacapra sp.</i>	3	4	1	1	4		3					1	4	21
CAMELIDAE	1												2	3
<i>Camelus sivalensis</i>	1												2	3
GIRAFFIDAE		1	3	2	10		3			1		3	4	27
<i>Sivatherium giganteum</i>		1	3	2	10		3			1		4	4	28
TRAGULIDAE				1									1	2
<i>Dorcatherium nagrii</i>				1									1	2
CERVIDAE	16	6	8	5	12	1	2	3				1	10	65
<i>Axis like-cervid</i>	1	1	1					1					1	6
<i>Cervus punjabiensis</i>	7	5	4	1	5	1	1					1	8	33
SUIDAE	2			2	3		1						2	10
<i>Propotamocheorus sp.</i>					1									1
<i>Sus brachygnatus</i>	1			2	2		1						2	8
EQUIDAE		1	3		2			1					3	10
<i>Equus sivalensis</i>		1			1								1	3
<i>Hipparion antilopinum</i>		1	2										2	5
REPTILIA	150	21	12	19	76		15	11	1			3	7	315
<i>Colossochelys</i>	40	10	1	4	21		5	1						82
<i>Geoclemys</i>	27	3	9		5		2	9					2	57
Turtles	60	4	2	8	46		8	1				3	4	136
<i>Varanus</i>	9													9
<i>Lacertilia</i>		1												1
<i>Gavialis</i>	1				1									2
<i>Crocodylus punjabiensis</i>	13	3		7	3				1				1	28
Mollusca							1							1
Pesces	1			1										2
PH	65	10	17	8	35	2	20	1				2	2	162
GH	36	14	23	14	53		24	1			1	3	1	170
TGH	4	15	3	5	16		21	5					2	71
IND					8									8
TOTAL	387	153	98	88	360	12	162	44	6	2	3	40	106	1467

PH: small herbivores; GH: large herbivores; TGH: very large herbivores; IND: undetermined.



**Fig. 12.** 3D Digital Video Microscopique Hirox of A9 with two parallel microgrooves above A4.  
**Fig. 12.** Vidéo digitale microscopique 3D Hirox d'A9 avec deux microsillons parallèles au-dessus d'A4.  
 Photo T. Calligaro, C2RMF.

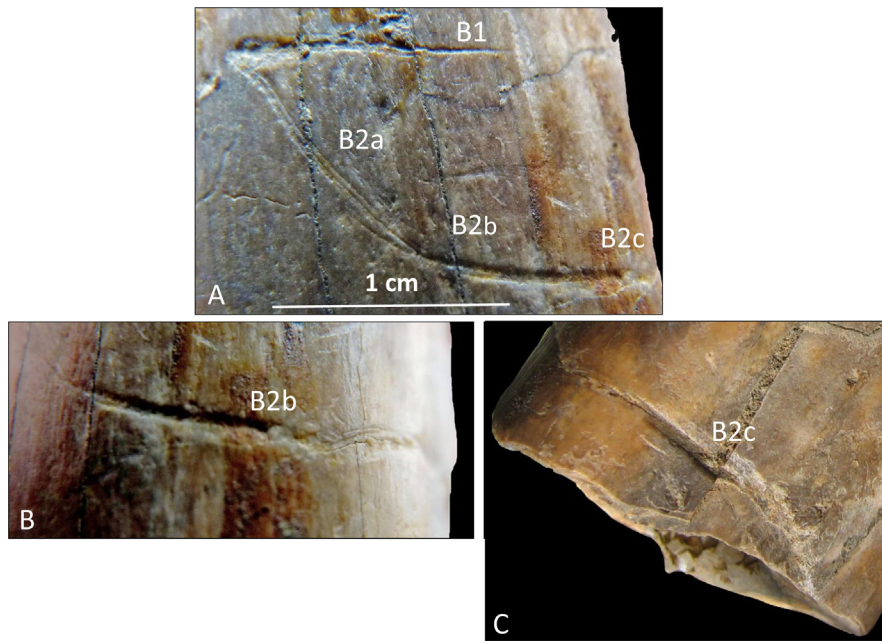
of the bone (Chapon Sao et al., 2016b). If we cannot conclude that these lithic tools were contemporary with the disarticulated carcasses, quartzite tools are evidenced by the traces on the tibia.

These observations constitute a corpus of converging data allowing the identification of fluvial environments rich in freshwater vertebrates, including *Hexaprotodon*, turtle *Geoclemys*, *Crocodylus* and *Gavialis*, but also a flood-plain with great terrestrial biodiversity composed of small, medium and large herbivores, and rare carnivores. Added to this biodiversity is a species whose traces of activities, visible on a bovid bone, reveal a very specific anatomy. This was characterized by fingers and an agile wrist whose movements of great precision were guided by eyes and by intention, with a good anatomical knowledge of the bovid carcass. At 2.6 Ma such a psychomotricity matches a central and peripheral nervous system known only in East Africa in Hominins, with axial skeletons in a permanent erect posture, *Australopithecus* and *Homo* whose emergence is estimated as at least 3 Ma ago (Coppens, 1975, 2013; Dambricourt Malassé, 2011). The tibia shaft of Masol

1 is not an exception, at least two other bones testify to the presence of a Hominin among this sub-Himalayan biodiversity. One trace on a Proboscidean diaphysis from Masol 8 remains uncertain (see Fig. 14D in Moigne et al., 2016).

### 3.4.2. Masol Choe, metacarpal R10286

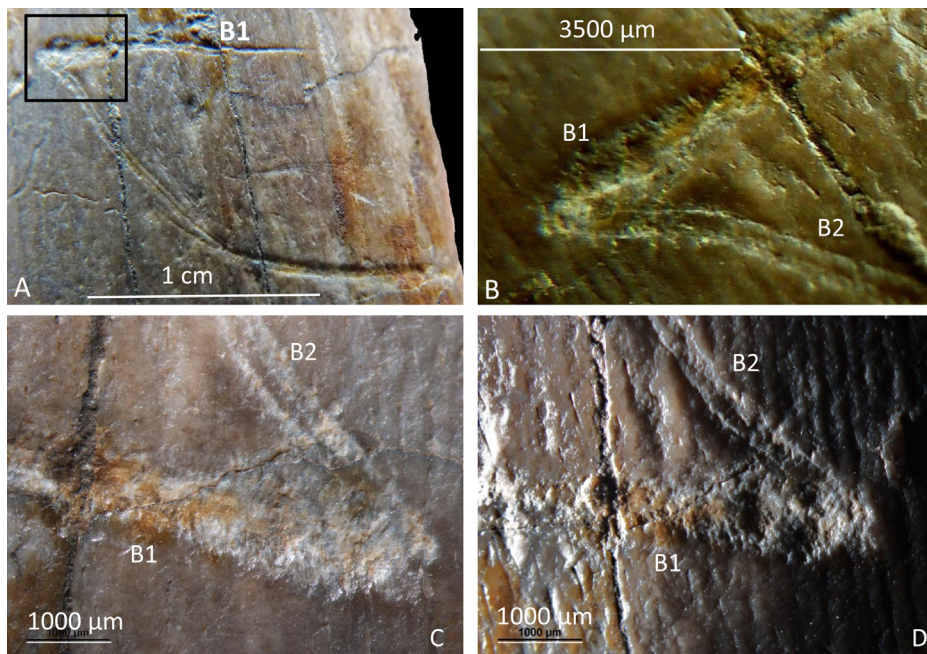
**3.4.2.1. Location and lithostratigraphic context.** The fossil is a distal metacarpal of a bovid stored since 2011 in the collections of the SAAR. It was collected on the small terrace T2 of the Pichhli Choe, 300 meters southwest of Masol 1 at a lower altitude, in a narrow passage of this seasonal torrent dug in the basal sequence of the fossiliferous Quranwala zone (c3, s3, c4, s4 of the general log), the same as Masol 1 due to the anticlinal structure (Fig. 18). The bone tissue is brown in color and highly mineralized like the numerous fossils of the Masol Formation (Moigne et al., 2016; Sahni and Khan, 1964, 1968). Its cortical surface is altered but the broken edges are not dulled and no trampling marks are visible; the bone has not been rolled. The metacarpal belongs to the bovid list of the Masol Formation and was



