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Human exploitation of a straight-tusked elephant (*Palaeoloxodon*) in Middle Pleistocene deposits at Pampore, Kashmir, India

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A B S T R A C T

Stone tools in association with Pleistocene elephant remains were recovered from Pampore, Kashmir, India, in 2000 from channel deposits in the Pampore Member of the Upper Karewa Group of sediments, which are interpreted as Middle Pleistocene in age. In March 2019 the elephant remains were re-examined to establish taxonomy, cause of death and evidence of human intervention, alongside study of the stone tools and age of the site. This paper reports the results of this work. Most of the elephant remains, including skull and tusks, are from a large adult, but at least two other elephants are also represented. Taxonomic analysis shows that the adult belongs to the genus *Palaeoloxodon*, but with a mix of features not seen in typical *Palaeoloxodon* skulls from the Indian Subcontinent. Pathology of the skull indicates severe sinusitis, which may have contributed to the death. No cut-marks from butchery were found on the elephant bones, although three elephant bone flakes were identified, linking human intervention with elephants at the site. The small lithic assemblage is in fresh condition with some refitting artefacts, both suggesting minimal post-depositional movement. Most of the artefacts consist of flakes, flake tools and cores, but with several points and blades suggestive of an early Mode 3 prepared core technology. This might indicate a late Middle Pleistocene age for the site. Further dating evidence using amino acid racemisation on elephant tooth enamel is ongoing, but consistent with this age. The association of stone tools with humanly-modified elephant remains is rare, while prepared core technology is currently scarce further north or east in Asia in the late Middle Pleistocene. The significance of the discovery is discussed in the wider context of Middle Pleistocene elephant-human interaction.

1. Introduction

1.1. Background

Over the last thirty years there have been important advances in the understanding of the early human occupation of the Indian subcontinent, but still with significant questions about the age of the various industries and the hominins involved (Patnaik and Chauhan, 2009; Dennell and Petraglia, 2012; Blinkhorn and Petraglia, 2017; Chauhan, 2020, 2023). With the growing number of early sites and hominin remains in China, dating back to over 2 Ma (Luo et al., 2020; Xing et al., 2021), there is renewed focus on south Asia, not just as an area for tracking populations and technologies from the West, but as a complex region that potentially also saw human dispersals from the East (Dennell and Petraglia, 2012; Boivin et al., 2013; Dennell, 2016, 2018). There are possible early flake industries such as Riwat in Pakistan at over 2 Ma

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(Dennell et al., 1988; Dennell, 1998), but the earliest Acheulean site at Attirampakkam in south India has yielded average cosmogenic dates of 1.5 Ma (Pappu et al., 2011). There are now numerous sites and findspots that record Acheulean technology, although few have firm dates (Corvinus, 1968; Mishra, 2007; Dennell, 2009; Haslam et al., 2011, 2012; Singh, 2018), and many undated pebble tool industries in the north of the Indian subcontinent covered by the term ‘Soanian’ (De Terra and Paterson, 1939) are thought to be late Middle Pleistocene in age (Chauhan, 2008a; Dennell, 2016). The earliest Middle Palaeolithic sites with Levallois technology are argued to be from c. 380 ka in south India (Akhilesh et al., 2018; Anil et al., 2022), yet in some areas, such as the Son Valley, the Late Acheulean lasted until c. 140 ka (Haslam et al., 2011; Shipton et al., 2013). Attribution of these industries to hominin species is also difficult, as there is only one hominin cranium from Middle Pleistocene deposits at Hathnora in the Narmada Valley (Sonakia, 1984; de Lumley and Sonakia, 1985; Sonakia and Biswas, 1998; Kennedy and Chiment, 1992; Patnaik et al., 2009; Sankhyan et al., 2012). The undated fossil was found in a secondary context and has a mix of archaic and modern features, which emphasises the importance of the Indian subcontinent as a crossroads for early human diaspora, as well as an important region of occupation, with its own distinctive identity.

This paper focuses on the evidence of stone tools and associated elephant remains from Pampore (Kashmir, India), to evaluate how they can be contextualised within the complexity of the Palaeolithic record of south Asia. The Pliocene and Pleistocene deposits of the Siwalik Hills provide one of the classical sequences for early discoveries of proboscidean fossils and understanding of the evolution of elephants (Falconer and Cautley, 1846; Murchison, 1867). The Pampore elephant is an important fossil from this region and contributes to furthering knowledge about their evolution in the Pleistocene, as well as potentially helping to constrain the age of the site. Pampore is also the only Middle Pleistocene site in the Indian subcontinent to have elephant remains in close association with stone tools and is briefly alluded to by Chauhan (2008b). The relationship between humans and elephants has been a topic of debate since the inception of Palaeolithic studies in the mid-19th century (Evans, 1860, 1872). However, convincing evidence of elephant exploitation has been rare, with little evidence of hunting, as opposed to scavenging. Earlier claims (e.g. Clark and Haynes, 1970; Leakey, 1971; Freeman, 1975; Goren-Inbar et al., 1994) have received greater scrutiny (e.g. Binford, 1987; Kaufulu, 1990; Villa et al., 2005; Wright et al., 2014; Haynes and Krasinski, 2021; Haynes, 2022a), but with the result that there are a growing number of sites with good evidence of elephant exploitation, and the use of bones for tools, including handaxes (e.g. Villa et al., 2005; Boschian and Saccà, 2012; Anzidei et al., 2012; Rabinovich et al., 2012; Saccà, 2012; Zutovski and Barkai, 2016). The evidence for human-elephant interaction at the Pampore site is fully investigated in this paper.

1.2. The Pampore site

The site is in a former quarry at Galander, near Pampore, 17 km to the south of Srinagar city. The quarry (33°, 59′, 24"N, 74°, 55′, 27"E) had been exploiting an outcrop of Pleistocene sediments, sandwiched

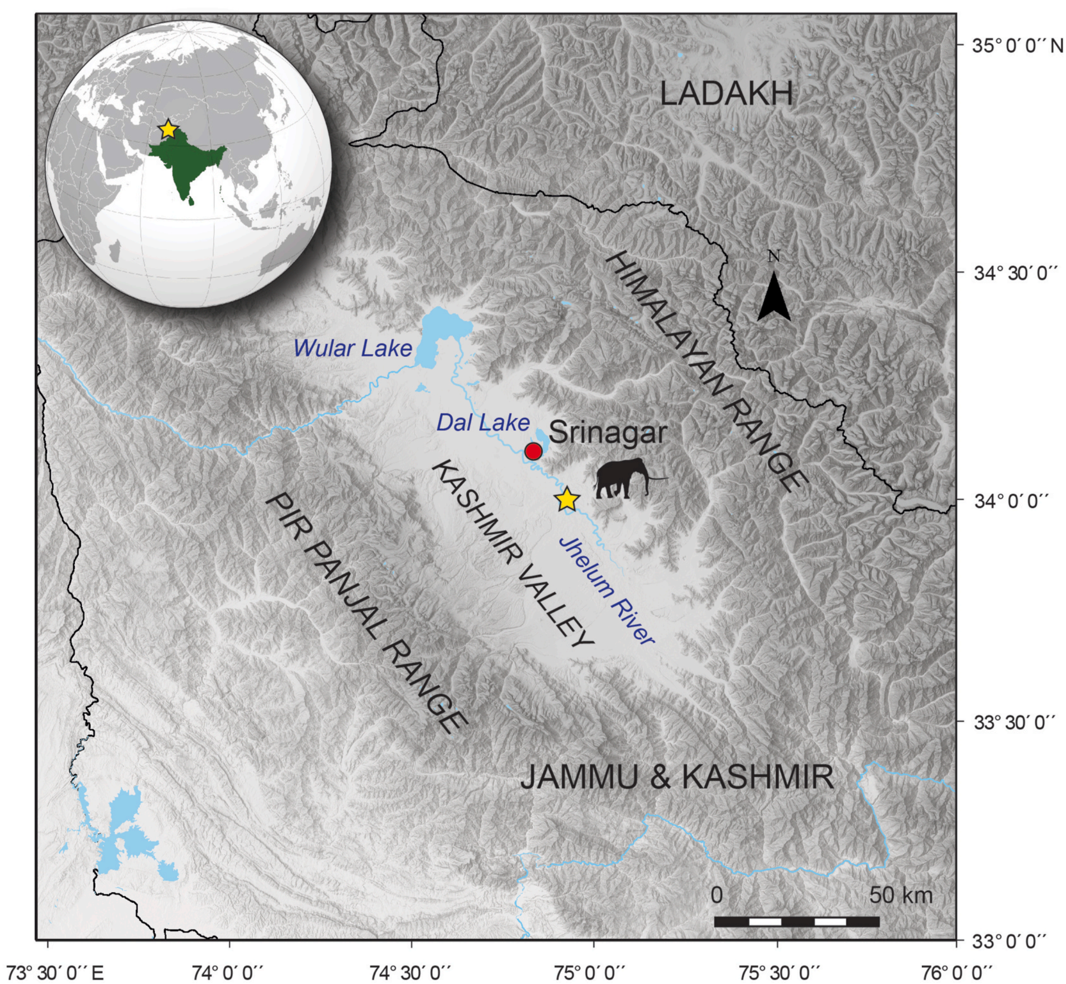

Fig. 1. Location of Pampore Elephant site (yellow star) in Kashmir Valley, India.

between the Srinagar to Jammu highway to the east and the Jhelum River to the west (Figs. 1–4). The elephant remains were discovered in late August 2000 by Dr Ghulam M. Bhat from the University of Kashmir, Srinagar, and his colleagues from the Government Degree College Sopore, Kashmir. A steep north-eastern facing section on the quarry edge, revealed c. 14 m of Pleistocene sediments, which were composed of predominantly clay, sand and silt, with sand-filled channels towards the base. The discovery of a large elephant skull within one of the channels led to several weeks of excavation during October and early November 2000. The poorly consolidated sediments above the channel deposits were a challenge for safe excavation (Fig. 2). Despite these difficulties, stone artefacts and further faunal remains were recovered within 20 m of the skull location towards the eastern end of the section.

2. Geology and environments

Pampore is located within the Kashmir Valley, an intermountain basin that lies within the Himalayan Ladakh and Pir Panjal ranges (Fig. 1). The foothills of the Himalaya are formed of the Siwalik Group of sediments that stretch from Nepal through northern India and into northern Pakistan. The Karewa Group of sediments are coeval with the Siwalik sediments of the Himalayan foothill belt. The Kashmir basin is about 140 by 60 km in area and is flanked by the Great Himalayan Range to the north-east and the Pir Panjal Range to the south-west. The basin is filled with sediments of the Karewa Group (Fig. 3), which broadly date from the Early Pliocene to Late Pleistocene (Farooqi and Desai, 1974; Burbank and Johnson, 1982, 1983; Singhvi et al., 1987; Bhatt, 1989; Agrawal et al., 1989).

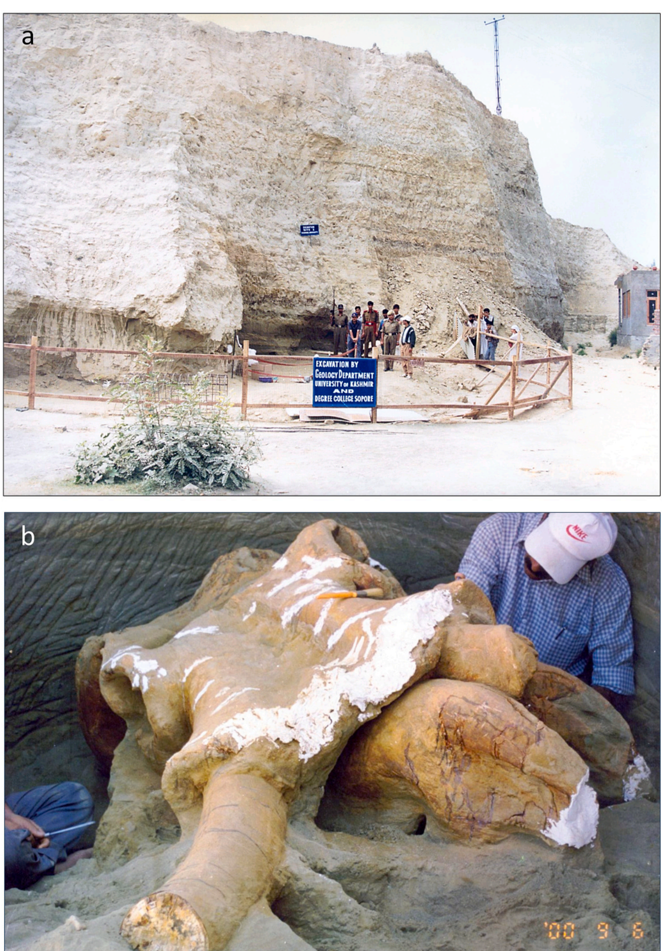

Fig. 2. a. Pampore elephant site. b. Elephant skull under excavation.

2.1. The Karewa Group

After early work by Godwin Austin (1859), the Karewa Group was first described in detail by De Terra and Paterson (1939) and has since been the subject of various investigations, with a formal stratigraphy provided by Bhatt (1989). It is this system that is followed here. As a group they are confined to the Kashmir Valley, and consist of fluvial, lacustrine and aeolian deposits that were deposited within a large lake basin. Marked periods of tectonic uplift in the Pir Panjal Hills resulted in periodic drainage of the lake basin and deposition of thick beds of conglomerate that have been used as marker horizons across the region. The lake once covered most of the basin, but through time became confined to the north-eastern area. The repeated sequence of fluvio-lacustrine and conglomerate deposits is overlain by largely aeolian sediments, interpreted as loess.

