3. "Resource-rich, stone-poor": *Early hominin land use in large river systems of northern India and Pakistan*

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Introduction

This chapter explores two related issues. The first is whether Early Pleistocene hominins were successful in colonizing the Indo-Gangetic floodplains of northern India and Pakistan; and the second is whether the paucity of evidence that they did so might help explain why the evidence for hominins in peninsula India dates to the Middle Pleistocene (Petraglia, 1998), with the exception of one recent, and unconfirmed, date of 1.27 Ma from Isampur, Karnataka (Paddayya et al., 2002). In an earlier paper (Dennell, 2003), I pointed out that current evidence indicates several major discontinuities in regional hominin records across Asia in the Early Pleistocene (see Figure 1). Peninsula India currently has one of the longest, as hominins were present at Dmanisi, Georgia, to the west at 1.75 Ma (Gabunia et al., 2000a), and Java to the east by ca. 1.6 Ma (Larick et al., 2001) and possibly by ca.1.8 Ma (Swisher et al., 1994). However, apart from a small amount of material that remains controversial from Riwat (Dennell et al., 1988) and the Pabbi Hills, Pakistan (Dennell, 2004; Hurcombe, 2004), there is no incontrovertible evidence that hominins were living in the northern part of the Indian subcontinent in the Early Pleistocene, even though it is the obvious corridor route between Southwest and Southeast Asia.

In this chapter, I suggest that Early Pleistocene hominins would have found it very difficult to colonize successfully extensive floodplains such as those of northern India and Pakistan, and current evidence suggests that if they were there at all, it was probably on an intermittent basis and at very low densities of population. Important geological changes in this region towards the end of the Early

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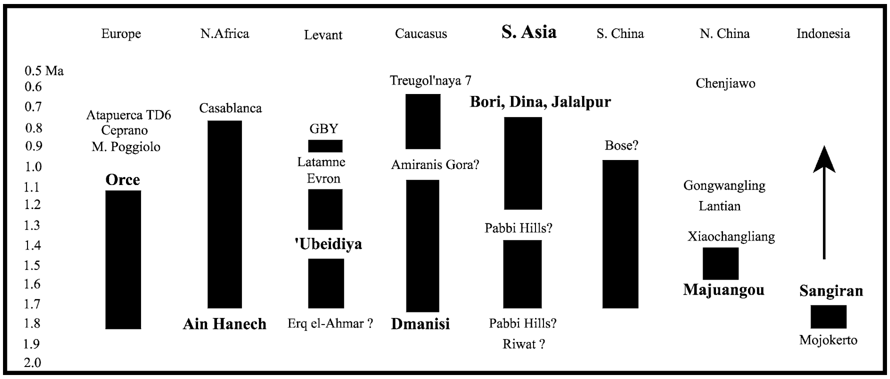

Figure 1. Discontinuities in the fossil and archaeological record for hominins in Eurasia during the Early and Middle Pleistocene prior to ca. 500 ka. Updated and adapted from Dennell, 2003: Figure 4. Names in **bold** indicate the earliest site or discovery in a region that is widely accepted as unambiguous

Pleistocene had potentially important consequences for hominins, notably in increasing the availability of stone for tool-making, and may have been a contributory factor in enabling them to colonize peninsula India in the Middle Pleistocene. We can begin by considering the characteristics of the modern Indo-Gangetic drainage system and its Early Pleistocene predecessors, and then the opportunities and problems that Early Pleistocene hominins might have encountered in these floodplain environments.

The Modern Indo-Gangetic Drainage System

The alluvial plains of the northern subcontinent cover some 770,000 sq km (roughly the same area as Spain and the U.K. combined), and include most of Sind, northern Rajasthan, most of the Punjab, Uttar Pradesh, Bihar, Bengal and half of Assam. The Ganges Plain is ca.1000 km from west to east, and the width varies from 500 km in the west, to < 150 km in the east. Figure 2 shows the modern drainage of the Indus, Ganges and Brahmaputra rivers. Its features were usefully summarized by Wadia (1974:364–365): "the whole of these plains, from one end to the other, is formed, with unvarying monotony, of Pleistocene and sub-Recent alluvial deposits of the Indo-Gangetic system, which have completely shrouded the old land surface to a depth of several thousands of metres….. The deposition of this alluvium commenced after the final phase of the Siwaliks [see below] and has continued all through the Pleistocene up to the present". He continues: "the Indo-Gangetic depression is a true fore-deep, a downwarp of the Himalayan foreland, of variable depth, converted into flat plains by the simple process of alluviation. On this view, a long-continued vigorous sedimentation, loading a slowly sinking belt of the Peninsula shield from Rajasthan to Assam….. the deposition keeping pace with subsidence, has given rise to this great tectonic trough of India". A more recent, and slightly divergent, view over the relative effects of deposition and subsidence is taken by Srivastava et al. (2003:18): "The sediment input to the Ganga Plain occurs at a rate in excess of the down flexing, causing sedimentation rate to exceed the subsidence rate. Hence the basin surface remained above sea level". Both agree over the extent of sedimentation, the depth of which is estimated at < 1000–2000 m, with the greatest depth in the northern part of the syncline. The sediments are primarily "massive beds of clay, either sandy or calcareous, corresponding to the silts, mud and sand of the modern

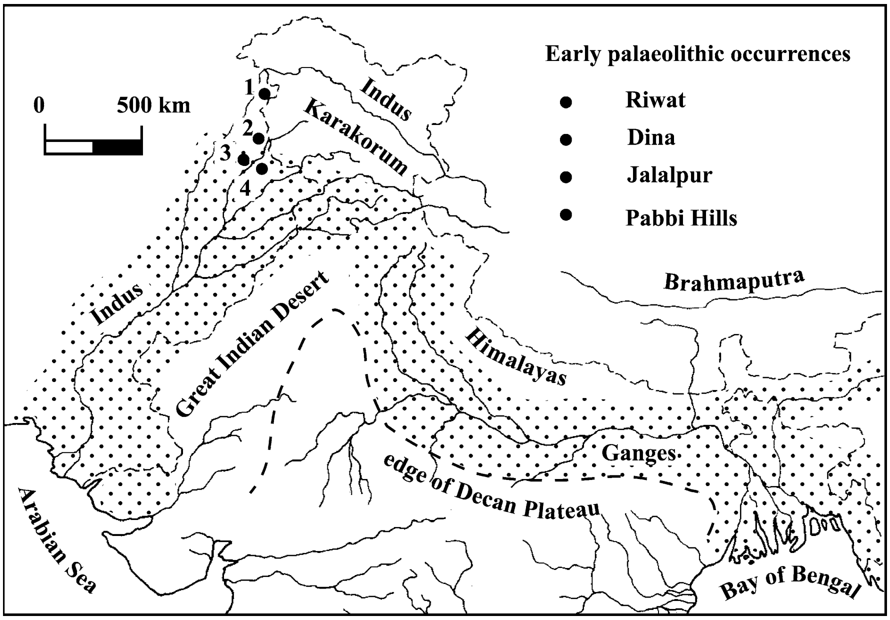

Figure 2. The Indo-Gangetic Plains, and location of archaeological occurrences mentioned in the text

rivers. Gravel and sand become scarcer as the distance from the hills increases. At some depth from the surface there occur a few beds of compact sands and even gravelly conglomerates" (Wadia, 1974:369). Figure 3 shows a schematic view of present-day topography and land-forms.

The highest part of the north Indian Plains, ca. 275 m a.s.l. between Saharanpur, Ambala and Ludhiana, separates the drainage systems of the Indus and Ganges. In addition to depositing an enormous thickness of sediment, both rivers and their major tributaries have frequently altered their courses. In the 16th century, the Chenab and Jhelum joined the Indus at Uch, instead of (as now) at Mithankot, 100 km downstream. Multan was then on the Ravi, whereas now it is 60 km from the confluence

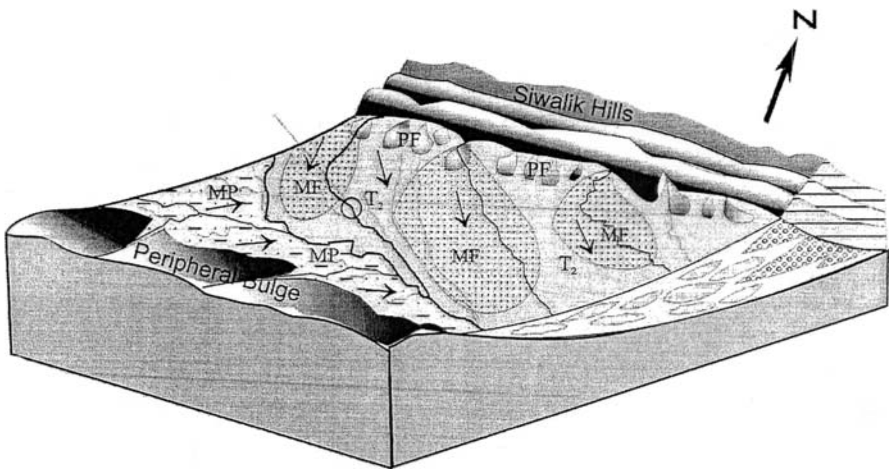

Figure 3. Schematic diagram showing geomorphic features of the modern Ganges (Ganga) Plain. Source: Srivastava et al., 2003: Figure 3. Key: PF – Piedmont Fan Surface; MF – Megafan Surface; T_1 River valley terrace surface; T_2 – Upland interfleuve surface; T_0 Active flood plain surface

of the Ravi and the Chenab. In the third century BC, the Indus was 130 km east of its present course, and its westward and often dramatic migration in subsequent periods is well documented (see e.g., Snelgrove, 1979). Similar changes have occurred in Bengal, notably the growth of the delta since 1750 to its current size of 130,000 sq km (roughly twice the size of Ireland), and a 60 km westward shift by the Brahmaputra (Wadia, 1974:369). Even more dramatically, the Kosi River has shifted 113 km westwards by at least 12 episodic changes of course in only the last 250 years (Wells, 1987).

The absence of evidence for occupation in the floodplains of the Indus and Ganges before the Middle Pleistocene can easily be explained as a consequence of massive sedimentation that has since occurred. However, the history of the Indo-Gangetic drainage system differs from that of many other large rivers in that its earlier history is well known as a result of tectonic uplift. This gives us one of the few windows we have on what these large river systems were like in the Late Pliocene and Early Pleistocene.

