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Research paper

Luminescence dating of a hearth from the archaeological site of Jiangxigou in the Qinghai Lake area of the northeastern Qinghai-Tibetan Plateau

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ABSTRACT

Archeological research over the past several years has started to provide evidence relevant to understanding both the timing of and processes for human colonization of the high Qinghai-Tibetan Plateau. Much of this research has been in the Qinghai Lake area and the Qaidam Basin in the northeastern Qinghai-Tibetan Plateau. However, chronological data are still limited. Recently, a hearth was discovered in the Jiangxigou site in the south of the Qinghai Lake area, which was likely used by prehistoric hunters. The site is in the mouth of a canyon approximately 4.5 km from Qinghai Lake. Previous ages in this site are based on ^{14}C dating only. The current study provides additional OSL dates for the hearth. The ages of four OSL samples bracketing the hearth range from 12.9 ± 0.9 to 14.4 ± 1.0 ka, but standard deviations overlap extensively and they likely represent the same age. The OSL ages show that by about 14.3 ± 1.0 ka prehistoric peoples were living in the Qinghai Lake area.

1. Introduction

The study of prehistoric human colonization in the Qinghai-Tibetan Plateau (QTP) has been studied since the 1950s (Huang, 2005). Extreme altitude, severe climate, and scant resources, all served as effective constraints to early humans who tested the idea of living on the 'roof of the world' (Rhode et al., 2009). The Upper Paleolithic human occupation of the Qinghai Lake Basin dates back to the terminal Pleistocene, and putatively older materials have been reported in the neighboring Qaidam Basin to the west (Huang, 1994; Huang and Hou, 1998; Brantingham et al., 2007; Sun et al., 2010). Archeological research over the past several years has started to provide evidence relevant to understanding both the timing of and processes responsible for human colonization of the QTP, especially in the QingHai Lake area and the Qaidam Basin in the northeastern QTP (Brantingham et al., 2007). By the early Holocene, people had found ways to make a living in the harsh QTP environment above 4500 m and other high-elevation plateaus in other parts of the world (Aldenderfer, 2003, 2006). The QTP ranks among the most challenging terrestrial habitats on earth for human occupation. An important step in this process of adjustment to life on the high QTP was successful habitation of slightly lower altitudes on its margins, a step that people apparently took first during the late Pleistocene (Madsen et al., 2006; Rhode et al., 2009).

The Qinghai Lake area is located in the northeastern margin of the QTP, and the basin floor has an elevation of about 3200 m (Fig. 1). To obtain evidence allowing us to determine when modern humans first entered the northeastern QTP, the Qinghai Lake Basin seemed an excellent place to begin (Rhode et al., 2009). Chronology is critical for understanding the timing and the pattern of human colonization of the QTP. Most of the published age data are based on ^{14}C dating (Madsen et al., 2006; Rhode et al., 2009), and luminescence ages are still few. As most of the archaeological sites in the Qinghai Lake area are located in the aeolian deposits, luminescence dating can play an important role in establishing age controls.

In this study, the optically stimulated luminescence (OSL) method was used to date 4 samples bracketing the hearth in Jiangxigou site on the southern margin of the Qinghai Lake area in order to provide further age controls for human habitation at the site.

2. Study area and sections

Qinghai Lake lies on the northeastern QTP (99°36′ ~ 100°46′ E and 36°32′ ~ 37°15′ N) (Fig. 1), with a lake surface area of 4473 km^2

