

LOCALITY 642, AN UPPER SIWALIK (PINJOR STAGE) FOSSIL ACCUMULATION IN THE PABBI HILLS, PAKISTAN

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ABSTRACT

Locality 642 in the Pabbi Hills, Pakistan, is a large fossil accumulation dated to ca. 1.2–1.4 Ma-old. Investigations showed that it lay in an abandoned channel, and contained numerous remains of bovids, followed by equids, rhinoceros and gazelle. *Pachycrocuta brevirostris* and a small felid were the only carnivores in evidence. Although there had been some fluvial disturbance, carnivores (most likely *Pachycrocuta brevirostris*) were primarily responsible for the accumulation. Useful new data were also obtained on the taxonomy, age profiles and community structure of large mammals during the Upper Siwaliks.

Key words: Upper Siwalik (Pinjor Stage), locality 642, Pabbi Hills, Pakistan

INTRODUCTION

The Upper Siwaliks are one of the longest-studied and best documented Plio-Pleistocene fluvial sequences in the world. Their sedimentological and palaeomagnetic characteristics have been described by several researchers in India, Pakistan and Nepal (e.g. Opdyke *et al.*, 1979; Azzaroli and Napoleone, 1982; Ranga Rao *et al.*, 1988; Corvinus and Nanda, 1994), and the dating of several sections has been strengthened by radiometric dates of volcanic ashes. Studies of Indian sections show that the boundary between the Tatrot and Pinjor Stages coincides with the Gauss-Matuyama boundary at ca. 2.5 Ma; the end of the Pinjor Stage is normally placed in the early Middle Pleistocene, ca. 0.6 Ma. Throughout this period, deposition was predominantly cyclical and fine-grained (see for example, Keller *et al.*, 1977; Reynolds and Johnson, 1985). The faunal features of the Tatrot and Pinjor Stages have been studied in great detail, first in the British period by investigators such as Falconer and Cautley (1845), Pilgrim (for example, 1913, 1939), Matthew (1929) and Colbert (1935), and in recent decades by several Indian scientists such as Badam (1979), Sabni and Khan (1988), Gaur (1987), Patnaik (2003) and especially Nanda (e.g. 1976, 1997). As a result, most Upper Siwalik mammals have been described in detail, and can be assigned to either or both the Tatrot and Pinjor Stages.

Most Upper Siwalik palaeontological investigations have concentrated on studying the taxonomic features of individual dental and/or cranial specimens. With few exceptions (e.g. Gaur and Chopra, 1984; Gaur, 1987; Patnaik, 2003), much less attention has been paid to studying the palaeoecological aspects of Upper Siwalik mammals, their variability, or taphonomic histories. In contrast, these topics have received much attention in recent years by investigators in Europe and Africa who have focussed on the analysis of fossil vertebrate localities, such as Venta Micena, Spain (Palmqvist *et al.*, 1996),

Untermassfeld, Germany (Kalke, 1999), the Omo Valley, Ethiopia (Dechant Boaz, 1994) and even dinosaur localities in the United States (e.g. Wood *et al.*, 1989). These investigations have been particularly informative in illuminating how animals died and were preserved, which parts of their carcasses were preserved, their probable age at death, and their immediate associates as part of an animal community. Much of this work is of interest to palaeoanthropologists, especially if hominids were present as prey or predator. Even if hominids were absent, faunal localities are still of interest in showing a "natural" background against which their activities as predators or scavengers elsewhere can be measured.

Here, we report on the excavation of locality 642, a large

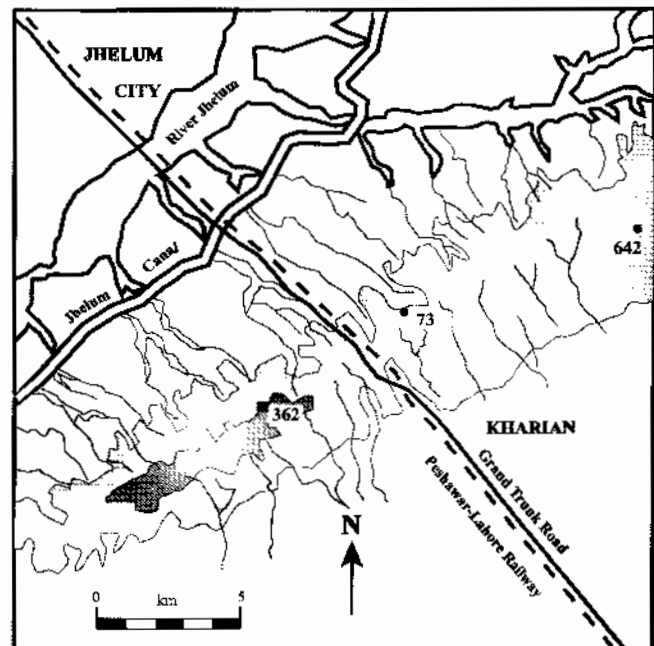


Fig. 1: Location of localities 73, 362 and 642. Localities 73 and 642 (shown by solid circles) are between 1.2 and 1.4 Mya-old; locality 362 is ca. 1.7-1.9 Mya-old.

