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Anthropic activities in the fossiliferous Quranwala Zone, 2.6 Ma, Siwaliks of Northwest India, historical context of the discovery and scientific investigations

Des activités anthropiques dans la zone fossilifère de Quranwala, 2,6 Ma, Siwaliks du Nord-Ouest de l'Inde, le contexte historique de la découverte et les investigations scientifiques

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A R T I C L E I N F O

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A B S T R A C T

The Siwaliks came to be known worldwide since the discovery in 1830 of a great ape in the Miocene molasses of the Potwar. One century later, pebble tools, flakes and handaxes attracted Prehistorians. A re-reading of the Yale-Cambridge Expedition in India (1935), during which *Ramapithecus brevirostris* was discovered, reveals that stone tools were discovered in the Upper Pliocene gravels of the Soan Basin. Since 2003, the National Museum of Natural History (France) and the Society for Archaeological and Anthropological Research (India) have conducted fieldwork in the northwestern Indian Siwaliks. The Quranwala Zone of Masol, the core of the Chandigarh anticline (Punjab), is well known for its Late Pliocene fauna rich in *Hexaprotodon*, *Cholossochelys*, *Stegodon*, bovids and *Hipparion* with the occurrence of *Equus* and *Elephas.* Fifty hectares have been surveyed during eight field seasons (2008 to 2015) with the discovery of choppers and marks on bones of the Quranwala Zone faunal assemblage, all collected on recent outcrops of the Latest Pliocene. This paper presents the historical context and the rigorous scientific process, which has led to the acknowledgment that some bones, dating back to the Latest Pliocene, present intentional and precise cut marks made by sharp edges in quartzite and an intelligence, which knew the anatomy of the bovid carcasses. Our pluridisciplinary works support anthropic

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activities 2.6 Ma ago in the sub-Himalayan floodplain and the probability of finding hominin fossils in the Quranwala Zone. This discovery is of immense importance to maintain the efforts of numerous generations in order to develop the prehistory of the Siwaliks and its contribution to the understanding of the hominization process between the Indus Basin, High and East Asia.

Mots clés :
Chaîne frontale des Siwaliks
Inde
Pliocène final
Traces de boucherie
Choppers
Plaine d'inondation sous-himalayenne
Hominiens

R É S U M É

Les Siwaliks sont mondialement connues depuis la découverte en 1830 d'un grand singe dans les molasses miocènes du Potwar (Pakistan). Un siècle plus tard, des galets aménagés, des éclats puis des bifaces attirent les préhistoriens. Une relecture de la Yale-Cambridge India Expedition (1935), à l'origine du *Ramapithecus brevirostris*, révèle la collecte d'outils dans des graviers du Pliocène supérieur du bassin de la rivière Soan. Depuis 2003, le Muséum national d'histoire naturelle (France) et la Society for Archaeological and Anthropological Research (Inde) mènent des recherches dans les Siwaliks du Nord-Ouest de l'Inde. La Zone Quranwala de Masol, le cœur de l'anticlinal de Chandigarh, est connue pour sa faune du Pliocène tardif riche en *Hexaprotodon*, *Stegodon*, *Cholossochelys* et *Hipparion*, avec présence d'*Equus* et *Elephas*. Cinquante hectares ont été prospectés pendant huit campagnes de terrain (2008–2015) après la découverte de choppers et des traces sur quelques os fossiles de la zone Quranwala, tous collectés sur les récents affleurements du Pliocène final. Cet article présente le contexte historique et la démarche scientifique longue et rigoureuse qui aboutit à la reconnaissance de traces de découpe sur quelques os fossiles de la fin du Pliocène. Ces traces ont été faites avec des tranchants en quartzite par une intelligence qui connaissait l'anatomie des carcasses de bovidés. Nos recherches pluridisciplinaires aboutissent à la conclusion d'une activité anthropique il y a 2,6 Ma dans la plaine d'inondation sous-himalayenne et donc à de probables fossiles humains dans la zone Qurawala. La découverte est d'une immense importance pour maintenir les efforts de nombreuses générations soucieuses du développement de la préhistoire dans les Siwaliks et de sa contribution à la compréhension des processus d'hominisation entre le bassin de l'Indus, la Haute Asie et l'Asie orientale.

1. High Asia and the origins of *Homo* genus

The Quaternary fauna and Neogene (Mio-Pliocene) of the Upper Indus Basin have been known since the end of the 19th century, and has forged the interest of paleontologists in the origins of Man in Asia, a century before the great explorations in the East African rift valley. Thus the Upper Indus Basin is the oldest part in the world where scientists began searching the evolutionary process capable of transforming the semi-erect anatomy of apes to the vertical human anatomy. The North of the Indian subcontinent and the Rift Valley share similarities. Tectonics is the most significant since it exhumes preferentially for several hundred kilometers, Tertiary and Quaternary fossiliferous formations, either by compression and elevation (Asia), or by rifting and collapse (Africa).

The Himalayan and Hindu Kush ranges, the Tibet and Pamir plateaus have resulted from the collision of the Indian and Asian plates; for this reason, North India belongs geographically to High Asia (Fig. 1). The Quaternary and Neogene correspond to the Siwaliks that extend from Pakistan to Bhutan (Fig. 2). These continental deposits contain species of great ape in the Miocene deposits, collected mostly in the North-West of the Siwaliks (e.g., Gilbert et al., 2014; Pickford and Tiwari, 2010; Pilbeam et al., 1977), and numerous stone tools, the oldest known in stratigraphy in Lower Pleistocene conglomerates in Pakistan dated over 2 Ma (Dennell et al., 2006). In contrast the southeastern Siwaliks are devoid of Pleistocene industries (Sarma and Hazarika, 2014). A historical synthesis has been recently published giving a rich bibliography (Chauhan, 2008). The dating of these stone tools industries and their relationships through time are the main focus of the research on prehistory in this region of Asia where the Indus Basin occupies a favorable geographical position for migration between the Arabo-African plate and Central Asia (Dambricourt Malassé, 2008; Dambricourt Malassé and Gaillard, 2011; Gaillard and Dambricourt Malassé, 2008).

Nevertheless the absence of human fossils in the Lower Pleistocene, or even in the Late Pliocene, constitutes a major handicap for the understanding of the origins and evolution of the genus *Homo* in this vast Asian biome. Indeed, the emergence of *Homo* anatomy in Eastern Africa is estimated at 3-million-years minimum (Coppens, 2013). The different evolutions of the nervous system revealed by the brain endocast (e.g., Falk et al., 2009) and also by the endocranial skull base (Dambricourt Malassé, 1993, 2006; Dambricourt Malassé et al., 1999), the different biological adaptations to climate and altitude, endemism or genes flow, directions of migrations and hybridization, are, however, essential to understanding the geographical and temporal distributions of many pebble tool industries in these southern borderlands of High Asia (Gaillard et al., 2002, 2008, 2010a, b, 2011, 2012, 2016). The explorations

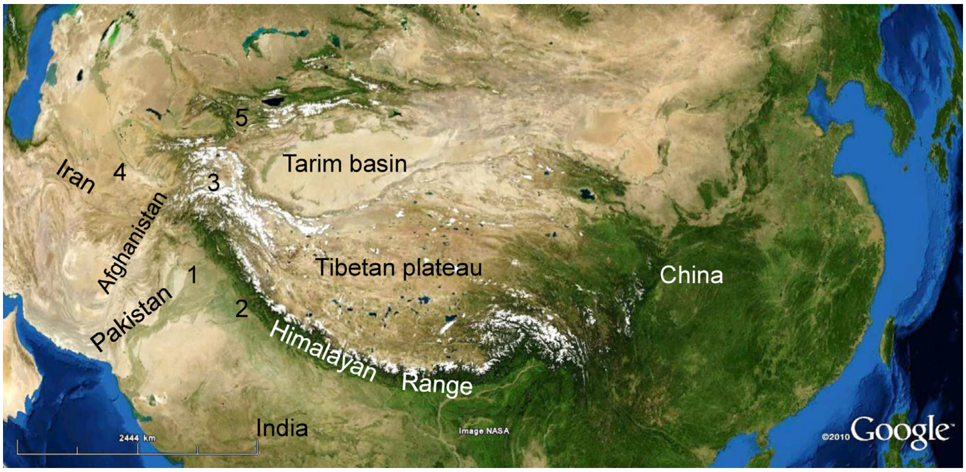

Fig. 1. Geographical map of High Asia. 1: Upper Indus Basin and Potwar Plateau (Pakistan); 2: Upper Indus Basin and Siwalik Frontal Range (State of Punjab, India); 3: Pamir plateau (Tajikistan); 4: Amu Darya Basin (Uzbekistan); 5: Kirghizstan (Google Earth modified).
Fig. 1. Carte géographique de la Haute-Asie. 1 : Bassin supérieur de l'Indus et le plateau de Potwar (Pakistan) ; 2 : bassin supérieur de l'Indus et la chaîne frontale des Siwaliks (État du Punjab, Inde) ; 3 : plateau de Pamir (Tadjikistan) ; 4 : bassin de l'Amou-Daria (Ouzbékistan) ; 5 : Kirghizstan (d'après Google Earth, modifié).

of karsts in the calcareous mountainous massifs and in the fossiliferous formations are therefore a permanent necessity (e.g., Patnaik et al., 2005; Sankhyan, 1985; Sharma, 1984).

As Dennell (2010) concluded: "we cannot be certain that hominins did not disperse out of Africa shortly after or even before stone tool-making became routine ca. 2.6 Ma". The discovery of anthropic activities in the Latest Pliocene of Indian Siwaliks (Coppens, 2016; Dambricourt Malassé, 2016; Dambricourt Malassé et al., 2016) contributes to the debate on the very old presence of *Homo* in Mainland Asia (Gao and Wang, 2010), supported by the recent dating of the human settlement in Longgupo Cave (Wushan county), which now reaches 2.48 Ma (Han et al., 2015).

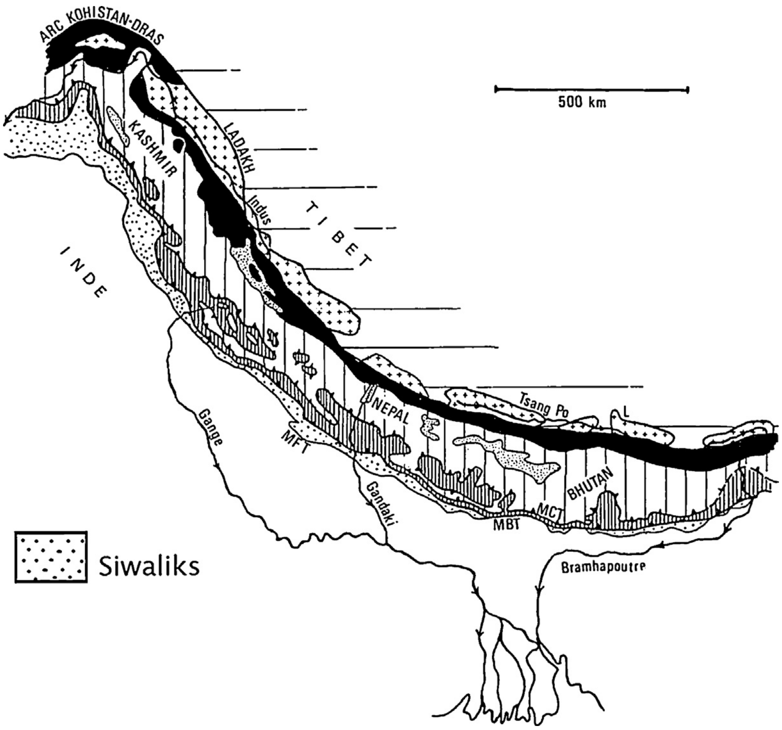

Fig. 2. Map of the Siwaliks in the sub-Himalayan range.
Fig. 2. Carte des Siwaliks dans la chaîne Sous-Himalayenne.