The group has been divided into the Lower and Upper Karewas, consisting of over 1300 m of sediment with up to 1200 m forming the Lower Karewas (Fig. 5). This comprises the Hirpur Formation, with the Dubjan, Rembiara and Methawoin Members. They are formed of a series of sands, clays and lignite interspersed with three main conglomerates. An unconformity marks the boundary with the Upper Karewas with two main formations. The lowermost Nagum Formation consists of gravel of the Shupiyan Member, which is found in the south-west of the basin, whereas the overlying sands, sandy clays and laminated clays of the Pampore Member are predominantly found in the north-east of the basin. The overlying Dilpur Formation consists of loamy silt, clay occasionally intercalated with thin sand. It is widely interpreted as loess interspersed with a series of palaeosols that reflect cooling and warming climatic phases (Singhvi et al., 1987; Chandra and Ahmed, 2013; Dar and Zeeden, 2020).

2.2. The age of the Pampore Member

The sediments at Pampore, with the elephant remains and lithic artefacts, are mapped as the Pampore Member, but the age of this member is uncertain. The maximum age is constrained by fission track dating of ash levels beneath the conglomerate of the Rembiara Member with dates of c. 2.4 ± 0.3 Ma (Burbank and Johnson, 1982; Bhatt, 1989, Fig. 5). These authors also suggested that palaeomagnetic studies placed the Olduvai subchron (currently dated at 1.93–1.77 Ma) in the lower part of the Methawoin Member, and that the Brunhes/Matuyama Boundary (currently dated at 0.78 Ma) was within the upper part of the Methawoin Member. Subsequent palaeomagnetic work placed the Lower Karewa/Upper Karewa boundary at either 0.2 Ma or 0.3 Ma (Agrawal et al., 1989; Basavaiah et al., 2010), implying that the Pampore Member post-dates this age. However, the boundary of the Lower and Upper Karewas is unconformable and therefore providing any age for this boundary is problematic. Equally, the interpretation of the palaeomagnetic results is only poorly constrained in age, principally by the fission track date of 2.4 Ma, and has largely been reliant on estimates of sediment accumulation and matching multiple normal and reversed events to the global palaeomagnetic framework. A further issue is that most of the palaeomagnetic work took place in the Rembiara and Romushu valleys, over 30 km to the south-west, where the Pampore Member is not represented. Therefore, it is not clear how the Pampore Member, as identified in the Pampore area, relates to the palaeomagnetic signals identified in the sections in those valleys.

The minimum age of the Pampore Member might be constrained by dates on the Dilpur Formation. These include ^{14}C dates of up to 40 ka, and TL ages of up to 130 ka (Bronger et al., 1987; Singhvi et al., 1987; Rendell and Townsend, 1988; Meenakshi et al., 2018; Dar and Zeeden, 2020, Fig. 5). However, some estimates based on sedimentation rates and the number of palaeosols (identified as warmer episodes) place the earliest loess at 350 ka (Bronger et al., 1987; Singhvi et al., 1987). It should also be noted that these minimum age constraints are based on the understanding that the boundary between the Nagum and Dilpur

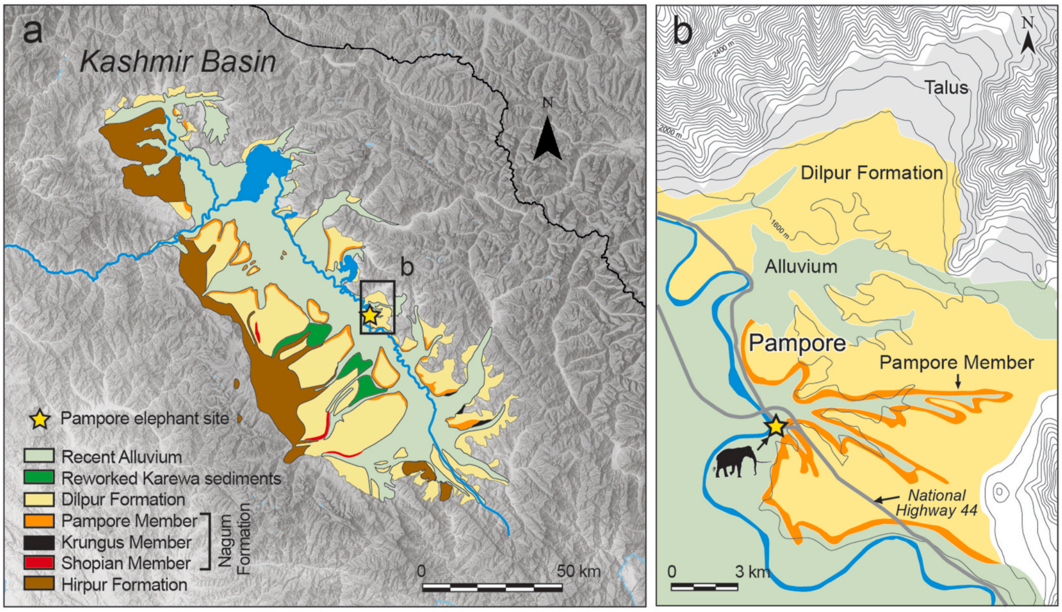

Fig. 3. Geological map of the Kashmir Valley (a) and the area around Pampore (b). The elephant site is marked with a star and was found within the Pampore Member.

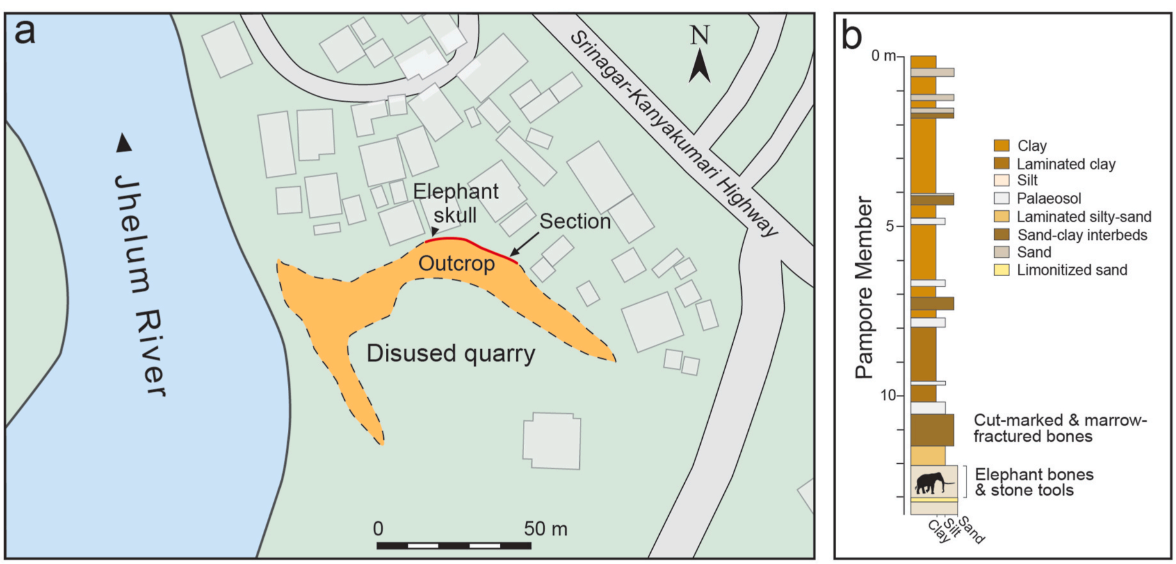

Fig. 4. Location of the Pampore Elephant site at Galander, near Pampore, with schematic section log through the sediments exposed in the outcrop.

Formations is not time transgressive. If it is time transgressive, then the age estimates of the Dilpur Formation may not always provide an effective age constraint.

The only other information on age is from biostratigraphy; vertebrate fossils from the Methawoin Member and Pampore Member, most notably *Equus* (Bhatt, 1989; Gaur and Kotlia, 1987; Kotlia, 1990; Parray et al., 2022), support an Early Pleistocene or later age for the upper part of the sequence since this genus appears in Eurasia only after 2.6 Ma (Bernor et al., 2019; Rook et al., 2019; Iannucci and Sardella, 2023). Overall, the balance of evidence suggests that the Pampore Member is Middle Pleistocene or possibly Early Pleistocene in age.

2.3. The sedimentary sequence at the Pampore site

The section at Pampore was on the northern side of an outcrop of fine-grained sediment on the edge of a former quarry (Fig. 4). The section was 13.75 m in height and consisted of a complex sequence of clays, silts and loosely consolidated sandstones, interspersed with evidence of palaeosol formation. They are interpreted as low-energy fluvial and lacustrine sediments laid down as part of a braided river system that flowed westerly into the Kashmir Basin from the Himalayas. There is little environmental evidence other than intermittent soil formation that may be indicative of stable, temperate conditions. Ostracods have been found at other sites in the Pampore Member (Kramer and Holmes, 2009), and during the excavation the team also observed their presence in the section, but the few samples that were examined post-excavation were found to be barren and this needs further detailed investigation.

The elephant fossils and stone tools were found in channel deposits towards the base of the sequence. The lowermost find was a complete elephant tusk within a sandy silt horizon, while the skull was discovered in overlying, loosely consolidated sandstone. Further fragmented elephant bones and the stone tools were discovered up to 20 m to the

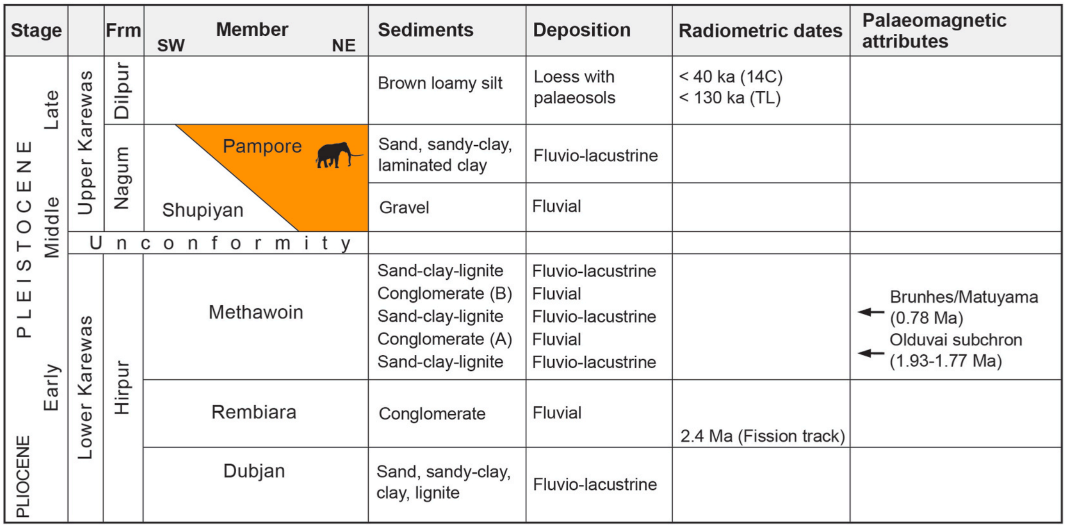

Fig. 5. Geological summary of the Karewa Group, based on Bhatt (1989) and Singhvi et al. (1987). Fission track dating is from Burbank and Johnson (1982). The dating of the Dilpur Member is based on Bronger et al. (1987), Singhvi et al. (1987), Rendell and Townsend (1988), Meenakshi et al. (2018) and Dar and Zeeden (2020). Palaeomagnetic attributions are based on Burbank and Johnson (1982), Agrawal et al. (1989) and Basavaiah et al. (2010).

south-east of the skull location in laminated silty sandstone. Although the remains occur in slightly different stratigraphic horizons, they are interpreted as being closely associated in age, as part of the same channel fill.

3. Intra-crystalline protein decomposition dating of enamel

A preliminary assessment of the age of the Pampore elephant and the associated sediments has been conducted using intra-crystalline protein decomposition (IcPD) dating (Supplementary Information 1). This technique involves comparing the extent of decomposition of the amino acids and proteins trapped within the crystalline structure of a biomineral to establish relative frameworks for dating. These relative frameworks can then be used to constrain dates, especially when known aged material is included for comparison (e.g. Penkman et al., 2011; Baleka et al., 2021; Dickinson et al., 2024).

To refine the age of the Pampore elephant, the extent of IcPD present in the Pampore elephant tooth enamel has been compared to that of an elephant tooth (GGM/CM/01) from River Terrace T1 in the Siwalik succession of Jammu (Kundal and Kundal, 2011). Additionally, a comparison was made with one elephant (JU/GD/VPL/9001) and one stegodon (JU/GD/VPL/9002) tooth from the mudstone horizon in the Pinjor Formation exposed in the Jammu and Kashmir region (Kundal et al., 2017a, b; Supplementary Information 2). The IcPD in the Pampore elephant enamel and the other proboscideans used for comparison is consistent with the amino acids being retained in a closed system and, therefore, suitable for dating (Penkman et al., 2011; Dickinson et al., 2019).

