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The earliest well-dated archeological site in the hyper-arid Tarim Basin and its implications for prehistoric human migration and climatic change

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ABSTRACT

The routes and timing of human occupation of the Tibetan Plateau (TP) are crucial for understanding the evolution of Tibetan populations and associated paleoclimatic conditions. Many archeological sites have been found in/around the Tarim Basin, on the northern margin of the Tibetan Plateau. Unfortunately, most of these sites are surface sites and cannot be directly dated. Their ages can only be estimated based on imprecise artifact comparisons. We recently found and dated an archeological site on a terrace along the Keriya River. Our ages indicate that the site was occupied at ~7.0–7.6 ka, making it the earliest well-dated archeological site yet identified in the Tarim Basin. This suggests that early human foragers migrated into this region prior to ~7.0–7.6 ka during the early to mid-Holocene climatic optimum, which may have provided the impetus for populating the region. We hypothesize that the Keriya River, together with the other rivers originating from the TP, may have served as access routes onto the TP for early human foragers. These rivers may also have served as stepping stones for migration further west into the now hyper-arid regions of the Tarim Basin, leading ultimately to the development of the Silk Road.

Introduction

It has been suggested that there were three processes for the occupation of the interior high Tibetan Plateau (TP) (Brantingham et al., 2003; Brantingham and Gao, 2006; Brantingham et al., 2007). These processes involved an initial colonization of lowland zones below 3000 m a.s.l. (such as Gansu, Inner Mongolia and the Xinjiang desert region), the colonization of a middle-elevation zone between 3000 and 4000 m a.s.l., and finally the colonization of the high plateau (>4000 m). The Tarim Basin (TB), to the north of the TP and with elevations of only 800–1200 m (Fig. 1), was likely an important region supporting initial human migration to the higher TP. Relatively abundant resources in the foothills of the western Kunlun Mountains in the transition zone between the TB and the Chang Tang region of the northern TP may have supported the upslope expansion of these early populations. This region is also where the famous Silk Road, supporting communication and human commercial trade between the East and the West, developed during the Holocene. Therefore, studies of archeological sites in and around the TB are crucial for the reconstruction of both cultural evolution and climatic change in this hyper-arid inland Asian area.

Over the last several decades, a large number of prehistoric archeological sites have been found in the TB. However, most of the sites are lag deposits on the modern ground surface, and thus offer no absolute ages. Sites thought to date to the early Neolithic have chronologies based on artifact characteristics and geomorphological setting, rather than on direct dating. Such sites include the Bash Sura site (Wang and Zhang, 1988), the Yeniuquan site (Taklimakan Desert archaeology group, 1990), the Qiemo (Yidilis, 1993), the Ashikule site (Huang and Wu, 1991), Kaerdun site (Taklimakan Desert archaeology group, 1990) and some sites found by Huang et al. (1988) on Yurungkash River, Niya River as well as Keriya River (see Fig. 1 for locations). There are, however, also a number of sites dated to the late

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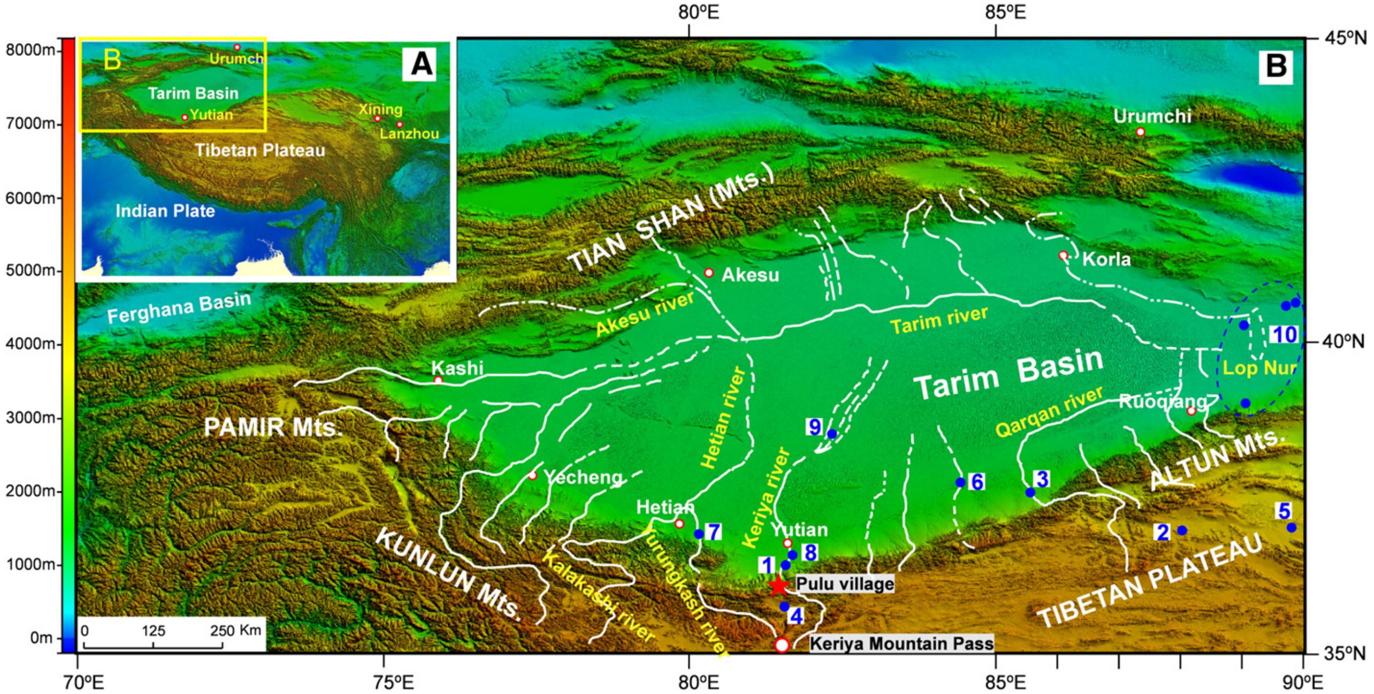