THE LOCATION, SEDIMENTARY CONTEXT AND EXCAVATION OF LOCALITY 642

Locality 642 was discovered in 1989 during survey near the village of Baroth (fig. 2), and comprises a very large concentration of fossils eroding from yellow-brown silts that now form the top of a low hill immediately in front of Sandstone 12 (figs. 3 and 4). It was originally located on a small stream channel that was peripheral to any main or permanent river course. The fossils accumulated on a land surface characterized by flash-flood conditions where pulses of sand were deposited, possibly as a suspended load, and subsequently became dry and desiccated. The yellow-brown silts containing the fossils overlay silty clays and fine purple clays that contain lamination lines (or a weakly developed cross-bedding), suggesting some alteration to the stream flow. Dessication cracks are evident by their subsequent infilling of finer purple clay, and suggest periods of drying out. These cracks bisected and displaced some bones, and thus developed after fossils had been accumulated. The immediate environment of the site was probably a loop in a braided channel system where the banks of the stream were breached and the sands deposited as a suspended load at the bend of the loop.

All fossil material (over 4200 specimens, including non-diagnostics) was collected from the surface, which was subdivided into three main zones (A, B, C) (see fig. 3). Much of this surface material was very badly degraded and encrusted in cemented sand, but it showed that the commonest animal present was a medium-sized bovid, followed by a larger type and also *Equus sivalensis* and *Rhinoceros sivalensis*. A very small bovid, identified as gazelle, was also present, as were a few dental specimens of *Pachycrocuta brevirostris* (Turner, 2004). Some bovid limb-bone elements were still articulated and held together by their matrix. Following the discovery of well-preserved cranial specimens during the excavation, the medium and large bovinds were identified as *Damalops palaeindicus* and *Hemibos triquetricornis* respectively (see below).

Prior to excavation, all surface fossil material was collected. Although discovered only the previous year, a further 1000

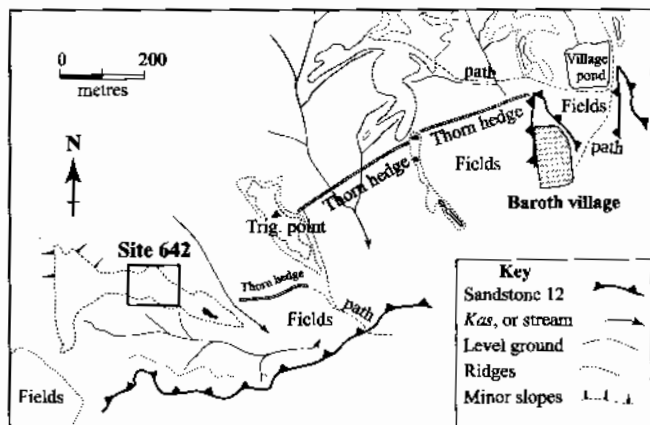


Fig. 2. Map of the area of locality 642, near Baroth, northern part of the Pabbi Hills (based on a map by Mike James and Saleem ul-Haq).

specimens had been exposed during the intervening year. These were collected according to the zones established in 1989. Two areas were identified as worth excavating: a small area where material was actively eroding, and a larger one where the density of fossils appeared highest. As the sediments were very compacted, fossils were excavated by first removing most sediment around them with small picks, chisels and hammers, and then the rest of the matrix with dental picks and small brushes. Some specimens, especially if badly cracked or fragile, were removed in plaster jackets made from the type of plaster-impregnated bandages used in hospitals. All specimens were recorded three-dimensionally, given unique numbers, and plotted on plans drawn at 1:10 (see fig. 5); orientation and dip were also recorded whenever possible. After excavation, further cleaning with dental picks and sometimes with dilute acetic acid took place to remove encrusted material. A complete catalogue of all material as well as an account of the excavation can be found in Beech and Anwar (2004).

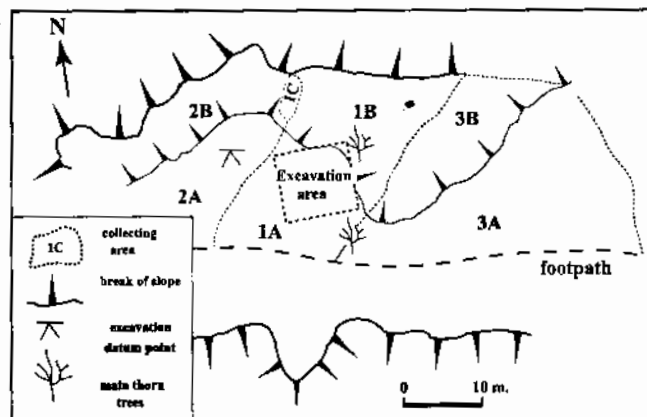


Fig. 3. Plan of locality 642 (based on a map by Mike James and Saleem ul-Haq).

RESULTS

The fossil assemblage consisted of poorly preserved fossils collected from the surface and well-preserved fossil remains recovered by excavation. Although some of the fossils from the surface collections are identifiable to taxon, most are categorized by size because of their poor preservation. The better-preserved material from the excavation allows a higher degree of analysis. The total number of fossils examined in this study was 5712, of which 627 were identifiable to taxon. These represented a minimum of 33 individuals from nine taxa. The remaining specimens were taxonomically indeterminate, but 775 were identified as bovinds and categorized by size. Although the percentage of indeterminate specimens is high, it is not uncommon for sites of a similar age (Brain, 1981, Potts, 1988). The list of species present, the minimum number of individual specimens (NISP) and the minimum number of individual animals (MNI) for each taxon are presented in Table 1. Table 2 shows the frequency of each skeletal element for the principal taxa.