The River Terraces T1-T3 in the Siwalik succession of Jammu are constrained by an upper age of 600 ka due to their stratigraphic position overlying the Boulder Conglomerate Formation (Ranga, 1993) and are therefore thought to date to the Middle Pleistocene-Holocene (Kundal

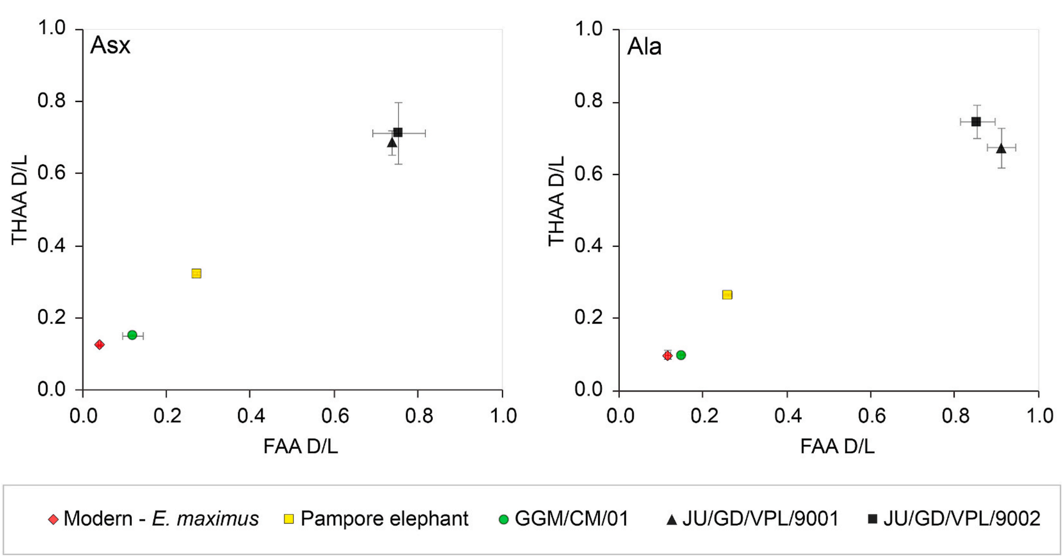

Fig. 6. Comparison free amino acid (FAA) vs. total hydrolysable amino acid (THAA) intra-crystalline racemisation in the proboscidean enamel from the Jammu and Kasmir region for two different amino acids: Asx (left) and Ala (Right). Modern *Elephas maximus* enamel has been included for comparison (data from Dickinson et al., 2019). GGM/CM/01: *Elephas* cf. *maximus*, River Terrace T1, immediately above the Upper Siwalik Boulder Conglomerate; JU/GD/VPL/9001: *Elephas planifrons*, mudstone horizon underlying volcanic ash bed in Pinjor Formation; JU/GD/VPL/9002: *Stegodon* cf. *insignis*, mudstone horizon underlying volcanic ash bed in Pinjor Formation. Error bars depict 1σ about the mean based on replicate sub-samples.

and Kundal, 2011). The elephant tooth (GGM/CM/01) is from River Terrace T1, which likely dates to the Middle Pleistocene (Kundal and Kundal, 2011). The extent of IcPD in the Pampore elephant enamel exceeds that of the elephant tooth from River Terrace T1 (Fig. 6), suggesting a greater age for the Pampore specimen.

The Pinjor mudstone horizon, from which proboscidean teeth JU/GD/VPL/9001 and JU/GD/VPL/9002 were recovered, immediately underlies a volcanic ash bed, dated to 2.48 Ma (Ranga et al., 1988), providing a minimum age estimate for the specimens. The extent of IcPD in the two specimens from the mudstone horizon is similar, consistent with the specimens being of a comparable age and is considerably greater than the extent of IcPD in the Pampore specimen (Fig. 6). Therefore, the extent of IcPD in the Pampore elephant enamel is consistent with an Early-Middle Pleistocene age. Additional samples from known age deposits in the region would be required for further refinement of this age estimate.

4. The Pampore elephant

4.1. Taxonomy

The Pampore site has produced the remains of at least three proboscideans, including a remarkably preserved skull and partial skeleton of a species of *Palaeoloxodon* (Figs. 2, 7 and 8). While initially thought to represent a single adult, a systematic investigation of the fragmentary postcranial remains has revealed the presence of at least one juvenile. In addition, there is an isolated tusk from a lower level at the site. The main Pampore specimen includes the most complete *Palaeoloxodon* cranium known from the Indian Subcontinent. In addition to the skull, both mandibles, the atlas, the left and right stylohyoids, partial thoracic vertebrae, ribs, partial scapula, and fragmented limb elements were recovered. Their size suggests that they may belong to the same individual as the skull. Although we could study the anterior surface of the skull and the upper and lower dentition, the left lateral surface remains covered in plaster, while the left dorsal surface was damaged in transport, and the entire skull lies embedded in a display platform preventing investigation of the posterior surface (Fig. 8).

The skull has a parieto-occipital crest (albeit greatly reduced), flaring premaxillaries, and a relatively broad frons, which are all traits seen in the genus *Palaeoloxodon* (Larramendi et al., 2020). The upper and lower third molars also show features characteristic of the genus such as cigar-shaped enamel loops with para-sagittal folding, the medially expanded loxodont sinuses on the worn enamel plates, and the dot-dash-dot wear pattern on the posterior plates (Fig. 7). The skull also possesses features atypical for known *Palaeoloxodon* skulls from the Indian Subcontinent (Larramendi et al., 2020), however, a more comprehensive taxonomic discussion is beyond the scope of this study, and a detailed description of the skull will be published separately (Jukar et al., 2024).

4.2. Pathology

The post-excavation breakage of the left parietal provided an opportunity for a detailed examination of the walls of the pneumatized cavities, which comprise the majority of the parietal volume. Upon inspection, the walls of these sinuses exhibited abnormal secondary bone formation. Secondary bone formation affected many of the compartments examined, where the new bone growths formed layers measuring up to 4 mm in thickness (Fig. 9). In other cavities, the affected walls displayed localized, thinner plaques of secondary bone (Fig. 9b).

Although there is insufficient evidence from clinical studies of elephants for a definitive diagnosis, the pattern of new bone growth observed in the Pampore elephant's sinuses is typical of secondary bone formation (periostitis) stimulated by inflammation of the respiratory epithelium lining the sinus cavities. This type of new bone growth resulting from chronic sinus infections is particularly well documented from human remains (Boocock et al., 1995; Roberts and Manchester, 2010; Davies-Barrett et al., 2021), but also from zooarchaeological studies of large herbivores (Wells, 1977; Bartosiewicz, 2013). Recent studies of chronic rhinosinusitis have focussed on reactive bone formation using computed tomographic scans CT and histological sections, although fewer studies have assessed how these changes are reflected in features of dry bone that can be applied to other non-human and human subjects (Dong et al., 2017, 2018; Dixon et al., 2020; Khalmuratova et al., 2020; Pokharel et al., 2022).

The incidence of periostitis affecting the sinuses of elephants is unknown, as it is rare for the skull to be sawn open and the sinuses examined, and even rarer for necropsies to focus on bone. Additionally, a review of paleopathology in elephants found no comparable cases, although it remains uncertain how routinely their sinuses have been

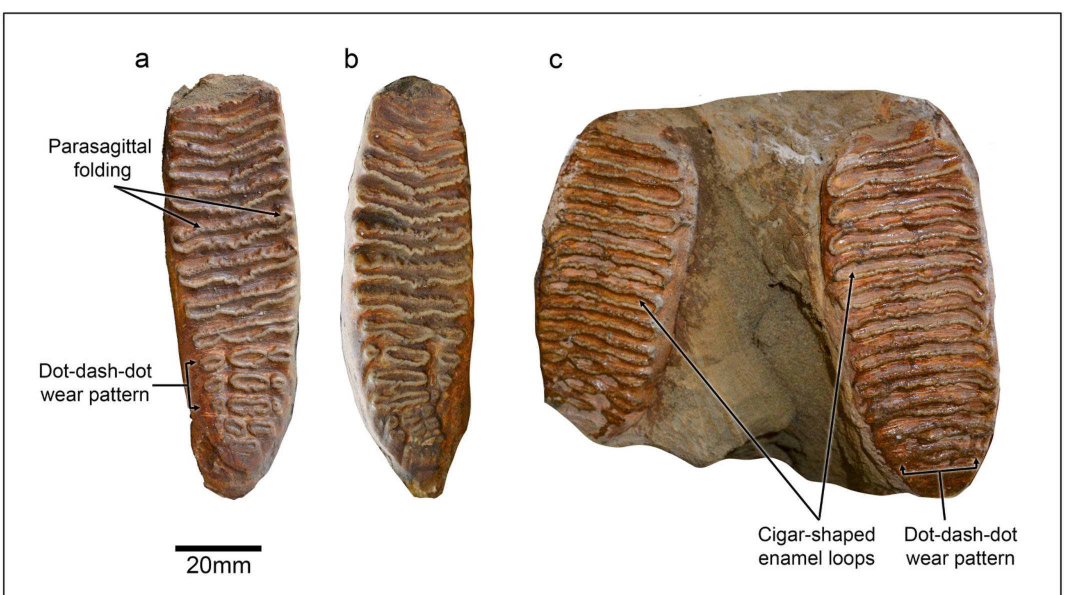

Fig. 7. Lower and upper dentition of WMNH-VP-F1. a, b, the left and right mandibular third molars. c, palate with left and right upper third molars. Scale bar equals 20 mm.

Fig. 8. Cleaning the elephant skull in Wadia Museum, University of Jammu, in 2019.

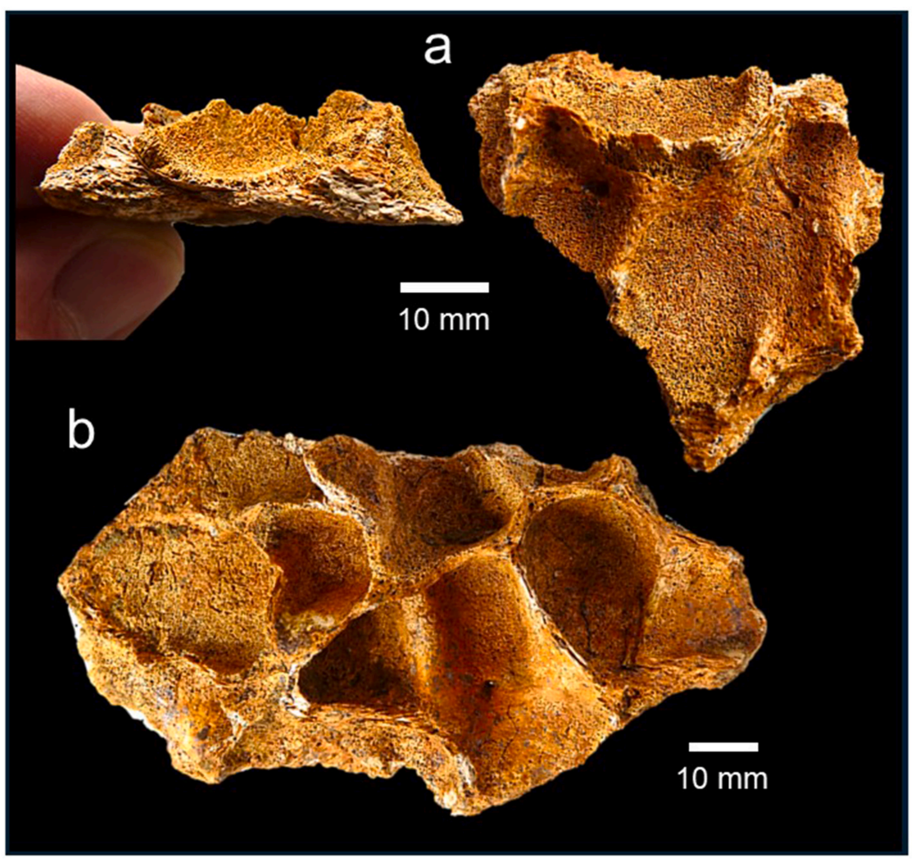

Fig. 9. Bone fragments from the left parietal of the Pampore elephant exhibiting secondary bone deposition resulting from a chronic sinus infection. Areas of the cavity walls with normal bone surfaces are visible in cavities on the right-hand side of the specimen illustrated in ‘b’, with adjacent cavity walls showing pathological overgrowths of spicular bone (cf. ‘a’, section view).

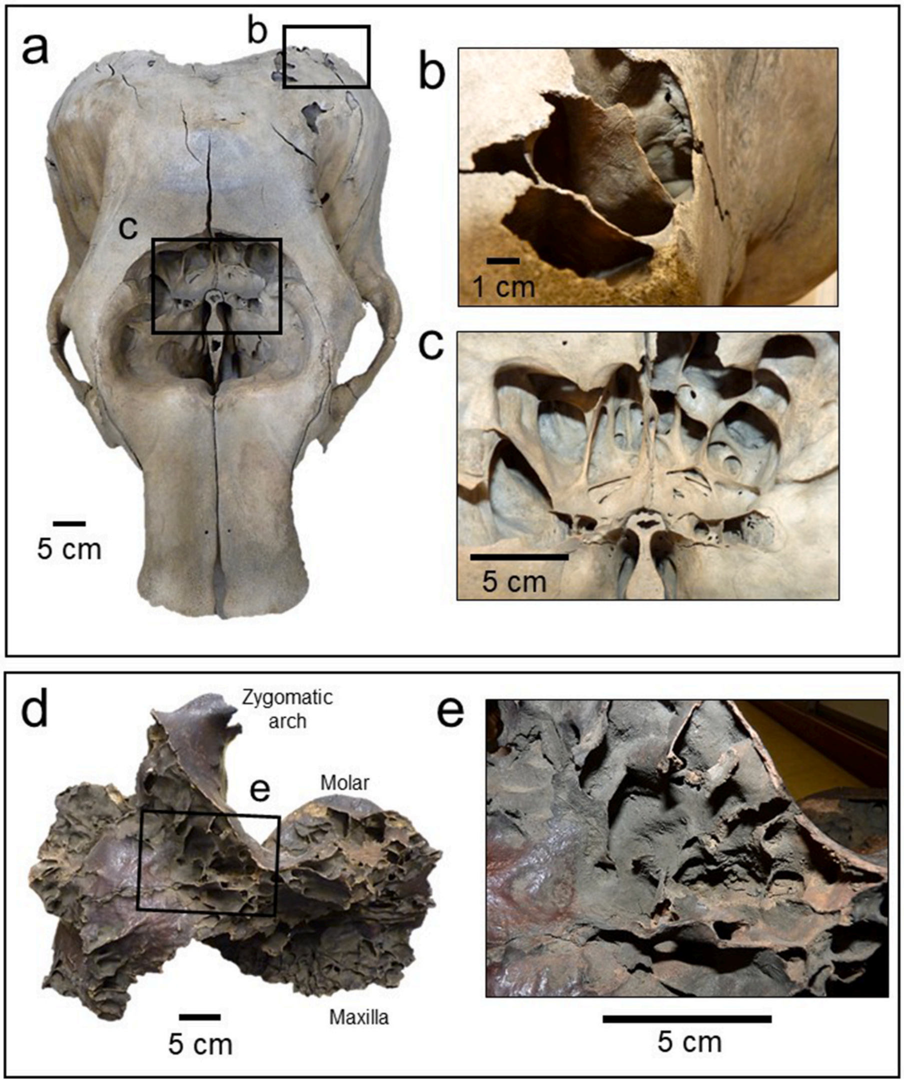

Fig. 10. Examples of sinus walls in crania of young and adult elephants showing typical smooth surfaces. a-c. Cranium of young male African elephant (*Loxodonta*), probably about eight years old at death (Natural History Museum, London Earth Sciences reference collection). d,e. Damaged cranium of adult straight-tusked elephant (*Palaeoloxodon antiquus*) with third molars in early wear, from Last Interglacial (MIS 5e) deposits at Peckham, south-east London (NHMUK PV OR 38491).

examined. Fig. 10 illustrates the features of the sinus walls in a relatively young African elephant compared with those in a much older straight-tusked elephant. In both cases, the walls are typical of normal (smooth) sinus walls in mammals. This supports the suggestion that the new bone layers observed on the sinus walls of the Pampore elephant are not features of normal bone growth, but rather indicative of pathology, likely due to a chronic sinus infection.