Figure. 1. Map showing the physical geography of the Tarim Basin, the location of the study site (red star), and some main rivers flowing into the Tarim Basin. Note: The blue solid circles are archeological sites in Tarim Basin: 1) Bash Sura site (Wang and Zhang, 1988); 2) Yeniuquan site (Taklimakan Desert archaeology group, 1990); 3) Qiemo site (Huang and Wu, 1991); 4) Ashikule site (Yidilis, 1993); 5) Kaerdun site (Taklimakan Desert archaeology group, 1990) and some sites found by Huang et al. (1988) on Niya River (6) Yurungkash River (7), as well as Keriya River (8); 9) site located on end areas of the Keriya River (Zhang et al., 2011) and sites around the Lop Nur region (10) (Lü et al., 2010).

Neolithic period (e.g., Debaine-Francfort, 1988; Lü et al., 2010; Zhang et al., 2011). As a result, the timing of the prehistoric occupation of the TB is still unclear, hindered by the lack of directly dated sites, especially for the sites of the earliest stage of human occupation.

We recently found and investigated a hearth on the bottom of an 18.1 m eolian sequence situated on a terrace of the Keriya River, a large river in the TP–TB transition zone that flows into the Taklimakan Desert (Fig. 1). Stone tools, a large number of bones, and charcoal, were associated with the hearth, providing an opportunity to precisely date the age of these artifacts and place constraints on cultural change in the region and on the climatic conditions that accompanied that change.

Previous studies have demonstrated the suitability of OSL and ^{14}C dating to determine the age of archeological sites in the TB (e.g., Zhang et al., 2011) as well as the TP (e.g., Madsen et al., 2006; Hou et al., 2012; Sun et al., 2012). Here we apply OSL and ^{14}C dating to provide a systemic chronological framework for this archeological site, and discuss the timing and possible routes of early human migration/occupation in the region in relation to corresponding paleoclimatic conditions.

Geological setting, section and samples

The TB, a large endorheic basin in northwestern China, is dominated by the Taklimakan Desert, the world's second largest dune field (Fig. 1). It is bordered by the Pamir Mountains to the west, the Tian Shan Mountains to the north, and the Kunlun Mountains to the south (Fig. 1). Due to its location north of the TP, the basin is characterized by hyper-arid conditions, with mean annual temperatures of 9–11°C and mean annual precipitation (MAP) of $<$100 mm ($<$50 mm in most places). The interior of the basin is an average of 800–1300 m a.s.l., with surrounding mountains exceeding 4000 m a.s.l. Glacier-fed streams transport clastic sediments from these high mountains into the basin, leading, over time, to the creation of huge alluvial fans along the foothills of these surrounding mountains. Superimposed on these fan surfaces and fan-derived river terraces are widely-distributed eolian sediments derived from the Taklimakan Desert (Liu, 1985; Fang et al., 2002a,b; Sun, 2002).

The Kunlun Mountains constitute the watershed between the TP and TB. Many rivers, originating in the western Kunlun Mountains on the northern margin of the TP, feed northwards into the Taklimakan Desert, connecting the TP and the TB. The Keriya River, located on the south-central TB margin, is one of these, and it originated from the Keriya (7176 m) and Qiongmuzitage (6920 m) peaks of the Kunlun Mountains (Fig. 1). The two main branches of the Keriya River, the Wugeyeke River and the Kulapu River, cross the steep upper slopes of the mountains and converge at Pulu village. The river then flows northward through the alluvial/fluvial plain and vanishes into the Taklimakan Desert. The full length of the Keriya River is about 800 km.

