industrial effluents. Sulphate shows negative correlation with methane emission.

Salinity also shows a negative correlation with methane emission. Salinity is low at Buckingham Canal (0.2 ppt) suggesting no marine influence, but in contrast Adyar estuary (13.93 ppt) has high salinity, thereby showing strong tidal influence. High salinity and sulphate concentration increases competitive interactions of sulphur-reducing bacteria and methanogens. These microbes compete for methane precursors in anaerobic environment[7]. Thus, a higher peak value of methane emission is obtained at Buckingham Canal (78.98 mg $CH_4 m^{-2} h^{-1}$) than at Adyar Estuary (53.95 mg $CH_4 m^{-2} h^{-1}$), at 13 h. But the average high methane efflux in estuary is due to high organic matter content in coastal wetlands of Madras city, a symbiotic co-existence of methanogens and sulphate-reducers[8].

Lower methane emission values in late afternoon at both the sites is due to increase in sediment temperature over the optimum value. Another reason is fall in the water level in the waterways due to low tide, which results in aeration of surface waters and may effect the activity of methanogens in the sediment.

Methane emission values from this study cannot be compared with the values obtained at the same sites by the earlier workers[8] because of different time and day of sampling. The values reported earlier[8] for August 1993–94 for Adyar Estuary is 23.24 ± 0.40 mg $CH_4 m^{-2} h^{-1}$ and for Buckingham Canal is 2.73 ± 0.14 mg $CH_4 m^{-2} h^{-1}$. These values are lower than found in the present study. The probable reason for this year-to-year variation in methane emission values could be due to different environmental conditions at the time of sampling. Further, the values reported earlier[8] are average of fortnightly sampling. The values reported in this paper can be considered to be representative of methane efflux at the study sites on 13–14 August 1996.

Thus, sediment temperature, solar radiation and time of day influence day-time variation in the methane emission in wetlands. Site-specific variability in the emission is due to variation in soil properties, organic matter, salinity and sulphate concentration. Thus for assessing the methane emissions from a wetland, diurnal variations should be considered to provide reliable values. Further refinement of these data needs to be done to understand the dial and spatial variations in methane emissions from an urban wetland that has strong anthropogenic influences, and hence site-specific complexity due to pollutant quality and quantity.

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Evidence of human occupation and humid climate of 30 Ka in the alluvium of southern Ganga Plain

Indra Bir Singh*‡, Shikha Sharma*, Maneesh Sharma*, Pradeep Srivastava* and Govindaraja Rajagopalan†

*Department of Geology, Lucknow University, Lucknow 226 007, India
†Birbal Sahni Institute of Palaeobotany, Lucknow 226 007, India

A stratigraphic horizon in the cliff of Yamuna river at Kalpi has yielded rich vertebrate fossils, namely an elephant tusk (3.54 m long), shoulder blade of elephant, molars of *equus*, *bovids*, *bos*, etc. along with fragments of bones showing definite evidence of human workmanship. Human femurs with unique pencil sharpening are also found in the calcrete conglomerate in Yamuna river bed, which are time equivalent to above horizon. This horizon represents deposit of humid climate around 30 Ka, and is affected by intense seismic event. This is so far the oldest human occupation site in the Ganga Plain.

GANGA Plain Foreland Basin is an actively subsiding basin with a wedge-shaped sediment fill, thinning towards the cratonic southern margin[1]. There is also evidence of upwarping in the peripheral bulge towards the cratonic margin, where rivers have responded by making deep incision[1-3]. There are evidences of neotectonic activity in the form of bending and tilting of beds, block movements, and conjugate system of faults during Middle to Late Holocene[4]. The rivers of southern part of the

‡For correspondence

Central alluvial plain and Marginal alluvial plain are highly sinuous and deeply incised exposing 15–30 m thick sections of fine grained Late Quaternary deposits. The incision becomes more prominent south of the axial river, namely the Yamuna river.

