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The faunal assemblage of the paleonto-archeological localities of the Late Pliocene Quranwala Zone, Masol Formation, Siwalik Range, NW India

L'assemblage faunique des localités paléonto-archéologiques de la zone Quranwala, Pliocène final, formation de Masol, chaîne frontale des Siwaliks, Nord-Ouest de l'Inde

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ABSTRACT

The Indo-French Program of Research 'Siwaliks' carried out investigations in the 'Quranwala zone' of the Masol Formation (Tatrot), Chandigarh Siwalik Range, known since the 1960s for its "transitional fauna". This new paleontological study was implemented following the discovery of bones with cut marks near choppers and flakes in quartzite collected on the outcrops. Nine fieldwork seasons (2008–2015) on 50 hectares of ravines and a small plateau recovered lithic tools and fossil assemblages in 12 localities with approximately 1500 fossils. Their study shows that the most abundant mammal species are the Proboscideans with *Stegodon insignis*. The transition with the Pleistocene fauna is evidenced by *Elephas hysudricus*, *Hipparion antelopinum* and *Equus sivalensis*. The freshwater mammal is also well illustrated with *Hexaprotodon sivalensis*. Bovids present the greatest variety with six tribes from the smallest to the largest. Two types of cervids are observed; *Sivatherium giganteum* is visible in several localities and *Merycopotamus dissimilis* in one. Turtles, with the giant terrestrial *Colossochelys* and the freshwater *Geoclemys*, are abundant. The aquatic predators are limited (crocodile) and terrestrial carnivores are very scarce (hyena, felid). The faunal assemblages match the Plio-Pleistocene transitional fauna, also described in the Pabbi Hills (Pakistan), and mark the beginning of the *Equus sivalensis* Biostratigraphic interval-Zone, which extends from 2.6 Ma to 600 ka. The systematic repetition of surveys has, therefore, allowed the collection of rare taxa, such as *Crocuta* (2010), *Merycopotamus dissimilis* (2014) and a large felid (2015). These latest findings are significant for the discovery of *Homininae* in Siwaliks.

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Mots clés :
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Plaine alluviale sous-himalayenne
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Assemblage faunique de Tatrot

RÉSUMÉ

Le programme de recherche franco-indien « Siwaliks » poursuit ses investigations dans la zone Quranwala de la formation de Masol, connue depuis les années 1960 pour sa faune de la fin du Pliocène, également nommée faune de transition Plio-Pléistocène. Notre étude paléontologique s'est imposée à la suite de la découverte de traces de découpe sur des fossiles proches de choppers et d'éclats en quartzite. Neuf campagnes de terrain (2008–2015) sur 50 hectares de paysage particulièrement accidenté (ravins et petits plateaux) ont permis d'identifier 12 localités où au moins un chopper était mêlé à des fossiles, lesquels totalisent 1500 spécimens. Leur étude montre que les mammifères les plus abondants sont les Proboscidiens, avec *Stegodon insignis* et *Elephas* en bien moins grand nombre. Les bovidés présentent la plus grande variété, avec six tribus de la plus petite à la plus grande taille. *Hexaprotodon sivalensis* vient en troisième position. *Sivatherium giganteum* est visible dans plusieurs localités, *Merycopotamus dissimilis* dans une seule. Deux types de cervidés au moins ont été observés. La faune de transition est attestée par la co-existence de *Stegodon* et *Elephas hysudricus*, d'*Hipparion antelopinum* et d'*Equus sivalensis*. Les fossiles de tortues sont abondants avec la forme terrestre géante *Colossochelys*, et celle d'eau douce, *Geoclemys*. En comparaison, les prédateurs sont peu représentés (crocodile), voire rares (hyène, félin), tandis que les primates (*Procynocephalus*) n'ont pas encore été observés. L'assemblage faunique correspond bien aux faunes de transition Plio-Pléistocène également décrites dans les Pabbi Hills (Pakistan) ; elle caractérise le début de la biostratigraphie de la zone intervalle *Equus sivalensis*, qui s'étend de 2,6 Ma à 600 ka. La répétition systématique des prospections a donc permis la collecte de taxons rares comme *Crocuta* (2010), *Merycopotamus dissimilis* (2014) et un grand félin (2015). Ces derniers résultats sont significatifs pour la découverte d'*Homininae* dans les Siwaliks.

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1. Introduction

This new paleontological study of the Tatrot faunas in the Chandigarh anticline (Punjab) of the Siwalik Frontal Range is the necessary consequence of an unexpected discovery during a field season of the Indo-French Program of Research 'Siwaliks' (Fig. 1) (Dambricourt Malassé, 2016). In 2009, a shaft of bovid tibia was collected in the Quranwala zone of the Masol Formation, near choppers and flakes, and showed marks on its cortical surface, which resembled butchery activities. At least two other bones with evidence of suspected hominin scavenging activities were recorded, and their hominin origins have been demonstrated by 3D topomiscroscopy and experimental protocols (Dambricourt Malassé et al., 2016a, b).

Eight years of surveys in the Masol inlier (2008–2015) recorded fossils and artifacts in twelve paleontological-archeological localities (Fig. 2). The fossils were documented with very precise geological and geomorphological data for each one of the localities in order to understand the local faunal associations, as well as the sedimentary context of their fossilization (silts, sands, gravels, riverbanks, channels, swamps, and fresh water).

Hence, this research completes the multidisciplinary analysis of the Masol inlier (Abdessadok et al., 2016; Chapon Sao et al., 2016a, b; Dambricourt Malassé et al., 2016a, b; Gaillard et al., 2016; Gargani et al., 2016; Tudryn et al., 2016). The study of the vertebrate fauna allows us to date these layers and identify the association of vertebrate (mammals and reptiles) in their environmental condition of fossilization and estimate the potential of finding hominins specimens.

2. General background

The Siwalik Group in the Himalayan foreland basin and foothills provides fossils from the Miocene (Murree Formation) up to the Middle Pleistocene (Boulder Conglomerate). They have been described for almost two centuries by world-renowned paleontologists who succeeded in the field (the Potwar Plateau in Pakistan, the Kashmir Valley, Lesser Himalayan foothills and the Siwalik Frontal Range in India). They produced the first important collections stored at the Geological Survey of India, Kolkata, in London (Falconer, 1868; Falconer and Cautley, 1846; Lydekker, 1879, 1883; Pilgrim, 1910, 1939), and in USA at the American Museum of Natural History (Brown et al., 1924; Colbert, 1935; Gregory et al., 1938) and the Yale University Museum (de Terra and Teilhard de Chardin, 1936). Among new species, the discovery of the first great ape found in mainland Asia gave support to the Central Asian hypothesis of the origin of the genus *Homo*, which was the prominent paradigm during the 1920s. This theory was developed by numerous paleontologists, such as Matthew, Osborn, Andrews and Gregory (American Museum of Natural History), Black (1925) (Union Medical College, Beijing) and, to a lesser extent, Teilhard de Chardin (National Museum of Natural History, Paris), former student of Marcellin Boule. After Ernest Hamy (chair of Anthropology of the National Museum of National History, 1870), human paleontology became an institutional science in the French Institution with Boule; as for other geologists, the 'Tertiary Man', or the 'Early Villafranchian Man' (Late Pliocene), was inconceivable (Dambricourt Malassé et al., 2016a).

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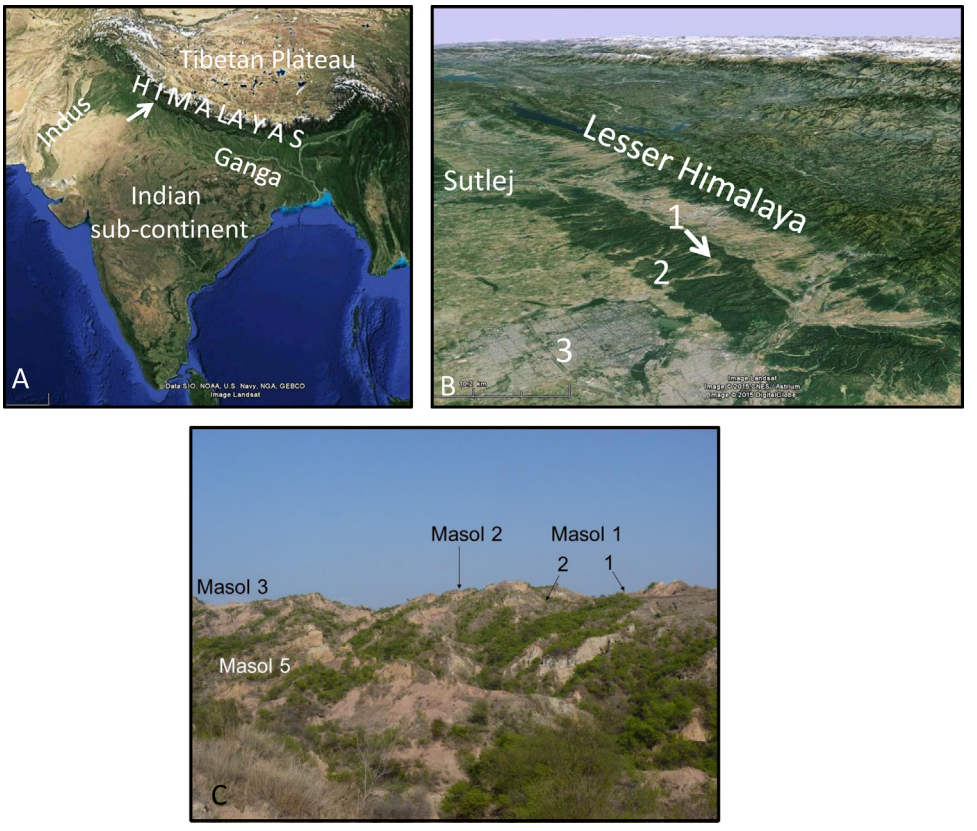


Fig. 1. A. Location of the Chandigarh's Siwalik Frontal Range, North India (arrow). B. Location of Masol site (1), north of Chandigarh (3), upstream of Patiali Rao (2). C. View on the Masol anticline and the dome with paleonto-archeological localities, on the dome Masol 1 with two sub-localites and Masol 2, Masol 3 at a pass, Masol 5 in the small watershed of Pichhli Choe; A and B according to Google Earth, C A. (map data © Google 2015). C: A. Dambricourt Malassé.

Fig. 1. A. Localisation de la Chaîne Frontale des Siwaliks de Chandigarh. B. Localisation du site de Masol (1), au nord de Chandigarh (3), en amont du Patiali Rao (2). C. Vue sur l'anticlinal de Masol avec les localités paléonto-archéologiques, sur le dôme Masol 1 avec deux sous-localités et Masol 2, Masol 3 à un col, Masol 5 dans le petit bassin versant du Pichhli Choe. A et B d'après Google Earth (données de carte © Google 2015) ; C : A. Dambricourt Malassé.

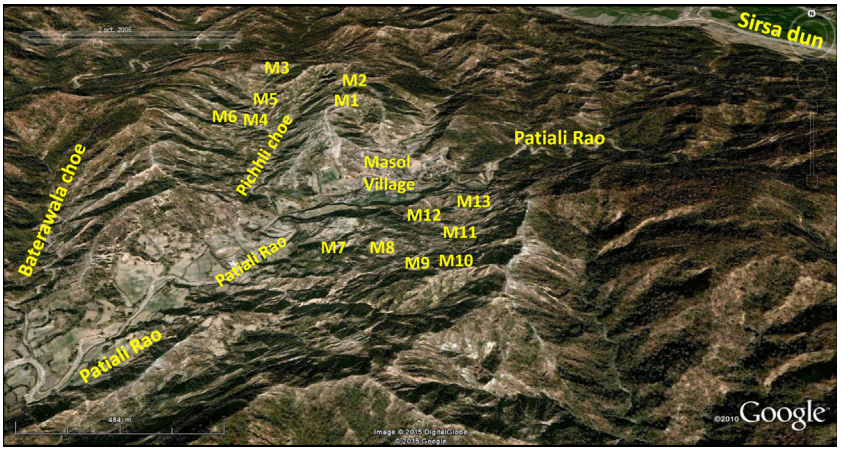


Fig. 2. Geomorphology of the Masol inlier with paleonto-archeological localities, M1, M2 on the anticline dome, M3 at a pass, M4, M5 and M6 in the Pichhli Choe, M7 to M13, on a circus, on the eastern rank of the Patiali Rao (Google Earth, map data © Google 2015).

Fig. 2. Géomorphologie de la boutonnière Masol avec les localités paléonto-archéologiques, M1 et M2 sur le dôme de l'anticlinal, M3 à un col, M4, M5 et M6 dans le Pichhli Choe, M7 à M13, dans un cirque, sur la rive orientale du Patiali Rao (d'après Google Earth, données de carte © Google 2015).

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Nevertheless, in 1926, Black did not hesitate to publish an isolated tooth from the surface of the Zhoukoudian karst that he attributed to *Sinanthropus pekinensis*, the first suspected 'Tertiary Man' discovered in mainland Asia (Black, 1926). Later, Teilhard de Chardin and Piveteau (1930) compared its faunal assemblage with those of the Nihewan Basin and dated the *S. pekinensis* to the Lower Pleistocene. In 1936, when de Terra and Teilhard de Chardin surveyed the Potwar Plateau and collected stone tools, the Plio-Pleistocene boundary was still unclear; the Tatrot and Pinjor Formations belong to the Upper Siwalik sub-group (Pilgrim, 1910, 1944), but Tatrot was considered Lower Pleistocene rather than Late Pliocene as it is today (de Terra and Teilhard de Chardin, 1936). Thus, the discussions about the Siwalik Group (Lower, Middle and Upper sub-groups) mainly concerned the equivalence of their Biostratigraphic succession with the European biochronology (Late Pliocene–Lower Pleistocene 'Villafranchian' faunae).