The potential health implications of a severe, potentially septic sinus infection in the Pampore elephant can be understood when considering the extensive sinus system that occupies a large proportion of the massive elephant skull and its vital role in the elephant's physiology (Steel, 1885; Spinage, 1994; Isaza, 2006). Structurally, this air-filled sinus system consists of thousands of small interconnecting, mucosal-lined cavities separated by thin, bony walls (Boas and Paulli, 1925; van Der Merwe et al., 1995; Isaza, 2006). This pneumatization occurs in all the bones of the cranium, contributing to the overall lightness of the skull. Additionally, it serves as a 'shock absorber', providing protection to the brain against potential damage during head-to-head clashes during fights. Moreover, these chambers are connected to the nasal cavity through multiple foramina, facilitating airflow and possibly providing a resonance chamber for vocalizations. Sinuses may also play a role in regulating body temperature, as the air within them can act as an insulator, helping to maintain thermal equilibrium.

Inflammation or infection of the sinuses, known as sinusitis, can occur due to various factors such as a penetrating wound, fungal, bacterial or viral infections, allergies to pollen, air pollution (e.g., dry dusty environments, smoke from naturally induced fires), or dental issues (Steel, 1885; Isaza, 2006; Charlotte Roberts, pers. comm. June 12, 2024). An upper respiratory infection can serve as the starting point, from which the infection may progress through the sinus system, potentially spreading to other areas within the cranium (Evans, 1910). When infected, elephants may experience symptoms such as nasal discharge, facial pain or pressure, coughing, fever, and difficulty breathing. In severe cases, sinus infections can worsen, leading to the spread of infection to surrounding tissues or the bloodstream, causing systemic illness. In some cases, chronic sinusitis can also result in structural damage to the sinuses or nearby structures, potentially affecting breathing or causing discomfort (Steel, 1885). Additionally, if an elephant's ability to breathe properly is compromised due to severe sinusitis, it may impact their overall health and potentially contribute to other health problems. Therefore, while sinus infections alone may not directly cause death in elephants, complications arising from such infections can pose risks to their health and well-being.

4.3. The bone assemblage

The elephant cranium was found upright in its original position, resting on the upturned mandible. Associated with the skull were an atlas vertebra, and right and left stylohyoids, almost certainly all from the same individual. In addition to the skull, several relatively complete elephant bones from at least two individuals were recovered from a narrow strip of deposits excavated along the foot of the section, extending approximately 20 m to the east of the elephant skull. These include two sets of articulated vertebrae (C7-T1 and two thoracic vertebrae), several vertebra fragments, substantial portions of at least three ribs, parts of two scapulae from different individuals, the proximal end of a humerus shaft with an attached unfused epiphysis, part of an ulna, the unfused proximal epiphysis of a femur, a pelvis fragment, a patella, an external cuneiform, two complete sesamoids, and a phalanx. An isolated tusk was observed in a sedimentary level, 2 m below the main fossil level under the concrete footings of a structure located about 50 m north of this section. In addition to the reasonably complete specimens, we assessed numerous non-identifiable pieces of elephant bone. Of these highly fragmented bones, only about 11 % in a sample of 150 pieces could be identified, at least to a general body part category (e.g., limb bone shaft fragment). This batch of individually bagged specimens included numerous fragments of the elephant skull and tusks (n = 124) with modern breaks that occurred during the lifting and transportation of the skull between institutions.

The challenges of safe excavation over a short period, inevitably led to the damaging of many of the bones, with some existing only as small fragments. Although modern toolmarks and preservatives obscured some of the surfaces, the bones exhibit no alterations indicative of high-energy natural taphonomic processes. As well as the lack of abrasion, the close anatomical association of elements, such as the mandible, stylohyoids, and axis vertebra with the cranium as well as the articulated vertebrae, in what is clearly a riverine depositional setting, indicate that these bones were not subjected to significant fluvial processes or long-distance transport. Post-depositional diagenetic pitting is present on a few pieces, but there are no signs of extensive root-etching, and the absence of weathering on the skull suggests limited exposure to the elements. Sedimentation was thus sufficient to bury the entire skull quickly, thereby protecting it from degradation by weathering and other pre-depositional destructive processes. Burial conditions were also conducive to bone preservation with mineralization from impregnation with iron oxides and manganese minerals.

4.3.1. Hominin modifications

Due to time constraints, we were unable to compile a comprehensive inventory of the faunal remains. However, all the material was examined for cut marks and impact features. The search for cut marks was hampered by damage caused during excavation or cleaning, which had sometimes removed, flaked, and scratched the bone surfaces. Additionally, the larger specimens, particularly the cranium and mandible were protected by plaster jackets prior to lifting, and glue, plaster gap-filling and preservatives were subsequently applied to strengthen them (Figs. 2 and 8). Unfortunately, this treatment further complicated the reliable identification of ancient surface features on the elephant skull.

Within the untreated material, however, we identified two cortical flakes (PMP F51, PMP F52 (112)) displaying hammerstone percussion features (Figs. 11 and 12). A third piece (PMP F50 (94)) also exhibits characteristics consistent with an impact from a hammerstone (Fig. 13). Significantly, these specimens are well preserved, and PMP F51 and PMP F52 (112) were partly protected in concreted sand. It was therefore possible to carefully remove the encasing sediment to reveal fine-scale features critical to the identification of the formation of the bone flakes.

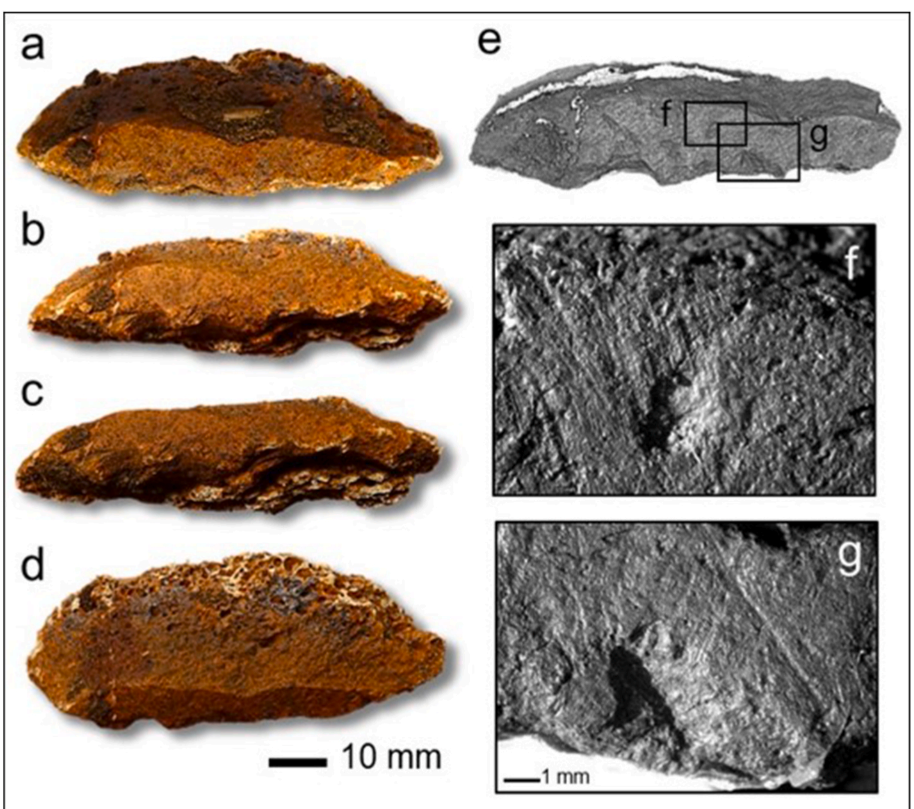

Fig. 11. General views (a–d) of elephant bone impact flake PMP F51. The impact surface (a, b, e) displays percussion pits associated with hammerstone striae (f, g). Impact zones are associated with a line of inner conchoidal percussion scars, some with hinge terminations (c).

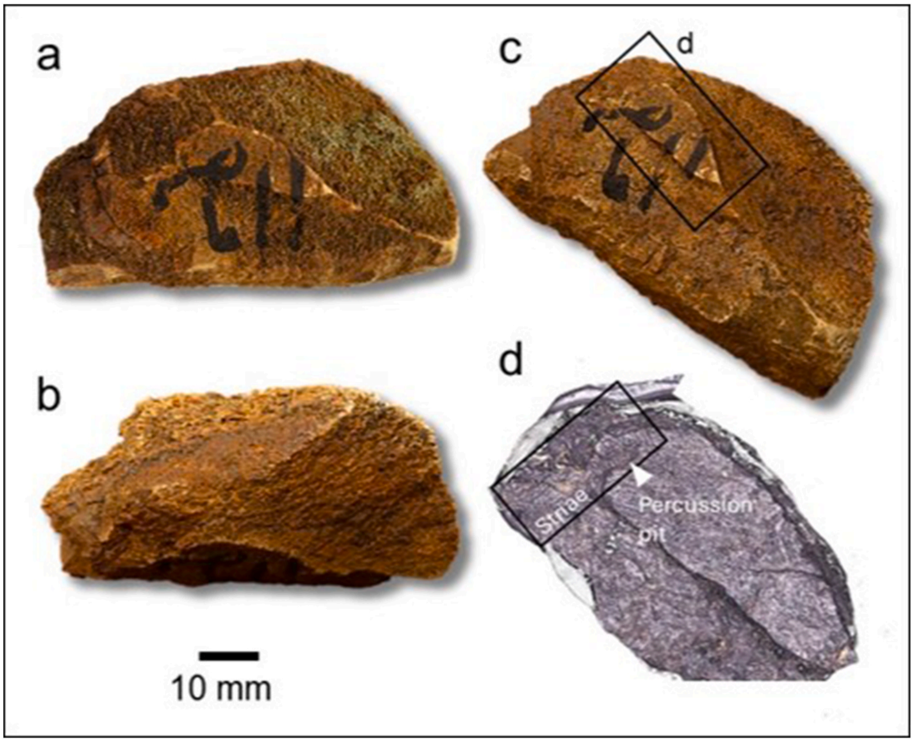

Fig. 12. Elephant bone impact flake PMP F52 (112), before (a) and after (b–d) removal of adhering sediment. The area outlined the rectangle (d) includes a percussion pit and striae from the hammerstone blow that detached the flake.

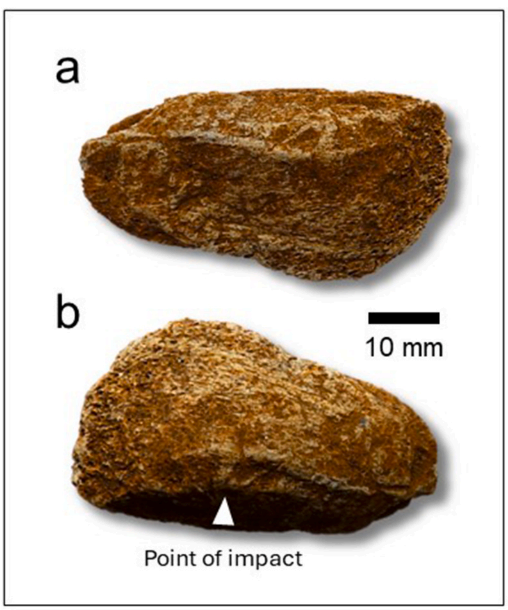

Fig. 13. Elephant bone impact flake PMP F50 (94) with a clear point and bulb of percussion.

4.3.2. Description of the impact flakes from the elephant-artefact horizon

4.3.2.1. PMP F51. This specimen is a lunate piece of elephant cortical bone, measuring 73 by 27 mm (Fig. 11). The cortical bone thickness measures 14 mm, while the total thickness of the piece, including the spongy bone, is 25 mm. The periosteal surface consists of a lunate area measuring 55 by 15 mm, with a sloping flaked surface on one side and a straighter face on the other, the latter exhibiting undercutting lunate flake scars. The straighter edge is punctured by a line of at least three semicircular notches with diameters from 7 to 11 mm, with corresponding negative flake scars extending to the spongy bone. These internal overlapping conical flake scars suggest as many as five separate impacts may have been involved. Some of the flake scars terminate in hinge fractures within the medullary bone.