The Miocene to Middle Pleistocene Precursors of the Indo-Gangetic Drainage System

Our chief source of information about the Late Pliocene and Early Pleistocene history of the Indo-Gangetic drainage system are Upper Siwalik deposits (ca. 3.3–0.6 Ma). These, like the Lower and Middle Siwaliks, are predominantly fluvial in origin, and resulted from the deposition of several kilometers of sediments in and along rivers that drained southwards from the Karakorum and Himalayas. The reason why so much is known about the Siwaliks is that they have been tilted and uplifted along large sections of the Himalayan forefront, and thus form low and often deeply dissected hills. Uplift ceased between ca. 2 Ma and 400 ka, and thus subsequent, post-Siwalik fluvial deposits are horizontally bedded. For the most part, Siwalik deposits record the history of second- and third-order tributaries of the modern Indus, Ganges and Brahmaputra, and thus provide information about the upper parts of these drainage systems after these rivers left the Karakorum and Himalayas.

The Upper Siwaliks comprises three stages, the Tatrot, Pinjor and Boulder Conglomerate (see Figure 4). Of these, the Pinjor Formation is the longest and most important paleoanthropologically, as its maximum span is from 2.5 to 0.6 Ma. The sediments are primarily, as with most Siwalik formations, sands, silts and clays; the finer sands and silts are often overbank deposits, and paleosols are also common but rarely well-developed. Soil carbonate analyses indicate that vegetation was overwhelmingly open grassland (Quade et al., 1993). There is no influx from loessic or glacial deposits. The loess over northern Pakistan is post-Siwalik; most of that preserved dates from 75-18 ka and was probably derived from fans along the Indus River (Rendell et al., 1989:92). Most Upper Siwalik deposits are too far from the Himalayan forefront to receive glacial debris.

The Upper Siwaliks have been investigated for over a century, and large amounts of vertebrate fossils have been collected from them, although often with little detailed attention to their provenance. Compared with other areas of southern Asia, there is a large amount of data on the fossil vertebrate record of the Late Pliocene and Early Pleistocene: the first monograph on Siwalik paleontology was published as early as 1845 (Falconer and Cautley, 1845); the first anthropoid apes were found in the 1870's (Lydekker, 1879): a large amount of fossil material was collected and studied in the British period (e.g., Pilgrim, 1913, 1939; Matthew, 1929; Colbert, 1935); and Indian paleontologists have been very active in the last 30 years (e.g., Badam, 1979; Sahni and Khan, 1988; Nanda, 2002). The absence of hominin remains cannot therefore be attributed solely to a lack of fieldwork. Why then have no hominin remains been found in the Upper Siwaliks? To answer

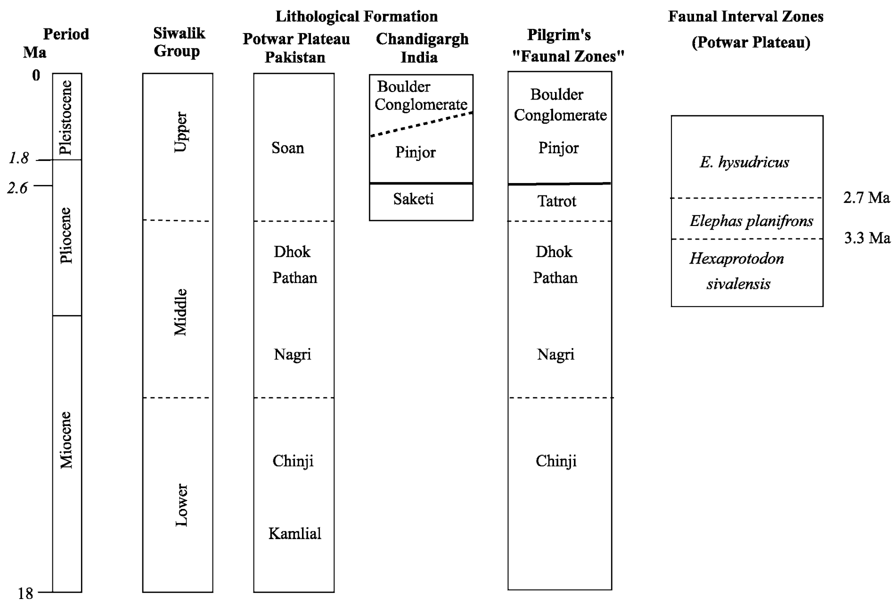

Figure 4. Zonation of the Upper Siwaliks. Source: Dennell, 2004: Figures 2.2 and 2.6, and Hussain et al., 1992: Figure 6

this question, we need first to consider the advantages and drawbacks of the types of floodplain environments presented by the Upper Siwaliks for early hominins.

Large-Scale Fluvial Systems, Early Pleistocene Hominins and the Availability of Stone

At first sight, the extensive floodplains of the Early Pleistocene ancestors of the Indus, Ganges, and their major tributaries should have been attractive areas for *H. erectus* to colonize, as water, a large range of mammalian, and probably also plant and other resources were widely available. There are several reasons, however, why these landscapes might have been beyond their capability to colonize successfully on a long-term basis.

Floodplains and Natural Hazards

The first drawback of large floodplains for early hominins is the summer monsoon, when most of the annual rainfall occurs. During this time, river levels can rise dramatically, and flood extensive parts of the floodplain. This is not in itself a hazard, unless one is unfortunate enough to be trapped on a channel bar or mid-stream island, or behind a levée when it breaks, but high flood levels are disruptive to movement, either through the formation of temporary bodies of water, or extensive waterlogging. A second and related problem comes from water-borne infections and illnesses, particularly after the main monsoonal rains. Bar-Yosef and Belfer-Cohen (2001) rightly suggested that epidemiological factors may have played an important, if invisible, part in influencing early hominin settlement and dispersal, and may have included malaria near water logged and flooded areas. There is also in South Asia a wide range of water-borne parasites and diseases, and large floodplains may also have been unhealthy places to stay in late summer. A third problem is that Indian rivers experience episodic major flood events on an average of every 20–25 years or so (Gupta, 1995). Although the flood waters do not persist, these flood events can have long term consequences on the geometry of the river bed and the direction of flow; rivers may change course afterwards, and among the effects noted are a widening of the stream channel, erosion of bars, and scouring of floodplains and stream beds (Baker et al., 1995). As explained below, these changes may have had consequences on lithic procurement.

Floodplains and Predator Avoidance

Wide, flat floodplains that were predominantly open grassland would also have afforded hominins few vantage points from which to assess risks and opportunities, and little protection (such as trees as places of refuge) from large predators such as *Pachycrocuta brevirostris*. Evidence from Zhoukoudian, China, indicates that this giant hyaenid frequently ate *H. erectus* in the Middle Pleistocene (Boaz et al., 2000), and Turner (1992) suggested that the abundance of large carnivores in Europe during the Early Pleistocene was an important factor in delaying the entry of hominins into that continent. Data from the Pabbi Hills, Pakistan (Dennell et al., 2005a), and from other Upper Siwalik localities Nanda (2002) indicate several large Early Pleistocene predators: the giant hyaenid *Pachycrocuta brevirostris*, the sabre-toothed *Megantereon*, the pantherine *Panthera uncia*, a large canid *Canis cautleyi*, as well as the hyaenids *Crocuta crocuta* and probably *Hyaenictis or Lycyaena*. The giant felid *Homotherium* may also have been present, as it is evidenced in neighboring regions in the Early Pleistocene. Crocodiles and/or gavials were also significant riverine predators. Analysis of the three fossil accumulations (localities 73, 362 and 642) that were excavated in the Pabbi Hills did not provide any indication that hominins were able to compete with large carnivores for prey or carcass segments in the Early Pleistocene (Dennell et al., 2005b, 2005c); as example, at locality 642 (1.4–1.2 Ma), *Pachyrocuta* was able to select prime adult *Damalops palaeoindicus* as its main prey (Dennell et al., 2005b).

Floodplains and Hominin Home Range Sizes

Because Early Pleistocene hominins appear to have had small home ranges, large floodplains that might commonly have been > 50 km wide and uniform over large distances might have been too large for them to exploit efficiently. Estimates of their average home range are usually based on inferences of the estimated height, weight and brain size of fossil hominins, and linked to known home range sizes of extant primates and modern gatherer-hunters. These estimates can be only approximate, and much depends on assumptions of their diet (particularly over how much meat was eaten). Nevertheless, they are useful aids to modeling early hominin behavior.

The extraordinarily complete 1.75 Ma old specimens from Dmanisi, Georgia, currently provide our best insights into the earliest known inhabitants of Asia. As Table 1 shows, they were remarkably small-brained. The most recent, and very detailed, taxonomic assessment is that these individuals represent the most primitive form yet found of *H. erectus* sensu lato, and that they may form part of the source population of *H. erectus* (a.k.a. *H. ergaster*) in East Africa, and *H. erectus* sensu stricto in Java (Rightmire et al., 2005). The one published post-cranial specimen (D2021, a proximal right third metatarsal) also indicates that they were short, with an estimated stature of only 1.48 ± 0.65 m (Gabunia et al., 2000:31). As might be expected for such primitive forms of *Homo*, their behavior also appears to have been very primitive. The large (4,446 pieces) and associated lithic assemblage has recently been classified as "pre-Oldowan", in the sense that it lacks the small retouched tools that feature in East African Oldowan assemblages (de Lumley et al., 2005). Although no details are yet available on their subsistence behavior, it is probable that the cognitive abilities of these hominins were very limited relative to later populations of *Homo*, and that they were

Table 1. Cranial capacities of specimens of early H. erectus *from Dmansi and later* H. erectus *from Java and Zhoukoudian (China)*

Specimen	*Description*	*Cranial Capacity* (cc^3)
D2280	Adult braincase, possibly male	775
D2282/D211	Partial cranium of a young adult	650–660
D2700/D2735	Complete skull of small subadult	600
D3444/D3900	Edentulous old cranium	625
Sangiran	Average of Sangiran 2,4,10,12,17, IX and Trinil 2	918
Zhoukoudian	Average of crania II,III,V,VI,X–XII	1029

Sources: Rightmire et al., 2005 for Dmanisi and Antón, 2002:Table 1 for Java and Zhoukoudian

not particularly sophisticated at dealing with complex subsistence strategies.