The Yangchang (YC) eolian section (36°13′8.8″ N, 81°31′14″ E, 2440 a.s.l.) in the village of Pulu is situated on the fifth terrace of the Keriya River (Fig. 2). There are a series of terraces on both sides of the Keriya River in the YC region. The observed highest terrace is at least 130 m higher than the modern river bed, and a hearth was found on the fifth terrace on the left bank of the Keriya River. The fluvial gravel layer is 8–10 m thick and 50 m above the modern river bed. The fluvial sand and 18.1 m thick eolian sediments, mainly composed of sandy loess bracketing a light brown weak paleosol, overlie on the gravels. A roughly circular (100 cm dia.) 15 cm thick hearth was found in the lower part of the loess section about 1 m above the fluvial gravels (17.1–17.25 m in depth) (Fig. 2).

A variety of artifacts including flakes, scrapers, and blades made from white quartzite were recovered from this hearth (Figs. 2 and 3). Some blades are long, with one blade measuring 54 mm in length (Fig. 3D). This production of abnormally large blades appears to be a characteristic of the early Holocene occupation of the northern TP. Recent work by Brantingham et al. (2013) in the eastern Kunlun Mountains area of the northern Tibetan Plateau suggests that such

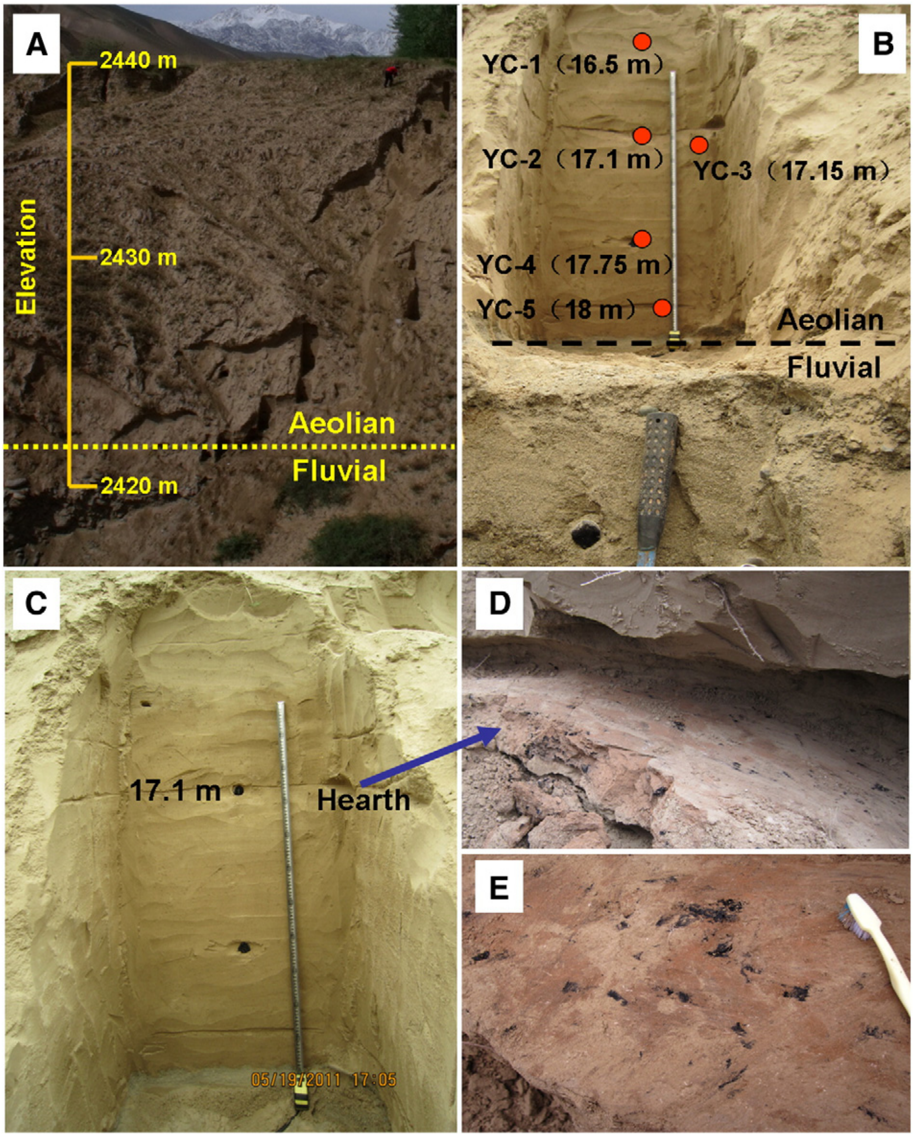

Figure. 2. (A, B) Photos showing the Yangchang loess section and the locations of the OSL samples. (C–E) The hearth found in the lower part of the section (17.1–17.25 m in depth).

blades are "…*technologically different from the Levallois-like flat-faced blade technology seen at Shuidonggou and other northeast Asian early Upper Paleolithic sites…We now believe…that this large blade and bladelet technology…is derived from microblade core reduction strategies. Indeed, in many respects, the large blades of the Chang Tang are simply "scaled-up" microblades*". Although the collection of stone tools from the Yangchang site in the foothills of the western Kunlun Mountains is small, it is remarkably similar to those in collections made by Brantingham et al. (2013) and suggests a link between the two regions during the early-to-mid Holocene.

