tively more humid climate equivalent to the present day prevailed in the region with the advent of an active SW monsoon. The arrival of much favourable climatic condition during the last two millennia or so could have been the aftermath of invigoration of SW monsoon. The appreciable increase in Cerealia and other culture pollen taxa signifies the further augmentation in the cereal-based agriculture practice in the region on the whole as well as in the area contiguous to the swamp. Although the monsoon precipitation was good, the swamp assumed a smaller stretch, which is evident from the reduction in wetland and aquatic taxa. This change in the status of the swamp might have occurred on account of reclamations of its wider and less waterlogged peripheral area by the tribals in order to cope with the food security of the escalating human population in the region during the recent past.

Thus, the pollen proxy database retrieved through the study of a 1.75 m deep sediment core from the Amjhera Swamp has documented the changing vegetation scenarios and contemporaneous climatic episodes in southwestern Madhya Pradesh in a definite time-frame since prior to the Mid-Holocene. The pollen sequence generated has demonstrated that this region supported the open mixed tropical deciduous forests during the time-brackets of 6000 to 5409 years BP and 4011 to 2178 years BP under a warm and less humid climate in response to reduced monsoon precipitation. These time-intervals of adverse climate were found to alternate with the warm and more humid climatic regimes between 5409 and 4011 years BP as well as 2178 years BP to the Present, which could be ascribed to increased monsoon precipitation as well indicated by the establishment of diversified and dense tropical deciduous forests.

The region was under the cereal-based agricultural practice right from the beginning of the sequence, i.e. since 6000 years BP; however, it has got accelerated during the last 2 millennia or so due to prevalence of more active SW monsoon. Further investigation of potential swamp and lake deposits from other regions of central India, using a concerted approach involving pollen, geochemical and isotope data is needed. This could significantly facilitate the simulation of precise trend of SW monsoon and its influence on the natural resource in central India during the Quaternary Period as well as in divulging the major climatic events from the Indian subcontinent in global perspective.


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New human fossils and associated findings from the Central Narmada Valley, India

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Explorations in the Central Narmada Valley have yielded a partial hominin femur and a humerus from a new locality, Netankheri located 3 km upstream from the previous hominin locality, Hathnora. The femur was recovered from the same Middle Pleistocene stratigraphic level that yielded calvarium at Hathnora and shares robust mosaic morphology of...
**Homo erectus and archaic Homo sapiens.** The mega mammalian fauna and large flake Acheulian artefacts excavated from the femur and the calvarium beds support existence of a large robust hominin at ~250 kya. The humerus was recovered from startigraphically higher and pre-YTA (~75 kya) stratum in association with unique Upper Palaeolithic fossilized bone artefacts and attributed to a ‘short and stocky’ earliest modern *H. sapiens* hitherto unknown in South Asia. This lineage probably evolved from a similar ‘short and stocky’ mode-3 archaic hominin documented earlier by two archaic clavicles and a 9th rib at Hathnora.

**Keywords:** Human fossils, humerus, femur, lithostratigraphy.

Since 1830s the Central Narmada Valley has yielded innumerable Palaeolithic artefacts and Pleistocene vertebrate fauna, but laying hands on human fossils always frustrated the explorers. Only the 1980s proved fortuitous with the discovery of a partial hominin cranium1, soon followed by two clavicles and a partial left 9th rib from Hathnora2–4, which brought Narmada Valley to the forefront of human evolution in South Asia. They generated considerable debate on the taxonomic status of Narmada hominin. The large, rounded and robust cranium eluded the experts as an ‘evolved’ *Homo erectus*5,6 or an ‘archaic’ *Homo sapiens*7–12 and then also attributed to *Homo heidelbergensis*13–15. But, the three tiny and robust postcranial bones remain an enigmatic mismatch to the cranium and opened up the possibility of another hitherto unknown pygmy-sized species or archaic population in the Narmada Valley2,4,15–17. A recent study15 based on many Palaeolithic and faunal findings recovered during five-year intensive explorations and trial excavations has strengthened this possibility. The recent findings also include two new human fossils and unique bone implements.