**Fig. 13.** A. Set B of the marks on the tibia shaft R10084 (B1, B2). B and C. Details of the trace B2.

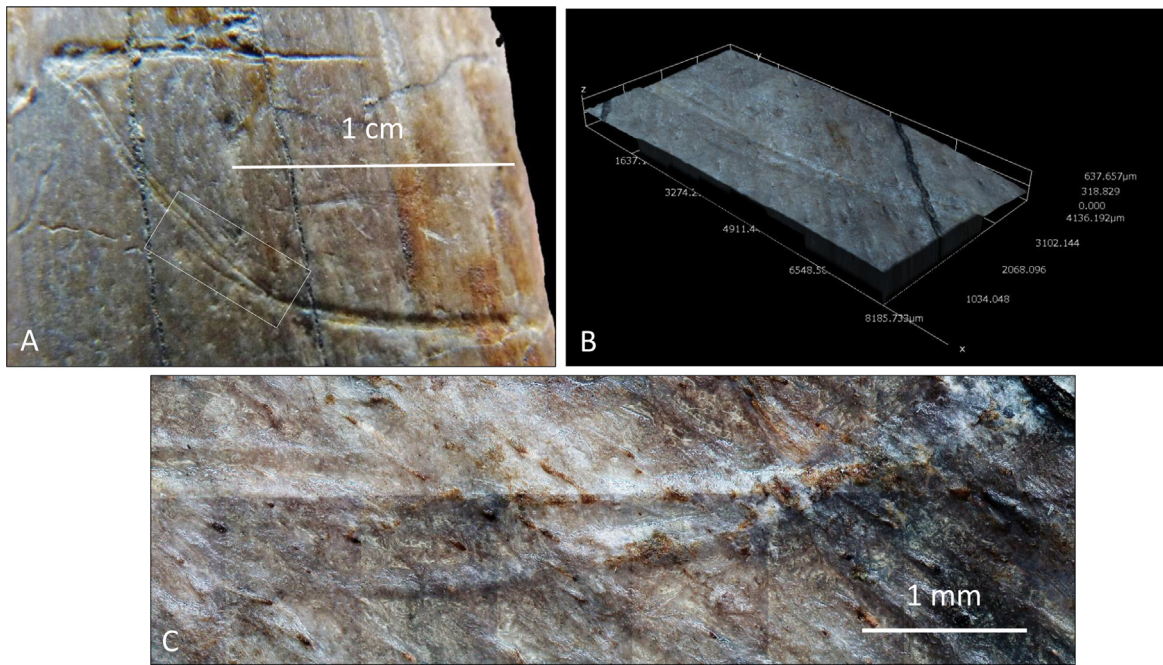
**Fig. 13.** A. Ensemble B des traces du fût tibial R10084 (B1, B2). B et C. Détails de la trace B2.

*Photo A. Dambricourt Malassé.*



**Fig. 14.** A. Trace B1 of the shaft R10084 and its beginning. B. Macrophotography of the beginning (photo A. Dambricourt Malassé). C and D. Photography of the beginning with a binocular microscope and different lightings (photo T. Calligaro, C2RMF).

**Fig. 14.** A. Trace B1 du fût R10084 et agrandissement de son amorce. B. Macrophotographie de l'amorce (photo A. Dambricourt Malassé). C et D. Photographie de l'amorce avec un microscope binoculaire et différents éclairages (photo T. Calligaro, C2RMF).



**Fig. 15.** A. Trace B2 of the shaft R10084 (photo A. Dambricourt Malassé). B and C. Magnification of its bifurcation (white rectangle) with the 3D Digital Video Microscope Hirox (photo T. Calligaro, C2RMF).

**Fig. 15.** A. Trace B2 du fût R10084 (photo A. Dambricourt Malassé). B et C. Observation de sa bifurcation (rectangle blanc) avec la vidéo digitale microscopique 3D Hirox (photo T. Calligaro, C2RMF).

probably unearthed from the basal members of the Quranwala zone.

**3.4.2.2. Description.** The metacarpal is broken at its proximal end. At its greatest length it is 14 cm long, and 7.5 cm at its greatest width, near the condyles (Fig. 19). Below the condyles there are parallel and linear incisions grouped on the dorsal side, 11 mm in length and perpendicular to the great axis (Fig. 19A). A large notch is visible in the direction of the dorsal surface prolonged by a green fracture; its surface, as well as the condyles, have been cropped by a rodent (*Rhizomys*) (Moigne et al., 2016). The surface of the bone is altered, but there is no trace of rodent (Fig. 19B).

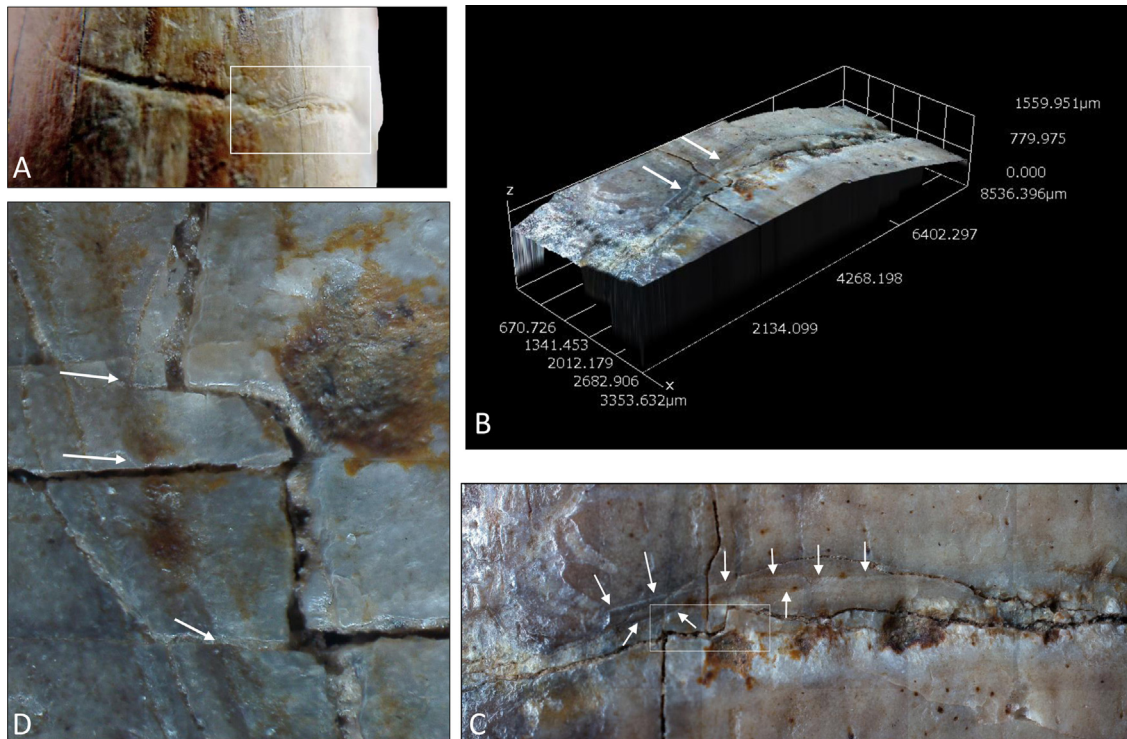
These parallel cut marks are centered on the greater curvature of the metacarpal at the end of the longitudinal furrow, located precisely on the insertions of the extensor tendons of the phalanges that cover the gutter. Seven traces are identified, *a* to *f* (Fig. 20), four are separated by the furrow: *a* and *b*, then *c* and *c'* that extends it; the greatest distance between two extremities perpendicular to the canon is 270 mm. In the lateral extension of the last trace (*f*), we see a conchoidal fracture of the cortical bone (*g*), which took away part of traces *b* and *c'*. This negative surface measures 170 mm at its greatest width and 160 mm at its greatest length.

The incisions were analyzed using X-ray microtomography of the AST-RX platform, National Museum of Natural History, Paris. (system v|tome|x 240, GE Inspection Technologies Phoenix| X - ray) (Fig. 21). Two traces, *d* and *e*, overlap with the same curved shape, *d* is significantly shorter, one end of *e* cuts *d*, its other end is cut by *f*. The profile in depth shows two parallel microgrooves (Fig. 21B

and C). These incisions are mineralized, and a large longitudinal crack of geological origin cuts the grooves located on one side of the furrow (*a*, *c*, *e*, *f*) (Figs. 20B and 21C). Comparison with an experiment on the foot of *Sus scrofa domesticus* is especially demonstrative of their intentional origin (Fig. 20A).

