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Pre-Quaternary hominin settlements in Asia : archaeology, bio-lithostratigraphy and  
magnetostratigraphy evidences at Masol, Siwaliks, Northwestern India

Peuplements pré-quaternaires en Asie : archéologie, bio-lithostratigraphie et  
magnétostratigraphie à Masol, Siwaliks, nord-ouest de l'Inde.

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## **Abstract**

The National Museum of Natural History, Paris, the National Centre for Scientific Research (CNRS/UMR 7194 and 8148) and the Society for Archaeological and Anthropological Research, Chandigarh, conduct paleontological and archaeological surveys in a sub-Himalayan territory well known for its Upper Pliocene fossiliferous deposits and named the Quranwala Zone. Since 2007, the team is investigating this formation in the Masol anticline and has collected four fossils with marks of butchery as well as numerous lithic artifacts. In this paper we show the first chopper extracted in stratigraphy from the deepest fossiliferous layer at more than 2.6 Ma as shown by the undisputable magnetostratigraphy, we describe the lithostratigraphy of the excavation, the techno-typology of the chopper and compare it with the collection of its locality and two other major paleonto-archaeological sites of Masol. The characteristics of this Masol lithic assemblage do not match those of the early Lower Pleistocene African Oldowan (2.55 Ma), but they are similar to those of the Chinese lithic industry of Longgupo (2.5 Ma). These activities open new perspectives regarding the phylogenetic and geographical origins of these Asian hominins as well as on their descendants, and justify the pursuit of surveys and test pits in the Quranwala zone.

**Keywords:** Siwaliks, India, Masol, late Upper Pliocene, Hominins, lithic technology

## Résumé

Le Muséum National d'Histoire Naturelle de Paris, le Centre National de la Recherche Scientifique (CNRS/UMR 7194 et 8148) et la *Society for Archaeological and Anthropological Research* de Chandigarh, poursuivent des prospections paléontologiques et archéologiques dans un territoire sub-himalayen bien connu pour ses gisements fossilifères du Pliocène supérieur et nommée la zone Quranwala. Depuis 2007, l'équipe enquête sur cette formation dans l'anticlinal de Masol et a récolté quatre fossiles avec des marques de boucherie ainsi que de nombreux artefacts lithiques. Dans cet article, nous présentons le premier chopper extrait en stratigraphie de la couche fossilifère la plus profonde et à plus de 2,6 Ma comme la magnétostratigraphie le démontre incontestablement, nous décrivons la lithostratigraphie de la fouille, la techno-typologie du chopper et le comparons avec la collection de sa localité et de deux autres sites paléonto-archéologiques majeurs de Masol. Les caractéristiques de cet ensemble lithique de Masol ne correspondent pas à celles de l'Oldowayen africain du début du Pléistocène inférieur (2,55 Ma), par contre elles sont similaires à celles de l'industrie lithique chinoise de Longgupo (2,5 Ma). Ces activités ouvrent de nouvelles perspectives sur les origines phylogénétiques et géographiques de ces hominiens asiatiques ainsi que sur leurs descendants, et justifient la poursuite des prospections et sondages dans la zone Quranwala.

**Mots clés :** Siwaliks, Inde, Masol, Pliocène supérieur final, Homininés, Technologie lithique

## 1. Introduction

### 1.1 History

The paleontological site of the Masol Formation belongs to a regional fossiliferous zone called Quranwala, this zone is visible along the Chandigarh anticline located in the Northwestern Indian sub-Himalayan foothills (Fig. 1 and 2).

Figure 1 - Location of the geological Masol Formation in the Siwaliks foothills.

A and C: map data ©Google 2016.

Figure 1 - Localisation de la Formation géologique de Masol dans la Chaîne frontale des Siwaliks. A et C : données cartographiques ©Google 2016.

The Chandigarh anticline is part of the Northwestern Siwalik Frontal Range famous for its Pliocene fossiliferous deposits (Quranwala zone, Khetpurali, Saketi) studied by Indian geologists and paleontologists since the 1960s. The geology of the Chandigarh anticline has been mapped by Sahni and Khan (1964, 1968) and completed later with a structural map for geomagnetism studies (Ranga Rao, 1993; Ranga Rao et al., 1995). The anticline emerged around 600 ka ago due to an intensification of the tectonic between the Indian and Asian plates, this period is called post-Siwalik. The deposits of Masol are the oldest and outcrop on

about 800 000 m<sup>2</sup> in an inlier (geological buttonhole) dig around the anticline axis and bordered by steep crests (Fig. 2).

Figure 2 - View on the Masol's watershed and a geological section of the Chandigarh's anticline, adapted to Sahni and Khan (1964, 1968). The white line drawn the limit of the Upper Pliocene from Sahni and Khan (ib) and the French-Indian surveys, the Quranwala zone is inside these limits and below the crests (Dambricourt Malassé 2020, map data ©Google 2016).

Figure 2- Vue du bassin versant de Masol et coupe géologique de l'anticlinal de Chandigarh, adaptée de Sahni et Khan (1964, 1968). La ligne blanche trace la limite du Pliocène supérieur d'après Sahni et Khan (ib) et les prospections franco-indiennes, la zone Quranwala se trouvant à l'intérieur de ces limites et en dessous des crêtes (Dambricourt Malassé 2020, données cartographiques ©Google 2016).

The sediments consist of silts and sandstones of fluvial and marshy origin. The Quranwala zone was mapped by Sahni and Kahn (1964, 1968), clearly identified in the inlier and well delimited in the stratigraphy. The faunal assemblage (Sahni and Khan, 1964, 1968; Badam, 1979; Nanda, 1981, 1996-1997, 2002, 2013; Nanda et al., 2018; Patnaik, 2012, see more in Moigne et al., 2016) and the magnetostratigraphy (Ranga Rao et al., 1995) have dated the deposits to the late Upper Pliocene (see more in Chapon Sao et al., 2016b). A small seasonal river, the Patiali Rao, gives access to the Masol village, then torrents such as the Picchli

choe allow to reach the fossiliferous deposits. This local watershed is no connected to the Himalayan rivers. As for any paleontological site, the thousands of fossils have been collected on the surface because of the erosion due to the combination of the monsoon rains and the uplift still going on. Some are kept at Chandigarh in the Department of Geology of the Panjab University, and at the Natural History Museum from the Government Museum and Art Gallery where they constitute a world known reference for the fauna of the late Pliocene in Asia.

## 1.2 The French-Indian program

The program of research has regularly recovered fossil bones with butchery marks (2009, 2011, 2017) and identified a dozen of localities where quartzite tools are associated with mineralized bones, they are collected exclusively in the Quranwala zone (Dambricourt Malassé, 2016, 2020; Dambricourt Malassé et al., 2016a , Gaillard et al., 2016) (Fig. 3). Since 2012 the program is sponsored by Yves Coppens who quickly formalized the discovery (Coppens, 2014, 2016).

Figure 3 - The Masol Formation in the inlier with the central dome and the paleonto-archeological localities (M1 to M13). The line is the axis of the anticline summit. Map data ©Google 2016.

Figure 3 - La formation de Masol dans la boutonnière avec le dôme central et les localités paléonto-archéologiques (M1 à M13). La ligne est l'axe du sommet de l'anticlinal. Données cartographiques ©Google 2016.

The multidisciplinary study of the French-Indian program has reconstructed the lithostratigraphic log from the bed of the Patiali Rao to the western crest, on a thickness of 170 meters and located the fossiliferous layers with precision (Tudryn et al., 2016). We have analysed the mineralogy and the lithostratigraphy of the major paleonto-archaeological localities (Abdessadok et al., 2016; Chapon Sao et al., 2016a), the faunal association illustrated by 1500 fossils (e.g. *Hipparion-Equus*, *Stegodon-Elephas*, *Merycopotamus*, Moigne et al., 2016) attested the late Upper Pliocene age and then, the normal polarity of the paleomagnetism confirmed that Masol Formation belongs to the Gauss magnetozone (Chapon Sao et al., 2016b). A modelling of the speed erosion is in progress to test the hypothesis of a post-Sivalik age of the stone tools (Gargani et al., 2016). More the erosion is speed, more the post-Sivalik age of the artifacts become inconsistent as the Pleistocene colluviums were the first to be evacuated by the important activity of waterfall and torrents. Finally, dating method of the sands extracted in stratigraphy was applied by the Cosmogenic Nuclide National Laboratory (ASTER CEREGE, Aix-en-Provence, France), but the  $^{26}\text{Al} / ^{27}\text{Al}$  rate show no cosmonuclides.

The synthesis of our data shows that the Quranwala zone includes two paleontological periods separated by about 100 meters of sterile sediments. Cut marks and tools were collected in the first period of 40 meters thick (from c3 to c7 of the lithostratigraphic log, see Fig. 5). The second period is very poor in fossils. The cut marks have been collected at the top and on both sides of the anticline, they are evidenced on a sharp tibia and a metapod of bovid, on an undetermined large splinter and on a tibia of *Stegodon* recovered in 2017. Their intentional origin has been demonstrated and confirmed by both microtomography and microscopical studies, and then completed by an experimental investigation on a fresh carcass with a quartzite pebble from Masol (Dambricourt Malassé et al., 2016b; Dambricourt Malassé, 2020).