Estimates based on body weight estimates for the Dmanisi hominins and early African *H. erectus* suggest home range sizes of up to 413 hectares (assuming a diet at the low end of the range of modern tropical foragers), but only 331 hectares if estimates are based on the third metatarsal (specimen 2021) from Dmanisi (Antón and Swisher, 2004:288). This figure implies an annual home range of ca. 82–100 sq km for a group of 25 early *H. erectus* (i.e., the smallest number assumed to be viable for mating and child-rearing), or an operating radius of only 5.1–5.6 km. As will be shown below, this estimate agrees very closely with estimates based on the distances over which hominins transported stone in the Early and Middle Pleistocene. On large floodplains that were uniform in relief and vegetation over several tens of kilometers, a foraging radius of this size could have been too small to include all the resources (such as stone, water, carcasses, plant foods, etc.) that were needed on a daily or weekly basis. While they might have offset those disadvantages by increased mobility and frequent relocation of their home range, the risks would have been high if the distances involved were considerable, especially as the weakest members of the group, such as the very young, pregnant females, and the infirm would have been vulnerable to predators. It is probably because of their small foraging ranges and limited cognitive abilities that Early Pleistocene *H. erectus* appears to have preferred areas such as small lake basins where a wide variety of resources were available within a small area. Examples are the lake basins at Dmanisi (Gabunia et al., 2000b), Erq el-Ahmar (if the flaked stones are accepted as artifacts, and assumed to be Early Pleistocene in age), ‘Ubeidiya and Gesher Benot Ya’aqov in the Jordan Valley (Feibel, 2004) and Nahal Zihor, Israel (Ginat et al., 2003); Dursunlu, Turkey (Güleç et al., 1999); Kashafrud, Iran (Arai and Thibault, 1975/77) (if its dating to the Early Pleistocene is accepted); and sites such as Majuangou and Xiaochangliang in the Nihewan basin, China (Zhu et al., 2003, 2004). Other favored locations (and for which the evidence for hominins is predominantly Middle Pleistocene) were small river valleys and stream channels, such as Evron, Israel (Ronen, 1991); Latamne, Syria (Clark, 1969); numerous Oldowan and Acheulean sites in Saudi Arabia (Petraglia, 2003); the Hunsgi-Baichbal valleys (Paddayya, 2001); in Spain, the upper parts of tributaries of the Duero (but not the main river itself) and along the Somme, Thames, Solent and Ouse in northern Europe (Gamble, 1999:143).

Floodplains and the Scarcity of Stone

The floodplains of northern India and Pakistan would also have been very deficient in one item that hominins appear to have depended upon after 2.5 Ma, namely flakeable stone. As Misra (1989a:18) commented, "In the case of the Ganga valley, the non-availability of stone, the basic raw material for making tools, may have been responsible for man avoiding this region". We noted above that the history of fluvial deposition in the Siwaliks, from 18 Ma to ca. 1 Ma, and thereafter, is primarily one of sand, silt and clay. Stone is virtually absent from most Upper Siwalik sequences before the Boulder Conglomerate Stage, when thick coarsely-sorted conglomerates were deposited on top of the predominantly fine-grained sediments of the Pinjor Stage (see below). When found in Pinjor Stage deposits, stone tends to occur as "stringers", or as thin layers a few meters long, in or by the active river channel. Stone also tends to be rare on the margins of floodplains, as often the nearest elevated ground (often several kilometers from the main river course) is usually formed of uplifted, earlier Siwalik exposures of silts and sands.

For stone-dependant hominins during the Late Pliocene and Early Pleistocene, access to what stone there may have been along the river channel is likely to have been highly seasonal. Stone, being the heaviest part of a river's bed load, would have been found in only the active, year-round channel, and most easily obtained when the river was at its lowest, i.e., immediately before the summer monsoonal rains, or in mid-winter. When river levels rose, after heavy spring rains and during the monsoon, it would have been inaccessible (see Figure 5). As noted above, the rivers in this region are prone to changes of course, so there need not have been any guarantee that stone would be available at a particular place from decade to decade, or even year to year. Major flood events could therefore have had important local consequences in re-arranging the location and amount of stone available along stream channels – for example, a previously-used source might have been buried, or scoured away; or other stone sources might have been exposed further downstream.

Two factors – transport distances, and coping strategies – need to be considered when assessing the competence (or otherwise) of early Pleistocene hominins to deal successfully with the problems of inhabiting an environment where stone was extremely scarce and not readily-available year-round.

Transport Distances Available data suggest that stone was carried in the Early and Middle Pleistocene over very short distances, typically less than 5 km. At Olduvai (Beds I and II), for example, most artifacts were made from stone obtainable within 2–4 km, and occasionally 8–10 km (Hay, 1976:183 quoted in Isaac, 1989:171). Petraglia et al. (2005) report that stone was rarely transported beyond 2 km in the Hunsgi Valley. The distances over which stone was obtained appear similar throughout the Lower Paleolithic in Europe (see Roebroeks et al., 1988; Gamble, 1999). At the Caune d'Arago (France), for example, 80% of lithics came from < 5 km; the maximum distance reported was 35 km (Gamble, 1999:126). The same pattern continues into the Middle Paleolithic: in Southwest France, 55–98% of stone came from < 5 km and 2–20% from 5–20 km. For all of Europe, only 15 of 94 raw material transfers from 33 sites/layers were > 30 km, and the average maximum distance was 28 km (see Gamble, 1999:126–127). Feblot-Augustins (1999) also observed that at 33 European lower and 19 Middle Paleolithic sites, > 90% of utilized stone came from < 3 km, and the rest usually from 5–12 km.

The same pattern appears to hold for Early and early Middle Pleistocene Asia: at Dmanisi, stone came from two nearby rivers (de Lumley et al., 2005:3), at 'Ubeidiya (Bar-Yosef and Goren-Inbar, 1993:121), and Gesher Benot Ya'aqov (Goren-Inbar et al., 2000), it was

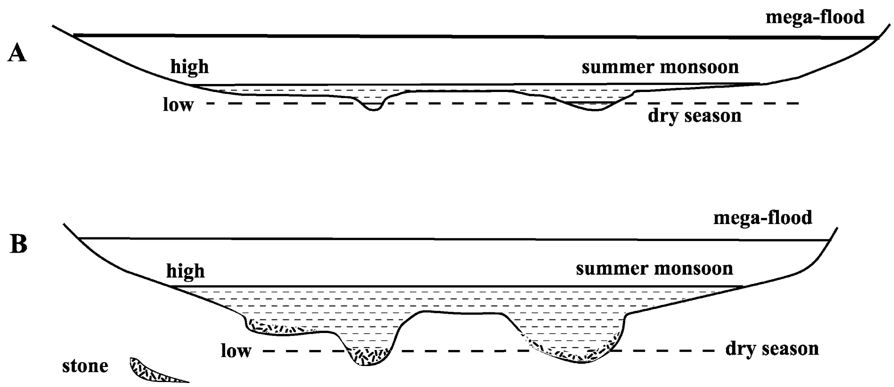

Figure 5. River levels and the probable seasonal availability of stone. Source: Dennell, 2004: Figure 11: 8. In A, the vertical and horizontal scales are the same. In B, the vertical scale has been exaggerated to show more clearly the effect of changes in river level on the accessibility of stone. As shown, stone might have been inaccessible for a substantial part of the year during and immediately after the summer monsoon. River levels can also rise dramatically in spring after heavy rains, and when snow melts in mountainous areas further upstream. Megaflood events could have major consequences on channel profiles, including burying or removing sources of stone, or exposing new ones

immediately available; at Dongutuo, Nihewan basin, North China, there was a nearby chert outcrop (Schick et al., 1991; Pope and Keates, 1994); at Xaiochangliang, also in the Nihewan basin, stone was available nearby (Zhu et al., 2001); at Dursunlu (Turkey), stone probably came from nearby hills (Güleç et al., 1999); at Dawādmi in Saudi Arabia, at least 24 Acheulean sites are known from along the northern side of an andesite dike near which there may have been a low-lying lake (Petraglia, 2003). At Evron (Israel), most of the lithics were made from stones in the adjacent stream channel, but a few from calcite geodes 5 km away (Ronen, 1991).

As might be expected, there are a few exceptions. Gamble (1999:126–127) notes that at the Caune d'Arago, a small amount of stone came from 35 km away, and as far as 80 km from Labastide d'Anjou; and Mishra (1994:61) notes that at Yedurwadi, one quartzite spheroid probably from a distance of > 50 km. Nevertheless, the pattern for Early Paleolithic sites is always that most stone was obtained, used and discarded within 5km of where it was found, and often less. This figure strengthens the estimates cited above that these hominins operated within a 5 km radius. As Gamble (1999:144) notes, they probably also lacked the social and exchange networks that enabled them to learn about and obtain resources associated with other groups. It is not until the late Pleistocene that stone (and other exotic items such as shell) was routinely transported > 80 km and even > 200 km from its source (Gamble 1999:315).

Coping Strategies How then did hominins cope with landscapes that were "resource rich, stone poor"? Options available were using very small stones; curation; caching; substitution of stone by other materials; and avoidance of stone-poor areas. One example of using very small and poor quality stone is the 2.3 Ma old assemblages from the Omo River, Ethiopia, where the tools are little more than smashed quartz pebbles (Merrick, 1976). Another example is the loess landscape of southern Tajikistan, where stone was extremely scarce and found mostly in stream beds. Stone tools were made from small pebbles of quartzite, limestone, schists, cornelian, porphyry and poor quality flint and chert. At Kuldara, ca. 955-880 ka and the oldest site in the region, 25% of flaked pieces were < 2 cm in length, and 50% were 2–4 cm long. At Kuratau I (620–570 ka), 18% were 2–3 cm long, and ca. 70% of all flaked stones showed flake removals of < 5 cm. Artifacts are also usually found in very low densities, or as isolated finds. At Kuldara, for example, only 96 items (of which only 40 are tools) were found in an area of 62 sq m, and at an estimated density of only one find per 4 m^3 of deposit. At Karatau, the density of flaked pieces was only 1.9 per sq m, although at Lakhuti 1 (530–475 ka), it was as high as 10.5 per sq m (Ranov, 2001; Ranov and Dodonov, 2003).