Indeed, the experiment was guided by the need to cut the flesh in the most efficient and comfortable way without worrying about the bone, according to movement perpendicular to the great axis of the metapodial, the left hand holding its proximal end. The intention did not concern the bone and the resistance of the leather made any reproduction of the fossilized marks impossible, the detail of the incisions and their trajectory were not predictable. Comparison with the fossilized notches showed the same organization, and was even possible to follow a chronology. Cutting began on the distal side (condyles), in to a direction perpendicular to the great axis of the metapodial. If the bone is positioned horizontally, with the condyles on the right, the movement is always from up to down, once from *a* to *b*, then shifted to the left from *c* to *c'*, a third time with the cut *d*, the movement restarted in *e* with renewed energy and ended in a large flake (from *f* to *g*). These incisions thus correspond to a succession of quick and energetic cuts focused on the area where the tendons of phalanges are attached, particularly resistant given the size of the metacarpal.

Fig. 20C shows the notch in the thickness of the bone in the shape of a funnel, and cropped (*h*) near a green fracture (*i*); three marks, possibly made by impacts, (*j*) and incision (*k*, *l*) are also visible near the broken area, little more than one centimeter from the bone removal



**Fig. 16.** Fracturing and mineralization of the trace B2. A. Location. B. Location of the trace analyzed with the 3D Digital Video Microscope Hirox (white arrows). C. Magnification of the picture B and location of the trace B2 showing two parallel microgrooves (arrows). D. Magnification of the picture C in the area of the fracturing which crosses B2 (two arrows) and its crystallized microcracking (single arrow).  
**Fig. 16.** Fracturation et minéralisation de la trace B2. A. Localisation. B. Vidéo digitale microscopique 3D Hirox, localisation de la trace observée (flèches). C. Agrandissement de la figure B et localisation de la trace B2 montrant les deux sillons parallèles (flèches). D. Agrandissement de C dans la zone de fracturation qui traverse B2 (deux flèches) et de sa microfissuration cristallisée (une flèche).

Photos B, C and D, T. Calligaro, C2RMF.

towards the proximal extremity (g). The whole therefore surrounds a missing area in the metacarpal, revealing the medullary cavity. This area is likely to be the result of strong percussions after the energetic incision of tendons, the intention being the consumption of the marrow. The violence of the shock is inferred from the embrittlement of the transversal section of the canon, cracked later within the sediments (Fig. 19A).

In conclusion, these traces match the incisions of a thick cutting edge in quartzite produced by a powerful gesture in order to cut the flexor tendons of phalanges and then to break the canon of the metacarpal to reach the marrow. The size of the notch, the profile of the incisions, and the impact inside the thickness of the bone, which removed a flake, reveal a succession of powerful impacts on the bone, made by a single quartzite; it can be assumed that the size of the edge corresponds to a chopper rather than to a thin flake.

### 3.4.3. Masol 13, R10298, splinter of bovid

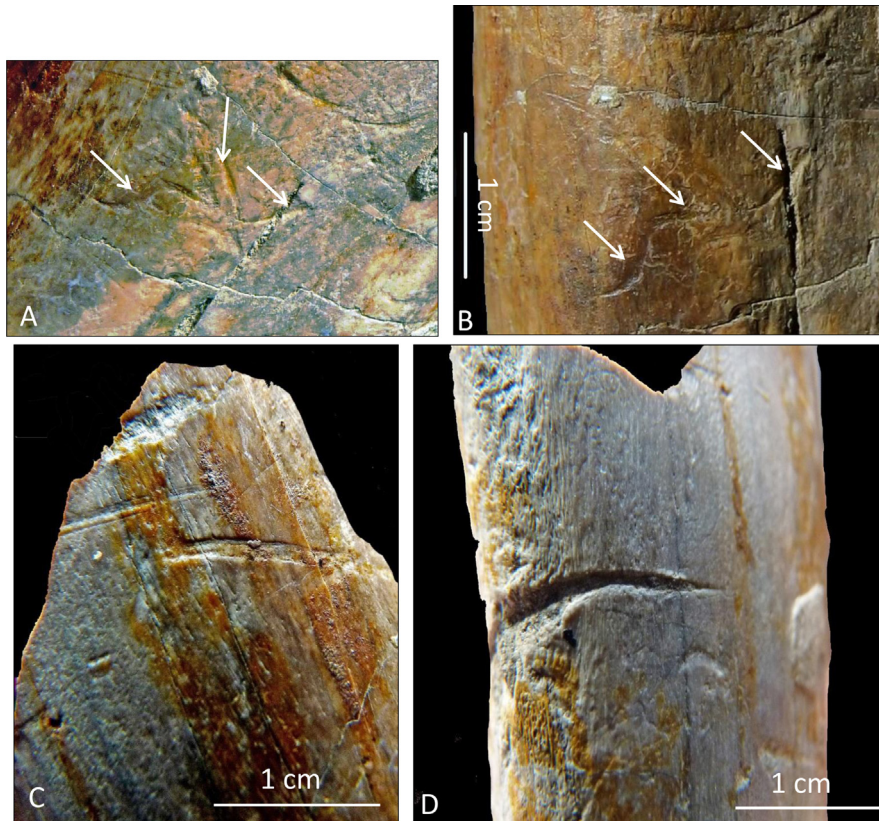
**3.4.3.1. Location and lithostratigraphic context.** Masol 13 is located on the left bank of the Patiali Rao, 700 meters beyond Masol 1 (Fig. 22A). The geomorphological contrast is particularly pronounced in the right bank. This sector of the Patiali Rao is a sort of broad bowl, lower than all the Masol 1 to Masol 6 localities (Fig. 2). The erosional process

has reached the c5 silt of the general log in an extensive area. Access is quick and easy, and this is the sector most surveyed by Indian paleontologists (Gaur, 1987). Fossils are less common (224 for all localities).

The sub-locality which provided the splinter recorded in 2011 is composed of brown silts stratigraphically just above the c4 sandstone visible at Masol 1. The two fossils are therefore separated in the sedimentary chronology only by this sandstone (Fig. 2). Blocks from c5 sandstones and quartzite cobbles cover this small butte of silts. Two choppers were collected among the cobbles, one less than one meter from a fossil.

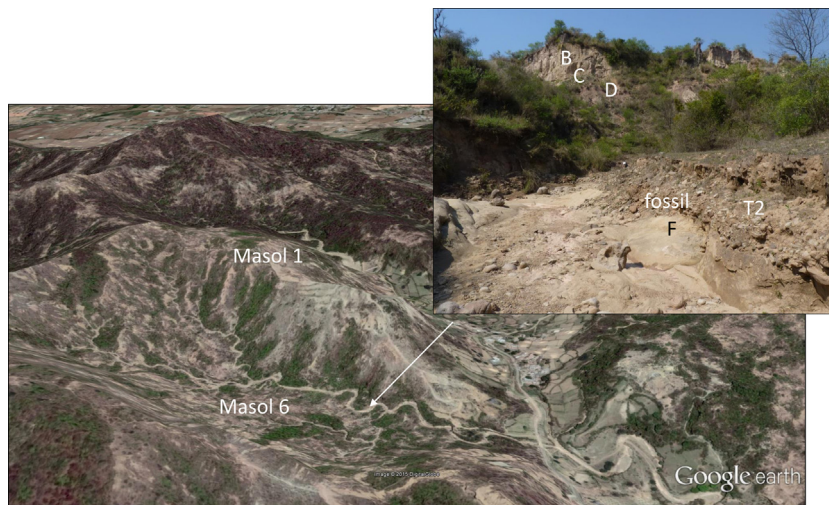
**3.4.3.2. Description.** The splinter measures 5 cm at its greatest length and 3 cm at its longest curvature. It belongs to a bovid. The specimen has been viewed with the 3D Digital Video Microscope Hirox and binocular microscope. The bone tissue is reddish-brown in color, the surface presents secondary cracking and many micro-perforations with white crystallization. The reddish-brown coloration indicates exhumation from the c5 dark red silts. The splinter bears a long trace perpendicular to the great axis of the bone, following its curvature in a regular way, formed by two parallel microgrooves, 12 mm long and about 1 mm wide (Fig. 23). One groove measures approximately 300  $\mu\text{m}$  between the two edges of the trace (Fig. 23D).