The first dating by ESR method (Electron spin resonance) have been applied by Pierre Voinchet to samples taken from two relic mounds of colluviums, rich in turtle bones and containing one chopper. The first at Masol 1 on the top of the anticline, is composed by the silts c3 and the sandstones s3, the second at Masol 9 in the depression of the anticline, is composed of silts c6 (see Fig. 3). The dating have given the same age of 200 ka. This age corresponds very likely to the onset of the erosion of the Quranwala zone.

The first localities studied were Masol 1 and Masol 2 on the dome, 120 meters from each other and separated by a relic hill composed of the oldest fossiliferous layers. Butchery marks, more than 500 fossils and numerous artifacts have been

collected around this hill on the silts c3. Masol 2 is rich in quartzite cobbles-pebbles. Since the cut marks are undisputable, two trenches were open in 2011 in the layer c3 in order to find them with artifacts in situ. One cobble was extracted in the trench A, while the trench B provided few cobbles and two stone tools at the limit between the silts in situ and the dismantled silts (Gaillard et al., 2016). Contrary to Soni and Soni assumption (2017), the Quranwala zone contains cobbles/pebbles and those collected at Masol 1 and Masol 2 could be collected on the silts indexed c3 and used for the butchery activity.

Figure 4 - Masol 12: a layer of cobbles-pebbles (white asterisk) inside the lowest fossiliferous silts c3 of the Quranwala zone and pebbles scattered on the eroded silts (picture A. Dambricourt Malassé, 2011).

Figure 4 - Masol 12 : un niveau de nodules-galets (astérisque blanc) à l'intérieur des limons fossilifères C3 les plus anciens de la zone Quranwala et des galets dispersés sur les limons érodés (photo A. Dambricourt Malassé, 2011).

Two geological seasons in 2013 and 2015 have surveyed the geomorphology of Masol Formation and especially the outcrops of the Quranwala zone. Patches of cobbles/pebbles are visible at Masol 3, 6, 7, 9, 12 and 13 and the erosional processes have nothing in common with the bed of a river (Gargani et al., 2016). Those hard materials were deposited by the floods of the Himalayan rivers before

2.6 Ma, while vertebrate carcasses accumulated in the floodplain. The association of fossils and pebbles limited to the Quranwala zone, is coherent and the cut marks reveal that hominins had access to this raw material for their scavenging activity during the flood decline.

These activities are the oldest known in Asia and their late Pliocene age is officially recognized by the scientific community since the declaration of the final statement of the international conferences “Who was who and who did what, where and when?” held at the Pontifical Academy of Sciences of the Vatican city in 2019 : “India, where cut marks on animal bones (2.7-2.8 million years old) have been found and identified in the sub-Himalayan region of Punjab (...). The Indian discovery (Masol) is very important but has to be confirmed – and the meat-eater using tools identified, as far as possible” (Coppens, 2020).

## 2. The first chopper in situ

The first stone tool in situ was spotted in 2016 by Mukesh Singh at Masol 1, a small part was emerging from the base of the silts c3. The quartzite cobble was unearthed in February 2017 and then the intentional origin of the split could be demonstrated (Fig. 6A). The excavation was 50 meters far from the marks of butchery collected in 2009 and in the vicinity of choppers, flakes (Fig. 12 and 13) and one core (Fig. 13, number 6) collected on the same silts being eroded. The

presence of stone tools on the surface was logic, especially since cobbles of quartzite are embedded in their colluviums at Masol 2.

Figure 5 - Stratigraphic log and magnetostratigraphy of Masol Formation (Gauss normal polarity) with the location of the excavation at Masol 1 (arrow) in the silts c3 which mark the lowest limit of the Quranwala zone (dotted line) (photo A. Dambricourt Malassé).

Figure 5 - Log stratigraphique et magnétostratigraphie de la formation Masol (polarité normale de Gauss) avec l'emplacement de la fouille à Masol 1 (flèche) dans les limons c3 qui marquent la limite inférieure de la zone Quranwala (ligne pointillée) (photo A. Dambricourt Malassé).

## 2.1 The excavation

The silts c3 are washed away by small gullies that drain rainfalls to a precipice (Fig. 5). The artifact was emerging from the flank of one of these small gullies. The erosional process due to the infiltration of the rainwater changes the aspect of the silts. For this reason, the excavation has required meticulous method under the scientific control of the UMR 7194 whose members have experience of excavations of open-air sites (e.g. Lumley et al., 2006). The steps of the excavation were filmed and photographed with careful observation of the artifact's matrix and trenches have been dug around it before extraction (Fig. 6).

Then samples of silts have been taken along the section for mineralogical analyses.

Figure 6 – Extraction of the chopper at Masol 1. A: the quartzite tool in 2016 (photo SAAR); B and C: excavation around the chopper; D: view on the excavation after the extraction of the chopper (\*), scale: 1 meter (photos A. Dambricourt Malassé).

Figure 6 - Extraction du chopper à Masol 1. A : l'outil en quartzite en 2016 (photo SAAR) ; B et C : fouille autour du chopper ; D : vue de la fouille après l'extraction du chopper (\*), échelle : 1 mètre (photos A. Dambricourt Malassé).

## 2.2 Macroscopical and microscopical study of the sedimentary matrix

The physical aspect of silts changes with the alteration. On the surface they form compact blocks and granules while they are compact, smooth and hard below the part infiltrated by the rainwater. A section of the excavation allows to follow this alteration and to locate the tool into the dismantling process. Four facies were distinguished and samples were taken from each of them for mineralogical analysis by Alina Tudryn at the Department of Geology of Paris Saclay University (GEOPS). The facies from the surface to the base are, a: free blocks of variable sizes and granules of silts, b: small blunt silty aggregates (< 5 cm) in their compact matrix, c: prismatic compact silts, d: compact and very hard silts (Fig. 7).

Figure 7 - Excavation of Masol 1: location of the section in the lithostratigraphic log with the physical aspect of the silts and the position of the chopper (drawn Salah Abdessadok).

Figure 7 - Fouille à Masol 1 : localisation de la coupe dans le log stratigraphique avec l'aspect physique des limons et la position du chopper (dessin Salah Abdessadok).

The artifact was 65 cm above the sand s2 (member F, Fig. 7) and covered by silt in a phase of dissolution but still compact with small nodules (Fig. 6-C). The tool long about 10 cm, was laying horizontally on its cortical surface with the 3/4 buried in the layer. Analyses of the samples show a regular evolution of the clay minerals from the base to the surface. Comparisons have been realized with samples from two sections of the silts c3 without alteration, the first was a few meters from the excavation and the second section was in the bed of the Picchli choe. The results show identical composition and evolution (decreasing smectite and increasing illite) (Fig. 8), these analyses indicate that the physical appearance of the silts simply corresponds to their dissolution on place without tracks of disturbance or secondary deposits. We confirm that the artifact was in situ in the deepest fossiliferous silts of the Masol Formation.

Figure 8 - Comparison of the evolution of the clay minerals from the member F to the lower level of the member E (silts s3 of the log) between geological sections at Masol 1 (S1 and S2), in the excavation and in the Picchli choe (Alina Tudryn and Salah Abdessadok).

Figure 8 - Comparaison de l'évolution des minéraux argileux depuis le membre F jusqu'au niveau inférieur du membre E (limons s3 du log) entre les coupes géologiques à Masol 1 (S1 et S2), dans la fouille et dans le Picchli choe (Alina Tudryn et Salah Abdessadok).

Masol 1 and Masol 2 are at the foot of a relict hill from the lowest Quranwala zone. Since the two trenches of 2011, a dozen of flakes, with very fresh, unrolled edges, have been collected on the outcrops of the lowest levels of the silts c3 - and not on their colluviums - (eyewitnesses Mukesh Singh, Anne Dambricourt Malassé, Dominique Cauche). These artifacts come from these levels already washed away by runoff and the chopper has been extracted just before it fall down in the gully. Today the tools are located under the enormous hill between the two localities.

### 2.3 Paleomagnetism and the age of the Masol Formation

The paleomagnetic measurements from the silts c3 up to the silts c17 confirm the normal magnetic polarities. The deposits are contemporaneous to the Gauss magnetozone in accordance with the Pliocene fauna and the previous magnetic

results. The Plio-Pleistocene boundary (2.588 Ma) is therefore more than 140 meters above the base of c3 (Chapon Sao et al., 2016b). The paleomagnetism applied to these basal silts, indicates an interesting magnetic excursion. Many observations from lacustrine and marine sediments in the world show multiple excursions predating the geomagnetic Gauss-Matuyama reversal and have been dated from 2.62 to 2.95 Ma (Chapon Sao et al., submitted). Given the huge sedimentary thickness that covers the tool without reaching the Neogene/Quaternary boundary, we expect an age much older than 2.6 Ma. The dating of the sands s3 covering the c3 silts are in progress (Gargani et al., 2018).