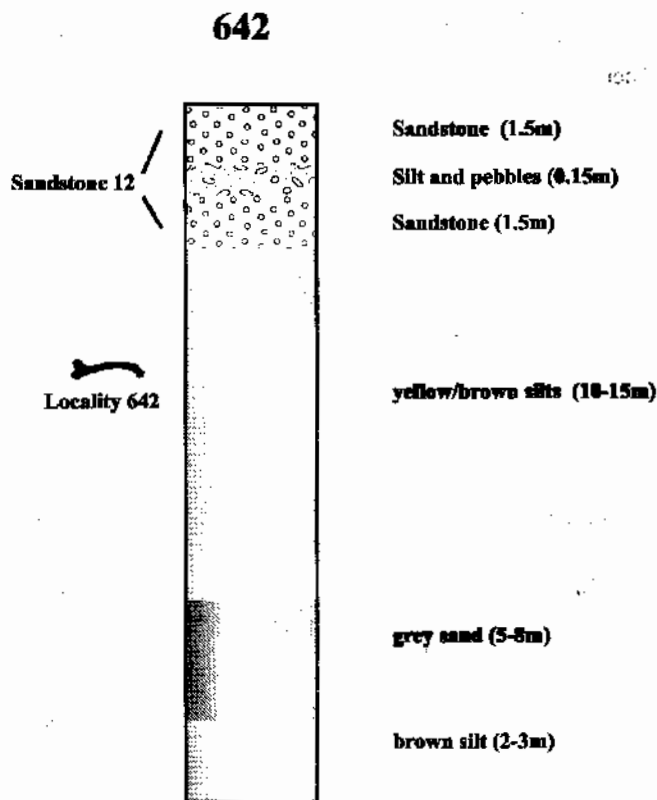


Fig. 4. Schematic section of profile near locality 642.

i. Types of animal present

Bovids dominate both the surface and excavated assemblage, and comprise ca. 90% of the total. *Damalops palaeindicus* is the most abundant single species in terms of the NISP (N = 465) and also in terms of the MNI (= 20). This was first identified as *Proamphibos lachrymans*, following Opdyke *et al.*'s (1979) identification of the Upper Siwalik material (including some from the Pabbi Hills) that they studied in the 1970's. Following the discovery of complete mandibles and a near-complete cranium (specimen 642EX1417), doubts arose over the identification of this taxon. Major differences in the horn cores, skull and dentition are evident: for example, the skull is not as elongate but is more slender in the Locality 642 specimen than that of Pilgrim's (1939) description of *Proamphibos lachrymans*. Equally, the cranial vault is narrow and higher. The horn cores, although not complete on the locality 642 specimen, show that they leave the skull at a less acute angle than those described by Pilgrim for *Proamphibos lachrymans*. With regards to the dentition, the occlusal surfaces show stronger affinities with the tribe Alcelaphini rather than the Bovini, the tribe to which *Proamphibos lachrymans* is attributed. The teeth are strongly hypsodont with a relatively short premolar to molar row and the absence of basal pillars and goat folds on the lower molars