The humain fossils discovered include a partial left humeral diaphysis (NTK-F-02-07; Figure 1 a) and a distal shaft fragment of the left femur (NTK-F07-05; Figure 1 b), and are deposited in the Palaeoanthropology Repository of the Anthropological Survey of India, Kolkata. They are recovered from two different stratigraphic levels of a new fossil locality, Netankheri (Figure 2 a), located about 3 km upstream from Hathnora along the northern bank of the River Narmada (Figure 3 a). The humerus was associated with several bone artefacts. The comparative morphometrics of the human fossils are presented in Table 1.

The humerus is mineralized and bears a dark grey hue as do the fossilized bone artefacts and exhibits post-fossilization linear cracks, especially on the medial border. The preserved portion below the radial sulcus (spiral groove) up to the upper margin of the olecranon fossa measures 84 mm. It yields an estimated maximum length of 240 mm (Table 1), which is even shorter than the mean length of five Chaurite humeri (291.4 ± 13.43 mm) as well as from a larger sample of 33 mixed mainland Eastern Indians plus the Chaurite (284.74 ± 27.19 mm). Interestingly, the NTK and Chaurite Nicobari population is shorter and stockier in the available comparative sample18,19, which includes Omo Kibish and Cro-Magnon 1.

It exhibits typical shape of the human humerus, cylindrical proximally, widening and turning prismatic distally. It is bounded by three borders and three surfaces, besides showing a medial bending or twisting on the posterior surface; this is where the brachialis narrows superiority and widens distally. Distally, the posterior surface is flattish and covered by the lateral and medial heads of the triceps brachii that give origin to part of the brachialis. The anterior border is smooth and rounded and provides attachment to the brachialis muscles. The lateral border has a sharp crest and is rough distally, uprising obliquely at the medial region. There is a broad, shallow, oblique depression in the centre. The medial border is broken at its centre.

It is pertinent to know whether the NTK humerus is of the archaic hominins or of modern humans. Studies20 show that the archaic/modern human dichotomy could be established by the proximal ulna, but this is not supported by the distal humeral morphology. As such the present specimen may only be suggested as ‘late archaic’ human from its mineralization also shared with the associated bone tools, which are typo-technologically early Upper Palaeolithic. A general metric similarity of the NTK humerus (Table 1) is notable with the humeri of the Chaurite Nicobarese, who have a short and stocky body frame. We do not associate the two Hathnora archaic hominin clavicles and the 9th rib to the Onge/Greater Andamanese directly15 on similarities in stature and biacromial diameter, but the Netankheri humerus now does establish a continuous occupation of the Central Narmada Valley by the ‘short and stocky’ early archaic hominins to ‘late archaic’ or ‘early modern’ *H. sapiens* throughout the Middle and Late Pleistocene.

The 81 mm distal-most shaft portion of the left femur is fully mineralized (Figure 1 b1, b2). It is detached from the condyles. The popliteal surface is well preserved posteriorly, but anteriorly the articular surface of the patellar deep notch and the intercondylar fossa are eroded. Direct comparisons with similar-sized mammalian femora ruled out their non-hominin identity and the specimens show a typical cylindrical shape of the femoral body or corpus femoris, which broadens and flattens distally near the condylar region forming a distinct triangular popliteal surface on its posterior aspect. The left aspect of the NTK femur reveals that it has larger and rounded lateral surface. This is compared to the relatively narrow and slightly pinched medial surface above the condyles, which flares more medially when the femur is held perpendicularly.
Figure 1.  a, Hominin humerus from Netankheri in anterior and posterior views. b1, b2, Hominin femur in anterior and posterior views. c, Comparison of the hominin femur with modern human, Java Homo erectus and Neanderthal. d1, Cross-section of Netankheri femur. d2, Comparison of Netankheri femur with those of two modern Indian femurs, Qafzeh 9, Skhul 5 and Tabun 3 femurs.