The periosteal surface is marked with pits and striations, discernible to the naked eye. To analyse these features in detail, the periosteal surface was moulded with Coltene President Light Body (green base), and casts were then made using Araldite with a brown colorant (Bello et al., 2011). These casts were examined using an Alicona InfiniteFocus microscope, which generated the high-resolution, three-dimensional images of the features shown in Fig. 11e–g.

Microscopic examination of the casts identified at least four distinct percussion pits, some with internal and marginal striae; much of the surrounding bone surface was also marked with discrete areas of shallower parallel striations (Fig. 11f and g). These marks are characteristic of impact features made with a hammerstone (Blumenschine and Selvaggio, 1988).

We interpret this specimen as an impact flake resulting from repeated hammering of an elephant bone with a stone implement. Initially, the bone was struck several times in an attempt to initiate the fracture. However, these initial attempts failed, requiring a subsequent, more forceful blow, possibly with a heavier hammerstone, to fully fracture the bone. The overall morphology of this flake closely resembles an impact flake produced in marrow processing experiments by Pickering and Egeland (2006, Fig. 4).

4.3.2.2. PMP F52 (112). This specimen is a sub-rectangular piece of elephant cortical bone, measuring 98 by 55 mm. It exhibits a central remnant of the periosteal surface (37 × 13 mm), surrounded by sloping flaked surfaces (Fig. 12). The cortex is 32 mm thick, with a total thickness including the medullary bone of 43 mm. On the periosteal surface, there are at least two percussion pits, one of which appears to have two main depressions, forming a linear plan form. The other includes a marginal pit with striae that extend for a short distance across the fracture edge (Fig. 12d). The morphology of the flake resembles an impact flake produced in a marrow-bone processing experiment, as depicted by Pickering and Egeland (2006, Fig. 4).

4.3.2.3. PMP F50 (94). A third flake of elephant cortical bone (Fig. 13), measuring 54 mm in length with a cortical thickness of approximately 26 mm, exhibits an impact point situated at the edge of the periosteal surface. Below this impact point, a distinct bulb of percussion is evident on the break surface. No percussion striae or pits were detected on the periosteal surface.

4.3.3. Higher group of bones

A second group of bones was found in a layer of sand with clay interbeds situated between 0.5 and 1.5 m above the deposits containing the elephant skull. Among these bones are a Kashmir stag (*Cervus* cf. *C. hanglu*) mandible with p3-m3 (Fig. 14) and six bone fragments consistent with a medium-sized mammal. One of the long bone shaft fragments is cut-marked (specimen number PMP F58, Fig. 15) and at least three other pieces (PMP F55, PMP F56, PMP F57 (5.11)) exhibit impact notches (Fig. 16). Long-bone shaft fragments, PMP F55 and PMP F56 both display single notches. Specimen PMP F57 (5.11), depicted in Fig. 16, exhibits scalar notches along one of the break edges on the medullar surface. These notches suggest uni-directional flaking, which also marked the periosteal surface with two percussion pits and hammerstone striae.

The cut marks on PMP F58 are situated on the near epiphyseal part of the shaft (Fig. 15). They comprise a band of closely spaced transverse incisions measuring up to 5 mm in length, displaying slightly asymmetric V-shaped profiles. A second set of at least three indistinct longitudinal incisions is present, with the longest measuring approximately 15 mm in length. The presence of minor striations along parts of the length of the incisions is indicative of cut marks made with a sharp stone edge. These cut marks, located on this portion (near the epiphysis) of a long bone shaft, are likely related to butchery activities, specifically the filleting of meat.

Although no artefacts were found at this level, the butchered bones attest to a later phase of human occupation at the site.

5. Stone artefact assemblage

The lithic remains were concentrated in the channel deposits c. 20 m along the quarry edge to the east of the elephant skull, associated with further fragmentary elephant remains. The assemblage consists of 87 pieces, all made of basalt, other than one flint flake. The basalt is found within a few hundred metres of the site as medium to large pebbles or boulders, and the one piece of flint is also from a local source.

The artefacts are all in very fresh condition, which suggests that they have undergone little movement since discard, an interpretation that is also supported by two pairs of refits. The assemblage consists of flakes, cores, retouched flakes and other retouched pieces, chips and knapping fragments (Table 1). The ratio of flakes to cores (c. 10:1) could be taken to show that all the flakes were knapped on site. However, it is clear from the size of the cores and their flake removals, together with the likely dimensions of the core-blanks, that they could not have produced all the flakes. The proportion of retouched pieces is comparatively high by comparison to many Lower Palaeolithic assemblages, whereas the number of chips is low for typical knapping scatters, although significantly they are present (e.g. Schick, 1986) (see Table 2).

Four of the six cores were made on flakes or broken flakes (Fig. 17). Two of these refit along a longitudinal break, showing that they had originally formed two parts of a flake at least 80 × 70 mm in size. There are at least five flakes removed from the ventral face. The last two of these removals were from the distal end, possibly causing the diagonal breakage of the original flake. Alternatively, they were removed after the breakage. The largest core is probably on a large, thick flake with discoidal working and a minimum of three flakes removed from each of the ventral and dorsal sides. The fourth piece is made on the proximal end of a large flake of unknown length, but 91 mm wide and 33 mm thick. There are two or possibly three removals from the dorsal side and a further two or three from the ventral side. The fifth core is part of a slab with two flakes removed from the side of the slab and a further flake removed from its surface. Finally, a spheroid-shaped core has been worked multi-directionally to the point of exhaustion, but intense battering on one side suggests that it was reused as a hammerstone (Fig. 18).

There are 67 flakes (>20 mm), of which 56 are complete. The complete flakes are up to 113 mm in maximum length with a mean of 74 mm, while the widths are up to 97 mm with a mean of 47 mm. The mean length/width (elongation) is relatively high for a core and flake assemblage at 1.49, a characteristic that is discussed below (Fig. 19).

Most of the flakes have little cortex or natural surface retained on their dorsal faces, suggesting that the flakes derive from later stages of knapping (Table 3). The technology predominantly reflects unidirectional knapping from unprepared platforms; most flakes were removed from plain or dihedral platforms, almost 80% having between two and five dorsal scars that were nearly all removed from the proximal end, and sometimes additional removals from the lateral edges. There was relatively little flaking from the distal ends.

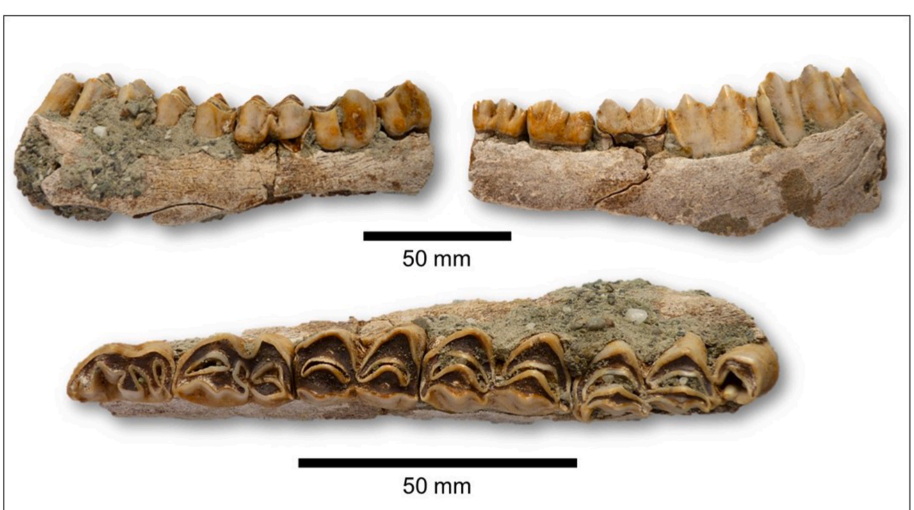

Fig. 14. Partial right mandible of *Cervus* cf. *C. hanglu*.

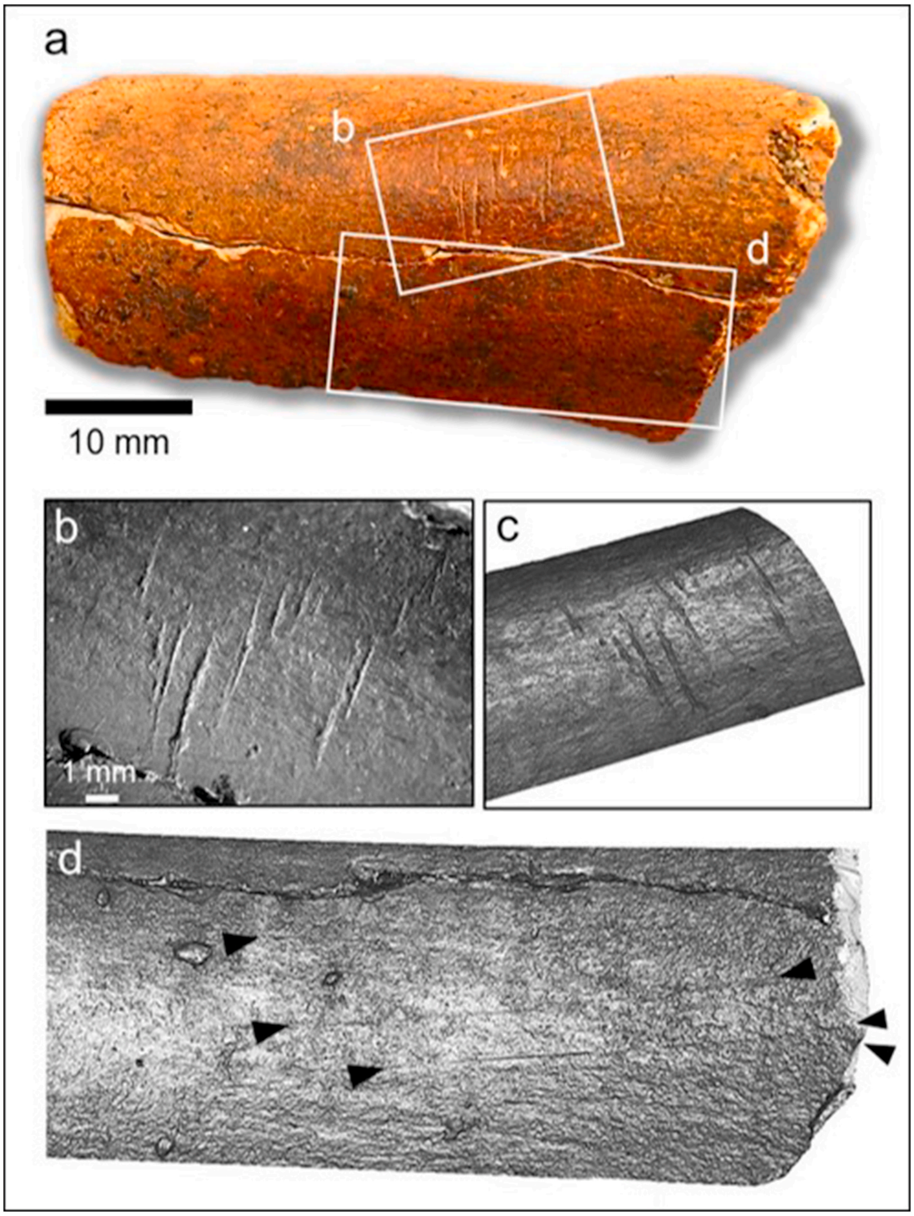

Fig. 15. Cut marks on a long bone shaft fragment (PMP F58) from a bed of sands with clay interbeds between 0.5 and 1.5 m above deposits containing the elephant bones and artefacts (Fig. 5b). Cleaning exposed short transverse cut marks (b, c) and shallower cut marks (d) running longitudinally across the surface of the bone.

There are nine flake tools with selected blanks reflecting the size range of the rest of the assemblage (Table 4). They can be characterised as denticulates, retouched flakes, a notch and a scraper, but the retouch is generally irregular, sometimes inverse and its positioning pays little adherence to typological form. A possible exception is provided by the pointed flakes, where there is slight modification to one or both lateral edges, although the retouch has not significantly altered the pointed form of the flakes. The impression of the assemblage is of *ad hoc* modification to flakes responding to immediate needs, rather than a formal tool kit.

The elongation of the flakes has already been noted. This characteristic is more marked on the larger flakes, with a steady increase with flake size category, the length to width ratio ranging from c. 1:1 for the 20–39 mm category to over 2:1 for flakes greater than 100 mm (Table 5). Although metrically the latter are blades, technically there is little systematic blade production and few parallel flake scars. The unidirectional flaking has produced an array of elongated flakes, some with a parallel or sub-parallel morphology and others with a pointed form (Table 6). Several of the pointed forms resemble Levallois points, and although there appears to be some intention in their production, they do not have the characteristics of classic Levallois as defined by Boëda (1988, 1995); there is no faceting of the platform or clear removal of preparatory flakes to fully pre-determine the outcome. However, many of the flakes with parallel and pointed morphologies fall into the category of an early form of prepared core or 'Mode 3' technology (Clark, 1969), where simple platforms are formed to remove flakes from a surface, and in this case by unidirectional flaking. This form of flake production is regarded as the precursor to classic Levallois flaking in showing some planning in the removal of flakes from cores. This aspect potentially helps with the age of the site as it is a technology that is associated with the Lower to Middle transition and is discussed in more detail in Section 6.

