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The first Indo-French Prehistorical Mission in Siwaliks and the discovery of anthropic activities at 2.6 million years

La première mission préhistorique franco-indienne dans les Siwaliks et la découverte d'activités anthropiques à 2,6 millions d'années

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ABSTRACT

This paper presents the first Indo-French Prehistorical Mission in the Himalayan foothills, northwestern India, and introduces the results of the multidisciplinary research program "Siwaliks" under the patronage of Professor Yves Coppens, from the Collège de France and Académie des Sciences, France. This program is dedicated to the discovery of cut marks on mineralized bovid bones collected among vertebrate fossils in a fluviatile formation named "Quranwala zone" in the Chandigarh anticline, near the village Masol, and located just below the Gauss–Matuyama polarity reversal (2.58 Ma). Artefacts (simple choppers, flakes) have been collected in and on the colluviums. This important discovery questions the origins of the hominins which made the marks.

RÉSUMÉ

Cet article présente la première mission préhistorique franco-indienne dans les piémonts himalayens du Nord-Ouest de l'Inde et introduit le programme de recherche pluridisciplinaire « Siwaliks », sous le parrainage du professeur Yves Coppens, du Collège de France et de l'Académie des sciences. Ce programme est dédié à la découverte de traces de boucherie sur des os minéralisés de bovidés, collectés parmi des fossiles de vertébrés d'une formation fluviatile nommée zone Quranwala dans l'anticlinal de Chandigarh, près du village de Masol et située juste sous la limite de l'inversion de polarité Gauss–Matuyama (2,58 Ma). Des artefacts (choppers simples et éclats) ont été collectés dans et sur les colluvions. Cette importante découverte interroge l'origine des hominiens auteurs de ces traces.

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1. The first Indo-French Prehistoric Mission

The first Indo-French Prehistoric Mission is a partnership between the Mixed Research Unit 7194 CNRS, National Museum of Natural History, Department of Prehistory, Paris, and the NGO Society for Archaeological and Anthropological Research, (SAAR), headquartered in Chandigarh, Union Territory in northern India. "Siwaliks" is the name bestowed at the research program developed to investigate geological formations in the Northwestern Himalayan foothills (Fig. 1A and B).

The name Siwaliks evokes the large geographical areas that have marked the story of human paleontology and prehistory in Asia well before the South African karsts and the East African Great Rift Valley. The history of the cooperation between the two partners is described in detail in these Proceedings of the French Academy of Sciences, entitled "Human origins on the Indian sub-continent" with a forward by Yves Coppens, Honorary Professor at the College of France and member of the Academy of Sciences. Ten articles are devoted to the discovery of human scavenging activities in the sub-Himalayan floodplains dating from 2.6 Ma (Fig. 1) (Dambricourt Malassé et al., 2016a) covering a multidisciplinary field of research:geomorphology; mineralogy; sedimentology; lithostratigraphy; paleomagnetism; paleontology; taphonomy; techno-typology of lithic assemblages; and microtopography of the cut-marks.

Prehistorical surveys were first conducted in the Hindu Kush in Pakistan between 1996 and 1998 (Dambricourt Malassé, 2008; Dambricourt Malassé and Gaillard, 2011; Gaillard et al., 2002). As early as 2002, Mukesh Singh, President of the SAAR, proposed to pursue the research in the Indian Himalayan foothills where he had surveyed the terraces during many years (Mohapatra and Singh, 1979), in the high valleys of Himachal Pradesh and in the Siwalik Frontal Range, a small chain that separates Himachal Pradesh and Punjab States (Fig. 1C). The Miocene formations of Himachal Pradesh are world-renowned for their extinct great apes *Sivapithecus* and *Indopithecus giganteus* (*Gigantopithecus bilaspurensis*), but much less for their karsts and their caves perched by the uplift of the Tibetan Plateau.

The site is a small inlier in the Siwalik Frontal Range near the Masol village, 30°50′ 2"N, 76° 50′ 31" E, north of the Union Territory of Chandigarh, the capital of Punjab and Haryana States, and 450 km east from Riwat, in the Potwar Plateau, Pakistan; Riwat is the locality where Dennell and his team collected a few artefacts in situ dated at least 2 Ma (Dennell et al., 1988; Hurcombe, 1989) and may date back to 2.58 Ma (Dennell, 1998) (Fig. 2). Masol is at the same latitude as two other majors prehistoric sites in China close to the River Yangtze: the cave of Longgupo, Wushan County, Gansu Province in Central South China, 3150 km away and dated to 2.48 Ma (Han et al., 2015), and the large fissure of Renzidong, Fanchang County, Anhui Province in Central East China, at a distance of some 3800 km dated to the maximum of 2.58 Ma (Hou and Zhao, 2010). The parallel passes through the Tibetan Plateau, especially the Mio-Pleistocene fossiliferous Zanda Basin (Wang et al., 2013) located 330 km north-east of Masol. This basin is crossed by the Langqen Zangbo River, or the Sutlej River in India which cuts through the Siwalik Frontal Range 30 km north of Chandigarh (Fig. 1C). Masol, Riwat, the Zanda Basin, Longgupo and Renzidong are below the Qinling Range (34°N), which separates conventionally Northern (Palearctic) and Southern (Eastern) China. The sources of the Indus, Sutlej and the Yangtze Rivers are located on the Tibetan Plateau.

The Siwalik Frontal Range has gradually risen since the Middle Pleistocene due to the progressive uplifting of the Himalayan Range generated by the tectonics between Indian and Eurasian plates. The Himalayan rivers filed their terraces on the margins of these foothills, rich in stone tool assemblages named Soanien (Gaillard and Dambricourt Malassé, 2008; Gaillard et al., 2011). The combination of the ongoing anticlinal folding and the monsoon rains excavates and exposes the Plio-Pleistocene fossiliferous layers, and by locations, terrestrial vertebrates, among which featured freshwater species, many reptiles such as the turtle *Geoclemys*, the crocodilian *Crocodylus* and *Gavialis* and the large herbivore, *Hexaprotodon*. The terrestrial species included the giant turtle *Colossochelys*, carnivores such as *Hyena* and *Panthera*, many herbivores of different sizes such as *Stegodon*, *Elephas*, *Hipparion*, *Equus*, *Hemibos*, *Sivatherium*, *Camelius*, rare species such as anthracothere *Mericopotamus dissimilis*, and two primates, namely, *Theropithecus* and *Procynocephalus* (e.g. Patnaik and Nanda, 2010; Patnaik et al., 2014).

Since 2012, the research program, "Siwaliks" is under the patronage of Yves Coppens (Coppens, 2016).