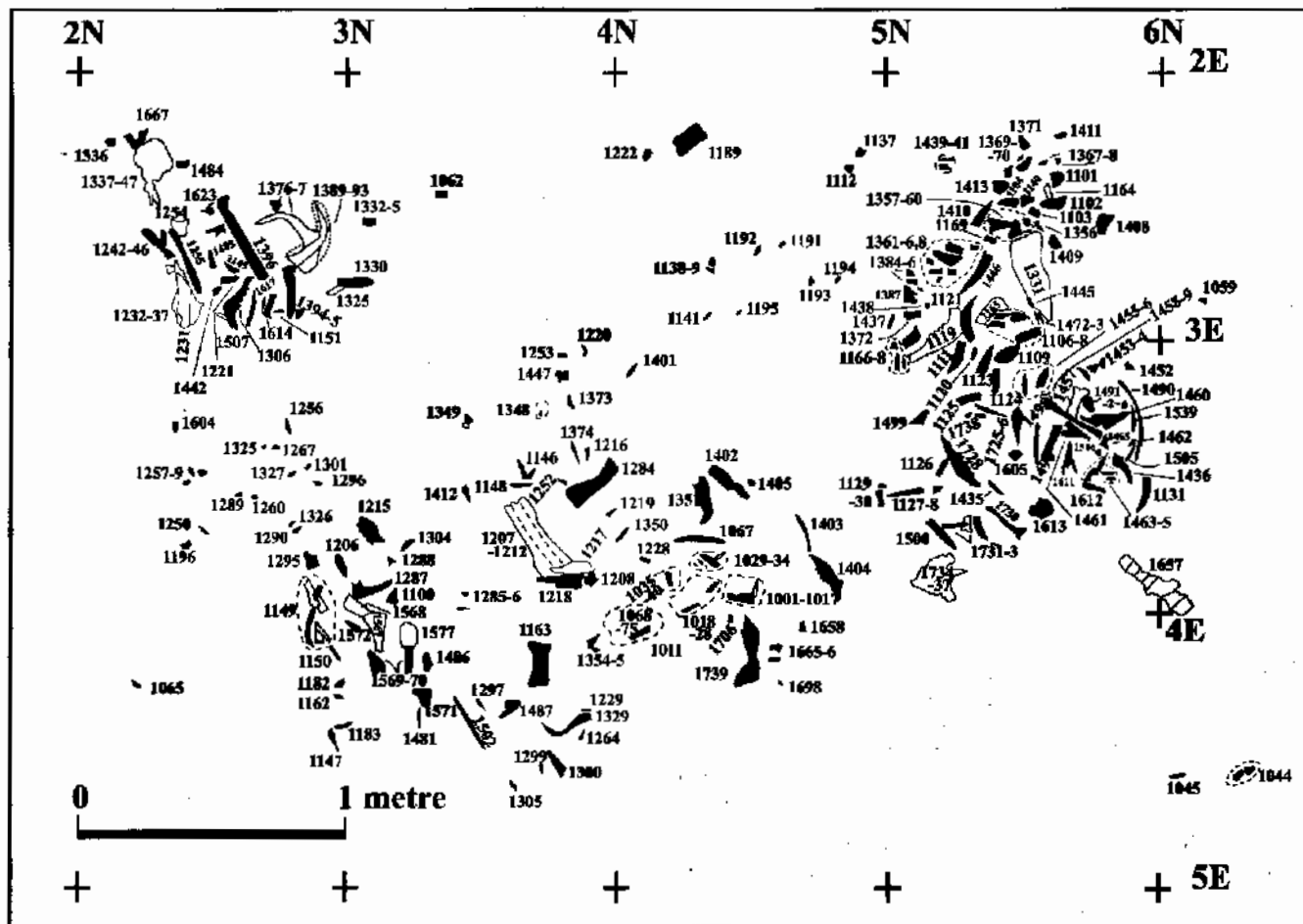


Fig. 5. Plan of excavation of locality 642, area A, level I. This shows the uppermost part of the larger of the two excavated areas.

Table 1: Number of individual specimens present (NISP) and minimum number of individuals (MNI) at locality 642.

Taxon	NISP	MNI
<i>Damalops palaeindicus</i>	465	20
<i>Hemibos triqueticornis</i>	20	3
<i>Equus sivalensis</i>	63	2
<i>Rhinoceros sivalensis</i>	34	2
<i>Gazella</i>	26	2
Suid	5	1
<i>Pachycrocuta brevirostris</i>	7	2
Felid sp. (medium)	4	1

would suggest affinities with the Alcelaphini (Gentry, 1978). Alcelaphini are a medium to large bovid, now largely confined to Africa, but the Pinjor Formation of the Siwaliks does contain related species (Gentry, 1978). The Locality 642 remains show a strong affinity to *Damalops palaeindicus* (Falconer), a Pleistocene bovid that is well documented in the Pinjor Formation and in Tajikistan, and with close relatives at Hadar (East Africa) (Gentry, 1981) and Langebaanweg (South Africa) (Gentry, 1980). The Locality 642 specimens are also similar to the *Damalops palaeindicus* specimens described and illustrated by Dmitrieva (1977: 99) from Tajikistan.

A large bovid, *Hemibos triqueticornis*, is represented by only 20 bones but at least three individuals can be recognised. This bovid is similar in size to a modern eland or African buffalo, with teeth that are strongly hypsodont and selenodont. The enamel is slightly rugose and usually ca 0.8 - 1.0 mm. thick but up to 1.5 mm thick; there is no cingulum. The cusps are strongly folded buccally. On the buccal side, there is a basal pillar between each cusp. The specific identification of *Hemibos* as *H. triqueticornis* is on the basis of its probable horn morphology. Pilgrim (1939: 259-269) recognised three types of *Hemibos* - *H. triqueticornis*, *H. acuticornis* and *H. antelopinus* - and provided detailed descriptions. Each was distinguished primarily on the basis of the angle at which the horns diverge outwards and backwards. In *H. triqueticornis* - the type identified here - the horns diverge at $>90^\circ$, and are tilted back considerably above the plane of the face, following criteria set out in Nanda (1979). The best examples from the Pabbi Hills are specimens 642EX1164 and 642EX1181 from locality 642.

Gazella sp.: One individual animal identified as gazelle was represented by 25 limb- and foot-bones and a few teeth, all from a restricted area of the surface of the locality. As five distal metapodia were found, a second individual is also represented. Some of the foot-bones were found fused together by their matrix, indicating minimal post-mortem disturbance. The post-cranial bones were small and very gracile, and the M_3 was exactly the same length (17.5 mm) as a specimen from the Dhok Pathan Formation identified by Pilgrim (1937: 809) as *Gazella*.

Equus sivalensis: All the equid material from locality 642 can be identified as *Equus*, and most probably as *E. sivalensis*,

the prevalent species of *Equus* in the Pinjor Formation.

There is no evidence of *Hipparion*, either at locality 642 or (contra Opdyke *et al.*, 1979) at any other fossil occurrence (dating back to 2.2 Ma) that we discovered in the Pabbi Hills. Although it was the second commonest species at locality 642 in terms of NISP ($N = 63$), only two individuals were represented.

Rhinoceros sivalensis: One individual is represented, and this was a juvenile. The complete skull excavated from Locality 642 (specimen 642EX1602) had the following diagnostic features characteristic of *Rhinoceros sivalensis*: a saddle shaped skull; a single horn; molars with parastyle, crochet absent, and concave ectoloph. Several other post-cranial specimens (mainly podial) were also found.

Suid. Four poorly-preserved mandibular specimens and a lateral 3rd pahalange were found on the surface, and are probably derived from one pig, type unknown. No suid specimens were found in the excavations.