There are several characteristics of the assemblage that suggest it is a selection of previously knapped flakes brought into the site. The flakes are generally large, and the assemblage does not contain sufficient smaller elements to represent a full knapping sequence, showing that little knapping has taken place on site (Schick, 1986). The small amount

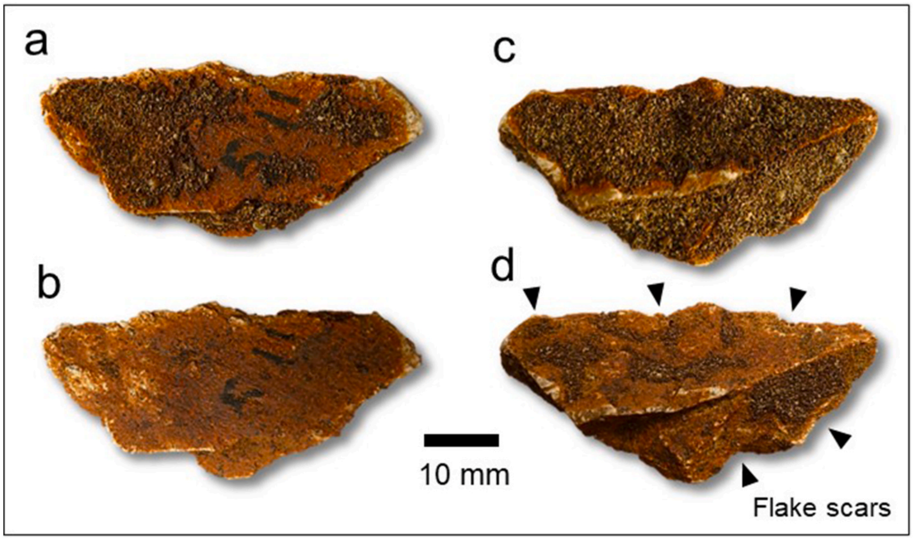

Fig. 16. Long bone shaft fragment (PMP F57) with percussion pits and internal flaking. Photographs 'a' and 'c' show the specimen in its original state before the removal of adhering sediment to expose percussion pits on the impact surface and the flaked medullary surface. This specimen is from the same level as the cut-marked specimen illustrated in Fig. 15.

Table 1
Composition of the lithic assemblage.

Flakes	58	2 pairs refits
Cores	6	Pair of refits
Flake tools	9	
Chips	7	Pair of refits
Knapping fragments	7	

Table 2
Ranges, means and standard deviations of the metrical data of complete flakes.

Complete flakes	Range	mean	sd	n
Max Length	22–113	74	25	55
Axial length	14–112	67	27	55
Axial width	18–97	47	19	55
Thickness	4–29	16	7	55
Axial length/width	0.48-3.41	1.49	0.59	55
Butt Width	3–71	26	13	53
Butt Thickness	1–23	10	5	53

of cortex or natural surface on the flakes indicates that the first stages of knapping are not present, suggesting that there has been selection of artefacts from the middle stages of the knapping process. Several of the flakes have had minor retouch added to their edges, pointing to *ad hoc* modification for use. These include three of the pointed flakes, which also characterise the assemblage. Most of the cores are also on large flakes, and at least one of these was flaked on site as shown by the two refitting halves. The exhausted core (see above), perhaps brought onto site with the larger flakes, appears to have been re-used as a hard hammer with concentrated battering in one area. Two of the other refits again suggest some knapping on site, which is supported by a distal-proximal refit of one of the pointed flakes. In essence the assemblage reflects a selection of larger flakes, including pointed and elongated forms, from the middle stages of the knapping process, together with a hammerstone. These were brought into the area of the elephant. Limited knapping took place on site to either modify tool edges, or to knap smaller flakes from larger flakes.

A notable aspect is the lack of handaxes, other bifacial tools, or obvious flakes from their manufacture. However, as the assemblage only consists of 87 pieces, which were selectively brought to the site, it is too small a group to be certain that handaxes were not being manufactured and used by the same group elsewhere in the landscape.

6. Discussion

6.1. *Pampore and the Lower to Middle Palaeolithic transition*

The occurrence of early Mode 3 technology at Pampore potentially helps with the dating of the site, but it is an aspect that needs to be understood within the regional context (see Fig. 20 for sites mentioned in the text). A number of other terms have been used for this technology, including 'Proto-Levallois', 'Simple Prepared Cores' and, most recently, 'Hierarchical Core Working' (HCW) (Wymer, 1968; White and Ashton, 2003; Malinsky-Buller, 2016). HCW covers several techniques that generally emerge within the Late Acheulean, and in many regions is the precursor to fully developed Levallois. The technology first became prominent in Africa (in various forms), south-western Asia and Europe from around 400 ka (Sharon and Beaumont, 2006; White et al., 2011; Malinsky-Buller, 2016; Moncel et al., 2020; Shipton, 2022).

The Pampore site lies in a broad region of the Indian subcontinent that has traditionally been characterised by 'Soanian' early Palaeolithic industries. The term was created by De Terra and Paterson (1939) for surface core, flake and pebble-tool assemblages in the Soan Valley of Pakistan, who argued that it was an Asian equivalent of the Oldowan. The term has subsequently been used to describe similar surface assemblages, particularly in Pakistan and northern India (see Gaillard, 2006; Chauhan, 2008a; Dennell, 2009), but included within these collections are elements that have been characterised as Mode 3 or prepared core technology (Chauhan, 2007; Lycett, 2007). Dennell and Rendell (1991; Dennell, 2016) have argued that the Soanian as originally defined has little validity, and that similar flake, core and pebble-tool surface industries remain poorly dated, but are probably late Middle Pleistocene in age. The pebble-tool character of the Soanian assemblages has few similarities to the Pampore assemblage, but the inclusion of prepared core technology in some of the assemblages might be of significance.

Further south in India, the Lower Palaeolithic to early Middle Palaeolithic transition is complex with greater diversity. The end of the Lower Palaeolithic is defined as the Late Acheulean (as with many areas outside Europe) and is characterised as having refined, often smaller, handaxes, the increased use of chert over quartzite, an increase in small flake tools and the introduction of Levallois technology (James and

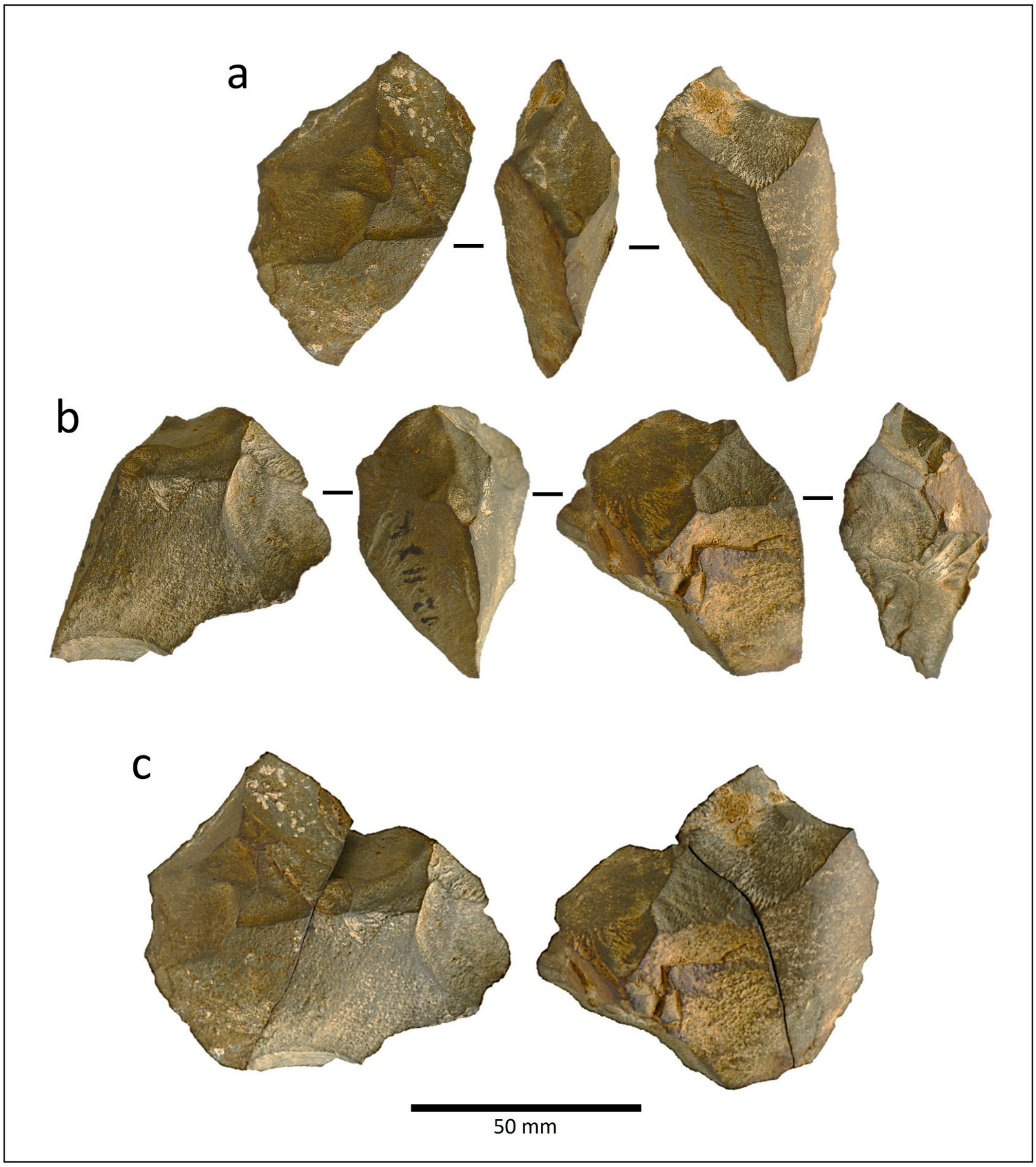

Fig. 17. Two parts of refitting core, made on a large flake. a Core fragment artefact No. 68. b. Core fragment artefact No. 69. c. Refitting of core fragments Nos 68 and 69.

Petraglia, 2005; Dennell, 2009). Despite an abundance of sites, there has been long debate about the dating of the transition and the definition of the different assemblages. For example, assemblages from Bariapur, Lakhmapur West and the lower levels at Bhimbetka III-23 have been classed as Late Acheulean, but include Levallois material, while assemblages from Lakhmapur East, Narayana Nellore and sites in the Kortallayer Basin are identified as Middle Palaeolithic with small handaxes (James and Petraglia, 2009; Shipton, 2016). None of these sites have good age constraints.

There are a few sites with better dating. In the Thar Desert, Singi Talav has an Acheulean assemblage dated to 177 ka (Blinkhorn et al., 2021), while 16R Dune has an early Middle Palaeolithic assemblage dated to c. 150 ka (James and Petraglia, 2005). In the Middle Son Valley there is also good evidence for the survival of transitional Late Acheulean-Middle Palaeolithic assemblages until late MIS 6; the sites of Bamburi, Sihawal and Patpara, have been dated by OSL to between c. 140 and 130 ka (Haslam et al., 2011; Shipton et al., 2013). The combined evidence shows assemblages that include refined handaxes, cleavers and the hierarchical preparation of Levallois cores from handaxe production.

However, in the last few years there are two sites in south-east India that point to an earlier date for the introduction or local development of Levallois or prepared core technology. The lacustrine site of Hanumanthunipadu is located in the upper Paleru River basin. The site has a minimum age of 247 ± 32 ka and has yielded 182 quartzite artefacts (>20 mm) in fresh condition (Anil et al., 2022). The quartzite is from sources c. 20 km away and has been partially reduced prior to further working on site. Many of the artefacts reflect Levallois technology with the production of points and flakes from two recurrent and preferential Levallois cores. A high proportion of the flakes have *ad hoc* retouch with a few scrapers and notches. In addition, there are five bifacial points or handaxes, three of which are small in size.

Another site in south-east India has a firmer age for the introduction of Levallois technology. At Attirampakkam, alluvial sediments of the Kortallayer River provide a sequence of Lower Palaeolithic assemblages (layers 8-6) below Middle Palaeolithic assemblages (layers 5-1) (Akhilesh et al., 2018). Layer 5 is dated by pIR-IRSL to 385 ± 64 ka with an assemblage characterised by a few, generally small handaxes,

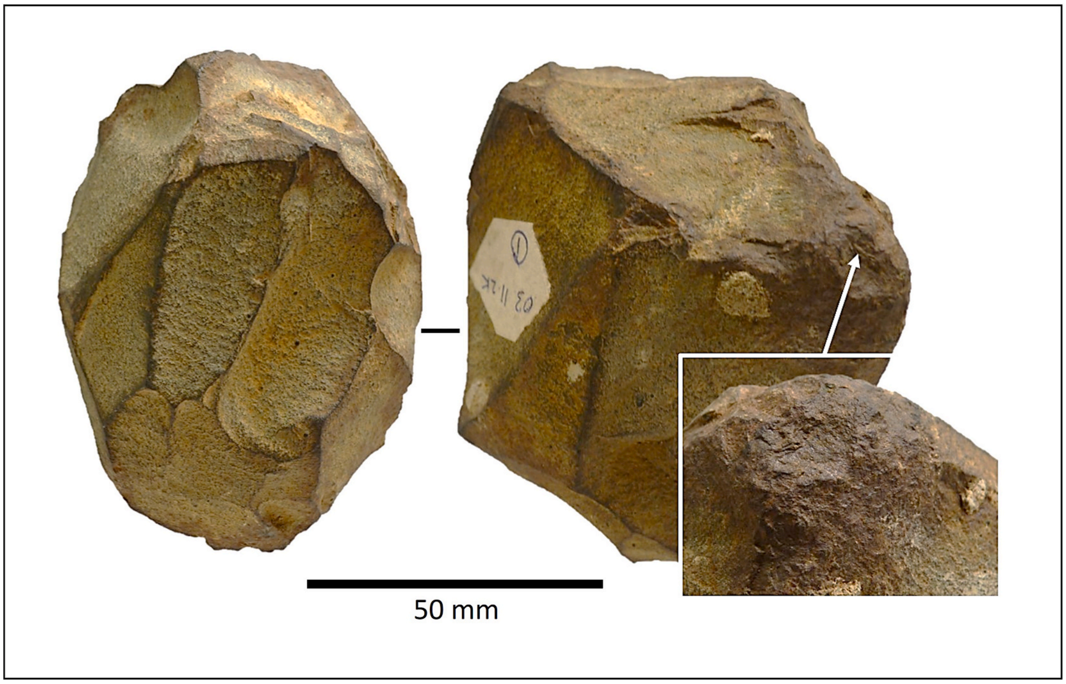

Fig. 18. Multiplatform core, artefact No. 73, possibly used as hammer-stone, with highlight of battered zone.