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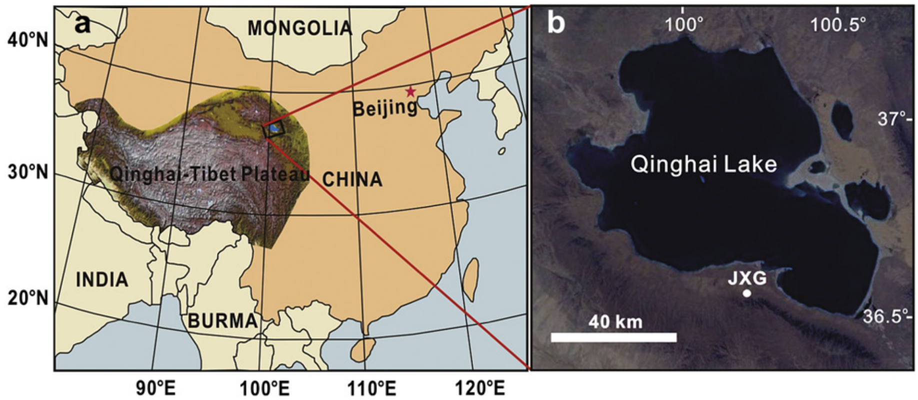

Fig. 1. Location of Qinghai lake in China (a), and the Jiangxigou (JXG) site to the south of the lake (b).

and a water volume of 850 × 10^8 m^3 (Ma, 1998). The present lake level of Qinghai Lake is 3193 m. The annual mean temperature is −0.3 °C, the highest monthly mean temperature is 10.9 °C (July), and the lowest monthly mean temperature is −13.5 °C (January) (Ma, 1998). The annual mean precipitation is 300–400 mm. The annual mean evaporation from the Qinghai Lake is about 1300–2000 mm.

Jiangxigou (JXG) is a stream flowing from south to north down a canyon toward Qinghai Lake. The JXG site 1 is located at approximately 3312 m elevation on the north side of the canyon mouth in the South Qinghai Mountains, approximately 4.5 km south of Qinghai Lake (Fig. 1b; Fig. 2a) (Madsen et al., 2006; Rhode et al., 2007). The Qinghai Nan Shan rises sharply to the south of the site, and to the north the fan delta of the stream grades to the modern shores of Qinghai Lake. The JXG1 section consists of cross-bedded aeolian sand on a steam terrace (Fig. 2a). The aeolian sand in the dune appears to have been winnowed from the exposed sands and gravels of the stream (Madsen et al., 2006; Rhode et al., 2007), and a detailed OSL chronology for this site will be presented by Liu et al. (2012).

In the JXG1 section, a hearth (at a depth of 1.45 m below the surface) was found during a field trip in the summer of 2010 (Fig. 2b). The hearth (represented by the stone in Fig. 2b) is buried in a loess layer. The isolated hearth was likely used by a small group of prehistoric hunters. Four OSL samples were collected. Sample JXG1-A was collected from loess 30 cm above the hearth, and JXG1-B from the hearth. Parallel to the hearth is a loess layer, and, we took one loess sample (JXG1-C1) from the right side of hearth. JXG1-D was taken from 15 cm below the hearth.