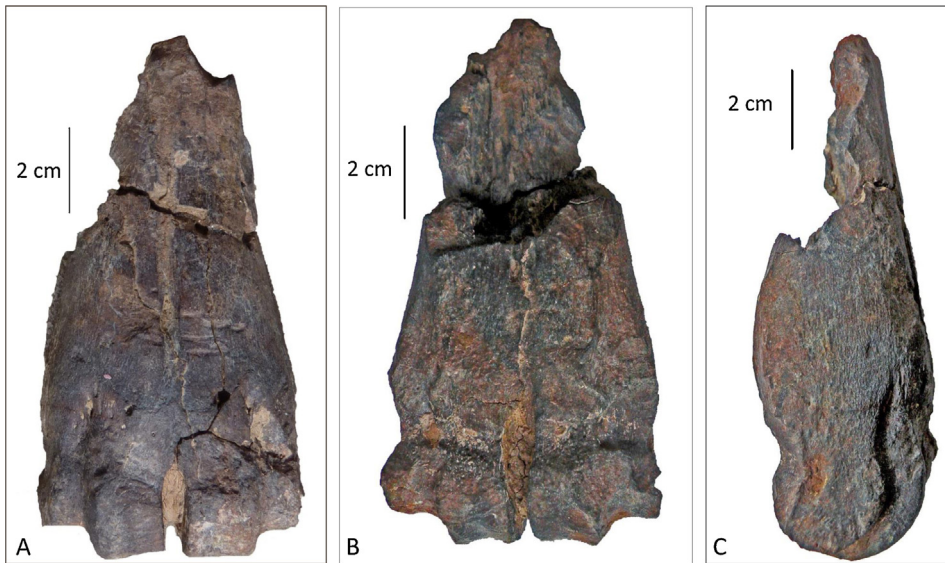
**Fig. 17.** Indeterminate traces of R10084. A. Winding trace intersecting two parallel marks (arrows). B. The same trace cracked (photos A. Dambricourt Malassé) (A and B same scale). C. Parallel traces. D. Great notch (photos A.-M. Moigne). Scale: the bar is 1 cm.

**Fig. 17.** Traces indéterminées de R10084. A. Une trace sinueuse qui recoupe deux traces parallèles (flèches). B. La même trace fissurée (photos A. Dambricourt Malassé) (A et B même échelle). C. Traces parallèles. D. Grande entaille (photos A.-M. Moigne). Échelle : la barre fait 1 cm.



**Fig. 18.** View on the Pichhli basin (Google Earth) and location of the terrace T2 where the metacarpal R10286 was collected. Inset, location of the fossil and the basal layers of the Quranwala zone B, C, D (E is under the slopes) and F (bottom of the bed) (photo A. Dambricourt Malassé).

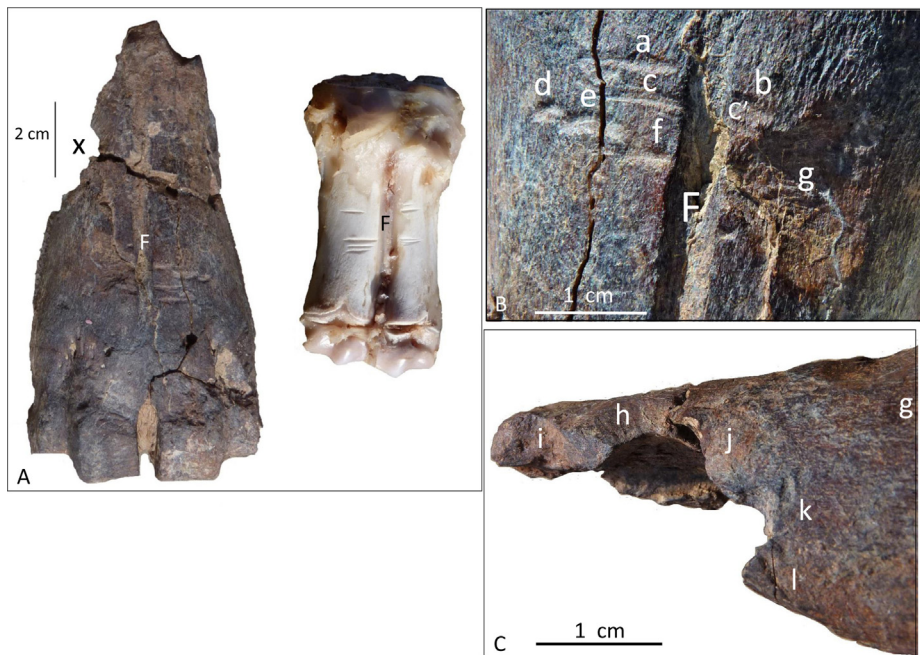
**Fig. 18.** Vue sur le bassin du Pichhli Choe (Google Earth) et localisation de la terrasse T2 où se trouvait le métacarpien R10286. En encart, vue sur la localité avec l'emplacement du fossile et la séquence basale de la zone Quranwala B, C, D (E est sous les éboulis de pente) et F qui forme le fond du lit (photo A. Dambricourt Malassé)



**Fig. 19.** Metacarpal R10286. A. Dorsal face (photo A. Dambricourt Malassé). B. Plantar face. C. Lateral view (photos A.-M. Moigne).  
**Fig. 19.** Métacarpien R10286. A. Face dorsale (photo A. Dambricourt Malassé). B. Face plantaire. C. Vue latérale (photos A.-M. Moigne).

The grooves are mineralized and cracked like the rest of the bone (Fig. 23E). The direction of the trajectory can be inferred through the presence of a third cut, which is very short at one extremity (Fig. 23A); the trace fades and disappears with the superficial wear of the bone (Fig. 23B). The extremity of this sort of “micro-scratch” is characteristic of

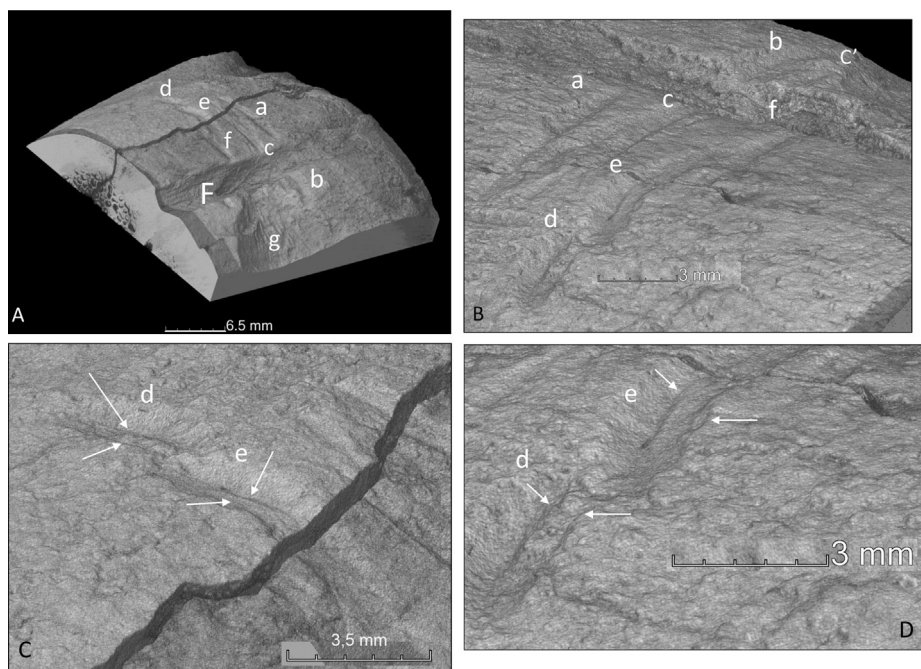
a quartzite cutting edge when it comes into contact with the bone tissue, and the profile of the groove fades when the gesture is shrinking. This “micro-scratch” matches the experimental traces of type *a* (Fig. 4B). This regular and well-engraved striation in the bone resembles neither the multiple striations of a crocodile tooth nor to a claw. Its



**Fig. 20.** Metacarpal R10286. A. Comparison of the traces with the experimental cut marks of *Sus scrofa domestica*: F: furrow; X: wide notch. B. Location of traces from ‘a’ to ‘g’, F: furrow. C. Detail of the notch (description from ‘h’ to ‘l’ in the text).

**Fig. 20.** Métacarpien R10286. A. Comparaison des traces avec les traces expérimentales de boucherie sur le métacarpien de *Sus scrofa domestica* : F : gouttière ; X : large encoche. B. Localisation des traces de « a » à « g », F : gouttière. C. Détail de l’encoche (description de « h » à « l » dans le texte dans le texte).

Photo A. Dambricourt Malassé.



**Fig. 21.** Metacarpal R10284. Microtomography of the traces at the platform AST-RX of the National Museum of Natural History conducted by Miguel Garcia Sanz and identification of the traces from 'a' to 'g'. F: furrow.