#### 2.4 The fauna and hominins potential

The faunal list of Masol 1 (n = 387) and Masol 2 (n = 153) matches with the biochronological unit of the late Upper Pliocene in the Siwaliks with *Stegodon insignis* and *Elephas hysudricus*, *Hipparion antilopinum* and *Equus sivalensis*, *Hexaprotodon sivalensis*, *Camelus sivalensis*, among bovids, cervids, and reptiles such as the giant turtle *Testudo atlas* (Moigne et al., 2016). A second molar of *Merycopotamus* was collected in 2017 about ten metres from the excavation (Fig. 9). This genus, rarely visible in the fossil record, disappeared in the Siwaliks after the Pliocene. This new collect demonstrates the richness of Masol deposits in rare species and therefore the necessity to maintain the research of plausible hominin fossils, as *Hyena* and *Panthera*, two hominin predators, are present in the fauna.

Figure 9 - Molar of *Merycopotamus* from Masol 1 (photo A. Dambricourt Malassé).

Figure 9 - Molaire de *Merycopotamus* de Masol 1 (photo A. Dambricourt Malassé).

### 3. Study of the artifact in situ

The tool referenced “Masol 1 North 2017 - 261” is an unifacial chopper shaped on a split cobble of quartzite. This blank had previously been obtained by the knapper by splitting in half the cobble placed on an anvil: one percussion on the cobble demonstrates the use of a freehand hammerstone to obtain two half split pebbles which were then shaped as a chopper (Fig. 10 and 11). The thinnest part of the support was shaped: 3 short, inverted, contiguous and overlapping removals were extracted to obtain a straight, slightly denticulated cutting edge, the average of fairly acute angle is  $66^\circ$ . The edges of the chopper are fresh and not blunt. There was no post-depositional transport.

Figure 10 - Masol 1 North 2017 number 261: chopper on quartzite split cobble (photo and drawing Dominique Cauche).

Figure 10 - Masol 1 Nord 2017 n° 261: chopper sur galet fendu en quartzite (photo et dessin Dominique Cauche).

Figure 11. Masol 1 North 2017 number 261: inferior face and profile (photo and drawing Dominique Cauche).

Figure 11. Masol 1 Nord 2017 n° 261: face inférieure et profil (photo et dessin Dominique Cauche).

These removals were extracted from the cortical surface of the support towards the lower surface (Fig. 10 and 11), as is most often the case among the other choppers discovered in the various paleonto-archaeological localities of Masol. The chopper is of modest dimensions: 91 x 75 x 30 mm but quite homogeneous with the average of the choppers from the other localities. During the 2017 field season, a total of 68 pieces was collected at Masol 1, Masol 2 and Masol 6, including 17 choppers. The average dimensions of these 17 choppers are 107.5 x 76.4 x 52 mm, with an average cutting angle of 62.9°. In addition, the shaping of choppers on split cobbles is also an important feature of Masol's industry: indeed, among the 17 choppers of 2017, 9 are shaped on split.

#### 4. Study of the Masol 1, Masol 2 and Masol 6 artifacts

The lithic industries recovered at the three major Masol localities 1, 2 and 6, delivered the largest number of artifacts. Their erosional context has been studied

during each field campaign, and we can sustain that a post-Siwalik making is geologically unlikely given the rapidity of erosion observed during the last 10 years.

#### 4.1 Masol 1 artifacts

During the 2017 field season, 4 new lithic artifacts were discovered at Masol 1, in and on the silts c3: the in situ chopper, two flakes (Fig. 12) and a split cobble, bringing to 23 the total number of pieces since the beginning of the fieldworks. This locality provides in majority the choppers (n=13), two split cobbles, one core (Fig. 13, number 6) and seven “ordinary” flakes (Fig. 12 and Fig. 13, numbers 1 to 5).

Five choppers are shaped on split or large flake, and nine are end choppers. When they are shaped on split or large flake, the cutting edge is shaped by extracting removals from the cortical surface towards the fracture plane of the support.

Figure 12 - Masol 1, 2017, quartzite flakes. 1- semi-cortical flake with smooth platform, Siret fracture and two longitudinal-unipolar removal negatives, 2- semi-cortical flake with cortical platform, Siret fracture and longitudinal-unipolar removal negatives. 1: Masol 1-260; 2: Masol 1-287 (photo and drawing Dominique Cauche).

Figure 12 - Masol 1, 2017, éclats en quartzite. 1- éclat semi-cortical à talon lisse, fracture de Siret et deux négatifs d'enlèvements longitudinaux unipolaires, 2- éclat semi-cortical à talon en cortex, fracture de Siret et négatifs d'enlèvements longitudinaux unipolaires. 1: Masol 1-260; 2: Masol 1-287 (photo et dessin Dominique Cauche).

The flakes are produced either by shaping the choppers or by *débitage* of the cores. The striking platforms are almost exclusively cortical, the anterior removals on the upper surface are few and most often of unipolar longitudinal pattern. However, on two of them (Fig. 13, numbers 4 and 5), the scars disposition can be bipolar, and orthogonal. In the latter two cases, the flakes are from core reduction sequences.

The core on quartzite pebble (Fig. 13, number 6) shows a first unidirectional reduction sequence from a single cortical striking platform, then a slight rotation of the core to produce a removal almost perpendicular to the other removals, again from a cortical striking platform. This core was flaked by direct free-hand percussion and shows no characteristics of the bipolar-on-anvil technique.

Figure 13 - Masol 1, quartzite flakes and core. 1- flake with cortical platform, single longitudinal removal negative and one reverse removal negative; 2- semi-cortical small flake, with cortical platform and single longitudinal removal negative; 3- flake with cortical platform and Siret fracture; 4- flake with cortical platform and multiple longitudinal bipolar removal negatives; 5- flake with cortical platform and multiple bipolar and orthogonal removal negatives; 6- core with cortical striking platform, whose removals are mainly unipolar except one orthogonal. 1: Masol 1-1; 2: Masol 1-16; 3: Masol 1-8; 4: Masol 1-27; 5: Masol 1-40; 6: Masol 1-4 (drawing Dominique Cauche).

Figure 13 - Masol 1, éclats et nucléus en quartzite. 1- éclat à talon cortical, avec un seul négatif d'enlèvement longitudinal et un négatif d'enlèvement inverse; 2- petit éclat semi-cortical, à talon en cortex et un unique négatif d'enlèvement longitudinal; 3- éclat à talon cortical et fracture de Siret; 4- éclat à talon cortical et multiples négatifs d'enlèvements longitudinaux bipolaires; 5- éclat à talon cortical et multiples négatifs d'enlèvements orthogonaux et bipolaires; 6- nucléus à plan de frappe cortical, à enlèvements tous unipolaires sauf un orthogonal. 1: Masol 1-1; 2: Masol 1-16; 3: Masol 1-8; 4: Masol 1-27; 5: Masol 1-40; 6: Masol 1-4 (dessin Dominique Cauche).

#### 4.2 Masol 2 artifacts

Masol 2 has yielded a large number of lithic artifacts (157 in total, 22 in 2017), forming an assemblage where heavy-duty tools are predominant (55.5%) ; the

cores are rare (3 pieces, 1.9%), but the flakes (52 pieces) and the percussors (11 pieces) are many.

Several large flakes/splits, obtained by bipolar-on-anvil percussion, are present, some of which are shaped as chopper (Fig. 14, number 1). The many choppers (including ¼ are “simple”, with single-removal) are most often on pebble (Fig. 14, number 2). Among the small flakes ("ordinary" flakes, Gaillard et al., 2016), some clearly show their production by bipolar-on-anvil percussion, that they had been used (Fig. 14, number 3) and even sometimes retouched (Fig. 14, number 7). Masol 2-276 (Fig. 14, number 8) shows more rough and irregular but nevertheless well marked retouch.

A large part of the ordinary flakes found are the by-products of the shaping of Masol choppers (cores are very rare), and it is possible to recognize some of them as Masol 2-272 (Fig. 14, number 6) which is typical of the shaping of Masol choppers, from the cortical surface towards the fracture plane of the flake/split which is its support (see Fig. 11 and Fig. 14, number 1). The raw and retouched flakes number 4 to number 8 in Fig. 14 have been discovered during the 2017 field season.

Figure 14 - Masol 2: quartzite choppers, raw and retouched flakes. 1- side chopper shaped on a pebble previously split by bipolar percussion on anvil. Double opposite bipolar impact points are present; 2- simple end chopper on pebble, with transverse cutting edge obtained by lateral removal; 3- fully cortical flake obtained by bipolar-on-anvil technique, with chipping due to the use of the sharp edge. Opposite double impact points are present; 4- cortical flake with smooth diedral platform, and showing retouch of use on the cutting edge; 5- flake with cortical platform and retouch of use; 6- flake with cortical platform, unipolar removal negatives and distal residue of inferior face of split; 7- fully cortical flake obtained by bipolar-on-anvil technique, then retouched in denticulate; 8- flake with cortical platform, unipolar removal negatives, and irregular retouch on the cutting edge. 1: Masol 2-63; 2: Masol 2-29; 3: Masol 2-241; 4: Masol 2-277; 5: Masol 2-274; 6: Masol 2-272; 7: Masol 2-275; 8: Masol 2-276 (drawing Dominique Cauche).