The area of study is located on the southern bank of the Yamuna river. The cliff section at Kalpi (Figure 1) is about 20 m thick and can be traced laterally for several hundred metres. About 250 m extent of this exposure has been studied in detail, and the lateral profile has been documented (Figure 2) based on closely-spaced vertical profiles. Approximately 1 km downstream, a large channel bar of the river exists where many fossil bones are found, loosened from the deposit by the river action.

The cliff in Kalpi section is exposed below the road bridge of NH 25 over the Yamuna river at Kalpi, and runs roughly in NW–SE direction. The succession is divisible into three lithological units which are described as events (Figure 2) below:

Event I constitutes the 5 m thick lower part of the section, and the base of this succession is not exposed. The sediments are reddish to brownish in colour and seem to be derived from the southern peninsular source. In the southeastern part, the succession starts with a 1.50 m thick clayey silt horizon; internally, it reveals thin lenses of fine sand and silt. Extensively bioturbated, it contains scattered calcareous nodules. Laterally, the succession merges with a 1 m thick horizon of mottled fine sand, possessing a prominent erosional base. The axis of this channelized horizon is oriented in SSW direction, and laterally it passes into mottled silt unit. These basal units are overlain by mottled silt and clayey silt horizons.

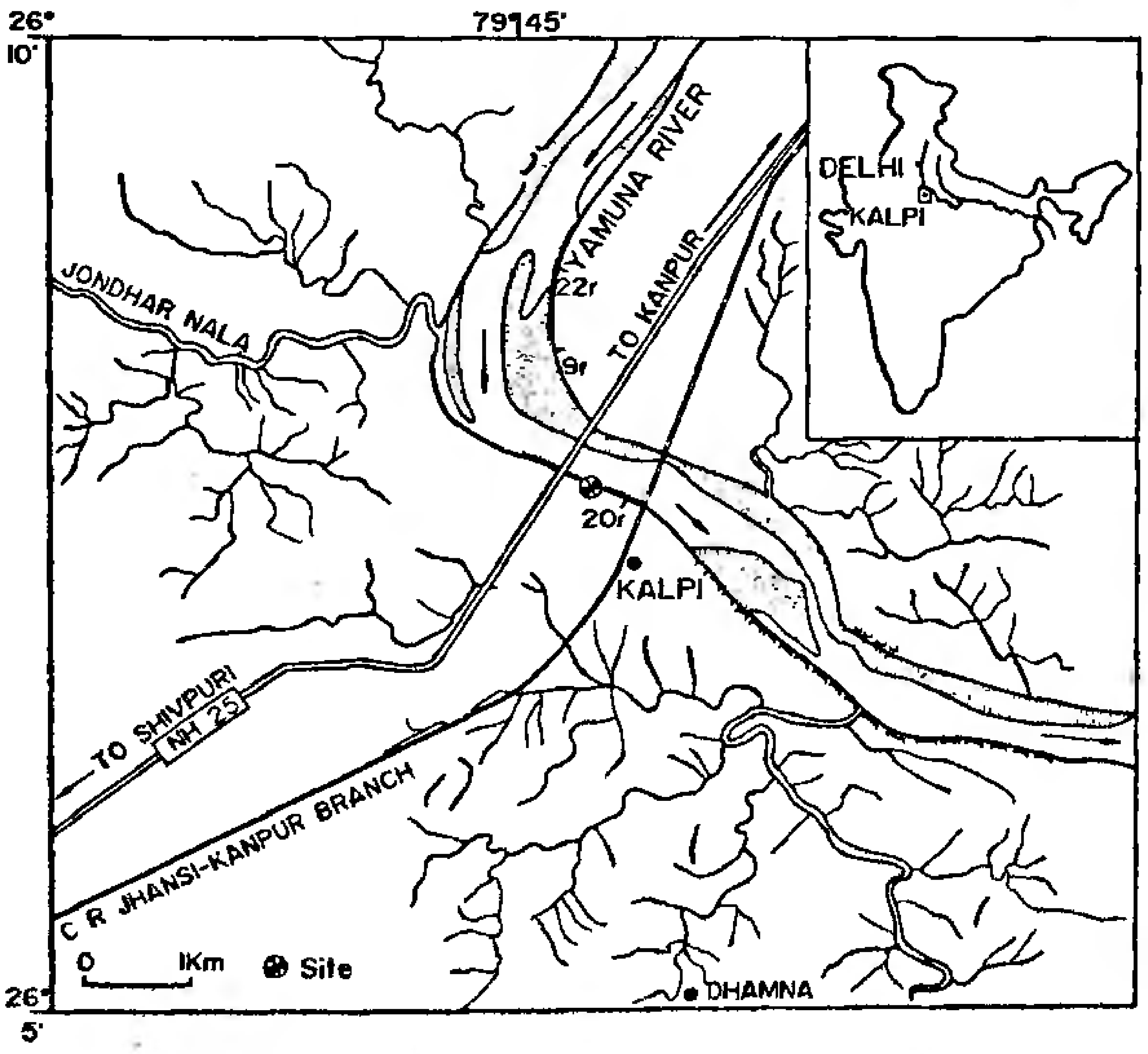

Figure 1. Location map of the study area.

This succession is also covered by 1.0–1.5 m thick mottled silt unit showing many well-preserved passively-filled burrows. This unit laterally passes into mottled fine sand and calcrete conglomerate (reworked calcrete) units. The marginal parts of the mottled fine sand units are clay-rich. Over this a 1 m thick channelized reworked calcrete unit exits, which can be laterally traced for 100 m.