2. The Upper Indus Basin

The areas less compressed by tectonics are the Potwar Plateau and the Pabbi Hills in Pakistan, and the Siwalik Frontal Range (or Siwalik Range) along the sub-Himalayan floodplain in India. Together they form the plains of Punjab. The Potwar extends over 12,000 km^2 (Barry et al., 2012) or > 20,000 km^2 (Winkler et al., 2011), from the foothills of Kashmir, limited by the Indus in the west and by the Jhelum in the south and east (Fig. 3). This plateau is a gigantic Mio-Plio-Pleistocene molasse composed of detrital deposits resulting from the uplift of the Tibetan Plateau, in unconformity on Eocene formations (Warwick, 2007). Some of these deposits appear without disruption from the Upper Pliocene to the Middle Pleistocene, which places the Indus Basin among the few areas in the world where hominids are likely to be visible over such a long period (Dennell et al., 2006). The Siwaliks extend towards India beyond the Pabbi Hills in two geomorphological structures: on the one hand, the Himalayan foothills of Jammu, followed towards the south by those of Himachal Pradesh, and, on the other hand, the Siwalik Frontal Range (SFR) separated from the foothills by a corridor named Dun (or Doon) (Figs. 3 and 5). The explorations became frequent in the Potwar after the discovery, in 1830, of the first fossilized ape ever seen in Mainland Asia (*Sivapithecidae*). Nearly two centuries of research offer today a well-documented magnetostratigraphic and paleo-environmental framework (e.g., Barry et al., 1980, 1982, 2012; Johnson et al., 1982; Dennell et al., 2006; Patnaik, 2012; Tariq and Jahan, 2014). The paleontological collections allow us to compare the species between Asia, Africa, and Europe in order to understand the evolutionary processes and to deduce the direction of migration based on orogenic and climatic factors.

The geological periods concerned with the apes, then by the first traces of human activities, belong to the Siwalik Group that extends from the Lower Miocene to the Middle Pleistocene. The Siwalik Group was divided into three subgroups by Pilgrim (1910, 1913): Lower Siwalik (18 to 11.2 Ma), Middle Siwalik (11.2 to 3.5 Ma) and Upper Siwalik (3.5 Ma to 600 ka) (Warwick, 2007). Each subgroup is divided into formations: the Lower Siwalik into the Kamlial and Chinji, the Middle Siwalik into the Nagri and Dhok Pathan. Fossil apes have been uncovered in the Chinji, Nagri and Dhok Pathan Formations. The Upper Siwalik is divided into the Tatrot, Pinjor and Boulder Conglomerate Formations. The Tatrot corresponds to the Upper Pliocene (Cande and Kent, 1995; Ranga Rao et al., 1979). The Pinjor corresponds to the Lower and Middle Pleistocene, its upper limit depends on the diachronic formation of the Boulder Conglomerate (BC). The BC is formed from 3.3 Ma in the north-west of Punjab, it appears ca. 1.79 Ma to the south-east, and then to 600 ka (Kumaravel et al., 2005; Nanda, 2002; Ranga Rao et al., 1988, 1995). The formations, which succeed the folded Middle Pleistocene, are classified as Post-Siwalik. The latter is therefore composed of late Middle Pleistocene, Upper Pleistocene and Holocene deposits.

3. The first essays for an archaeological stratigraphy

3.1. The Yale North India Expedition (1933)

The stone tools collections intensified in the Potwar in 1929–1930, with the Lieutenant Todd in the core of the plateau at Pindi Gheb, and in the Southeast at Chitta (Fig. 3). In 1927 and 1928, the geologist Helmut de Terra participated in the expedition of Emil Trinkler between Kashgar (Tarim Basin) and Leh (Ladakh), and then in 1931 he obtained from Yale University (New Haven, USA), the geological study of these prehistoric sites, accompanied by two British archaeologists, Jaketta and Christopher Hawkes, and a student in paleontology at Yale University, Edward Lewis. The 'Yale North India Expedition' took place in 1932–1933 and collected new tools; those of Chitta were similar to the Pindi Gheb assemblages but they were attributed to the Lower Palaeolithic because of their coarser facture (Hawkes et al., 1934). Lewis explored the foothills of Himachal Pradesh in the region of Hari Talyangar and collected a

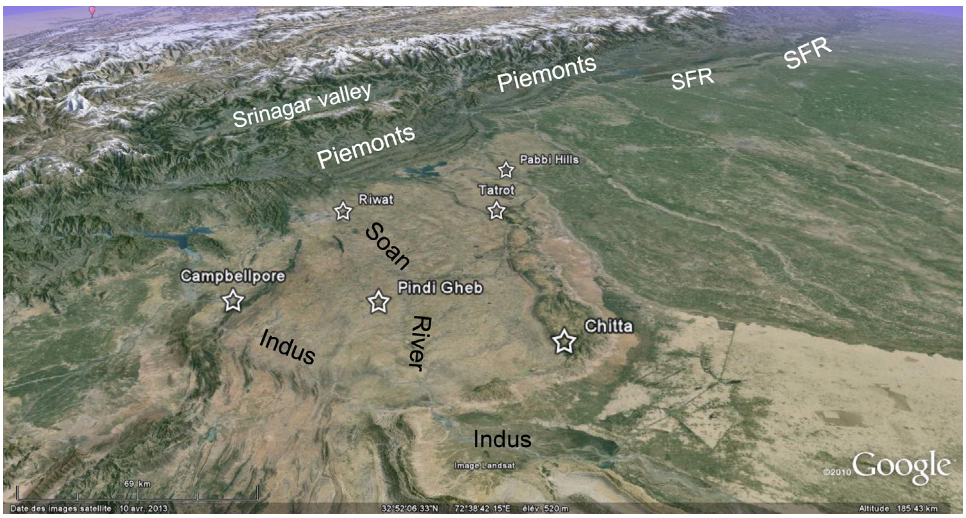

Fig. 3. View of the Potwar Plateau in the Northeast of the Punjab plain et of the Kashmir (Srinagar valley) (after Google Earth).

Fig. 3. Vue sur le plateau de Potwar dans le Nord-Est de la plaine du Penjab et sur le Cachemire (vallée de Srinagar) (d'après Google Earth).

right upper jaw of an ape in the Nagri Formation (Late Miocene). He created the taxon *Ramapithecus brevirostris* to distinguish it from the *Sivapithecus* because of its facial morphology and proposed to make it an ancestor of the human lineage (Lewis, 1937).

3.2. The Yale-Cambridge India Expedition (1935)

In 1933, De Terra was considering extending the geological investigations from Kashmir to central India. His aim was to establish the stratigraphic correlations between the moraines of the intermontane Karewa Basin in the Kashmir Valley (Fig. 3) and the Quaternary fluvial terraces of both the Indus and Narmada Basins. The geologist based his approach on two assumptions, (a) the equivalence of moraines and terraces with the four Alpine glaciations and (b) their deposits posterior to the Boulder Conglomerate. De Terra invited the French paleontologist and geologist Pierre Teilhard de Chardin, honorary advisor of the National Geological Survey of China, while the University of Cambridge entrusted Thomas T. Paterson, a Bachelor's degree in geology to work with him. Henri Breuil who held the chair of Prehistoric Ethnography at the Institut de Paléontologie Humaine, Paris, would oversee Paterson's work on stone tools: "*I reiterate the great desire of De Terra that you 'supervise' quietly the work of Paterson. You will see that our little Exped. can provide a fundamental basis to the Prehistory of India. It will have to be very solid*" (Letter to Henri Breuil, 18 December 1935 in Teilhard de Chardin, 1935: 225). The fossils would be sent to New York, the apes entrusted to Gregory and other fossils to Colbert, the specialist of the Siwaliks fauna.

For Marcellin Boule, administrator of the Institut de Paléontologie Humaine since 1910, the main issue of prehistory was the correlation between the stone tools and the Quaternary glaciations. In 1930, the discord concerned the age of the oldest industries pre- Chellean and Chellean, Boule attributed them to the third interglacial (Riss/Würm) whilst others to the second interglacial (Mindel/Riss) (Denizot, 1930). For Denisot, chairman of geology at Montpellier University, France, the "Tertiary Man" was a true taboo; nevertheless he did not exclude industries older than the pre-Chellean. At the same time, the prehistory of Mainland Asian developed with the discovery of the flake industries at the Zhoukoudian cave under the supervision of Teilhard de Chardin. These industries became the basis of the theory of Manghin according to which the handaxes and the cleavers belong only to European, Near Eastern and African traditions. Thus Teilhard would report his observations to Boule and Breuil with stratigraphic logs and annotated photos (Hurel and Vialet, 2004).

The Boulder Conglomerate (BC) was considered as the older moraine, therefore it was inconceivable to find flakes and chopping tools in this BC, and of course, in the Pinjor and Tatrot terraces of the Upper Siwalik. De Terra divided the survey of the Potwar between Paterson near the foothills, and Teilhard and himself covering the Plateau and the Salt Range (the southeastern limit). They highlighted two tectonic phases, one during the Pliocene (much folded Middle Siwalik), and a second during the Middle Pleistocene (Upper Siwalik folded in synclines on the Middle Siwalik). The cross sections showed no evident correlations between moraines and terraces of the Potwar. Later, their equivalence with the Alpine glaciations would prove unfounded (Dennell, 1981; Rendell et al., 1989). The review of their geological, paleontological and archaeological records takes into account this fundamental reconsideration.

3.3. Tools in the Upper Siwalik gravels created problems

3.3.1. The locality of Kund

In the basin of the Soan, at the locality of Kund, De Terra and Teilhard observed pockets of gravel in a Boulder Conglomerate which have abraded the Upper Siwalik to the top of the Dhok Pathan. They found rolled chopping tools which were named "pre-Chellean". The two geologists published no discussion about them (Terra and Teilhard de Chardin, 1936), the locality was not mentioned, neither on the map of Terra and Paterson (1939: 302) nor in Paterson's analysis. The tools are only mentioned in a geological cross section (Terra and Paterson, 1939: 281, fig. 162). Their presence in eroded Upper Siwalik deposits was unexpected. The scenario repeated itself twice in the Soan Basin. The next was Chauntra, south of Kund, which probably sparked doubts in Teilhard's mind who measured the enormity of the task, the campaign in the Potwar was too short (maximum 4 weeks, 7–8 hours per day) to verify the preliminary interpretations (letter to Breuil on 24 October, Teilhard de Chardin, 1935: 218).

3.3.2. Chauntra, section 15

The section 15 at the Chauntra locality, illustrates the difficulties generated by the presupposition of the four post-BC glacial terraces. The site had two localities. The first was at the top of a relief formed by pink sandy silt belonging to the Siwalik Group: '*These constitute resistant beds in the Dhok Pathan and Tatrot zones and are largely buried under loess and Potwar gravel (fig. 172, A)*' (Terra and Paterson, 1939). On the uppermost level of the silts, extents of coarse gravel were composed of '*water-worn boulders and pebbles derived from Siwalik sandstone mainly*'. Among these sandstone blocks and in the same perimeter, the geologists observed cobbles of quartzite "*there are also quartzite constituents such as occur in many ancient Soan terrace deposit, however, no true terrace flats are preserved in the neighborhood*". The spatial organization did not correspond to a post-Boulder Conglomerate terrace. According to De Terra, the blocks were produced by the dismantlement of sandstones; however the common stratigraphic origin for the quartzite cobbles was not mentioned. In the pink silts, which adjoined the accumulation of blocks, Teilhard de Chardin had collected stone tools in quartzite with polished removal surfaces. Paterson described them: '*the oldest is very worn and one or two handaxes very primitive, probably Abbevillian; cores which mostly take the form of large pebbles crudely struck at random, one or two massive flakes with large plain platforms, resembling those of Boulder Conglomerate and few smaller flakes*'.