Figure 14 - Masol 2 : choppers, éclats bruts et retouchés, en quartzite. 1- chopper latéral aménagé sur galet préalablement fendu par percussion bipolaire sur enclume. Deux points d'impact bipolaires opposés sont présents; 2- chopper simple sur galet, dont le bord tranchant transversal à été obtenu par un enlèvement latéral; 3- éclat totalement cortical obtenu par percussion bipolaire sur enclume, montrant des esquillements d'utilisation du bord tranchant. Les deux points d'impact opposés sont présents; 4- éclat cortical à talon dièdre lisse, et montrant des retouches d'utilisation du bord tranchant; 5- éclat à talon cortical et retouches d'utilisation; 6- éclat à talon cortical, à négatifs d'enlèvements unipolaires et un

résidu distal de la face inférieure du galet fendu initial; 7- éclat totalement cortical obtenu par percussion bipolaire sur enclume, puis retouché en denticulé; 8- éclat à talon cortical, avec négatifs d'enlèvements unipolaires et retouches irrégulières sur le bord tranchant. 1: Masol 2-63; 2: Masol 2-29; 3: Masol 2-241; 4: Masol 2-277; 5: Masol 2-274; 6: Masol 2-272; 7: Masol 2-275; 8: Masol 2-276 (dessin Dominique Cauche).

#### 4.3 Masol 6 artifacts

The locality of Masol 6 has delivered a total of 87 lithic artifacts, including  $\frac{3}{4}$  heavy-duty tools (mainly choppers and large pebble splits). Only one core is identified (1.1%, Fig. 18). The ordinary flakes, produced by core reduction sequences and chopper shaping, are relatively numerous: 19 flakes, 2 of which are retouched. The main characteristic of the industry in this area is the high number of splits and large flakes (20 in total) obtained by bipolar-on-anvil percussion. Some of the large cutting flakes show marks of their use on the cutting edge (Fig. 17, number 2 and 3).

The 2017 field season was particularly rich in fossil fauna (*Stegodon*, turtle eggs, small herbivores) and lithic artifacts. A total of 20 lithic pieces were collected in the colluviums or on the silts being eroded. The material includes the same types of lithic artifacts than during the previous fieldworks (Gaillard et al., 2016): simple choppers (Fig. 15), choppers, split pebbles, bipolar large flakes some of

which are retouched or show traces of their use (Fig. 17), and so-called "ordinary" flakes of smaller dimensions. The novelties are two large anvils (Fig. 16), one core (Fig. 18) and one hammer.

Figure 15 - Masol 6N 2017 number 300: simple end chopper on quartzite pebble (drawing and photo Dominique Cauche).

Figure 15 - Masol 6N 2017 n° 300 : chopper primaire en bout de galet en quartzite (dessin et photo Dominique Cauche).

Each anvil is a macro-crystalline quartzite half pebble that was previously fractured in half, and this fracture plane was likely used as a stable base for each anvil (Fig. 16, down). Indeed, at the top of the curved face is in one case a deep cup (Fig. 16, number 1) and in the other case a large irregular cup associated with a perpendicular fracture of the anvil (Fig. 16, number 2).

Figure 16 - Masol 6N 2017: two anvils in the form of macro-crystalline quartzite half-pebbles. At the top, the upper curved surfaces with the traces of the

percussion. At the bottom, the lower surfaces in the form of fracture planes. 1: Masol 6N-306; 2: Masol 6N-292 (photo Dominique Cauche).

Figure 16 - Masol 6N 2017: deux enclumes sous la forme d'hémi-galets en quartzite macro-cristallin. En haut, les deux surfaces bombées avec les traces de percussion. En bas, les faces inférieures correspondant à des fractures planes. 1: Masol 6N-306; 2: Masol 6N-292 (photo Dominique Cauche).

The smaller of the two anvils (number 306), with an almost rounded outline, is 143 x 122 x 53 mm. The largest anvil (number 292), with a more oval outline, is 182 x 121 x 81 mm. The violence of the impact shocks not only left traces in the form of a large cup, but also fractured part of the anvil in one case.

These percussion marks on these anvils are evidence of the violence of the strikes and are in logical proportion to the large flakes and splits produced, that are found among the material (Fig. 17).

Figure 17 - Masol 6N 2017: large macro-crystalline quartzite flakes, raw or retouched, produced by bipolar-on-anvil percussion. 1- large flake with cortical platform and cortical distal edge, *Siret* accident and bipolar removal negatives; 2- large cortical flake showing many chips and retouches on the cutting edge; 3- large flake with cortical platform and cortical lateral edges. The left cutting edge

shows denticulated retouch. 1: Masol 6N-305; 2: Masol 6N-293; 3: Masol 6N-307 (drawing and photo Dominique Cauche).

Figure 17 - Masol 6N 2017: grands éclats de quartzite macro-cristallin, bruts ou retouchés, produits par percussion bipolaire sur enclume. 1- grand éclat à talon et bord distal en cortex, accident de Siret et négatifs d'enlèvements bipolaires ; 2- grand éclat cortical montrant de nombreux écrasements et retouches sur le bord tranchant ; 3- grand éclat à talon et bords latéraux corticaux. Le bord tranchant gauche présente des retouches denticulées. 1: Masol 6N-305; 2: Masol 6N-293; 3: Masol 6N-307 (dessin et photo Dominique Cauche).

These large bipolar percussion products are massive: for example, the macro-crystalline quartzite large flake (Fig. 17, number 1) measures 110 x 90 x 48 mm. The platform and the distal part are cortical, there is a *Siret* accident and the removal negatives pattern is longitudinal and bipolar due to the percussion on anvil. Another massive macro-crystalline quartzite flake at Masol 6 measures 153 x 98 x 50 mm (Fig. 17, number 3) and was produced also by bipolar technique. The platform is cortical, as well as the two lateral edges. The left cutting edge shows denticulated retouching over an area of 45 mm. Another large massive macro-crystalline quartzite flake was present at Masol 6 (Fig. 17, number 2). It measures 165 x 140 x 55 mm and is also produced from bipolar technique. Its upper surface is cortical, and on the lower surface a percussion point is visible, as

well as a hollow bulb. One of the sharp edges, very extensive, shows evidence of its use.

Other flakes of varying sizes, splits pebbles and fractured pebbles are also witnesses of bipolar technique at Masol 6.

The M6's collection counts one core. This artifact is an angular pebble of good quality microcrystalline quartzite (Fig. 18). Two main flakes were obtained from the same cortical striking platform, but on two adjacent sides. These flakes are of modest dimensions (40 x 55 mm and 40 x 38 mm). This core was probably flaked by direct freehand percussion, we cannot see on it evidences of bipolar-on-anvil technique. The production of flakes by core reduction was not a frequent activity in general, the predominant technology was the shaping of choppers, mostly with few and unifacial removals, as well as the fracturing of pebbles by bipolar percussion (often cleaving of pebbles according their wide plan), in order to obtain blanks that were often large in size, with sharp edges and usable as such or sometimes shaped as choppers or retouched.

Figure 18 - Masol 6N 2017 number 298: core on angular pebble of microcrystalline quartzite. The striking platform is unique and cortical, and the unipolar removals on two adjacent surfaces of the pebble (drawing and photo Dominique Cauche).

Figure 18 - Masol 6N 2017 n° 298 : nucléus sur galet anguleux en micro-quartzite. Le plan de frappe est unique et cortical, et les enlèvements sont unipolaires sur deux surfaces adjacentes du galet (dessin et photo Dominique Cauche).

#### 4.7 Masol 6-North artifacts, field season 2019

The sector of Masol 6-North is typical of the erosional context which provided every year new fossils and artifacts. The 2019 field season collected 14 artifacts and 18 fossils (turtle, bovids, *Stegodon*) and 20 bone splinters. Fossils and artifacts are coming from the silts in situ, whose the dip and the inclination of the eroded outcrops are in the opposite direction of the natural slope (Fig. 19). The study of this lithic collection is in progress (Singh et al.).

Figure 19- Masol 6-North. On the left, the silts c6 and sandstone s6 in situ, on the right, the outcrops of the silts c6 in the direction of the dip magnified by the erosion, with cobbles and one chopper near a large dark block of silt (and handle of a hammer). The tool was 2 meters below a large splinter of a long bone (picture A. Dambricourt Malassé 2019).

Figure 19- Masol 6-Nord. A gauche, les limons c6 et le grès s6 in situ, à droite, les affleurements des limons c6 dans le sens du pendage amplifié par l'érosion, avec des galets et un chopper près d'un gros bloc de limon foncé (et le manche du

marteau). L'outil lithique se trouvait à 2 mètres sous une grande esquille d'os long (photo A. Dambricourt Malassé 2019).

## 5. Review of the study

At the end of the 2017 field season, Masol's industry totals 308 pieces, including the material from localities Masol 7 to 13. This industry is characterized by:

- the predominance of large/heavy-duty tools for nearly 50% of all parts (mainly simple choppers or choppers with rare removals, and some chopping-tools, and large flakes/splits)
- the high frequency of artifacts obtained by bipolar technique (especially large flakes and splits of cobbles)
- the scarcity of cores (less than 2%) and therefore the low frequency of reduction sequences.

