known source in northwest Gujarat. The evidence of an isolated palaeoliquefaction feature itself does not constitute the proof for an independent source near Bet Dwarka. A systematic survey of the area has not been made yet, to search for similar structures from the nearby areas. Therefore, validity of our postulation of an independent large seismic source either in the Gulf of Kachchh or the onshore region is contingent upon the discovery of several coeval liquefaction features of comparable dimensions at least within the 30–50 km radius of Dwarka that will satisfy Obermeier's (ref. 8) fourth caveat, as discussed earlier. On the other hand, if the frequency and size of contemporary features tend to increase away from this location, it would argue for a distant source. We, therefore, emphasize the need to conduct more studies to define this seismic source and constrain the earthquake chronology. Occurrence of an earthquake about 2000 years ago from an unknown source poses new questions on future hazard in the region.

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Human settlement of the last glaciation on the Tibetan plateau

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An archaeological site with 19 handprints and footprints of *Homo sapiens* and the remnant of a fireplace have been found on hot spring travertine at an elevation of 4200 m on the Tibetan plateau. The prints were pressed on soft travertine by humans. The age of the prints and fireplace is estimated to be around 20,000 years using the optically stimulated luminescence method. The result suggests that humans came to the plateau much earlier than was previously thought. This evidence of human settlement implies that the Tibetans occupy high plateau much earlier than the Andeans and the ice sheet did not cover the entire Tibetan plateau during the Last Glacial Maximum.

The literature-recorded history of Tibet is 1400 years old. Archaeological findings of prehistoric remnants are rare on this plateau[1] because of lack of archaeological field expedition. In some geoscience expeditions, different stone tools have been found in central, north and western Tibet without dating information[2,3]. Only an archaeological site on the northern plateau was dated as 4000 years with Palaeolithic tools. Some authors considered that the civilization progression on the plateau was behind the

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surrounding areas[4]. A Neolithic remnant was discovered on the wet and warm eastern slope of the plateau in 1977. The remnant is located at an elevation of 3100 m and dated as 4690 ± 150 years BP[3]. Therefore, Bowles believed that the Tibetans immigrated from other places to the plateau in the late Neolithic age[5].

An archaeological site has been found in the central Tibet by the first author, which is located on the slope of a mountain near the Quesang River (90°57′E and 30°3′N), about 85 km from the Tibetan capital, Lhasa. The slope is covered by layered calcareous travertine with many remnants of hot spring outlets. The travertine is chemical deposition of hot spring and the thickness of the travertine layers ranges[5] from several centimeters to 30 m. Nineteen handprints and footprints and a remnant of fireplace were found on surfaces of the layers (Figures 1 and 2), which is 30–50 m from a present hot spring outlet at an elevation of 4200 m. The prints can be divided into two groups; one group is shallow casts with a depth of 2–3 mm on a 21° slope and another one deep casts with a depth of 4–7 mm on a 6° slope. The two groups are separated by a fault. The shallow group is on the downcast of the fault. The toes of human feet on the shallow casts can be easily identified (Figure 1). The bottoms of the deep casts are often covered by moss and soil, which makes the casts very obvious but the details of toes cannot be seen. Obviously the deep casts suffered much weathering than the shallow casts. Because they developed on the same layer of travertine, they might experience different exposing periods.

In order to date the formation period of the prints, the origin of the prints must be investigated. Two possible causes may bring about the formation of the prints: art carving and human hand and foot press when travertine was soft. A damaged handprint has been found and the lower part of the palm press still remains. The thin-section across lower part of palm of the print has been made and the layering structure can be clearly seen (Figure 3). It is obvious that the curved surface layer with handprint is continuous and is not cut by carving. The morphology of the prints also matches perfectly the anatomic characteristics of human hands and feet. Therefore, the possibility of art carving may be rejected and the prints seem to be the moulds of human hands and feet.