**Fig. 21.** Métacarpien R10284. Microtomographie des traces à la plateforme ASR-RX du Muséum national d'histoire naturelle réalisée par Miguel Garcia Sanz et identification des traces de « a » à « g ». F : gouttière.

Photos A. Dambricourt Malassé.

complete fossilization in fine silts excludes the action of gravel after its exhumation. The curve of the surface is a physical constraint; such regular pressure came from a fast force imposed on the bone, rather than from the long and slow irregular pressure of the bone on gravel. Binocular microscopy shows the extreme fineness of the cutting edge, which seems to correspond with the fine sharp edge of a quartzite cobble, chopper or flake, leaving a V-shaped profile (Fig. 23F). The binocular microscopy shows the extreme fineness of the cutting edge which seems to correspond to a fine sharp of a quartzite cobble, chopper or flake, leaving a V-shaped profile. These two regular and parallel microgrooves, well-engraved on a curved surface with a “micro-scratch” at its start, match with the repertory of intentional cut marks. After eliminating all natural and animal causes, we can assume they were made by a quartzite cutting edge.

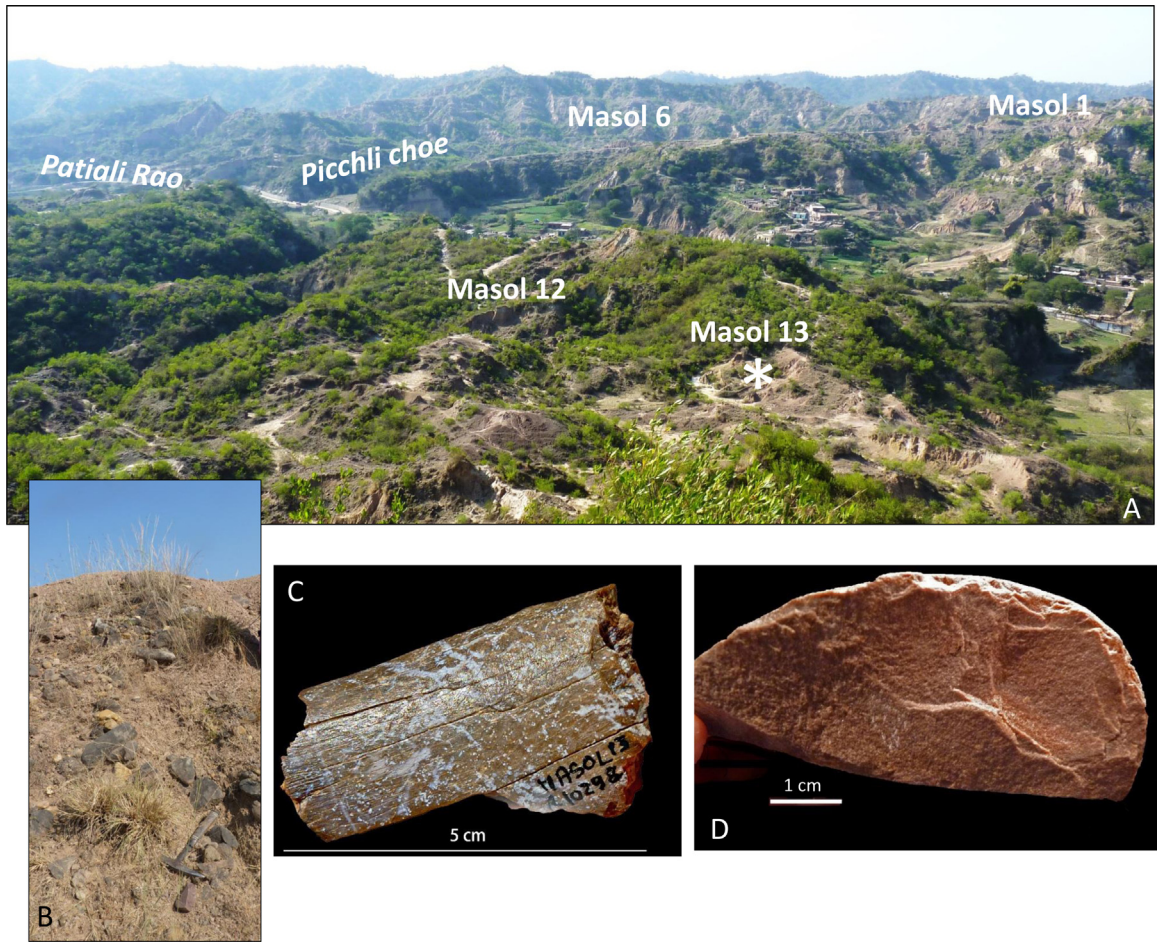
**3.4.3.3. Discussion.** The R10298 splinter belongs to the fauna assemblage collected from Masol 13, composed of 37 fossils with a majority of Bovidae (17) including 1 *Hemibos*, and 1 *Sivacpra*, 4 Proboscideans with 1 *Stegodon*, 4 Hippopotamidae (*Hexaprotodon sivalensis*), 1 Giraffidae (*Sivatherium*), 1 deer (*Cervus punjabiensis*), 3 fossils of turtle and 1 *Variani*. There are no crocodiles. We cannot conclude the age of the two choppers collected in the same conditions, but we can infer that a sharp quartzite edge is the origin of the two microgrooves that are 120 millimeters long. The supply of raw material would have been immediate, as shown by the dispersion of the quartzite cobbles

on the silts. Their presence on these silts is possible, as the Masol 12 locality is about 50 meters from the bone splinter with a layer of various cobbles and pebbles quartzite in stratigraphy in the c3 silts.

#### 4. Discussion and conclusion

Of 1469 fossils, 45 show green fractures, 12 bear traces of carnivores and 3 show many traces of a sharp quartzite edge. Traces of carnivores are visible at Masol 13, at Masol 8 on a bovid shaft and the rib of *Stegodon*, and at Masol 9 on the humerus of a young *Stegodon* (Moigne et al., 2016). In terms of statistics, carnivores are rare (6 fossils with 1 *Panthera* and 5 *Hyena*), but in terms of surface, their representation is not negligible: about 1500 fossils have been collected in 7 years from an inlier of 50 hectares (0.5 km<sup>2</sup>), whereas the hunting territory of a clan of *Hyena* (3 to 80 individuals) is about 30 km<sup>2</sup>. The Quranwala zone of the Masol Formation represents a great concentration of carcasses accumulated in a fluvial context, with terrestrial scavenging activities. Anthropoc activity is evidenced by three bones that are statistically significant when comparing the fossiliferous surface. For comparison, among 30,000 fossils collected on the island of Java, only five bear anthropic cut marks (Choi, 2003) although the island has the greatest concentration of *Homo erectus* in Asia.

The apparent conditions for the inhumation of the tibia shaft at Masol 1 correspond to those of calm water. In the Potwar Plateau (Pakistan), such a site suggests scavenging activity rather than the accumulation of carcasses



**Fig. 22.** A. Masol 13. B. A chopper Masolo13-281 (close to the hammer) among the sandstone and quartzite cobbles on silt B+. C. The splinter Masol 13 R10298. D. The chopper Masol 13-281.

**Fig. 22.** A. Masol 13. B. Un chopper M13-281 (extrémité du marteau) parmi les grès et les galets de quartzite sur les limons B+. C. L'esquille R10298. D. Le chopper M13-281.

Photos A. Dambricourt Malassé.