Evidence for curation in the Early Paleolithic is very rare, and most artifacts seem to have been made and used expediently. One example is from Mudnur VIII at Hunsgi-Baichbal valley, where ca. 24 massive handaxes of limestone were found without any associated blocks of raw material or/and debitage, and which may have been a cache meant for future use (Paddayya and Petraglia, 1995:349). A third is the piece of antler of *Megaceros* from Boxgrove (524–476 ka) that was probably used as a soft hammer (Roberts and Parfitt, 1999:395). Another example may be a type of hemispherical or polyhedral core that was found in the Pabbi Hills and represented by 14 examples, and which showed evidence of wear on one face (Hurcombe, 2004:231). Otherwise, curation does not appear to have provided Early Pleistocene hominins with a solution to the problem of dealing with extreme scarcities and/or seasonal shortages of stone.

Evidence that in some situations, hominins used stone sparingly is provided by recent work at Hata in Ethiopia (Heinzelin et al., 1999). Here, the explanation offered is that late Pliocene hominins were operating in areas where stone was very scarce, in contrast with areas such as Gona, where stone was naturally very abundant (as was evidence of tool-making). It is worth quoting the discussion of this evidence at some length:

> Nearly contemporary deposits at Gona, only 96 km to the north, produced abundant surface and in situ 2.6-Ma Oldowan artifacts. In contrast, surveys and excavations of the Hata beds have so far failed to reveal concentrations of stone artifacts. Rare, isolated, widely scattered cores and flakes of Mode I technology appearing to have eroded from the Hata beds have been encountered during our surveys. Most of these surface occurrences are single pieces. Where excavations have been undertaken, no further artifacts have been found … At the nearby Gona site, abundant Oldowan tools were made and discarded immediately adjacent to cobble conglomerates that offered excellent, easily accessible raw materials for stone-tool manufacture. It has been suggested that the surprisingly advanced character of this earliest Oldowan technology was conditioned by the ease of access to appropriate fine-grained raw materials at Gona. Along the Karari escarpment at Koobi Fora, the basin margin at Fejej, and the lake margin at Olduvai Gorge, hominids also had easy access to nearby outcrops of raw material. In contrast, the diminutive nature of the Oldowan assemblages in the lower Omo [made on tiny quartz pebbles] was apparently conditioned by a lack of available large clasts. The situation on the Hata lake margin was even more difficult for early toolmakers. Here, raw materials were not readily available because of the absence of streams capable of carrying even pebbles. There were no nearby basalt outcrops. The absence of locally available raw material on the flat featureless Hata lake margin may explain the absence of lithic artifact concentrations … The paucity of evidence for lithic artifact abandonment at these sites suggests that these early hominids may have been curating their tools (cores and flakes) with foresight for subsequent use … The Bouri discoveries show that the earliest Pliocene archaeological assemblages and their landscape patterning are strongly conditioned by the availability of raw material (Heinzelin et al., 1999:628–629).

As we shall see below, these conclusions could have been written for the evidence from the Pabbi Hills, notably the absence of nearby large sources of flakeable stone, the rarity of flaked stone across the landscape, the preponderance of isolated finds, and the failure of excavations to find artifacts in situ.

There is very little evidence that Early or Middle Pleistocene hominins used materials other than stone when the latter was scarce or not available. Fossilized wood is effectively a type of stone, so its use in the (undated)

Anyathian Early Paleolithic of Myanmar is not strictly an example of substitution, especially as it is widely available throughout Myanmar (Oakley, 1964:232). Even if bone was very occasionally flaked (as with, for example, the bone handaxe from Castel di Guido, Italy [Gamble, 1999:137]), stone was still used to flake it. Arguments that bamboo was used instead of stone in Indonesia and mainland southeast Asia (Pope, 1989) are unconvincing, as in all other areas used by hominins, stone was always used if available along with organic materials such as wood. Nevertheless, one interesting example that may show the substitution of bone for stone comes from Kalpi, on the Ganges Plain in the Yamuna Valley: here, Middle Paleolithic lithic artifacts, dated to ca. 45 ka, were made from small (2–4 cm) quartzite pebbles, and were greatly outnumbered by a variety of bone artifacts, including scrapers, points and burins (Tewari et al., 2002). This is the first Middle Paleolithic evidence from the Ganges Plain, and may indicate how hominins were later able to overcome the scarcity of workable stone in these large floodplain environments. At this point, we can consider the fossil and archaeological record of the Upper Siwaliks.

The Mammalian Fossil Record of the Upper Siwaliks

The Pinjor Stage is one of the most detailed for the Early Pleistocene, and includes at least 49 vertebrate taxa (Nanda, 2002). Although fossil collecting has at times been haphazard and unsystematic, we can assume that after a century or so, the main animals have probably been recorded. Nevertheless, consideration of the adult body size and types of animals recorded indicate that the full range has yet to be established. The genera listed in the Pinjor Stage are overwhelmingly medium (> 50 kg) to large (> 250 kg) herbivores. Figure 6 shows the mammals represented in the Pabbi Hills (Dennell, 2004; Dennell et al., 2005a), which has a long and often fossil-rich sequence spanning 2.2–0.9 Ma that is broadly similar to other Upper Siwalik sequences of the same age-range. As can be seen, very few taxa were found that are within the size range of hominins, and the few that were (e.g., gazelle, small pigs and small carnivores) were also very rare. A second feature of the Upper Siwalik vertebrate record is that rare taxa are sampled very poorly. For example, *Pachycrocta, Megantereon, Canis cautleyi, Ursus* and anthracotheres are recorded (but by only a few specimens each) in the Pabbi Hills sequence in Pakistan, but not in India; conversely, *Camelus* (Opdyke et al., 1979), *Theropithecus* (Delson, 1993) and small primates (Barry, 1987) are recorded in India but not Pakistan; and in neither country is *Homotherium* recorded, even though it was present at Dmanisi to the west (Gabunia et al., 2000b), Kuruksay, Tajikistan, (Sotnikova et al., 1997) to the north, and Longuppo, China, to the east (Wanpo et al., 1995). The absence of hominins is not therefore as well established as might at first sight appear.

Hominin Remains in Fluvial Contexts

Hominin remains are very rare from fluvial deposits, and most of those known are from rivers that were probably smaller than many of those indicated by the Upper Siwaliks. The principal finds are shown in Table 2. As shown, most finds have been of crania or mandibles; post-cranial remains are rare, although six femora were found at Trinil, two tibiae at Solo (Ngandong) (Day, 1986), a tibia fragment at Sambungmachan, and a clavicle at Narmada in India (Sankhyan, 1997). Most discoveries of hominin remains in fluvial deposits have tended to be "one-offs", in the sense that further searching in the same deposits has rarely led to the discovery of other hominin remains. There are a few exceptions: a partial one is Swanscombe, where a third piece of cranium was found in 1955 that miraculously joined

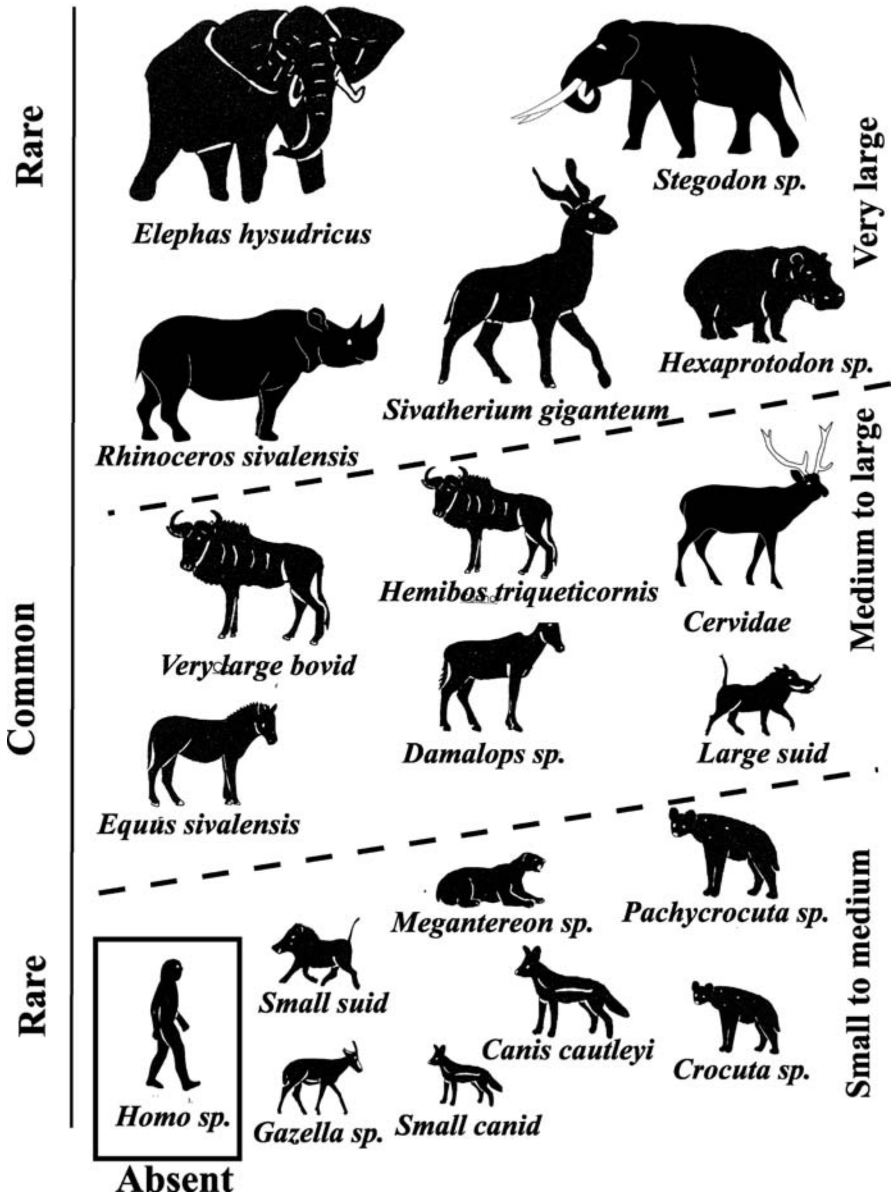

Figure 6. Type and body size of mammals represented in the Pabbi Hills, Pakistan. The taxa shown are broadly similar to those from comparable Indian exposures. As shown, most taxa are considerably larger than humans. Those nearest in body size – the mammalian carnivores, gazelle and small pigs – were very rare. The commonest taxa were medium to large ungulates, particularly bovids: note that there were at least two types of cervid, and probably two other types of medium-sized bovids in the Pabbi Hills that have not been shown here. Very large mammals were rare, especially if counts of fragmented tooth and tusk are ignored. Current absence of hominins from the Upper Siwaliks can be explained in large part by the bias towards the preservation of taxa larger than humans. Data derived from Dennell (2004)