Figure 2.  Stratigraphic position of the human humerus and femur at Netankheri. a, U2 and U3 boulder conglomerate units of Surajkund Formation, Baneta Formation and humerus (inset). b, Baneta section. c, Excavated section between U2–U3 and part of the Baneta section. d, Site of the femur and Stegodon fossil. e, Excavated section of femur site in yellow Surajkund sands above the submerged U1 cemented boulder conglomerate.
Although limited by the degree of preservation, the most notable feature of the NTK femur is low development of its medial and lateral lips. This results in a subcircular/ovoid shape to the diaphysis in cross-section (Figure 1d1). This is contrary to the characteristics of modern human femora, where the two lips emerge into prominent ridges. The linea aspera ridges result in a posterior pilaster or flatness. In this respect, besides being robust, the NTK femur is comparable to the robust and rounded femur of the Neanderthal man, which mostly lacks the pilaster (Figure 1c). Although no direct comparison was possible, some apparent similarity may be observed with the ‘late archaic’ hominins21–24, e.g. Tabun 3, Qafzeh 9 and Skhul 5 (Figure 1d2). The metric comparison (Table 1) also leads to a conclusion that the NTK femur is closer to the Neanderthal femur than the Java H. erectus.

The two hominin fossils were received from two different stratigraphic levels exposed near the village Netankheri, located (22°50′25″N; 77°53′6″E) along the northern bank of the east-west flowing River Narmada and 3 km upstream and east of Hathnora (Figure 3a). The Netankheri Quaternary litho-stratigraphic section (Figure 3c) is 19.2 m thick; its 3.7 m lower part is attributed to the Middle Pleistocene Surajkund Formation and the remaining 15.5 m upper portion to the Upper Pleistocene Baneta Formation25. Like Hathnora (Figure 3b), the Surajkund Formation at Netankheri is comprised of three distinct cemented pebble conglomerate beds26, denoted as U1, U2 and U3 with inter-layers of yellow sands. The
Table 1. Metric comparison of the Narmada fossilized humerus and femur with modern mainland Indians and Chaurite Nicobarese of Andaman–Nicobar Islands