Carnivores: The main carnivore at locality 642 was *Pachycrocuta brevirostris* (Aymard, 1846). The main specimens were: 642EX1287 (the posterior portion of a left horizontal mandibular ramus with P/4 and M/1 in place); 642EX1390 (a left maxilla with the root of P1/, complete P2/, P3/, P4/ and broken M1/ in place); and 642 GB I (surface collection), a right horizontal mandibular ramus containing the P/3 and P/4 and with a separated M/1. Further details can be found in Turner (2004). A second type of carnivore that was probably a small felid was also represented by a few specimens, notably 642FS28/18, a find of five proximal metatarsals, still held together by their matrix, and 642EX1240, a femur shaft.

It is interesting to note that no evidence was found of turtle or crocodile, even though their remains (mainly scute and loose teeth respectively) were very common in many fossil occurrences in the Pabbi Hills. Their absence here, and at other large fossil accumulations at which mammalian carnivores are present, is strong circumstantial evidence that the fossil material at locality 642 was not deposited by or in a river. As we shall see below, there is some evidence that stream action has modified the site, even if it was probably not the primary means by which animal remains were accumulated.

ii. Age profiles

A population profile based on dentitions was determined for *Damalops palaeindicus*. Age profiles for other taxa were difficult to determine as good dentitions did not survive. The estimates of age are based on published data of eruption rates and wear stages, namely those of Spinage (1967), Atwell (1980) and Atwell and Jeffery (1987). Although these ageing methods do not provide an absolute age at death, the eruption rates are fairly standardised for bovids. The mandibles were grouped into three broad categories based on the presence of the deciduous molars (juvenile), the eruption of the M3 (prime

Table 2: Skeletal part breakdown for principal taxa at locality 642.

Skeletal Part		<i>Damalops palaeindicus</i>	<i>Hemibos triquetricornis</i>	<i>Gazella</i>	Bovid Medium	Bovid Large	<i>Equus sivalensis</i>	<i>Rhinoceros sivalensis</i>	<i>Pachyrocute brevirostris</i>	Carnivore	Suid
Cranial		4	-	-	2	-	1	1	-	-	-
Horncore		139	3	-	247	6	-	-	-	-	-
Mandible		75	-	1	92	7	12	3	2	-	3
Maxilla		14	-	1	4	2	3	-	1	1	-
Tooth		74	1	3	282	13	24	7	3	-	1
Atlas		5	-	-	7	-	-	-	-	-	-
Axis		2	-	-	6	-	-	-	-	-	-
Vertebrae		7	-	-	11	-	-	-	-	-	-
Ribs		-	-	-	-	-	-	1	-	-	-
Scapula		15	3	-	1	-	2	-	-	-	-
Pelvis		4	-	-	-	1	-	-	-	1	-
Humerus:	Proximal	1	-	-	-	-	1	1	-	-	-
	Distal	12	3	1	7	4	-	-	-	-	-
	Complete	-	-	-	-	-	-	1	-	-	-
Radio-ulna:	Proximal	7	1	-	5	-	-	1	-	-	-
	Distal	5	-	-	5	-	-	-	-	-	-
	Complete	1	-	-	-	-	-	1	-	-	-
Ulna:	Proximal	2	1	-	-	1	-	1	-	-	-
Femur:	Proximal	1	-	-	-	-	-	1	-	2	-
	Distal	3	-	-	1	1	-	1	-	-	-
Tibia:	Proximal	2	-	-	1	1	-	-	-	-	-
	Distal	3	-	1	11	2	4	-	-	-	-
	Complete	2	-	-	-	-	-	-	-	-	-
Metacarpals:	Proximal	6	1	2	10	-	-	-	-	-	-
	Distal	4	-	1	18	1	4	-	-	-	-
	Complete	5	-	-	-	-	-	-	-	-	-
Metatarsal:	Proximal	12	1	2	19	1	-	1	-	-	-
	Distal	6	-	-	2	-	1	-	-	-	-
	Complete	6	-	-	-	-	-	-	-	-	-
Metapodial:	Proximal	4	1	-	6	-	-	-	-	-	-
	Distal	16	1	6	4	3	5	1	-	-	-
	Complete	-	-	-	-	-	-	2	-	-	-
Carpals/Tarsals		5	2	2	-	-	-	6	-	-	-
Calcaneus		0	1	-	-	4	1	-	-	-	-
Astragalus		2	1	-	1	2	2	3	-	-	-
Phalanges:	1st	6	-	3	2	1	1	-	1	-	-
	2nd	3	-	-	2	1	-	-	-	-	1
	3rd	1	-	-	-	-	-	-	-	-	-
Totals		454	20	23	746	51	61	32	7	4	5

adult), heavily worn cusps and exposed dentine (senile adult). The range for *Damalops palaeindicus* is wide, with juveniles to very old individuals being represented, but also remarkably even with six juveniles, seven prime adults and seven senile adults.