Table 2. Pliocene and Pleistocene hominin skeletal remains from fluvial deposits

Site	*Date*	*Element(s)*	*Age*
Binshof, Germany	1974	Skull	21, 300 ± 320 BP; now 3090 ± 45 BP
Ceprano, Italy	1994	Skull fragment	Middle Pleistocene
Dali, China	1978	Cranium	Middle Pleistocene
Hahnöfersand, Germany	1973	Skull fragment	36, 300 ± 600 BP; now 7500 ± 55 BP
Lantian, China	1963	Mandible	Lower/Middle Pleistocene
Mauer, Germany	1907	Mandible	Middle Pleistocene
Narmada, India	1982	Skull fragment, clavicle	Middle Pleistocene
Olduvai OH9, Tanzania	1960	Calvarium	Lower Pleistocene
Omo SL7A, Ethiopia	1967	Mandible	Late Pliocene
Paderborn, Germany	1976	Skull fragment	27, 400 ± 600 BP; now 238 ± 39 BP
Saccopastore I, Italy	1929	Cranium	Upper Pleistocene, level 5
Saccopastore II, Italy	1935	Cranium	Upper Pleistocene, level 7
Sambungmachan, Indonesia	1973 onwards	3 calvaria, 1 tibia fragment	Middle or Upper Pleistocene
Steinheim, Germany	1933	Calvaria	Middle Pleistocene
Swanscombe, U.K.	1935–6, 1955	3 conjoining skull fragments	Middle Pleistocene
Hadar, AL-333, Ethiopia	1975–1977	13 individuals; > 200 pieces	Pliocene
Ngandong (Solo), Indonesia	1931–3, 1976–80	14 crania, 2 tibiae, 1 innominate fragment	Late Pleistocene
Trinil, Indonesia	1891–1900	Calotte, 2 teeth and perhaps 5 femora	Early Pleistocene

Sources: Day, 1986, except for: Sankhyan, 1997 and Sonkalia, 1985 for Narmada; Johanson et al., 1982 for AL-333; Bronk Ramsey et al., 2002 for Hahnöfersand, Paderborn and Binshof; these are included because they were thought to be Pleistocene in age when discovered. Ascenzi et al. (1996) for Ceprano; Oakley K et al. (1971: 254) for Saccopastore; and Oakley K. et al. (1975: 79) for Lantian.

Notes: the context is problematic at Sambunmachan. The *Homo ergaster* skeleton WT15000 (Kenya) is excluded as that was derived from the edge of a swamp, not a river. Two notorious fakes from fluvial contexts have been excluded but are otherwise consistent with the above: the Moulin Quignon mandible of 1863, and the Piltdown skull cap and mandible of 1913–15.

the other two, conjoining pieces found in 1935 and 1936; even so, all three can be counted as part of just one skeletal element. Two of the most unusual sets of hominin remains from fluvial contexts are the calotte and six femora from Trinil, and the 14 crania and two tibiae from Solo (Ngandong). The integrity of these assemblages is questionable: the femora at Trinil were probably from an overlying layer (Bartsiokas and Day, 1993), and the Ngandong remains may have been reworked from an earlier mass-drowning event (Dennell, 2005). The most startling exception is the "first family" from Hadar, with at least 13 individuals represented by virtually all skeletal elements; this find is unique, and wholly unlike other discoveries of hominins in fluvial deposits.

There are two other taphonomic issues that may also be relevant to why hominin remains have yet to be found in the Upper Siwaliks. Both are indicated by data from the Pabbi Hills, Pakistan, where over 18 months of fieldwork was dedicated to looking for hominin remains from both surface exposures and by the excavation of fossil concentrations, and so the absence of hominins cannot be attributed to lack of fieldwork or searching. These investigations also paid more attention to taphonomic issues than previous studies of the Upper Siwaliks, and provide some further insights into the type of fossil record from this type of fluvial landscape (Dennell, 2004:341–362).

Fragmentation Fossil specimens (as from other Siwalik exposures) were often very fragmented, and this clearly affected the preservation and identification of rare and small taxa such as hominins. Carnivores, for example, were also very rare, as were remains of gazelle. Overall, only ca. 30% of the fossil material ($> 40,000$ specimens) collected on modern erosional surfaces could be identified to taxon and anatomical part, but this proportion varied (exceptionally) from 50% at a few localities to (commonly) $< 10\%$. Fragmentation rates tended to be highest on flat surfaces (where fossils are fully exposed to heavy rain and trampling), and lowest on steep, actively eroding slopes. The material collected was heavily biased to larger taxa, and the most robust parts of the skeleton.

Where animals are preserved A very striking feature of the Pabbi Hills data is that large areas contained very little fossil material. Although $> 40,000$ fossils (including non-diagnostics) were collected from over 600 places, over half came from 20 concentrations. Two types were recognized. The first were channel bar deposits, where fossils had accumulated through down-stream transport, and from predation (probably by crocodile) near the stream margins. The second were found away from the active river margins, in abandoned channels and on the floodplain, and were accumulated by carnivores. These concentrations were not only the largest source of data, but also the richest in that they account for almost the full range of taxa found. The only exception was an anthracothere, represented by three specimens. Some taxa were better represented outside these concentrations, such as *Elephas, Stegodon* and *Sivatherium*, and large felids. On the whole, however, the Pabbi Hills is a record that is biased towards those animals that died near or at an active stream margin, or those eaten by a predator. What are missing are those in woodlands, such as primates; small mammals such as hare; ones perhaps smart enough not to be caught by a hyaena or crocodile; and those that died away from stream margins. Although some hominins died in streams or were eaten by hyaena (as at Zhoukoudian, see Boaz et al., 2000) and possibly by crocodile (as with the 1953 ["*Meganthropus*"] mandible from Sangiran [von Koenigswald, 1968] or Olduvai OH7 [Davidson and Solomon, 1990]), there are sadly (for paleoanthropologists) no indication of similar, but probably rare, fates in the Pabbi Hills.

In summary, the absence of hominin remains from the Upper Siwaliks is not simply due to insufficient fieldwork, although more fieldwork is obviously desirable. While the absence of fossil evidence for hominins before 1.7 Ma in the Pabbi Hills sequence could be seen as genuine evidence of absence, the same argument is harder to apply to the material collected from Sandstone 12 (1–4–1.2 Ma), which comprised half the total amount found, and was often extremely well preserved. Hominins should have been in South Asia by this time, and the recent date (if accepted) of 1.27 Ma from Isampur in south India (Paddayya et al., 2002) indicates that they may have been in peninsula India by this date. The main reasons for the absence of hominin fossils appear to be the bias towards the preservation of animals larger than hominins; the bias against carnivores and other rare taxa; the extent of fragmentation which lessens even further the preservation of smaller animals; and the limited circumstances under which most fossils were preserved. Additionally, hominins may also have been very scarce in these large floodplains. Though we might now better understand the nature of the haystack, the hominin needle is still elusive.

The Archaeological Evidence for Hominins in the Upper Siwaliks

There are only three sets of archaeological evidence for hominins from Upper Siwalik deposits. The first and least controversial were the discovery of three handaxes in conglomerates at Dina and Jalalpur (Rendell and Dennell, 1985), in contexts just above the Brunhes-Matuyama boundary and thus ca. 0.6–0.78 Ma. These are still the earliest definite indications of the Acheulean in South Asia, apart from the recent ESR date of 1.27 Ma from Isampur (Paddayya et al., 2002). The other sets may be Early Pleistocene in age, and are derived from Riwat, in the Soan Valley, and the Pabbi Hills. Each can be briefly summarized.

The Soan Valley (Riwat) (33⁰ 40′N; 73⁰ 20′E)

The artifact assemblage from Riwat, in the Soan Valley, has been described elsewhere (Rendell et al., 1987, 1989; Dennell et al., 1988; Dennell and Hurcombe, 1989:105–127), and only the key issues of identification, context and dating will be considered here.

Identification The assemblage is extremely small, and discussion normally focuses on three pieces (see Figure 7). The main one (R001) is a large core (168 × 118 × 74 mm) that was struck eight or nine times in three directions; there are clear impact points and ripple scars on at least three of the flake removals (see for example, Dennell and Hurcombe, 1989:113, Figures 7.6, 7.8). The size of flakes removed (average 6.6 × 6.2 mm) is within the range of those seen at Olduvai Gorge, Bed I. Several Paleolithic archaeologists (including several far more authoritative on early Paleolithic lithic technology than the author) who have seen a resin cast of this object (unfortunately the only one so replicated) have accepted it as demonstrating unambiguously intentional flaking. A second piece (R014) is a large flake (132 × 79 × 58 mm) that had been struck from a cobble; there is a clear bulb of percussion and associated ripple marks on the dorsal face, and at least three flakes were struck along the side (see Dennell and Hurcombe, 1989:Figure 7.10), creating an edge straight in side view. There were eight scar surfaces resulting from flaking in three directions (Dennell and Hurcombe, 1989:115). A third piece (R88/1) is a flake (59 × 45 × 20 mm) with a clear positive flake scar on one face, a negative one on the other (see Dennell and Hurcombe, 1989:116, Figure 7.15), and evidence of flaking from three directions.