<table>
<thead>
<tr>
<th>Skeletal population</th>
<th>Sample or number and statistic value</th>
<th>M–L</th>
<th>A–P</th>
<th>Girth</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Humerus mid-shaft measurement</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Netankheri fossil (NTK-F-02-07)</td>
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<td>18.3</td>
<td>18.7</td>
<td>67.5</td>
<td>84=240* est</td>
</tr>
<tr>
<td>Mainland Eastern Indians + Chaurite Islanders</td>
<td>33</td>
<td>16.02</td>
<td>16.56</td>
<td>60.02</td>
<td>284.70</td>
</tr>
<tr>
<td>SD</td>
<td>2.65</td>
<td>2.43</td>
<td>5.82</td>
<td>24.19</td>
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</tr>
<tr>
<td>SE</td>
<td>0.46</td>
<td>0.42</td>
<td>1.01</td>
<td>4.21</td>
<td></td>
</tr>
<tr>
<td>Chaurite Islanders</td>
<td>5</td>
<td>19.21</td>
<td>19.08</td>
<td>65.95</td>
<td>291.4</td>
</tr>
<tr>
<td>SD</td>
<td>3.15</td>
<td>1.20</td>
<td>4.75</td>
<td>13.43</td>
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</tr>
<tr>
<td>SE</td>
<td>1.41</td>
<td>0.54</td>
<td>2.46</td>
<td>6.00</td>
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<td>KNM-WT 15000F</td>
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<td>17.3</td>
<td>11.8</td>
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<tr>
<td>Gombore IB-7594</td>
<td>1</td>
<td>15.6</td>
<td>11.61</td>
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<td>ATD6-148</td>
<td>1</td>
<td>14.0</td>
<td>7.0</td>
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<tr>
<td>BOD-VP-1/2b</td>
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<td>18.0</td>
<td>9.0</td>
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<tr>
<td>Kabwe</td>
<td>1</td>
<td>18.4</td>
<td>11.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skhul IV</td>
<td>1</td>
<td>18.6</td>
<td>14.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Omo Kibish I-r (KHS-1–30)</td>
<td>1</td>
<td>19.9</td>
<td>11.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Omo Kibish I-l (KHS-1–31)</td>
<td>1</td>
<td>20.6</td>
<td>12.0</td>
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</tr>
<tr>
<td>Cro-Magnon 1</td>
<td>1</td>
<td>20.7</td>
<td>14.0</td>
<td></td>
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<tr>
<td>Dolni Věstonice</td>
<td>4</td>
<td>16.8 ± 1.7</td>
<td>9.1 ± 2.8</td>
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<td></td>
</tr>
<tr>
<td>Sima de los Huesos</td>
<td>6/9</td>
<td>15.7 ± 2.0</td>
<td>8.6 ± 1.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neandertals</td>
<td>21/23</td>
<td>15 ± 2.2</td>
<td>7.7 ± 1.8</td>
<td></td>
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</tr>
<tr>
<td><strong>Femur distal mid-shaft measurement</strong></td>
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<tr>
<td>NTK-F-07-05 (L)</td>
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<td>44.85</td>
<td>38.05</td>
<td>125.5</td>
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<tr>
<td>Neanderthal (R)'</td>
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<td>47.3</td>
<td>40.7</td>
<td>133.5</td>
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<tr>
<td><em>Homo erectus</em> (L) (Java)'</td>
<td>1</td>
<td>37.65</td>
<td>34.15</td>
<td>114.5</td>
<td></td>
</tr>
<tr>
<td><em>Homo erectus</em> (Tautavel)'</td>
<td>1</td>
<td>36.9</td>
<td>32.55</td>
<td></td>
<td>NA</td>
</tr>
<tr>
<td>Modern Indians (<em>Homo sapiens</em>)</td>
<td>18</td>
<td>34.87</td>
<td>27.68</td>
<td>102.85</td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>34.87</td>
<td>28.11</td>
<td>104.65</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SE</td>
<td>3.643</td>
<td>2.93</td>
<td>10.095</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

M–L, Medio-lateral and A–P, Antero-posterior diameter; all measurements in millimeter. *est, Estimated; 'Measurements on replicas, and on original Eastern Indian c housed in the Anthropological Survey of India, Paleanthropology Laboratory, Kolkata. On original at Tautavel, France taken in July 2009; access courtesy Henry de Lumley and Tony Chevalier.

cemented U¹ remains submerged in River Narmada most of the time such that it remains largely unexplored and unmeasured exactly, except the sequences of yellowish-brown coarse sand and pebbles above it. The U²/U³ units of the cemented gravel here are collapsed and spread as a gravely sand bar for a longer distance by the recent neotectonic anticlines and synclines. The collapsed segment contains the fragments of Vindhyan sandstone and other volcanic materials like chert, jasper, agate, etc. derived from the Satpura Hills, which serve as the raw material for the Middle to Upper Palaeolithic artefacts. The Baneta overlies disconformably as fine brown calcareous clayey silt with grey sand lenses and thick brown silty-clay.