2. The Siwaliks and the origins of *Homo* genus (1930s-1970s)

The first fossil Asian ape was found in 1879 in the Potwar Plateau, the Western molasse of the Siwaliks bordered by the Indus River and crossed by the Soan River. Lyddeker named the specimen *Sivapithecus* well before the discovery in 1933 of the *Proconsul* in Kenya, Eastern Africa. In 1934, Lewis collected a partial maxillary in the Miocene formations of Himachal Pradesh at Haritalyangar, 80 km north-west of Masol (31° 32′ N, 76°38′ E) (Fig. 1C, Fig. 2, Fig. 3A and B). The famous YPM 13799 (Yale Peabody Museum) was assigned to a new genus, *Ramapithecus brevirostris*, because of its prognathism apparently less developed than *Sivapithecus*, Lewis proposed to consider the new fossil as an ancestor of the genus *Homo*. The Upper Indus Basin and the Himalayan foothills became the cradle of humankind up to the 1970s thanks to the works of Simons and Pilbeam; nevertheless the maxillary YPM 13799 was reclassified as a *Sivapithecus* (for a review see Kelley, 1988; Patnaik and Chauhan, 2009; Pillans et al., 2005; Vogel, 1975). The primate list of Haritalyangar was completed by the discovery of a mandible of a large species *Indopithecus giganteus* (CYP 359/68, Chandigarh Yale Paleontology), the magnetostratigraphy dating this assemblage from the Dhok Pathan Formation, to 8.5 Ma (Patnaik and David, 2007), while other analyses concluded that "*the sedimentary environments and fauna suggest that Haritalyangar primates lived within a river floodplain setting, which included open forest vegetation with patches of bamboo, in a seasonally wet sub-humid to semi-arid climate*" (Pillans et al., 2005). The absence of apes in the fossiliferous formations of late

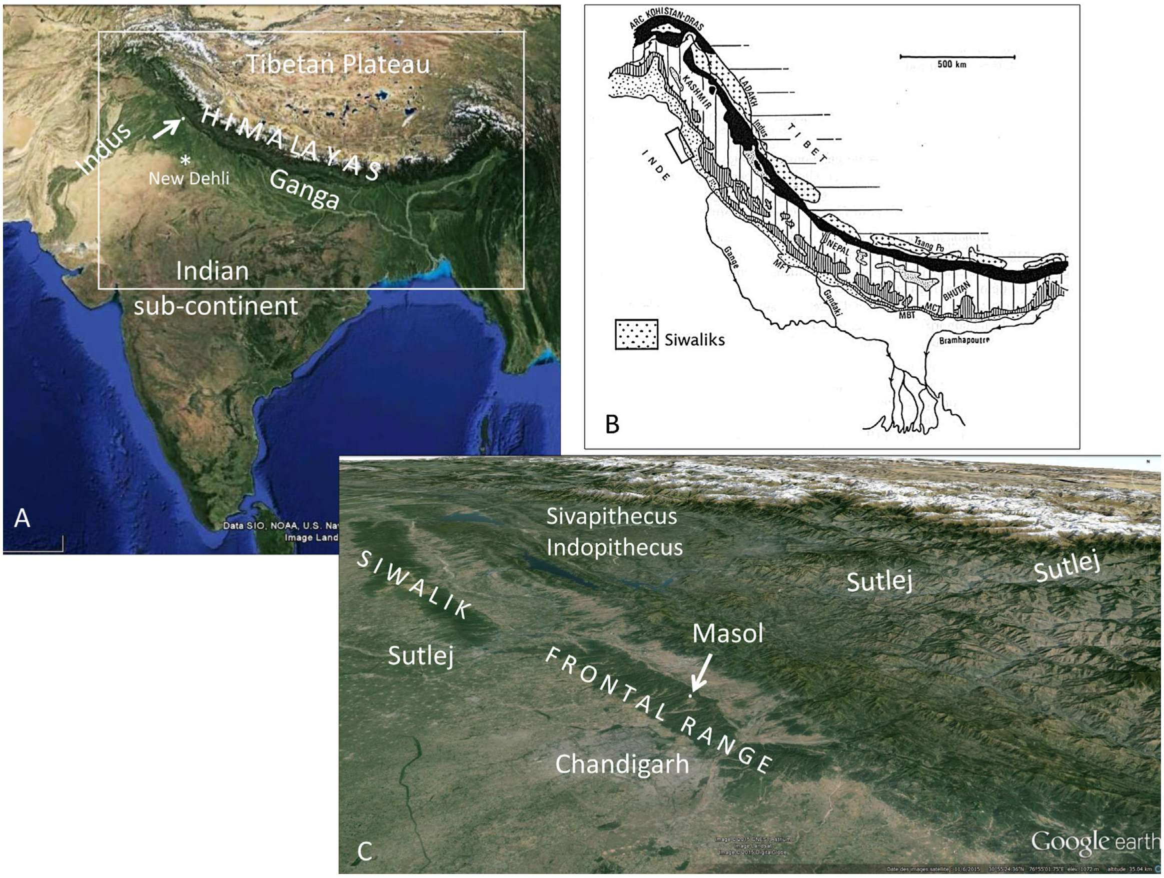

Fig. 1. Localisation of Masol in the Himalayan foothills. A. Masol in the Siwalik Frontal Range (arrow). B. The geological map of the rectangle A showing of the Siwaliks formations. C. Enlargement of the rectangle B showing the Siwalik Frontal Range (Punjab), the location of Masol and the Himachal Pradesh foothills with the sector of Sivapithecidae.

Fig. 1. Localisation de Masol dans les piémonts himalayens. A. Masol dans la chaîne frontale des Siwaliks (flèche). B. Carte géologique du rectangle A montrant les formations Siwaliks. C. Agrandissement du rectangle B montrant la chaîne frontale des Siwaliks (Punjab), la localité de Masol et les piémonts de l'Himachal Pradesh avec le secteur des Sivapithecidae.

Map data ©Google2015.

Pliocene (Tatrot) has been interpreted as "*the extinction of Sivapithecus in the Siwaliks linked to fragmentation of its forest habitat in response to decreasing rainfall*" (Pillans et al., 2005). However, Sankhyan (2011) has put forward counter-arguments, this question is debated in the paragraph 8 "Research perspective".

In 1947, the karsts of Makapan Valley, South Africa, yielded new fossils named *Australopithecus africanus*, dating from between 3.0 and 2.6 Ma, attesting to a very clear verticalisation of the axial skeleton since the hypophyseal fossa (the pituitary lodge) that imposed an osteo-skeletal architecture in permanent bipedal posture as shown by the pelvis. These skeletons had no equivalent among extant and fossil great ape species, paleontologists saw a transitory grade between the apes – semi-erected from the hypophyseal fossa to the sacrum, quadrumanous and occasionally bipedal – and the *Homo* genus, with the cerebral trunk and the spinal-cord completely verticalized, consecutively bimanous and bipedal. Others such as the world-renowned geologist-paleontologist Teilhard de Chardin (1881-1955), and counselor of the Wenner-Gren Foundation in the early 1950s, considered *Australopithecus* as a parallel phylum to the *Homo* lineage. The face looked ape-like and the brain endocast seemed too small to represent the inventor of the tools collected in Makapansgat. For the French paleontologist, who had studied the "granitization" – or "continentalisation" – of China, travelled extensively in India, Burma and Java, and contributed to the development of prehistory in Asia, the old lithic industries of Makapansgat, exemplified the emergence of *Homo* very close to *Australopithecus*, inducing his conviction of the South-African origins of the human lineage.