Context Core R001 was found firmly embedded in 1983 in an outcropping gritstone/-conglomerate horizon near the base of a gully 70 m. When found, it was obvious that some flake scars extended into the outcrop, and thus the piece could not have been flaked after exposure. After the piece had been removed, the socket showed the flake scars that were on the core (see Dennell and Hurcombe, 1989: Figure 7.22). A resin replica was made of the socket and surrounding gritstone, and the replica of the core can be re-inserted into it. Piece R014 was chiselled out of a gritstone block that had been detached from the same gritstone/conglomerate section nearby (Hurcombe and Dennell, 1989:102, 105). Flake R88/1 was found in 1988 in a freshly-eroding vertical section 50 m from the core R001. The intervening section was drawn at a scale of 1:20, and all stones > 2 cm were drawn and recorded (see Dennell and Hurcombe, 1989:116; Figure 7.16). Of the 1,264 stones in that section, not a single one showed any signs of flaking (Hurcombe and Dennell, 1989:121). Contra Klein (1999:329) it is therefore wholly inaccurate to say that the claimed artifacts “represent simply one extreme along a continuum of naturally flaked pieces”.

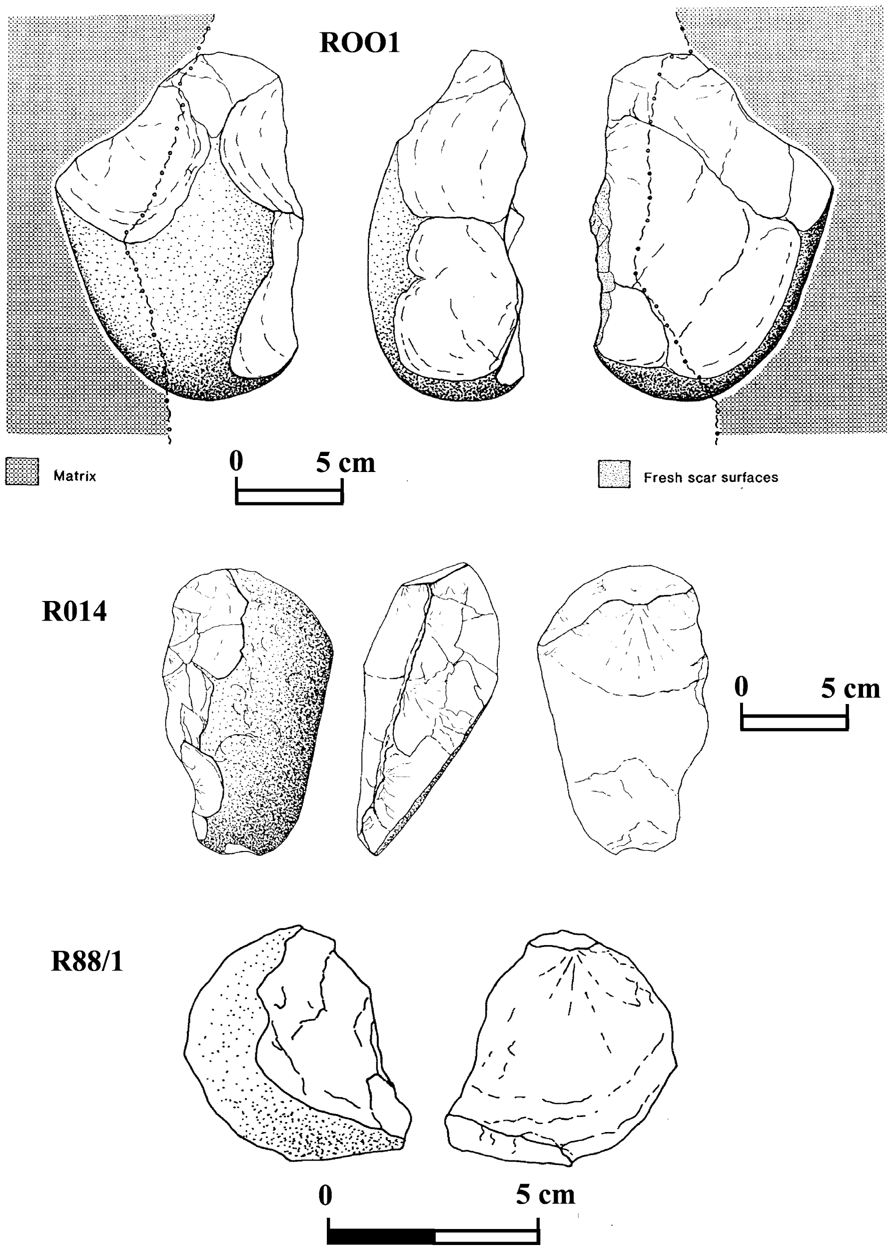

Figure 7. Flaked pieces R001, R014 and R88/1 from the lower conglomerate horizon at Riwat, Soan Valley, Pakistan. Source: Dennell and Hurcombe, 1989: Figures 7.8, 7.10 and 7.15

Dating The Soan Valley consists of a syncline that dips gently at ca. 10–15° on its southern side, but rears up almost vertically on its northern limb (see Figure 8). Its stratigraphic sequence and age were investigated very thoroughly by American geologists whose primary interest was in the evolution of the Himalayan forelands. They concluded that the Soan Syncline formed in the late Pliocene (Burbank and Johnson, 1982, 1984; Johnson N.M. et al., 1982; Burbank and Raynolds, 1984; Raynolds and Johnson, 1985; Johnson, G.D. et al., 1986). This age estimate was based on paleomagnetic evidence that showed that the basal deposits of the syncline belonged to the early Matuyama Chron; and by the observation that the vertical layers of the northern limb of the syncline were

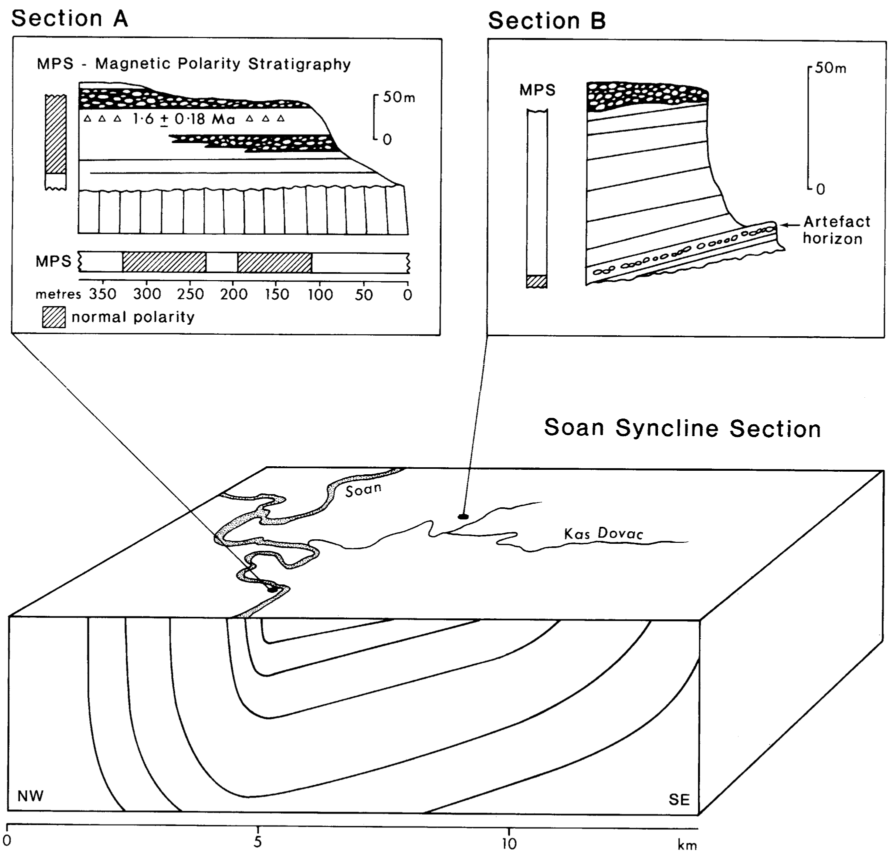

Figure 8. The dating of the artifact-bearing lower conglomerate horizon at Riwat, Soan syncline, Pakistan. The sediments containing the artifact-bearing horizon (section B) slope at 10–15°, but are folded vertically in the part containing section A. Here, they are overlain unconformably by horizontal deposits containing a volcanic ash dated at ca. 1.6 Ma. Source: Dennell et al., 1988: Figure 4

truncated, and unconformably overlain by horizontally-bedded fluvial deposits. These had a normal polarity, as well as a volcanic tuff that was dated by K/Ar to 1.6 ± 0.2 Ma (see Figure 8). This age estimate was consistent with assigning the surrounding horizontal deposits with normal magnetic polarity to the Olduvai Event. If one allowed for the time needed for the folding of the northern limb of the syncline through almost 90°, the truncation of the exposed deposits, and the subsequent deposition of overlying horizontally bedded fluvial deposits ca. 1.6 Ma, a late Pliocene age was entirely convincing for the deposition of the fluvial deposits of the Soan Syncline. No one has ever questioned the dating of the Soan Syncline sequence.

Rendell et al. (1989:71–75; Rendell et al., 1987) demonstrated that the artifact-bearing horizon was integral to the Soan Syncline, and not part of a later channel fill. She also showed through very close sampling (280 samples from 71 sampling points with a mean spacing of 1.7 meters) that all the deposits above the artifact-bearing horizon had a reversed polarity, as would be expected it they were deposited in the Matuyama Chron. An additional important, but rarely noticed, point was that these deposits (including the artifact bearing horizon) had all been rotated by 30° during the tilting and folding that had taken place. In contrast, no rotation was observed in the overlying, 1.6 Ma-old horizontal strata that capped the Soan Formation. This clearly indicates that the rotated deposits were older than 1.6 Ma.

Whether or not this evidence is accepted as indicating that hominins were present in South Asia by or before 1.9 Ma depends upon the criteria by which evidence of stone tool making is considered convincing. The obvious limitations of the Riwat assemblage is that it is very small; was found in a secondary context even if there is little indication of abrasion and rolling; and is not associated with any other evidence of hominins, such as cut-marked bone or hominin remains. If the evidential threshold is set at, for example, a minimum of 100 unambiguous artifacts, in a primary context, and preferably with associated cut-marked bones, the Riwat assemblage is clearly unacceptable as indicating the presence of hominins. For this author, the main reason for not rejecting the small assemblage from Riwat is the opinion of all those who have seen the cast of core R001 and are more knowledgeable than himself about early lithic technology that it could not have been flaked naturally. Additionally, no sceptic has ever demonstrated that stones found in stratified contexts that clearly pre-date the first appearance of hominins or humans have similar flaking characteristics to the pieces found in context at Riwat: such contexts might be, for example, an Oligocene conglomerate in the Old World, a Middle Pleistocene conglomerate in the Americas, or one a few millennia old in New Zealand or Malagasy.