It is impossible that humans can press hands and feet on the hard travertine layer to form the prints. Therefore, the possible time for print formation is when the travertine was soft. From current water pools of the hot spring on slope near the site (200 m away), it can be observed that calcite mud is depositing at bottoms of the pools. At the edges of the pools the mud is hardened because of dehydration. The first author pressed his hands on the mud in 1998 and a hard mould of the hand was formed on the travertine in 2000. From this experiment and the observation, it can be concluded that formation period of the prints is basically the same as that of the

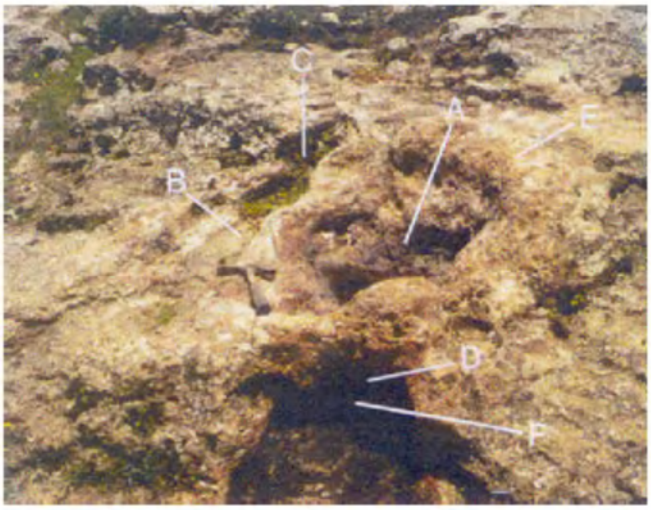

Figure 2. The fireplace A, Dug hearth; B, broken flue; C, flue outlet; D, entrance of flue; E, edge of hearth, made of calcite mud; and F, firewood loading tunnel.

Figure 1. A group of handprints and footprints on spring travertine layer.

Figure 3. Curved beddings caused by hand palm press (handprint).

travertine. The calcite mud is the chemical deposition of the hot spring water that contains a high concentration of Ca^{2+} (137 mg l^{-1}), CO_2 (285 mg l^{-1}) and other elements (Mg, Na, K, S, Li, B and U). When the water flows downslope and high concentration of CO_2 in water is released into the air, the water becomes supersaturated with respect to calcite. Then calcite is deposited in the form of mud. This is because the highly supersaturated water can create many nuclei of calcite crystals in water and these nuclei receive their own deposition separately. When the nuclei grow bigger, they settle down at the bottom of water pool to form a layer of mud. Current measurement shows that total concentration of Ca^{2+} of the spring water at the bottom of the slope has reduced to one third of its original concentration at the spring outlet.

The formation processes of the handprints and footprints, therefore, can be shown by the following steps. When the ancient humans pressed their hands and feet on the newly formed mud, the moulds of their hands and feet were formed on the mud. As soon as the mud was dehydrated, it turned into hard calcareous travertine. The moulds were covered by new travertine layer lately because the covering layer on the prints was found near a group of shallow casts, which have been used as construction materials by local people in 1999. The different periods of cast exposition of the two groups can be demonstrated by weathering degree of the prints. The deep casts have a longer exposition period than the shallow one because of higher weathering degree. The cause of the exposition is a geomorphological process. Because the incision of slope gully, the unconsolidated sediments under travertine layers were eroded away and the travertine layers collapsed and formed a fault between the two groups. The new travertine layer that covers the prints slid away because of formation of steeper slope angle and the prints were exposed to air to receive weathering. However, the times of exposition need to be investigated in future.

Nineteen prints, some of them deliberately pressed (Figure 1), were concentrated on a small area near the current spring outlet. The shapes of most of the handprints and footprints are relatively well preserved and their morphological characters can be observed clearly and measured (Table 1). From their morphological characters, at least six individuals can be identified, including two children. Two hands (21.2 cm long) and two feet (27 and 26 cm long) are larger than the average hand and foot sizes of the present Tibetan males.

A well-structured fireplace (Figure 2) was discovered 4 m away from a group of the prints. It is partially damaged but the basic structure is preserved. The fireplace was used and the inner wall was burnt to reddish-brown (Figure 2 *A*). The fireplace was first excavated in the travertine layer and then unconsolidated calcite mud was used to make the upper edge (Figure 2 *E*) of the fireplace and its chimney system. The chimney system starts at the ceiling of the firewood loading tunnel (Figure 2 *F*) at left side of the fireplace (Figure 2 *D*), and negative pressure in the flue (Figure 2 *B*) sucks the smoke to the back of the fireplace (Figure 2 *C*) to be released away from the person using the fireplace. Such a complicated and smart structure has not been seen at the fireplaces of the Neolithic sites found around the plateau, which were simply made of stone pieces without chimney. There might be a