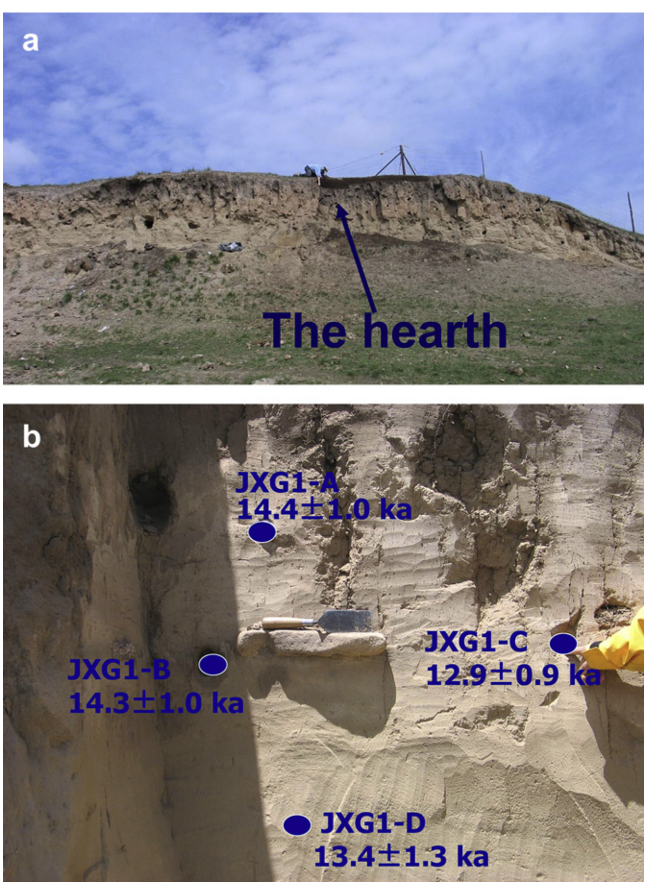

Fig. 2. Views of the Jiangxigou section (a), and the hearth and OSL samples with their ages (b). The hearth (represented by the stone in (b)) is buried in a loess layer.

3. Samples preparation and measurement techniques

Laboratory preparation included treatment with HCl (10%) and H_2O_2 (30%) to remove carbonates and organics, and dry sieving to isolate grains of 38–63 μm. The 38–63 μm fraction was treated with 35% H_2SiF_6 for 2 weeks to remove feldspars (e.g. Berger et al., 1980; Roberts, 2007; Lai, 2010). The resulting quartz grains were washed with 10% HCl and water. Quartz purity was monitored by IR stimulation. Any samples with measurable IRSL signals were retreated with H_2SiF_6 to avoid equivalent dose (D_e) underestimation (e.g. Roberts, 2007; Lai and Brückner, 2008). Pure quartz grains were then deposited on stainless steel disks using silicone oil.

OSL measurements were carried out on a Risø TL/OSL-DA-20 reader. Stimulation was by blue LEDs (470 ± 20 nm) for 40 s at 130 °C, and detection was through 7.5 mm Hoya U-340 filters. Preheat was using 260 °C for 10 s, and cut-heat 220 °C for 10 s. Signals from the first 0.64 s stimulation were integrated for growth curve construction after background subtraction (using the last 25 channels in the shine-down curve). The concentrations of uranium, thorium and potassium were measured by neutron activation analysis (Table 1). The cosmic ray dose rate was estimated for each sample as a function of depth, altitude and geomagnetic latitude

Table 1
Sample information and environmental radioactivity.

Sample ID	Depth (m)	Quartz grain size (um)	K (%)	Th (ppm)	U (ppm)
JXG1-A	1.15	38–63	1.66 ± 0.07	10.98 ± 0.31	2.76 ± 0.18
JXG1-B	1.45	38–63	1.65 ± 0.07	8.09 ± 0.23	2.14 ± 0.16
JXG1-C1	1.45	38–63	1.67 ± 0.08	9.14 ± 0.26	2.37 ± 0.16
JXG1-D	1.60	38–63	1.66 ± 0.08	6.69 ± 0.21	1.39 ± 0.12

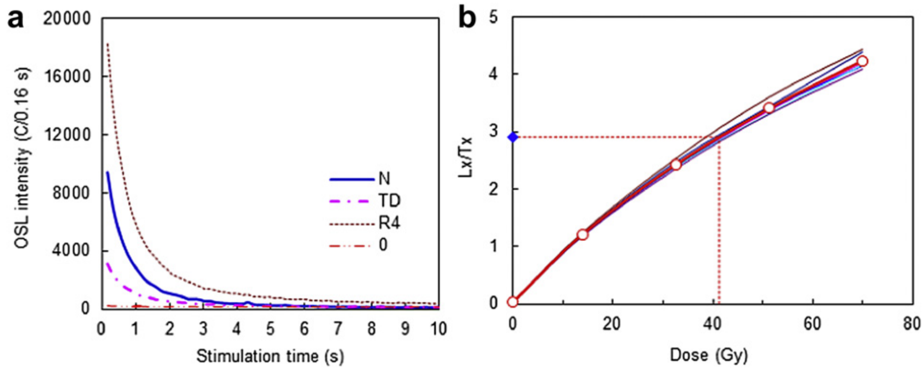

Fig. 3. Luminescence characteristics of sample JXG1-A. (a) Shine-down curves. (b) Growth curves. The line with empty circle denotes the SGC.