Event I is capped by 10–30 cm thick horizon of spongy calcrete. Cutting through this horizon and penetrating into the underlying sediments are rhizocretes, which may possess diameters up to 10 cm.

Event II makes about a 4 m thick succession, comprising light grey, micaceous fine sandy sediments. The sediments resemble those derived from Himalayan-source rivers[1] coming from the north. The contact between event I and II is distinct, marked by the development of spongy calcrete or reworked calcrete conglomerate horizons. At a few places without calcrete, there are prominent load structures and other soft sediment deformation features at the contact. There may be a non-depositional hiatus between event I and II.

This succession is essentially made up of four thin, lensoidal units of mottled fine sand, which are interrupted by thin bands of mottled silt and clayey silt. The top two bands of mottled fine sand extend laterally for more than 200 m. The sediments are extensively mottled, with a few calcretized burrow networks. At places, horizons with well-preserved small scale ripple cross-bedding are also present.

The sediments of event II show prominent liquefaction throughout the succession which can be laterally traced over a kilometre. Of varying degrees, the liquefaction has caused extensive plastic deformation of the laminae (Figure 3 *a*). In addition, later calcretization has produced cylindrical nodules due to cementation of deformed laminae. Fracture planes are prominent and also filled by calcrete. Scattered in the succession are remains of many vertebrates, namely *bovids*, *equus* (Figure 3 *b*) and elephants (Figure 4 *a*, *b*). Worked bone artefacts are also common, indicating human occupation of the site.