Table 1. General morphological characters of the footprints and handprints on travertine layers

Foot print	Length (cm)	Left/right foot	Hand print	Length (cm)	Left/right foot
F1	25	Left	H1	21.2	Right
F2	25.3	Right	H2	19.1	Right
F3	22.5	Left	H3	21.1	Left
F4	20.5	Right	H4	16	Right
F5	24.8	Right	H5	13.4	Right
F6	22	Left	H6	21.2	Right
F7	19.2	Right	H7	18	Right
F10	21.5	Left	H8	16	Right
F11	17.5	Right			
F12	27	Right			
F13	26	Right			

Table 2. Dose rates, palaeodoses and optical dates for quartz grains in travertine (ref. 11)

Sample code	Location	Alpha counting rate*	Dose rate (Gy/ka)	Palaeodose (Gy)	Optical age (kyr)
XZI	Fireplace	1.65 ± 0.07	0.88 ± 0.094	18.1 ± 1.7	20.6 ± 2.9
XZ2	Print 1	1.43 ± 0.07	0.824 ± 0.055	17.4 ± 1.3	21.1 ± 2.1
XZ3	Print 2	1.45 ± 0.06	0.784 ± 0.054	17.0 ± 1.2	21.7 ± 2.2

*The alpha counting rate is for 42 mm in diameter ZnS screen in unit of count per kilo second.

shelter around the area because small dug holes in sinter were found nearby and some broken pieces of travertine beds are scattered on the ground, which might be part of the construction materials of a shelter wall. It seems that this place was used as a campsite or home base because the hot spring could provide a better living condition for *Homo sapiens* on this frigid and arid plateau.

Based on the above examinations, the materials from the travertine layer with the prints and the inner wall could be dated by certain dating techniques. The samples for dating were taken from the surface travertine layer on different print locations, and from the inner wall of the used fireplace. Initial study with the U-series dating method indicates that the travertine was not a close system with addition of detrital thorium content from dust, though the uranium content is only 0.057 ppm (D.C. Ford, pers. commun.). The wood ash in the fireplace was seriously contaminated as soil's vegetation were mixed in it. Optical dating of quartz grains in the deposits may be the only suitable method for such materials[7,8], as strong winds in arid and cold plateau can provide abundant well-bleached quartz grains that are very suitable for optical dating[9]. The luminescence dating method is particularly adaptable for the samples collected from the inner wall of the stove because the clock was reset when using fire[10].

The ages obtained with optical dating were 21.1 ± 2.1 and 21.7 ± 2.1 kyr for two travertine samples from two separated print places respectively and 20.6 ± 2.9 kyr for baked samples in the fireplace (Table 2). Similar ages obtained from heated and unheated samples rule out the possibility of age overestimation due to incomplete bleaching of OSL signals prior to deposition[11]. Even for the smallest De value measured from all the three samples, the corresponding age is also in the Last Glacial Maximum (LGM).

The dates suggest that the prints and the fireplace were formed in the same period with consideration of the dating error. The site is the oldest archaeological site on the plateau, indicating that human settlement on the plateau took place much earlier than previously thought. From the skills of fireplace construction, it suggests that human evolution on the plateau is not behind the surrounding areas, but is at least simultaneous with that in the areas. The finding also indicates that *Homo sapiens* could adapt to a very cold environment. The annual average temperature of this site was – 1°C to – 3°C during the last glaciation according to the oxygen isotope record[12]. Because the ages of the prints and fireplace are within the LGM, human settlement challenges the hypothesis that an ice sheet with huge thickness covered the entire plateau in the LGM[13–15]. However, the finding agrees with recent discoveries that the Tibetan plateau was too dry to support ice expansion in the LGM[16–19]. The find also contributes to human evolution and adaptation theory. Human genetic studies show that the Tibetans are more adapted than the Andeans to high elevation because of less admixture or constriction of their gene pool, and they might have lived on the high plateau for 25,000 years – about 14,000 years earlier than the Andeans[20]. However, the theory needed support from archaeology[21]. This discovery has provided a chronometrically proofed archaeological site to fill the gap of the genetic theory on human evolution of high plateau population.

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