We consider 3 types of *chaînes opératoires* that can be linked to each other:

- the cleavage (split fracture) of the large cobbles along their wide plane or their oblique fracturing, by bipolar-on-anvil technique. The blanks obtained, most often of large dimensions, are either used, raw or retouched, or shaped as choppers (unifacial or bifacial), which corresponds to the second *chaîne opératoire*

- the shaping of tools on entire, fractured or split cobble, which is the main *chaîne opératoire* that produces the most common tools and most of the by-products, namely small flakes (so-called "ordinary" flakes)
- the production of flakes on cores, the least frequent *chaîne opératoire* and also showing very short, simple reduction sequences.

There are no terrasses in the silts but patches of pebbles and cobbles brought from the Himalayan terrasses by the rivers during the floods. The raw material is exclusively in macro- or microcrystalline quartzite, a very hard raw material to knap, which imposes a strong constraint. Knappers have adapted to this characteristic by practicing bipolar-on-anvil technique most often, in order to produce effective cutting tools for the treatment of carcasses.

The technical solutions adopted by knappers in Masol are different from the one described in Africa at the very beginning of the Pleistocene. Lithic assemblages of early African Oldowan (Mode I) from the Early Pleistocene (Ethiopia) are characterized by the exclusive production of small flakes by reduction sequences on cores, sequences that could be important in terms of the amount of flakes produced on each core (Semaw et al., 1997, 2003; Stout et al., 2010; Lumley et al., 2018). In an oldest period, at Lomekwi 3 in Kenya dated to 3.3 Ma (Harmand et al., 2015; Lewis and Harmand, 2016), knapping strategy was also oriented towards the production of flakes.

On the other hand, the technical features of Masol's industry are to be compared with the industry found at the Longgupo site in China (Huang et al., 1995), where the stratigraphy is dated from 2.2 Ma at a upper layer to 2.5 Ma at a deeper layer (Han et al., 2015). This abundant Longgupo industry (nearly a thousand pieces) has been precisely described (Boëda and Hou, 2011a, b), and its particular characteristics are at the origin of the name "Longgupo culture" (Wei et al., 2014). The heavy-duty tools are predominant (choppers-chopping-tools), bipolar technique is the most frequent, on a very hard raw material (Triassic limestone), with in particular the production of splits (hemi-blocks) and flakes; cores are rare (2.2%), and flakes (called "unipolar") very mainly from the shaping of tools. All these features are found among Masol's lithic assemblages, even with regard to the proportions of retouched flakes. If we compare Masol's lithic collection with that of the Xihoudu site, which has only 39 pieces (Shen et al. 2020), we can see a similarity in technical behavior through the strong representation of the bipolar technique.

## 6. Conclusions

The chopper discovered in situ at Masol 1 shows the characteristics of the heavy-duty tools discovered in the other paleonto-archaeological localities:

- a chopper on split quartzite cobble, therefore with a cortical dorsal face
- dimensions corresponding to the average chopper size (about 10 cm) of Masol industry

- a robust and effective cutting edge, obtained by removing 3 flakes, from the cortical surface to the fracture plane of the split.

This chopper and the artifacts collected from the various localities are in a very good state of conservation: they are not blunt or rolled and edges are sharp. This fresh aspect is in favour of their recent and natural exhumation from the silts in which they were embedded since the late Upper Pliocene. Moreover we observe a great lithic homogeneity between the artifacts of each paleonto-archaeological locality and the quartzite pebbles embedded in the fossiliferous silts. Then the choppers of Masol are simpler than the Soanian industry collected during previous fieldworks on the river terraces outside the Chandigarh anticline (Gaillard and Dambricourt Malassé, 2008; Gaillard et al., 2016). Since one chopper is present in situ in the c3 silts of Masol 1 and taking account the lithostratigraphical and geomorphological conditions, it is quite reasonable to consider the other artifacts of Masol 1 collected on the silts c3 and their colluviums, as part of the same techno-lithic assemblage. Ultimately, we can sustain that the Masol collection recorded since 2008 come from fossiliferous silts in place and being eroded. This lithic production is strongly supported by cut marks on four bones collected in four localities on either side of the anticline axis.

To conclude, the chopper in situ and the indisputable cut marks on bones from the deepest layers of the Quranwala zone, definitively attest that hominins lived in the sub-Himalayan plain during the late Upper Pliocene (Coppens, 2016, 2020;

Dambricourt Malassé et al., 2016a; Li et al., 2017; Prat, 2018; Plummer and Finestone, 2018). This lithic industry associated with fossil fauna, some of them with butchery marks, is the oldest currently described in Asia and the second in the world after Lomekwi 3 (Kenya). Henceforth Masol makes it possible to reconsider the age of artifacts discovered in stratigraphy in the Siwaliks of Pakistan, 5 meters above a paleomagnetic inversion, supporting an age of 2.45 Ma (Dennell et al., 1988) as well as the age of 2.4 Ma for the Xihoudu site, Shanxi Province (Shen et al., 2020). In addition, the strong similarities between the techno-typological features of the Masol and Longgupo industries support the very old dispersal of hominins in Asia (Hou and Zhao, 2010; Li et al., 2017; Zhu et al, 2018; Shen et al., 2020), and resume the question of their settlements in the sub-Himalayan floodplains before 1.8 Ma (Dennell, 2007), we can now conclude an extension outside the Indian subcontinent from the end of the Pliocene (Dambricourt Malassé et al., 2016a, Dambricourt Malassé, 2020).

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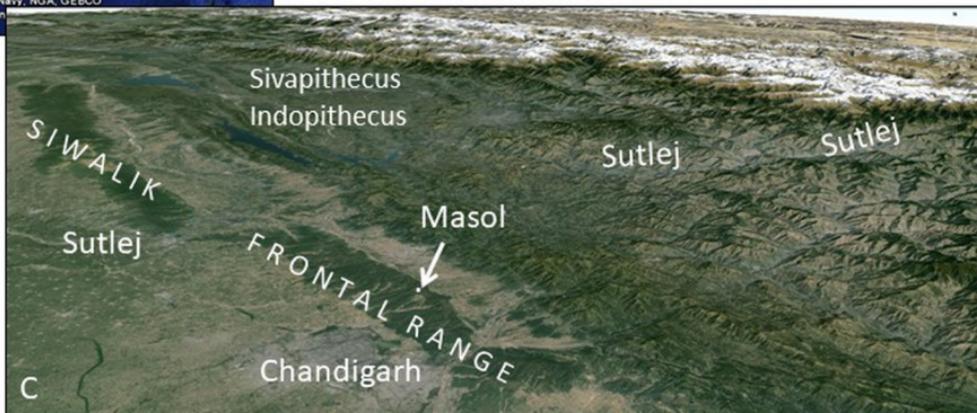
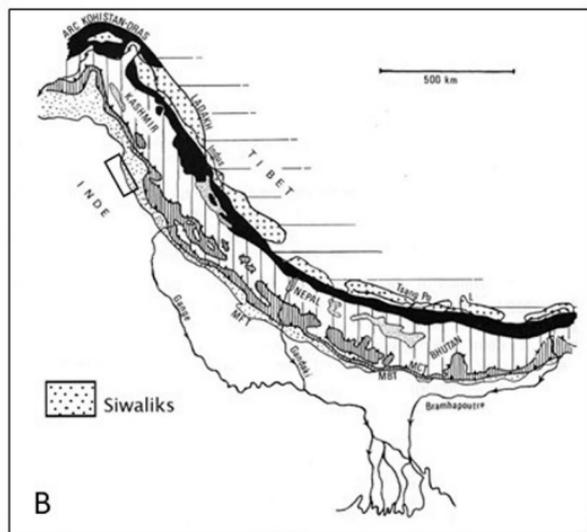
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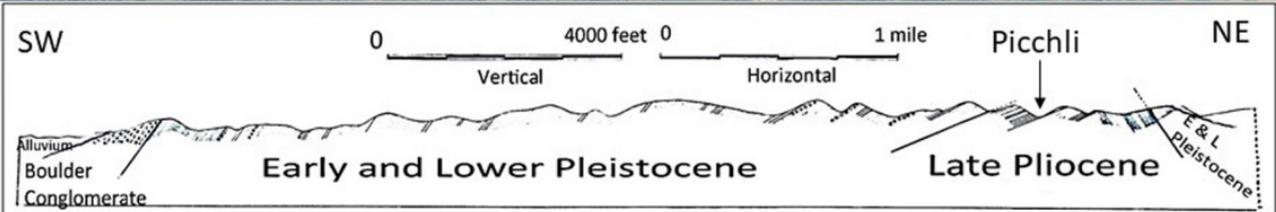
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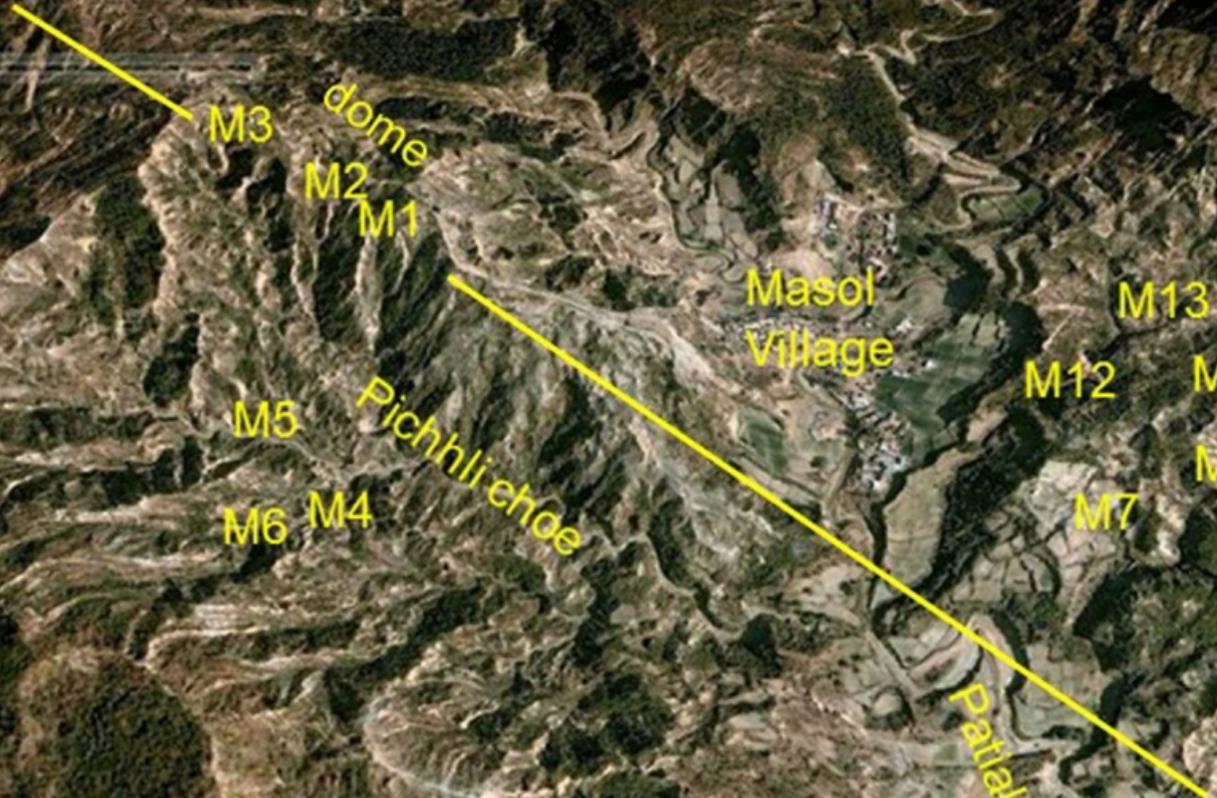
Google Earth  
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23 Janv. 2006



