

A short chronology for the peopling of the 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 responsible for human colonization of the Tibetan Plateau. This harsh, high-elevation environment is known to exact a heavy demographic toll on recent migrants, and such costs likely erected a substantial biogeographic barrier to initial human colonization. This chapter presents a series of simple metapopulation models that link processes of colonization to mutually exclusive archeological predictions. Current archeological evidence from the northern Tibetan Plateau suggests that seasonal forays into high elevation settings were “adaptive radiations” coincident with the appearance of both Early (ca. 30 ka) and Late Upper Paleolithic (ca. 15 ka) adaptations in low-elevation source areas around the Plateau. More permanent occupation of the Plateau probably did not begin before ca. 8200 ka and may have been driven by “competitive exclusion” of Late Upper Paleolithic foragers from low-elevation environments by emerging settled agricultural groups. The appearance of specialized epi-Paleolithic blade and bladelet technologies on the high Plateau, after 8200 ka, may indicate “directional selection” impacting these new full-time residents. An adaptive radiation of agriculturalists into the mid-elevations of the Plateau, this time leading to year-round occupation, is again seen after 6000 Cal yr BP. The short chronology presented here contradicts genetic-based models suggesting that human populations may have been resident on the Tibetan Plateau for as long as 30,000 years. If the short chronology withstands further empirical scrutiny, it suggests either that initial colonists were genetically predisposed to the rapid accumulation of mutations leading to successful physiological adaptation, or that high-elevation selective pressures are much more severe than usually conceived.

1. The Biogeographic Problem

Few environments are as harsh and unforgiving as the Tibetan Plateau. With an average elevation of approximately 5000 m above sea level (a.s.l.) (Fielding *et al.*, 1994), temperatures on the Tibetan Plateau are uniformly cold, precipitation is sparse, and floral and faunal diversity and abundances are low. Because of low atmospheric pressure at altitude, oxygen is also a rare commodity, a fact that has important and far-reaching consequences. These harsh conditions have well-known negative impacts on human demography. Generally, fertility is much reduced and mortality much increased among recent migrants to high elevation (Moore *et al.*, 2000; Moore *et al.*, 2001; Barker and Hanson, 2004; Moore *et al.*, 2004). While many of these severe demographic costs to life at high elevation have been solved evolutionarily among long-resident populations (Beall, 2001; Beall *et al.*, 2004), there was likely a substantial biogeographic barrier to initial human colonization of the Plateau. Delineating how and when human populations managed to colonize this extreme environment thus may reveal much about the evolution of human biogeographic capacities (Brantingham *et al.*, 2003).

The simplest possible model for the colonization of an environment envisions the recipient area to be colonized as connected to a large, stable metapopulation (MacArthur and Wilson, 1967; Brown and Lomolino, 1998; Hubbell, 2001). The large metapopulation ensures that there is an endless supply of potential colonists, while its stability suggests that colonists of different types exist in fixed (but not necessarily equal) frequencies. Colonists move from the metapopulation into the recipient area according to some dispersal process, usually associated with the reproductive cycle or population growth, and either establish a successful colony, or fail to do so. Successful colonization has a very specific meaning in metapopulation models. It refers to the

establishment of a population that is continuously present from the moment of colonization (i.e., it is not there only seasonally) and is capable of successfully reproducing over more than one generation, ensuring continuity in genetic and (if relevant) cultural information. Successful colonization does not mean that populations do not fluctuate within the recipient area, just that there is no local extirpation following colonization. Moreover, a population that is established within a recipient area need not be isolated from the metapopulation. On the contrary, the recipient population may receive a continuous stream of dispersers from the metapopulation. Continuous contact with the metapopulation may be particularly important in a sub-optimal habitat that inflicts heavy costs in terms of mortality and fertility. Repeated dispersals from the metapopulation might, in this context, “rescue” the recipient population from extirpation. However, repeated rescuing also tends to work against the development of specialized local adaptations by diluting the effects of selection. In the absence of a “rescue effect,” one might expect the evolution of adaptations (behavioral and/or biological) to offset the costs of life in a suboptimal habitat. In other words, the colonizing population becomes self-sustaining and does not need rescuing from the meta-population.

2. Plateau Colonization Models and Archeological Predictions

From the general model presented above it is possible to derive a series of specific models for assessing the primary mechanisms driving colonization of the Tibetan Plateau. These simple models are more tractable than a full metapopulation model recognizing that the Tibetan Plateau is a vast region for which we have only limited archeological information. Each of the models is based on the following assumptions about initial conditions. First, assume that the core biogeographic problem lies in how human groups, resident as a metapopulation in the low-elevation source areas surrounding the Plateau, successfully colonized any portion of the high Plateau. We can represent the essential components of this problem abstractly as two areas, one for the low-elevation source area and one for the high-elevation recipient area to be colonized (Fig. 1A). The two areas are assumed to be connected by one or more corridors that would allow colonization of the high-elevation area if the appropriate conditions to drive colonization are present within the source area metapopulation. Initially, the source area is occupied by a population presenting an adaptation A, the unique set of behavioral attributes that makes survival in the low-elevation area possible (Brantingham *et al.*, 2004b). However, adaptation A is unsuited to colonization of the high-elevation recipient area. In other words, there is a hard biogeographic barrier between the low-elevation source area and the high-elevation recipient area. The obvious archeological prediction based on these initial conditions is that the low-elevation area will contain archeological sites with a unique adaptive