The Pabbi Hills (32^0 50′N, 73^0 50′E)

The flaked stone assemblage that was found during the surveys for fossil material has been described in detail by Hurcombe (2004:222–292). Overall, 607 pieces of flaked stone were considered as artifacts (i.e., intentionally flaked). The density of flaked stone was extremely low. Although flaked stones were found in 211 places, they were found as isolated pieces in 45% of all cases, and in 78% of cases, not more than three were found. Approximately half (n = 307) were found on exposures of Sandstone 12; 102 on exposures younger than Sandstone 12 and probably 1.2–0.9 Ma; and 198 on exposures of deposits that belonged to, or were earlier than, the Olduvai Subchron, and thus ca. 2.2–1.7 Ma. Most of the artifacts were simple cores (41%) and flakes (58%); a selection is shown in Figure 9. Almost all (96%) of the lithic assemblage was made of quartzite, and only 2.8% showed any signs of deliberate retouch. The non-quartzite component consisted of 12 small pieces of flint, including six micro-cores, four hammerstones and six fragments of polished stone axes: these are all probably neolithic or later. The quartzite assemblage is typologically consistent with the very simple, unstandardized type of assemblages that are elsewhere classed as Oldowan, and is also broadly similar to the much large assemblage from Dmanisi (de Lumley et al., 2005). Significantly, there were no examples of the type of Acheulean bifaces, prepared cores, or blades that are common on Middle and Upper Pleistocene exposures that we have examined elsewhere in northern Pakistan.

Because these artifacts are all surface finds, there is of course no direct indication of their age. Various possibilities can be considered as a series of probabilities. The least likely is that the flaked stones were recent in origin, and the result of, for example, shepherds flaking stones (if available) out of boredom, or sharpening their axes by pounding the blade on cobbles, as suggested (but not observed) by Stiles (1978:139). We saw no evidence of any recent tradition of flaking quartzite, and the behavior of bored shepherds that we observed is most unlikely to have resulted in the type of flaked stones that we found. They would in any case have had to carry stone with them in anticipation of allaying their tedium with some knapping as naturally occurring stone is virtually absent in the Pabbi Hills. Contra Mishra (2005), the flaked assemblage cannot

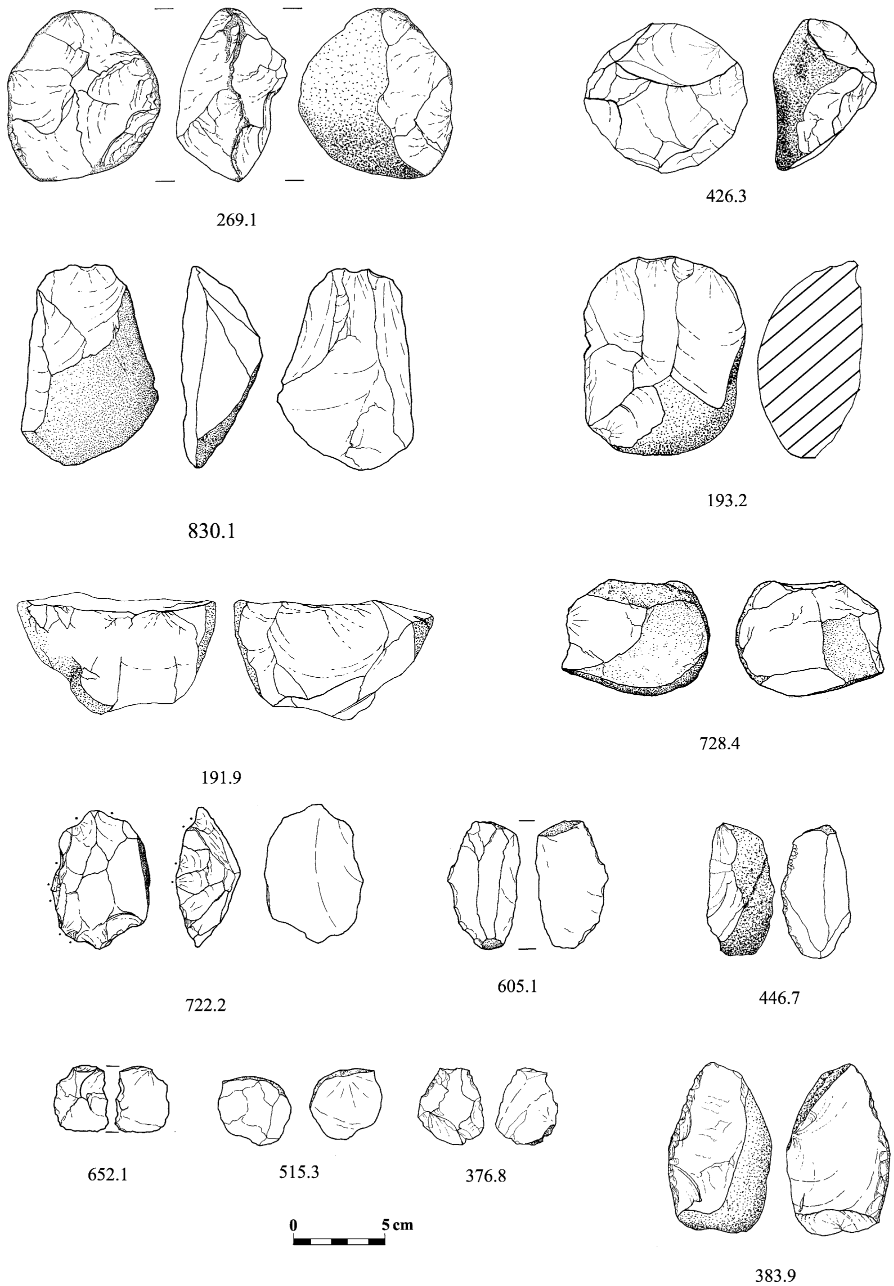

Figure 9. A selection of stone tools from the Pabbi Hills. Source: Hurcombe, 2004

be confused with or derived from rail and road ballast from the Peshawar-Lahore railway line and the Grand Trunk (or G.T.) road that run alongside each other and cut through the Pabbi Hills. Hurcombe's field observations showed that ballast is smashed, not flaked, and typically comprises small angular fragments with none of the flaking characteristics seen in the artifact assemblage. The artifacts were also found at higher elevations than the road and railway, and usually several kilometers away, as indicated in the numerous maps showing where material was collected (see Dennell, 2004). Additionally, areas near the road and railway were not surveyed because of dense vegetation.

A second possibility is that the quartzite artifacts were derived from reworked residues of deposits that formed after the anticline was formed 400 ka. This too is thought very unlikely. First, there is no evidence that the fossil material found on the surveys is a mixture that includes fossils from the last 400 ka. Secondly, there is no evidence of the type of flaked stone (for example, Acheulean bifaces or Levallois cores) that we found elsewhere in northern Pakistan on Middle and Upper Pleistocene exposures. Given the size of the areas surveyed for stone tools and vertebrate fossils (often several times), and the thoroughness of collecting (with the smallest item weighing only 1 gm [Hurcombe, 2004:224])), it is inconceivable that objects as distinctive as a handaxe would have been missed. Known later types (such as the polished stone axes and flint micro-cores that are probably neolithic) account for only a dozen or so pieces. Thirdly, it is most unlikely that stone (or fossil) would have remained on erosional surfaces in the Pabbi Hills throughout the Middle and Upper Pleistocene. All of the evidence accumulated during the surveys indicated that fossils were eroded very rapidly, and either destroyed shortly after exposure, or washed into gullies and thence out of the Pabbi Hills during the summer monsoon. Our own experiments of placing marked stones on such surfaces and monitoring their movement over a 10-year period implied that stones on the flatter areas at the base of slopes might have remained there for perhaps tens but not hundreds of years; on slightly steeper slopes, for a few to many tens of years; and on the steeper slopes, they would have moved quickly once exposed but then been reburied, or incorporated into part of a steep but stepped slope which acted as a series of small terraces. It might therefore have taken a stone a few hundred, or even a few thousand years to work its way down a 20 meter slope of this kind into a gully. However, it does not seem likely that even in these stable areas the erosion processes would have taken scores of millennia. These findings strongly imply that most of the stone artifacts on slope surfaces in the Pabbi Hills are highly unlikely to be derived from residues of post-Siwalik material from the last 400 ka (see Hurcombe, 2004:245–249).

The final possibility (and in our view, the least implausible) is that the quartzite flaked stone assemblage eroded from the underlying Upper Siwalik strata and are thus (depending on the age of the exposures on which they were found) between 2.2 and 0.9 Ma. As none of this material was found in situ, the case for dating it to the Early Pleistocene remains circumstantial. Nevertheless this type of field survey data forms an important part of the archaeological literature, and those readers who might reject this evidence on the grounds that it was found on the surface might reflect how much other data collected by field surveys elsewhere should also be rejected.

Implications of the Evidence from Riwat and the Pabbi Hills

The evidence from Riwat and the Pabbi Hills can be interpreted in two ways. If it is rejected on the grounds that the Riwat assemblage is too small, and in a secondary context, or that none of the Pabbi Hills material was found in a datable context, the obvious conclusion to be drawn is that there is no evidence that hominins occupied the Indo-Gangetic drainage basin during the Early Pleistocene. If so, the absence of hominins from the subcontinent during the Early Pleistocene might indeed be genuine. (This conclusion also implies that hominins may have entered Java ca. 1.6–1.8 Ma without crossing South Asia). An alternative possibility is that the evidence from Riwat and the Pabbi Hills is consistent with the observations made earlier on the limited availability of stone in these Upper Siwalik landscapes. In the Riwat area of the Soan Valley, stone was available on only one occasion in a 70-meter sequence of sands and silts, and some were used for making tools. In the Pabbi Hills, stone was probably scarce at all times, especially when rivers rose in the monsoon and covered the few sources of stone available. The type and patterning of stone tools across that landscape is consistent with what has been found in other stone-poor landscapes such as Hata, Ethiopia. Another relevant example, this time from the Ganges Plain, comes from Anangpur near Delhi. Here, Sharma (1993) reported Acheulean handaxes in a gravel deposit at the base of sands and silts from a former paleochannel of the Yamuna: in other words, in the one part of this sequence when stone was available, it was used by hominins.