The faunal associations of the Potwar Plateau did not correspond exactly to the European one, and generated debates between paleontologists over the presence of *Archidiskodon* in the Tatrot type locality (Sahni and Khan, 1968), the first appearance of *Equus* at the base of the Pinjor Formation (de Terra and Teilhard de Chardin, 1936) and *Leptobos* in the Pinjor Formation. Numerous paleontologists proposed to compare this biostratigraphy with the sequences observed in the South of China and in the Southeast Asian archipelago by discussing the correlations of the Tatrot Formation with the Kaliglagah and Tjidjulang beds, and the Pinjor Formation with the Djetis or Puchangan beds (e.g., Bergh et al., 2001; Colbert, 1935; Hooijer and Colbert, 1951; Koenigswald, 1956; Mishra et al., 2010; Pilgrim, 1939). The Mio-Pliocene biochronology of the Siwaliks became very important when the same taxa were found in the Mio-Pliocene sequences of East and South Africa (Harris, 1976), and recently with *Antilopini* of the Middle Awash (Ethiopia) (Bibi, 2011), as well as with the scarce fossiliferous areas of the Baynunah Formation in the United Arab Emirates (Bibi et al., 2013; Gilbert et al., 2014).

3. The Chandigarh anticline and the Quranwala zone

The Chandigarh anticline is a geological structure of the Siwalik Frontal Range (or Siwalik Range), 200 km southeast of the Potwar Plateau and just at the boundary between the Indus and the Ganga Basins, near the township of Pinjor (Pilgrim, 1913). Its fossiliferous deposits have been studied since the beginning of the twentieth century, but the most important investigations date back to the 1950–60s with the geologist M.R. Sahni and the creation of the Geology Department of the Panjab University in Chandigarh (Union Territory). Badam (2000) published a historical review for the 18th commemoration dedicated to Sahni. Today the geological and fossiliferous sequences of the Chandigarh anticline are well known; they are composed of only the Upper Siwalik: (i) the top of the Tatrot Formation, the complete sequence of the Pinjor Formation and irregular Boulder Conglomerate Formation (Sahni and Khan, 1968) (Fig. 3).

The Plio-Pleistocene boundary was suspected at the uppermost level of the Quranwala zone, a fossiliferous horizon of the Tatrot Formation as defined by Sahni and Kahn (1964, 1968). Later, Nanda proposed that the Quranwala zone assemblage corresponded to the transitional fauna between Pliocene and Pleistocene, composed of genera such as *Hipparion* and *Stegodon*, which will extinct during the Pleistocene and new genera as *Equus* and *Elephas*, which will develop, and called it pre-Pinjor (Nanda, 1981, 1994, 1996–1997, 2002). In the same way, the Tatrot Formation was renamed the Saketi Formation, in a fossiliferous Pliocene sector located 50 km southeast of Masol in the Himachal Pradesh foothills. The paleomagnetism was measured in the 1990s along the Patiali Rao, a seasonal river flowing from the Masol inlier to the Indus plain, giving a precise description of the different magnetic polarity reversals (Patnaik, 2012; Patnaik and Nanda, 2010; Ranga Rao, 1993; Ranga Rao et al., 1995; details in Chapon Sao et al., 2016a). The Gauss/Matuyama reversal is now identified in the Chandigarh anticline between the Tatrot and Pinjor Formations, and paleontologists have admitted that the *Stegodon*/*Elephas* association characterizes the Latest Pliocene period and is visible below this paleomagnetic reversal, which actually corresponds to the Plio-Pleistocene boundary (Kumaravel et al., 2005).

The majority of the fossils collected in the Chandigarh anticline comes from the Quaranwala zone, dated to Latest Pliocene, and is particularly mineralized. The fossils of the Pinjor Formation are less numerous and bones are less mineralized. The fossils also correspond to the very beginning of the Pleistocene and they have been recovered in pockets by Sahni and Khan on short sedimentary sequences, the thickness of which has been estimated only at 15 feet (5 m) above the uppermost limit of the Tatrot Formation (Sahni and Khan, 1964). Thus, all these fossil assemblages can be regarded as Plio-Pleistocene transitional species, the majority between 80–100 m below this limit (Chapon Sao et al., 2016b; Sahni and Khan, 1964, 1968).

4. The fossil sample: stratigraphic origin and description

Fossils from the Chandigarh anticline are stored and exhibited in the Centre of Advanced Study Museum, Panjab University, Chandigarh. The fossils of the Indo-French program 'Siwaliks' have been stored, classified and preserved at the Society for Archaeological and Anthropological Research, Chandigarh; they have been restored when necessary, then determined according to the previous works of the University of Punjab (e.g., Badam, 1973, 1979; Gaur, 1987; Nanda, 1981). The projected surface of the Masol inlier covers around 80 hectares, but the core of the anticline is devoid of fossil and the paleontological sector covers a surface of 50 hectares. Up to now, 1500 fossils have been stored, and 1469 have been described: 869 herbivores, 37 crocodilians and five carnivores. They come (1) from fortuitous collecting in the Quranwala zone (referenced 'Masol' in the list), which belongs to the collections of the "Society for Archaeological and Anthropological Research" (SAAR, Chandigarh), (2) two trial trenches excavated in 2011 in the Masol 2

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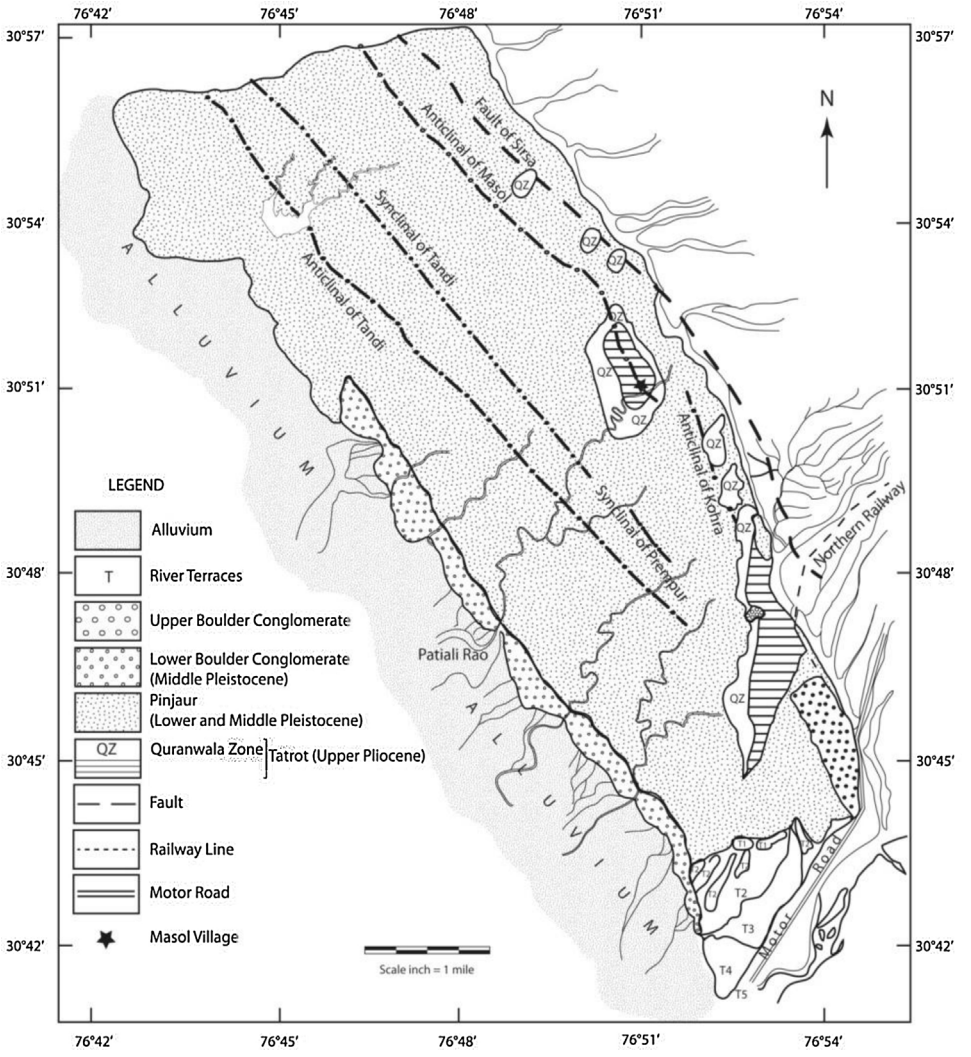


Fig. 3. Geological map of the Chandigarh Siwalik Frontal Range (Abdessadok, Fig. 1A in Chapon Sao et al., 2016, Sahni and Khan, 1968, modified).
Fig. 3. Carte géologique de la chaîne frontale des Siwaliks de Chandigarh (Abdessadok, Fig. 1A in Chapon Sao et al., 2016, d'après Sahni et Khan, 1968)

locality and (3) (the majority) during the eight field seasons (referenced Masol 1 to Masol 13 in the list) (Dambricourt Malassé et al., 2016a). The whole of the collection makes it possible to establish a good diagnosis of the faunal assemblages from the various localities, and the number of specimens is significant and allows comparisons (Table 1).

4.1. Stratigraphic origin

The base of the fossiliferous Quranwala zone has been defined at Masol 1 (Abdessadok et al., 2016; Chapon Sao et al., 2016b). In the stratigraphic log (Fig. 4), the c unit refers to clays/silts layers and the s unit refers to sandstones. The fossiliferous sequence begins with pink and orange silts (members E–D of c3 unit), covered by fine grey sandstone and micaceous sandstone (s3 unit), overlaid by thick coarse sandstone with crossing beddings (s4 unit). The oldest paleontological-archeological localities are in units c3 (members E–D), s3 and s4, at Masol 1, Masol 2, Masol 5 and Masol 7; Masol 12 is composed of c3 (members E–D) and s3, which yielded fossils but is devoid of tools and has been selected because of a quartzite cobble layer in the stratigraphy between two silt deposits. One bovid tibia with cut marks has been recorded from a Masol 1 sublocality at the top of the dome, unearthed from the unit s3 (Fig. 1D). One bovid metacarpal with cut marks has been collected in the small T2 terrace of the Pichhli Choe where this seasonal torrent cuts the c3 unit (members E–D), s3 and s4 below the Masol 6 locality. The other localities belong to the middle sequence of the log composed of the units c3 to c6 and s5 to s6, the top of the Masol 2 sequence, Masol 3, 4 and 6 on the western rank of the Patiali Rao. On the eastern rank, the localities are Masol 8, 9, 10, 11 and 13 in a geological circus forming a large surface of brown silts. This silty surface (unit c5) is sporadically covered by pebbles/cobbles in quartzite and dismantled sandstones at the base of M6, M8 and M13. A bovid bone splinter with cut marks has

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Table 1
Faunal list of Masol localities (NISP, number of identifiable specimens present) (Total includes the collection of the "Society for Archaeological and Anthropological Research" (SAAR)).
Tableau 1
Liste de la faune des différentes localités de Masol (NR nombre de restes) (le total inclut la collection de la « Society for Archaeological and Anthropological Research » (SAAR)).

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

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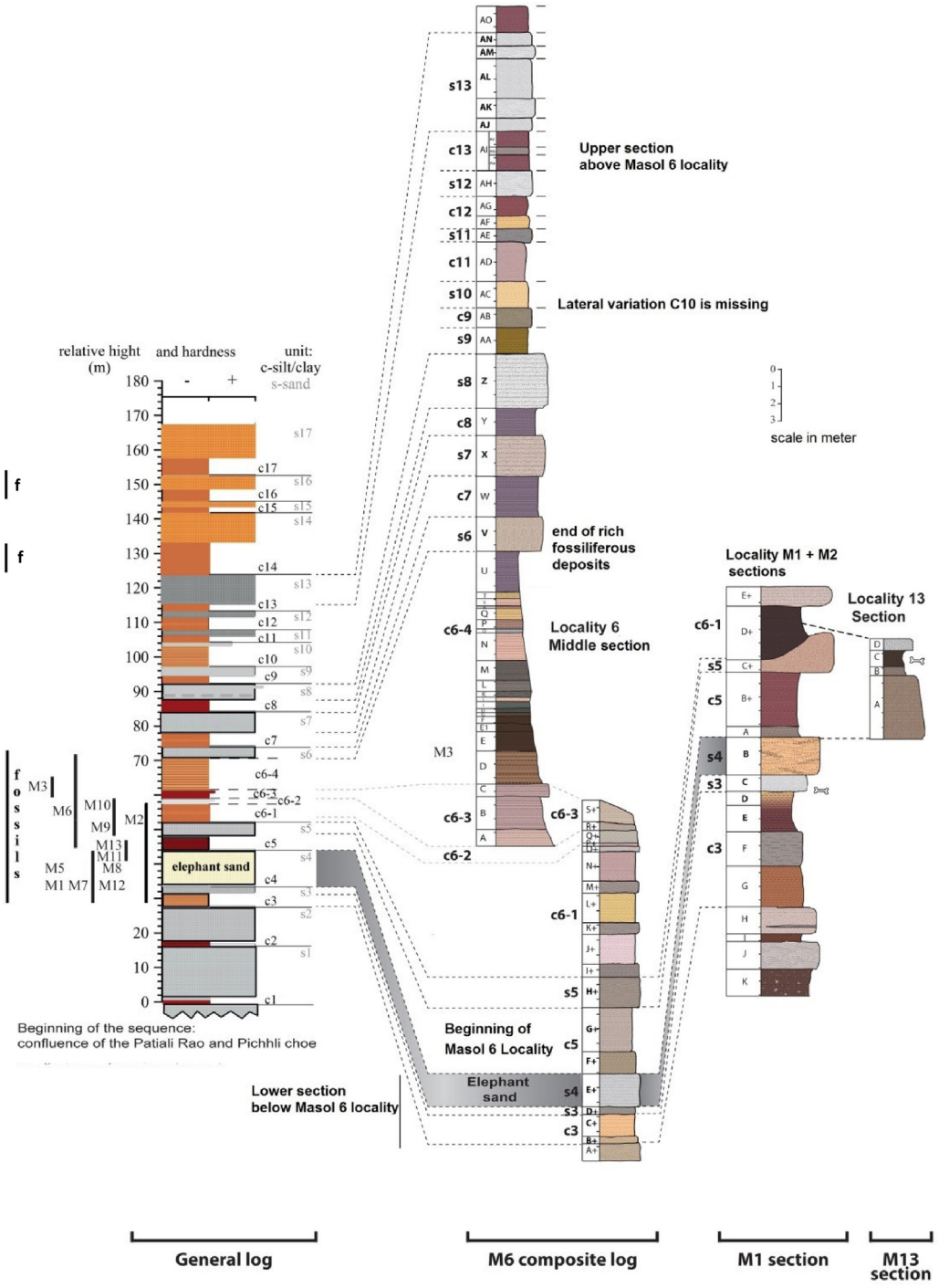


Fig. 4. Log of the Quranwala Zone of Masol Formation with paleontological-archeological localities (in Chapon Sao et al., 2016b).
Fig. 4. Log de la zone Quranwala de la formation de Masol avec les localités paléonto-archéologiques (in Chapon Sao et al., 2016b).

been recorded at Masol 13. Masol 9 is a small circus formed in eroded sandstones (unit s5) and silts (unit c6–1), and rounded by relic cliffs of the sequences s5–c6, Masol 10 is just above M9. Then starting from the sandstones s6 unit, fossiliferous deposits disappear as on the western rank. The last sequence of the log corresponds to the uppermost part of Masol 6 cliffs, which extend from s6 to s13 and c7 to c13 until the crest lining the Pichhli Choe watershed. In 2015, rare fossils have been collected at Masol 6, just below the crest in sandstones unit s13, in conglomerate unit s14 and on the crest in silt unit c17. They have not been studied.