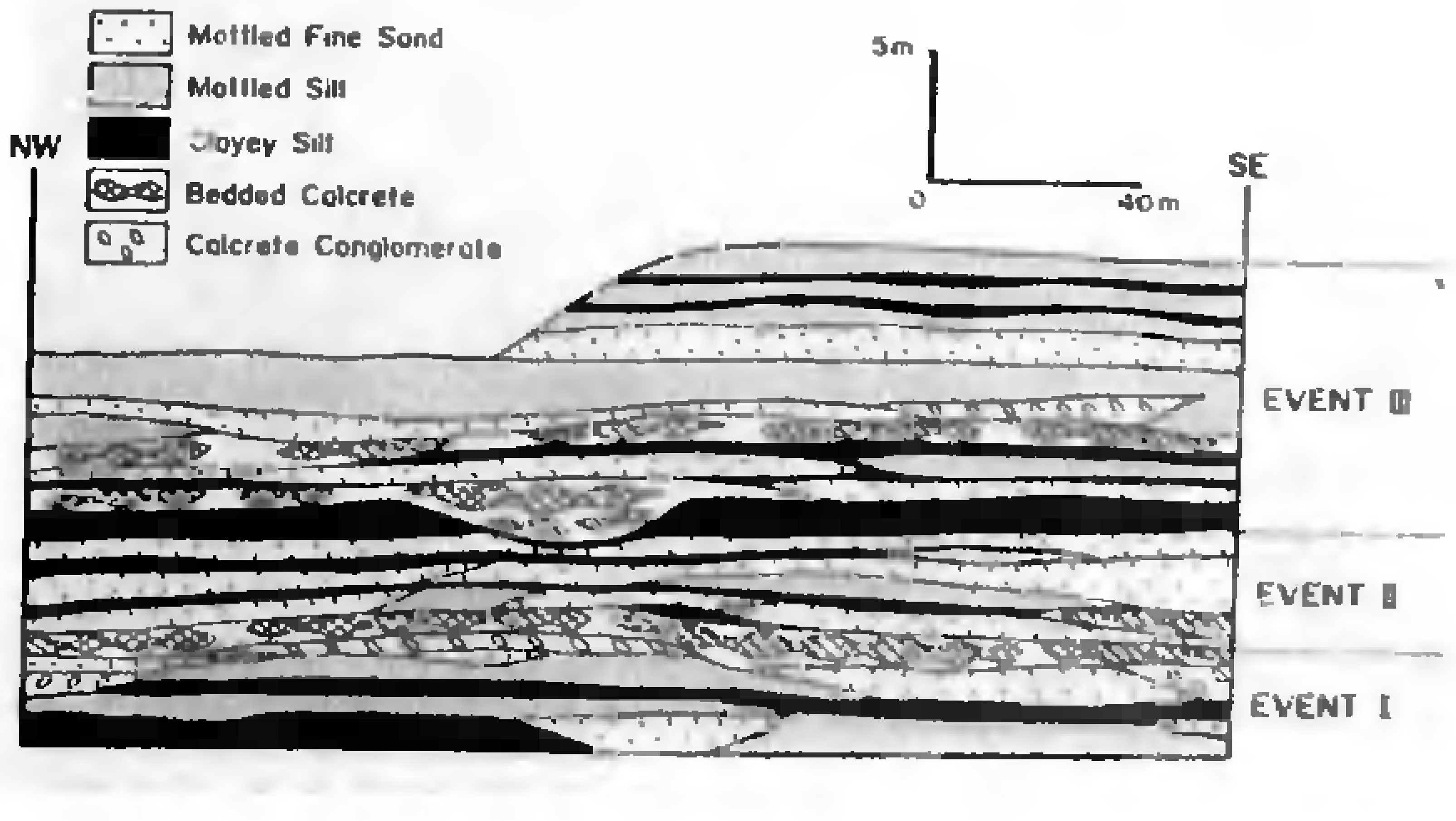

Figure 2. Lateral profile on the southern bank of Yamuna river at Kalpi. Note the three events.

Event III forms the topmost lithological unit and consists of reddish to dark brown coloured sediments. The contact between events II and III is sharp, marked by a change in the nature of sediments from grey, micaceous to reddish-brown sediments. Occasionally calcrete is found at the contact of events II and III. All the lithounits of the Kalpi section actually show development of calcrete nodules, though their relative abundance is highly variable. As in the case of event I, the sediments of event III also indicate a southern cratonic source.

The lower unit of event III contains a 2.5 m thick horizon of clayey silt, which internally shows presence of dcm thick bands of fine sand and silt. It is overlain by a succession of mottled fine sand, extensively calcretized, at times with ripple laminations. This unit shows prominent channelized basal contact and accretes laterally into a mottled fine sand unit devoid of calcrete.

Moving vertically from the lower unit, we see a thin clayey silt horizon, overlain by a 1.5 m thick horizon of mottled fine sand laterally passing into mottled silt unit. Above it there is ~ 1 m thick sheet-like bedded calcrete horizon which in turn is overlain by mottled fine sand unit laterally wedging out into a lensoid channelized horizon of reworked calcrete conglomerate. The topmost horizon (~ 5 m thick) is mainly composed of sheet-like mottled silt units with thin bands of mottled fine sand and clayey silt.