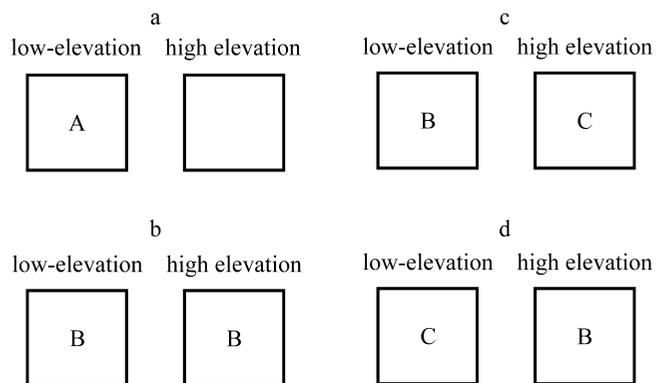


Fig. 1. Metapopulation models for the colonization of the Tibetan Plateau. a, initial conditions have the low-elevation source area occupied by a population presenting an adaptation A unsuited to colonization of the high-elevation source area. The high-elevation recipient area is unoccupied. b, an adaptive radiation occurs when an adaptation B evolves within the low-elevation source area and is sufficient to allow colonization and survival in the high-elevation environment without any subsequent modifications. c, directional selection occurs if a population moving into the high-elevation environment finds that its low-elevation adaptation is insufficient for long-term survival. Strong selective pressures in the high-elevation environment drive the appearance of new traits C to ensure survival. d, competitive exclusion occurs when some low elevation groups favor retaining ancestral adaptive traits B over adoption of a novel adaptation C and are forced to occupy more marginal habitats as a result.

signature A, but that there will be no contemporaneous archeological record in the high-elevation area.

Model 3: Adaptive Radiation. We can extend the model of initial conditions to consider a case where a new adaptation B evolves within the low-elevation source area and replaces adaptation A. For example, this new adaptation might consist of different mobility strategies, novel forms of social organization, or new technologies that alter the relationship between humans and their resource base. Assume also that adaptation B, unlike the ancestral adaptation A, is sufficient to ensure colonization of and survival in the high-elevation area. The biogeographic barrier between the source and recipient area collapses and individuals from the low-elevation area colonize the high-elevation area, deploying adaptation B *without modification* (Fig. 1B). We will refer to this process as an “adaptive radiation” (Schluter, 2000). It is critical to recognize that selective pressures present in the low-elevation environment were responsible for driving the emergence of adaptation B. In other words, adaptation B did not evolve to deal with the biogeographic barrier between areas. Rather, the collapse of the barrier was merely a *byproduct* of evolution in response to some other selective conditions. There are four primary archeological predictions based on this model of adaptive radiation. First,

low-elevation sites should show the emergence of novel adaptive traits *B*, replacing ancestral adaptive traits *A*. Second, high-elevation sites should show *exactly* the same adaptive traits *B* seen in low-elevation sites. Third, the high-elevation sites with *B* should be of equal age or younger than sites in low-elevation environment showing *B*. Finally, to be uniquely representative of an adaptive radiation, sites in high-elevation areas *must be older* than any sites in lower elevation areas presenting additional novel adaptations *C* (see below).

Model 2: Directional Selection. An alternative model also begins with a new adaptation *B* evolving in the low-elevation source area. Adaptation *B* allows some limited initial expansion into the high-elevation recipient area, but it is insufficient on its own to ensure successful colonization of the high-elevation area. Unique traits evolve in the high-elevation area and the resulting new adaptation *C* is sufficient to ensure survival (Fig. 1C). In this case, we can say that the evolution of adaptation *B* softened the biogeographic barrier between areas, but unique selective pressures in the high-elevation environment were ultimately responsible for ensuring successful colonization. In other words, the observed adaptive traits in the high elevation are not a simple byproduct of evolutionary processes operating in low-elevation environments, but a direct response to the biogeographic problem of colonizing an extreme environment. We refer to this process as “directional selection.” Four archeological predictions arise from this simple model. First, low-elevation sites should show the emergence of novel adaptive traits *B*, replacing ancestral adaptive traits *A*. Second, high-elevation sites should show novel adaptive features *C* not seen in low-elevation sites. Third, the high-elevation sites with *C* should be of equal age or younger than sites with *B* seen in low elevation. Finally, however, the sites with novel features *C* should either be unique to the high-elevation area, or older than any sites with *C* seen in the low-elevation area. This last prediction is necessary to

allow for the possibility that specialized adaptations evolved in the extreme, high-elevation area may have been exported subsequently to low-elevation environments.

Model 3: Competitive Exclusion. A final model also begins with the emergence of a new adaptation *B* in the low-elevation source area. While this adaptation might have ensured a minimum level of survival within the high-elevation area, little or no occupation actually ensues. At some later point in time, a second novel adaptation *C* appears in the low-elevation area. Segments of the low elevation population retaining – for whatever reason – the ancestral adaptation *B* are displaced or marginalized into high-elevation area, rather than being replaced by *C* (Fig. 1D). In this case, we might say that the evolution of adaptation *B* softened the biogeographic barrier between areas, but that additional demographic or cultural pressures in the low-elevation area ultimately were necessary to drive the dispersal of individuals onto the high Plateau. We refer to this process as “competitive exclusion”. Four archeological predictions may be derived from this model. First, low-elevation sites should show the emergence of novel adaptive traits *B*, replacing ancestral adaptive traits *A*. Second, low-elevation sites should show emergence of a second set of novel adaptive traits *C*, replacing adaptive traits *B*. Third, high-elevation sites will show a retention of the ancestral traits *B* and should be contemporaneous with or younger than sites with *C* seen in the low-elevation area. Finally, sites with features *B* should be confined to the high-elevation area, or are older than any sites with *C* that appear subsequently in the high-elevation area.

These models are clearly simplifications of what must be a complex process. However, they do establish a series of mutually exclusive predictions that may be tested with relatively small data sets. Here we concentrate on evaluating these models with data collected by us and other researchers working in northwest China and the northern Tibetan Plateau (Fig. 2).