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Fig. 5. Masol R10181, *Stegodon insignis*, right hemimandible with D4-M1 (scale 10 cm), SAAR fossil collection (picture A. Dambricourt Malassé).
Fig. 5. Masol R10181, *Stegodon insignis*, hémimandibule droite avec D4-M1 (échelle 10 cm), collection de fossiles de la SAAR (photo A. Dambricourt Malassé).

4.2. Mammals

The most common mammalian families of the collection are *Elephantidae, Hippopotamidae*, and *Bovidae*.

Proboscidea: Proboscids are very common (252 fossils), represented by tusks, molars, mandibles, skulls, scapulae, ribs, long bones and foot bones. The Proboscideans represented in the various lists of the Chandigarh anticline comprise numerous species (Badam, 1979; Gaur, 1987; Gaur and Chopra, 1984). For many years, it was admitted that the association of *Stegodon, Mammuthus* and *Elephas* could be characteristic of the Latest Pliocene and appeared below the Gauss-Matuyama paleomagnetic reversal (Agarwal et al., 1993; Hussain et al., 1992). In this collection, the challenge was to determine whether it was possible to recognize several Proboscideans among *Stegodon insignis*, *S. bombifrons*, *S. ganesa*, *E. planifrons*, *E. hysudricus*, *E. platycephalus*, *Pentalophodon sivalensis* and *Stegolophodon stegonoides* (according to the nomenclature of Shoshani and Tassy, 2005).

S. insignis has been identified from 77 fossils, such as isolated teeth, lower jaws and skull fragments. The morphology of the lateral view of the maxillary corresponds to *S. insignis* (Falconer and Cautley, 1846; Hooijer, 1955). The teeth formula has few thick blades and the crown is low: lower unworn M1, Masol 1 R10181, 8 blades, height = 50 mm, length = 160 mm and width = 75 mm, lamina thickness = 19.6 mm, enamel thickness = 4.7 mm (Fig. 5). The dental ranges of *S. insignis* are larger and narrower than *S. bombifrons*, the lamina is narrower and the enamel is finer. A complete talus presents a *Stegodon*-like morphology (Falconer and Cautley, 1846), Masol 6 R10584: height = 137 mm, width = 116 mm, Dap = 65 mm).

E. hysudricus: only one species (16 fossils) was identified (Falconer and Cautley, 1846). The material is composed of one skull with the fourth molar, or the first true molar, broken on the level of the roots. The isolated teeth are not very high, with quite separate plates. The lamellate frequency is seven and the enamel thickness is around 3 mm and folded. The lower unworn last molar Masol R11082 presents 11+ plates with a laminar frequency of five (number of plates per 10 cm of anteroposterior length) (Fig. 6): length = 230 mm, greatest width = 75 mm, height = 103 mm. On the occlusal surface, characteristic rhombuses are present in the center of the plate (thickness = 10.4 mm).

Hexaprotodon sivalensis is well-documented (120 fossils). The hippos are the most abundant taxon at the different localities; the fossils include several skulls, mandibles, isolated teeth and postcranial remains, including small bones and the axial skeleton. The cranial elements (10 remains) from Masol 1, Masol 2 and Masol 6 confirm its taxonomic status. A cranial fragment at Masol 2 presents the roots of the last molar, the zygomatic apophysis and the base of the orbital pit. Occipital and parietal parts are also significant of the taxonomic attribution. The Masol 1 R10482 jawbone was discovered in a block of sandy concretion revealing its stratigraphic origin (S3), but most of the isolated teeth and mandibles were collected on the silts of Masol 1 and Masol 2. It bears D3, D4 and M1 still in bud; M1 is 1/3 larger than *H. s. koenigswaldi* from the Lower Pleistocene formation of Sangiran (Indonesia).

The mandibular symphyses are broad on the labial massif and the six incisors are placed on a single range.

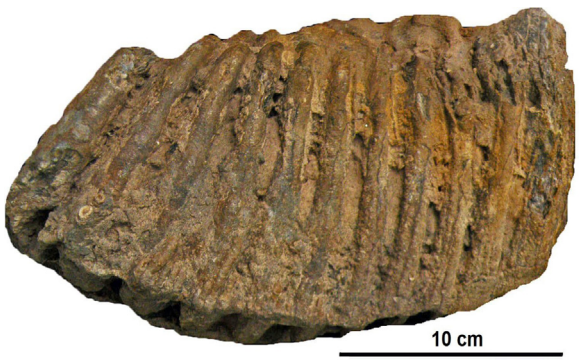


Fig. 6. Last lower molar Masol R10182, *Elephas hysudricus*, SAAR collections, SAAR fossil collection (picture A.-M. Moigne).
Fig. 6. Dernière molaire inférieure, Masol R10182, *Elephas hysudricus*, collection de fossiles de la SAAR (photo A.-M. Moigne).

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Table 2
Hexaprotodon sivalensis dental measurements (mm) per locality, isolated teeth (R) and teeth on lower or upper jaw. Note the great variation due to dimorphism and use-wear stage (germs and used teeth are not measured). Masol without reference corresponds to the SAAR collection without location.
Tableau 2
Hexaprotodon sivalensis; dimensions dentaires (mm) par localité, dents isolées (R) et dents sur les mandibules et maxillaire (*n*). Noter la grande variation en raison du dimorphisme sexuel et du stade d'usure (les germes et les dents usées ne sont pas mesurés). Masol sans référence correspond aux collections de la SAAR sans localisation.

Locality	Specimen	Type	DMD min–max	DVL min–max
Masol 1	R10174	I 1 inf	30–26	34
Masol 1	R11345	I2 inf	24–20	22–18
Masol 1	R10022	I3 inf	28–20	24.3–24
Masol 1	*n* = 4	M2 inf	54–36.6	39.4–25.6
Masol 6	*n* = 6	M3 inf	78–61	40–27.5
Masol 2	*n* = 2	C sup	49–47.5	47.5–35.3
Masol	R11080	I3 sup	20.5	22.5
Masol 1	R10135	Ml sup	46.6	38.8
Masol 8	*n* = 6	M2 sup	52–46.8	51–43.6
Masol	*n* = 3	M3sup	49–55.4	51–45.7

The I1 and I2 present almost the same section size (Masol 2 R11014, R10188), and this feature could be considered primitive (Hooijer, 1950). Lower jaw bones are high, thick and the base of the ramus is flat. Six mandibles (from Masol 1, Masol 6 and, Masol 8) bear the last molar; its measurements correspond to a very large *Hexaprotodon sivalensis* (Hooijer, 1950) (Table 2).

The isolated higher canine (Masol R10117) is deeply grooved along the posterior surface and testifies to a strong individual, probably a male. As with the postcranial bones (ulna, pelvis, and metapodial bones), the *H. sivalensis* tibia measurements are within the size range of *Hippopotamus*: the transverse distal diameter of Masol 13 R10255 are 82 mm and 73 mm for *H. s. koenigswaldi*.

Bovidae are represented by many subfamilies in Asia (e.g., Patnaik and Nanda, 2010). Here, there are 239 remains, including 62 teeth and ankle fragments. The Bovidea have been separated into six tribes: *Bovini*, *Alcelaphini*, *Boselaphini*, *Hippotragini*, *Reduncini* and *Antilopini*. Unfortunately, no complete skull has been recorded, but the taxa were identified based on of ankle morphology and dental features, such as the lower P4 morphology, the presence or absence of the basal pillar, the basal cingulum and the hypsodonty index (Dennell et al., 2006; Gaur, 1983, 1987; Gentry, 1978b; Pilgrim, 1939).

Bovini are the largest bovids, referred to as *Hemibos* or *Leptobos*, as well as *Bubalus*. Bovini is a large type with hypsodont and selenodont teeth. The ankles are either oval shaped or already more flattened with a clear former hull. *Hemibos* and *Bubalus* present cavernicolous osseous ankles, with quadrangular or triangular sections with a hull well defined on the higher face. The horns develop first, slightly backwards, and then go down lower than the top of the frontal bone (Gaur and Chopra, 1984; Hooijer, 1958; Pilgrim, 1939). *Bubalus* sp.: the enamel is thick, rugose without cingulum, the basal pillars are more or less developed, and the styles are clear. The largest teeth present the *Bubalus* fold on both anterior and posterior surfaces. *Hemibos triquetricornis*: the teeth of large individuals are filled with cement, the styles are thick and parallel and the lower molars developed additional styles (Gromova, 1968). Postcranial bones are often reduced to articulations but can be separated into two main groups. The maximal weight estimated according to the distal humerus width (Masol 2 R10184) and distal metacarpal width (Masol 6 R10285) is close to 1000 kg.

Hippotragini: twenty-one remains are identified with a partial skull including the frontal and the two straight, divergent, backwards cylindrical ankles. Many cylindrical fragments have been recovered on the Masol localities, which can be confused with highly mineralized antlers. Teeth are hypsodont, lower molars with the *Capra* fold, middle size with a rather short premolar raw. The lower P4 have a broad bulbous metaconid. The last lower molars, incomplete, without cement, have straight and thin styles, and are vertical and parallel. Alveolar crumpling of *Capra* type and coast punts correspond to the model B or open habitat adapted ruminants (Köhler, 1993). These fossils are assigned to the subfamily *Hippotragini* (*Sivatragus brevicornis* (Pilgrim, 1939) is known in the Tatrot Formation). Postcranial bones are identified in Masol 1.

Boselaphini (three teeth) are represented by characteristic upper teeth in Masols 1 and 5, but the complete study of the dental collection requires more evidence. This kind appears frequently in the faunas of this period. Dental remains approach the well-known *Duboisia* in the Pleistocene sites of Southeast Asia with open teeth, no cement, discrete basal cingulum and smooth enamel, and are less hypsodont than are other *Bovidae*. The size is bigger than *Duboisia kroenesenii* and resembles the biggest species, *D. saatensis* (Geraads, 1979) (Fig. 7A, Masol 5 R11267*:* maximal length = 24.6 mm, basal width = 20 mm). Dental occlusion (cutters) does not allow for their classification among specialized animals (Köhler, 1993; Rozzi et al., 2013).

Reduncini tribe (18 remains): two mandibles are close to *Sivacapra* sp.; the teeth are fairly hypsodont, small with unmolarised P4 and a strong *Capra* fold, which confirms their dimensions and assignation to the subfamily *Reduncini* (Fig. 5B). They were compared with the mandible type from the Centre of Advanced Study Museum, Panjab University, (UPM Chandigarh) (Gaur, 1987). Postcranial remains bring some indications: the morphology of the metacarpal bones rather resemble the A3 *Gazella* type (Köhler, 1993), without a sagittal sulcus (previously described in the Pinjor Formation as *Gazella* and *Indoredunca*).

Merycopotamus dissimilis: anthracotheres were first described in the Upper Siwalik (Falconer and Cautley, 1846) but they are scarce. One large upper molar (Masol 5 R11286: length = 28.5 mm, width = 28.5 mm, height = 15 mm) was determined as *M. dissimilis* (Fig. 7C). The tooth is an upper M3, unworn and very well preserved, the crown is selenodont, brachyodont with rugose enamel teeth, as a typical browser animal. Until now, no postcranial bones have been identified.