M3 dome  
 M2  
 M1  
 Masol Village  
 M13  
 M12 M11 M10  
 M8 M9  
 M7  
 M5 Pichhli choe  
 M6 M4  
 Patali Rao



277 m

Image © 2015 DigitalGlobe

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Date des images satellite 23 Janv. 2006

30°49'50.78"N 76°50'29.38"E élév. 469 m

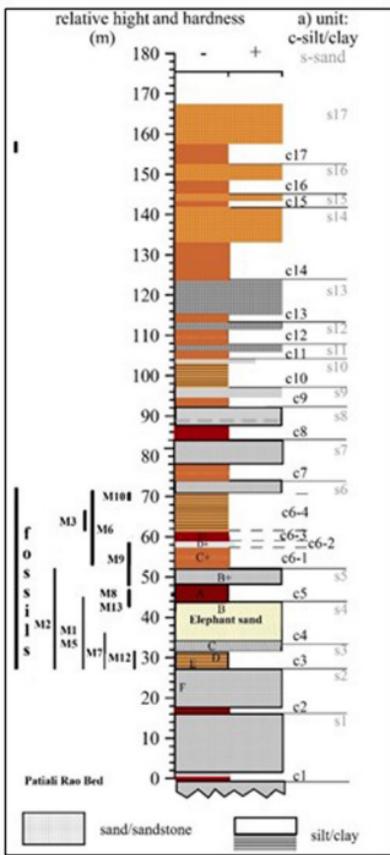
Altitude 2.63 km



c3

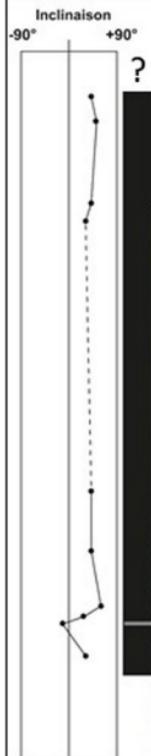
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c3



Tudryn et al., 2016

Gauss  
normal polarity

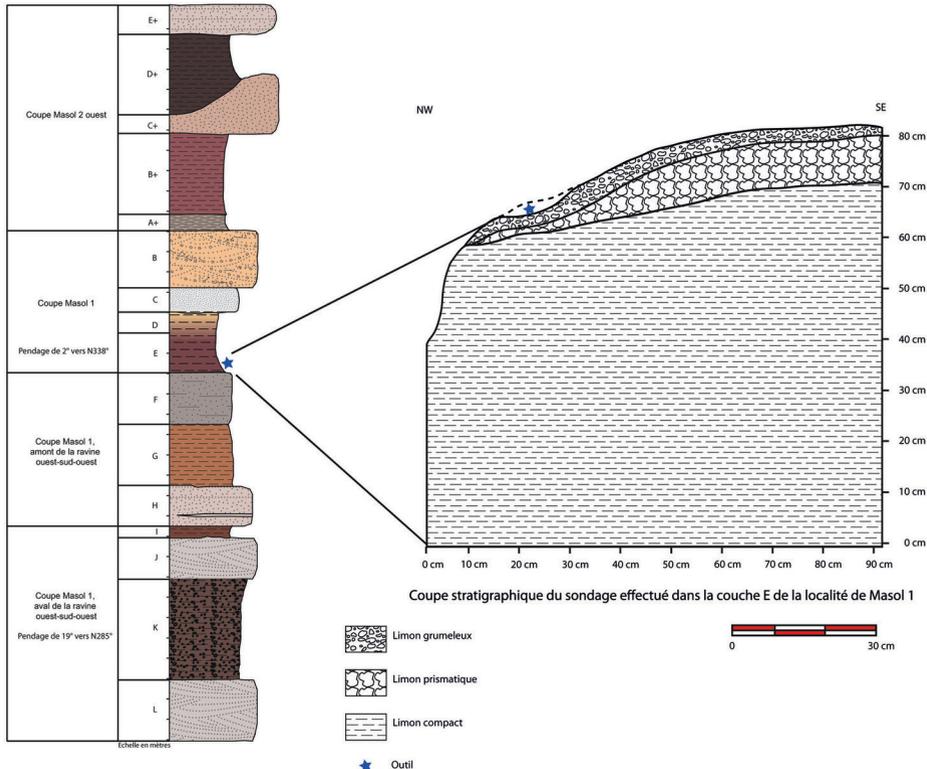


Chapon Sao  
et al., 2018

Masol 1







E+  Fine-grained sandstone, laminated, pale brown, 1.20 m thick

D+  Silt, brown in color, prismatic structure, from 2.50 to 4 m thick

C+  Fine-grained sandstone, from 0.80 to 3 m thick

B+  Silts, wine in color, 4 m thick

A+  Brown silts, 0.80 m thick

B  Medium to coarse-grained sandstone with gravels and clays lenses, interbedded stratification, 2.80 m thick

