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

YongJuan Sun, ZhongPing Lai, David Madsen, GuangLiang Hou

ARTICLE INFO
Article history:
Received 15 October 2011
Received in revised form 18 January 2012
Accepted 21 January 2012
Available online 30 January 2012

Keywords:
Qinghai-Tibetan plateau (QTP)
Qinghai lake area
Jiangxigou archaeological site
Luminescence dating
Prehistoric occupation pattern

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 14C 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 14C 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 km²
and a water volume of $850 \times 10^8 \text{ m}^3$ (Ma, 1998). The present lake level of Qinghai Lake is 3193 m. The annual mean temperature is $0.3 \, ^\circ\text{C}$, the highest monthly mean temperature is $10.9 \, ^\circ\text{C}$ (July), and the lowest monthly mean temperature is $-13.5 \, ^\circ\text{C}$ (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 stream 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.

## 3. Samples preparation and measurement techniques

Laboratory preparation included treatment with HCl (10%) and $\text{H}_2\text{O}_2$ (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% $\text{H}_2\text{SiF}_6$ 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 $\text{H}_2\text{SiF}_6$ 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.

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Depth (m)</th>
<th>Quartz grain size (um)</th>
<th>K (%)</th>
<th>Th (ppm)</th>
<th>U (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>JXG1-A</td>
<td>1.15</td>
<td>38–63</td>
<td>1.66 ± 0.07</td>
<td>10.98 ± 0.31</td>
<td>2.76 ± 0.18</td>
</tr>
<tr>
<td>JXG1-B</td>
<td>1.45</td>
<td>38–63</td>
<td>1.65 ± 0.07</td>
<td>8.09 ± 0.23</td>
<td>2.14 ± 0.16</td>
</tr>
<tr>
<td>JXG1-C1</td>
<td>1.45</td>
<td>38–63</td>
<td>1.67 ± 0.08</td>
<td>9.14 ± 0.26</td>
<td>2.37 ± 0.16</td>
</tr>
<tr>
<td>JXG1-D</td>
<td>1.60</td>
<td>38–63</td>
<td>1.66 ± 0.08</td>
<td>6.69 ± 0.21</td>
<td>1.39 ± 0.12</td>
</tr>
</tbody>
</table>
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 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 (L0) and test dose (TN), 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 (L0/T0) were matched with the SGC to obtain a D0 value. The SGC D0s are in good agreement with SAR D0s (Table 2). The final D0 is the mean value of all the D0s for each sample. OSL ages with their D0s 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 14C 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.
Madsen et al. (2006) have reported archaeological and chronological investigations at Jiangxiougou #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 BP. Our OSL dates of the newly found hearth confirm their 14C 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 Palaeolithic entry of the middle-elevation zone (step 2) took place ~15,000 cal a BP, while the Late Upper Palaeolithic 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 (14C) for Selling Co in the interior of the high QTP (Yuan et al., 2007); 40–30 ka (14C) 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 Jiangxiougou 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 14C 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 about 14.3 ± 1.0 ka (sample JXG1-B) prehistoric people (possibly hunters) occupied the site.

Acknowledgements

This work was supported by the China Geological Survey (1212011120046), China NSF (41121001, 41172168, 41161018), the "Strategic Priority Research Program" of the Chinese Academy of Sciences (Climate Change: Carbon Budget and Relevant Issues, Grant No. XDA05120501), and the One Hundred Talent Project of the Chinese Academy of Sciences granted to ZPL (A0961). We thank the anonymous reviewer for very helpful comments.

Editorial Handling by: R. Grun

References