Teilhard was not associated to the monograph, but he published a review for '*L'Anthropologie*', whose director was Marcellin Boule. In a long footnote, the geologist developed an analysis of Paterson's assessment regarding Chauntra. The postulate of the four post-BC terraces forced De Terra to imagine "a ghost" of the T1, but Paterson who prospected only the foothills, concluded the disappearance of T3. Teilhard made it clear he was the inventor: *'the brutal study of the stratigraphic facts'* justified his insistence: *'His analysis underestimates the important site of Chauntra (p. 310), cemented gravels seem much older than runoff of the Potwar gravels that overcome them and they might well correspond to T1, this is obviously the opinion of De Terra (p. 289–290)*' (Teilhard de Chardin, 1939–1940: 310). Teilhard used the conditional, since the quartzite cobbles and coarse gravel could come from the sandstones. The first conclusions published with De Terra already stipulated this conclusion: "*One site, in the Soan valley, south of Chauntra proved to be especially rich in worn Chellean tools (. . .) evidently redeposited from an earlier gravel which is here preserved in patches overlying Dhok Pathan*" (Terra and Teilhard de Chardin, 1936: 819). Old tools among quartzite cobbles without any traces of post-BC terrace and which rather dated back to the Tatrot Formation created a real problem.

3.3.3. *Chakri, section 16*

A third site showed the probability that stone tools of the Indus Upper Basin dated back to the Latest Pliocene (Fig. 4). This was locality 4 of the section 16. A Post-Siwalik loess covered the entire archaeological locality. The underlying deposit included an ancient ravine dug in gravelly sediments. Chipped pieces of quartzite were collected in the gravel at the bottom of the ravine. Then, flakes and cores were collected among patinated cobbles under the loess. De Terra related the cobbles of quartzite and the trap cobbles to the same horizon as that of Chauntra, but without questioning the age of the tools. The geological cross section published in De Terra and Paterson was consistent with Wadia's geochronology, which includes Chauntra in the Upper Siwalik, but De Terra decided to assign the sandstone to Dhok Pathan. The geologist based his reasoning on the fossiliferous locality 99 from the same section, and in stratigraphic continuity, from which "*Mastodon, Merycopotamus and Hipparion, clearly indicate their Pliocene age*" (Terra and Paterson, 1939: 291). But the questioning was not justified since this fauna assemblage is observed in Tatrot. The Chauntra locality (section 15) was therefore contemporary to the Chakry localities 4 and 99 (section 16) attributed by Wadia to the Upper Siwalik. Ultimately, these gravels presented a stratigraphic position consistent with Tatrot, but this last one has never been proposed, their common point being the rolled stone tools associated with them.

According to De Terra and Paterson, older artefacts were wide and massive fragments of quartzite, with small retouch obtained by brutal fractures on cobbles. They were sometimes related to *Elephas namadicus* whose occurrence follows closely the Plio/Pleistocene transition. De Terra named these very old industries 'Pre-Sohan'. Two other later lithic typologies were reported, one to the Acheulean tradition and the second to the 'Soanian' rich in chopping tools. De Terra and Paterson considered having highlighted different evolutionary stages of this new industry, the Early, the Middle and the Late Soanian, Paterson reproduced the model of the Clactonian sequence of the Barnham St. Gregory's collection (England) he studied (Dennell, 2014). The distinction with the Acheulean will take on its extent with Hallam Movius (Peabody Museum, Harvard, USA), who accompanied De Terra and Teilhard in 1938 during their last and short mapping of the terraces in Burma (Terra et al., 1938).

In 1938, Teilhard de Chardin was appointed Corresponding Member of the American Museum of Natural History of New York, which entrusted him with the planning of new surveys in the Sutlej, the last of the four tributaries of the Indus River (Fig. 5). The project was interrupted by the Second World War. The dissolution of the British colonial Empire on 15 August 1947 led to Partition which divided the Indus Basin between India and Pakistan.

4. The development of the prehistoric sciences in the Upper Indus Basin after the Partition (1947)

4.1. *The confirmation of human activities to more than 2 Ma in Pakistan*

4.1.1. *The Joint Yale Peabody Museum-Geological Survey of Pakistan (Yale-GSP) (1973)*

Pakistan archaeology took off in the 1960s with A.H. Dani as founder in 1962 of the Archaeology Department of the Peshawar University. In 1960, a geologist of the Punjab University (Lahore, Pakistan) discovered a locality in the Salt Range at Jalalpur, with nine tools in a conglomerate containing quartzite cobbles. These tools were attributed to the Early Soanian (Marks, 1961). In 1973, the 'Joint Yale Peabody Museum-Geological Survey of Pakistan (Yale-GSP)' applied paleomagnetic analyses to Middle Siwalik of the Soan Basin, in the region of Khaur (Barry et al., 1980, 1982). Khairpur University also ran its own research in 1974 with Salim (1994) who explored the Soan Basin and found new localities.

4.1.2. *The 'British Archaeological Mission to Pakistan' (1979–1999)*

In 1979, Ishtiaq Khan, Director-General of Archaeology and Museums of Pakistan, allowed cooperation between the University of Peshawar and the University of Cambridge. The 'British Archaeological Mission to Pakistan' was led by Bridget Allchin. From 1981 to 1985, Helen Rendell of University College London and Robin Dennell from Sheffield University explored the Soan Basin, south of Rawalpindi (Rendell et al., 1989). Rendell and Dennell surveyed about 12 months in the Soan valley contra 4 weeks for De Terra and Teilhard. Their fieldwork questioned the geochronology of De Terra which could no longer be linked with the Alpine glaciations (Allchin, 1986). Helen Rendell (1989, 17–18) concluded that De Terra's terrace sequence was fundamentally flawed and incorrect: "*The evidence put forward by De Terra and Paterson fails to sustain the evidence of any link whatsoever between Pleistocene river terraces and Palaeolithic sites. Terrace sequences in the middle Soan valley appear to be highly fragmented, and for the most part, erosional features*" and recently Dennell (2014) wrote:

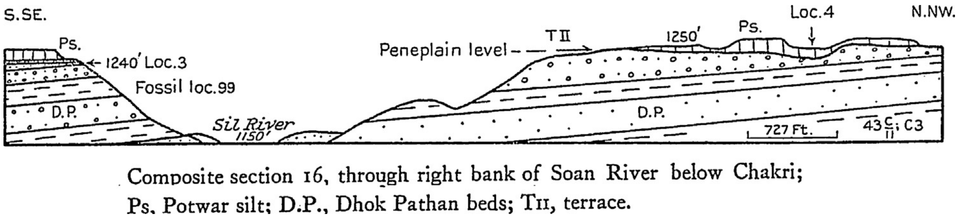

Fig. 4. Geological cross section of the Soan Basin, section 16 of Chakri locality (Terra and Paterson, 1939).

Fig. 4. Coupe géologique du bassin de la Soan, section 16 de la localité de Chakri (Terra et Paterson, 1939).

"Terra mistook uplifted exposures of Middle and Upper Siwalik (Pliocene to Early Pleistocene) conglomerates for terraces. In places, he constructed an idealised composite sequence of what he thought had happened but which had little correspondence with what was observed at that locality". Concerning the Chauntra locality which caused Teilhard to react quite vividly, Rendell and Dennell visited the locality in 1981 and could not identify De Terra's section, they concluded that the drawing of sections was largely speculative (pers. com).

In 1983, the British Mission discovered the Riwat locality (Fig. 3), a conglomerate below a cliff, including fossils, a cobble with 8 or 9 flake removals in three directions with good flake scars (R001), and about 50 m away, a flake in situ, with a positive bulb of percussion on one side and a negative one on the other (R88/1) (Dennell and Hurcombe, 1992; Dennell et al., 1988; Hurcombe and Dennell, 1993). Paleomagnetic and structural geology contributed to situate the conglomerate in the geochronology. The polarity indicated the negative Matuyama Chron which begins at 2588 Ma ± 0.7 ka. The last one has two positive sub-chrons, the first at 1.8 Ma (Olduvai) and the second at 2,14–2,15 Ma (Reunion). However the synclinal structure of the Upper Siwalik dates back to between 2.1 and 1.9 Ma and the conglomerate is prior to folding. As no positive inversion is observed in the series covering the conglomerate, tools are clearly under the sub-chron 2,14–2,15 Ma (Dennell et al., 1988). Results reinforced the hypothesis of a very old Asian human occupation suspected since the discovery of the Mojokerto child skull (Perning 1) in Indonesia (Terra et al., 1938).

From 1986 to 1990 the 'British Archaeological Mission to Pakistan' continued its investigations on the left bank of the Jhelum, in the Pabbi Hills where the Upper Siwalik is exposed from 2.5 Ma to 500 ka: 40,000 fossils and 600 artefacts (cores and flakes) were collected on the surface (Hurcombe, 2004). The authors did not hesitate to conclude that some tools were extracted from the fossiliferous strata over 2 Ma: "*many of which are believed to be derived from fossil-bearing deposits and may thus be up to two million years old*". The last mission was organized in 1999 (Dennell et al., 2006).

Finally, since 1935, the results of prehistoric surveys of the Upper Siwalik in the Potwar and Pabbi Hills have exceeded 2 million years and have made human presence since the end of the Pliocene at Chauntra and Chakri plausible.

4.2. The development of the Indian prehistoric sciences from 1950 to 1990

As a result of the Partition of India, the terraces providing lithic tools in abundance are in Pakistan, while the upper courses of the four Indus tributaries, the Jhelum, the Chenab, the Ravi and the Sutlej, are in India. The

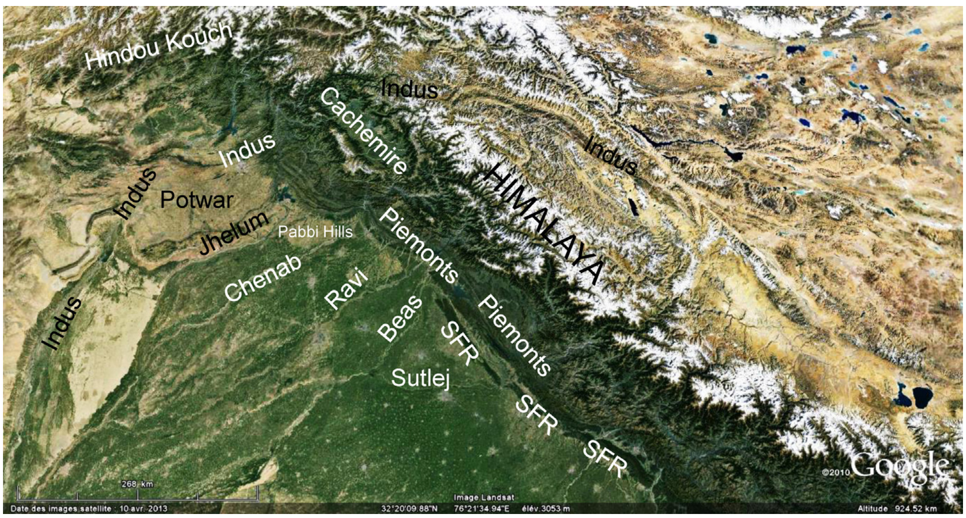

Fig. 5. Geographic satellite view of the Upper Indus Basin (after Google Earth).

Fig. 5. Vue satellite géographique du bassin supérieur de l'Indus (d'après Google Earth).