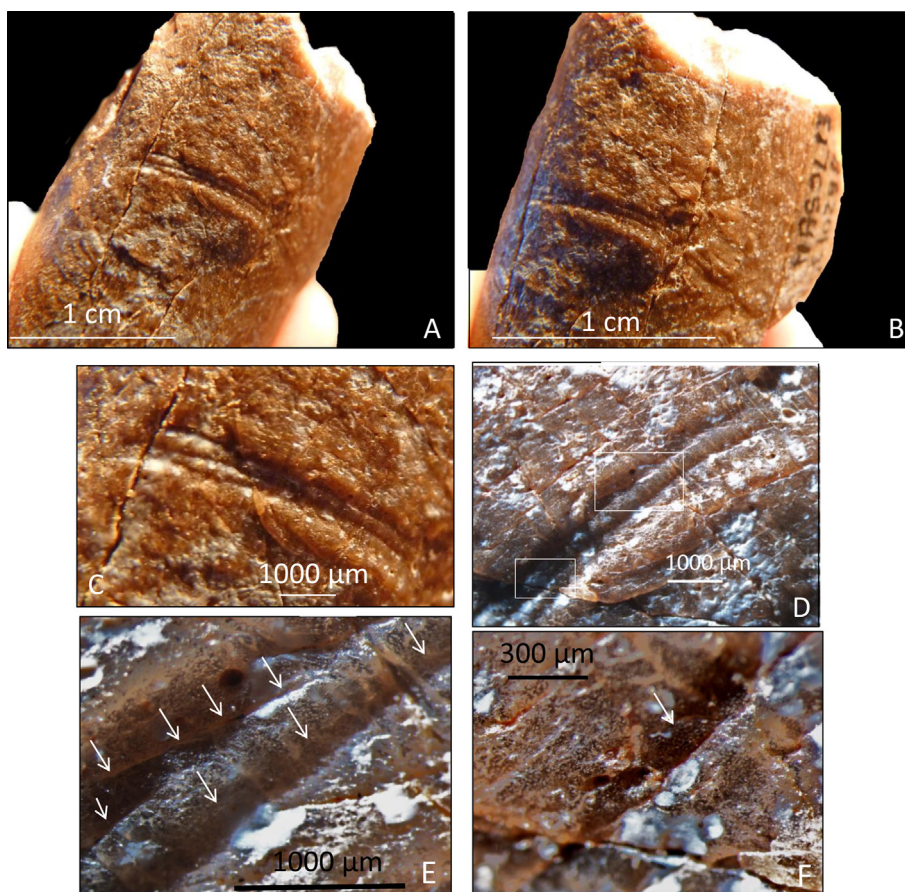
after a natural disaster (flood) (Pilbeam et al., 1979). At Masol, crocodiles are represented by dermal plates but not numerous, they could explain the disarticulated carcasses of large herbivores, whereas they swallowed their smaller prey. Nevertheless the conditions for the inhumation of the splinter R10298 at Masol 13 are rather than those of monsoon flood given the patch of quartzite cobbles (Abdessadok et al., 2016; Chapon Sao et al., 2016b) as supported by the taphonomic study. The concentration of disarticulated carcasses is characterized by:

- the same proportion for the axial and appendicular skeletons;
- no selection in the size of the carcasses from small cervids to very large herbivores, *Hexaprotodon*, *Sivatherium* and *Stegodon*;
- mixed carcasses of terrestrial and aquatic turtles (Moigne et al., 2016).

The sub-Himalayan floodplain was exposed to the monsoon, and fast and powerful floods may explain the sudden

formation of cobble beds on the silts transported from the fluvial terraces of the foothills where the rivers emerged from the Himalayan range. At the same time such torrential floods should surprise the herds of herbivores evolving on the floodplain and the giant turtles which occupied ponds or mud holes during the rainy season. After the waters receded, the plain must have been littered with cobble beaches and cadavers, accessible to terrestrial scavengers, *Hyena*, *Panthera* and Homininae, since the raw material for cutting was directly accessible on-site.

To conclude, after comparing the fossilized marks with experimental cut marks made by sharp quartzite edges, their anthropic origin can be in no doubt. The intelligence reflected by these cut marks required a morphofunctional organization of the forelimb (arm, wrist and fingers), and a complexity of the neural network in which very probably the cerebral and cerebellar neocortex were already connected (Dambricourt Malassé, 2011). These connections observed in *Homo sapiens* (Weaver, 2005) could match to the evolutionary stage of the nervous system when its equilibrium began to reach the vertical and permanent



**Fig. 23.** The splinter Masol 13 R10298 with two main parallel microgrooves. A. The first extremity of the trace and the micro-scratch. B. The second extremity of the trace. C. Magnification of the micro-scratch (photos A. Dambricourt Malassé). D. Binocular microscopy showing the mineralization and the profile of the same grooves than photo C. E. Magnification with the binocular microscope of the largest rectangle picture D, one groove with two fine microgrooves. F. Magnification of the microgroove visible in the smaller rectangle, photo D (photos T. Calligaro, C2RMF).

**Fig. 23.** L'esquille Masol 13 R10298 avec deux principaux microsillons parallèles. A. La première extrémité de la trace avec la microgriffure. B. La seconde extrémité. C. Agrandissement de la microgriffure (photos A. Dambricourt Malassé). D. Microscopie binoculaire montrant la minéralisation et le profil des microsillons de la photo C. E. Agrandissement au microscope binoculaire du grand rectangle photo D, un microsillon et deux microsillons très fins. F. Agrandissement au microscope binoculaire du microsillon dans le petit rectangle photo D (photos T. Calligaro, C2RMF).

orientation of the neural trunk, specific to the hominins *Australopithecus*, *Paranthropus*, *Homo* and then *Homo sapiens* (Dambricourt Malassé, 2006, 2011, 2016). It would be interesting to determine the circumstances that led these hominins to scavenge in sub-Himalayan paleoecosystems during the late Pliocene, and to compare these sub-tropical countries with the areas occupied by hominins before 2.6 Ma in the East African Rift.