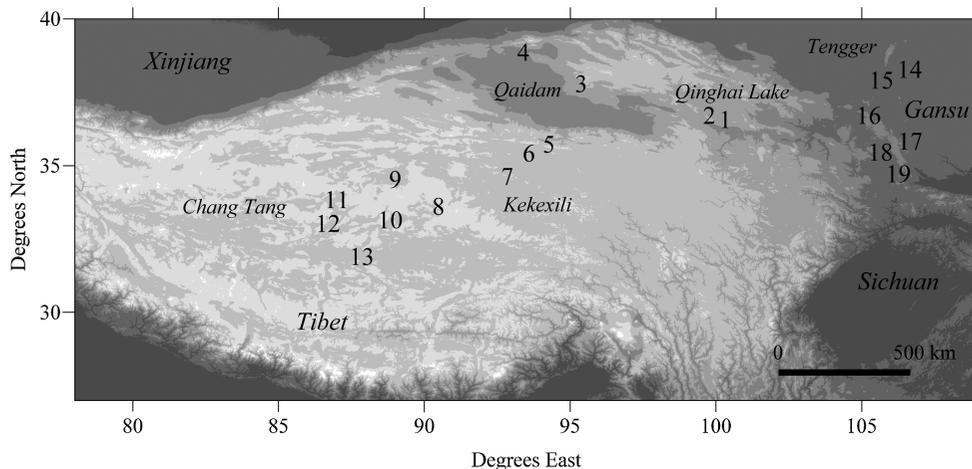


Fig. 2. Digital elevation model of the Tibetan Plateau showing the locations of sites discussed in the text. Middle-elevation step sites: 1, Jiangxigou 1 and 2; 2, Heimahe 1 and 3; 3, Da Qaidam; 4, Lenghu locality 1. High-elevation step sites: 5, Xidatan 2; 6, police station 1 and 2; 7, Erdaogou; 8, Obsidian source at Migriggyangzham co; 9, Dogai coring; 10, Shuanghu; 11, Margog Caka; 12, Yibug Caka; 13, Nyima. Low-elevation step sites: 14, Shuidonggou; 15, Pigeon Mountain; 16, Tongxin; 17, Guyuan (Punyang); 18, Zhuang Lang; 19, Dadiwan Neolithic.

The arid regions of northwest China, including portions of Xinjiang, Gansu, Inner Mongolia, and Ningxia, are treated as the primary low-elevation source area (below 3000 m.a.s.l.) for populations colonizing the northern Tibetan Plateau. The northern Plateau includes all of Qinghai Province and portions of the Tibetan Autonomous Region north of Seling Co (N31.5°). We further subdivide the northern Plateau into two elevational steps; the middle-elevation step (between 3000 and 4000 m.a.s.l.) is represented by the Qinghai Lake basin in the east and the Qaidam Basin in the west. The high-elevation step (above 4000 m.a.s.l.) is bounded in the north by the Muztag–Kunlun–Anyimaqen Mountain ranges and in the south by the Himalayas. It is topographically undifferentiated (Fielding *et al.*, 1994) consisting of many short river drainages and small, shallow lake basins. Archeological evidence from areas the southern Tibetan Plateau (south of Seling Co) is discussed as appropriate (see also Aldenderfer and Zhang, 2004).

3. Paleoclimate and Paleoenvironment on the Tibetan Plateau

The pattern of Late Pleistocene and Holocene paleoclimatic fluctuations on the Tibetan Plateau and in the surrounding regions is broadly consistent with the global glacial–interglacial sequence (see Wunnemann, this volume). Here we occasionally refer to coarse-grained chrono-stratigraphic makers including Marine Isotope Stage 3 (MIS 3, ca. 50–25 ka¹), the Last Glacial Maximum (LGM) (ca. 25–15 ka), the post-glacial period (ca. 15–11.5 ka) and the Holocene (<11.5 ka). Primarily, however, we discuss the colonization of the Tibetan Plateau in relation to the Heinrich events (Bond *et al.*, 1992; Bond *et al.*, 1993) as seen in the speleothem $\delta^{18}\text{O}$ record from Hulu Cave, Jiangsu Province, China (Fig. 3) (Wang *et al.*, 2001). The Hulu Cave speleothem provides a high-resolution record of the relative strengths of the Southeast Asian Summer Monsoon and the Winter Monsoon (Siberian High Pressure cell) over the last ca. 75 ka (Wang *et al.*, 2001). In general, the cold-dry Winter Monsoon strengthens with increase in $\delta^{18}\text{O}$ values in the Hulu record and peaks in intensity during Heinrich events and the Younger Dryas. Conversely, the warm-wet Southeast Asian Summer Monsoon strengthens with decrease in $\delta^{18}\text{O}$, with numerous peaks in monsoon strength seen between Heinrich events (Wang *et al.*, 2001). These circulation systems are central to paleoenvironmental fluctuations in continental east Asia. Table 1 lists the calendar ages of Heinrich events H5–H1 and the Younger Dryas, as determined from the Hulu record, as well as two major climatic events of the Holocene determined by other proxies.

Major characteristics of the low-elevation environments bordering the northern Tibetan Plateau are controlled by the balance of precipitation and evaporation and, consequently, on the location of the northern boundary of the Southeast

¹ All ages reported in thousands of years before present (ka) are calibrated unless otherwise indicated.