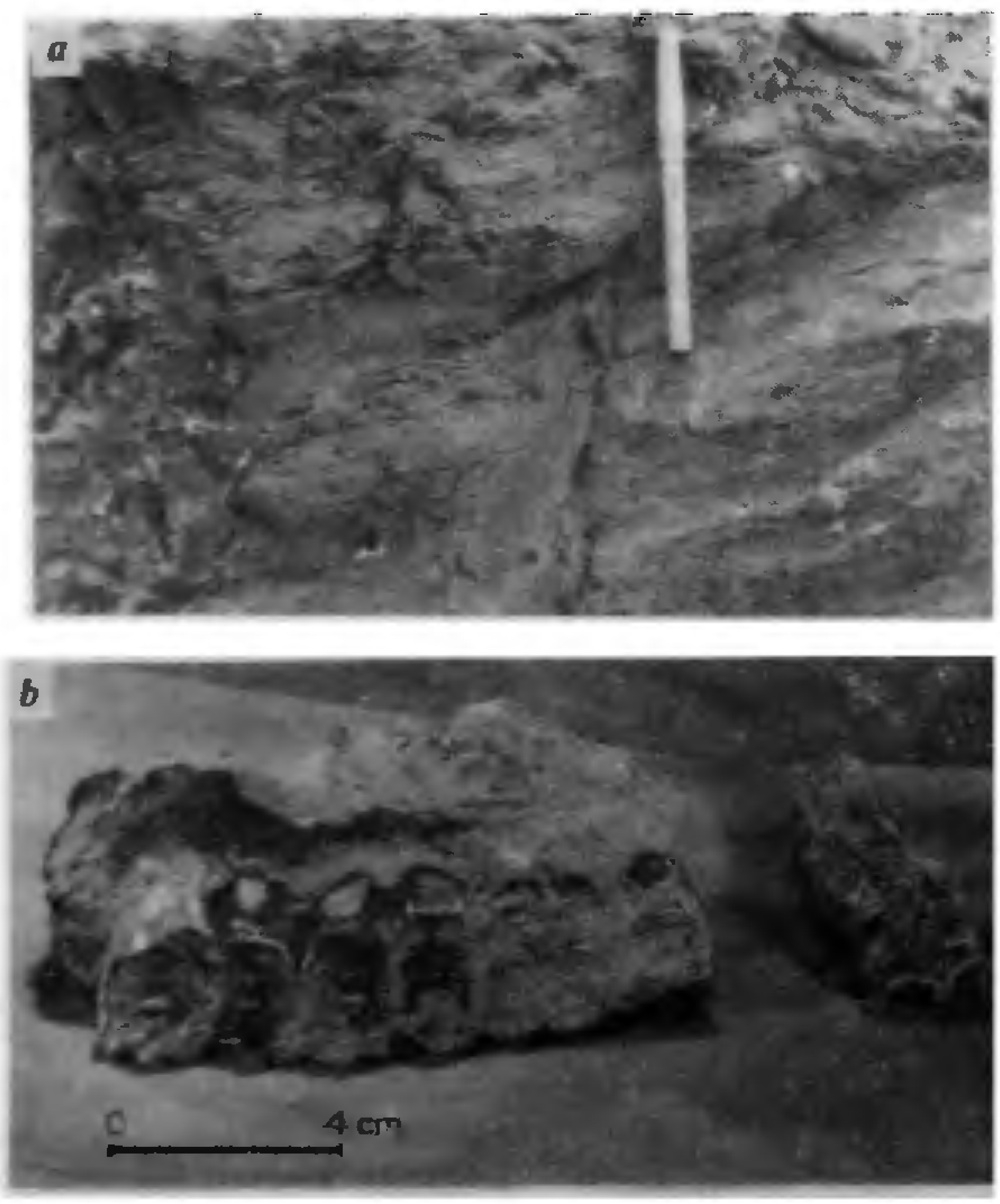

Figure 3. ***a***, Plastic deformation of laminae due to liquefaction; ***b***, molars of ***bovid*** (left) and ***equus*** (right).