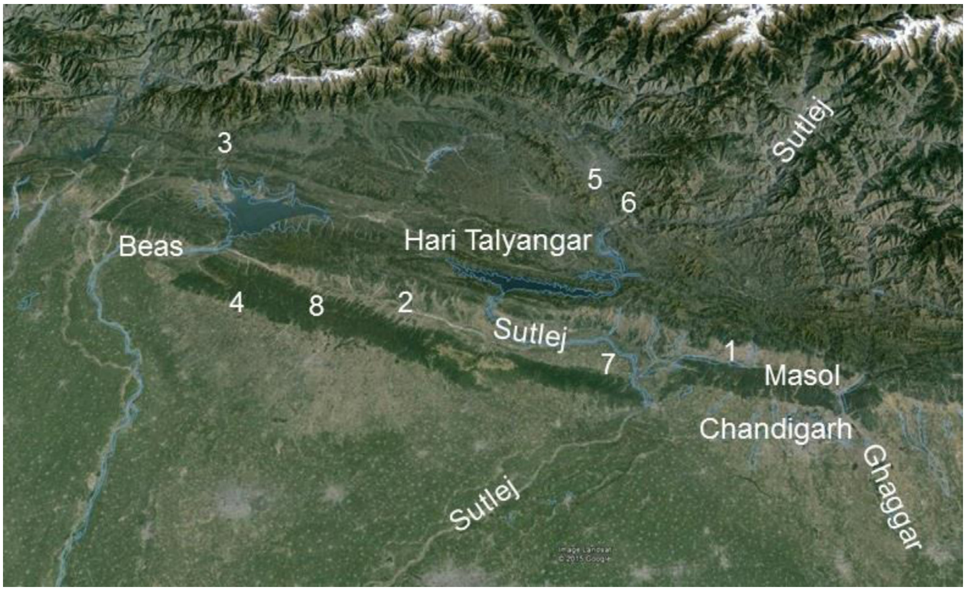

Fig. 6. Geographical view of the Siwalik Frontal Range (Punjab) and piedmont (Himachal Pradesh) with major places, Masol and Hari Talyangar (*Sivapithecidae).* 1: Sirsa River; 2: Sohan River; 3: Bangaga River; 4: Atbarapur; 5: Sunder Nagar; 6: Bilaspur caves; 7: Jhandian; 8: Janauri anticline (after Google Earth).

Fig. 6. Vue géographique de la chaîne frontale des Siwaliks (Penjab) et des piémonts (Himachal Pradesh) avec les principaux lieux, Masol et Hari Talyangar (Sivapithecidae). 1 : Rivière Sirsa ; 2 : rivière Sohan ; 3 : rivière Bangaga ; 4 : Atbarapur ; 5 : Sunder Nagar ; 6 : grottes de Bilaspur ; 7 : Jhandian ; 8 : anticlinal de Janauri (d'après Google Earth).

geomorphological configuration of the surveys changes radically (Figs. 3 and 5). In India, the Siwalik ranges are distributed between the Himachal Pradesh in the Northwest, and the Punjab in the Southeast. In the plains (Punjab), the Upper Siwalik is compressed along the Himalayan foothills in an alignment of anticlines of low altitude, the Siwalik Frontal Range (SFR). In the foothills (Kashmir, Jammu, Himachal Pradesh), the Upper Siwalik is exposed with the Middle Siwalik, particularly straightened and compressed. In between, the dun is filled by alluvial deposits of two rivers that drain the slopes before joining the Sutlej: the Sohan on its right bank and the Sirsa on its left bank (Fig. 6). Their terraces cover the Upper Siwalik foothills and the northern margin of the SFR, which clearly postdate the folded Boulder Conglomerate. In the piedmont, the terraces of the Chenab and the Sutlej are associated with ancient moraines, while the Mio-Pleistocene sedimentary sequences outcrop to the surface, with great apes in the narrow bands of the Nagri and Dhok Pathan (Saketi and Hari Talyangar).

The first tools were collected in 1951 on the terraces of the Sirsa near Nalagarh by archeologists Prüfer and Sen. In 1953, the Archaeological Survey of India (ASI) and the new Panjab University in Chandigarh undertook research in the foothills and in the dun, up to its southernmost limit, collecting flakes and chopping tools on the Sohan and Sirsa terraces. Their dating was the main difficulty. In 1957 the ASI, the Geological Survey of India (Calcutta), the Deccan College (Pune) and the Maharaja Sayajirao University (Vadodara) tried to establish correlations with the Pleistocene moraines. Geologists studied the Piedmontese terraces of the Beas and of its tributary, the Banganga. From the 1970s, R.V. Joshi, Director of the Prehistory Branch of ASI, intensified these researches, so that in 1975 the assessment totaled ten sites including Haripur and Dehra Gopipur, with choppers, discoid, scrapers, cores, numerous flakes and localities with handaxes (Deshpande, 1975).

In 1960, Sahni and Khan mapped the Chandigarh anticline, a part of the SFR cut to the north by the Sutlej River and to the south by the Ghaggar (Fig. 6). The hills, gullied by the monsoon, are accessible by large seasonal torrents named *choes*, such as the Patiali Rao, which takes its source at Masol. From the southern to the northern margins, Sahni and Khan identified successively Boulder Conglomerate, Pinjor without disruption to Tatrot visible here, in a narrow fringe along the dun, and also in a geological 'buttonhole' at Masol (Fig. 7). A sector of Tatrot turns out to be particularly fossiliferous; the two geologists called this formation "Quranwala Zone", the name of a local village (Sahni and Khan, 1964, 1968).

In 1962, Panjab University maintained the research with Gunjan V. Mohapatra, Former Professor in the Department of Ancient Indian History, Culture and Archeology. The Surveys extended from the foothills of Jammu to the terraces of the Ghaggar (Fig. 6). Baldev Karir explored the Sirsa, Mukesh Singh the Kulbhushan, Surinder Pal, K.K. Rishi and Vipnesh Bhardwaj the terraces of the foothills and the SFR. In 1976 Rishi and Bhardwaj explored the southern fringes of the SFR and discovered Acheulean tools in the bed of a *choe*, at Atbarapur (Kumar and Rishi, 1986).

In 1977, Mukesh Singh explored the Sirsa, and then from 1978 to 1981, he covered the SFR from the Beas to the Ghaggar, prospecting the Januaury and Chandigarh anticlines. Surinder Pal surveyed the Beas and the Banganga in

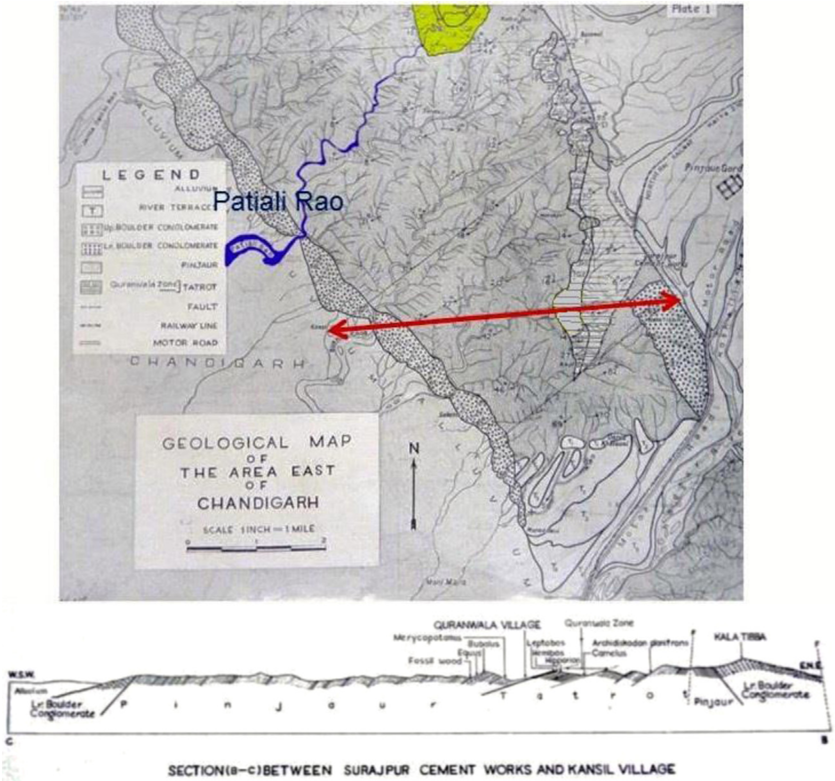

Fig. 7. Geological map of the Siwalik Frontal Range North to Chandigarh with the Patiali Rao reaching the buttonhole of Masol (in yellow) and a cross section (along the red line) showing the anticline structure with the Quranwala zone (Sahni and Khan, 1968).

Fig. 7. Carte géologique de la chaîne frontale des Siwaliks au nord de Chandigarh avec le Patiali Rao remontant jusqu'à la boutonnière de Masol (en jaune) et une coupe transversale (le long de la ligne rouge) montrant la structure anticlinale avec la zone Quranwala (Sahni et Khan, 1968).

the foothills. The first syntheses were published in 1978. In the foothills, the oldest industries were discovered on the terraces of the Beas and the Sutlej (Joshi et al., 1978). The Indian prehistorians found again the gradation of Terra and Paterson: the Early Soanian composed of large rolled choppers, Late Soanian and Evolved Soanian (Mohapatra, 1981; Mohapatra and Singh, 1979a, b; Mukherji, 1979). In Sirsa, the Late Soanian is clearly linked to the Middle Paleolithic: "*The Pinjore-Nalagarh dun lithic industry belongs to the pebble tool tradition like that from the Soan Valley in the Potwar, Beas Valley in Kangra and the Jammu region. The character of this industry is seen in its peculiar typology and technique which are quite distinct from those of the Chelles-Acheulean tradition*" (Karic, 1985: 120). Bhardwaj collected again new Acheulean artefacts in Himachal Pradesh (Bhardwaj, 1991).

In addition to these prehistoric studies, paleontology developed with the Department of geology in Punjab University. The fauna of Tatrot, called Saketi in this sector, has been studied since the beginning of the 20th century starting with Pilgrim (Badam, 1973; Gaur, 1987; Khan, 1962; Nanda, 1994, 2002). Palynology has also been the subject of an analysis in the region of Chandigarh (Saxena and Singh, 1980). All the analyses have revealed a landscape of rivers slowly meandering whose vast flood plains were the main factors of sedimentation. The vegetation has been dominated by savannah since about 7 Ma, a period where a regime of monsoon settled due to sufficient elevation of the Tibetan Plateau (Quade et al., 1989). The Tatrot/Pinjor transition is marked by a relative drying and cooling of the climate with particularly abundant species diversification.

4.3. The prehistoric research in high valleys of Upper Indus Basin

In the 1990s, collections were sufficient to compare the Soanian and the Acheulean of the Upper Indus Basin. The chair of Prehistory of the National Museum of Natural History and the Institut de Paléontologie Humaine (Henry de Lumley) joined the study of the Panjab University collections (Gaillard, 1993, 1995; Gaillard and Mohapatra, 1988), while Singh joined the Prehistory laboratory in 1989 to study the lithic collections of the Roussillon terraces (eastern Pyrenees, France). At the same time a new paleoanthropological axis of research developed in the Laboratory, between the Siwaliks and Pamir, based on the works of Vadim Ranov (Dushanbe Academy of Sciences, Tadjikistan). Ranov observed 'chopper-chopping tool complex' in the foothills, high valleys and plateaus of Central Asia, in Uzbekistan, Tajikistan and Kyrgyzstan. This lithic tradition is visible from Early Pleistocene in the Pamir piedmonts (Kul'dura, 900–950 ka,) to Early Holocene on the Pamir Plateau at altitude 4200 m (Markansou-Oshkona, ca 10,500 BP). Ranov concluded the existence of nomadic hunter-gatherers adapted to the glacial and interglacial climatic oscillations, keeping the chopping tools tradition (Davis and Ranov, 1999; Ranov, 1972; Sankalia, 1976). He took into account the Upper Indus Basin and, in 1978, with Mohapatra and Singh, he prospected the karsts of the foothills cut by the Sutlej where they collected a core in a cave of Bilaspur area (Fig. 6) (Gupta, 1979).