Equidae: (*n* = 10 fossils) The equid fossils are few and only the teeth or some long bones could be attributed to a genus (*n* = 8). Horses were also discovered in situ during

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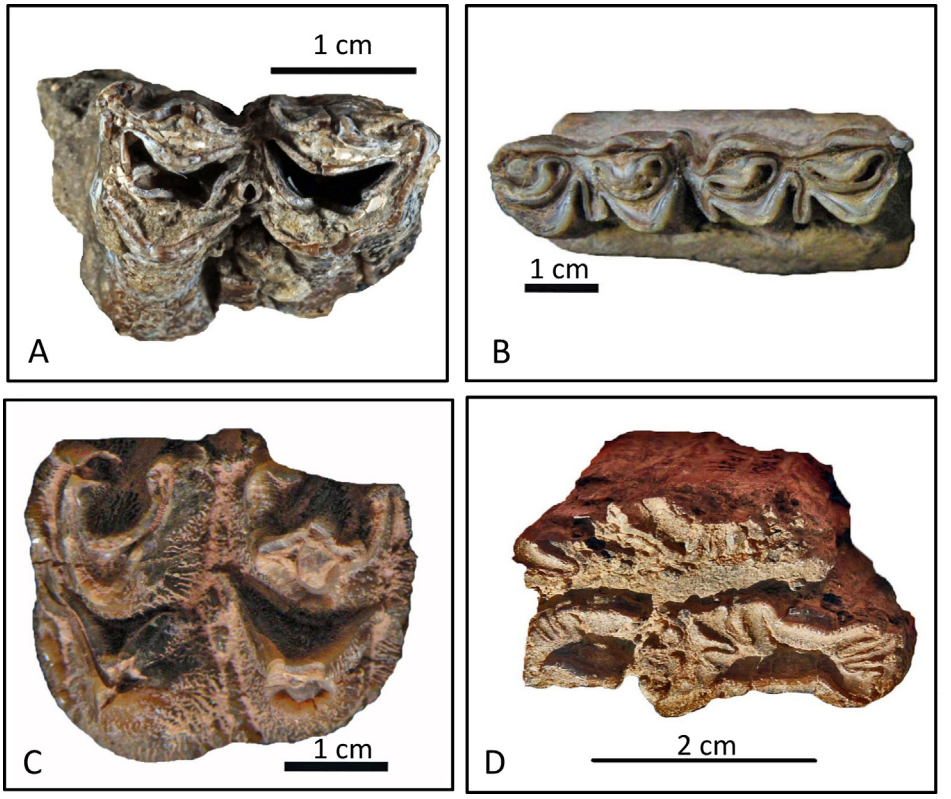


Fig. 7. A. *Duboisia* sp. Masol 5 R11267, last upper molar. B. *Sivacapra* sp. Masol 2 R10109, left lower jaw with M1 and M2. C. *Merycopotamus dissimilis*. Masol 5 R11286, left upper last true molar. D. *Hipparion*, premolar, occlusal surface (picture A.-M Moigne).
Fig. 7. A. *Duboisia* sp. Masol 5 R11267, M3 supérieure. B *Sivacapra* sp. Masol 2 R10109. hémimandibule droite avec M1 et M2. C. *Merycopotamus dissimilis*, Masol 5 R11286, M3 supérieure gauche. D. *Hipparion*, prémolaire, vue occlusale (photo A.-M. Moigne).

Table 3
Hipparion antelopinum; comparative measurements (mm) of the forth Upper Premolar * after Gaur, 1987.
Tableau 3
Hipparion antelopinum; dimensions comparées de la P4 supérieure (en mm), *d'après Gaur, 1987.

Locality	Specimen	Length	Width	Index	*L* protocone
Masol B	R10500	22.5	23.5	0.9	9.6
Colbert, 1936	–	23.6	21.8	1.08	–
Badam, 1973	S/3	24	25	0.9	–
*E. sivalensis**	–	30	34.5	1.15	–

the trench excavation at Masol 2. Two genera are distinguished: *Hipparion* and *Equus.*

***Hipparion antilopinum*:** the upper premolar Masol 3 R10050 is small, the occlusal surface is damaged but on transverse breakage, the protocon is clear, isolated and oval shaped (Table 3), which is characteristic of the *Hipparion* type as well as the true second premolar (Masol R10471: length = 40 mm, width = 24 mm). *Hipparion* presents the morphological diagnosis of *H. antelopinum*: "*crenulated fossette, tendancy of the protocone to be round, complexity of the enamel ridge, open hypoconal groove complexity of pli caballin fold*" (Gromova, 1968). The measurements correspond with *H. antelopinum* (Badam, 1973; Colbert, 1935) (Fig. 7 D).

E. sivalensis: the isolated lower M2 (Masol ind. R11459) is related to *E. sivalensis* according to Falconer and Cautley (1846) and Colbert (1935). This specimen is larger than PUA 135B (Centre of Advanced Study Museum, Panjab University, Gaur, 1987). One tooth has been collected in trench B at Masol 2 (the base of the Quranwala zone).

Tragulidae: In reviews of Siwalik fossils, the Tragulid genus *Dorcatherium* is commonly determined with four species from the Miocene to the Pleistocene. The extended genera of Tragulid *Hyemoschus* or *Tragulus* are very similar to *Dorcatherium* (Gentry, 1978a). *Dorcatherium nagrii* would appear to be the most advanced among the Dorcathers of the Siwaliks, and is probably the ancestor of the extant species (Gaur, 1992). The attribution to *D. nagrii* is mostly established on the size criteria: lower teeth are selenodont, not hypsodont, narrow, very small, not specialized and characteristic of no ruminant artiodactyls. The fragmented mandible from Masol 6 R10264 with the last molar (length = 11 mm) is in the maximum range of this species.

Giraffidae: the fossils ($n = 27$) have been collected from Masol 3, 6, 8, 11 and 13, but only rarely at Masol 2 and 5: one ossicone, eight teeth and one postcranial skeleton were assigned to the very large Giraffid, *Sivatherium giganteum*. The gigantic male Pleistocene giraffid with four ossicones was first described from the Upper Siwalik (Falconer and Cautley, 1836). The anterior ossicones are conical and the

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Table 4
Sivatherium giganteum; dental measurements (mm) of Masol specimens compared with those of Kenyan *KNMER/*Sivatherium cf. maurusium* (Harris, 1976).
Tableau 4
Sivatherium giganteum ; dimensions dentaires (mm) comparées à celles de l'espèce kenyanne *KNMER/*Sivatherium cf. maurusium* (Harris, 1976).

Locality	Specimen	Type	Length	DVD max	DVD anterior	DVD posterior	DVD third lobe	Height
Masol3	R10122	P4inf	50.1	35	–		–	50
Masol	R10213	P4inf	40	30	29.6	–	–	30
*KNMER	777	P4inf	41.7	29.5	–	–	–	–
UPM	A/811	M1inf	55	34	35	34	–	35
Masol	R10213	M1inf	43	23.2	30	28.8	–	22
*KNM-ER	780	M1inf	45.4	30	–	–	–	–
UPM	A/542	M1inf	55	29	–	–	–	–
UPM	A/542	M2inf	57	-	–	–	–	–
Masol	R10213	M2inf	50	30	31.8	32	–	34
Masol	R10213	M3inf	63	30	31	30	17	35
*KNMER	$n = 5$	M3inf	60.4–66.1	27–33	–	–	–	–
UPM	A/542	D2inf	21.3	13.2	–	–	–	12
UPM	A/542	D3inf	33	22	–	–	–	16
UPM	A/542	D4inf	63	29	26	26	29	22
*KNMER	797	P3inf	34.5	42.5	–	–	–	–
Masol 13	R10301	P3sup	40	33	–	–	–	50

posterior ossicones are palmate. One posterior straight portion was found, which presents rare humps and a discrete groove (Masol 2 R10479, diameter 85 × 80 cm). According to the diagnosis, the teeth (Table 4) are thick with rough enamel ($e = 3$ mm) and very strong styles (Arif and Vos, 1989; Churcher, 1978; Gaur, 1987; Harris, 1976). Two mandibles were assigned to adult individuals (Masol 6 R10787 and R10213): the ramus height under M1 is between 70 and 75 mm, with a thickness between 40 and 47 mm. The molars (raw length = 160 mm) are more slender than the jawbone A/795 from the Centre of Advanced Study Museum (Panjab University), which bears the cheek deciduous teeth and the first true molar (Badam, 1973). The body skeleton and limbs are heavy (Colbert, 1935). The postcranial skeleton bones are a distal humerus (Masol 6 R10715), an ulna and a proximal tibia, a talus and a navicular (Masol 13 R10303); on the latest, the articulation is oblique compared to the bone axis. The medial crest is very low and forms a continuous, oblique line; the calcaneus facet is broad, as are the two facets for the metatarsal (Masol 13 R11455).

Camelidae: (three fossils) *Camelus sivalensis* was first described in the Tatrot Formation from Pakistan (Gaur, 1981) and in the Pinjor Formation (Gaur et al., 1984). The collection is limited with two teeth and one phalanx. The fourth upper premolars from Masol 1 are complete and worn flat. The first phalanx is broken (Masol ind. R11439) close to the Falconer observation, proximal width = 28.4 mm (3.9–4 inch), length = 19.6 mm (1.6–1.9 inch) (measurements in inches, Falconer and Cautley, 1846).

Cervidae: At least three genera of cervids are present in the Siwalik: *Cervus punjabiensis* (Badam, 1979) *Axis* or '*Dama*-like' (Dennell et al., 2006) and *Rucervus* or 'Muntjac like' (Gaur, 1981). Many fragments of antlers, dental and postcranial remains were found. The antler from Masol 1 was associated with the bovid striated diaphysis. The beam and the brow tine are a refitting of several antler fragments and the distal part of the beam shows a flat tine (Masol 1 R10020, diameter = 35 mm, height of first tine is 70 mm, diameter: 20 mm). This middle size antler, ornamented by subparallel grooves, can be related to *C. punjabiensis* (Badam, 1973).

A shed antler (Masol 1 R10483) and a 'massacre' antler enriched the collection as an *axis* morphology with a very open angle between the brow tine and the thin and smooth beam without ornaments. This morphology is also observed in the Pabbi Hills (Dennell et al., 2006). Teeth are often broken and postcranial skeleton is abundant. Waiting for new discoveries, the nomenclature is still open, but these two kinds lived in the sub-Himalayan floodplain before 2.6 Ma. Several long bones are well preserved, in particular, a distal tibia (Masol 3 R10059, distal width = 32.3 mm, distal anteroposterior diameter = 30.2 mm). The metapodial bones are all broken.

Suidae: Suids are rather rare (six remains) from Masols, 1, 5, 6 and 8, although they have been already indexed in different studies since Falconer, who described most of the species. More discussions were conducted on the comparison between *Potomochoerus* and *Prototamochoerus*, an Asian genus. Three hemimandibles, an upper jaw, isolated teeth and postcranial bones, help us recognize two genera in Masol.

Propotamochoerus: The hemimandible from Masol 3 R10266 bears three premolars and three molars (Fig. 8). The diastema is broken, but the inner large section of the canine root is visible and corresponds to a male. (Masol 3 R10266: length of cheek teeth is 110 mm, molar row is 67.6 mm). The fourth premolar is large and square. The third molar is very short and simple with five cusps as *Propotamochoerus*. The horizontal ramus is thin (height = 45 mm, thickness under M1 = 28.5 mm).

***Sus* sp.**: the second hemimandible, Masol 5 R10476 is a *verrucosus* type. The lower row bears four premolars and three molars (Fig. 8). The last molar is absent and the diastema is broken. It is a female without a canine root. The molar size is similar to *Prototamochoerus*, but the premolars are less developed than on the first specimen. The first premolar is located near the canine tooth. The horizontal ramus is low and thick (thickness under M1 = 42 mm) with the typical bulges on the mesial and lateral side. The measurements of the lower second molar are close to

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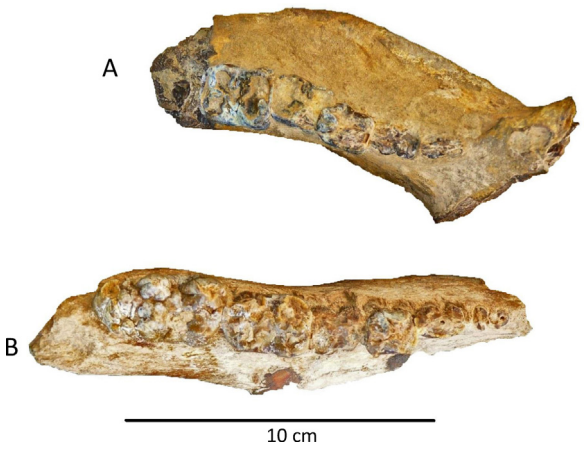


Fig. 8. *Sus* (up) and *Propotamochoerus* (below), left hemimandible (scale 10 cm) (picture A. Dambricourt Malassé).
Fig. 8. *Sus* (en haut) et *Propotamochoerus* (en bas), hémimandibule gauche (échelle 10 cm) (photo A. Dambricourt Malassé).

Javanese *S. brachygnatus* (Bouteaux et al., 2007) or Chinese *S. lydekkeri* (Echassoux et al., 2008). Without the lower M3, it is difficult to report it as *S. falconeri*. Postcranial bones, such as the tibia and talus, are robust.

Carnivora: In the Tatrot Formation, the carnivores are said to be rare (Gaur, 1983) but many taxa were described by different authors: *Canis pinjorensis, Crocuta crocuta, Pachycrocuta brevirostris, Felis, cf. Panthera uncia, Megantereon cultridens, cf. Canis cautleyi*, and a herpestid, etc. Carnivore remains in the collection are limited; there are five remains: four Hyenids and one *Panthera* sp. Their presence is in accordance with tooth marks observed on the long bones of large bovids or hippos. One mineralized coprolite was also discovered in Masol 9 (R11001).

***Hyenidae*:** one retro-articular process of the temporal bone with the temporo-mandibular joint (Masol 1 R10243), one vertebra axis (Masol 5 R10289) and a canine tooth fragment (Masol 5 R10290) correspond to the morphology and the size of *Pachycrocuta* (Fig. 9).

***Panthera* sp.**: a left hemimandible (Masol 6 R10542) is composed of three pieces collected in 2013 and 2015 (Fig. 10). The mandibular corpus is complete until the symphysis, but is broken at the beginning of the masseteric part of the vertical ramus. The premolar crown is broken, and the large canine crown is partially damaged. The size of the dental alveoli corresponds to an adult animal. A long wear facet due to the upper canine tooth is visible on the distal part of the canine tooth that extends from the apex toward the neck of the crown. The mandibular ramus presents two premolars and the first molar (carnassial). It is thick: higher after the canine and lower and thicker at the retromolar level with a flat base. The short diastema is visible between the canine tooth and the first premolar P3. Three foramens are visible below the canine. The edge of the symphysis is slightly convex. The alveolar shape appears distinctly divergent in its canine arch: height of the horizontal ramus = 30 mm, maximum length of lower raw = 54 mm (Fig. 10).