The splintered bones are yet unidentified, but appear to be derived from small-to-medium-sized mammals. The sediments around the hearth are brownish red in color, probably due to heat oxidation. The hearth contains a large amount of broken and burned bone, as well as numerous large charcoal fragments. Five OSL samples were collected in and around the hearth (Fig. 2 and Table 1) to obtain a systemic OSL chronology for this hearth: one stratigraphically above the hearth at a depth of 16.5 m, two below the hearth at depths of 17.75 and 18.0 m, one in the hearth at 17.15 m, and another ca. 1 m away from the hearth at 17.0 m. Additionally, two bones and two charcoal fragments were collected from the hearth for ^{14}C dating to cross-check the OSL ages (Table 2). Three charcoal fragments with diameters larger than 2 cm were collected for plant identification.

OSL and ^{14}C dating

OSL dating

OSL samples were collected by hammering steel tubes (about 22 cm long cylinder with a diameter of 4 cm) into freshly-cleaned sections. In the laboratory, we scraped the sediments (~2–4 cm) at each end of the tube for dose rate measurement. The unexposed materials in the middle part of the tube were used to extract quartz for equivalent dose (D_e) determination. The grain size fraction of 38–63 μm was extracted using wet sieving after 10% HCl and 30% H_2O_2 treatment to remove carbonates and organics, respectively. The grains were then etched by 35% fluorosilicic acid for about two weeks to dissolve feldspars (Roberts, 2007; Lai and Brückner, 2008), and then washed with 10% HCl to remove fluoride precipitates. In order to avoid age underestimation caused by feldspar contamination, the purity of the isolated quartz was checked by infrared (IR, 830 nm) stimulation. The results show that no obvious IRSL signals were observed in our samples. Quartz