The Netankheri U¹ level that yielded hominin femur, yielded only a few mammalian fossils; the notable were the molar fragments of *Stegodon insignis ganesa*. The reason is obvious – the submergence of U¹ most of the time at Netankheri, but U¹ gets occasionally exposed at Hathnora. Therefore we were able to get an assemblage of complete crania and mandibles of *Equus namadicus, Elephas namadicus, Bos namadicus, Bubalis palaein- dicus* and *Hexaprotodon namadicus* from Hathnora (Figure 4). One complete mandible of *E. namadicus* was excavated in shallow waters with an Acheulian tool embedded between the mandibular ramii, which is a direct evidence of the contemporaneity of the fauna and the cultural artefacts. The fauna from U¹ suggests a Middle Pleistocene age for the Hathnora hominin calvarium and for the Netankheri femur.

Like the fauna, only a few heavy-duty Acheulian implements were recovered from the Netankheri U¹ level, among which a pick is a distinct cultural finding. But again, the U¹ at Hathnora that contained the hominin calvarium yielded a remarkably huge collection of over 100 heavy-duty large flake Acheulian handaxes and cleavers, besides a few heavy picks and chopping tools, many of them recovered in situ along with the mega mammals mentioned above. The calvarium and the femur therefore are derived from the same larger robust archaic *H. sapiens* sharing *H. erectus* and *Homo neanderthalensis* mosaic morphology or like a *Homo heidelbergensis*.

The U¹/U² interface at Netankheri has yielded fragmentary fossils and lighter refined Acheulian artefacts but no
Figure 4. Excavated mammalian fauna associated with hominin calvarium and femur in U1 cemented boulder conglomerate. 1, *Bos namadicus* skulls and maxilla; 2, *Rhinoceros* sp. mandible; 3, *Bubalus palaeindicus* cranium; 3, 4, *Cervus dvauceli* antler; 5, *Elephas hysudricus* upper molar; 6, *Hexaprotodon namadicus* cranium; 7, *Hexaprotodon namadicus* mandible; 8, *Stegodon insignis* upper partial molar; 9, Cranium of *Elephas hysudricus*; 10, Mandible of *Elephas namadicus*; 11, Partial cranium of *Equus namadicus*; 12, Fauna from U2 yielding the clavicles and rib fossils at Hathnora: fragments of *Axix axix* antlers, a partial bivalve pelecypod and *Crocodylis* sp. tooth spike.

hominin fossil. But, at Hathnora this interface has yielded three hominin bones, two clavicles and the rib associated with tiny Middle Palaeolithic implements (Figure 6 b, ix–xiii). The inferred body dimensions from these indicate a pygmy-sized short and stocky archaic non-Acheulian (Figure 6 b, ix–xiii) *H. sapiens* (Figure 6 c, 2, 3, 5), distinct from the large flake robust Acheulian (Figure 5) hominin of the U1 level. The earlier findings of the light-duty Palaeolithic implements from Hathnora claimed to be associated with the calvarium were the handiwork of this short and stocky population. The fossil and archaeological evidence from Hathnora, therefore represent two types of culturally and physically distinct anatomically archaic hominin populations in the Central Narmada Valley.

The U2/U3 interface at Hathnora has yielded fossil fragments; we dug out an antler of the *Axix axix* at Hathnora. But, at Netankheri the U2/U3 (Figure 3 c) has yielded the human humerus along with an isolated dentition of *Equus* sp. But, the important associations are with the bone implements discovered for the first time in Narmada Valley at Netankheri and Amkheri just on the opposite bank and at a few other localities with collapsed upper Surajkund gravel (Figure 3). They were found along with other lithic tools of quartzite, chert, chaledony, jasper and agate (Figure 6 b). They are mostly of splintered bone fragments, which show marks of secondary chipping and intentional modifications resulting in shapes found among the Middle and Upper Palaeolithic industries. Some of the better recognized typo-technological categories found include, spatulas-cum-end-scrapers, dagger, knives, borers, awls, burins, blades, etc. (Figure 6 a).