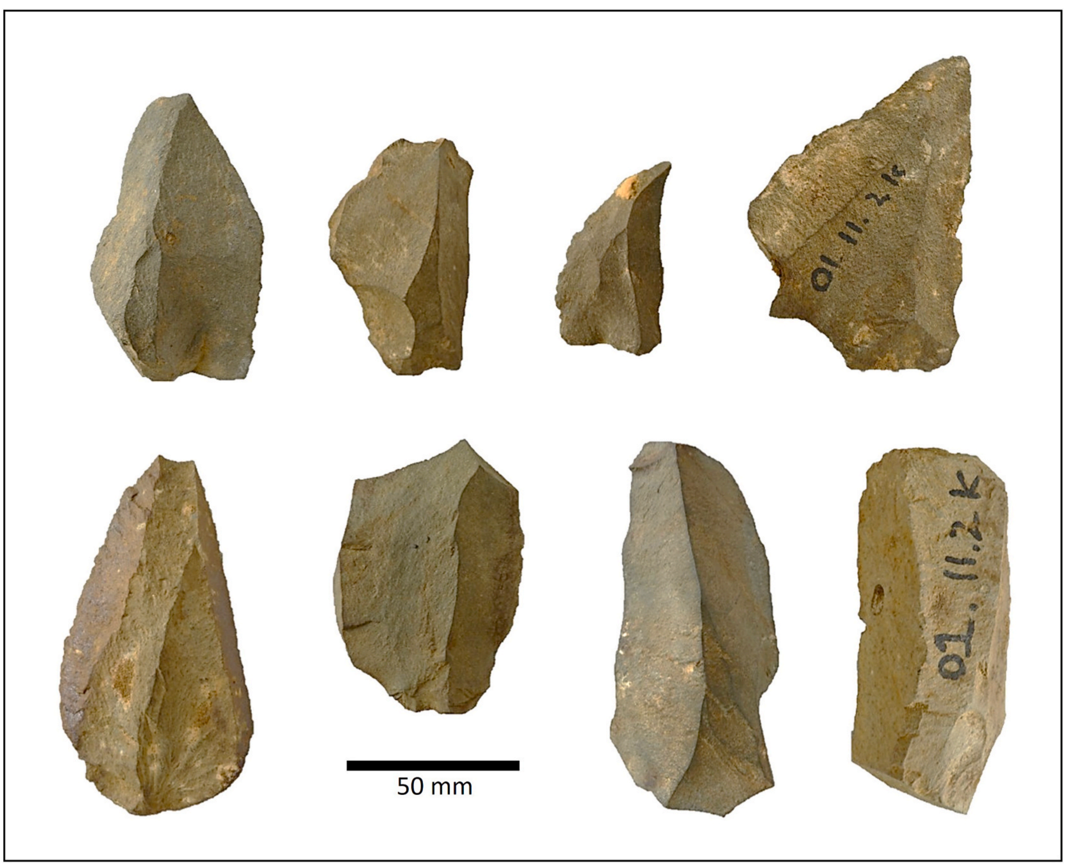

Fig. 19. Pointed and elongated flakes, indicative of early Mode 3. From top left, artefact Nos 14, 25, 18, 12, 13, 4, 11, 17.

together with Levallois cores, flakes and points, and a high frequency of small retouched flake tools. The assemblages from Layers 4-2 (268 ± 68, 210 ± 64 ka and 172 ± 41ka respectively) show the continued use of Levallois technology, more proficient blade technology, the production of small flake tools, but a further reduction in handaxes.

Although there are strong arguments for the indigenous development of Levallois technology in India, there are also similar sites to the west. In the Armenian Highlands there is good evidence of the timing of the

Table 3
Technological data for complete flakes.

		n	%
Cortex	100% cortex	1	1.9
	>50% cortex	2	3.7
	<50% cortex	15	27.8
	No cortex	36	66.7
Number of dorsal scars	0	1	1.8
	1	4	7.3
	2	11	20.0
	3	18	32.7
	4	7	12.7
	5	7	12.7
	6	4	7.3
	7	1	1.8
	8	1	1.8
	9	0	0
	10	1	1.5
Dorsal scar pattern	1 – proximal	29	52.7
	2 – proximal, L/R lateral	9	16.4
	3 – proximal, L + R lateral	5	9.1
	4 – proximal, L/R lateral, distal	5	9.1
	5 – L/R lateral	0	0
	6 – distal	0	0
	7 – proximal, distal	5	9.1
	8 – L + R lateral	0	0
	9 – proximal, L + R lateral, distal	0	0
	10 – cortical	1	1.8
	11 – L/R lateral, distal	0	0
	12 – L + R lateral, distal	0	0
Butt type	Plain	38	71.7
	Dihedral	9	17.0
	Cortical	3	5.7
	Natural	0	0
	Marginal	3	5.7
	Soft hammer	0	0
	Mixed	0	0

Table 4
Description of flake tools.

Cat. No.	Type	L	W	Th	Description
1	Retouched flake	94	62	22	Irregular retouch on both lateral edges of pointed flake
2	Retouched flake	89	51	21	Irregular retouch on lateral edge of pointed flake
3	Denticulate	89	61	26	Steep, denticulated inverse retouch on lateral edge
4	Scraper	81	58	16	Retouch on lateral edge
5	Denticulate	73	44	15	Slightly denticulated retouch on lateral edge
7	Notch	38	36	16	2 small flakes removed from distal end to form double notch
8	Retouched flake	49	46	19	Irregular retouch on distal end of broken flake
9	Denticulate	58	41	17	Denticulated retouch on lateral edge of flint flake
10	Retouched flake	76	45	21	Marginal retouch on lateral edge of pointed flake
Mean		72	49	19	

Lower to Middle Palaeolithic transition at Nor-Geghi-1 in the southern Caucasus (Adler et al., 2014; Frahm et al., 2021; Gill et al., 2021). In the southern part of the site, the assemblage is focused on bifacial technology, with occasional simple prepared cores and Large Core Technology (LCTs) with preferential removals with $^{40}Ar/^{39}Ar$ dates >335 ka, possibly attributed to MIS 11c. The stratigraphically higher northern end of the site has been dated to c. 335-325 ka, possibly MIS 9e, with an assemblage of refined handaxes and Levallois technology. Most of the artefacts are made on local obsidian within a few km of the site, although about 3.2% come from Pokr Arteni 70 km to the west, while a tiny proportion (0.3%) come from Pokr Sevkar some 120 km to the south-east.

Table 5
Ranges, means and standard deviations for the axial length/width measurements for different complete flake length categories showing increasing elongation with size.

Complete flake length categories	Axial length/width			n
	Range	mean	sd	
20–39 mm	0.48-1.67	0.96	0.39	11
40–59 mm	0.89-1.77	1.28	0.36	7
60–79 mm	0.71-3.41	1.49	0.44	18
80–99 mm	0.90-3.41	1.83	0.66	15
≥100	1.68-2.30	2.08	0.28	4

The evidence from the Indian sub-continent suggests multiple origins and localised developments for the introduction of Middle Palaeolithic technology during the late Middle Pleistocene from MIS 11, through to its widespread establishment by the end of MIS 6. The situation may in part reflect the geography of a peninsula dissected by mountain chains and major rivers (James and Petraglia, 2005) with continuous occupation leading to regional developments. An additional factor was periodic climate change, when during cold climate the Thar and Arabian deserts would have been arid barriers to population movement from the west. However, increased rainfall during interglacials would have led to easier passage through these regions, with the potential for gene-flow and cultural diffusion. Although evidence is rare, late Acheulean occupation of the Arabian Desert has been found at An Nasim (Scerri et al., 2021), Khall Amayshan (Groucutt et al., 2021), and Saffaqah (Scerri et al., 2018; Shipton et al., 2018). Periodic population dispersals from western Asia, with localised developments in the Indian subcontinent are likely to have resulted in the complex cultural and technological signatures that are apparent in the archaeological record.

Placing the Pampore assemblage within this complexity is problematic. The simplicity of the HCW technology at Pampore suggests an earlier rather than a later date within the Late Acheulean or Early Middle Palaeolithic. Unfortunately, the lack of handaxes cannot be used to assess the age. As discussed above, the assemblage is too small to indicate whether this absence is real or simply a sampling issue. Given these problems, it seems reasonable to suggest that the occurrence of HCW at Pampore reflects one of the dispersals of people or cultural diffusion of ideas from neighbouring areas of western Asia, that may have occurred between 400 and 300 ka.

6.2. *Human and elephant interaction*

The interaction of humans and elephants has long been a topic of interest in Lower and Middle Palaeolithic research, with greater scrutiny of earlier reports, and now taking into account taphonomic considerations where the evidence consists of the simple association of elephant skeletal material with stone tools. Where there is more direct evidence of interaction through modification of the skeletal material, questions still arise as to whether this shows simple exploitation of elephant bone for tool manufacture, or bone breakage and cutmarks indicative of butchery. Further debates surround evidence of hunting, trapping or post-mortem exploitation of carcasses. Pampore, as the only Middle Pleistocene site in the Indian subcontinent to have humanly-modified elephant remains in close association with stone tools (Chauhan, 2008b), can contribute to these wider debates (e.g. Clark and Haynes, 1970; Haynes, 1991, 2002, 2022b; Blumenschine and Selvaggio, 1991; Goren-Inbar et al., 1994; Howell et al., 1995; Villa et al., 2005; Santonja et al., 2014; Wright et al., 2014).

For medium to large mammals, the characteristic features of bones broken with hammerstones to extract marrow were first described in detail by Bunn et al. (1980) and Binford (1981). Bunn's work identified breakage patterns in limb bones from Early Palaeolithic sites in northern Keyna that closely mirrored those induced experimentally by

Table 6
Ranges, means and standard deviations of the lengths and widths of complete flakes with parallel, sub-parallel or pointed morphologies. Most pieces were oriented with the axis of percussion, except three pointed pieces that were re-oriented to reflect the axis of the point.

Complete flakes	Length				Width			
	Range	mean	sd	n	Range	mean	sd	n
Parallel morphology	85–112	97	10.4	6	29–53	42	8.6	6
Sub-parallel morphology	68–99	79	11.2	6	33–41	38	3.3	6
Pointed morphology	56–112	82	18.7	10	20–71	48	16.0	10

Fig. 20. Sites mentioned in the text. White circles denote sites with elephant remains; red circles denote sites with lithic assemblages. Middle Son Valley sites are: Bamburi, Sihawal and Patpara. Didwana sites are: Singi Talav and 16R Dune. Latium sites are: Ficoncella, Castel di Guido, Polledrara di Cecanibbio and Fontana Ranuccio. Nadung'a 4 (Kenya), Mwanganda's Village (Malawi) and Namib IV (Namibia) are not shown.

hammerstone blows (Bunn, 1982). The experiments demonstrated that the most effective technique for breaking open bulky marrow-bones involved resting the shaft on an anvil and then striking its upper surface with a hammerstone. If more than one blow was necessary to induce a longitudinal break, additional blows along the length of the shaft typically resulted in opening the marrow cavity with a clean break. The resulting fractured bones exhibited characteristic internal conchoidal scars on the medullary cavity of the bone shaft. The blows also detached distinctive bone flakes with lunate platforms and features similar to conchoidally fractured stone (Bunn et al., 1980).

Haynes (1991, 2002) presents a critical perspective on supposed Palaeolithic elephant butchery sites, suggesting that many instances of bone-breaking, flaking, and cut-marking attributed to Palaeolithic activities are instead the result of natural processes. His research on natural elephant bone accumulations showed that elephant bones can be broken and scratched naturally, for example, by trampling, in ways that closely resemble the evidence of human butchery and tool-making activities (Haynes, 2017, 2020, 2022a, 2022b; Haynes and Krasinski, 2010, 2021; Haynes et al., 2020, 2021).

While Haynes (1991, 2002) highlights the challenge of identifying intentionally fractured elephant bones based solely on spiral fracture and conchoidal flakes, he does not consider the diagnostic features inflicted by tools used to crack or knap bones. These may include roughened, irregular percussion pits, that correspond to the tip of the percussor, being left on the periosteal surface of the bone. Additional associated abrasions may result if the percussor or bone moves slightly as the bone is impacted, leading to percussion striae. These features are diagnostic of marrow processing, being absent in assemblages where bones have been cracked, chewed, and flaked by carnivores, for example (Blumenschine and Selvaggio, 1988, 1991; White, 1992; Galán et al., 2009; Coil et al., 2020).

The three impact flakes recovered from the Pampore elephant-artefact horizon were in good condition and showed no signs of modification before, or during burial. The overall morphology of the flakes and the pits coupled with striae on the periosteal surface show all the characteristics of marks made by a stone percussor on bone. The position and patterning of the features corroborate the inference that they were made during intentional fracturing of bones with thick cortical walls. Moreover, the morphology and break profiles of the cortical flakes from Pampore suggest that the bones from which they derive were still fresh when broken.