(Prescott and Hutton, 1994). Water content was taken as 5 ± 5% for all samples. An alpha efficiency (a-value) of 0.035 ± 0.003 (Lai et al., 2008) was adopted. Finally, the elemental concentrations were converted into an annual dose rate according to Aitken (1998).

4. OSL dating procedures

4.1. OSL characteristics

Fig. 3a shows typical quartz OSL decay curves of natural dose (N), test dose and regeneration doses, and Fig. 3b the growth curves for sample JXG1-A. The OSL signal decreased very quickly within the first second of stimulation, suggesting that the samples are fast component dominated. The signals of the first 0.64 s stimulation were integrated for growth curve construction. A zero dose cycle was incorporated in the SAR protocol to test the effect of thermal transfer. The decay curve of 0 Gy regeneration dose shows negligible thermal transfer. The recycling ratios are consistent to within 10% of unity (0.9–1.1) for all samples.

The preheat plateau and dose recovery test were used to choose a suitable preheat temperature and to evaluate the suitability of SAR protocol. For the preheat plateau test, 20 aliquots from sample JXG1-A were used. The preheat temperatures were chosen to be 220, 240, 260, 280, and 300 °C (for 10 s), and four aliquots were used for each of the temperature point. The cut-heat was 220 °C for 10 s. The plot of D_e vs temperature showed a good plateau was seen from 220 to 280 °C. Therefore, the preheat temperature of 260 °C was chosen for the SAR measurement. For dose recovery test, 10 aliquots were bleached with blue LED for 100 s at room temperature. A laboratory dose 42 Gy was then given, followed by SAR measurements to determine the D_e. The average recovered D_e is 40.6 Gy. The ratio (0.97) between the given and measured dose is close to unity, indicating that a known-laboratory dose can be recovered.

4.2. D_e determination

The D_e was determined using both the single aliquot regenerative-dose (SAR) protocol (Murray and Wintle, 2000) and a standardized growth curve (SGC) method (Roberts and Duller, 2004; Lai, 2006; Lai et al., 2007). The application of SGC could significantly reduce the machine time. For each sample, six aliquots were measured by SAR for D_e determination (Fig. 3b). The shapes of the six growth curves are similar. The average of the six growth curves was constructed as a SGC for each sample, and then twelve additional aliquots were measured for their natural (L_N) and test dose (T_N), during which OSL measurement was under the same condition as those for growth curve construction and the SAR procedure. The test dose corrected natural OSL signals (L_N/T_N) were matched with the SGC to obtain a D_e value. The SGC D_es are in good agreement with SAR D_es (Table 2). The final D_e is the mean value of all the D_es for each sample. OSL ages with their D_es and dose rate information are listed in Tables 1 and 2.

5. Dating results and discussions

It has been proposed (Rhode et al., 2007) that (1) the Jiangxigou #1 and #2 sites reflect substantially different settlement types in a large regional settlement organization, (2) it is possible that the record at the two Jiangxigou sites contains different economic orientations related to the transition from Epipaleolithic hunting to Neolithic pastoralism, and (3) the pattern of the JXG #2 site may represent full-scale year-round occupation of the upper regions of the plateau by early Neolithic pastoralists, while that at JXG #1 may represent occupation by a small party of mobile hunters. As a result, the chronology of Jiangxigou sites is of great interest. Previous chronology is based on ^{14}C dating only, and we here provide an initial trial of OSL dating.

The four OSL samples from JXG #1 give similar ages, within error, from 12.9 ± 0.9 to 14.4 ± 1.0 ka (Fig. 2b). Sample JXG1-B was collected from within the hearth, and some of the quartz grains in the sample could have been heated by fire. As the section is of aeolian origin, and no obvious hiatus is observed, it is reasonable to expect that the four OSL ages are in agreement within error. The ages show that at about 14.3 ± 1.0 ka (sample JXG1-B), prehistoric people (possibly hunters) had visited the site.