Of the other taxa at Locality 642 the *Rhinoceros sivalensis* individual was a juvenile. Due to wear on the dentition, the

Pachyrocute brevirostris individual is thought to represent a more mature adult. One of the equids is thought to have died young, possibly as a sub-adult with the permanent dentition erupting. At least one juvenile is represented in the *Hemibos triquetricornis* material, based on the fusion of long bones. The gazelle was probably a young adult, judging from the lack of wear on the teeth.

iii. The size of the Bovid and Equid remains

Measurements of the adult bovid material were compared to those published by Walker (1985) and then assigned to a weight class (Vrba, 1980). The smallest herbivore is the one identified as gazelle, whose remains are distinct in that they are very small and gracile. Measurements suggest a Body Weight Class of <26 kg. The *Damalops palaeindicus* remains fall in the Weight Class C (125–342 kg), consisting of medium to larger bovids with measurements within the modern hartebeest to wildebeest range. Figure 6 shows the size of distal metacarpals attributed to *D. palaeindicus* and *Gazella*. As can be seen, those attributed to *Damalops* are very tightly clustered, and distinct from *Gazella*. The largest bovid present, *Hemibos triquetricornis*, is in Weight Class D (>343 kg) with measurements either within, or exceeding those of modern African buffalo.

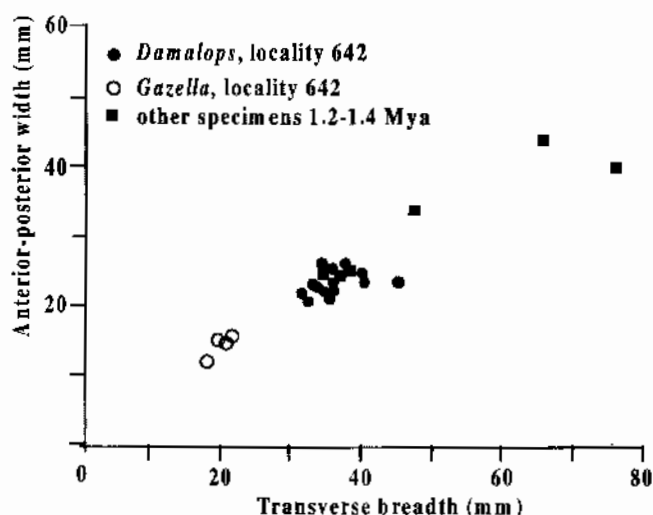


Fig. 6: Scattergram of bovid distal metacarpals. As no distal metacarpals of *Hemibos* were found at locality 642, other of the same age range from elsewhere in Sandstone 12 are shown to give an indication of size.

Fig. 7 shows the size of equid distal metapodia from locality 642 as well as locality 73 (another excavated fossil occurrence of the same age) and other specimens from Sandstone 12. As is evident, there is very little variation in size, and they are all smaller than the earlier specimens (ca. 2.5 Ma) of *E. sivalensis* from Mangla-Samwal, Mirpur (Hussain *et al.*, 1992).

INTERPRETATION OF THE FOSSIL ACCUMULATION

The two main factors that were responsible for the accumulation of fossils at locality 642 were carnivores and stream action. Bones were also modified by weathering, root action, compression and trampling.

i. Carnivore damage

Evidence that carnivores had damaged some bones was clearly indicated by puncture marks, bite marks leaving the tooth row outline, gnawing damage and breakage patterns.

Some mandibles had their ascending and horizontal rami removed, thus exposing the tooth roots, and some metapodia showed extensive gnawing to the distal ends and puncture marks to the shaft or proximal ends. A few horn cores had been gnawed, sometimes along their entire length. Spiral fractures were evident on some long bones, as were other forms of fracture, but not all of these were unequivocally due to carnivores. Bones damaged by carnivores included those of *Rhinoceros*, *Damalops*, *Hemibos* and *Equus*, as well as *Pachycrocuta brevirostris*. Such cannibalistic behaviour is not uncommon for hyaenas (Balestra, 1962; Kruuk, 1972), although Kurten (1968: 66) regarded these gigantic hyaenas as less of a carrion feeder and more of an active hunter than other hyaenid species. Overall, fewer than 10% of the specimens showed unequivocal carnivore damage. This proportion is perhaps not significant, as the recognition of carnivore damage depends upon how much of the surface is well preserved and free of encrustations. Additionally, the extent of damage inflicted by carnivores is dependent on such factors as prey vulnerability, size of feeding groups, and predator-prey ratios (Haynes, 1980a, 1980b, 1983).

The carnivore most likely to have damaged bones would have been a hyaenid. The puncture marks are large and deep, and were present on the largest animals, which suggests an animal with a powerful bite. A small carnivore with sharp teeth (such as a small felid) was also evident from some damaged bones. The striations were fine and non-uniform in direction that is suggestive of chewing by a small carnivore, and not the highly characteristic parallel broad grooves produced by rodent gnawing (Brain, 1981). The tooth mark evidence for the presence of two carnivores is entirely consistent with the fossil evidence from this site for *Pachycrocuta brevirostris* and a small felid. Two coprolites were also recovered and may well be the result of the larger carnivore.

The gazelle remains were unusual in terms of the way they had been damaged. Apart from one distal metapodial, all the post-cranial remains were spatially restricted, and derived from one animal. Parts preserved included two distal humeri, one distal radius, one distal and one proximal tibia, four proximal and distal metapodia, three 1st and two 2nd phalanges. None of these bones showed obvious carnivore damage such as puncture marks, tooth scour or pit marks. Although spiral fractures are present (N=3), other fracture types not so indicative of carnivore predation are also present. One interpretation of these remains is that they represent a single consumption event, whereby the main body of the carcass was consumed, leaving these fragments of bone relatively untouched.