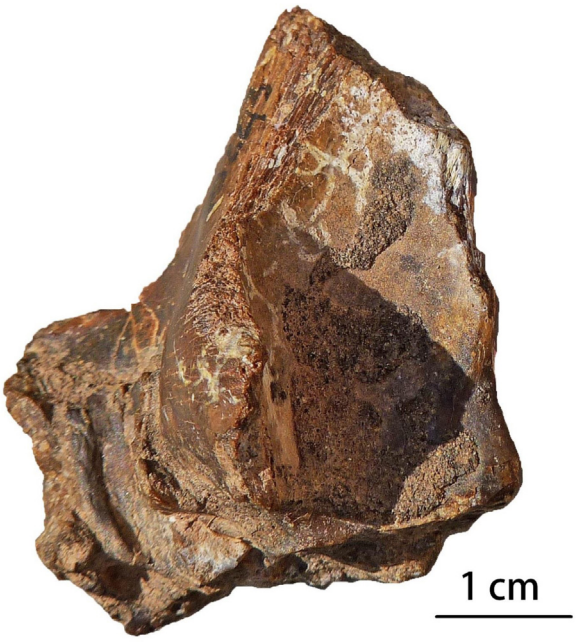


Fig. 9. *Hyena*, basal view of a right TMJ, size of *Pachycrocuta* (picture A. Dambricourt Malassé).
Fig. 9. *Hyena*, vue basale de l'os temporal droit, avec l'ATM, taille de *Pachycrocuta* (photo A. Dambricourt Malassé).

4.3. Reptiles

More than four types of turtles could be described in these localities and include the large freshwater turtle *Geoclemys* and the very large terrestrial *Colossochelys*. This diversity will be analyzed in a future research program. The crocodilians have been described in the Quranwala zone (Sahni and Khan, 1968). We have collected 29 fossils, teeth, mandibles and dermic plates of *Crocodylus penjabensis*, according to the upper jaw Masol 6 R11032 (Fig. 11) and one *Gavialis* tooth at Masol 1.

5. Expected species

Rodentia: fossil specimens are known in Tatrot (Patnaik, 2001, 2012). They have been evidenced in the collection by tooth marks on nine bones of large bovids at Masols 3, 6 and 13, which can be assigned to *Rhizomys*, but no fossils have yet been recorded.

Primates:

Cercopithecidae: the *Procynocephaplus* was first recorded in 1848 in the Pinjor beds near Dehra Dun, 120 km southeast of Chandigarh, and was called *P. subhimalayanus*. A well-preserved mandible has been recovered in the 60th, 10 km south of the limit of the Quranwala zone near Bunga (Verma, 1969), in the Pinjor Formation close to Khetpurali section were Tatrot is exposed. Patnaik and Nanda (2010) suspect a Tatrot origin. The fossil was assigned to *P. pinjaury*. The dental microwear was recently analyzed to evaluate the dietary proclivities (Williams and Holmes, 2012). Verma did not exclude *Procynocephalus* from the Latest Pliocene of the Siwaliks due to the presence

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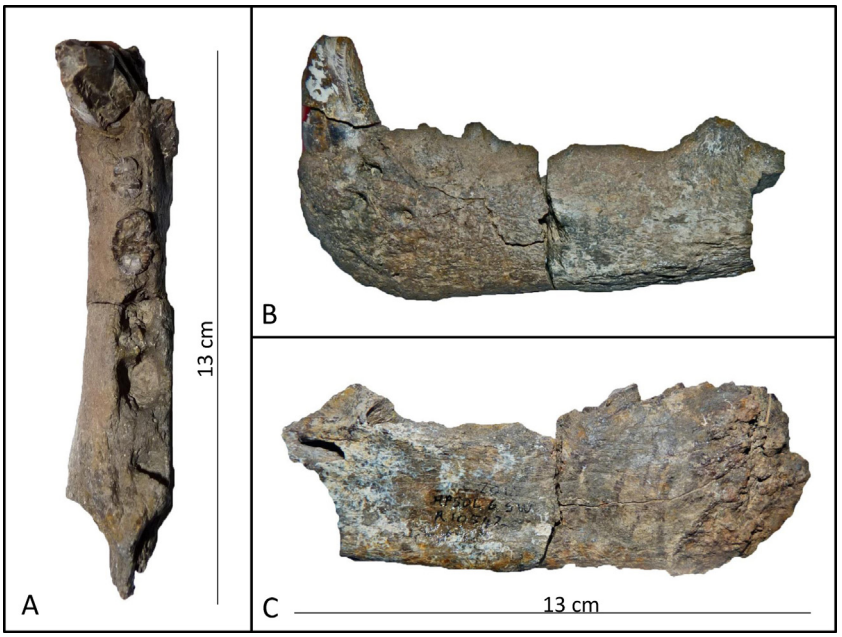


Fig. 10. *Panthera*, left hemimandible. A. Occlusal view. B. External lateral view. C. Inner lateral view. (picture A. Dambricourt Malassé).
Fig. 10. *Panthera*, hémimandibule gauche. A. Vue occlusale. B. Vue latérale externe. C. Vue latérale interne (photo A. Dambricourt Malassé)



Fig. 11. Right hemimandible Masol 6 R11032, *Crocodylus penjabensis* (scale 10 cm) (picture A. Dambricourt Malassé).
Fig. 11. Hémimandibule droite Masol 6 R11032, *Crocodylus penjabensis* (échelle 10 cm) (photo A. Dambricourt Malassé).

of *P. wimani* in China within the *Hipparion* assemblage of the Honan Province dated to Late Pliocene (Howells and Tsuchitani, 1977). *Procynocephalus* were also associated with cut marks and an enigmatic hominoid fragmented jaw with two worn molars in Longgupo deposits (Wushan County, Gansu Province, central China). This assemblage has been recently dated to 2.48 Ma (Han et al., 2015).

Hominin: the only *Hominin* known in Asia is the genus *Homo*, whose presence is now expected at least 2.48 Ma in Longgupo cave, central China (Han et al., 2015). Strong teeth from Longgudong cave, near Longgupo in Jianshi County, Hubei Province, Central China and dated around 2 Ma (Matuyama period, Hou and Zhao, 2010), have been assigned to a hypothetical *Meganthropus* (Zhang et al., 2004). No fossil has been recovered in Masol, but, as for the Rodents, their marks have been identified indubitably on three bovid bones made by flakes and/or choppers in quartzite with intentional gestures (Dambricourt Malassé et al., 2016a, b).

6. Discussion

The vertebrate taxa of the different localities are grouped according to the lithostratigraphy (Abdessadok et al., 2016; Chapon Sao et al., 2016b; Tudryn et al., 2016) and then compared with other Late Pliocene localities in Himachal Pradesh (Nanda, 2002) and in the Pabbi Hills, Pakistan (Dennell et al., 2006) (Table 5). The *Elephantidae* and *Bovidae* are always abundant, but pygmy hippos (30%) associated with crocodilians and freshwater turtles, confirm the main fluvial environment as lithostratigraphic (Badam, 1987; Gaur and Chopra, 1984; Nanda, 2002; Patnaik, 2012; Pilgrim, 1910; Sahni and Khan, 1968).

Boselaphini, Propotamochoerus, Camelus, Equus and *Merycopotamus* have been collected in the basal sequence. *Panthera*, *Dorcatherium* and *Hipparion* (teeth and/or mandibles) identified in the middle sequence are not necessarily excluded from the basal one.

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Table 5
Distribution of genera/species (% NISP) from Masol, the Tatrot Formation from Chandigarh anticline (Gaur and Chopra, 1984), the Saketi/Tatrot Formation (Nanda, 2002) and the Plio-Pleistocene beds from Pabbi Hills (Dennell et al., 2006). Masol localities are grouped by stratigraphic units (Chapon Sao et al., 2016b).
Tableau 5
Distribution des espèces (% NISP) à Masol, dans le Tatrot de l'anticlinal de Chandigarh (Gaur et Chopra, 1984), Saketi/Tatrot (Nanda, 2002) et les couches plio-pléistocènes des Pabbi Hills, Pakistan (Dennell et al., 2006). Les localités de Masol sont groupées selon la répartition stratigraphique (Chapon Sao et al., 2016b).

Taxon	Masol Basal sequence	Masol Middle sequence base	Masol Middle sequence up	Tatrot Gaur Chopra	Saketi/Tatrot Nanda	Pabbi Hills Dennell
Elephas hysudricus	2.8	6.5	2.7	0	X	X
Stegodon insignis	18.6	8.1	20	X	X	X
Anancus perimensis	–	–	–	–	X	–
Pentalophodon khetpuraliensis	–	–	–	–	X	–
Hippohypus tatroti	–	–	–	–	X	–
Propotamochoerus sp.	–	–	0.9	–		–
Potamochoerus sp.	–	–	–	X	–	suid
Sus brachygnatus/verucoid	1.7	1.6	1.8	–	–	X
Hexaprotodon sivalensis	31.1	35.5	21.8	X	X	X
Hemibos triqueticornis	17.5	21	15.5	–	–	X
Leptobos	–	–	–	X	–	–
Bubalus sp.	1.7	–	1.8	–	–	–
Proamphibos kashmiricus	–	–	–	–	X	X
Boselaphini/Duboisia	2.3	–	–	–	–	–
Reduncini/Sivacapra	3.4	6.5	4.5	–	–	–
Gazella	–	–	–	–	–	X
Hippotragini/Hippotragus sp.	7.3	1.6	3.6	–	–	–
Damalops palaeindicus	–	–	–	–	–	X
Dorcatherium nagrii	–	–	0.9	–	–	–
Camelus sivalensis	0.6	–	–	–	X	–
Sivatherium giganteum	1.7	12.9	11.8	X	–	X
Rucervus simplicidens	–	–	–	–	–	–
Axis – Dama-like	1.1	1.6	0.9	–	–	X
Cervus penjabensis	7.9	3.2	8.2	–	–	X
Anthracothere	0.6	–	–	–	X	X
Equus sivalensis	0.07	–	0.14	–	X	X
Cormohipparion theobaldi	–	–	–	–	X	–
Hipparion antilopinum	0.07	–	0.07	–	X	–
Canid	–	–	–	–	–	X
Pachycrocuta sp.	1.1	1.6	–	–	–	X
Panthera	–	–	0.9	–	–	–

Stegodon and *Elephas* are represented in a proportion of 20/3. This co-occurrence is significant from a biochronological point of view. Indeed the first appearance of *Elephas hysudricus* (and *Cervus*) has been dated to c. 2.7 Ma in the Mangla-Samwal area in Jhelum basin, Pakistan (Hussain et al., 1992). According to the Biostratigraphic zones based on magnetostratigraphy and fauna, *Elephas hysudricus* is referred to as the *Equus sivalensis* Biostratigraphic interval-zone beginning around 2.6 Ma (Nanda, 2002). The Quranwala zone has been dated just below the Gauss-Matuyama magnetic reversal in the Patiali Rao (Ranga Rao, 1993; Ranga Rao et al., 1995; see Chapon Sao et al., 2016a). These results confirm the former proposition of Colbert (1951) and Sahni and Khan (1964, 1968), who dated the Tatrot Formation to the Late Pliocene. *Stegodon* is well known in the Siwaliks since 4 Ma (Middle Siwalik), and was associated with the *Elephas planifrons* Biostratigraphic interval-zone since 3.6 Ma, but it is also associated with *E. hysudricus* during the Middle Pleistocene in the Post-Siwalik Narmada beds (Central India).

The anthracotheres mostly refer to the Middle Siwalik, but Sahni and Khan (1968) collected fossils in the Quranwala zone and then at the very beginning of the Pinjor Formation (Early Pleistocene). Later, a maxillary from the Mangla-Samwal anticline, Pakistan, dated between 2.4 and 2.65 Ma, confirmed the presence of *Merycopotamus* until the end of the Pliocene in the sub-Himalayan floodplain (Hussain et al., 1992). Anthracotheridae was also found in the Pabbi Hills pre-1.8 Ma (Dennell, 2008). Finally, *Merycopotamus* is listed in the *Equus sivalensis* Biostratigraphic interval-zone where the last appearance is dated close to 2.5 Ma (Nanda, 2002). This taxon is associated with the faunal group of the uppermost part of the Tatrot Formation (called the Saketi Formation since the studies of this fossiliferous zone in Himachal Pradesh, Nanda, 2013).

The association of *Hipparion* and *Equus* in the Quranwala zone is coherent with the Upper Siwalik biozone: *Equus sivalensis* appears before 2.6 Ma and *Hipparion antilopinum* disappears there around 1.5 Ma. In Jammu and Potwar, the horses are definitely associated with *Hipparion* (Barry et al., 1982), and the end of the Saketi (or Tatrot) Formation is characterized by the scarcity of the *Hipparionines* (Nanda, 2002).

Hexaprotodon sivalensis is well known since the Lower Siwalik, but then disappeared in many localities in the early Pinjor Formation (Dennell, 2005; Shoshani and Tassy, 2005). It disappeared in the Pakistani Siwalik group around 3.5 Ma (Dennell et al., 2006), but was still present in the

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Pabbi Hills due to the favorable water environments with deep rivers (Dennell, 2005), and in the South of the sub-Himalayan floodplain around 2.6 Ma as evidenced in the Masol Formation.