The sediments of the Kalpi section are highly oxidized and do not show preservation of any organic matter, which can be dated by ^{14}C-method. On the other hand, this succession is rich in calcrete nodules throughout. These calcrete nodules seem to have been formed by groundwater soon after deposition. The dating of calcrete nodules by ^{14}C-method has several inherent problems[5,6], however, we felt dating the calcrete nodules might give us the approximate age of this succession. Two samples were dated by ^{14}C-method, using the standard procedure. One sample (BS-1322) from the upper part of event I gives an age of > 40 Ka; the other sample (BS-1323) from the lower part of event III gives an age of 28,530 + 1090 years.

The fluorine to phosphorus ratio in bones from archaeological sites are useful in obtaining approximate ages[7–9]. The various bones from event II give a 100 F/P_2O_5 ratio of 3.0–5.0, which corresponds to the age of 20–35 Ka (Kshirsagar, unpublished data).

The bone fragments from event II show signs of human workmanship which are rather crude, and seem to be of Late-Palaeolithic affinity corresponding to the above age. The present-day climate of the Kalpi region is semi-arid. However, the rich fauna of event II would demand a humid climate. During the 28–33 Ka time interval a strong monsoon in India and south Asia prevailed; hence more humid climate[10,11].

Although the precise dating of event II is not yet available, the evidence seems to indicate its deposition during the humid climate event of 28–33 Ka.