Since 1992 the aim of this anthropological axis is the search for human fossils in archaeological context from the Early Pleistocene, assuming migrations from the Indus Basin to High Asia (Dambricourt Malassé, 2008, Dambricourt Malassé and Gaillard, 2011). The theme developed in 1993 with Singh who prospected again the karsts of Bilaspur, and in 1994 with Magraner (1958–2002) from the 'Prehistory laboratory and Quaternary' of the 'School of Higher Studies' (EPHE, Burgondy University). Magraner surveyed the high valley of the Chitral River (Upper Indus Basin, Hindu Kush) whose upper course, the Yarkhun, allows access to the Amu Daria River, the Pamir Plateau and the Tarim Basin (Fig. 1). In 1996, the Ministry of Foreign Affairs entrusted the "French Archaeological Mission to Pakistan" to the Prehistory Laboratory of the Museum, in partnership with the EPHE and the Archaeology Department of the University of Peshawar. One trench was open in a large cave of the Chitral gol which provided pottery, and stone tools were collected on a terrace of the Yarkhun near the Boroghol pass which gives access to the Amu Darya. This assemblage dated to 5000 years BP maximum, belongs to an unknown industry (Gaillard et al., 2002). Thus we observed that hunter-gatherers could join the Pamir from the Upper Indus Basin during the interglacial period of Middle Holocene. The 'French Archaeological Mission in Pakistan' so-called 'Hindu Kush', ended in 1999. In 2002, Singh initiated a research project with the Department of Cultural Affairs, Archaeology and Museums of Punjab and proposed to associate the Prehistory Laboratory of the Museum, keeping the paleoanthropological cap with the surveys of Bilaspur's caves and the Upper Siwalik paleontological sites of the Himachal Pradesh and Siwalik Frontal Range.

5. The Indo-French Missions in the Siwaliks

5.1. First Period 2003-2009

From 2003 to 2006, Singh, Dambricourt Malassé and Gaillard covered all inventoried sites (Fig. 6). The localities visited in the Himachal Pradesh foothills, from the Beas to Bilaspur, included the sector of Hari Talyangar (*Sivapithecus* and *Indopithecus giganteus*). A fossiliferous locality was discovered in Charinaya, several caves were visited in the high valley of Sunder Nagar and in the karsts of Bilaspur where a trench permitted to evaluate an important filling. Similarly, the terraces of the Sirsa and the Sohan were observed, as well as the Januari anticline. Few Acheulean tools were collected again in Atbarapur (Gaillard et al., 2008, 2011). The Late Soanian site of Jhandian, known since 1970 on the northern fringe of the SFR, was studied in 2006 and 2007. The locality is an old terrace of the Sutlej formed when the Januari anticlinal had already uplifted; thus, this deposit is a Post-Siwalik terrace elevated by neotectonics. Small choppers were collected among the cobbles but their dating remained problematic. The program of research

Fig. 8. The first chopper in the Quranwala Zone at Masol 1 collected by Mukesh Singh in February 2008 on Tatrot silts below local dismantled Late Pliocene sediments (C3 and C4 of the stratigraphic log).

Fig. 8. Le premier chopper dans la zone Quranwala à Masol 1 recueilli par Mukesh Singh en février 2008 sur des limons du Tatrot sous des sédiments du Pliocène final érodé localement (C3 et C4 du log stratigraphique).

was therefore refocused on the initial paleoanthropological objectives. The strategy consisted in finding fossils as close as possible to quartzite cobbles in stratigraphy. The choice fell on the Chandigarh anticline where the Plio-Pleistocene fossiliferous formations are accessible by the Patiali Rao River. In November 2007, visits conducted by Singh with Karir, Rishi, Dambricourt and Gaillard reached the village of Masol built in the core of the anticline on the two riverbanks, and surrounded by the Quranwala Zone (Dambricourt Malassé, 2007).

On February 1st 2008, at the top of a plateau dominating the village 100 meters above the Patiali Rao, Mukesh Singh collected a chopping tool under a small butte of colluviums deposited on Tatrot pinky silts (Fig. 8). In March 2009, Singh, Dambricourt, Gaillard and Hazarika, visited the locality. The butte was composed of silts, blocks of sandstone and numerous bones of *Colossochelys* visible in the nearby small cliffs of the Qurawala Zone. Several fossils, a few quartzite cobbles, choppers and flakes in quartzite were collected on the surface in the perimeter of the butte. Thirty meters further, Manjil Hazarika collected a fragment of diaphysis on the eroded outcrops of a small cliff from the Quranwala Zone. This was identified as a bovid tibia, referenced R10084 (Moigne et al., 2016). The highly mineralized bone presented various traces on the cortical surface; some of them, by their size, morphology, spatial organization and trajectories around a crest for aponeurosic attachment, evoked a fine butchery activity, which needed a complete investigation to be rejected or confirmed (Fig. 9).

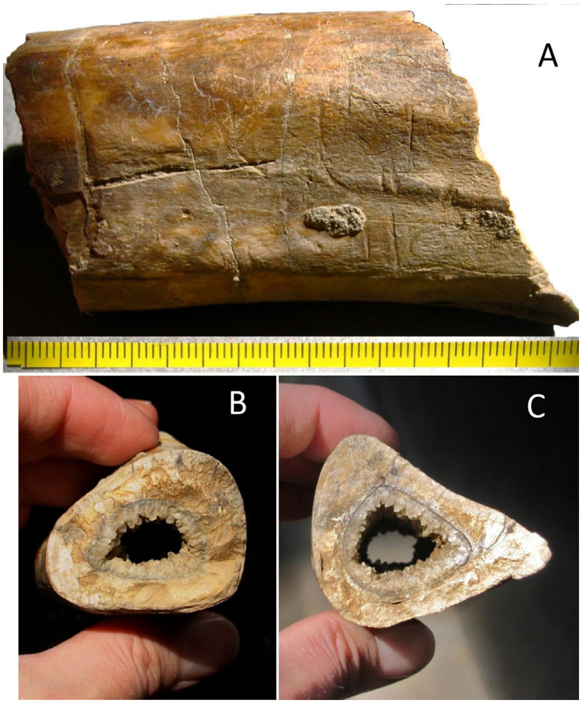

Fig. 9. A. The palmar face of the tibia R10084 with cut marks collected in the Quranwala Zone at Masol 1 in March 2009 by Manjil Hazarika. B and C. The two mineralized extremities and the crystallization of the medullar canal, demonstration in Dambricourt Malassé et al., 2016 (photo A. Dambricourt Malassé).

Fig. 9. A. La face palmaire, avec les traces de découpe, du tibia R10084 recueilli dans la zone Quranwala à Masol 1 en mars 2009 par Manjil Hazarika. B et C. Les deux extrémités minéralisées et la cristallisation du canal médullaire, démonstration in Dambricourt Malassé et al., 2016 (photo A. Dambricourt Malassé).

5.2. Second Period 2010–2015

The Quranwala Zone is a classical reference for the paleontologists (e.g., Nanda, 2013; Stidham et al., 2014, more details in Moigne et al., 2016). Paleomagnetism and fossil assemblages have corroborated each other (Ranga Rao, 1993; Ranga Rao et al., 1995). The fossil species correspond to the associations observed during the Latest Pliocene and lie under the Gauss/Matuyama boundary, they come from fluvial, swampy environments and semi-arboreal savannah. At Masol, the Latest Pliocene appears in the form of an eroded dome, drawing a geological 'buttonhole' of 80 hectares, in which the lowest layers of the Quranwala Zone begins about 130 meters below the Gauss/Matuyama Reversal (Fig. 10).

The plateau on which the first chopper and the tibia with cut marks have been collected corresponds to the summit of the anticline while the small fossiliferous hills, which covered it, belong to the lowest layers of the Quranwala Zone. The massif is isolated to the south by the Patiali Rao, to the east by a deep ravine in the oldest Masol Formation poor in fossils, to the west by the Pichhli choe basin in the youngest one, i.e. the complete sequence of the Quranwala Zone, and, to the north by the lowest layers of the Quranwala Zone. This geomorphology makes impossible any contribution of the Pinjor Formation (Pleistocene). This first paleonto-archeological locality was named Masol 1, stratigraphically situated about 130 meters below the Gauss/Matuyama reversal, thus the fossils dated back to more than 2.588 Ma (Figs. 11–13).

In 2010, the first steps were taken with the Archaeological Survey of India for 3D Video Digital Microscopy of the traces (micron scale) at the Center for Research and Restoration of Museums of France, Paris (C2RMF, Le Louvre). It was also necessary to understand the origin of the quartzite cobbles and to ensure the local origin of the bovid diaphysis.

The erosion of the anticline structure "in onion" reduces considerably the probability of collecting lithic tools in stratigraphy (Fig. 12). The geomorphology and the tectonics determine the erosion and the condition for the collection of all the material: block of sandstone or conglomerates, cobbles and fossils accumulated all together on the outcrops of the layers from which they were unearthed. If fossils with cut marks and stone tools are in the layers, they obey to the same process. All paleontologists accept that the fossils come from those layers; we had no reason to reject one of them only because of the cut marks on its surface, but the origin of the tools is an open question.

Eight field campaigns have succeeded since 2008, thirteen localities have been identified, one because of its significant stratigraphic and geological data (beds of cobbles in place) and twelve with fossils and stone tools, three providing new paleontological data with *Hipparion*

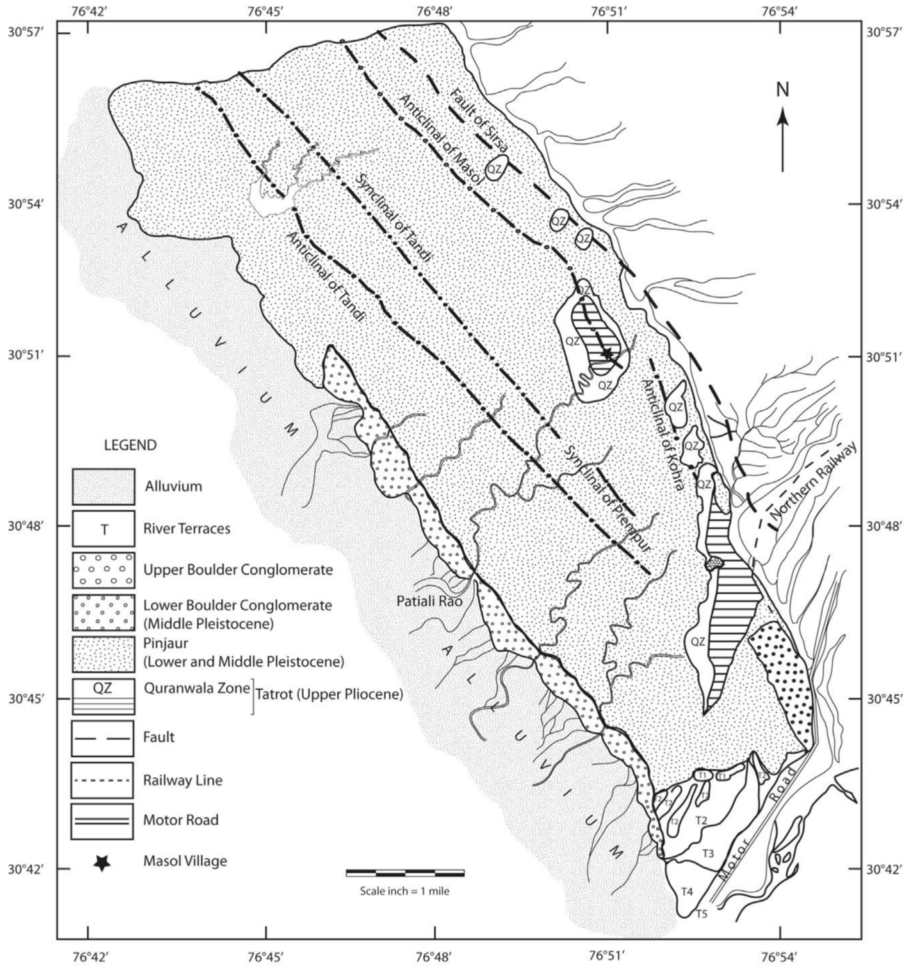

Fig. 10. Geological map of Chandigarh anticline (drawing S. Abdessadok, according to Sahni and Khan, 1968).