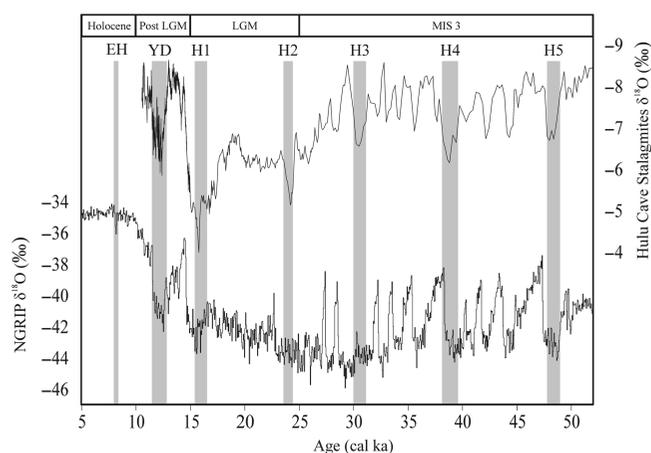


Fig. 3. Hulu and NGRIP oxygen isotope sequence. The Hulu speleothem record is a high-resolution proxy of the relative strengths of the Southeast Asian Summer Monsoon and the winter monsoon (siberian high pressure cell). The NGRIP record is a proxy of global continental ice volume and provides a broad measure of global temperatures. Shown in light gray are the cold-dry heinrich events

Table 1. Ages of Sub-Milankovitch Scale Climatic Events in China.

Event	cal BP	standard deviation
Holocene aridification	4,000	-
Holocene cold-dry event	8,200	-
End Younger Dryas ^a	11,473	80
Start Younger Dryas ^a	12,823	80
H1 ^b	15,781	-
H2 ^b	24,180	-
H3 ^b	30,490	-
H4 ^b	38,800	-
H5 ^b	47,990	-

^a Ages estimated from the Hulu records by Wang *et al.* (2001);

^b Age estimated by author from published Hulu record.

Asian Summer Monsoon (Winkler *et al.*, 1993). As this boundary has fluctuated over the course of the Late Pleistocene so has the location of desert-Loess Plateau transition, the sizes of internally draining lakes and the distribution of flora and fauna. In general, northwest Chinese deserts were at least as large as at present during the Early Glacial, before H5 (ca. 47.9 ka) and again between H2 and H1 (24.2–15.8 ka) (Xiao *et al.*, 1995; Ding *et al.*, 1999; Bush *et al.*, 2002). They were substantially smaller than present during the Early Holocene (11.5–8.2 ka) and during portions of MIS 3. Lake high stands are correlated with the warm-wet events that followed H4 (ca. 38.8 ka) and H3 (ca. 30.5 ka) (Fang, 1991; Pachur and Wunnemann, 1995; Zhang *et al.*, 2004) (Wunnemann, this volume). Most basins were

completely dry between H2 and H1 (ca. 24.2–15.8 ka), and much smaller lakes appeared again in only during the Holocene. Steppe grasslands may have been at their largest extents, and maximum taxonomic diversity, in the periods immediately following H4 (38.8 ka), H3 (30.5 ka) and H1 (15.8 ka) (Herzschuh, this volume). They were greatly reduced in size and diversity between H2 (24.2 ka) and H1 and probably also during earlier Heinrich events. There is general recognition that conditions were warm and wet during the Early Holocene, but there appears to some regional variability in this pattern. The deserts of northwest China may have been persistently more arid from the Younger Dryas on. The western Loess Plateau, by contrast, seems to have supported *Betulus*, *Quercus* and *Ulmus* forests during the Early Holocene (Chen *et al.*, 2003; An *et al.*, 2004). Both areas register a brief period of cold-dry conditions around 8200 Cal yr BP, which appears to be a Heinrich-like event (Wang *et al.*, 2002a; Clarke *et al.*, 2003; Morrill and Jacobsen, 2005; Schmidt and LeGrande, 2005). Both north and northwest China become increasingly arid following ca. 7800 Cal yr BP and there is a precipitous drop in humidity ca. 4000 Cal yr BP (An *et al.*, 2005). Faunal communities, including many of the medium and large-sized ungulates present today on the Tibetan Plateau (Schaller, 1998), may have readily tracked these fluctuations by altering their geographic distributions. However, there is a lack of evidence to say much more than this.

Climatic and environmental conditions on the middle-elevation step of the northern Plateau parallel those in the surrounding low-elevation areas. In particular, many of the large, internally draining lake basins appear to have reached maximum high stands during MIS 3, roughly 35–25 ka (Chen and Bowler, 1986; Huang *et al.*, 1987; Ma, 1996; Owen *et al.*, 2006). All of the lakes on the middle-elevation step appear to have been dry between H2 (ca. 24.2 ka) and the Early Holocene (<11.5 ka), when shallow, saline lakes reemerged in some basins. Vegetation histories, though poorly known, suggest that coniferous forests (primarily *Picea*, *Pinus*, and *Abies*) occupied the slopes of the Qilian Mountains during the middle portion of MIS 3, with steppe or desert steppe dominating the basin bottoms (Herzschuh, this volume). Desert steppe remained widespread following the LGM and was replaced with alpine steppe and meadow in some areas (e.g., Qinghai Lake basin) only with the return of greater humidity during the Early Holocene (Herzschuh, this volume; Wunnemann, this volume).

Despite forceful claims to the contrary (e.g., Kuhle, 1999), at no point during the Late Pleistocene does there appear to have been a continent-sized ice sheet covering the Tibetan Plateau (Benn and Owen, 1998; Owen *et al.*, 2003). Rather, discrete periods of glacial advance were restricted primarily to montane valleys. Glaciation on the high Plateau as a whole is controlled by the availability of moisture, since temperatures are always low enough to ensure ice buildup. However, the timing of ice buildup along the southern boundary of the Plateau is asynchronous with that along the southern boundary; the Himalayas receive most of their precipitation from the South Asian Summer Monsoon, which strengthens during interstadials and interglacials, while the Kunlun–Muzutag–Anyimaqen receives most of