C  Friable sandstone, whitish grey and locally micaceous, 1.10 m thick

D  Orange silts, 1 m thick

E  Silts, wine in color, 2 m thick

F  Grey sandy silts, 2.50 m thick

G  Yellow-brown silts, 3 m thick

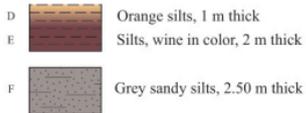
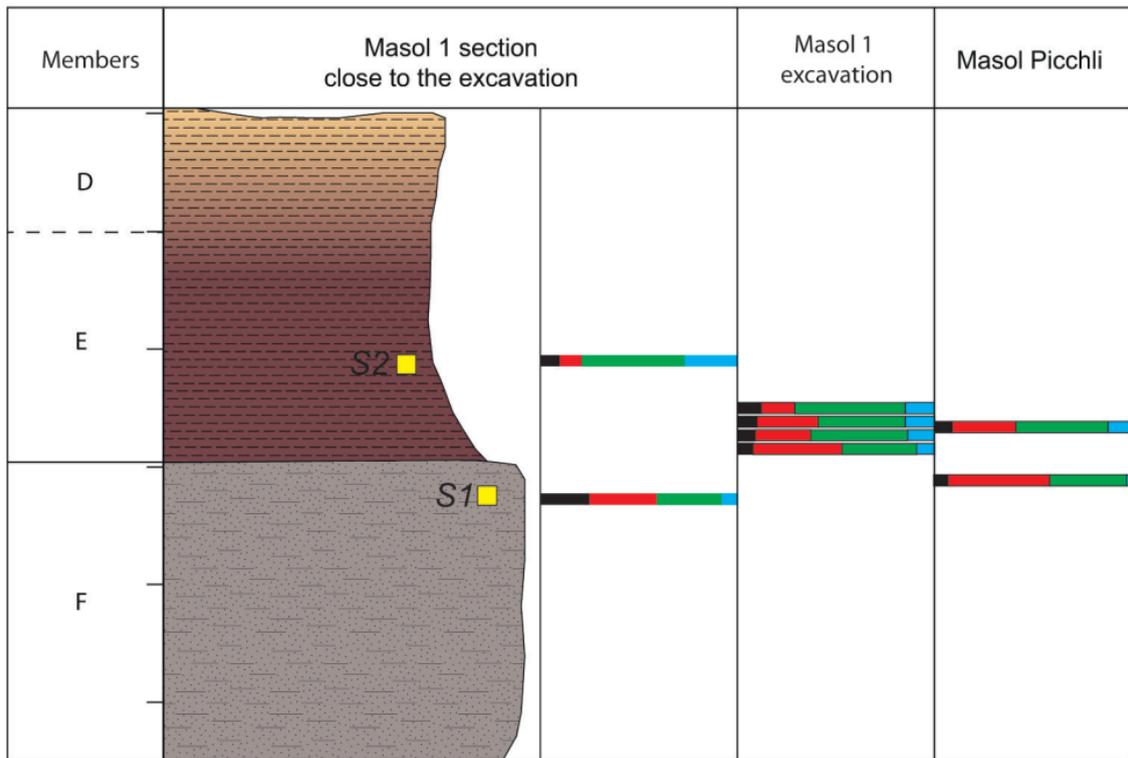
H  Very fine-grained sandstone, 2 m thick, friable, intercalating a thin clay lamina, 5 mm thick and 2 m long. At the top, the sandstone becomes coarser

I  Silts, wine color, prismatic structure, 0.50 m thick

J  Thick sandstone, very hard, cross-bedded, 2 m thick

K  Variegated silts, brown with oxidation marks, yellow-brown in color, with greyish green marks, 2 m thick

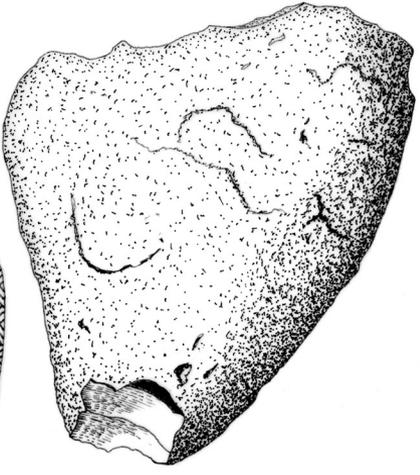
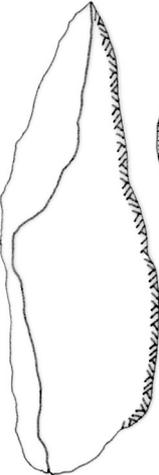
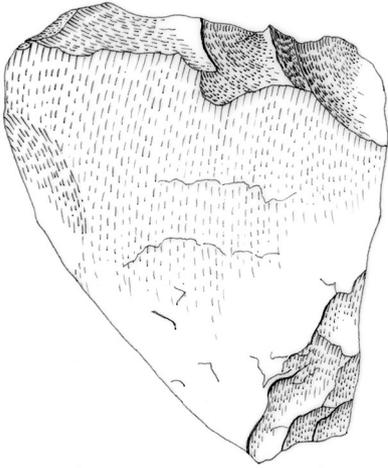
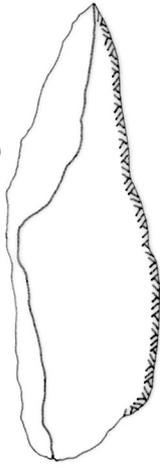
L  Friable sandstone, grey in color, at least 3 m thick. The base of the sandstone outcrops in the bed of Pichlih choe

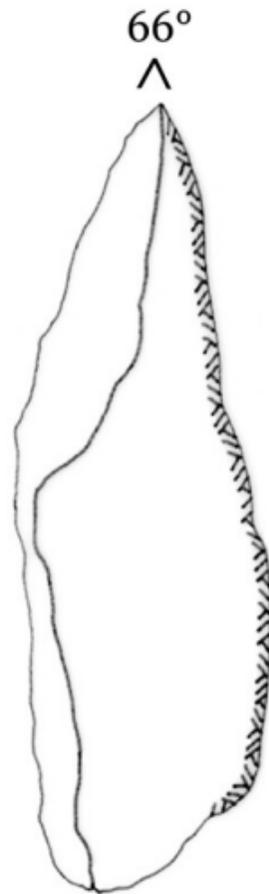
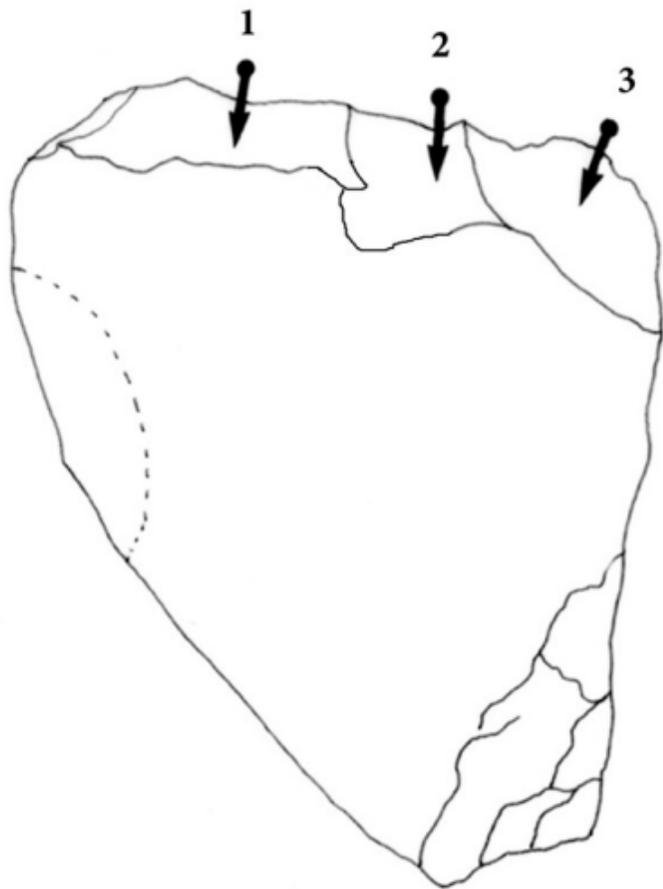




1 cm

10 cm

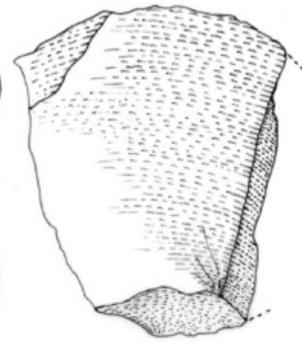
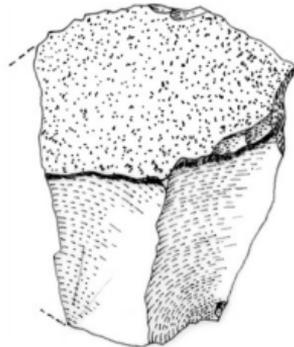




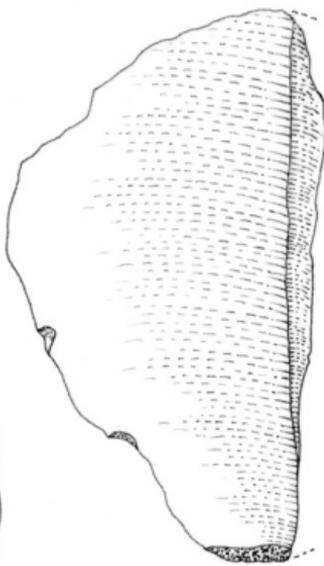
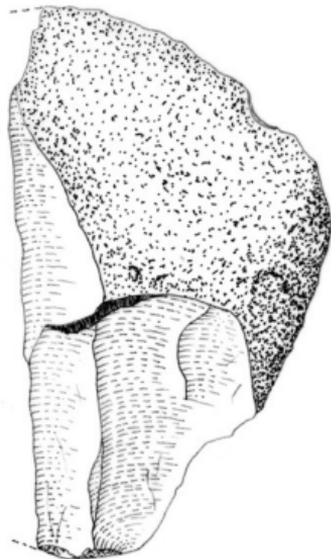
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0