Fig. 10. Carte géologique de l'anticlinal de Chandigarh (dessin S. Abdessadok, d'après Sahni et Khan, 1968).

(tooth, Masol 3), *Merycopotamus dissimilis* (*Anthracotheriidae*) (tooth, Masol 5) and a felid (hemimandible, Masol 6). This association recalls the Chakry localities 4 and 99 (section 16) of Terra and Teilhard de Chardin seen above.

In 2011, a bone splinter similar to the bovid diaphysis R10084 of Masol 1, was collected in its very close perimeter, and then in 2013, a second splinter collected in the same conditions, was reassembled with the diaphysis (Fig. 14). The mineralized edges and the proximity of the three bones indicate that the tibia stayed in the slopes after the bone broke naturally (Dambricourt Malassé et al., 2016, this issue). Its stratigraphic origin has been identified by comparing the fossilization with the lithostratigraphy of the small cliff, and, with the fossils collected at the top the silt C3 (Fig. 11), and in the slopes on which the bovid diaphysis has been uncovered (Chapon Sao et al., 2016a). The same year 2011 two trial trenches were opened at Masol 2, 140 m north to Masol 1, the two localities being in stratigraphic continuity (Rapport collectif, 2011). This choice was guided by choppers and flakes associated to Large Mammals fossils scattered on 20 meters all along a cliff being eroded (broken tusk, Proboscidean scapula, long bones, fragmented skull of *Hexaprotodon*, splinters of fossilized ivory) (Fig. 15).

The first trench (A) was chosen for its proximity to the skull, the second due to the accumulation of cobbles of quartzite among blocks of the local dismantled sandstone. The stratigraphic position of the two trenches was well identified in the sequence of Masol, the lowest layer of the trenches is the silt C3 on which the first chopper was found in 2008 under the colluvium, and the upper part is the dismantled sand C4. The limit between C3/C4 corresponds to the level from which the bovid diaphysis R10084 has been unearthed (Abdessadok et al., 2016; Chapon Sao et al., 2016a; Tudryn et al., 2016) (Fig. 11). Three cobble tools and one flake were recorded in the lowest layer of the trench B with fossil bones (Gaillard et al., 2016).

Thus, it was of the utmost importance to develop a strategy adapted to the geomorphology dominated by compression tectonics, in other word, to invent a scientific protocol for the prehistoric understanding of the field. The best chances to find stone tools in situ are the vertical sections as in Masol 1, whereas the dip of the structural

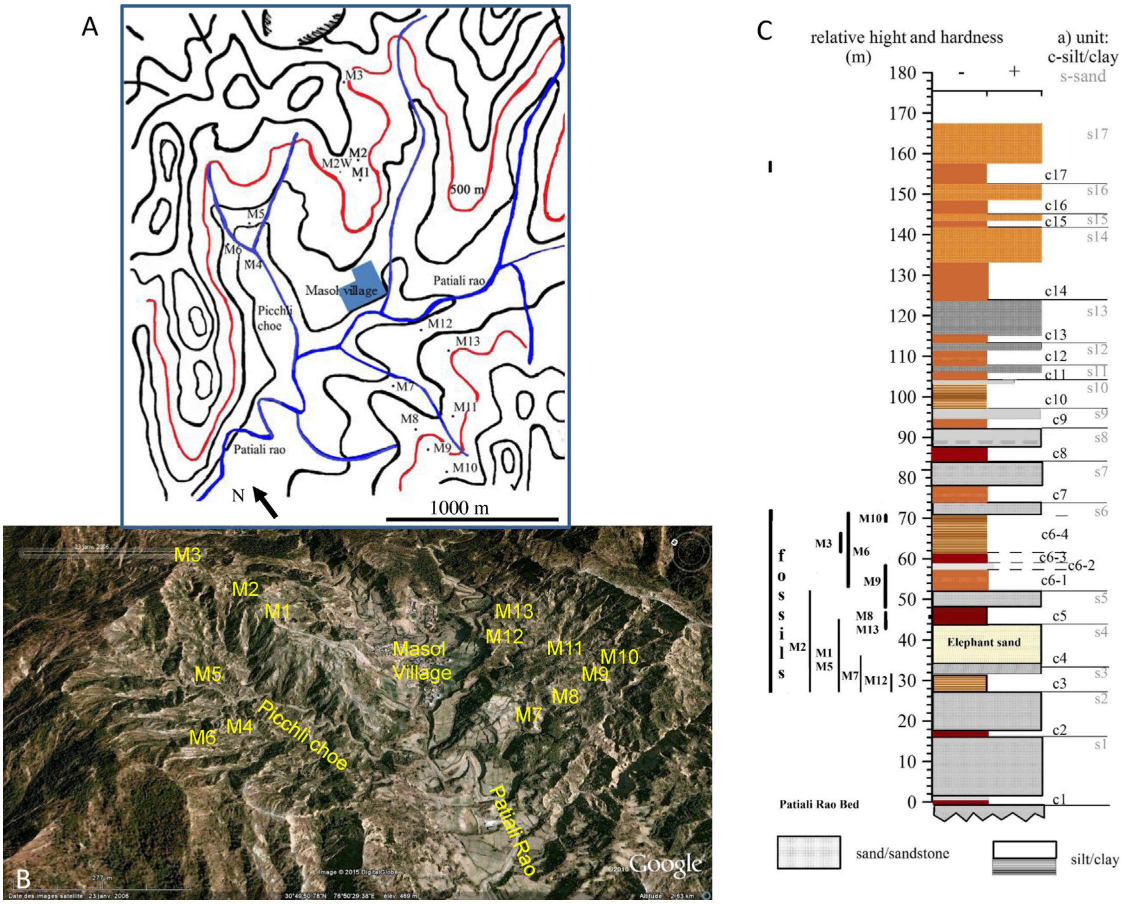

Fig. 11. The paleonto-archaeological localities in the Quranwala Zone of Masol. A. Topographical map with the Patiali rao and the Pichhli choe. B. Geomoprhological view (after Google Earth, modified). C. Stratigraphic log (Chapon Sao et al., 2016a; Tudryn et al., 2016).

Fig. 11. Les localités paléonto-archéologiques dans la zone Quranwala de la formation Masol, A. Carte topographique avec le Patiali Rao et le Pichhli choe. B. Vue géomorphologique (d'après Google Earth, modifié). C. Log stratigraphique (Chapon Sao et al., 2016a ; Tudryn et al., 2016).

Fig. 12. View of the geological buttonhole of Masol Formation, right bank of the Patialo Rao with the dip of the strata of the anticline underlined by the vegetation on the structural surfaces and the ravines (photo A. Dambricourt Malassé).

Fig. 12. Vue de la boutonnière de la formation Masol, rive droite du Patialo Rao, avec le pendage des strates de l'anticlinal, souligné par la végétation sur les surfaces structurales et les ravins (photo A. Dambricourt Malassé).

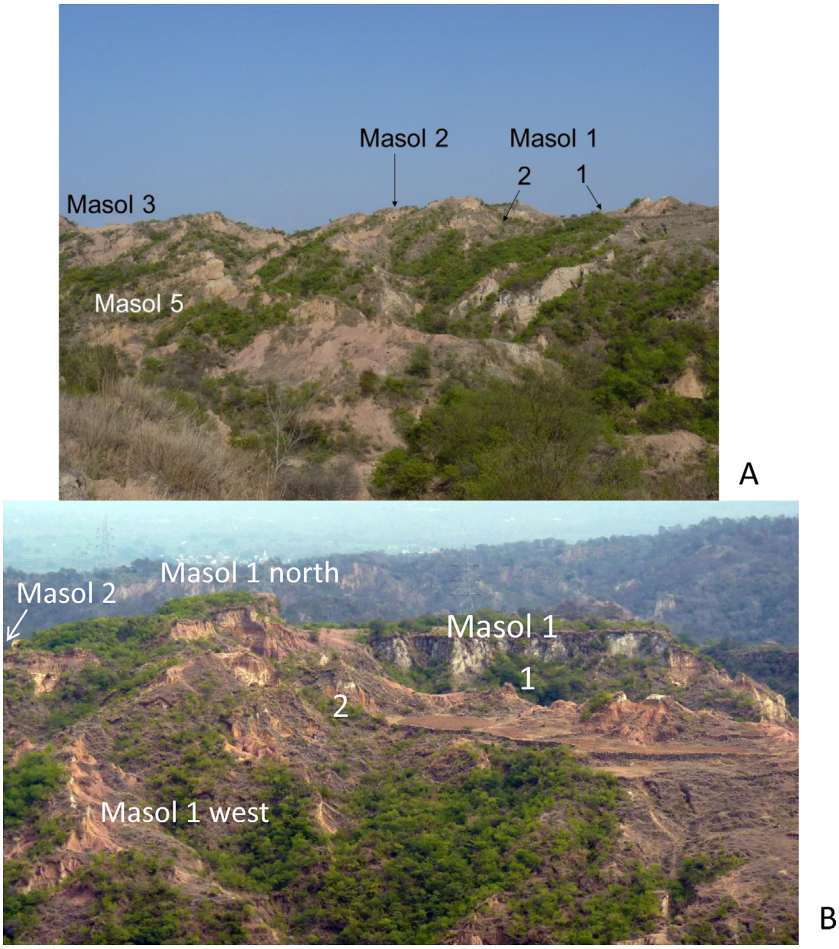

Fig. 13. A. View on the Qurawala Zone (or QZ) eroded by the Pichhli choe and the top of Masol anticline (Masol 1, Masol 2). B. View on Masol 1 and Masol 2. 1: QZ colluvium with the chopper found in 2008, 2: QZ slopes where the tibia R10 514 with cut marks and the splinter which connects, were found respectively in 2009 and 2013 (photo A. Dambricourt Malassé).

Fig. 13. A. Vue sur la Zone Qurawala (ou QZ) ravinée par le Pichhli choe et le sommet de l'anticlinal de Masol (Masol 1, Masol 2). B. Vue sur Masol 1 et Masol 2. 1 : Colluvions de QZ avec le chopper trouvé en 2008 ; 2 : les pentes de QZ où le tibia R10084 aux traces de boucherie et l'éclat qui s'y raccorde ont été collectés respectivement en 2009 et 2013 (photo A. Dambricourt Malassé).

surfaces "in onion" favors the accumulation of removed cobbles and fossils in their lowest areas, often bordered by ravines or rivulets. The research necessitated a complete investigation of the field to obtain an overview of the litho-stratigraphic distribution of the fossils, quartzite cobbles, bones and stone tools, with a geomorphological methodology to modeling the incision speed of the 'buttonhole'. This constitutes the most important innovation of the scientific investigations on the field, realized by Julien Gargani. Thus, geomorphological and tectonic studies were conducted to understand the processes of erosion, to approach the speed of incision and to estimate the time elapsed since the exhumation of the paleonto-archeological localities. The more the oldest formations will have been exposed recently, the more the probability that tools and fossils are contemporaneous, increases. The surveys have sought the greatest possible number of lithic tools and bones associations, through an analysis of fossilized traces (carnivores, crocodiles, rodents, trampling, weathering, etc.), to observe a possible logic in the spatial organization between quartzite cobbles, fossil taxa, taphonomy and lithic techno-typology.

From 2012 to 2015, four field seasons were conducted under the patronage of Yves Coppens, honorary Professor at the College of France and member of the Academy of Sciences. The team is composed by seven researchers on the field to cover geomorphology, structural geology, sedimentology, mineralogy, paleomagnetism, paleohydrology, paleontology, taphonomy and lithic techno-typology, plus two researchers in laboratories for Dating ESR of colluviums in which choppers have been recorded. Approximately 1500 fossils and about 260 lithic tools have been collected during the survey of 50 hectares composed by talus, ravines, cliffs and small plateaus, always in the Pliocene Formation, called Masol Formation.