Intentional human breakage of the bones is also supported by other lines of evidence that exclude natural processes. This includes the geological and depositional context, which rules out the possibility of natural high-energy processes, such as debris flows and sediment compaction, being responsible for producing the impact flakes. Additionally, while the fluvial regime may have been affected by seasonal floods, the burial sediments are predominantly fine-grained and devoid of natural clasts larger than granules (>4 mm), eliminating high-energy impacts from boulders as a mechanism for breaking the elephant bones and detaching impact flakes. Moreover, breakage from pressure exerted by earthmoving machinery can also be ruled out as the bone horizon is effectively shielded by being deeply buried, with over 13 m of fine-grained sediments overlying it. Furthermore, while trampling by elephants and intentional activities such as kicking, carrying, and dropping bones of their ancestors can lead to bone breakage (Stuart and Larkin, 2010), there are no documented instances of cortical impact flakes resembling the Pampore examples having been produced in this manner (Haynes, 1991, 2002). Thus, on the basis of multiple lines of evidence – excavation context, burial and depositional context, morphology of pieces with platforms, notches, impact points associated with pits and striae, conchoidal morphology – we conclude that the bone flakes lie in an undisturbed context and are not the product of natural agencies.

The pathology of the skull of the Pampore elephant suggests that it had developed severe sinusitis, and this could have contributed to its death in that location. Although there are no cutmarks that survive on the bones, the close association with stone tools is strongly suggestive of human exploitation. A selected assemblage seems to have been brought to that location perhaps with the intention of butchery. Direct evidence of exploitation comes in the form of elephant bone flakes, although whether they are from the mature adult or the juvenile is not clear. Evidence of other butchery survives as cutmarks and percussion damage on deer or other medium-sized mammal bones from the site.

Beyond India there is a growing list of the co-occurrence of stegodon, elephant or mammoth skeletal remains and stone tools during the Middle Pleistocene. The following is a brief review of the evidence from selected Middle Pleistocene sites in Eurasia and Africa to place Pampore in the wider context (see Fig. 20 for sites mentioned in the text). For a more comprehensive review see Haynes (2022a).

The issue of bone survival has affected potential sites across many non-karstic areas of southern Asia, including India. Although there are abundant remains of stegodon, any association with human activity is not clear (Haynes, 2022a). Two exceptions are caves in south China. Panxian Dadong Cave has a long sequence dating to between MIS 8 to 6 (Liu et al., 2013). Among the human fossil, lithic and faunal assemblages are the remains of *Stegodon orientalis*. Analysis of the age profiles of the teeth shows the over-representation of young and juveniles, which has led to the suggestion that the skeletal remains of stegodon were introduced into the cave by humans (Schepartz et al., 2005). The second site is Xinglong Cave, where the deposits are constrained in age by U-series dates to between c. 200 to 130 ka (Peng et al., 2014). Two tusks of *Stegodon* cf. *orientalis* were found with lithic artefacts, other mammalian remains and four human teeth. The tusks are interpreted as being brought into the cave by humans.

In Israel, at Gesher Benot Ya'aqov (GBY), dating to c. 0.77 Ma, part of a sub-adult *Palaeoloxodon recki* skull was recovered from layer II-6 lakeside sediments in close association with an assemblage of basalt flakes and a large core (Goren-Inbar et al., 1994). Fragments of tusks, teeth and a limb bone were found nearby and might be from the same individual. The authors argue the case for a kill site based on the fresh condition of the skull, arguing against a natural bone trap or in situ miring of the elephant, but there is no direct evidence for the cause of death. They suggest that there is deliberate damage to the bone below the nasal cavity, perhaps from removing the trunk, and that in combination with crushing of the occipital and basal parts of the elephant's head, there is evidence of the removal of the brain. In later accounts, the occurrence is described as a butchery rather than kill site (e.g. Finkel and Barkai, 2024).

At a much later date in Israel, Revadim Quarry has clear evidence of elephant exploitation of *Palaeoloxodon antiquus* (Rabinovich et al., 2012), where minimum ages for the multi-level site range between 500 and 300 ka. Elephant remains dominate the fauna, which are in close association with rich lithic assemblages, including handaxes. Among the remains are several shaped fragments of elephant bone, one possibly a small handaxe, together with the rare occurrence of cutmarks on two ribs and a scapula. The paucity of limb bones compared to other skeletal elements is suggested to be due to the removal of these for processing offsite. The authors argue that the site shows long-term exploitation of elephant in an area of gullies and rills, and seasonal water hollows.

For Africa the evidence from Middle Pleistocene sites is remarkably rare compared to those from the Early Pleistocene. Nadung'a 4 in the Lake Turkana area of Kenya dates to sometime between 1.0 and 0.7 Ma (Delagnes et al., 2006). The site occurs within sediments reflecting seasonal marshland cut by sinuous channels, one of which contained the partial carcass of a young adult *Palaeoloxodon recki*, including the skull, a scapula and long bones. The carcass was surrounded by rich scatters of in situ flakes, flake tools, cores and hammerstones, but no handaxes, and there was minimal other fauna. The lack of cutmarks might be due to the poor preservation of bone surfaces, and it is the isolated occurrence of in situ artefacts with the carcass that suggests human exploitation. The only other sites are Mwanganda's Village in Malawi (Clark and Haynes, 1970; Kaufulu, 1990; Wright et al., 2014) and Namib IV in Namibia (Shackley, 1980; Haynes, 2022a), but the artefacts at both sites are abraded and there are taphonomic reasons that may account for their association with elephant remains.

In Europe all but two of the elephant sites associated with humans are with the remains of *Palaeoloxodon antiquus*. In southern Greece, ongoing excavations at the site of Marathousa 1 are revealing a palaeolandscape of marshy lake-edge deposits, rich in fauna, flora and simple stone tools, probably dating to the end of MIS 12 (Panagopoulou et al., 2018). Of particular note is Area A, which has a high density of stone tools associated with remains of an individual elephant. Other evidence of exploitation includes cutmarks, percussion damage and flakes on elephant bone.

Italy has a particularly rich record of human use of elephant carcasses. At the MIS 16 site of Notarchirico in Venosa, Level A1 contained a skull, tusks and nearby mandible in close association with an assemblage of flakes and handaxes (Piperno and Tagliacozzo, 2001). Although there is no direct evidence, they are interpreted as scavenging of at least part of the carcass. Similarly, Ficoncella, in the Latium region north-west of Rome, attributed to MIS 13, had the skull and vertebrae of an elephant with two concentrations of small flint flakes and a larger limestone flake adjacent to the carcass (Aureli et al., 2015). The remains were in floodplain deposits, and the fresh condition of the artefacts and some refitting suggests that they are in situ. There are gnaw marks on the bones, but no cutmarks.

More direct evidence of elephant exploitation comes from several other sites in the Latium region. The rich MIS 11 site of Fontana Ranuccio contains numerous remains of elephant and stone tools, but also elephant bone flakes and handaxes (Biddittu and Celletti, 2001; Angelucci et al., 2023). Later evidence of scavenging of elephants comes from two sites dating to MIS 10-9. At Castel di Guido, the remains lay at the bottom of a gulley associated with handaxes and flakes, including those made from elephant bone (Saccà, 2012). There is also the rare survival of cutmarks on two ribs and a limb bone, which together with breakage patterns on other bones are suggested to indicate butchery for meat and marrow extraction. At Polledrara di Cecanibbio, a mired elephant was exploited for bone raw material, and probably for meat and marrow (Anzidei et al., 2012; Cerilli et al., 2023). The remains are associated with bone tools, but not handaxes, and the stone tools retained evidence of use-wear from meat and bone.

Later sites are also evident, such as at Poggetti Vecchi in Tuscany dating to the MIS 7/6 transition (Aranguren et al., 2019). A concentration of fossil bones and teeth, predominantly of elephant, were found in lake-edge sediments on a living floor scattered with stone tools, worked, charred sticks made from boxwood, together with worked bone, including elephant.

In Spain the evidence for the Middle Pleistocene is more limited, although it should be noted that at the Early Pleistocene site of Fuente Nueva-3 (1.3 Ma) the association of stone tools and hyaena coprolites associated with part of a carcass of *Mammuthus meridionalis* led to the interpretation of primary scavenging by humans over hyaenas (Espigares et al., 2013). At the much later site of Ambrona (MIS 11-10), earlier claims of human elephant interaction have more recently been questioned on taphonomic grounds with natural processes argued to be largely responsible for the faunal-lithic associations (Howell et al., 1995; Villa et al., 2005; Santonja et al., 2014). Despite this, cutmarks have been identified on several bones, including those of elephant, perhaps reflective of low intensity exploitation of elephant and other fauna in the local area (Santonja et al., 2014).

More convincing evidence comes from Aridos to the south-east of Madrid (Yravedra et al., 2019). Dating to MIS 11, Aridos 1 has the partial remains of an adult female elephant from an area c. 50 m^2, preserved in low energy alluvial sediments alongside stone artefacts, including flakes from handaxe manufacture. Their fresh condition and refitting show that they are in situ, and several are in direct contact with the bones, including the skull. Nearby, part of an articulated skeleton of an adult male was recovered from Aridos 2, again in low energy alluvial sediments in direct association with stone tools. A number of artefacts show use-wear with meat polish (Ollé, 2005), and several ribs and scapulae have damage from butchery, possibly from evisceration and defleshing respectively (Yravedra et al., 2010).

In northern Europe, despite an abundance of elephant skeletal material, evidence of butchery or exploitation is rare. In the UK, the 'Ebbsfleet Elephant Site' near Swanscombe in Kent, dating to MIS 11 (Wenban-Smith, 2013). An abundance of simple cores and flakes was found in association with the remains of an elephant in stream deposits, dating to MIS 11. Despite detailed examination of the skeletal remains for bone breakage and cutmarks, none were identified. The lack of direct evidence for exploitation is also the case for Schöningen in northern Germany, dating to MIS 9. In one area of the site, recent excavations in lake-edge sediments have revealed the almost complete carcass of a female adult elephant together with a few small flakes, some of which refit, and several bone tools. Again, there are no cut-marks or signs of human bone breakage (Serangeli et al., 2023). Finally, La Cotte de St Brelade on Jersey provides an example of mammoth (*M. trogontherii*) exploitation dating to MIS 7-6, where various skeletal parts were found with stone tools in at least two levels within a long sequence of deposits in a marine-cut ravine. Although earlier interpretations suggested a mass-kill with the driving of herds over the edge of the ravine (Scott, 1980, 1986), more recent reappraisal has argued for a more gradual build-up of bone within the deposits, with indications of butchery, but not hunting (Scott et al., 2014).

From this brief review of the evidence for human-elephant interactions, there are several common patterns. First, the vast majority of sites appear to be lake or river-edge locations where elephants are likely to have become mired, died and subsequently exploited. Many of the sites are associated with simple, often small flakes, and although handaxes are occasionally present, they do not seem to be an essential tool for butchery. Cutmarks are rare, while bone-breakage and evidence of manufacture of bone tools is a more common occurrence. The reasons for the rarity of cutmarks on elephant bone have been widely discussed and appear to be due in particular to the thickness of the periosteum, as well as the articular cartilage and other tissues (e.g. Crader, 1983; Haynes, 1991; Villa et al., 2005). With the growing evidence of the use of elephant bone for tool manufacture, it seems that the intention of elephant exploitation was commonly for bone raw material supply, as well as meat and fat acquisition.

The lack of evidence for hunting at Middle Pleistocene sites, stands in contrast to a new study of elephant exploitation during MIS 5e at Neumark-Nord in northern Germany. An aspect of the new research over the last 15 years has built on previous work in examining human-elephant interaction (Gaudzinski-Windheuser et al., 2023; Starkovich, 2023). The sediments were deposited over a period of 2000 years, and the results of a detailed study of large assemblages of elephant remains have shown that the age-profiles and sex of the population has an overrepresentation of mature adult males and is suggested by the authors to show selective hunting. Repeated patterns of butchery indicate highly skilled dismemberment of the carcasses, predominantly for fat and meat. Unlike earlier sites, there are numerous cutmarks, but very little bone-breakage, suggesting that meat, rather than raw material, acquisition was the main purpose. The results have implications for group size and group aggregations for effective hunting and butchery, but also the methods by which meat could be preserved and stored for long-term consumption. The site of Lehringen, also in northern Germany, lends support to the hunting of elephant during MIS 5e (Movius, 1950; Gaudzinski-Windheuser et al., 2023). Here a carcass of an elephant was discovered in marshland sediments with a 2 m long wooden spear made of yew found between the ribs, alongside several lithic artefacts. The elephant may well have been mired, but then killed with the use of the spear.

By contrast, with the evidence from MIS 5e, Pampore fits into a general pattern of behaviour that seems to have been commonly practised during the Middle Pleistocene across Eurasia. The evidence supports exploitation of elephant carcasses, which in many cases appears to be as a source of bone raw material for tool manufacture. Scavenging for meat is often less evident, but this may be due to the difficulties of detecting clear signs of butchery, such as cutmarks, due to the thickness of the periosteum and other tissues, or preservation of bone surfaces. If some form of hunting was practised, it is not clear from the evidence, and given the proximity to water at many of the elephant sites, miring in marshland and swamp was more than likely to have been the cause of death in many cases.

7. Conclusions

The Pampore elephant was a mature male and is one of the most complete *Palaeoloxodon* skulls known. The site has evidence of human exploitation of the elephant through the association with stone artefacts, and the presence of elephant bone flakes and breakage patterns attributable to humans. Indications of sinusitis from the skull could have contributed to the death of the elephant, perhaps weakened when mired in soft channel sediments. The associated stone artefacts were brought to the location in a mainly finished form, from a local source of basalt. They include elongated, sometimes pointed, flakes, which suggest an early Mode 3 technology and perhaps indicate a late Middle Pleistocene age for the site. There is little evidence of hunting, but certainly of elephant bone exploitation, which extends the growing list of Middle Pleistocene sites with such evidence to northern India.

CRediT authorship contribution statement

Ghulam M. Bhat: Site geology and interpretation, Fieldwork. **Nick Ashton:** Lithic analysis, Writing. **Simon Parfitt:** Bone flaking, breakage and cutmark studies, Writing, Figures. **Advait Jukar:** Palaeontology, Writing. **Marc R. Dickinson:** AAR dating. **Bindra Thusu:** Site geology and interpretation. **Jonathan Craig:** Site geology and interpretation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

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