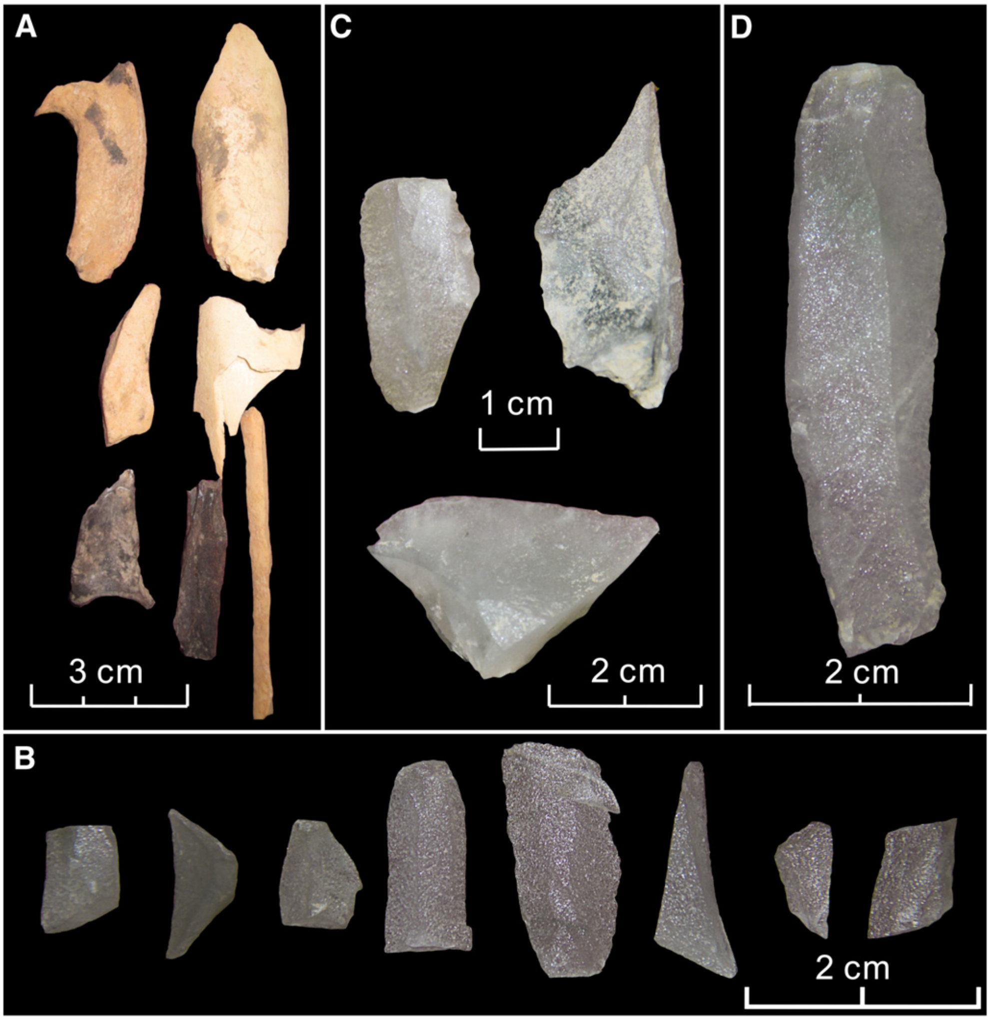

Figure. 3. Artifacts associated with the Yangchang hearth: (A) unidentified faunal remains, (B) unmodified flakes and blade flakes, (C) edge-modified white quartzite flake scrapers and (D) large microblade. Scales are in cm.

grains were then fixed onto the center (diameter of 0.5 cm) of stainless steel discs (with a diameter of 1 cm) using silicone oil.

Experiments were performed using an automated Risø TL/OSL-DA-20 reader at the Luminescence Dating Laboratory of Qinghai Institute of Salt Lakes, Chinese Academic Sciences. A preheat plateau test was conducted on sample YC-3 to determine the preheat temperature. The test temperatures were at 220, 240, 260, 280, and 300°C, respectively, and four aliquots were used at each preheat temperature. A plateau of D_es was clearly identified from preheat temperatures of 220–280°C. Therefore, preheat at 260°C for 10 s was chosen for natural and regenerative doses, and a cut-heat at 220°C for 10 s for test doses. The luminescence was stimulated using blue LEDs ($\lambda = 470 \pm 20$ nm) for 40 s at

Table 1
OSL dating results for five samples from the YC section.

Sample ID	Depth (m)	U (ppm)	Th (ppm)	K (%)	Water content (%)	Dose rate (Gy/ka)	D_e (Gy)	OSL age (ka)
YC-1	16.50	2.91 ± 0.19	9.75 ± 0.34	1.71 ± 0.09	5 ± 2	3.26 ± 0.18	22.5 ± 0.3	6.90 ± 0.40
YC-2	17.10	3.05 ± 0.19	9.05 ± 0.24	1.70 ± 0.06	5 ± 2	3.20 ± 0.16	24.7 ± 0.4	7.72 ± 0.41
YC-3	17.15	2.73 ± 0.18	9.81 ± 0.33	1.72 ± 0.09	5 ± 2	3.21 ± 0.18	25.6 ± 0.5	7.98 ± 0.47
YC-4	17.75	2.71 ± 0.15	9.69 ± 0.32	1.67 ± 0.09	5 ± 2	3.14 ± 0.17	25.7 ± 1.1	8.17 ± 0.57
YC-5	18.00	2.95 ± 0.17	10.48 ± 0.28	1.73 ± 0.06	5 ± 2	3.33 ± 0.17	28.2 ± 0.6	8.46 ± 0.46

Table 2
Radiocarbon dating results for four samples from the hearth in the YC section.

Sample ID	Lab number	Depth (m)	Dating material (dating method)	^{14}C age (yr BP)	Cal. age (2σ) (cal yr BP)
YC 1		17.15	Charcoal (conventional ^{14}C dating)	6510 ± 70	7564–7279
YC 2	BA110720	17.10	Charcoal (AMS ^{14}C dating)	6220 ± 45	7253–7006
YC 3	BA110721	17.10	Bone (AMS ^{14}C dating)	6280 ± 60	7409–7006
YC 4	BA110722	17.15	Bone (AMS ^{14}C dating)	6220 ± 70	7276–6942

130°C and detected using a 7.5 mm thick U-340 filter (detection window 275–390 nm) in front of the photomultiplier tube. Irradiations were carried out using a ^{90}Sr/^{90}Y beta source built into the Risø reader.

Equivalent dose (D_e) was measured using the Single Aliquot Regeneration (SAR) (Murray and Wintle, 2000) protocol. For each sample, 12–18 aliquots were measured. The final D_e for a sample is the average of all the 12–18 D_es. OSL dating results are listed in Table 1.