Teilhard de Chardin was looking for a geophysical theory of the *Homo* origins, i.e. dependent on the formation of the continents and their accretions which, consequently, modified the climatic conditions and forced the species to evolve together (the theory of continental drift was not accepted at this epoch). Man, wrote Teilhard, was born "*of the double caprice of genes*" during the "*favorable conditions*" created by the "*shape of the continents*" (Teilhard de Chardin, 1949). The theoretician of the evolutionary processes combined the growing complexity of the terrestrial

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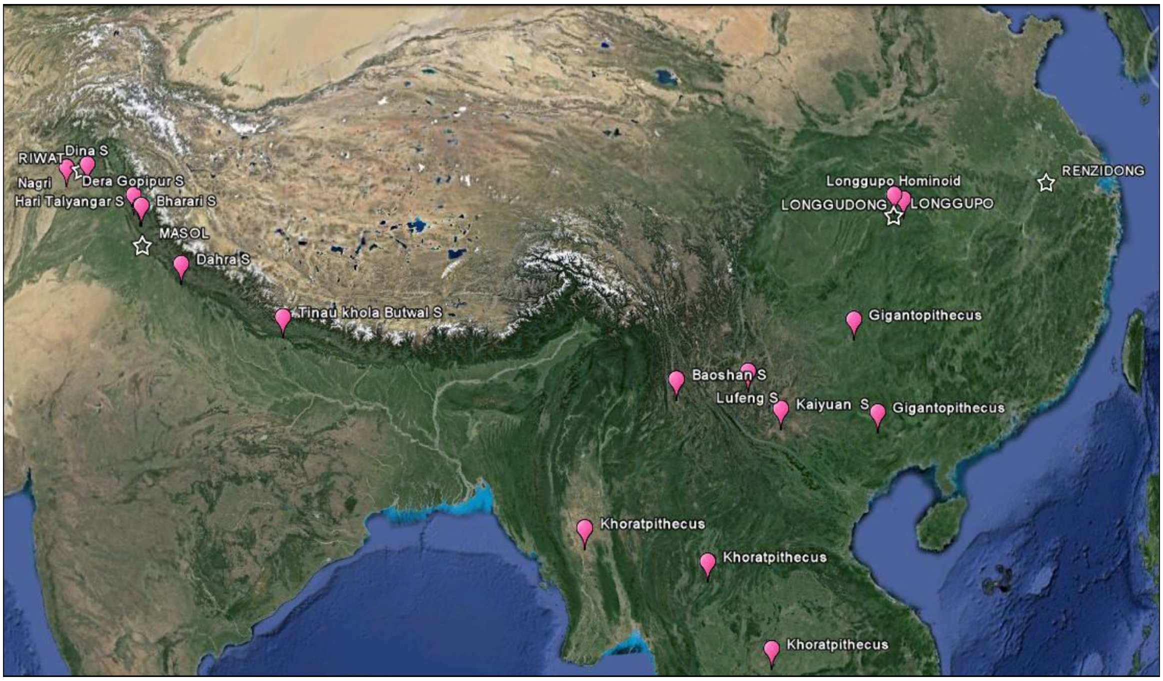

Fig. 2. Location in South Asia of Mio-Pleistocene fossil great apes and Plio-early Pleistocene paleo-anthropological localities (stars): Riwat, Masol, Longgupo, Longgudong and Renzidong.

Fig. 2. Localisation en Asie du Sud de grands anthropoïdes fossiles mio-pléistocènes et des localités paléoanthropologiques du Pliocène final (Masol) et du Pléistocène inférieur (étoiles) : Riwat, Longgupo, Longgudong et Renzidong.

Map data ©Google2015. Distribution of Sivapithecus according to Pickford and Tiwari (2010).

organisms to the "granitization" of the planet because of its spherical surface which constituted a planetary constraint, a closed system. As a specialist in Tertiary mammals, and especially of the first primates (Omomyideae), and, in contact with the anthropologists specialists in Asian *Homo erectus* (*Sinanthropus* and *Pithecanthropus*), Teilhard was able to observe how the primates had distinguished themselves among mammals, from the Tertiary up to the Quaternary, in particular, with respect to the complexification of the cerebral neocortex with *Homo erectus* and later *Homo sapiens*. At that time, paleoanthropologists described a process of "telencephalisation", or the increasing complexity of the more anterior vesicle of the embryonic neural tube (Dambricourt Malassé, 1988).

The increasing complexity of the telencephalon (cerebral hemispheres) is the directing wire of the Teilhard's geolamarckian theory on human origins, affirmed, in particular, by Jean Piveteau (1899-1991), the founder in 1938 of the Chair of Vertebrates and Human Paleontology at the Sorbonne University, Paris, where Teilhard taught the late 1940s. His scientific inheritance is transmitted in France thanks to world-renowned Professors from the National Museum of Natural History, Yves Coppens (2006, 2014), former Head Laboratory of Anthropology, and Henry de Lumley, former Head Laboratory of Prehistory (Dambricourt Malassé, 2004a). Indeed, the scientific theory of Teilhard de Chardin is capable to embrace the very long durations at the continental scales, taking into account not only the anatomical adaptations to global climate changes, but also the increasing complexity of the central nervous system up to the emergence of the reflexive consciousness.

Anthropologists and primatologists agree that this complexity expected in the fossil record, refers to a brain organization, sufficiently developed and irrigated by vascularisation, to allow a reflection of information so effective that it results in the emergence of symbolic and conceptual thought. But this cephalic organization must, necessarily, be accompanied by a neuroanatomical system allowing eye-hand coordination in order to shape an object to the image of the abstract project.

3. Africa, permanent bipedality and axial verticality

A new chapter opened in 1974-1975, which focused on the adaptation of the locomotor apparatus, or appendicular skeleton, with the discovery of *Australopithecus* in the Afar Depression in Ethiopia, where the dislocation of the African plate creates a new oceanic floor. The East-African rift became the geophysical hypothesis linking the shape of the continents, the climate and the origins of hominines with the theory of Yves Coppens, "(H)omo Event" (origin of the genus *Homo*) and "The East Side Story" (origin of the genus *Australopithecus*) (Coppens, 1975, 1976, 1978, 1979, 1980, 1981).

The emphasis on locomotion began to show an anatomical evolution more complicated than the scenario of the verticality origins, as imagined by Lamarck (1802) and, subsequently, taken over by Darwin (1871), namely, a slow and gradual post-natal acquisition with inheritance of acquired characters after birth, arising from the choice to walk in straightened posture more frequently due to the

Fig. 3. Himalayan fossiliferous foothills. A. Haritalyangar village in Himachal Pradesh. B. Forest mountains of Haritalyangar. C. The inler and the anticline dome of Masol with Masol 1 locality.

Fig. 3. Piémonts fossilifères himalayens. A. Village de Haritalyangar dans l'Himachal Pradesh. B. Paysages forestiers et montagneux d'Haritalyangar. C. La boutonnière et le dôme de l'anticlinal de Masol, avec la localité de Masol 1.