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## References

- Abdessadok, S., Chapon Sao, C., Tudryn, A., Dambricourt Malassé, A., Singh, M., Gaillard, C., Karir, B., Bhardwaj, V., Pal, S., Moigne, A.-M., Gargani, J., 2016. Sedimentological study of major paleo-archaeological localities of the Late Pliocene Quranwala Zone, Siwalik Frontal Range, northwestern India. In Human origins on the Indian sub-continent. C. R. Palevol 15 (this issue).
- Baquedano, E., Domínguez-Rodrigo, M., Musiba, C., 2012. An experimental study of large mammal bone modification by crocodiles and its bearing on the interpretation of crocodile predation at FLK Zinj and FLK NN3j. *Archaeol. Sci.* 39, 1728–1737.
- Barroso Ruiz, C., Lumley, M.A., Moigne, A.-M., Riquelme Cantal, J.A., Echasoux, A., Valensi, P., Bermejo, L., 2003. Signification paleoetnológica de los restos humanos neandertalenses de la cueva des Boquete de Zafarraya: Tafonomía, fracturación, marcas de cortes, combustion. In: Barroso Ruiz, C. (Ed.), *El Pleistoceno superior de la Cueva cel Boquete de Zafarraya*. *Arqueología Monografías*, 15, Junta de Andalucía, Sevilla, pp. 389–421.
- Barroso Ruiz, C., Caparros, M., Moigne, A.-M., Riquelme Cantal, J.A., Monclova Bohorquez, A., 2014. Did Neanderthals and carnivores compete for animal resources nutritional in the surroundings of the Cave of Zafarraya. *J. Taphonomy* 3–4, 395–415.
- Bello, S.M., Soligo, C., 2008. A new method for the quantitative analysis of cutmark micromorphology. *J. Archaeol. Sci.* 35, 1542–1552.
- Bello, S.M., Parfitt, S.A., Stringer, C., 2009. Quantitative micromorphological analyses of cut marks produced by ancient and modern handaxes. *J. Archaeol. Sci.* 36 (9), 1869–1880.
- Bouteaux, A., Moigne, A.-M., Semah, F., Jacob, T., 2007. Les assemblages fauniques associés aux sites à *Homo erectus* du dôme de Sangiran (Pléistocène moyen, Java, Indonésie). *C. R. Palevol* 6, 169–179.
- Bouteaux, A., Moigne, A.-M., Setiagama, K., 2009. Études archéozoologiques de sites javanais pléistocènes : les sites de plein air du Dôme de Sangiran (Java Central) et le site en grotte de Song Terus (Java Est). In: Vila, E., Gourichon, L., Choyke, A.M., Buitenhuis, H. (Eds.), *Proc. VIIth Internat. Symposium on the Archaeozoology of southwestern Asia and adjacent areas*. *Archaeozoology of the Near East VIII*, TMO 49, Paleorient, pp. 79–98.
- Bouteaux, A., Moigne, A.-M., 2010. New taphonomical approaches: the Javanese open air sites (Sangiran, Central Java). *Quatern. Int.* 223–224, 220–225.
- Braun, D.R., Harris, J.W.K., Levin, N.E., McCoy, J.T., Herries, A.I.R., Bamford, M.K., Bishop, L.C., Richmond, B.G., Kibunjia, M., 2010. Early hominid diet included diverse terrestrial and aquatic animals 1.95 Ma in East Turkana, Kenya. *Proc. Nat. Acad. Sci. U S A* 107 (22), 10002–10007.
- Chapon Sao, C., Abdessadok, S., Dambricourt Malassé, A., Singh, M., Karir, B., Bhardwaj, V., Pal, S., Gaillard, C., Moigne, A.-M., Gargani, J., Tudryn, A., 2016a. Magnetic polarity of Masol 1 Locality deposits, Siwalik Frontal Range, Northwestern India. In Human origins on the Indian sub-continent. C. R. Palevol 15 (this issue).
- Chapon Sao, C., Abdessadok, S., Tudryn, A., Dambricourt Malassé, A., Singh, M., Karir, B., Gaillard, C., Moigne, A.-M., Gargani, J., Bhardwaj, V., 2016b. Lithostratigraphy of Masol paleo-archaeological localities in the Quranwala Zone, 2.6 Ma, Northwestern India. In Human origins on the Indian sub-continent. C. R. Palevol 15 (this issue).
- Choi, K., (PhD) 2003. *Subsistence and Tool Use Behavior of Homo erectus in Java: an Experimental and Taphonomic Approach*. University of Wisconsin-Madison (302 p.).
- Coppens, Y., 1975. Évolution des Hominidés et de leur environnement au cours du Plio-Pléistocène dans la basse vallée de l’Omo en Éthiopie. *C. R. Acad. Sci. Paris, Ser. D* 281, 1693–1696.
- Coppens, Y., 2013. Hominid evolution and the emergence of the genus *Homo*. In: Battro, A., Dehaene, S., Singer, W. (Eds.), *Neurosciences and the Human Person: New Perspectives on Human Activities*. Pontifical Academy of Sciences, *Scripta Varia*, Vatican City, p. 121.
- Coppens, Y., 2016. Forward. In Human Origins in Indian sub-continent, Human origins on the Indian sub-continent. C. R. Palevol 15 (this issue).
- Dambricourt Malassé, A., 2006. Évolution du chondrocrâne et de la face des grands anthropoïdes miocènes jusqu’à *Homo sapiens*, continuités et discontinuités. In: *Climats, cultures et sociétés aux temps préhistoriques. De l’apparition des hominidés jusqu’au Néolithique*. C. R. Palevol 5, 109–117.
- Dambricourt Malassé, A., 2011. *Les équilibres bipèdes permanents, origine embryonnaire, morphogénèse, équilibre occluso-postural, conséquences pour l’évolution psychomotrice et comportementale des hominidés*. Habilitation à Diriger des Recherches. Université de Technologie de Compiègne, Laboratoire de BioMécanique et BioIngénierie (713 p.).
- Dambricourt Malassé, A., 2016. The first Indo-French Prehistorical Mission in Siwaliks and the discovery of anthropic activities at 2.6 million years. In Human origins on the Indian sub-continent. C. R. Palevol 15 (this issue).
- Dambricourt Malassé, A., Singh, M., Karir, B., Gaillard, C., Bhardwaj, V., Moigne, A.-M., Abdessadok, S., Chapon Sao, C., Gargani, J., Tudryn, A., Calligaro, T., Kaur, A., Pal, S., Hazarika, M., 2016. Anthropic activities in the Quranwala Fossiliferous Zone, 2.6 Ma, Siwaliks of northwestern India, historical context of the discovery and the scientific investigations. In Human origins on the Indian sub-continent. C. R. Palevol 15 (this issue).
- Dennell, R.W., Rendell, H., Hailwood, E., 1988. Early tool-making in Asia: two-million year-old artefacts in Pakistan. *Antiquity* 62, 98–106.
- Dennell, R.W., 1998. Grasslands, tool-making and the Hominid colonization of Southern Asia: a reconsideration. In: Petraglia, M.D., Korisettar, R. (Eds.), *Early Human Behaviour in Global Context*. Routledge, London, pp. 280–303.
- Domínguez-Rodrigo, M., Pickering, T.R., Bunn, H.T., 2010. Configurational approach to identifying the earliest hominin butchers. *Proc. Natl. Acad. Sci.* 107 (49), 20929–20934.
- Domínguez-Rodrigo, M., Pickering, T.R., Bunn, H.T., 2012. Experimental study of cut marks made with rocks unmodified by human flaking and its bearing on claims of ~ 3.4-million-year-old butchery evidence from Dikika, Ethiopia. *J. Archaeol. Sci.* 39 (2), 205–214.
- Drumheller, S.K., Brochu, C.A., 2014. A diagnosis of *Alligator mississippiensis* bite marks with comparisons to existing Crocodylian datasets. *Ichnos* 21, 131–146.
- Echassoux, A., Moigne, A.-M., Moullé, P.E., Li, T., Feng, X.B., Li, W., Wu, Z., 2008. Les faunes de grands mammifères du site de l’Homme de Yunxian, Quyanhekou, Hubei, Chine. In: de Lumley, H., Li, T. (Eds.), *Le site de l’Homme de Yunxian*. Éditions Recherches sur les civilisations, CNRS, Paris, pp. 253–364.
- Gaillard, C., Singh, M., Dambricourt Malassé, A., Bhardwaj, V., Karir, B., Kaur, S., Pal, S., Moigne, A.-M., Sao Chapon, C., Abdessadok, S., Gargani, J., Tudryn, A., 2016. The lithic industries from the Late Pliocene Quranwala Zone, Masol Formation, Siwalik Frontal Range, Northwestern India. In Human origins on the Indian sub-continent. C. R. Palevol 15 (this issue).
- Gargani, J., Abdessadok, S., Tudryn, A., Chapon Sao, C., Dambricourt Malassé, A., Gaillard, C., Moigne, A.-M., Singh, M., Bhardwaj, V., Karir, B., 2016. Geology and geomorphology of Masol paleo-archaeological site, Late Pliocene, Chandigarh anticline, Siwalik Frontal Range, NW India. In Human origins on the Indian sub-continent. C. R. Palevol 15 (this issue).
- Gaur, R., 1987. *Environment and Ecology of Early Man in Northwest India*. B.R. Publishing Corporation, Delhi (252 p.).
- Han, F., Bahain, J.J., Deng, C., Boëda, E., Hou, Y., Wei, G., Huang, W., Garcia, T., Shao, Q., He, C., Falguères, C., Voinchet, P., Yin, G., 2015. The earliest evidence of hominid settlement in China: Combined electron spin resonance and uranium series (ESR/U-series) dating of mammalian fossil teeth from Longgupo cave. *Quatern. Int.* xx, 1–9, <http://dx.doi.org/10.1016/j.quaint.2015.02.025>.
- Harmand, S., Lewis, J.E., Feibel, C.S., Lepre, C.J., Prat, S., Lenoble, A., Boës, X., Quinn, R.L., Brenet, M., Arroyo, A., Taylor, N., Clément, S., Daver, G., Brugal, J.P., Leakey, L., Mortlock, R.A., Wright, J.D., Lokorodi, S., Kirwa, C., Kent, D.V., Roche, H., 2015. 3.3-million-year-old stone tools from Lomekwi 3, West Turkana, Kenya. *Nature* 521, 310–315.
- de Heinzelin, J.J., Clark, D., White, T., Hart, W., Renne, P., Woldegabriel, G., Beyene, Y., Vrba, E., 1999. Environment and behavior of 2.5 million year-old Bouri Hominids. *Science* 284 (5414), 625–629.
- Hou, Y.M., Zhao, L.X., 2010. An archeological view for the presence of early humans in China. *Quatern. Int.* 223–224, 10–19.
- Jin, C.Z., Zheng, L.T., Dong, W., Liu, J.Y., Xu, Q.Q., Han, L.G., Zheng, L.L., Wei, G.B., Wang, F.Z., 2000. The Early Pleistocene deposits and mammalian fauna from the Renzidong Fanchang, Anhui Province, China. *Acta Anthropol. Sin.* 19 (3), 185–198.
- Kimbel, W.H., Walter, R.C., Johanson, D.C., Reed, K.E., Aronson, J.L., Assefa, Z., Marean, C.W., Eck, G.G., Bobe, R., Hovers, E., Rak, Y., Vondra, C., Yemane, T., York, D., Chen, Y., Evensen, N.M., Smith, D.P.E., 1996. Late Pliocene Homo and Oldowan tools from the Hadar formation (Kada Hadar member), Ethiopia. *J. Hum. Evol.* 31, 549–561.
- de Lumley, M.A., Lordkipadnize, D., 2006. L’Homme de Dmanissi (*Homo georgicus*), il y a 1 810 000 ans. *C. R. Palevol* 5 (1–2), 273–281.
- McPherron, S.P., Alemseged, Z., Marean, C.W., Wynn, J.G., Reed, D., Geraads, D., Bobe, R., Béarat, H.A., 2010. Evidence for stone tool-assisted consumption of animal tissues before 3.39 million years ago at Dikika, Ethiopia. *Nature* 466, 857–860.
- McPherron, S.P., Alemseged, Z., Marean, C., Wynn, J.G., Reed, D., Geraads, D., Bobe, R., Béarat, H., 2011. Tool-marked bones from before the