its moisture from the Westerly Jet Stream, which strengthens during stadials and glacials (Benn and Owen, 1998; Owen *et al.*, 2005). Lake systems on the high Plateau are complex, reflecting hydrological contributions both from low and high-pressure circulation systems as well as glacial ice melt. In general, moderately large lakes may have been present on the high step of the Plateau before H2 (ca. 24.2 ka) (Wang *et al.*, 2002b). These were greatly reduced in size during the LGM and, following glacial termination (ca. <15.8 Cal yr BP), expanded to reach their highest stands of the Late Pleistocene, fed by abundant glacial meltwater (Wei and Gasse, 1999). Most lakes for which we have a record show progressive desiccation over the course of the Holocene. We know much less about Late Pleistocene and Holocene floral and faunal communities on the high-elevation step of the Plateau. Holocene pollen records from lakes on the western (e.g., Sumxi Co) and eastern (e.g., Zoige basin) extremities of the high Plateau suggest that floral communities alternated between steppe and desert-steppe during warm-wet and cold-dry events, respectively (Vancampo and Gasse, 1993; Yan *et al.*, 1999). On the northern high Plateau, where conditions are far more arid today, the alternation may have been between desert-steppe and unvegetated landscapes. Fauna must have tracked these changes – populations growing in size and expanding their range under steppe conditions, but suffering severe reductions in size and range contractions under desert-steppe or desert conditions (Schaller, 1998).

4. The Chronology of Human Colonization

The Low-elevation Source Area. The number of dated archaeological sites in low-elevation environments surrounding the Tibetan Plateau has grown apace in recent years. Irrespective of their archaeological characteristics, these sites provide compelling evidence that at least some portion of the low-elevation source area of the Plateau was continuously occupied from 35 ka onwards, though population sizes and distributions may have fluctuated widely in response to climatic and environmental change. Numerous sites in northwest China are now confidently dated to MIS 3, with the largest cluster of sites falling in the time period immediately preceding and during H3 (ca. 30.5 ka) (see Barton, Brantingham, and Ji, this volume). The best known of these sites is Shuidonggou, located on the western margins of the Ordos desert, with dates ranging continuously from ca. 35–29 ka (Madsen *et al.*, 2001; Brantingham *et al.*, 2001a; Ningxia Institute of Archaeology, 2003). Far fewer sites are assigned to the time period between H3 and H2 (ca. 24.2 ka), but several of those that have been identified are in western Gansu (Barton, Brantingham, and Ji, this volume). Shuidonggou Locality 2 contains occupations falling within the earlier part of this period and Tongxin 3, Tongxin 8, and Guyuan 3 fall midway between these events (see also Gao *et al.*, 2004). Farther to the east, the Xiachuan Localities 1 and 2 may have occupations representing the period just prior to the LGM (Barton, Brantingham, and Ji, this volume) (Chen and Wang, 1989; Chung, 2000).

There are nearly as many sites falling, between H2 and H1 (24.2–15.8 ka) – the LGM – as in the preceding time period. Sites reported by Barton, Brantingham, and Ji (this volume) cluster in two events immediately following H2 and immediately preceding H1 (see also Ji *et al.*, 2005). Zhuang Lang 5, located on the western Loess Plateau has two archeological horizons dated to ca. $20,070 \pm 360$ and $24,140 \pm 240$ Cal yr BP, respectively. A number of well-known sites date to the period following glacial termination. Xiaonanhai and Hutouliang contain stratigraphic components that date to the Bølling–Allerød and the Younger Dryas events (ca. 12.8–11.4 ka) (Lu, 1999). However, these sites lie much to the east of the Tibetan Plateau. The Pigeon Mountain localities, by contrast, are located within the desert source area of the Plateau and are well dated to between $15,135 \pm 338$ (Beta 97242) and $11,608 \pm 183$ (Beta 86732) (Elston *et al.*, 1997; Madsen *et al.*, 1998).

Following the Younger Dryas (ca. 11,473 Cal yr BP) there is a substantial gap in the record of dated sites in the low-elevation source area of the Plateau, which probably reflects a lack of research on deposits of the right age (Madsen and Gao, this volume). By ca. 7800 Cal yr BP we have good evidence for the presence of sedentary agriculture populations on the western Loess Plateau (Lu, 1999; An *et al.*, 2004). Occupations remain fairly intense through the Dadiwan (ca. 7800–7350 Cal yr BP), Yangshao (6800–4900 Cal yr BP) and Majiayao Culture periods (ca. 5300–4300 Cal yr BP), but appear to be smaller and more dispersed by the middle of the Qijia Culture period (ca. 4300–3900 Cal yr BP) (An *et al.*, 2005).

The Middle- and High-Elevation Steps. Only two archeological sites on the middle-elevation step and a handful of sites on the high-elevation step of the Tibetan Plateau

may represent initial human forays onto the Plateau prior to H2 (ca. 24.2 ka). Lenghu locality 1 (N38.85, E93.41, 2,804 m.a.s.l.) is a surface scatter of stone tools found horizontally stratified between two well-preserved beach ridges (Fig. 4). The archeological materials are found above the 45 m beach ridge containing ice wedge casts dated by OSL to 14.9 ± 1.5 ka (Owen *et al.*, 2006) and TL to 18.51 ± 2.22 ka (Ma, 1996) (Table 2). The beach ridge preserving the ice wedge casts must correspond to a lake high stand older than H2 (ca. 24.2 ka). The archeological materials are also below the elevation of two higher beaches, one of which may be assigned an age of ca. 37.21 ± 1.13 ka based on radiocarbon dating of carbonate from a lake marl in the same section (Ma, 1996). One of the two higher beach ridges (at 57 or 70 m above the current lake surface) may correlate with the warm-wet event following H4 (ca. 38.8 ka), while the 45 m beach may correlate with the warm-wet event following H3 (ca. 30.5 ka). Given that stone tool assemblages have yet to be found in the Lenghu basin below the elevation of the H3 beach (unpublished field observations), we tentatively assigns these materials a minimum age of around 30.5 ka and maximum age of 38.8 ka. In support of this conclusion, we note that the degree of wind ablation seen on the artifacts is consistent with a very long period of surface exposure. The lithic technologies – Early Upper Paleolithic-type large blade cores and tools (Brantingham *et al.*, 2001a) – are consistent with those seen in lower elevation areas surrounding the Plateau at the same time (see below).