Pictures: A. Dambricourt Malassé.

depletion of forest cover. In this Lamarckian perspective, a verticalized appendicular skeleton, or the permanent bipedality, did not have to show adaptation to arboricolism. Yet, a neonate *Australopithecus* was born with a small brain, an axial skeleton verticalized since the pituitary lodge, different from *Homo* genus (Dambricourt Malassé, 2004b) and a lower appendicular skeleton with large and short pelvis which imposed a permanent bipedality on the ground, but the upper appendicular skeleton, the hands and the feet were adapted to arboricolism. The genus *Australopithecus* differentiated in sub-species adapted to a range of environments between the forest-galleries, sparse woodlands and grasslands, thus, the link between the nervous system already verticalized at birth, the small brain (cerebral hemispheres), the forest depletion became less evident.

4. The cradle of humankind

Where and when did *Homo* emerge? The scavenging activities by the use of lithic tools attest to animal feeds in the basic diet of the hominids (muscles, marrow, brain, grease) and the need for a supply of energy for more complex cerebral functional connectivity. The age of the oldest cut-marks on bones is, therefore, an indicator of this hominization process. The year 2015 has been rich in discoveries in this regard.

Concerning the intentional cut marks fossilized on a rib found at Dikika, Ethiopia, dating back to 3.4 Ma, it has been confirmed they were made with a sharp stone held by a hand (Thompson et al., 2015); concerning the oldest stone tools in Africa, the lithic assemblages from the Lomekwi 3 in West Turkana, Kenya, was found in situ and dated to 3.2 Ma (Harmand et al., 2015) and the oldest artefacts and cut marks in Asia at Longgupo in Central China are dated to 2.48 Ma (Han et al., 2015). Who were the hominids related to these elaborate activities?

The oldest fossils confidently assigned to *Homo* genus are two partial faces collected in the same geological conditions than *Australopithecus* and dated from more than 2 Ma. These specimens included the mandible of Uraha in Malawi (HCRP - UR 501, East Africa) which date to ca 2.4 Ma (Schrenk et al., 1993), and a maxillary from

Afar (AL 266, Hadar, Ethiopia) which date to ca 2.3 Ma (Kimbel et al., 1997). A new hemimandible, Ledi-Geraru (LD 350-1 Afar, Ethiopia) dating from 2.8-2.75 Ma, was presented as the oldest fossil of *Homo* genus (Villmoare et al., 2015a). The authors agree on the australopithecine conformation of the mandibular symphysis, but assume however, a morphogenetic transitional species, half-human and half-australopithecine. The taxonomic value of the suspected human features has given rise to debate (Hawks et al., 2015; Villmoare et al., 2015b). Finally, recent fossil hominids found in South Africa have been attributed to *Homo naledi*, nevertheless the geochronology is unknown (Berger et al., 2015). Since the dating is not established, in the current state of paleontological research, there is no consensus on the presence of *Homo* genus before the Plio-Pleistocene transition (2.588 Ma); the oldest specimen is located in the southern limit of the rift valley in Malawi. The authors of the cut-marks from Dikika and the artefacts of Lomekwi 3 could be species of *Australopithecus* or close relative (*Kenyanthropus platyops*), nevertheless, it is highly probable that remains of *Homo* genus exist somewhere since at least 3 Ma ago (Coppens, 2013).

5. The discovery of anthropic activities in the Siwaliks at 2.6 Ma

5.1. The beginning

In 2007, one objective of the "Siwaliks" program consisted of verifying if clusters of quartzite could be observed among paleontological formations in the Chandigarh Siwalik Hills, in order to find stone tools in association with fauna and hominids from 1.8 Ma. The geological formations are small anticlines parallel to the Himalayan Range, dug by gullies and seasonal rivers (or *choe*) fed by the monsoon rains. At that time, the Plio-Pleistocene transition was still often associated to the Olduvai sub-chron. We have explored a small inlier formed by silt and fluvial sands dating from the late Pliocene, rich in terrestrial and freshwater vertebrates, crossed by the Patiali Rao River. Masol is a village built by sedentary nomads on the two banks of the river, the bed of which allows access to the plain during the dry season. The dome of the anticline is eroded and forms of a small plateau. In 2008, Mukesh Singh collected there a chopper in fossiliferous colluvium. In 2009, the team was composed of Mukesh Singh, Anne Dambricourt Malassé and Claire Gaillard. Singh invited Manjil Hazarika, who was at that time Erasmus Mundus student in Quaternary and Prehistory at the National Museum of Natural History, Paris, and at Chandigarh, to the 3rd LIMPACS Conference, organized by Bahadur Kotlia (Nainital University, Uttar Pradesh). Manjil Hazarika recovered a bovid shaft tibia, particularly mineralized and similar to other fossils from the locality (Masol 1 or M1), a few meters beyond the colluvium in which the first chopper was collected. The bone attracted attention due to many traces which highly resembled the intentional cuts marks (more details in Dambricourt Malassé et al., 2016a). The cut marked shaft tibia was collected at the top of the anticline among other fossils with similar mineralization, while a few choppers and flakes were scattered on the colluviums of the fossiliferous outcrops (Fig. 3C). The question arose as to whether we were in the presence of a scavenging site frequented by hominins.

All the data published on the Chandigarh anticline had to be gathered. In the 1960s, two geologists, Sahni and Khan (1964, 1968), mapped the geology and named this fossiliferous formation "Quranwala zone" and integrated them into the upper part of the Tatrot Formation, the end of the Pliocene (see maps in Dambricourt Malassé et al., 2016a). The cliffs of Masol correspond to the outcrops of ancient fluvial formations from a Himalayan river similar to the current Sutlej. These deposits have been unearthed by compressive tectonics which began in this region around 600 ka ago (more details in Gargani et al., 2016). The geologists gave the name of Masol to the Tatrot Formation which follows the anticline axis. Many studies of the fossil vertebrates made the inlier of Masol an international reference for the Tertiary-Quaternary transition in South Asia (e.g. Badam, 1973, 1979; Gaur, 1987; Karir et al., 1975; Nanda, 1994, 2002; Patnaik, 2003, 2013; Pilgrim, 1913; Sahni and Khan, 1968). Indeed, the *Stegodon-Elephas* and *Hipparion-Equus* assemblages illustrate the period approaching the global cooling that characterizes the Quaternary. Later, paleomagnetic measurements were recorded all along the Patiali Rao and have shown that the fossils collected in the inlier are located under the Gauss–Matuyama paleomagnetic reversal (Ranga Rao, 1993; Ranga Rao et al., 1995) dating from 2.588 Ma (Cande and Kent, 1995; Gradstein et al., 2004).