Fig. 4 displays the OSL decay curve (A), growth curve (B) and D_e distribution (C) for sample YC-2 (17.1 m). The OSL signal decayed very quickly within the first second of stimulation, indicating that the signals are dominated by the fast component. The signals of the first 0.64 s stimulation were integrated for growth curve construction. The thermal transfer effect was tested by comparing the sensitivity-corrected OSL signals of 0 Gy to the sensitivity-corrected nature signals (Fig. 4A) for each aliquot, and this ratio is in general as low as <3% which is negligible. The recycling ratios for five samples are within 10% of unity (0.9–1.1).

The dose recovery test was applied to the YC-3 (17.15 m) to test the validity of the SAR protocol (Murray and Wintle, 2003). Six aliquots were bleached with blue LED for 100 s. A laboratory dose of 20 Gy was then given, followed by SAR measurements to determine the D_e of each aliquot. The measured mean D_e value was 19.1 ± 1.16 Gy. Therefore, the ratio between the given and measured doses was 0.955 ± 0.058, indicating that SAR protocol is suitable for the D_e estimation of samples from the archeological sites.

The concentrations of U, Th, and K were measured by Neutron Activation Analysis at the China Institute of Atomic Energy in Beijing, China. The alpha efficiency was taken as 0.035 ± 0.003 (Lai et al., 2008). The cosmic-ray dose rate was estimated for each sample as a function of depth, altitude and geomagnetic latitude (Prescott and Hutton, 1994). The water content was taken as 5 ± 2% for all samples. Conversion factors used in dose rate calculation are based on Adamiec and Aitken (1998).

^{14}C dating

The charcoal and bones found in the hearth are suitable for ^{14}C dating, and both AMS ^{14}C dating and conventional ^{14}C dating are applied in this study. One charcoal (YC 2) and two bone samples (YC 3 and YC 4) from 17.1 to 17.15 m were dated by AMS ^{14}C dating in the Radiocarbon Dating Laboratory of Peking University, and one charcoal sample from 17.15 m (YC 1) was dated by conventional ^{14}C in the Radiocarbon Dating Laboratory of Lanzhou University. All radiocarbon dates were calibrated to calendar year (cal yr BP) using OxCal 4.2 program (Bronk Ramsey, 2009) with INTCAL13 model (Reimer et al., 2013).

Dating results

OSL ages with their D_e values are given in Table 1. The ages of the five samples from depths of 16.5, 17.1, 17.15, 17.75 and 18.0 m are 6.90 ± 0.40, 7.72 ± 0.41, 7.98 ± 0.47, 8.17 ± 0.57 and 8.46 ± 0.46 ka, respectively. All these ages are in accord with their stratigraphic order. The two samples taken at the same depth as the hearth, at depths of 17.1 and 17.15 m, indicate that the OSL age of the hearth can be considered to be ~7.72 ± 0.41 to 7.98 ± 0.47 ka.

The details of the ^{14}C samples and the dating results are listed in Table 2. The ^{14}C results for the two charcoal fragments and two bone samples from the hearth are 6510 ± 70 ^{14}C yr BP, 6220 ± 45 ^{14}C yr BP (BA110720), 6280 ± 60 ^{14}C yr BP (BA110721) and 6220 ± 70 ^{14}C yr BP (BA110722), and their corresponding calibrated calendar ages are 7279–7564, 7006–7253, 7006–7409 and 6942–7276 cal yr BP, respectively (Table 2). The three AMS ^{14}C dating results with different materials present overlapping age ranges. Therefore, an age of 6942–7564 cal yr BP for the hearth is indicated by the ^{14}C dating results.

The OSL ages compare well with the ^{14}C ages within one sigma error, although the OSL ages appear a little older than the ^{14}C ages, demonstrating that both OSL and ^{14}C dating are suitable for the archeological sites in the TB–TP margin. Moreover, the relevant older OSL ages reveal that these ^{14}C ages are of in situ deposition and are not affected by old carbon (e.g., woods from dead trees, ancient buildings, and tombs); therefore, the ^{14}C ages are considered to represent the age of this site, and we believe the Yangchang archeological site was populated between 7.0 and 7.6 ka.

Discussion

Chronology of early human activities in the transition zone between the Tibetan Plateau and the Tarim Basin

The OSL and ^{14}C dating results for the artifact-bearing section of the eolian profile are in relatively good agreement and suggest both methods are suitable for dating archeological sites in this region. The comparison of OSL and ^{14}C dating results has also been utilized in determining the age of archeological sites from the TP (e.g., Madsen et al., 2006; Hou et al., 2012; Sun et al., 2012), and in these studies the two methods produced suitably close results within error. As we noted, in the TB as well as in other places in Xinjiang, a large number of prehistoric sites were investigated, but no precise chronology was reported because they are surface sites, whose age estimations are based solely on comparing their geomorphologic settings and typological to well-dated sites elsewhere. For example, the Bash Sura site (1 in Fig. 1B, Wang and Zhang, 1988), situated on the third terrace of the Keriya River, contains some stone cores, scrapers and microblades, and was believed to be formed at ca. 9 ka based on artifact characteristics. The Yeniuquan Palaeolithic site (2 in Fig. 1B, Taklimakan Desert archaeology group, 1990), situated on the Altun mountain hinterland and contained some wedge microcores, scrapers and microblades, was believed to be between the late Paleolithic and early Neolithic periods based on artifact characteristics. The Qiemo site (3 in Fig. 1B, Yidilis, 1993), situated on the Qarqan river, the Ashikule site (4 in Fig. 1B,