Forty six kilos of sediments were sent to France (i) for the paleomagnetism of Masol 1 locality where the bovid diaphysis R10084 was recorded; the analyses confirm the positive polarity (Chapon Sao et al., 2016b); (ii) for the lithostratigraphy and the mineralogy of three major places

Fig. 14. Reassembling of a splinter on the tibia R10084 by Anne-Marie Moigne in 2013. Inset, the splinter of 2011.

Fig. 14. Remontage d'une esquille sur le tibia R10084 par Anne-Marie Moigne en 2013. En encart, l'esquille de 2011.

Fig. 15. A. View on Masol 2, with Masol 1 behind the crest, and two trenches open in 2011. B and C. The trench B in dismantled sandstone with many cobbles on the wine silt in place. ¤: choppers and flakes. Proboscidean fossils: *: broken tusk and scapula; **: long bones; ***: fragmented skull; ****: splinters of fossilized ivory tusk. Dotted line: the dip of the sedimentary layers (photo A. Dambricourt Malassé).

Fig. 15. A. Vue sur Masol 2 avec Masol 1 derrière la crête et deux sondages ouverts en 2011. B et C. Le sondage B dans le grès démantelé, avec de nombreux galets sur le limon lie de vin en place. ¤ : choppers et éclats, fossiles de Proboscidien : * : défense brisée et omoplate ; ** : os longs ; *** : crâne fragmenté ; **** : éclats d'ivoire fossilisé. Ligne pointillée : le pendage des couches sédimentaires (photo A. Dambricourt Malassé).

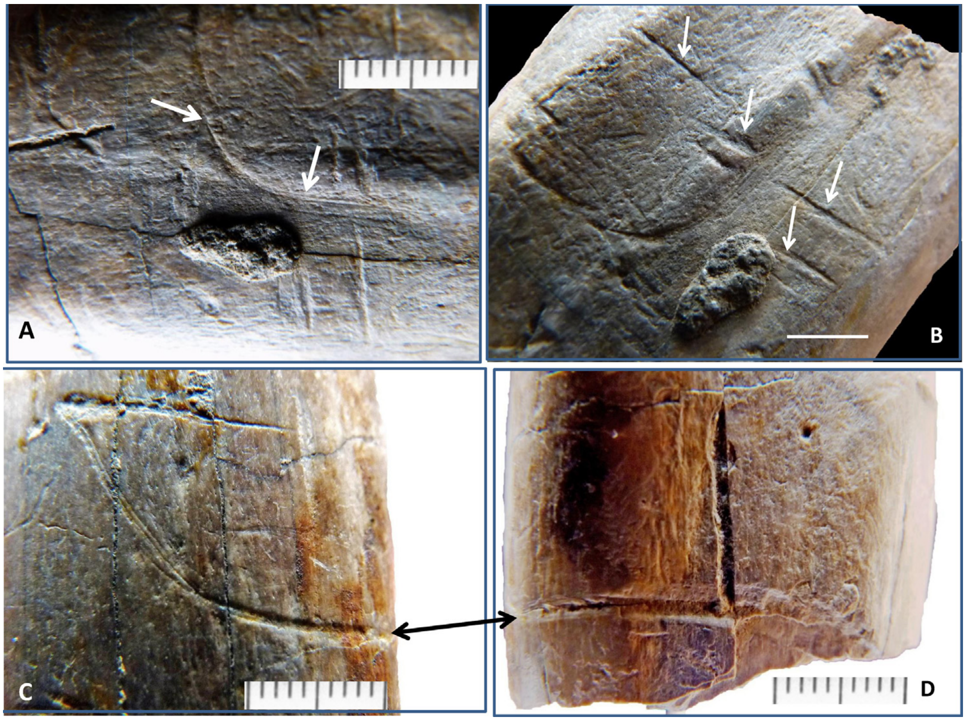

Fig. 16. Cut marks on the tibia R10084 which have been analyzed at the micron scale, A and B, palmar face, C and D, dorsal face. Scale: 1 cm, demonstration in Dambricourt Malassé et al., 2016 (photo A. Dambricourt Malassé).

Fig. 16. Traces de découpe sur le tibia R10084, qui ont été analysées à l'échelle du micron, A et B, la face palmaire, C et D, la face dorsale. Échelle : 1 cm, démonstration in Dambricourt Malassé et al., 2016 (photo A. Dambricourt Malassé).

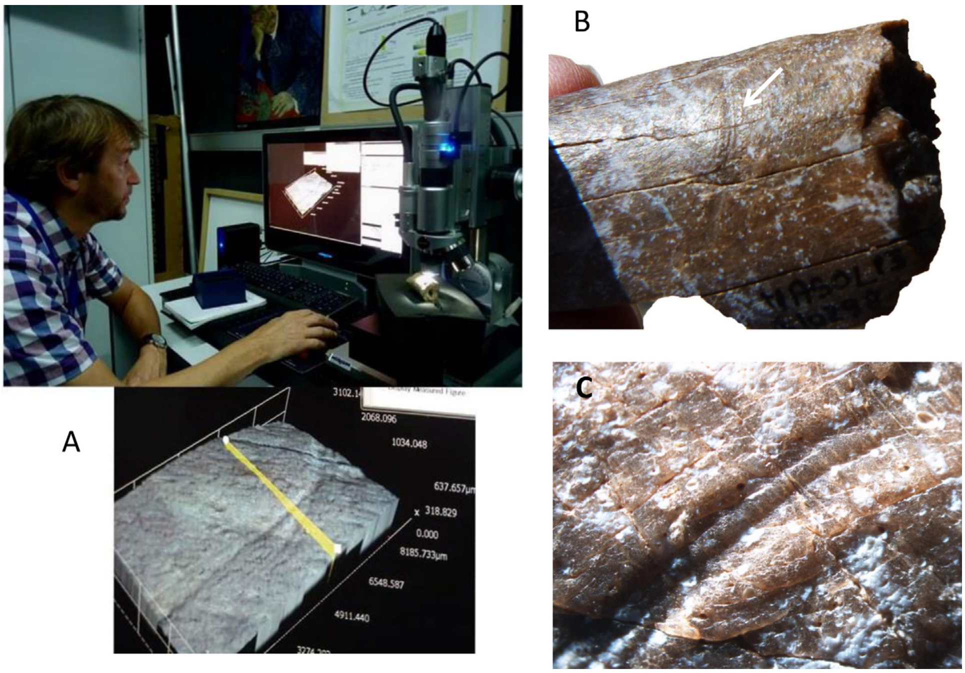

Fig. 17. A. 3D Digital Video Microphotography of a tool mark at the micron scale on the tibia R10084, by Thomas Calligaro with the High Dynamic Microscope HIROX of C2RMF, Paris. B. The large splinter R10298 with cut marks seen by Amandeep Kaur. C. A binocular microscope view of the splinter R10298 showing the fossilization of the cut marks, C2RMF, Paris (photos A and B: A. Dambricourt Malassé – photo C: T. Calligaro).

Fig. 17. A. Microphotographie numérique 3D à l'échelle du micron d'une trace d'outil sur le tibia R10084, par Thomas Calligaro, à l'aide du microscope dynamique HIROX, C2RMF, Paris. B. La grande esquille R10298 avec des traces de découpe, vues par Amandeep Kaur. C. Une vue au microscope binoculaire de l'esquille R10298 montrant la fossilisation des traces de découpe, C2RMF, Paris (photo A et B : A. Dambricourt Malassé – photo C : T. Calligaro).

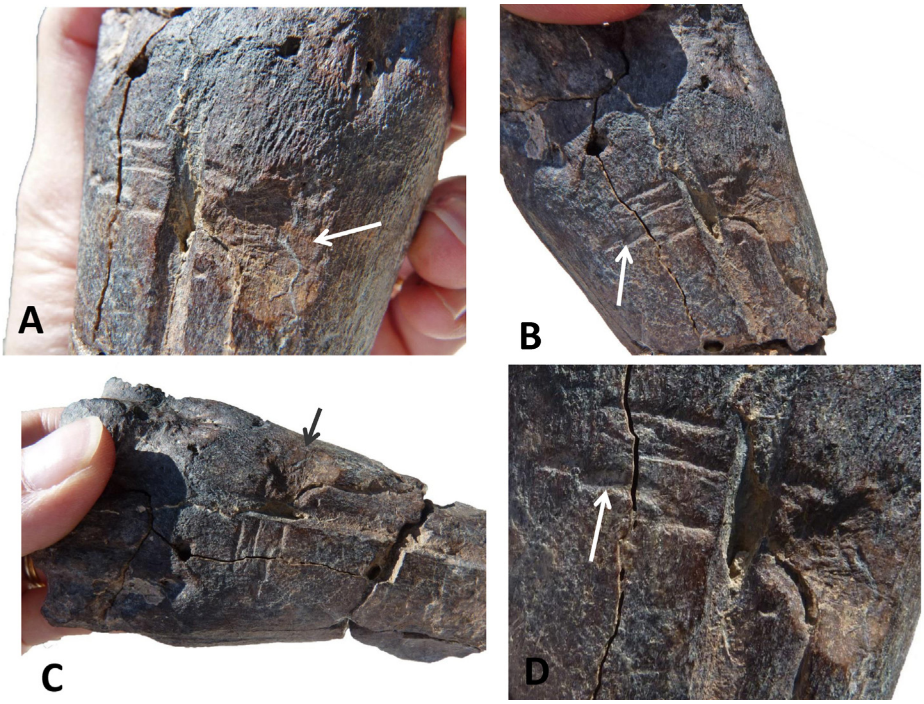

Fig. 18. Cut marks made by a sharp edge in quartzite on the bovid metapodial R10286 (Pichhli choe). The negative surface of a bone flake (A and C) and two incurved and superposed marks among other cut marks (B and D) (photo A. Dambricourt Malassé, demonstration in Dambricourt Malassé et al., 2016).
Fig. 18. Traces d'un tranchant en quartzite sur le métapode de bovidé R10286 (Pichhli choe). La surface négative d'un éclat d'os (A et C) et deux marques incurvées superposées parmi d'autres traces de découpe (B et D) (photo A. Dambricourt Malassé, démonstration in Dambricourt Malassé et al., 2016).

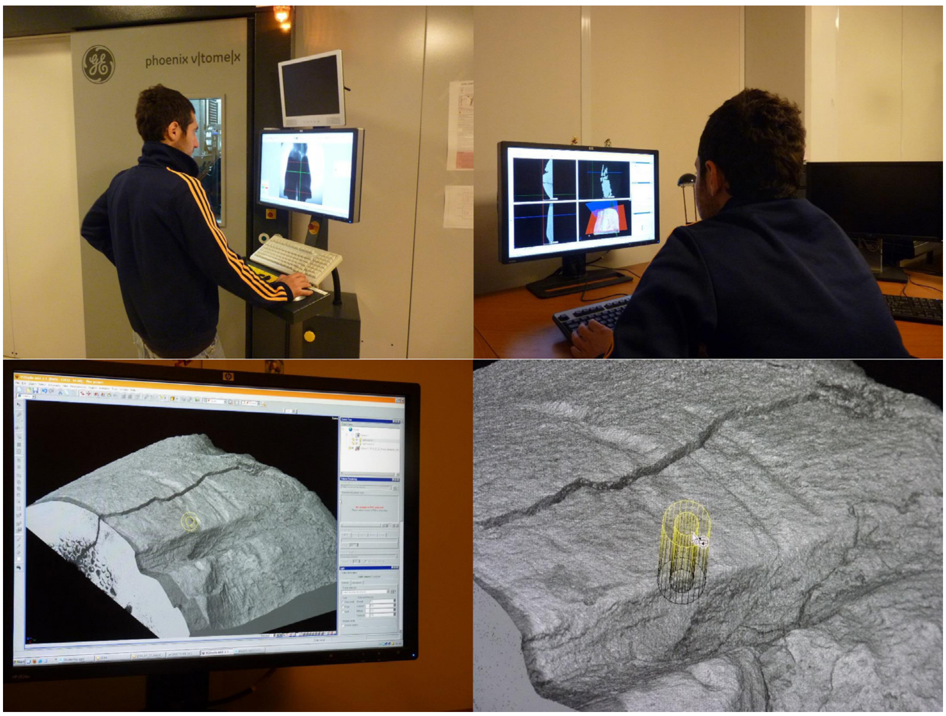

Fig. 19. Microtomography by Miguel Garcia Sanz of cut marks on the metapodial R10286 (Pichhli choe) at the AST-RX Plateform, National Museum of Natural History, Paris, (photo A. Dambricourt Malassé) (demonstration of the lithic origin in Dambricourt Malassé et al., 2016).
Fig. 19. Microtomographie par Miguel Garcia Sanz de traces de découpe sur le métapode R10286 (Pichhli choe) à la plateforme AST-RX du Muséum national d'histoire naturelle, Paris (photo A. Dambricourt Malassé, démonstration de l'origine lithique des traces in Dambricourt Malassé et al., 2016).