- Oldowan change the paradigm. *Proc. Natl. Acad. Sci. U S A* 108, E116.
- Milan, J., Kofod, J., Bromley, R.G., 2010. Crocodylian–chelonian carnivory: Bite traces of dwarf caiman, *Paleosuchus palpebrosus*, in reared slider, *Trachemys scripta*, carapaces. In: Milan, J., Lucas, S.G., Lockley, M.G., Spielmann, J.A. (Eds.), *Crocodyl Tracks and Traces*. New Mexico Museum Natl. Hist. Sci. Bull. 51, 195–199.
- Moigne, A.-M., Barsky, D.R., 1999. Large mammal assemblage from Lower Paleolithic sites in France: La Caune de l'Arago, Terra-Amata, Orgnac3 and Cagny l'Épinette. In *The role of Early Humans in the Accumulation of European Lower and Middle Paleolithic Bone Assemblages*. Römisch-Germanisches Zentralmuseum 42, 219–235.
- Moigne, A.-M., Sémah, F., Sémah, A.M., Bouteaux, A., Rokhus Due, A., 2004. Mammalian fossils from two sites of the Sangiran Dome (Central Java, Indonesia). In: *The biostratigraphical framework of the Javanese Pleistocene Late Neogene and Quaternary biodiversity and evolution: Regional developments and interregional correlations*. Terra Nostra, Schriften der Alfred-Wegener-Stiftung 2. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart, pp. 176–178.
- Moigne, A.-M., Grégoire, S., de Lumley, H., 2005. Les territoires de chasse et d'exploitation des matières premières des hommes préhistoriques de la Caune de l'Arago entre 600 000 ans et 400 000 ans. *CTHS* 126, 17–31.
- Moigne, A.-M., Cho, T.S., Moule, P.E., 2011. Les faunes du Paléolithique ancien de Corée du Sud. In: de Lumley, H., et al. (Eds.), *Les Industries du Paléolithique ancien de la Corée du Sud dans leur contexte stratigraphique et paléoécologique*. CNRS, Paris, pp. 417–435.
- Moigne, A.-M., Dambricourt Malassé, A., Singh, M., Bhardwaj, V., Gaillard, C., Kaur, S., Karir, B., Pal, S., Abdessadok, S., Chapon Sao, C., Gargani, J., Tudryn, A., 2016. The faunal assemblage of the paleo-archaeological localities of Masol Formation, Late Pliocene Quranwala Zone, NW India. In *Human origins on the Indian sub-continent*. *C. R. Palevol* 15 (this issue).
- Njau, J.K., Blumenschine, R.J., 2006. A diagnosis of crocodile feeding traces on larger mammal bone, with fossil examples from the Plio-Pleistocene Olduvai Basin, Tanzania. *J. Hum. Evol.* 2, 142–162.
- Pilbeam, D.R., Behrensmeyer, A.K., Barry, J.C., Shah, S.M.I., 1979. Miocene sediments and faunas of Pakistan. *Postilla* 179, 1–45.
- Prat, S., Brugal, J.P., Tiercelin, J.J., Barrat, J.A., Bohn, M., Delagnes, A., Harmand, S., Kimeu, K., Kibunjia, M., Texier, P.J., Roche, H., 2005. First occurrence of early Homo in the Nachukui Formation (West Turkana, Kenya) at 2.3–2.4 Myr. *J. Hum. Evol.* 49, 230–240.
- Ranga Rao, A., 1993. Magnetic polarity stratigraphy of Upper Siwalik of northwestern Himalayan foothills. *Curr. Sci.* 64, 863–873.
- Ranga Rao, A., Nanda, A.C., Sharma, U.N., Bhalla, M.S., 1995. Magnetic polarity stratigraphy of the Pinjor Formation (Upper Siwalik) near Pinjore, Haryana. *Curr. Sci.* 68 (12), 1231–1236.
- Rivals, F., Moigne, A.-M., de Lumley, H., 2002. La chasse aux petits bovidés de la Caune de l'Arago (Tautavel, France) : opportunisme ou sélection des proies. *Anthropozoologica* 36, 3–12.
- Rivals, F., Testu, A., Moigne, A.-M., de Lumley, H., 2006. The Middle Pleistocene argali (*Ovis ammon antiqua*) assemblages at the Caune de l'Arago (Tautavel, Pyrénées-Orientales, France): were prehistoric hunters or carnivores responsible for their accumulation? *Int. J. Osteoarchaeol.* 16 (3), 249–268.
- Roche, H., Delagnes, A., Brugal, J.P., Feibel, C.S., Kibunjia, M., Texier, P.J., 1999. Evidence for early hominids lithic production and technical skill at 2.3 Myr, West Turkana, Kenya. *Nature* 399, 57–60.
- Roche, H., Brugal, J.P., Delagnes, A., Feibel, C., Harmand, S., Kibunjia, M., Prat, S., Texier, P.J., 2003. Les sites archéologiques plio-pléistocènes de la Formation de Nachukui (Ouest Turkana, Kenya) : bilan préliminaire 1996–2000. *C. R. Palevol* 2 (8), 663–673.
- Sahni, M.R., Khan, E.J., 1964. Boundary between the Tatrots and Pinjurs. *Res. Bull. Panjab Univ.* 12, 263–264.
- Sahni, M.R., Khan, E.J., 1968. Stratigraphy, structure and correlation of the Upper Shiwaliks, East of Chandigarh. *J. Palaeontol. Soc. India* 5–9, 61–74 (1960–1964).
- Semaw, S., 2000. The World's Oldest Stone Artefacts from Gona, Ethiopia: their implications for understanding stone technology and patterns of human evolution between 2.6–1.5 million years ago. *J. Archaeol. Sci.* 27, 1197–1214.
- Semaw, S., Rogers, M., Quade, J., Renne, P., Butler, R., Domínguez-Rodrigo, M., Stout, D., Hart, W., Pickering, T., Simpson, S., 2003. 2.6-Million-year-old stone tools and associated bones from OGS-6 and OGS-7, Gona, Afar, Ethiopia. *J. Hum. Evol.* 45 (2), 169–177.
- Sam, Y., Moigne, A.-M., 2011. Rôles des Hommes et des Carnivores dans l'accumulation osseuse des niveaux profonds d'Orgnac 3 (Ardèche, France). Exemple des niveaux 7–8. Prédateurs dans tous leurs états, évolution, biodiversité, interactions. Mythes, Symboles XXXI<sup>e</sup> Rencontres internationales d'archéologie et d'histoire d'Antibes. Ed. APDCA, Antibes, pp. 351–367.
- Thompson, J.C., Shannon, P., McPherron, S.P., Bobe, R., Reed, D., Barr, W.A., Wynn, J.G., Marean, C.W., Geraads, D., Alemseged, Z., 2015. Taphonomy of fossils from the hominin-bearing deposits at Dikika, Ethiopia. *J. Hum. Evol.* 86, 112–135.
- Tudryn, A., Abdessadok, S., Gargani, J., Dambricourt Malassé, A., Singh, M., Gaillard, C., Bhardwaj, V., Chapon Sao, C., Moigne, A.-M., Karir, B., Pal, S., Miska, S., 2016. Stratigraphy and paleoenvironment during the Late Pliocene at Masol paleo-archaeological site (Siwalik Range, NW India): preliminary results. In *Human origins on the Indian sub-continent*. *C. R. Palevol* 15 (this issue).
- Vercoutère, C., Patou-Mathis, M., Giacobini, G., 2014. Rôles des agents biologiques non-humains dans l'origine et l'histoire des assemblages osseux de grands mammifères issus de sites archéologiques pléistocènes : pseudo-objets. In: Denys, C., Patou-Mathis, M. (Eds.), *Manuel de taphonomie*. Errance, pp. 263–270.
- Weaver, A.H., 2005. Reciprocal evolution of the cerebellum and neocortex in fossil humans. *Proc. Natl. Acad. Sci. U S A* 102 (10), 3576–3580.
- Westaway, M.C., Thompson, J.C., Wood, W.B., Njau, J., 2011. Crocodile ecology and the taphonomy of early Australasian sites. *Environ. Archaeol.* 16, 124–136.
- Zhang, S.S., Han, L.G., Jin, C.Z., 2000. On the artifacts unearthed from the Renzidong Paleolithic site in 1998. *Acta Anthropol. Sin.* 19, 126–135 (in Chinese).