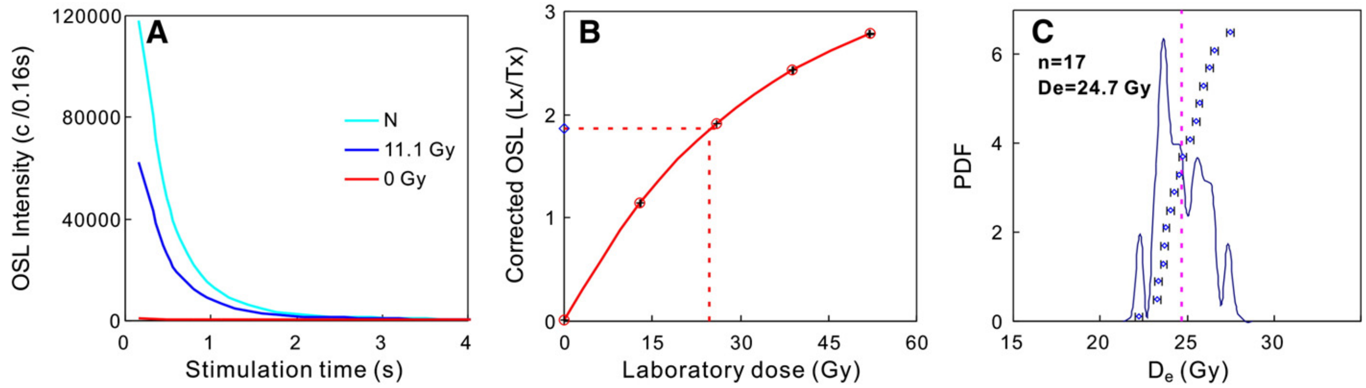

Figure. 4. OSL decay curves (A), a growth curve (B) and D_e distribution (C) for sample YC-2.

Huang and Wu, 1991), situated on alluvial fan of Kalatashi Mountain, and the Kaerdun site (5 in Fig. 1B, Taklimakan Desert archaeology group, 1990), 200 km east of Yeniuquan site, were all believed to be in the early Neolithic period based also on artifact characteristics. Some sites found by Huang et al. (1988) on terraces and alluvial fan of the Yurungkash River (6 in Fig. 1B), the Niya River (7 in Fig. 1B) as well as the Keriya River (8 in Fig. 1B) were believed to be between the late Paleolithic and early Neolithic periods based on artifact characteristics and the sediments containing the artifacts (see Fig. 1 for locations). There are also a number of sites which have precise ages, such as the site located on tail-streams of the Keriya River (9 in Fig. 1B, Zhang et al., 2011), and sites around the Lop Nur region (10 in Fig. 1B, Lü et al., 2010), however, they were only dated to be in the late Neolithic period (about 2 ka) using OSL and ^{14}C dating. This reliance on artifact comparisons means that the exact timing of early human migration into the TB, and to the transitional zone between the TP and TB, remains largely speculative.

According to our OSL and ^{14}C chronology, prehistoric human foragers must have entered this region sometime before ca. 7.0–7.6 ka. Although it is possible that evidence of earlier occupation may be found in the future, indeed likely, that evidence of earlier occupations will be found, the Yangchang archeological site is, at present, the earliest precisely dated site in the Tarim Basin and the Tarim Basin/TP transitional zone.