The site of Xiao Qaidam (N37.46, E95.52, 3,100 m.a.s.l.) is similar to Lenghu locality 1 in several respects. Stone cores and flakes are found on the surface of a feature interpreted as a relict beach ridge associated with a high stand of

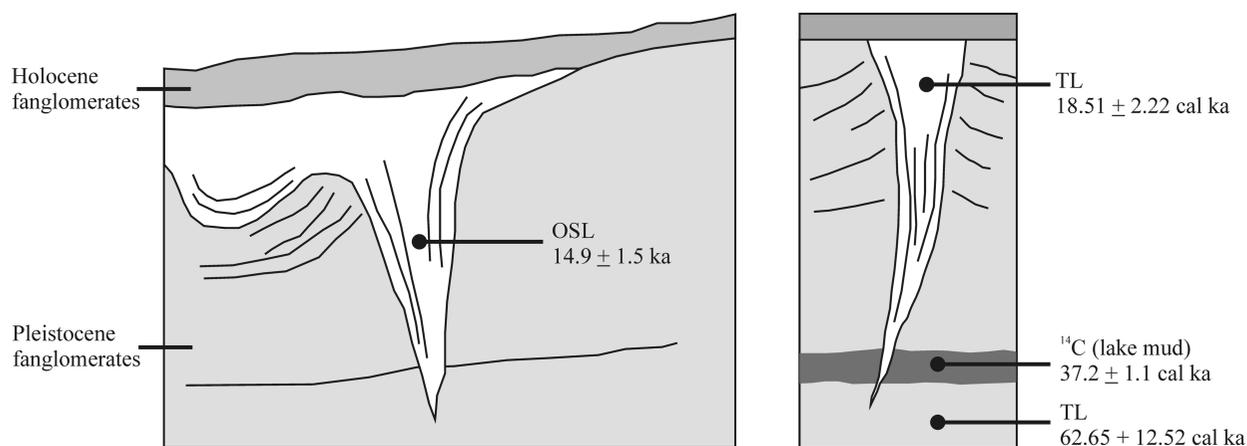


Fig. 4. OSL, TL and radiocarbon dates for ice-wedge casts and other sedimentary features in the ~45 m beach (ca. 2,780 m.a.s.l.) at Lenghu. The OSL and TL dates on the two separate ice wedge casts indicate that the underlying beach gravels must have accumulated before H1 (15.8 Ka) and probably before H2 (24.2 Ka). The most likely timing for the ~45 m high stand is the warm-wet event following H3 (30.5 Ka). The radiocarbon dated lake mud in this section may correspond to a lake high stand that formed one of two beaches at ~57 and ~70 m above the current lake surface, respectively. Artifacts found on the surface above the ~45 m and below the ~57 m beach are assigned a minimum age of ca. 28–30 ka and maximum age of ca. 37 ka based on their horizontal stratigraphic position.

Table 2. OSL and TL Dates.

Site	Unit/Feature/Depth	N	E	Age Cal yr BP	SD	Lab Number	Reference
Heimahe 1	49 cm below surface	36.73	99.77	6,995	520	UIC1568	this paper
Heimahe 1	89 cm below surface	36.73	99.77	15,310	1,080	UIC1570	this paper
Heimahe 1	134 cm below surface	36.73	99.77	11,785	880	UIC1567	this paper
Heimahe 1	159 cm below surface	36.73	99.77	14,940	1,115	UIC1566	this paper
Heimahe 1	234 cm below surface	36.73	99.77	26,550	1,770	UIC1569	this paper
Yeniugou Valley	183 cm below surface	35.92	94.67	8,600	700	QD4A	Owen <i>et al.</i> , 2006
Lenghu Ice Wedge Cast	45 m beach	38.85	93.42	14,900	1,500	QBOSL6A	Owen <i>et al.</i> , 2006
Lenghu Ice Wedge Cast ^a	45 m beach	38.85	93.41	18,510	2,220		Ma 1996

^aThermoluminescence (TL) age

the lake in the Xiao Qaidam basin. Huang (1987) correlates the inferred high lake stand with radiocarbon dated ostracods in a sediment core from the adjacent Da Qaidam basin and assigns a tentative minimum age of 37.9 ± 3 ka to the Xiao Qaidam assemblage based on this correlation. Owen *et al.* (in press) have collected samples for OSL dating of the Xiao Qaidam beach ridge, which might provide better age control for the site. Results of this study are still pending. Our own field investigations at Xiao Qaidam succeeded in relocated Huang's (1987) sites, but failed to find any material associated with the surface lithics that might be directly dated. Of greater concern, however, is our discovery of lithic technologies identical in character to those at Xiao Qaidam (e.g., raw material type, size and shape, technological forms) in direct association with Han Dynasty aged (ca. 2000 Cal yr BP) ceramics in the nearby Iqe River (Yucha He) drainage (unpublished data). This association brings into question the pre-H2 age assignment for the Xiao Qaidam materials.

Several sites have been discussed as representing possible pre-H2 occupation of the high-elevation step of the northern Plateau (An, 1982; Huang, 1994; Brantingham *et al.*, 2001b; Aldenderfer and Zhang, 2004). However, none of these sites have directly associated chronometric dates (see Huang, 1994; Aldenderfer and Zhang, 2004). Age assignments for most of these sites have been based on lithic technological typological systematics, usually emphasizing the presence of Middle Paleolithic-type tools (e.g., side scrapers). Some sites in the Chang Tang, identified by Schaller (1998) and reported by Brantingham, Olsen *et al.* (2001b), have technological characteristics reminiscent of Middle Paleolithic Levallois technology, which might suggest an age of ca. 30 ka, or even earlier (see Brantingham *et al.*, 2001a). But, other assemblages present characteristics that appear to be derived from the northeast Asian Early Upper Paleolithic, which lead Brantingham, Olsen *et al.* (2001b) to suggest that they may be LGM in age, i.e., falling between H2 at 24.2 ka and H1 at 15.8 ka. However, current evidence, discussed in detail below, suggests that these early age assignments may not be warranted. Rather, the lithic technologies seen at sites in the Kekexili, Chang Tang, and other areas of the high Plateau are now reliably dated at one site to the Early Holocene (ca. 8200–6400 Cal yr BP).