As the local origin of the shaft tibia was safe, we had to verify the anthropic origin of the traces, as well as their mineralization identical to the bone and to find the stratigraphic origins of the stone tools. In 2011, two mineralized bones, a metacarpal and a large splinter of bovid from two distinct localities, again showed marks of the same type. In 2011 and 2012, two large splinters with the same mineralization were collected in the vicinity of the cut marked diaphysis (Masol 1), the second one was restuck on the tibia shaft. These traces were all the more interesting and convincing as choppers and flakes were recovered in the same conditions of ongoing erosion. Today, 12 localities over an area of 50 hectares have each yielded at least one artefact associated with fossils on the outcrops, or, in and on their recent colluviums. These artefacts (about 250) are simple choppers, flakes and rare nucleus (Gaillard et al., 2016).

5.2. Organization of the field research

Since 2009, choppers, flakes and bones of large mammals are collected all along the foot of a large cliff in ongoing erosion, according to the dip of its fossiliferous layers, 80 m north of Masol 1 (Fig. 4), the locality was named Masol 2. In 2011, a first step consisted to dig two trial trenches in order to find artefacts in stratigraphy (Fig. 5A and B), the second trench B1 provided many pebbles of quartzite, four artefacts and very fragmented fossils (Chapon Sao et al., 2016b; Gaillard et al., 2016). The analysis of the data collected required excellent knowledge, not only of lithostratigraphy, but of geomorphology (dip) and, above all, of the speed of outcrop erosion, which seemed very fast. Then, the fauna assemblage of Masol 1 and Masol 2 had to be placed in

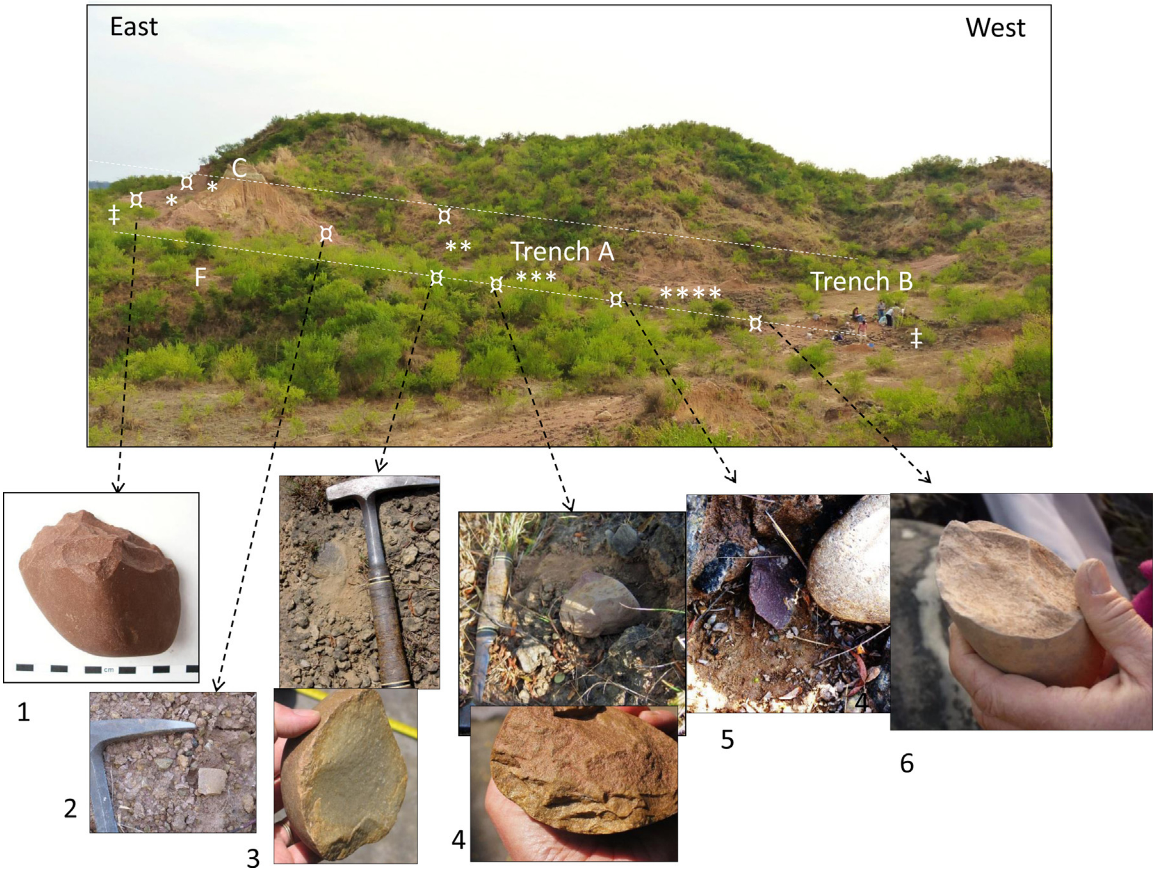

Fig. 4. Masol 2, distribution of fossils and artefacts according to the dip of silts between two layers of sandstones (C and F) at the foot of a cliff, and location of the trenches A1 and B1. Dotted lines: dip of the silts between the sandstones C and F; ¤ : artefacts in quartzite; ‡ : clusters of quartzite pebbles; *: scapula and tusk of Proboscidean; **: two Proboscidean diaphyses; ***: *Hexaprotodon* maxillary; ****: tusk splinters.

Fig. 4. Masol 2, répartition des fossiles et des artéfacts selon le pendage de limons entre deux couches de sable (C et F) au pied d'une falaise en cours d'érosion et localisation des sondages A1 et B1. Pointillés : pendage des limons entre les couches C et F ; ¤ : artefacts en quartzite ; ‡ : amas de galets de quartzite ; * : omoplate et défense de Proboscidien ; ** : deux diaphyses de Proboscidien ; *** : maxillaire d'*Hexaprotodon* ; **** : esquille de défense.

Pictures: A. Dambricourt Malassé.

the fauna list of the Quranwala zone and the origin of the quartzite pebbles had to be studied by mapping the geology of the inlier.

Moreover, the 12 paleontogical-archeological localities necessitated the understanding of their distribution in the lithostratigraphy. This study and the analysis of the dips would permit to observe either a logical distribution of the tools in association with the fossils recently unearthed, or, a random dispersal whatever the nature of the outcrops, i.e. fossiliferous or sterile. Finally, the Pliocene origin of the artefacts could not be conceptualized without an excellent knowledge of the speed of the erosion and of the rivulet incision which evacuates the sediments, the fossils and the quartzite pebbles.

The bibliography was useful but geologists had ceased to explore the Siwalik Hills of Chandigarh more than 20 years ago. The French team had to undertake the geological fieldwork advised by Baldev Karir, retired Professor of Chandigarh University and member of the SAAR (Dambricourt Malassé et al., 2016a; Karir, 1985; Karir et al., 1975). Since there was little doubt with respect to the anthropic origin of the traces and that the local origin of the fossil were safe (Abdessadok et al., 2016; Chapon Sao et al., 2016b; Gargani et al., 2016; Moigne et al., 2016; Tudryn et al., 2016), I solicited in 2011, the patronage of Yves Coppens, Honorary Professor at the College of France, and the financial support of the French Ministry of Foreign Affairs (MAE) for a research program covering a 4-year period (2012-2015). A period of 4 weeks per year, during the winter period from February to March, was the necessary time-frame to study the geology, geomorphology and tectonics of the 50 hectares, relatively poor in vegetation, and to pursue the search for hominids, stone tool marks on bones and localities for excavation.