The Boulder Conglomerate, Tectonic Uplift and the Availability of Stone

The end of the Pinjor Stage is marked by the Boulder Conglomerate Stage, which is composed of large, poorly sorted clasts that often include the type of quartzites suitable for flaking stone. As researchers working in Pakistan (e.g., Opdyke et al., 1979:32; Rendell et al., 1989:41) have pointed out, this is not a "stage" as it is not synchronous across northern India; rather, it marks the inception of coarse conglomeratic deposition following a steepening of river gradients in local river basins, and thus its age varies considerably. As shown in Figure 10, the timing of this change in bed-load varies in India from 1.72 Ma at Nagrota-Jammu to 0.6 Ma at Parmandal-Utterbeni (see Nanda, 2002). In Pakistan, its age ranges from 1.9 Ma in the Soan Valley and Rohtas anticline, to shortly after the Olduvai Subchron (i.e., post 1.77 Ma) at Mangla-Samwal, to Late Matuyama times in the Chambal area, ca. 0.7 Ma at Dina, and only < 0.5 Ma in the Pabbi Hills (see Opdyke et al., 1979:31; Rendell et al., 1989:41).

The deposition of these conglomerates has a two-fold significance for understanding the hominin colonization of India. The first was that it introduced large amounts of flakeable stone into landscapes that had previously been stone-poor or even stone-free, thus providing hominins with readily available stone. As these conglomerates – or "coarse pebbly phases" (Opdyke et al., 1979) during the early Pleistocene were probably relatively short events, and usually followed by the more familiar deposition of sands and silts, the opportunities for hominins were probably local and short-lived; i.e., while stone was available along a particular river. Obvious examples are the Acheulean handaxes that were found in early Middle Pleistocene conglomerates at Dina and Jalalpur (Rendell and Dennell, 1985). The second and much more significant consequence was the uplift that occurred in the late Early and early Middle Pleistocene across much of northern India and Pakistan (Amano and Taira, 1992): a very dramatic example is the 1300–3000 m of uplift that resulted in the formation of the Pir Panjal, or "lesser Himalaya" in Kashmir (Burbank and Raynolds, 1984:118; Valdiya, 1991). This uplift marked the end of the Siwalik Series and the on-set of post-Siwalik deposition, and exposed previously buried conglomerates. Thereafter, the year-round availability of stone along many river systems – particularly their middle and upper parts – was no longer problematic. In many areas (such as the Potwar Plateau, Pakistan), these conglomerates are either exposed in river sections, or as sheets, where their overlying finer sediments have been eroded. As evidenced by numerous finds of handaxes, prepared cores and blades, these exposures were commonly used as sources of raw material during the Middle and Upper Pleistocene. A good example is from the Thar Desert of India. Here, the earliest formation is the Jayal, which is composed of coarse gravels and cobbles, and was probably deposited in the Late Tertiary to Early Pleistocene, before the arrival of hominins. In the Middle Pleistocene, it was uplifted to form an extensive ridge up to 50 m above the surrounding plain, and was used as a source of raw material

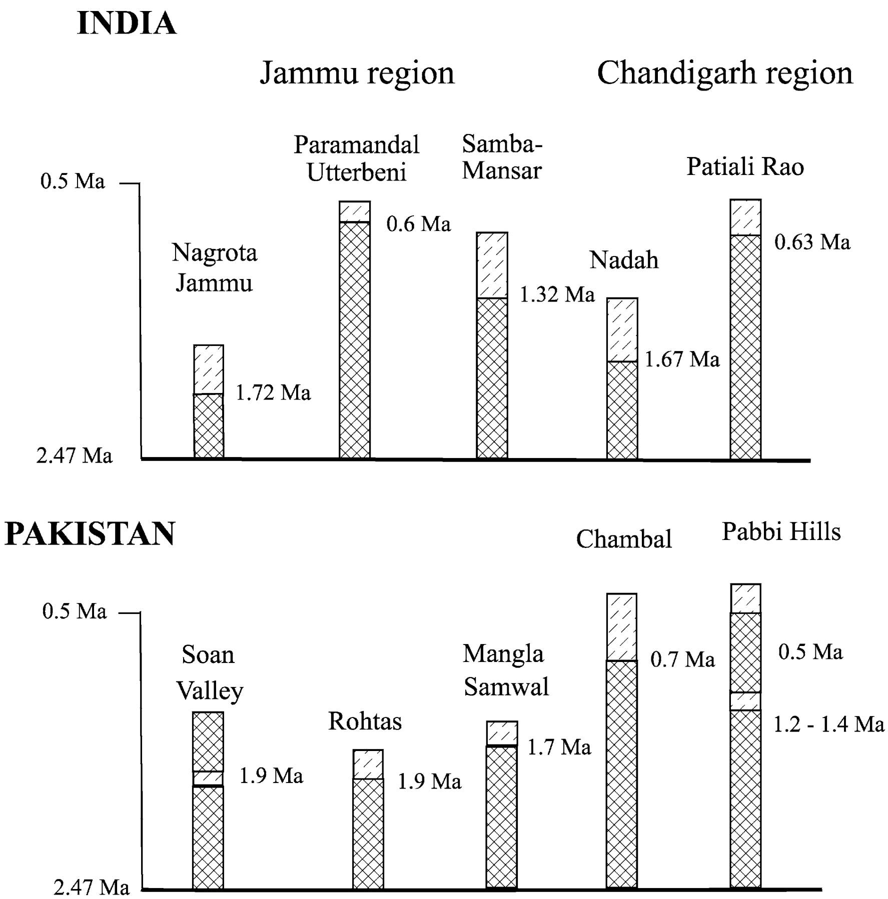

Figure 10. The timing of the deposition of conglomerates across northern India and Pakistan. The Indian data are from Nanda (2002: Figure 3); the Pakistani data are from Opdyke et al. (1979) and Rendell et al. (1989:41)

(Misra, 1989b; Misra and Rajaguru, 1989), as evidenced by early Paleolithic artifacts found on and in its surface.

I thus suggest that the increased availability of stone resulting from the deposition of conglomerates and (more importantly) their subsequent uplift and re-exposure may have been a key factor that facilitated the sustained occupation of northern India during the Middle Pleistocene, and possibly also the colonization of the Indian peninsula at that time. We should also bear in mind that Middle Pleistocene hominins had larger brains (averaging 918–1029 cc^3 in the case of *H. erectus* at Sangiran and Zhoukoudian (Antón, 2002; see Table 1), and were undoubtedly better at dealing with complex environmental situations than their Early Pleistocene counterparts. Estimates of home range size based on body and brain sizes indicate a marked increase, to ca. 452 hectares for later *H. erectus*, and 471 hectares for early *H. sapiens* (Antón and Swisher, 2004:288), or operational radii of 11.9 and 12.2 km respectively. Nevertheless, as noted above, the distances over which stone was routinely transported did not increase significantly until the Late Pleistocene.

Discussion

The paucity of archaeological evidence from the fluvial landscapes of northern India is not atypical of other large river systems. The Nile is an excellent example, particularly as it is often cited as the obvious corridor by which hominins left Africa. It is especially telling that Bar-Yosef (1994, 1998), one of the staunchest advocates of this idea, was able to cite only a report by Bovier-Lapierre (1926) as evidence for this early dispersal. This report, on the plain of Abbassieh outside Cairo, mentions but does not describe the presence of "eoliths" at the base of a sand-dominated section that includes at higher levels uncontroversial examples of developed Acheulean bifaces. The eoliths are given short shrift in the text, and of course none of this material is dated. The use of the Nile as a corridor during the late Pliocene and Lower Pleistocene is otherwise uncorroborated (see e.g., Wendorf and Schild, 1975:162, 1976), despite its appearance on numerous maps showing the alleged migration of hominins out of Africa in the Early Pleistocene. There is no fossil or archaeological evidence for Early Pleistocene hominins from the Tigris-Euphrates in Iraq, or the great rivers of South East Asia, such as the Irrawaddy, Chao Phraya, Mekong and Yangtse. Previous explanations of the absence of evidence have tended to cite the accumulation of silt as our chief restriction on finding evidence (e.g., Robson-Brown, 2001:198). While not denying the importance of this factor, I suggest that the prevalence of silt and sand would also have been problematic for the early hominins that we are trying to investigate, particularly because of the scarcity of workable stone (particularly when stone sources were submerged), and the inability of hominins to transport stone more than a few kilometers from its source. Early small-brained but tool-dependent hominins might have encountered severe problems in scheduling on the one hand their access to static, patchy and seasonally-available resources of the stone they needed to deflesh carcasses before other carnivorous competitors intervened, and on the other hand, to the mobile resources of meat upon which they depended. This suggestion carries two implications. One is that hominin dispersal across the river systems of northern India and Pakistan was not simply a matter of foraging uninterruptedly through the flood-plains of these major river systems, but involved a complex set of local adaptations that may well have restricted mobility because of the need to stay near localized sources of stone. These large rivers might not have been corridors so much as widely spaced and frequently changing stepping-stones, depending upon where and when stone was easily available. Secondly, when stone did become available prior to the uplift of the Middle Pleistocene – as when conglomerates were deposited, for example, in the Soan Valley, and later, at Dina and Jalapur – hominins made use of it, but probably then sought out new areas when it became unavailable. Accounts of hominin dispersals across southern Asia need therefore to recognize that large-scale sedimentary systems may have proved more challenging to early stone-dependent hominins than to other mammals. After all, they were not in the same situation as hyaenas or large cats that can rely upon their teeth, claws, power and speed to kill their prey; instead, it was the ability to flake stone that enabled them to access meat and bone-marrow, make a wide range of implements from wood, and thus increase the quantities and types of plant and other types of foods that they could eat. As Petraglia (1998:381) remarked:

> If preservation conditions or archaeological sampling are shown not to be the cause for the absence of early sites, it is also possible that the lack of identified occurrences in Early Pleistocene or Early Middle Pleistocene contexts, and the wealth of sites in the mid-Middle Pleistocene, may be due to … the relative success of hominids in adapting to environments.

The floodplains of the Indus and Ganges may provide one example where early hominins were generally unsuccessful.

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