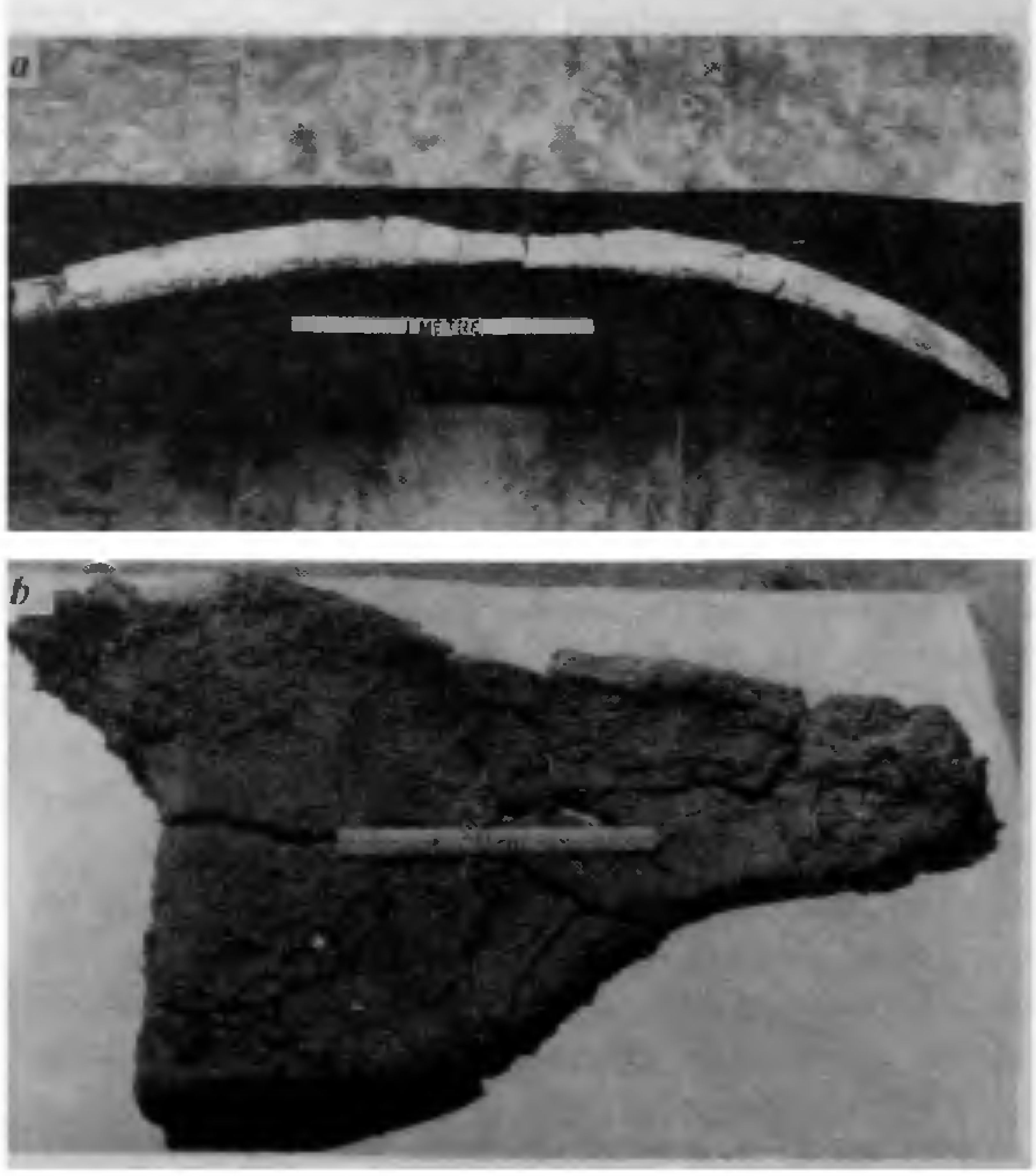

Figure 4. ***a***, A 3.54 m long elephant tusk; ***b***, One-m-long shoulder blade of elephant.

The sediments of event II yield several skeletal parts of vertebrate animals. The most remarkable is the 3.54 m long tusk of an elephant, although about 10 cm of a proximal part has been lost during excavation. The tusk is totally recrystallized and replaced by secondary carbonate (Figure 4 *a*). It has a maximum diameter of 17 cm, and shows a well-preserved root canal and the tip. A 1 m long shoulder blade of an elephant (Figure 4 *b*) has also been recovered, which is also recrystallized. In addition, a number of bone pieces and molars of *bovids*, *equus* (Figure 3 *b*) and *bos* have also been recovered.

The fine, sandy lithofacies of event II after few hundred metres laterally merges into a horizon of calcrete conglomerate, and due to warping, this horizon is exposed in the river bed. Fluvial action has loosened the sediments of this horizon exposing a large number of vertebrate fossil bones including molars of *equus*, *elephas*, *bos*, *bovids*, hippopotamus, and skeletal parts of crocodiles and turtles.

As previously mentioned, a large number of bone fragments exhibiting evidence of human workmanship appeared in event II. For example, a bone splinter with black patina and three parallel lines (perhaps from peeling) is shown in Figure 5 *a*. Pieces of bones with flake scars and sickle-shaped edges are common (Figure 5 *b*). Figure 5 *c* shows the distal end of a metacarpal with mid shaft and fused epiphysis of *Bos* sp.; a portion of the anterior and posterior cortex of the bone has been peeled off. This material clearly indicates that humans used this site and made various tools out of the bones.

In the channel bar sediments, along with the vertebrate fossils, several specimens of human femur also have been found. The femur bones display cut marks at the distal end resembling pencil sharpening, which have been neatly made and polished (Figure 6). Workmanship on the femurs was done before they were completely dried; otherwise a breaking pattern would have developed.

The three events identified in the Late-Quaternary succession of the Kalpi section represent changes in the climate and source of material. The sediments of event I represent deposition in the interfluve areas under semi-arid climate when only sediments from the southern peninsular source were supplied. The presence of channelized calcrete conglomerates near the top of event I may represent an increase in rainfall.