5.3. The fieldwork and laboratory analyses

Since 2012, the members of the UMR 7194 on the field were Claire Gaillard who studied the lithic industry stored at the SAAR (Gaillard et al., 2016); Anne-Marie Moigne who studied nearly 1,500 fossils and analyzed the taphonomy (Moigne et al., 2016); Salah Abdessadok

Fig. 5. The fieldwork: Masol 2. A. The trench A1. B. The trench B1; Masol 6, giant shell of *Colossochelys*. C. Half-shell in the silts after recent erosion. D. Collect of shell pieces fall down in a gully.

Fig. 5. Le terrain: Masol 2. A. Le sondage A1. B. Le sondage B1 ; Masol 6, carapace géante de *Colossochelys*. C. Demi-carapace dans les limons après une érosion récente. D. Collecte des morceaux de carapace tombés dans un ravin.

Pictures: A. Dambricourt Malassé.

who studied the lithostratigraphy on the field in the main localities (Masol 1/Masol 2, Masol 6, Masol 13) and analyzed the sedimentology (Abdessadok et al., 2016); and Cécile Chapon Sao for the lithostratigraphic study and the paleomagnetism (Chapon Sao et al., 2016a,b). In the field, I collected and recorded artefacts and fossils in their geomorphological and lithostratigraphical context (pictures, films, schema and graphics) and at the SAAR classified the collection by localities stored in the better condition of conservation (large and solid boxes). The regularity of the fieldwork effort allowed the collection of rare species such as *Merycopotamus dissimilis* (Anthracothere) and *Panthera*, confirming the efficiency of the survey to recover fossil hominids. In 2014 and 2015, I solicited two geologists of the University Paris Sud-Paris Saclay (UMR 8148, GEOPS, Geosciences), Julien Gargani and Alina Tudryn. Gargani conduced the geomorphological study and established a first model estimating the speed of incision (Gargani et al., 2016) while Tudryn completed the mineralogical and lithostratigraphic study and compiled the synthetic stratigraphic log of the prospected sequence (Tudryn et al., 2016). Finally, Pierre Voinchet dated the colluvium containing choppers and fossils by the ESR method in France, the results of which are being finalized.

Mukesh Singh was assisted by Baldev Karir and Surinder Pal, all have surveyed the Himachal Pradesh foothills and the Siwalik Frontal Range since the 1970s and have acquired a great experience on its geomorphology (see more in Dambricourt Malassé et al., 2016a). The Indian team was completed with Amandeep Kaur, a volunteer student for the excavations and fieldwork, who observed cut marks on a splinter (Masol 13) and Vipnesh Bhardwaj, teacher in Ancient India History, also volunteered for fieldwork. We were welcomed and advised by the Mayor of Masol, and assisted by villagers during the trial trenches, as well as for the transport of large and heavy fossils with camel and donkey.

6. Bilan

6.1. Geology, geomorphology and stratigraphy

The studies of geology and geomorphology allow now to master the lithostratigraphy and the spatial distribution of the paleontological-archeological localities and the clusters of quartzite pebbles. These pebbles were deposited at the same time that the carcasses, some artefacts appeared in the colluvium, but other were collected on outcrops ongoing erosion (e.g. artefacts 1, 2 and 3, Figs. 5 and 6).

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Fig. 6. Masol 6. A and B. Partial hemimandible of *Panthera* on silts. C. Chopper in quartzite on the same silts at around 15 m.
Fig. 6. Masol 6. A et B. Fragment d'hémimandibule de *Panthera* sur les limons. C. Chopper en quartzite sur les mêmes limons à une quinzaine de mètres. *Pictures: A. Dambricourt Malassé.*

It is notable that all artefacts were associated with at least one fossil and the majority were in the vicinity of quartzite pebble clusters: Masol 2, 3, 5, 6, 7, 9, 13 (M4 is now a sector of M6, and M10 a sector of M9). The synthetic stratigraphic log, the observation of the dips and the study of the geomorphology, have allowed interpreting the data from the two trenches open at Masol 2. The four artefacts of the trench B1 were found in the upper part of silts altered by the dismantled layers, they origins in situ cannot be certified. Nevertheless, these silts are those on which artefacts were collected all along the foot of the large cliff and the same as those of Masol 1, 80 m away where the cut-marked tibia shaft was recovered, these layers form the base of the Quranwala zone (Chapon Sao et al., 2016b). The incision of the deepest sector which provided two artefacts in the vicinity of *Merycopotamus*, (Masol 5), 380 m beyond a cut marked metacarpal (Picchli Choe), occurred recently (Gargani et al., 2016).

6.2. Fauna, climate and cut marks

The taxonomic and taphonomic study of 1,500 fossils distinguished three orders of reptiles (crocodilian, turtle, and lizard), two families of carnivores (Hyenidae and Felidae) and ten families of herbivores (Moigne et al., 2016). There were few crocodiles and carnivores (four *Crocuta* and one *Panthera*). Tooth marks on bones reveal the presence of rodents and green fractures were very probably caused by carnivores. The accumulation of carcasses was not distinguishable with respect to the size or to the different parts of the skeleton, and small bones were very well represented. The mineralogical, sedimentological and lithostratigraphic analyses of the fossiliferous layers, allow concluding to the natural origin of the accumulation caused by seasonal monsoon with significant flooding (Abdessadok et al., 2016; Chapon Sao et al., 2016b; Tudryn et al., 2016). The faunal list allows inferring a sub-tropical environment with grassland and opening woodland.

Primates such as the Cercopithecidae are usually associated with *Homo erectus* (Ciochon and Larick, 2000), they have not been collected at Masol; nevertheless, the *Procynocephalus* was present in the Plio-Pleistocene transitional formations in the Chandigarh region. The first *Procynocephalus* was recovered in 1848 in the Pinjor Formation (Lower Pleistocene) near Dehra Dun, 120 km south-east of Chandigarh and named *P. subhimalayanus*. In the 1960s, a very well-preserved mandible was collected 10 km south of the limit of the Quranwala zone near Bunga at the boundary between the Tatrot and Pinjor Formations (Verma, 1969). The jaw was assigned to *Procynocephalus pinjaury* and considered a descendant of the species *Procynocephalus wimani*, known to the Honan Province of China within the *Hipparion* assemblage, and dating from the late Pliocene (Howells and Tsuchitani, 1977). For this reason, Verma did not exclude *P. pinjaury* from the latest Pliocene of the Siwaliks. Similarly, Patnaik and Nanda (2010) suspected its origin to be in the Tatrot Formation. The dental microwear was analyzed to evaluate the dietary proclivities of this specimen; the results inferred widespread grassland (Williams and Holmes, 2012). New fossils of *Procynocephalus* were observed in China among artefacts recovered in situ, in the large fissure of Renzidong

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in Anhui Province, Central East China, the age can be close to 2.58 Ma (Hou and Zhao, 2010), and in the fauna list of Longgupo, associated with cut marked bones and a partial mandible of a *Homo* or hominoid (Ciochon, 2009; Ciochon and Larick, 2000) dating from 2.48 Ma (Han et al., 2015). These discoveries constitute a coherent and convergent corpus of data suggesting the presence of *Procynocephalus* in the paleo-sub-Himalayan flooplain and in the vicinity of hominins during the late Pliocene.