Suidae like *Propotamochoerus* appears 4 Ma ago in the Middle Siwalik (Barry, 1995); *P. hysudricus* is observed in the Jammu region (Agarwal et al., 1993) and sometimes is mentioned in the Pinjor Faunal list. In China, this last one is still present at the end of the Lower Pleistocene (Echassoux et al., 2008). The faunal list of the *Equus sivalensis* Biostratigraphic interval-zone includes a great number of suid species; nevertheless, the *Sus* genus cannot be identified without the lower last molar. Within the Masol assemblage, the *Suidae* are scarce (less than 2%); however, a complete hemimandible with three premolars, a large lower P4 and a simple M3 can be assigned to *Propotamochoerus* without problem, as this genus is characteristic of Tatrot.

Camelus sivalensis first appears in the Middle Siwalik in Pakistan (Barry et al., 1982) and at the top of the Saketi Formation (Nanda, 2002). *Camelus* and *Hexaprotodon* are attributed to the *Elephas planifrons* Biostratigraphic interval-zone.

S. giganteum appears in the Siwalik Group after 2.9 Ma (Barry, 1995). This is considered a common taxon in the *Elephas planifrons* Biostratigraphic interval-zone from the uppermost part of this group and developed during the next *Equus sivalensis* Biostratigraphic interval-zone.

Bovidae are abundant but the determination is not easy without crania and horncores. The taxonomic keys used for Masol collection allow the assignation to the tribe's level based on the dental material. The connection between these observations and the historical nomenclature needs more data and will be addressed in future work. The presence of *Proamphibos* or *Probison* is not yet possible in this collection. Nevertheless, the large bovids can be assigned to *Hemibos* related to the *Equus sivalensis* Biostratigraphic interval-zone. The mid-sized bovid is close to the *Hippotragini*. On the other hand, the *Boselaphini* is very similar to the specimen described in Southeast Asia and *Sivacapra*, and is also well known in the Pinjor Formation. As these mid-size bovids are not yet connected to the Tatrot Formation, the Masol assemblage can testify that these bovids were clearly associated with the faunas of their uppermost deposits and appear around 2.6 Ma.

Tragulidae are known from the Miocene. *Dorcatherium nagrii* is the most advanced species of this family and very similar to the current genera *Tragulus*, which was already described in the Tatrot Formation (Gaur, 1992) and can be added to the reference list of the *Equus sivalensis* Biostratigraphic interval-zone.

Cervidae are not completely described; in particular, due to the postcranial remains, but with typical antlers, we can assume two genera in the Masol localities: a mid-sized *Cervus punjabiensis* and an *Axis* or *Dama*-like small cervid. The latter may be compared with *Rucervus simplicidens*, which is described in the literature. The first appearance of *Cervus* is described in the Mangla-Samwal anticline (Pakistan), with *Equus sivalensis* and *Elephas hysudricus* (Hussain et al., 1992).

The localities of the Masol anticline present many similarities with the Mangla-Samwal anticline and can be correlated to the *Equus sivalensis* Biostratigraphic interval-zone. This well dated association gives a good indication of the appearance of many taxa and could link the Mangla-Samwal area, Jammu area and the uppermost part of the Tatrot Formation (the Saketi Formation in Himachal and the Siwalik Frontal Range).

The carnivores are rare in the fauna of Masol; primate specimens, such as *Procynocephalus pinjaury*, have not been yielded in this sector of the Siwalik Frontal Range and the lack of *Rhinocerotidea* is noted. This fact is observed in the Tatrot of Pabbi Hills 300–400 km northwest of Chandigarh in Pakistan (Dennell et al., 2006; Jablonski, 2004). Nevertheless, those data cannot be seen as definitively significant of a biochronological frame because rhinos and carnivores are abundant in the Pinjor Formation; they had necessary ancestors in the Asian Late Pliocene. Yet, 300 km northeast of the Chandigarh anticline, in the uppermost Himalayan basin of the Sutlej River, the Zanda Basin (Tibet) provided *Coelodonta thibetana* dated to 3.7 Ma, a rhino genus that adapted to climate cooler than that in the sub-Himalayan floodplain (Deng et al., 2011).

This new fossiliferous collection of the Tatrot Formation coming from the Masol sector has been recorded because of some cut marks and many stone tools associated with the same outcrops. The cut marks show, without any doubt, the presence of a very old *Homo*-like *Hominin* (Dambricourt Malassé et al., 2016b). This presence in a sub-Himalayan *Equus sivalensis* Biostratigraphic interval-zone opens new horizons for the origins of taxa engaged in an evolutionary dynamic of appearance-disappearance. This dynamic is the prelude of the consequences due to the first Quaternary glaciation closely linked to the Tibetan Plateau uplifting. For the prehistoric approach, one critical point is the examination of the faunal association among which this *Homo*-like *Hominin* evolved, the origins of all these species since the Miocene and the direction of their migrations. Genera, such as *Elephas*, *Stegodon*, *Hexaprotodon* and *Hipparion, Equus*, or families, such as *Cervidae*, derived from Asian Miocene ancestors having no exchange with Africa, have been noted before the Pliocene (Wang et al., 2013). For instance, *Equus* appears in East Africa around 2.3 Ma and *Elephas* around 1.9 Ma, whereas *Stegodon*, *Hexaprotodon* and *Cervidea* migrated toward South Asia. Many widespread taxa, such as *Sivatherium, Bovidae*, *Tragulidea* and *Suidea*, are known during the Miocene or Pliocene in Asia, but also in Africa and in Europe. For the bovids, except *Boselaphini*, the genera *Bovini*, *Hippotragini, Alcelaphini, Reduncini* and *Antilipini* can be compared between Asia, South Africa, East Africa, and mostly *Bovini* with Europa. "*The fossil bovid record provides evidence for greater biological continuity between Africa and Eurasia in the late Miocene and earliest Pliocene than is found later in time*" (Bibi, 2011). Thus, African antelopes were the ancestors of sub-Himalayan *Hippotragini* dated to 3 Ma (Martinez-Navarro, 2010). Later *Tragulidae* and *Sus* migrated toward South Asia. Large bovids, such as *Bos*, are probably the descents of the Late Pliocene rather than the Early Pleistocene species from Upper Siwalik. Indeed, they are observed as early as the Lower Pleistocene on the main islands. In the same way, rare carnivores developed later and colonized the greatly expanded Sunda as *Elephas*, *Bubalus*, *Epileptobos* and *Boselaphini* (Bergh et al.,

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2001; De Vos, 1996; De Vos and Long, 2001; Mishra et al., 2010).

7. Taphonomy of the Herbivora

No bones have been recorded in anatomical connection, as all are mineralized. Differential preservation of 864 fossils (Table 6) shows that the axial and appendicular skeletons are represented approximatively in the same proportions: respectively, 47.2% and 52.8%, with the greatest frequency for the shaft, the ribs, the teeth and the mandibles. For the appendicular skeleton without the extremities, the anterior (49%) and posterior (51%) skeletons are also in the same proportion. The bones of the extremities are often small and represent 9.2% of the skeleton, a good representation rather rare. These percentages reflect the equitable preservation of the different parts of the skeletons despite the lack of connection. This could be interpreted as the result of successive processes of conservation since the dead of the animal, taking into account the lithostratigraphic context characteristic of the sub-Himalayan floodplain (Abdessadok et al., 2016; Tudryn et al., 2016). This one was regularly exposed to the seasonal monsoon and the changes of the hydraulic energy from the Himalayan rivers. The layers of quartzite cobbles interstratified within silts illustrate these changes in the hydraulic regime. They could correspond to fast and powerful flooding, taking away herds of herbivores from all sizes, with their carcasses being accessible for the rare scavengers after the water receded.

The alteration of the fossils is heterogeneous, even within a single locality; often some of the bones have been fractured, especially the long bones. They present important cracking due to geological pressure and tectonic activity; this is the case for the very large, well-preserved herbivores, such as Proboscideans and *Hippopotamidae*



Fig. 12. Fracturing of a mineralized bone from a very large Herbivora caused by tectonic pressures of the Chandigarh anticline (picture A. Dambricourt Malassé).
Fig. 12. Fracturation d'un os minéralisé de très grand herbivore provoquée par les pressions tectoniques de l'anticlinal de Chandigarh (photo A. Dambricourt Malassé).

(Fig. 12). In contrast, the bones of cervids or small bovids are rather intact. The surface is frequently scaled according to the areas considered. Some are also affected by several phases of landfill and can be covered by very hard sandstone or gravel (Fig. 13). In some localities, the layers rich in manganese and iron have colored the bony tissues as brown or black (Fig. 13C). In other areas, the fossils are clear (beige-pink) and, in the medullar cavity, they are full of calcite crystals. This diversity of fossilization allows researchers to recognize when the carcasses were buried quickly, as very few have moved since their depository, and why no complete skeletons have been recovered. Finally, some bones show different types of traces on their surfaces, which can be attributed to biological alterations, teeth marks and possible trampling. One isolated trace on a big diaphysis of *Proboscidean* resembles a long cut mark with two parallel

Table 6
Proportional abundance of various skeletal elements in the Masol fossil assemblage. Small herbivora: Cervidae, *Duboisia, Sivacapra*, Suidae, Tragulidae, Large Herbivora: Bovidae, Equidae, *Camelus*, Very Large Herbivora: Proboscidean, Hippopotamidae, *Sivatherium*, Anthracoteriidae.
Tableau 6
Abondance relative des différents éléments squelettiques de l'assemblage fossile de Masol. Petits herbivores : Cervidae, *Duboisia, Sivacapra*, Suidae, Tragulidae, grands herbivores : Bovidae, Equidae, *Camelus*, très grands herbivores : Proboscidiens, Hippopotamidae, *Sivatherium*, Anthracoteriidae.

	Little herbivora	Large herbivora	Very large herbivora	Total	%
Maxillary	2	2	10	14	1.6
Mandible	14	19	24	57	6.6
Teeth	12	50	103	165	19.1
Skull	18	17	15	50	5.8
Vertebrae	2	21	24	47	5.4
Ribs	–	34	41	75	8.7
Scapula	1	3	10	14	1.6
Humeri	1	16	11	28	3.2
Radius/ulnae	3	13	18	34	3.9
Pelvis	4	5	15	24	2.8
Femora	1	11	17	29	3.3
Tibia	6	14	6	26	3.0
Astragali	5	12	6	23	2.7
Calcanei	–	6	–	6	0.7
Metapodial	2	11	1	14	1.6
Metacarpal	1	6	–	7	0.8
Metatarsal	3	11	3	17	2.0
Phalanges	1	6	7	14	1.6
Shaft	5	127	88	220	25.4
Total	81	384	399	864	99.8

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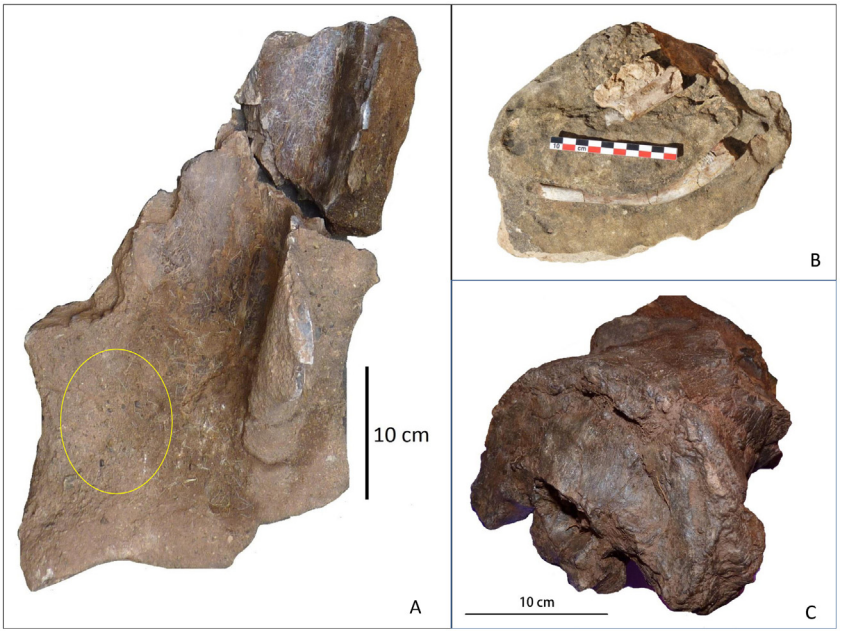


Fig. 13. Different types of fossilisation. A. Masol 2 East, scapula of *Proboscidean* partially covered by gravels (circle). B. Masol 2 West, cervid antler in sandysilt. C. Masol 2 South West, skull of *Sivatherium* strongly colored by manganese (Photo A. Dambricourt Malassé).
Fig. 13. Différents types de fossilisation. A. Masol 2 est, omoplate de proboscidien partiellement recouverte de graviers (cercle). B. Masol 2 ouest, bois de cervidé dans des limons sableux. C. Masol 2 sud-ouest, crâne de *Sivatherium* fortement teinté par le manganèse (Photo A. Dambricourt Malassé).