Brought by some northern river, the sediments of event II were deposited in a rather humid climate, as evidenced by low degree of oxidation of the sediments, and the presence of rich vertebrate fauna indicative of swampy region with a humid climate. These animals attracted the human hunters who occupied this area. This is the oldest record of human occupation of Ganga Plain alluvium. At the end of deposition of event II,

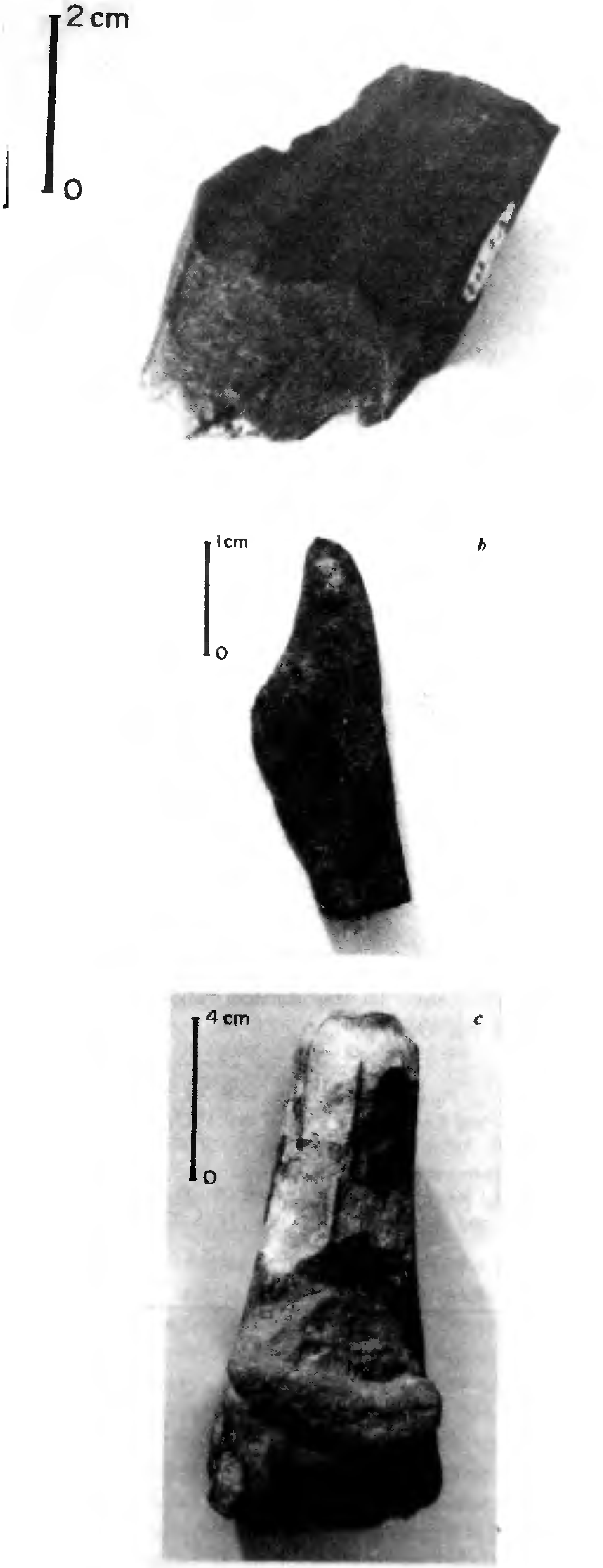

Figure 5. *a*, A bone splinter showing peeling effect; *b*, A piece of bone with sickle-shaped edge; *c*, Distal end of metacarpal showing peeling effect.

Figure 6. Femur bones showing cut marks at distal ends resembling pencil sharpening.

the area experienced intense seismic activity, which led to the liquefaction of this sequence. We believe the age of this seismic event to be ca. 28 Ka, before the deposition of event III.

Finally, the deposition of sediments of event III marks a change in the source of sediments, i.e. from the southern peninsular region. The lower part shows many channels and may have been deposited in a somewhat humid climate; later, conditions became semi-arid. A detailed analysis of these sediments may provide information on the climatic changes during Late Pleistocene–Holocene in the Ganga Plain.

The blackening effect and human workmanship on the bones from sediments of event II, and pencil sharpening features on human femurs from the reworked calcrete conglomerate are unique features and need careful study since this is the earliest sign of human occupation in the Ganga Plain.

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