Only one site on the entire Plateau has been discussed as falling between H2 and H1. Located approximately 85 km outside of Lhasa, at 4200 m.a.s.l., Chusang (or Quesang) consists of a series of hand and footprints and a possible hearth found in a now-hardened spring travertine (Zhang and Li, 2002; Aldenderfer and Zhang, 2004). Zhang and Li (Zhang and Li, 2002) failed to recover datable charcoal from the possible hearth, but did retrieve what are described as aeolian quartz grains from within the travertine matrix. OSL dates of 20.6 ± 2.9 , 21.1 ± 2.1 , and 21.7 ± 2.2 ka were determined from these materials, providing possible maximum ages for the hand and footprints. Taken at face value, these ages suggest that human populations may have ventured into high elevations as early as 21 ka. More recent age determinations may suggest an age of around 11 ka (see Aldenderfer, this volume). However, extensive replication of any dates from this site is necessary given the possibility that non-aeolian, detrital sand grains may make up a fraction of the quartz being used for dating. It is unclear whether the Chusang travertine is a carbonate-cemented sediment or a true calcite flowstone. If the former, then any detrital sand grains incorporated from in situ sediment are more likely to be unbleached, leading to OSL ages that are too old.

Three sites in the Qinghai Lake basin register human occupation of the middle-elevation step of the Plateau in the interval between H1 (ca. 15.8 ka) and the beginning of the Younger Dryas (ca. 12.4 ka) (Madsen *et al.*, 2006). Jiangxigou 1 (N36.59, E100.3, 3,330 m.a.s.l.) is a buried archeological site located at the head of a small stream flowing north into Qinghai Lake. The site lies approximately 136 m above the current lake surface. Multiple simple hearth features and associated stone technology, fragmentary bone and large rocks are found buried within an aeolian sedimentary stack. Charcoal recovered from hearth features 1 and 3 yielded AMS radiocarbon dates of $14,690 \pm 150$ and $14,760 \pm 150$ Cal yr BP, respectively (Table 3) (Madsen *et al.*, 2006). Similar ages have been obtained from a nearby site, locality 93–13, first identified and dated in 1993 as part of a geomorphological investigation of Qinghai Lake depositional environments (Porter *et al.*, 2001; Madsen *et al.*, 2006). This site also consists of two stratigraphically separate, isolated hearths dating to $14.6 \pm .35$ and $14.5 \pm .33$ ka, respectively (Table 3).

Table 3. Radiocarbon Dates.

Site	Unit/Feature	N	E	¹⁴ C yr BP	¹⁴ C yr SD	Cal yr BP	Cal yr SD	Sample Material	Lab Number	Reference
Lenghu	highest stand mud	38.85	93.41	31,700	800	37,210	1,130	carbonate	-	Ma (1996)
Jiangxigou 1	Feature 3	36.59	100.3	12,470	60	14,760	150	charcoal	Beta 208338	this paper
Jiangxigou 1	Feature 1	36.59	100.3	12,420	50	14,690	150	charcoal	Beta 149997	this paper
Locality 93-13	Lower hearth	-	-	12,420	120	14,601	348	charcoal	AA-12318	Porter et al. (2001)
Locality 93-13	Upper hearth	-	-	12,370	90	14,528	333	charcoal	AA-12319	Porter et al. (2001)
Heimahe 1	Surface 2 ^a	36.73	99.77	11,480	60	13,390	90	charcoal	Beta 194545	this paper
Heimahe 1	Surface 1	36.73	99.77	11,220	50	13,140	60	charcoal	Beta 194544	this paper
Heimahe 1	Secondary hearth	36.73	99.77	11,160	50	13,080	90	charcoal	Beta 169901	this paper
Heimahe 1	Secondary hearth	36.73	99.77	11,140	50	13,040	60	charcoal	Beta 169902	this paper
Heimahe 1	Primary hearth	36.73	99.77	11,070	40	12,970	60	charcoal	Beta 149998	this paper
Heimahe 1	Loess block	36.73	99.77	11,040	70	12,940	90	charcoal	Beta 194543	this paper
Heimahe 1	Surface 4	36.73	99.77	10,850	40	12,790	50	charcoal	Beta 169903	this paper
Heimahe 1	Surface 4	36.73	99.77	10,670	60	12,690	40	charcoal	Beta 194542	this paper
Jiangxigou 2	max 100 cm depth	36.59	100.3	8,170	50	9,140	90	charcoal	Beta 194541	this paper
Jiangxigou 2	81 cm depth	36.59	100.3	7,330	50	8,130	70	charcoal	Beta 208336	this paper
Jiangxigou 2	60–70 cm depth	36.59	100.3	4,850	40	5,580	60	charcoal	Beta 209350	this paper
Heimahe 3	Primary hearth	36.72	99.78	7,630	50	8,450	50	charcoal	Beta 208334	this paper
Xidatan2	T5 possible hearth	35.71	94.26	5,670	40	6,460	40	charcoal	Beta 194553	this paper

^a no archaeological remains were found in association with surfaces 1,2 and 4 at Heimahe 1. These may represent natural fires