The first cut marked fossil, Masol 1 R10084, is a tibia shaft about the size of a *Leptobos*. Its cortical bone is yellow color and covered by a thin crust of micaceous sand similar to other fossils from the same dismantled hillock. Its stratigraphic origin was the yellow silt capped by friable micaceous sandstone. The second cut marked fossil, Masol R10286, is a broken distal metacarpal of large bovid, also covered by rodent teeth marks. The metacarpal was collected 200 m southwest of Masol 1, on a small terrace of a seasonal torrent, the Pichhli Choe, which dug its bed in the same silts and sandstones than those of Masol 1. The third cut marked fossil, Masol 13 R10298, is a splinter collected 700 m from Masol 1, among a rich fauna of herbivores, no crocodile and carnivores have been recovered here (Chapon Sao et al., 2016b; Dambricourt Malassé et al., 2016a, 2016b).

The images acquisition of the cut marks at the micron scale was achieved in Paris on July 2014 with the authorization of the Archaeological Survey of India, in collaboration with Thomas Calligaro (UMR 171) using the 3D Dynamic Digital Microscope of the C2RMF, and with the microscanner of the AST-RX plateform from the National Museum of Natural History in collaboration with Miguel García Sanz (UMS 2700) (Dambricourt Malassé et al., 2016a). An experimental study was conducted in France on a metapodal of *Sus scrofa domesticus* with a quartzite pebble collected at Masol (this type of experimentation is not desirable in India). The comparison showed spectacular similarities: the whole of observations have confirmed the lithic and manual origins of the marks made with agile and precise gestures, to break the bones and eat the marrow (Dambricourt Malassé et al., 2016b).

6.3. *The lithic artefacts*

No artefacts were in situ, but, of 2,500 fossils, only five specimens were collected in stratigraphy: two at Masol 6 with one hemimandible of small herbivore and a giant turtle transported with a camel (Fig. 5C and D), then two hemimandibles of the same antelope in the silts at Masol 1, and, finally, one Proboscidean skull with two large tusks in a section in a cliff. This represented 0.27% of the collection from 50 hectares of gullied slopes. The deficiency of artefacts in the geological section does not mean an archaeological sterility of the fossiliferous layers. In any case, the cutting edges of choppers or flakes were necessary to leave marks on fossilized bones in three distinct localities.

The techno-typological study shows "mostly heavy-duty tools with a majority of choppers, rather end-choppers than side-choppers, among which the 'simple choppers' (shaped by one single removal) are frequent" (Gaillard et al., 2016), a finding which is compatible with a scavenging activity at 2.6 Ma (Fig. 6). We tested the extreme hardness of the quartzite pebbles; the direct percussion was unsuccessful, the bipolar percussion was applied with pebbles recovered at Masol and a large pebble of quartzite (30 cm long) stored at the SAAR used as anvil, we obtained flakes after several shocks of very great power. The clusters of quartzite pebbles in the inlier of Masol do not provide so large stones.

7. Discussion and preliminary conclusion

The small number of fossils with cut marks must be replaced in a comparative context: at Java in South East Asia, only five bones to 30,000 fossils carried cut marks (Choi, 2003). In this regard, the small inlier of Masol was rather an exceptional site. The lack of tools on the slopes of the oldest and youngest geological layers devoid of fossils corresponded to what we would have expected if the collected artefacts and fossils were in the same layers before the current erosion. The study of the speed erosion and the observation of the lithostratigraphic condition of the collect, suggested that some artefacts were in the fossiliferous layers before erosion, especially since they did not match with Soanian or Hoabhinian-like assemblages, as demonstrated by Gaillard (Gaillard et al., 2016). The verisimilitude of lithic artefacts of late Pliocene age is strongly supported by the cut marks and the modeling of the erosion speed. The question could be solved by large excavations at Masol 1 and Masol 2. Concerning the absence of hominid fossils, it can be compared to that of rodents which left traces on several bones but are missing among the fossils. The chance to find remains of hominid is encouraged by the collect of rare carnivore and herbivore such as *Panthera* and *Mericopotamus*.

After 7 years of research devoted to geomorphology, the incision speed, lithostratigraphy, mineralogy, paleomagnetism and paleontology of the Quranwala zone, it is now possible to conclude that the cut marks on bones attest to the presence of hominins in the sub-Himalayan floodplain during the Late Pliocene. These hominines were familiar with an environment regularly exposed to monsoon and floods in the plain, where Himalayan rivers provided carrion for meat, grease, marrow and also raw material for the stone tools. Insofar as, on the ground, there is no hard stone other than the quartzite pebbles with a mean size of 15 cm, hominins likely used the direct percussion that gives an idea of their muscle power. The hominins of Masol had a good anatomical knowledge of the carrion as shown by the marks on the bones, which reveal organized, agile and precise gestures. The discovery of anthropic scavenging activity in Siwaliks dating from 2.6 Ma raises now the question of the geographic and phyletic origins of these hominines.

8. Research perspectives

The identification of regions where *Homo* emerged is obviously constrained by the accessibility of the fossiliferous formations and the Afar Depression in Ethiopia is exceptional in this regard. The presence of apes in the late Miocene and lower Pliocene formations is also a criterion

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of first importance. The geographical paradigm has shifted, firstly, from South Asia to South Africa, then to East Africa and to Central Africa around the paleolake Chad since the discovery of *Australopithecus barhelgazhali* (3.5-3 Ma) (Brunet et al., 1995) and *Sahelanthropus tchadensis* (7 Ma) (Brunet et al., 2002).

In the context of the African paradigm, the presence of hominids in the Siwaliks leaves no other choice than their attribution to the *Homo* genus. Many questions will have to be solved. Now, it is necessary to postpone the emergence of the genus to a date that takes into account a large number of parameters, such as the time for a new species to reach a sufficient demographic size rather than to disappear (natural selection). The population must reach sufficient demographic size to extend beyond its reproduction area, yet *Homo* puberty is the most delayed among the primates and slowed down the frequency of births. It is necessary to evaluate the parameters that would have forced the populations to move until the shores of the Red Sea to the Upper Indus Basin over the generations for their supply of meat and marrow. The biological continuity between African and Eurasian bovid species is observed during late Miocene and then, but in early Pliocene, it decreases (Bibi, 2011).