(Masol 1, 6, 13) (Chapon Sao et al., 2016a); and (iii) for the magnetic and clay mineralogy to identify the environmental variations (Tudryn et al., 2016). The geomorphology and the incision speed were studied for modeling the regressive erosion process (Gargani et al., 2016), 1469 fossils have been studied by locality, the taxonomy determined, the spatial distribution observed carefully (Moigne et al., 2016) and the lithic tools (flakes, choppers, hammers) have been described by locality (Gaillard et al., 2016).

The biodiversity of the Quranwala Zone presents a great wealth with around twenty taxa of aquatic and terrestrial species, herbivores and rare carnivores. The list overlaps the previous inventories with particularly *Hexaprotodon* best represented, numerous fossil of *Stegodon insignis* associated to *Elephas*, *Equus* associated to *Hipparion*, and *Merycopotamus*. The stratigraphy of the complete sequence indicates the levels in which the concentration of fossils is the highest (Chapon Sao et al., 2016a). After three years of geological investigations the last field season was conducted in February 2015 to determine the best locality to excavate and to confirm the Tatrot/Pinjor limit on the western bank of the Patiali Rao by paleomagnetism and measurement of cosmonucleids accumulated in sandstones. The conclusion converges on the Masol 1 sub-locality where the bovid diaphysis R10084 with cut marks has been recorded among other fossil bones nearby two cobble tools.

6. The success of the Indo-French cooperation: cut marks at 2.6 Ma minimum

The bovid tibia R10084 and its splinter belong to the fossil assemblage of Masol 1 (Chapon Sao et al., 2016a; Moigne et al., 2016). The particularity of the tibia is the marks on the cortical bone (Fig. 16). The aim was to verify if they had the mineralization of the cortex and if their profiles were those of gravels, crocodile, carnivore teeth, claws or quartzite tools. Two other bovid bones showed similar marks, the splinter R10298 of Masol 13 and a metacarpal R10286

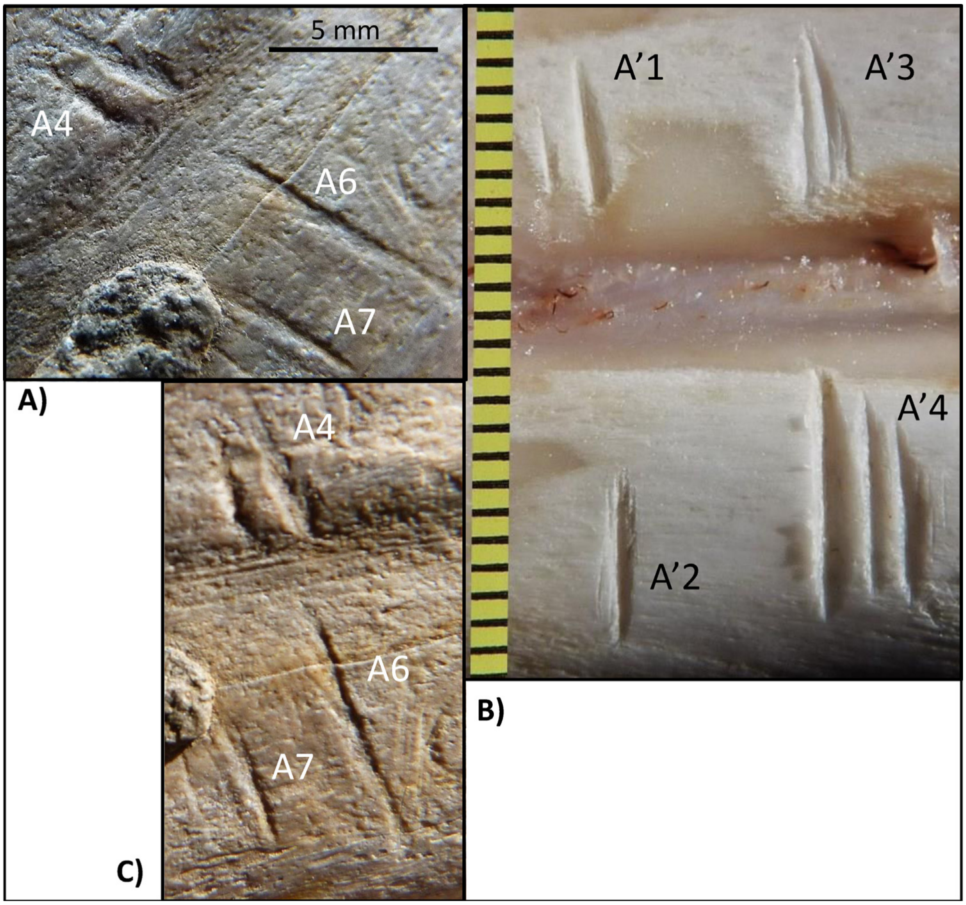

Fig. 20. Comparison between the fossilized cut marks on the bovid diaphysis Masol 1 R10084 from the Late Pliocene Quranwala Zone, Upper Siwalik, and the experimentation on a foot of *Sus scrofa.* A and C. Some fossilized cut marks A4, A6 and A7. B. Experimental butchery activity with a cobble quartzite of the Quranwala Zone: A′1, A′2, A′3 and A′4 (photo A. Dambricourt Malassé, see more in Dambricourt Malassé et al., 2016, this issue).

Fig. 20. Comparaison entre les traces fossilisée du métacarpien de bovidé Masol 1 R10084, Pliocène tardif de la zone Quranwala, Siwalik supérieur, et celles de l'expérimentation sur un pied de *Sus scrofa*. A et C. Quelques traces de boucherie, A4, A6 et A7. B. Les traces de boucherie expérimentale avec un galet de quartzite de la Zone Quranwala : A′1, A′2, A′3 et A′4 (photo A. Dambricourt Malassé, voir la démonstration in Dambricourt Malassé et al., 2016).

Fig. 21. General view of Masol 5 and detail of the slope from which one core was extracted in 2014 (circle) (photo A. Dambricourt Malassé).
Fig. 21. Vue d'ensemble de Masol 5 et le détail de la pente dans laquelle un nucléus fut extrait en 2014 (cercle) (photo A. Dambricourt Malassé).

from the small terrace T2 of the Pichhli choe (Dambricourt Malassé et al., 2016).

In 2014, the Archaeological Survey of India allowed their study in France. Those of Masol 1 and Masol 13 were observed with Thomas Calligaro at the 'Center of Research and Restoration of the Museums of France' (C2RMF) with the 3D Digital Video Microscope Hirox at the micron scale, and then with a binocular microscope. Their fossilization has been observed on the screen and numerized by the Digital Video (Fig. 17). The traces on the metapodial R10286 were scanned by microtomography and reconstructed in 3D at the AST-RX platform of the National Museum of Natural History by Miguel Garcia Sanz (Figs. 18 and 19).

All the marks were made before mineralization. We have made experimentations with quartzite cobbles collected at Masol, in India on a recent skeleton of a wild cervid, and in France on a foot of *Sus scrofa*, then compared the results with the fossils and the collection of animal marks of the "Institut de paléontologie humaine", Paris. Thirty years of experience in major sites such as La Caune de l'Arago (France), Zafarraya (Espagne), Sangiran dome and Song Terus (Indonesia), Yunxian (China) and South Corea strengthen the conclusion (see the references of Moigne in Dambricourt Malassé et al., 2016). Their shape and profile have been described in details, they correspond exactly to the type of cut marks made by the sharp edge of a chopper, or a flake in quartzite, and cannot be confused with natural scratches, teeth of crocodile, hyena or felid (Fig. 20).

7. Conclusion: marks of butchery older than 2.588 Ma and the age of stone tools

In many respects, Masol site reminds Chauntra and Chakri in the Potwar Plateau when De Terra and Teilhard de Chardin found themselves confronted with the Pre-Sohan tools. The typology of Masol industry corresponds to a very simple technology different from the Soanian and made with powerful strike force. All the assemblages are dominated by the choppers and especially end choppers mostly comprised of heavy-duty tools. Cores are rare, overall these assemblages refer to high energy activities (Gaillard et al., 2016, this issue).

The Post-Siwalik terraces around the Chandigarh anticline provide human settlements during Upper Pleistocene. Hunter-gatherers could penetrate the SFR since the beginning of the uplift (ca. 600–400 ka) and select the exposed cobbles of the Pinjor (Pleistocene), rich in conglomerates. But the ravines have not ceased to widen until today under the double influence of the permanent uplift of the Tibetan Plateau and the monsoon. The most recent exposed Late Pliocene formations in the Masol buttonhole are either in the deep sector of the Quranwala Zone, like Masol 5 (Gargani et al., 2016) (Figs. 11 and 13), or at the top of the anticline with the relict reliefs being eroded as Masol 1 and 2. One core was collected in such a recent slope near a Proboscidean vertebra at Masol 5 in 2014 (Fig. 21). Above all, the lithic industry appears circumscribed to the fossiliferous Quaranwala Zone, 130 meters below the Gauss/Matuyama reversal, whereas the conglomerates become more frequent at the top of the Zone close to the Plio/Quaternary boundary, after which the fossils disappear quickly (Sahni and Khan, 1968). Exposed since more long time, they seem devoid of artefacts despite numerous cobbles of quartzite, the link with the frequency of fossils could be the first explanation.

Since cut marks were made by quartzite cobbles abundant in many locations in association with fossil bones, we cannot exclude the hypothesis that some artefacts collected in the same conditions than the fossils, were contemporary (Gaillard et al., 2016, this issue). The origin of the stone tools is an open question and the search of artefacts in situ, as well as fossil hominids, is a realistic fieldwork. The very small number of bones with cut marks is relative, in Java where the concentration of *Homo erectus* specimens is the highest in Asia, only five bones carry cut marks among 30 000 fossils (Choi, 2003). The recent discovery of a buried lithic industry at Lomekwi 3 locality, West Turkana, Kenya, dated back to 3.3 Ma (Harmand et al., 2015), namely the Lomekwian tradition, includes cores, flakes, anvils and hammers. Such an assemblage demonstrates the very old emergence of psychomotor abilities, which will develop with the human lineage.

Finally after eight years of surveys and a multidisciplinary study of the Quranwala Zone including geomorphology, paleomagnetism, lithostratigraphy, mineralogy, paleontology, taphonomy, traceology and lithic techno-typology, it is now possible to conclude the probability of finding fossil hominins in this sub-Himalayan floodplain before the Gauss/Matuyama reversal. Seen in its historical context, the Masol discovery is of immense importance to develop the prehistory of the Siwaliks in India and enlighten the role of the Upper Indus Basin in the radiation of *Homo* genus in Asia.

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