Bone splinters resulting from bone crunching or by digestion by carnivores were not recovered. Bones produced as a product of feeding are described by Potts (1988:100-101) and are quite distinctive, triangular flakes of bone, displaying

both the cortical bone and the bone cavity. The vast majority of the Locality 642 bone fragments were sections of bone ranging from a quarter of the bones circumference to a full shaft piece. It is of course possible that splinters were consumed by carnivores and removed from the site by regurgitation and/or defecation, but as two coprolites were found, this clearly was not always the case. It is unlikely that bone splinters were winnowed out by subsequent fluvial action as many small fragments of bone and teeth were found.

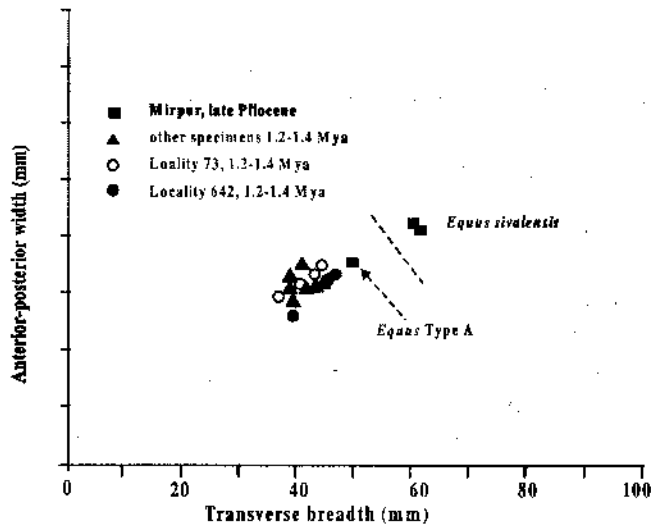


Fig. 7 : Scattergram of equid distal metapodia from the Pabbi Hills and Mirpur

ii. Fluvial modification

Many bones lay in clusters and without showing any preferred orientation. However, 54% of 97 isolated bones showed a north-south alignment. These were predominantly from the uppermost levels. In the lower levels, an east-west orientation was more apparent. This patterning may indicate the action of stream water. Some clusters of bone may also have been the result of stream action, especially if they had been transported as articulated units (Coard, 1999; Coard and Dennell, 1995), or if bones had piled against each other and then come to rest (see Haynes, 1980b).

There is no conclusive evidence that the assemblage was winnowed by stream action, although a few bones showed the rounding and smoothing typical of stream action. Behrensmeier (1975) suggested a "teeth to vertebrae ratio" as an indicator of winnowing, on the basis of teeth being the densest element and vertebrae one of the least dense, and, therefore, most likely to be removed by flowing water from a bone accumulation. For *Damalops palaeindicus* there are 7.4 teeth for every vertebra (based on loose teeth only). For the medium sized mammals the ratio is still high, with 5.4 teeth to every vertebra. For the largest mammals, 32 teeth are recorded but no vertebrae are present. Although such a high ratio of teeth to vertebrae suggests a high degree of winnowing, similar

ratios would be expected if carnivores had preferentially transported head and limb segments of carcasses to the locality.

iii. Post-depositional agencies

Post-depositional agents of modification include sub-aerial weathering, root damage, compression and trampling.

Weathering: Although many bones were encrusted with calcite, weathering stages (as devised by Behrensmeier (1975)) were assigned to as many as possible. Just over 89% of the bones in the excavated assemblage fall in Behrensmeier's stage 2 or below, indicating a short period of exposure (perhaps less than three years) before burial. The weathering on ca. 12% of the bones was classed as stages of 3 or 4, which could represent up to 15 years exposure. The extent of weathering was not related to anatomical element or position on the site, but may have been related to body size. Most of the bones assigned to stage 3 or 4 come from the largest genera (*Rhinoceros*, *Hemibos*, *Equus*), which may indicate something taphonomically distinct about the larger and more robust genera. There is some evidence that the larger the animal, the more resistant its bones are to weathering (Behrensmeier, 1978; Gifford, 1981; Lyman and Fox, 1989). Heavily constructed bones are also more weather resistant (Gifford, 1981) and larger bones take longer to bury. The carcasses of larger species may have lain on the surface for several years longer than those of smaller animals (including most of the *Damalops palaeindicus*) that may have been buried rapidly. The presence of mudballs suggests episodes of rapid sedimentation.

The anatomical part representation of the largest animals is reminiscent of a lag deposit, particularly if they had been transported as dry and articulated carcasses (Coard, 1999; Coard and Dennell, 1995). Skeletal parts such as crania, mandibles, metapodia and scapula are present whereas the more transportable vertebrae, phalanges etc. are not. The distribution of the *Rhinoceros* bones suggests that the skeleton disarticulated *in situ*. The humerus, ulna, radius, metapodia, skull, and teeth fragments are all in close proximity as a major cluster of bones and trail in a NE direction, roughly in line with the palaeostream. It is possible that the animals were deposited on the landscape, subjected to disarticulation and weathering, and during disarticulation, the more transportable bones were winnowed out. This fluvial action may have caused subsequent depositional events with some of the material being transported in and then trapped, which may explain why the small and highly transportable gazelle bones and the more transportable elements of other species are also present.