The emergence of the *Homo* genus very likely dates back to earlier than 3 Ma. The oldest fossil whose appendicular skeleton is human-like is a distal humerus from Kanapoi in Kenya, dating from 4.2 Ma, assigned to *Homo*? (Senut, 1979). The appendicular skeleton of Kadanuumuu (KSD-VP-1/1, Ethiopia), dating from 3.58 Ma, resembled to human anatomy but the remains were assigned to *Australopithecus afarensis* (Haile-Selassie et al., 2010). This human-like anatomy reminds the hypothesis of Yves Coppens and Brigitte Senut about a *Praeanthropus* grade before *Homo* (Senut, 2003). In the African paradigm, the most probable cradle of *Homo* genus is the north of the Rift Valley, rather than Central and South Africa.

The first Asian paradigm is interesting. The comparison between the geographical distribution of fossil apes and the oldest human occupations including Riwat, shows clearly a superposition (Fig. 2). The partial mandible of Longgupo was first assigned to a descendant from *Homo habilis*, then, a dozen of years later, to a "mystery ape". This revision arose from the paradigm of "Out of Africa" dating from 1.8 Ma; "*such classifications are always open to interpretation. But I am now convinced that the Longgupo fossil and others like it do not represent a pre-erectus human, but rather one or more mystery apes indigenous to southeast Asia's Pleistocene primal forest. In contrast, H. erectus arrived in Asia about 1.6 million years ago.*" (Ciochon, 2009).

With the new dating of Longgupo (2.48 Ma) and Masol (2.6 Ma), the mandible could be seen as a remain of the hominin expected at Masol. If this view is incorrect, then the oldest Pleistocene fossil hominins of South Asia are three massive molars collected at Longgudong cave, close to Longggupo, and assigned to a hypothetical *Meganthropus* (Dong, 2006; Zhang et al., 2004) dating approximately from 2 Ma (Matuyama period, Hou and Zhao, 2010). *Meganthropus* is coherent with the expected anatomy of Masol hominins which have broken quartzite pebbles and used their sharp edges for their scavenging activities.

The extension area of *Sivapithecidae* towards the Indo-Gangetic plain can be evaluated thanks to the Potwar Plateau, which has not undergone the compression as in Himachal Pradesh, and all along the Himalayan range where the Mio-Pliocene layers are sometimes compressed up to the vertical. An important fossiliferous gap is observed in Indian foothills between the Upper Miocene in altitude (Himachal Pradesh) and the Late Pliocene in the Siwalik Frontal Range near the plain (Punjab), probably due to the very compressed geological layers. The fossiliferous deposits disappear, more than 5 million years of paleontological story are missing between the youngest Dhok Pathan assemblage (8 Ma) and the oldest Tatrot fauna (2.6 Ma) (Patnaik, 2013), that does not imply the extinction of *Sivapithecus* and *Indopithecus* during the lower Pliocene. The collect of fossils is considerably limited compared the Great Rift Valley; in Africa, the tectonics opens a book on the ape's evolution, whereas it closes this story in South Asia along the contact between the Indian and Asian plates, from the Hindu Kush foothills to the Indo-Sino-Myanmar ranges.

The ecological changes in the Himalayan floodplain during Late Miocene–Early Pliocene were studied by faunal assemblages, floras and analysis of tooth enamel (Patnaik et al., 2014) and they correspond to a fragmentation of tropical and sub-tropical forests with extension of grassland. These ecological changes in Africa are interpreted as the cause of the permanent bipedality, but in Asia, the same factors would have provoked the extinction. Nevertheless, the use of bipedal balance was well developed during the final Miocene in the Yunnan by *Lufengpithecus* from Shihuiba in South China, as shown by the femoral neck of PA 1276 (Xu and Liu, 2008). Finally, Grehan and Schwartz (2009) defend arguments for the Asian paradigm of *Homo* genus origins.

The emphasis on the locomotor apparatus of *Australopithecus* represents a major phase of the research into the evolutionary process of *Homo* genus. The co-existence of small brain, permanent bipedality and arboricolism was unexpected and the expected link with the increasing complexity of the nervous disappeared. This paradox was raised in the years 1980-1990 thanks to the distinction between the bipedality of the appendicular skeleton, and the verticality of the axial skeleton which surround the nervous system. Given the considerable implications of the Masol discovery in the current context of human paleontology and prehistory in Asia and Africa, it is necessary to recall the origins of the verticality. The straightening of the nervous system occurred in the amniotic liquid and at the scale of a few mm in relation with the phylogenetic increasing complexity of the neurogenesis and the cephalo-caudal control of the embryogenesis, 30 years of research have been recently synthesized (Dambricourt Malassé, 2011b). Since 1987, I remind in paleontology (Dambricourt Malassé, 1988) that the skull base is flat in all mammal embryos, aligned with the cephalo-caudal axis. Therefore, all embryos of fossil and extant species developed with a skull base aligned with the future vertebral column. All mammals keep this embryonic conformation after birth, except the Simians. At birth, the posterior base is more and more flexed from monkeys to modern *Homo sapiens*. The verticalisation of the skull base is an embryonic process due to neural tube kinetics (future nervous system). In its cephalic part, these kinetics induce spiral curvatures during the last week of the embryonic period which provoke the straightening of the base below the pituitary lodge (Dambricourt Malassé, 1988, 1993, 2006, 2011a, 2011b). Pongidae (Asia) and Panidae (Africa) share the same embryonic flexure at birth, less flexed than *Homo sapiens*, they exhibite shorter kinetics and a faster embryonic process. These kinetics are unchanged from their common ancestor, dating from at least 20 Ma. Only a prolongation of the embryonic cephalic kinetics common to the African and Asian apes can explain an increasing lowering of their embryonic skull base (Dambricourt Malassé, 1988, 1993, 2002, 2004b, 2005, 2006, 2009, 2010, 2011a, 2011b; Dambricourt Malassé and Deshayes, 1992; Dambricourt Malassé et al., 2000), this evolution was saltationist all along the embryonic axis thanks to the homeotic genes (Dambricourt Malassé, 1993; Dambricourt Malassé and Lallouet, 2009). The permanent bipedality is a postnatal consequence of the increasing complexity of the embryonic development, especially of the nervous system. Teilhard de Chardin was right in the great lines, this process started with the first monkeys 39 Ma ago, but acting with thresholds, or emergences, after millions years of stability. This discovery does not contradict radiation and speciation of a new morphogenetic pattern with adaptations of the appendicular skeleton to different ecological niches, and of the facial and dental growth to different diets.

Consequently, it is not surprising that the evolutionary threshold of neural verticality, especially of the cerebellum, was accompanied by the emergence of new concepts and new agility to create choppers or chopping tools (Dambricourt Malassé, 2011b). If *Sahelanthropus tchadensis* and its descendants could transmit such increasing complexity until a new embryonic threshold (*Australopithecus*), why *Lufengpithecus lufengensis*, for instance, already adapted to frequent bipedality in South Asia, could not transmit the same evolutionary properties? To conclude, the discovery of anthropic activities in the sub-Himalayan floodplain at the end of the Pliocene, should stimulate the research on the increasing complexity of the nervous system in close relation with the appendicular skeleton since the embryogeny, and its relationships with environmental changes at the planetary scale.

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