Table 2
OSL dating results.

Section ID	Sample ID	D_e–SAR	D_e–SGC	Final D_e (Gy)	Aliquot number	Dose rate (Gy/ka)	OSL age (ka)
JXG1	JXG1-A	41.30 ± 1.30	42.10 ± 0.97	41.82 ± 0.76	6[a] + 12[b]	2.90 ± 0.19	14.4 ± 1.0
	JXG1-B	39.20 ± 1.60	35.90 ± 1.04	36.95 ± 0.93	6[a] + 12[b]	2.58 ± 0.18	14.3 ± 1.0
	JXG1-C1	35.50 ± 0.90	34.70 ± 1.42	34.98 ± 0.98	6[a] + 12[b]	2.71 ± 0.18	12.0 ± 0.9
	JXG1-D	29.00 ± 6.40	34.20 ± 1.13	32.42 ± 2.12	6[a] + 12[b]	2.42 ± 0.17	13.4 ± 1.3

Water content is taken as 5 ± 5% for all samples.
[a] aliquot numbers using SAR.
[b] aliquot numbers using SGC.

Madsen et al. (2006) have reported archaeological and chronological investigations at Jiangxigou #1. They found multiple simple hearth features and associated stone technology, fragmentary bone and large rocks within an aeolian section, and dated two charcoal samples recovered from hearth features using AMS radiocarbon dating to 14,690 ± 150 and 14,760 ± 150 Cal a BP. Our OSL dates of the newly found hearth confirm their ^{14}C chronology and add new data for the chronology of peopling of the QTP.

The colonization of the high altitude of the QTP can be divided into three steps: Step 1: colonization of lowland zones (<2500 m; e.g., Gansu Lowlands); Step 2: colonization of the middle-elevation zone (Qinghai Lake area & Qaidam Basins, 2500–4000 m); and Step 3: colonization of the High Plateau (gt; 4000 m) (Brantingham et al., 2003, 2007; Rhode et al., 2007). The chronology of peopling in the QTP has been increasingly investigated in recent years. It is believed that Late Upper Paleolithic entry of the middle-elevation zone (step 2) took place ~15,000 cal a BP, while the Late Upper Paleolithic entry of the High Plateau margins (step 3) took place ~13,000 cal a BP (Brantingham et al., 2003, 2007; Brantingham and Gao, 2006; Madsen et al., 2006; Rhode et al., 2007).

However, this migration chronology is in conflict with previous age determinations for the peopling of the QTP: 40–30 ka (^{14}C) for Selling Co in the interior of the high QTP (Yuan et al., 2007); 40–30 ka (^{14}C) for the Xiao Qaidam site in the Qaidam Basin of the middle-elevation zone (Huang et al., 1987); 28–37 ka (OSL) for Lenghu site in the Qaidam Basin (Owen et al., 2006); 20 ka (OSL) for footprints and a fireplace in Lhasa in the interior of the QTP (Zhang and Li, 2002). Sun et al. (2010) tried to date lake terraces associated with the Xiao Qaidam site using OSL, and inferred that the site could be of Holocene age. However, they could not find materials suitable for OSL dating from the layer assumed to contain the stone tools (described in detail by Huang et al., 1987). These interpretive differences suggest more dating work is required to refine the chronology of human colonization of the QTP.

6. Conclusions

Chronology is critical for understanding the timing of the peopling of the QTP. The Jiangxigou site is an important one in the Qinghai Lake area and has been investigated a number of times recently (e.g. Madsen et al., 2006; Rhode et al., 2007). Previous ages in this site are based on ^{14}C dating only. We present here OSL dating results for a newly identified hearth found in the site in summer of 2010.

The ages of the four OSL samples collected from in and around the hearth range from 12.9 ± 0.9 to 14.4 ± 1.0 ka. All four are within the error ranges on one another. The OSL ages show that at about 14.3 ± 1.0 ka (sample JXG1-B) prehistoric people (possibly hunters) occupied the site.

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