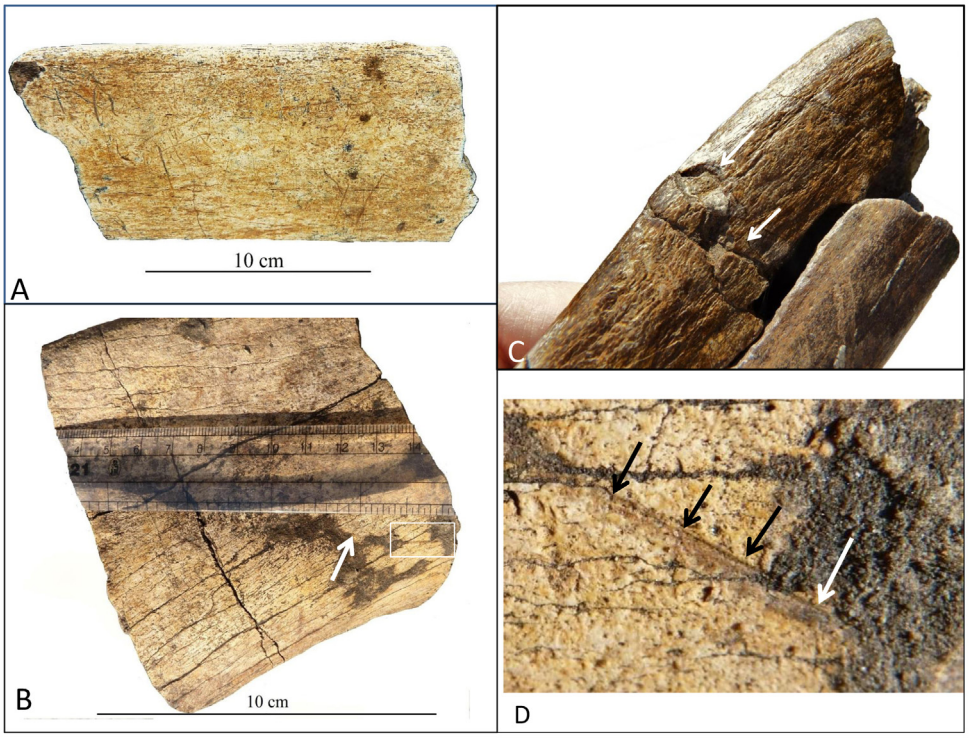


Fig. 14. Fossilized marks. A. Masol 3 R11154, rib with numerous damages with random striations. B. Masol 8 R10893, ulna, *Hexaprotodon*, marks made by the pressure of a canine tooth (arrows). C. Masol 8 *Proboscidean* diaphysis, long mark with two microgrooves (arrow). D. Enlargement of the trace in the white rectangle Fig. 14C (Photo A. Dambricourt Malassé).
Fig. 14. Marques fossilisées. A. Masol 3 R11154, côte avec de nombreuses striations aléatoires. B. Masol 8 R10893, ulna, *Hexaprotodon*, marques faites par la pression d'une canine de carnivore (flèches). C. Masol 8 grande diaphyse de Proboscidien avec une longue marque formée de deux micro-rainures parallèles. D. Agrandissement de la trace dans le rectangle blanc de la Fig. 14C (Photo A. Dambricourt Malassé).

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microgrooves on a minimum length of 3 cm. Nevertheless, the cortical bone is destroyed, with typical carried features (Fig. 14C and D). However, at least three fossils of *Bovidae*, a tibia shaft (Masol 1 R10084) about the size of a *Leptobos*, a distal metacarpal (Pichhli Choe R10286) and a large splinter (Masol 13 R10298) present a set of traces that cannot be confused with trampling (Dominguez-Rodrigo et al., 2010). These marks have been rigorously identified as intentional cut marks made by a sharp edge of a quartzite cobble (or flake) through an experimental protocol, and have been compared with collections of animal marks (Dambricourt Malassé et al., 2016b).

8. Conclusion

The faunal list of the Masol Formation based on the collections from the 12 localities matches the results of former studies on the Tatrot Formation (The Late Pliocene of the Upper Siwalik sub-group). This faunal association is classic in this sector of the Siwalik Frontal Range and is directly linked with water bodies, as witnessed by the strong presence of *H. sivalensis* in all the paleontological-archeological localities, which becomes rare and then absent in the Pinjor Formation. *Elephantidae* correspond to 40% of determinate bones, with the domination of the *S. insignis*, while *Elephas* is rare (2% of determinate teeth). Bovids represent 25% of mammals and correspond to at least five taxa; the most frequent is *Bubalus*, and the group *Leptobos-Hemibos* is also well represented by many mid-sized bovids (*Hippotragini*, *Reduncini*, and *Boselaphini*). The giant giraffid *S. giganteum* is observed in many localities (skull, ossicone, teeth and limb bones), as is *Camelus*. Cervids and suids are also observed with a *Dama*-like mid-sized cervid and a *Verrucosus*-like suid. The scarce anthracothere *M. dissimilis* has been found again (one molar), along with a rare carnivore with a *Panthera* (one hemimandible). Until now, no *Rhinoceros* or *Procynocephalus* have been described in the collections of the 12 localities. The exceptional occurrence of *Hipparion* with *Equus* is characteristic of this period in the sub-Himalayan floodplains. This corresponds to the lower part of the '*E. sivalensis* Biostratigraphic interval-zone', following Nanda's framework (Nanda, 2002). A preliminary overview of the biochronology of the so-called "transitional fauna" showed the origins of herbivores; most originated from Miocene Asian species (*Hipparion*, *Equus*, *Hexaprotodon*, *Elephas*, *Stegodon, Cervidae*), and the migrations from the sub-Himalayan floodplain occurred toward South Asia. The presence of a *Homo*-like *Hominin* evidenced by uncontestable cut marks on bovid bones from the Quranwala zone opens new horizon for the understanding of the oldest Asian sites, such as Riwat (at least 2 Ma, Pakistan, stone tools associated with fauna), Longgupo (cut marks, stone tools, unknown Hominoid, 2.48 Ma) and Longgudong (unknown *Hominin* assigned to *Meganthropus* Matuyama chron), both located in central China long before the Olduvai paleomagnetic event (1.8 Ma).

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References

Abdessadok, S., Chapon Sao, C., Tudryn, A., Dambricourt Malassé, A., Singh, M., Gaillard, C., Karir, B., Bhardwaj, V., Pal, S., Moigne, A.-M., Gargani, J., 2016. Sedimentological study of major paleonto-archeological localites of the Late Pliocene Quranwala Zone, Siwalik Frontal Range, northwestern India. In: Human origins on the Indian sub-continent. C. R. Palevol 15 (this issue).

Agarwal, R.P., Nanda, A.C., Prasad, D.N., Dey, B.K., 1993. Geology and biostratigraphy of the Upper Siwalik of Samba Area, Jammu foothills. J. Himalayan Geol. 4 (2), 227–236.

Arif, M., Vos, de J., 1989. Description of *Sivatherium giganteum* (Mammalia, Giraffidae) material from site H GSP 8460 in the Upper Siwaliks of Pakistan. Proc. Kon. Ned. Akad. Wet B 92 (3), 169177.

Badam, G.L., (Ph.D. Thesis) 1973. Geology and palaeontology of the Upper Siwaliks of a part of Pinjore-Nalagarh area. Faculty of Science and Mathematics, Panjab University, Chandigarh.

Badam, G.L., 1979. Pleistocene fauna of India with special reference to the Siwaliks. Deccan College, Pune.

Badam, G.L., 2000. Pleistocene vertebrate palaeontology in India at the threshold of the Millenium. J. Paleontol. Soc. India 45, 1–24.

Barry, J.C., 1995. Faunal turnover and diversity in the terrestrial Neogene of Pakistan. In: Vrba, E.S., Denton, G.H., Partridge, T.C., Burckle, L.H. (Eds.), Paleoclimate and Evolution. Yale University Press, New Haven and London, pp. 115–134.

Barry, J.C., Lindsay, E.H., Jacobs, L.L., 1982. A biostratigraphic zonation of the Middle and Upper Siwaliks of the Potwar Plateau of northern Pakistan. Palaeogeogr., Palaeoclimatol., Palaeoecol. 37, 95–130.

Bergh, G.D., van der, de Vos, J., Sondaar, P.Y., 2001. The Late Quaternary palaeogeography of mammal evolution in the Indonesian Archipelago. Palaeogeogr., Palaeoclimatol., Palaeoecol. 171, 385–408.

Bibi, F., 2011. Mio-Pliocene faunal exchanges and African biogeography: The record of fossil bovids. PLoS One 6 (2), e16688.

Bibi, F., Hill, A., Beech, M., Yasin, W., 2013. Late Miocene fossils from the Baynunah Formation, United Arab Emirates: Summary of a decade of new work. In: Wang, X., Fortelius, M., Flynn, L.J. (Eds.), Neogene Terrestrial Mammalian biostratigraphy and chronology in Asia. Columbia Univ. Press, New York, pp. 583–594.

Black, D., 1925. Asia and the dispersal of primates. Bull. Geol. Soc. China 4 (2), 133–183.

Black, D., 1926. Tertiary man in Asia: the Chou Kou Tien discovery. Nature 118, 733–734.

Bouteaux, A., Moigne, A.-M., Semah, F., Jacob, T., 2007. Les assemblages fauniques associés aux sites à *Homo erectus* du dôme de Sangiran (Pléistocène moyen, Java, Indonésie). C. R. Palevol 6, 169–179.

Brown, B., Hellman, M., Gregory, W.K., 1924. On Three Incomplete Anthropoid Jaws from the Siwaliks, India. Am. Mus. Novitates, 130.

Please cite this article in press as:Moigne, A.-M., et al., The faunal assemblage of the paleonto-archeological localities of the Late Pliocene Quranwala Zone, Masol Formation, Siwalik Range, NW India. C. R. Palevol (2016), http://dx.doi.org/10.1016/j.crpv.2015.09.016

Chapon Sao, C., Abdessadok, S., Dambricourt Malassé, A., Singh, M., Karir, B., Bhardwaj, V., Pal, S., Gaillard, C., Moigne, A.-M., Gargani, J., Tudryn, A., 2016a. Magnetic polarity of Masol 1 Locality deposits, Siwalik Frontal Range, northwestern India. In: Human origins on the Indian sub-continent. C. R. Palevol 15 (this issue).

Chapon Sao, C., Abdessadok, S., Tudryn, A., Dambricourt Malassé, A., Singh, M., Karir, B., Gaillard, C., Moigne, A.-M., Gargani, J., Bhardwaj, V., 2016b. Lithostratigraphy of Masol paleonto-archeological localities in the Quranwala Zone, 2.6 Ma, Northwestern India. In: Human origins on the Indian sub-continent. C. R. Palevol 15 (this issue).

Churcher, C.S., 1978. Giraffidae. In: Maglio, V.J., Cook, H.B.S. (Eds.), Evolution of African mammals. Harvard Univ. Press, Cambridge, Mass, pp. 509–535.

Colbert, E.H., 1935. Siwalik mammals in the American Museum of Natural History. Amer. Philosophy Soc. Trans., N.S. 26, 401p.

Dambricourt Malassé, A., 2016. The first Indo-French Prehistorical Mission in Siwaliks and the discovery of anthropic activities at 2.6 million years. In: Human origins on the Indian sub-continent. C. R. Palevol 15 (this issue).

Dambricourt Malassé, A., Singh, M., Karir, B., Gaillard, C., Bhardwaj, V., Moigne, A.-M., Abdessadok, S., Chapon Sao, C., Gargani, J., Tudryn, A., Calligaro, T., Kaur, A., Pal, S., Hazarika, M., 2016a. Anthropic activities in the Quranwala Fossiliferous Zone, 2.6 Ma, Siwaliks of Northwestern India, historical context of the discovery and the scientific investigations. In: Human origins on the Indian sub-continent. C. R. Palevol 15 (this issue).

Dambricourt Malassé, Moigne, A.-M., Singh, A., Calligaro, M., Karir, T., Gaillard, B., Kaur, C., Bhardwaj, A., Pal, V., Abdessadok, S., Chapon Sao, S., Gargani, C., Tudryn, J., Garcia Sanz, A.F M., 2016b. Intentional cut-marks on bovids from the Quranwala Zone, 2.6 Ma, Siwalik Frontal Range, NW India. In: Human origins on the Indian sub-continent. C. R. Palevol 15 (this issue).

Deng, T., Wang, X., Fortelius, M., Li, Q., Wang, Y., Tseng, Z.J., Takeuchi, G.T., Saylor, J.E., Säilä, L.K., Xie, G., 2011. Out of Tibet: Pliocene woolly rhino suggests high-plateau origin of Ice Age megaherbivores. Science 333, 1285–1288.

Dennell, R.W., 2005. Early Pleistocene hippopotamid extinctions, monsoonal climates and river system histories in South and South-West Asia: comment on Jablonski (2004). Quatern. Int. 126–128, 283–287.

Dennell, R., 2008. The taphonomic record of Upper Siwalik (Pinjor stage) landscapes in the Pabbi Hills, northern Pakistan, with consideration regarding the preservation of hominin remains. Quatern. Int. 192, 62–77.

Dennell, R., Coard, R., Turner, A., 2006. The biostratigraphy and magnetic polarity zonation of the Pabbi Hills, northern Pakistan: an Upper Siwalik (Pinjor Stage) Upper Pliocene–Lower Pleistocene fluvial sequence. Palaeogeogr., Palaeoclimatol., Palaeoecol. 234, 168–185.

De Vos, J., 1996. Faunal turnovers in Java in relation to faunas of the continent. Odontologie 1, 32–36.

De Vos, J., Long, V., 2001. First settlements: relations between continental and insular, Southeast Asia. In: Sémah, F., Falguères, C., Grimaud-Hervé, D., Sémah, A.M. (Eds.), Origine des peuplements et chronologie des Cultures paléolithiques dans le Sud-Est asiatique. Semenanjung Editions, Art'com, Paris, pp. 225–249.

Dominguez-Rodrigo, M., Pickering, T.R., Bunn, T.H., 2010. Configurational approach to identifying the earliest hominin butchers. Proc. Natl. Acad. Sci. USA 107 (49), 20929–20934.

Echassoux, A., Moigne, A.-M., Moullé, P.-E., Li, T., Feng, X.B., Li, W., Wu, Z., 2008. Les faunes de grands mammifères du site de l'Homme de Yunxian, Quyuanhekou, Hubei, Chine. In: Lumley, H., de Tianyuan, L. (Eds.), Le site de l'Homme de Yunxian, Quyuanhekou, Quingqu, Yunxian, Province of Hubei. CNRS Éditions, Paris, pp. 253–364.

Falconer, H., Cautley, P.T., 1836. *Sivatherium giganteum*, a new fossil ruminant genus, from the valley of the Markanda, in the Sivalik branch of the sub-Himalayan Mountains. J. Asiatic Soc. Bengal, 38–50.