Diagenetic changes: Root damage, bone deformation and desiccation damage. Some bones had suffered from root damage. This could be seen in some long bones, where roots had grown into the bone cavity and then split the bone, and also in some mandibles, where the horizontal ramus had split

away from the main body of the mandible. This process is depicted in Behrensmeyer (1978: fig. 5). The resulting damage is a fracture that is difficult to distinguish from carnivore or other types of damage. There was also some evidence of bone deformation. The commonest type was plastic deformation, which happens when the bone is soft. The compression of some of the larger bones and the near-complete *Damalops palaeindicus* skull may be due to sediment compression, as one whole side of the cranium had been pushed forwards. The near complete *Equus* skull (642EX1609) shows similar compression damage. Metapodia were also affected, particularly on articular ends where the bone appears to have been softened and then compressed. Such compression is usually localised. Although there are many forms of deformation (Shipman, 1981) and as many reasons for deformation, such localized damage may be due to trampling (Haynes, 1980b). Deformation due to sediment filling cracks in the bone and then pushing the bone apart was also evident. Damage resulting from deformation was not enough to obscure the identification of specimens, but it did make them useless for measurements.

Trampling: Some bones may have been moved by the trampling effects of other animals. Some *Damalops palaeindicus* metapodia show differential weathering at the proximal as opposed to the distal end, suggesting that the less weathered end was pushed down into the protective sediment. This change in declination is suggestive of displacement due to trampling, and has been observed experimentally (Gifford-Gonzalez *et al.*, 1985), and in other fossil localities (Hill and Walker, 1972). Displacement of conjoining bones is also a feature of trampling (Olsen and Shipman, 1988), and is evident here. Conjoining bones were sometimes displaced up to 25 cm apart, with no obvious signs of carnivore gnawing to account for the displacement.

CONCLUSIONS

Our investigations show that a number of agencies were involved in the accumulation of material at locality 642. The sedimentary context was an abandoned channel in which water was intermittent, and thus some material shows sorting and alignment as a result of stream flow. Some animals may have died there naturally. Although it is possible that a large hyaena such as *Pachycrocuta* could have dragged a complete rhinoceros head, there is no obvious reason why it should have done so as it is poor in meat and the head was largely undamaged, and the rhinoceros may have died there of other causes and then been scavenged. Predators were certainly a major accumulating agent, and the most likely one was the large hyaenid, *Pachycrocuta brevirostris*. There is no evidence that they used this locality as a den, as there is no evidence of their young, and the two carnivore coprolites are probably more indicative of casual defecation than the sustained use of

the area as a den. Carcass parts, notably head and limb segments of bovids and horse, were probably transported by them into the channel setting and then defleshed. We thus suggest that the assemblage was largely autochthonous, and sampled a community of *Pachycrocuta*, *Damalops*, *Hemibos*, *Gazella*, *Equus* and *Rhinoceros*, all of which are typical of the open grassland indicated by Quade *et al.*'s (1993) study of the soil carbonates of the Pabbi Hills.

This study, when considered against the other results of our investigations in the Pabbi Hills, cautions us against generalising about the taphonomic histories of large Siwalik fossil concentrations, even when their sedimentary context is similar. In the course of our investigations, we excavated two other localities (73 and 362) that were also in fluvial silts and fine sands. Each had its own distinct characteristics. Locality 73, for example, was used as a den, as young hyaena and coprolites were present. It was also much smaller and with far clearer spatial limits (2 x 1m) than locality 642. Locality 362 (1.7-1.9 Ma) was also very small and well defined, but was not used as a den, and consisted only of head and limb parts, plus a partial skeleton (at the base) of a large canid, *Canis cautleyi*. Only one type of carnivore was present at locality 362, whereas locality 642 had two, and locality 73 has evidence of at least six—*Pachycrocuta*, *Crocuta*, *Panthera*, and a canid, an ursid and a herpestid. There were also clear differences between 73, 32 and 642, and other large fossil accumulations in active channel deposits. In these, crocodile and turtle remains were common, there was more evidence of fluvial sorting, and less evidence of articulated body parts. It is also likely that these contain a higher proportion of allochthonous elements.

There are further benefits of excavating large fossil concentrations such as locality 642. One is that they facilitate investigations of the behaviour of extinct taxa such as *Pachycrocuta*. Our evidence strongly suggests that it was an active predator, and not just a scavenger of carcasses killed by other predators. At locality 642, it was the only large predator, and was clearly eating the meatiest parts of adult bovids and horses. This is in contrast to the evidence from other localities, such as Venta Micena in Spain, where it is thought to have scavenged prey killed by other larger predators (Palmqvist and Arribas, 2001). Another benefit of this type of investigation is that it offers opportunities of exploring population variability as well as community structure. As shown by the size of bovid distal metapodials, for example, those attributed to *Damalops* show remarkably little variation in size. This may indicate either that adult males and females were not dimorphic in size, or that hyaenas were targeting prime adults. This further implies that prey was abundant, and they could ignore very young individuals. The number of complete bones in the excavated portion of 642, and the rarity of evidence of bone-gnawing and -crushing, also implies that meat was readily available. The numbers involved also imply that *Damalops* was gregarious, and more easily preyed upon

than more solitary types than *Hemibos*, *Equus*, *Rhinoceros* or *Gazella*. Excavations of fossil concentrations such as locality 642 are also important in showing what they do *not* contain. As example, there are no Proboscidean remains from 642, or from localities 73 and 362, or from the surface collections of other similar localities (156, 214, 610). This is presumably because they were invulnerable to predators when alive, and scavenged at the place of death.

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