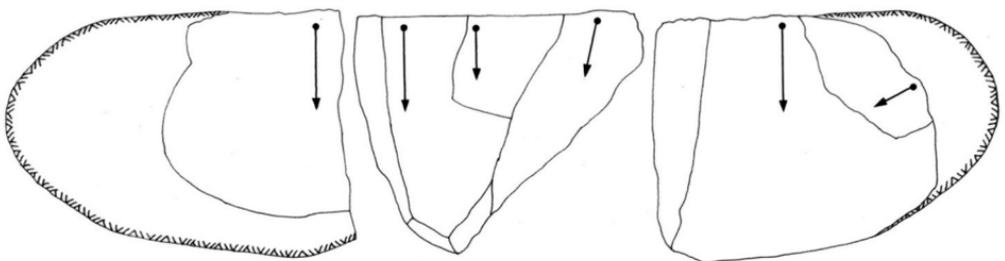
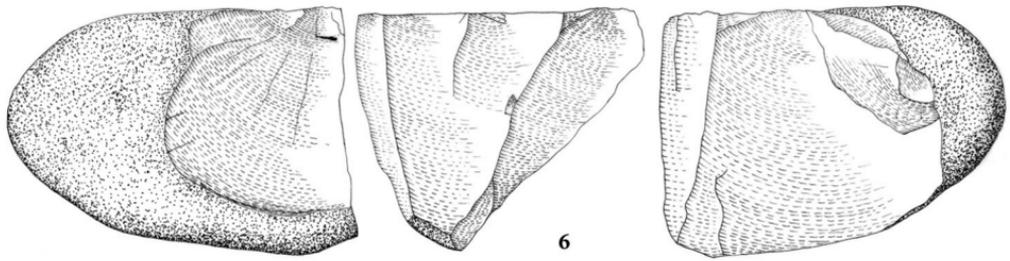
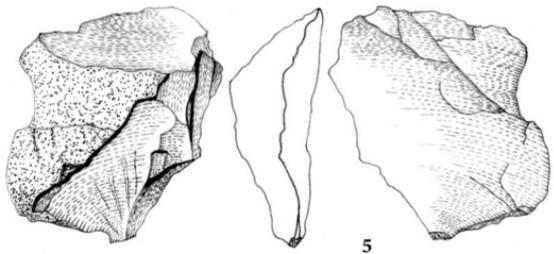
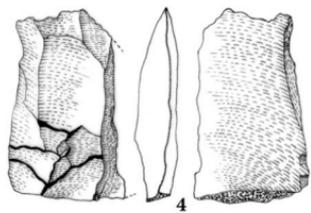
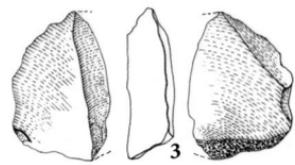
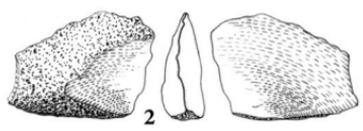
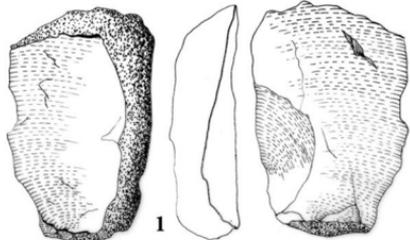


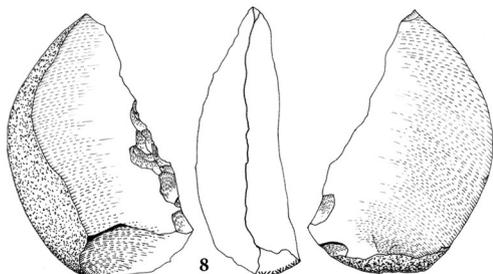
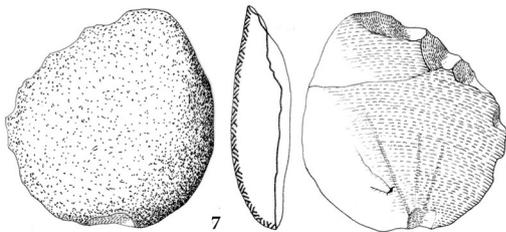
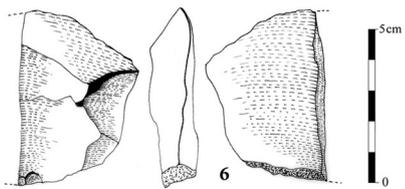
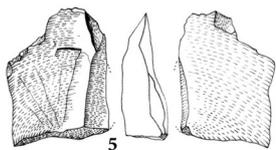
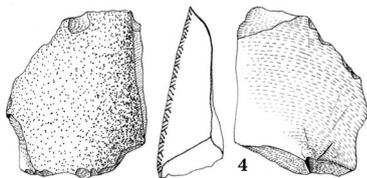
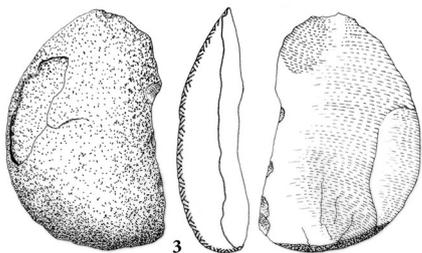
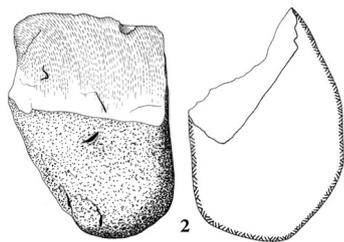
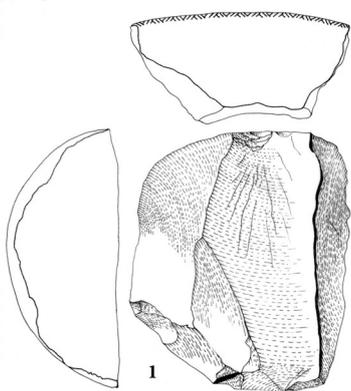
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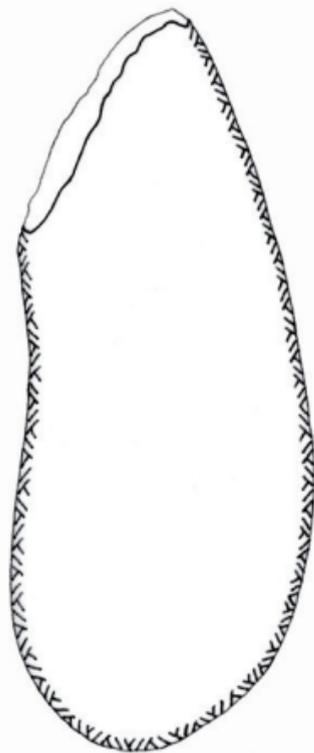
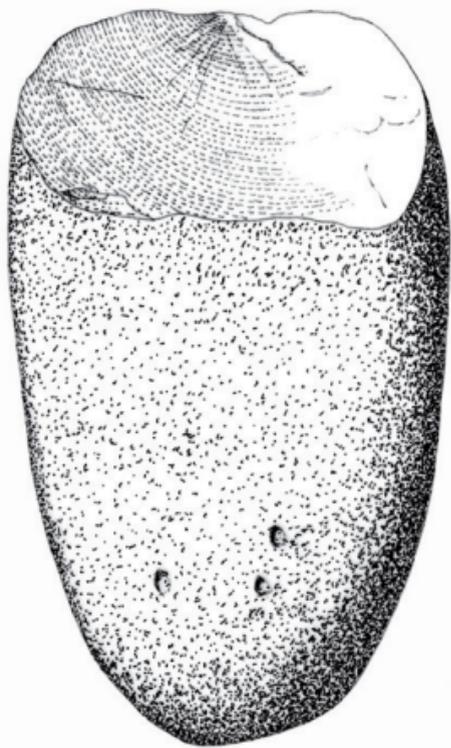


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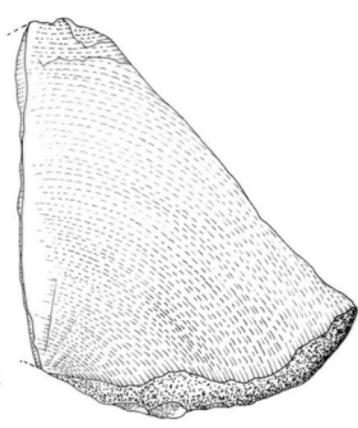
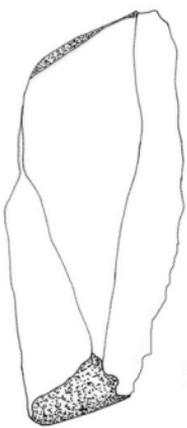
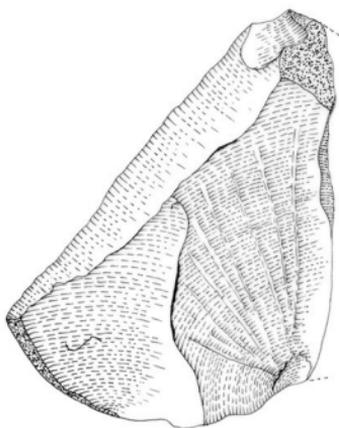




0 5cm







1



2



3