Paleoclimatic conditions during occupation of the Yangchang archeological site

The hearth in the Yangchang loess section is contained within a weak light brown paleosol that occurs in the section at a depth of 17–17.6 m. The paleosol is relatively fine-grained (44–55 μm) in comparison to the coarser loess characterizing the rest of the section (44–134 μm, with a 58 μm average), suggesting that it formed in a relatively more humid climate. The three charcoal fragments from the hearth were investigated microscopically using a reflecting light microscope at the Institute of Archaeology, Chinese Academy of Social Sciences. The three fragments were identified to tree and shrub species: *Populus* sp., *Tamarix* sp. and *Hippophae rhamnoides*. At present, these species grow only in the river flood plain, and even there they occur only in small sizes. The presence of these species is in accord with pollen records from Lop Nur (Wu, 1994) and from six sites in Xinjiang (Zhao et al., 2009a), which indicates that the mid-Holocene (~8.5–5 ka) period had a relatively more humid climate compared to the early and late Holocene. Multi-proxy studies of sediments from the Taitema Lake area (Zhong et al., 2005) and from Loulan (Jia et al., 2010) also suggest a humid mid-Holocene climate. Sedimentological and geochemical studies of paleoshorelines of a lake in the middle Kunlun Mountains also suggest that high lake levels occurred during the period (Li, 1992). Multi-proxy studies of sediments from the Tarim River area (Feng et al., 1999) reflect a warm and humid climate lasting from ~8.0 to 3.0 ka. Together, these proxy records from in and around the TB indicate a relatively warm and humid climate at ~8–6 ka. This local record of increased effective moisture is synchronous with a mid-Holocene humid climate identified both in regions influenced by the Asian summer monsoon (Wang et al., 2005; Zhao et al., 2009b; An et al., 2012; Yu and Lai, 2012, in press) and in regions controlled by the Westerlies (Chen et al., 2008; Zhao et al., 2009a). This broad expression of a humid climate during the mid-Holocene suggests that its principal cause was increased summer solar isolation in the Northern Hemisphere (Wang et al., 2005). The resulting wide-spread mid-Holocene enhancement of ecosystem productivity may have fostered a rapid expansion of human foragers whose subsistence economy depended on the collection of wild plants and animals, particularly in the modern arid regions of northwestern China.

Possible access routes onto the Tibetan Plateau

Brantingham and Gao (2006) (see also Brantingham et al., 2007) hypothesize that after the last glacial maximum human foragers gradually moved from low land areas in Gansu, Inner Mongolia and Xinjiang, to a middle-elevation zone around Qinghai Lake, the Qaidam Basin, and similar areas on the TP margin, before finally reaching the high TP during the early Holocene. This model has gained support from work in the Qinghai Lake and eastern Kunlun Mountains regions (Madsen et al., 2006; Rhode et al., 2007; Sun et al., 2012; Brantingham et al., 2013), but other studies have suggested other possible routes for the migration of prehistoric human forages from surrounding lowlands onto the plateau, such as from Sikkim and Nepal (Aldenderfer, 2003) to the south of the TP, from Qinghai (Su et al., 2000), one from the east up the major river valleys onto the central plateau (Ren, 2000), and, finally, one suggesting migration up the middle and upper Yangtze River valley in Sichuan on the southeastern margin of the TP (van Driem, 1998). It also seems possible that prehistoric foragers migrated to the TP from the northern TB, given that passage through the western Kunlun Mountains was likely similar to that through the eastern Kunluns and may have been easier than through the Himalayas. However, while early Holocene sites have recently been identified and dated along an eastern Kunlun Mountains route from the Qaidam Basin into the Tibetan Chang Tang (Brantingham et al., 2013), no archeological evidence supporting a western Kunlun Mountains route from the TB into the Chang Tang has been offered.

The YC loess section containing archeological remains in this study lies on a tributary of the Keriya River. The river originates in the West Kunlun Mountains and descends northwards into the Taklimakan Desert, TB, and we surmise that this might have been a possible route along which prehistoric groups migrated onto the TP. Historically, the river valley has been part of a travel route called the “Keriya Pass Road” or the “Tibet Road” that runs through North Pulu village, where the YC section is located, to the Ali region in Tibet via the Keriya Mountain Pass (Wei, 2006). This route has been a crucial trading route connecting the TP and the TB at least since the Tang Dynasty (~800 AD), and today is a well-known route for adventure tourism. One modern highway route and at least four minor roads connect the TP and the TB (Du and Tang, 2011), and all of them run through river valleys, including the Keriya River valley, which originates in the Kunlun Mountains and extends into the TB. All of them may have been possible pathways through which human foragers reached the high Tibetan Plateau. The similar production of large blades, in both the Chang Tang and the western Kunlun Mountains foothills on the TB margin, suggests such routes were being used by the early Holocene.

Conclusions

We have investigated and dated an archeological site in an eolian loess sequence from the transitional zone between the northern Tibetan Plateau and the southern Tarim Basin. Optically stimulated luminescence and ^{14}C dating of samples from in and around a hearth in the cultural deposits suggest that the site was occupied between ~7.0 and 7.6 ka. The Yangchang site is the earliest precisely dated site yet found in the southern Tarim Basin. This firmly established chronology suggests that early Holocene foragers migrated into this region at least before ~7.0–7.6 ka. The optimal climate of the early mid-Holocene may have provided a natural impetus for the expansion of human populations during this period. The location of this early site on a terrace of a major river originating in the Kunlun Mountains on the northern TP may indicate that these early human groups reached the high TP via a series of rivers that exit the Kunlun Mountains and extend into the Tarim Basin.

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