An electron spin resonance (ESR) date of >236 kya fits within the biostratigraphic and cultural time of the findings, though more recent attempts based on linear uranium uptake show a confusingly wider range of 40–280 kya. We may provisionally keep the U1 hominin fossils, the Hathnora calvarium and the Netankheri femur at around 250–200 kya, and the U1/U2 Hathnora postcranial fossils at ~150 kya in consideration of the other sources of evidences presented above.
Figure 5.  

a, Excavations conducted at U1 level of Hathnora hominin calvarium site.  
b, Excavation of a submerged and embedded *E. namadicus* mandible in U1 bottom, seen with a stone artifact stuck between the ramii.  
c, Cleavers from U1 level.  
d, Large flake Acheulian implements recovered *in situ* at the U1 level.

Figure 6.  

a, Bone and stone implements associated with human humerus at Netankheri and similar sites.  
i–iii, Spatula-cum-end scrapers; iv, Backed knife; v, Dagger; vi, Burin; vii, Borer; viii, Awl.  
b, Small mode 3 lithic implements excavated at Hathnora clavicle site; such tools were also recovered from Netankheri humerus site.  
i,ii, Scraper; i, Blade; xi, Arrow head point; xii, Scraper; xiii, Backed knife.  
c, Narmada right and left clavicles (2, 3) compared with the Greater Andamanese clavicles (1A, 1B), and 9th rib (5) compared with modern human 9th rib; 6, Netankheri human humerus.
The date of Netankheri humerus and the bone implements recovered within the collapsed U²/U³ interface of the Surajkund Formation (Figure 2a) located below the Baneta Formation stratigraphic boundary may be assessed from the YTA datum\(^{30,31}\) of ~75 kya. Only the Baneta and Hirdepur formations of the Central Narmada Valley are known to contain the Youngest Toba ash layers\(^{32–34}\). Therefore, the humerus is older than 75 kya or we may keep the date range tentatively between 80 and 70 kya until a more specific date is obtained.

The present findings would have several implications in understanding human evolution in South Asia. The analysis presented above indicates presence of two types of early archaic hominins to early modern humans in Narmada Valley during Middle to Late Pleistocene. The larger hominin was widespread during Middle Pleistocene at lower Surajkund at U² stratigraphic level 250–200 kya and hunted mega mammals with typical large flake Acheulian mode-2 implements. The short and stocky hominin appeared at the Middle Surajkund level at ~150 kya during later Middle Pleistocene and hunted relatively small game animals using refined Acheulian and Middle Paleolithic mode-3 implements.

The Netankheri humerus (80–70 kya) provides evidence for an adaptive continuity of the archaic short and stocky hominins and their evolution during Upper Pleistocene to early modern \(H. sapiens\), who likely formed the ancestral substratum for the later short-bodied populations of South Asia including the pygmies. Thus, the ‘short and stocky’ mode-3 archaic hominins may have been \(but\) an early (Pre-Toba) ‘African import’ to South Asia via the Arabian Peninsula\(^{35–37}\). They might have survived the ‘volcanic winter’\(^{38–40}\) due to unique cultural adaptations, such as bone tool technology, which could have facilitated rapid attainment of anatomical modernity\(^\ref\text{15}\). The recent mtDNA M signatures >60 kya found in the Munda\(^{41,42}\) inhabiting the eastern/northeastern fringes of Narmada Valley, who, interestingly also share these signatures with the Andaman pygmies, likely attest continuity of the ‘short-bodied’ populations. Recent archaeological studies have demonstrated widespread northward\(^\ref\text{45}\) and south–eastward\(^\ref\text{44}\) expansions of Narmada-like Late Acheulian to Upper Paleolithic and Mesolithic hominins. Moreover, there is considerable anatomical gap between the NTK humerus (~70 kya) and later Pleistocene (~30 kya) occupants of the Fa Hien cave in Sri Lanka\(^\ref\text{45}\) as well as Darri-L-Kur of northeastern Afghanistan\(^\ref\text{46}\), which would continue to fuel the debate on ‘continuity’ versus ‘replacement’.

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