Falconer, H., Cautley, P.T., 1846. Fauna Antiqua Sivalensis, being the Fossil Zoology of the Sewalik Hills, in the North of India. Part I. Proboscidea, London.

Falconer, H., 1868. Palaeontological memoirs and notes of late Hugh Falconer with a biographical sketch of the author, 2. Murchison Ch. (Ed), London.

Gaillard, C., Singh, M., Dambricourt Malassé, A., Bhardwaj, V., Karir, B., Kaur, S., Pal, S., Moigne, A.-M., Sao Chapon, C., Abdessadok, S., Gargani, J., Tudryn, A., 2016. The lithic industries on the fossiliferous outcrops of the Late Pliocene Masol Formation, Siwalik Frontal Range, north-western India (Punjab). In: Human origins on the Indian sub-continent. C. R. Palevol 15 (this issue).

Gargani, J., Abdessadok, S., Tudryn, A., Chapon, C., Dambricourt Malassé, A., Singh, M., Gaillard, C., Moigne, A.-M., Karir, B., Bhardwaj, V., 2016. Geology and geomorphology of Masol paleonto-archeological site, Late Pliocene, Chandigarh, Siwalik Frontal Range. NW India. In: Human origins on the Indian sub-continent. C. R. Palevol 15 (this issue).

Gaur, R., (Unpublished thesis) 1981. Palaeontology and palaeoecology of Plio-Pleistocene Upper Siwalik sediment in the Northeast of Chandigarh, India. Panjab University, Chandigarh.

Gaur, R., 1983. On the occurrence of *Leptobos falconeri rutimeyer* in the Tatrot Formation of Upper Siwaliks near Chandigarh. Bull. Ind. Geol. Assoc. 16 (1), 77–83.

Gaur, R., 1987. Environment and ecology of early man in Northwest India. B.R. Publishing Corporation, Delhi.

Gaur, R.P., 1992. On *Dorcatherium nagrii* (Tragulidae, Mammalia) with a review of Siwalik Tragulids. Rivista italiana di paleontologia e stratigrafia 3 (98), 353–370.

Gaur, R., Chopra, S.R.K., 1984. Taphonomy Fauna, environment and ecology of Upper Siwaliks Plio-Pleistocene near Chandigarh, India. Nature 308 (5957), 353–355.

Gaur, R., Raghawan, P., Chopra, S.R.K., 1984. On the remains of *Camelus sivalensis* (Artiodactyla, Camelidae) from Pinjor Formation of Upper Siwaliks. Indian J. Earth Sci. 11 (2), 158–165.

Gentry, A.W., 1978a. Tragulidae and Camelidae. In: Maglio, V.S., Cooke, H.B.S. (Eds.), Evolution of African Mammals. Harvard Univ Press, Cambridge Mass, pp. 536–539.

Gentry, A.W., 1978b. Bovidae. In: Maglio, V.S., Cooke, H.B.S. (Eds.), Evolution of African Mammals. Harvard Univ Press, Cambridge Mass, pp. 540–581.

Geraads, D., 1979. Un nouveau bovidé (Artiodactyla, Mammalia) du Plio-Pléistocène de Java : *Duboisia* (?) *sartonoi n. sp*. Bull. Mus. Natl. Hist. Nat. 4, 371–376.

Gilbert, C., Bibi, F., Hill, A., Beech, J.M., 2014. Early guenon from the late Miocene Baynunah Formation, Abu Dhabi, with implications for cercopithecoid biogeography and evolution. Proc. Natl. Acad. Sci. USA, http://dx.doi.org/10.1073/pnas.1323888111.

Gregory, W.K., Hellman, M., Lewis, G.E., 1938. Fossil anthropoids of the Yale-Cambridge India expedition of 1935 Carnegie Institution of Washington. Contrib. Palaeontol. 495, 1–27.

Gromova, V., 1968. Fundamentals of paleontology. Mammals, 13. Israel Program for scientific translation, Jerusalem.

Han, F, Bahain, JJ, Deng. C, Boëda, Hou, E. 2015 http://www.sciencedirect.com/science/article/pii/S1040618215001160 - aff5 Y.

Hamy, E.T., 1870. Précis de paléontologie humaine. J.-B. Baillière et fils, Paris.

Harris, J.M., 1976. Pliocene Giraffoidea (Mammalia, Artiodactyla) from East Rudolf. In: Savage, R.J., G, Coryndon, S.C. (Eds.), Fossil vertebrates of Africa, 4. Academic, London, pp. 283–332.

Hooijer, D.A., 1950. The fossil hippopotamidae of Asia, with notes on the recent species. Zoologische Verhandelingen 8.

Hooijer, D.A., 1955. Fossil Proboscidea from the Malay archipelago and the Punjab. Zoologische Verhandelingen 28.

Hooijer, D.A., 1958. Fossil Bovidae from the Malay archipelago and the Punjab. Zoologische Verhandelingen 38.

Hooijer, D.A., Colbert, E.H., 1951. A note on the Plio-Pleistocene boundary in the Siwalik Series of India and in Java. Am. J. Sci. 249, 533–538.

Hou, Y., Zhao, L., 2010. New Archeological Evidence for the Earliest Hominin Presence in China. In: Fleagle, J.G., Shea, J.J., Grine, F.E., Baden, A.L., Leakey, R.E. (Eds.), Out of Africa I: the first hominin colonization of Eurasia. Springer, Dordrecht, Heidelberg, London, New York, pp. 87–96.

Howells, W.W., Tsuchitani, P.J., 1977. Palaeoanthropoloy in the People's Republic of China. National Academy of Sciences, Washington DC, pp. 40–65.

Hussain, S.T., Bergh, G.D., van den Steensma, K.J., de Visser, J.A., de Vos, J., Arif, M., van Dam, J., Sondaar, P.Y., Malik, S.B., 1992. Biostratigraphy of the Plio-Pleistocene continental sediments (Upper Siwaliks) of the Mangla-Samwal Anticline, Azad Kashmir, Pakistan. Proceedings of the Koninkijke Nederlandse Akademi van Wetenschappen 95 (1), 65–80.

Jablonski, N.G., 2004. The hippo's tale: how the anatomy and physiology of Late Neogene Hexaprotodon shed light on Late Neogene environmental change. Quatern. Int. 117, 119–123.

Koenigswald von, G.H.R., 1956. Remarks on the correlation of mammalian faunas of Java and India and the Plio-Pleistocene boundary. K. Ned. Akad. Wet. Amsterdam, BV 59 (3), 201–204.

Köhler, M., 1993. Skeleton and habitat of recent and fossil ruminants. Münchner Geowissenschaftliche Abhandlungen, A 25, 1–88.

Kumaravel, V., Sangode, S.J., Kumar, R., Siddaiah, N.S., 2005. Magnetic polarity stratigraphy of Plio-Pleistocene Pinjor Formation (type locality), Siwalik Group, NW Himalaya, India. Current Sci. 88 (9), 1453–1461.

Please cite this article in press as:Moigne, A.-M., et al., The faunal assemblage of the paleonto-archeological localities of the Late Pliocene Quranwala Zone, Masol Formation, Siwalik Range, NW India. C. R. Palevol (2016), http://dx.doi.org/10.1016/j.crpv.2015.09.016

Lydekker, R., 1879. Further notices of Siwalik mammals. Records of the Geological Survey of India 12, 33–52.
Lydekker, R., 1883. Synopsis on the fossil vertebrate of India. Record Geological Survey of India 16, 61–69.
Martinez-Navarro, B., 2010. Early Pleistocene faunas and Pleistocene hominin dispersals. In: Fleagle, J., Shea, J.G., Grine, J.J., Baden, F.E., Leakey, A.L.R.E. (Eds.), Out of Africa I: The first Hominin colonization of Eurasia. Springer, Dordrecht, Heidelberg, London, New York, pp. 207–224.
Mishra, S., Gaillard, C., Hertler, C., Moigne, A.-M., Simanjuntak, T., 2010. India and Java: contrasting records, intimate connections. Quatern. Int. 223–224, 265–270.
Nanda, A.C., 1981. Occurrence of Pre-Pinjor beds in the vicinity of Chandigarh. In: Proc. Neogene-Quaternary Boundary Field conference, India., pp. 113–116.
Nanda, A.C., 1994. Upper Siwalik mammalian faunas from Chandigarh and Jammu regions with comments on certain faunal discrepancies. In: Ahmed, A., Sheikh, A.M. (Eds.), Geology in South Asia-1. Hydrocarbon Institute of Pakistan, Islamabad, pp. 39–45.
Nanda, A.C., 1996–1997. Comments on Neogene\Quaternary Boundary and associated faunas in the Upper Siwalik of Chandigarh and Jammu. In: Proc Regional GEOSAS Workshop on Quaternary Geology of South Asia, Madras, pp. 120–136.
Nanda, A.C., 2002. Upper Siwalik mammalian faunas of India and associated events. J. Asian Earth Sci. 21, 47–58.
Nanda, A.C., 2013. Upper Siwalik mammalian faunas of the Himalayan foothills. J. Palaeontol. Soc. India 58 (1), 75–86.
Patnaik, R., 2001. Late Pliocene micromammals from the Tatrot Formation (Upper Siwalik) exposed near Village Saketi, Himachal Pradesh, India. Palaeontographica 261, 55–81.
Patnaik, R., 2012. Indian Neogene Siwalik mammalian biogeography. Chap. 17. In: Wang, X., Flynn, L.J., Fortelius, M. (Eds.), Fossil mammals of Asia Neogene biostratigraphy and chronology. Columbia Univ. Press, pp. 423–444.
Patnaik, R., Nanda, A.C., 2010. Early Pleistocene Mammalian faunas of India and evidence of connections with other parts of the world. Chap. 9. In: Fleagle, J.G., Shea, J.J., Grine, F.E., Baden, A.L., Leakey, R.E. (Eds.), Out of Africa I: ThefFirst Hominin colonization of Eurasia. Springer, Dordrecht, Heidelberg, London, New York, pp. 129–143.
Pilgrim, G.E., 1910. Notices of new mammalian genera and species from the territories of India. Records of the Geological Survey of India, 11., pp. 63–71.
Pilgrim, G.E., 1913. The correlation of the Siwaliks with mammals horizon of Europe. Records of the Geological Survey of India, 43., pp. 264–326.
Pilgrim, G.E., 1939. The fossil Bovidae of India. Mem. Geol. Surv. India (Palaeontol. Indica) 26, 1–356.
Pilgrim, G.E., 1944. The Lower Limit of Pleistocene in Europe and Asia. Geol. Mag. 81, 28–38.
Ranga Rao, A., 1993. Magnetic polarity stratigraphiy of Upper Siwalik of north-western Himalayan foothills. Curr. Sci. 64, 863–873.
Ranga Rao, A., Nanda, A.C., Sharma, U.N., Bhalla, M.S., 1995. Magnetic polarity stratigraphy of the Pinjor Formation (Upper Siwalik) near Pinjore. Haryana. Current Sci. 68 (12), 1231–1236.
Rozzi, R., Winkler, D.E., de Vos, J., Schulz, E., Palombo, M.-R., 2013. The enigmatic bovid Duboisia santeng (Dubois, 1891) from the Early-Middle Pleistocene of Java: a multiproxy approach to its paleoecology. Paleogeogr., Paleoclimatol., Palaeoecol. 377, 73–85.
Sahni, M.R., Khan, E.J., 1964. Boundary between the Tatrots and Pinjaurs. Res. Bull. Panjab Univ. 12, 263–264.
Sahni, M.R., Khan, E.J., 1968. Stratigraphy, structure and correlation of the Upper Shiwaliks, East of Chandigarh. J. Palaeontol. Soc. India 1960–1964 (5–9), 61–74.
Shoshani, J., Tassy, P., 2005. Advances in proboscidean taxonomy and classification, anatomy and physiology, ecology and behavior. Quatern. Int. 126–128, 5–20.
de Terra, H., Teilhard de Chardin, P., 1936. Observations on the Upper Siwalik formations and the Later Pleistocene deposits in India. Proc. Amer. Philosophical Soc. 76, 791–822.
Teilhard de Chardin, P., Piveteau, J., 1930. Les mammifères fossiles de Nihowan (Chine). Annales de Paléontologie 19, 1–134.
Tudryn, A., Abdessadok, S., Gargani, J., Dambricourt Malassé, A., Singh, M., Gaillard, C., Bhardwaj, V., Chapon Sao, C., Moigne, A.-M., Karir, B., Pal, S., Miska, S., 2016. Stratigraphy and paleoenvironment during the Late Pliocene at Masol paleonto-archeological site (Siwalik Range, NW India): preliminary results. In: Human origins on the Indian sub-continent. C. R. Palevol 15 (this issue).
Verma, B.C., 1969. Procynocephalus pinjori sp. nov. a new fossil primate from the Pinjor beds (Lower Pleistocene) east of Chandigarh. J. Paleontol. Soc. India 13, 53–57.
Williams, F.L., Holmes, N.A., 2012. Dental microwear texture analysis of late Pliocene *Procynocephalus subhimalayanus* (Primates: Cercopithecidae) of the Upper Siwaliks, India. Central European J. Geosci. 4, 425–438.
Wang, X., Flynn, L.J., Fortelius, M., 2013. Fossil Mammals of Asia: Neogene Biostratigraphy and Chronology. Columbia University Press, New York.
Zhang, Y., Zhang, Z., Liu, W., 2004. The hominid fossils. In: Zheng, S. (Ed.), Jianshi Hominid Site. Science Press, Beijing, pp. 26–36.

Please cite this article in press as:Moigne, A.-M., et al., The faunal assemblage of the paleonto-archeological localities of the Late Pliocene Quranwala Zone, Masol Formation, Siwalik Range, NW India. C. R. Palevol (2016), http://dx.doi.org/10.1016/j.crpv.2015.09.016