Heimahe 1 (N36.73, E99.77, 3,210 m.a.s.l.), 65 km to the west of Jiangxigou 1, is situated away from the mountain front in the flood plain of the small Heimahe (he = river). The site lies approximately 16 m above the current lake surface. Two hearth features with associated cultural debris are found buried within a sedimentary stack that grades upwards from fine-grained alluvial deposits to aeolian silts (Fig. 5). The primary hearth has yielded date of $12,970 \pm 60$ Cal yr BP and a directly associated secondary hearth feature two dates of $13,040 \pm 60$ and $13,080 \pm 90$ Cal yr BP. These point to an average age of occupation of $13,010 \pm 109$ Cal yr BP. Several other burned surfaces have been identified at elevations slightly above and below the hearth features (surface 3), but laterally distributed over a distance of ca. 5 m to the north and south. It is uncertain whether these burn features are cultural in origin. They are broadly consistent in age with the two true hearths identified at the site (Table 3). Close inspection of Fig. 5 and Tables 2 and 3 reveals that the OSL and radiocarbon dates are offset with respect to one another. A complex depositional history for the sediments used in OSL dating, may partially explain the lack of comparability across dating techniques. Overall, the Heimahe 1

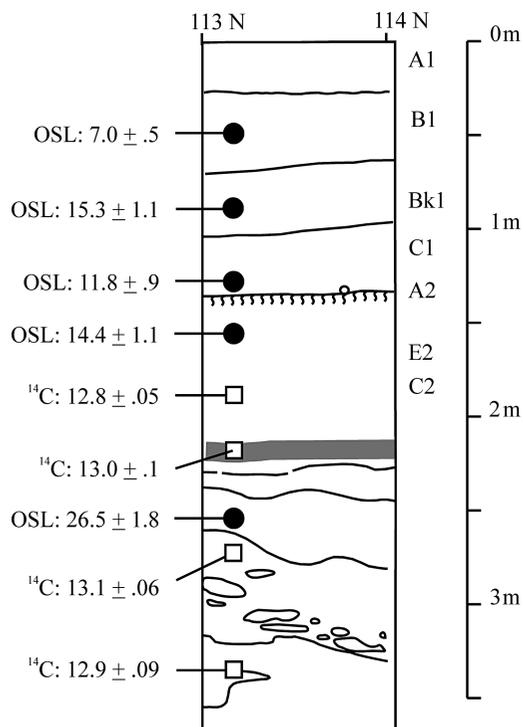


Fig. 5. Schematic stratigraphic section for Heimahe 1 showing the depth of dating samples and the cultural surface. The cultural surface (gray) is found at a maximum depth of about 2.11 m below the surface. The sequence begins as coarse sand alluvium at the base and fines upwards towards silt-dominated alluvium at the top. A pre-Younger Dryas soil is located at a depth of ca. 1.4 m below the surface. OSL dates are shown as filled circle, radiocarbon dates as open squares.

sequence appears to have accumulated rapidly ca. 13 ka and that human occupation was approximately coincident with the initiation of sedimentation at the site (Table 2).

No sites are known presently from the high-elevation step of the Plateau dating to the interval between H1 and the onset of the Younger Dryas, despite having deposits of appropriate age (Brantingham *et al.*, in prep; Van Der Woerd *et al.*, 2002), and neither area has yet to yield sites falling within the Younger Dryas (ca. 12,823–11,473 Cal yr BP). Van Der Woerd *et al.* (2002), however, identified what appears to be a fire hearth on the first terrace (T1') of the Xiadawu River (N35.0, E99.18, 4,000 m.a.s.l.) located at an unconformity between terrace gravel fill and a ~1-m thick loess deposit. The feature returned a radiocarbon age of $11,010 \pm 27$ Cal yr BP suggesting a possible human occupation on the high-elevation step of the Plateau shortly after the end of the Younger Dryas. However, this site has not been described by archeologists, so little more can be said about the nature of this possible occupation. Chusang, mentioned above, may also date to ca. 11 ka, though we reiterate our concerns about the geochronology at this site.

An occupation signature is again detected on the middle-elevation step of the Plateau during the Early Holocene, up to and including the Holocene ca. 8200 Cal yr BP cold-dry event. In the Qinghai Lake basin, two sites have been dated to this interval. Jiangxigou 2 (N36.59, E100.3, 3,330 m.a.s.l.), across the drainage from locality 1, is a 1.2-m thick midden and ash deposit with abundant cultural materials. Radiocarbon ages of 9140, 8130, and 5580 Cal yr BP, all in stratigraphic order, suggest that this is a multi-component site (Table 3). Preliminary OSL dates on small ceramic sherds from the same sequence yielded ages of $6.8 \pm .6$, $4.4 \pm .5$, and $1.8 \pm .3$ ka. These are also in stratigraphic order and consistent with the radiocarbon determinations. They further support the conclusion that this is a multicomponent site. Heimahe 3 (N36.72, E99.78, 3,202 m.a.s.l.), radiocarbon dated to ca. 8450 Cal yr BP, is contemporaneous with Jiangxigou 2. Like the earlier occupation at Heimahe 1, however, Heimahe 3 is an isolated hearth with a small collection of associated cultural debris. The feature is located at a depth of 1.94 m at a transition between alluvial and loess sedimentation.

The oldest, reliably dated site on the high-elevation step of the Plateau is assigned to Early Holocene. Xidatan 2 (N35.71, E94.26, 4,300 m.a.s.l.) lies on the middle (T4) of three glacial outwash terraces in a small unnamed tributary of the Kunlun River (Fig. 6) (Brantingham *et al.*, in prep). Loess overlies the outwash debris on the two upper terraces and varies in thickness from <.3 to 2.0 m. It is eroded in irregular patches leaving blowout depressions between intact loess stacks. Stone cores, flakes, and tools are found at the surface in the blowout depressions over nearly the entire length of the terrace (ca. 385 m), but dense concentrations of artifacts occur midway up the terrace. Small-scale test excavations established that the eroded surface materials originate from a buried context within the loess cap on T4, at an average depth of 30 cm below the surface and 15 cm above the terrace gravels. The age of the Xidatan

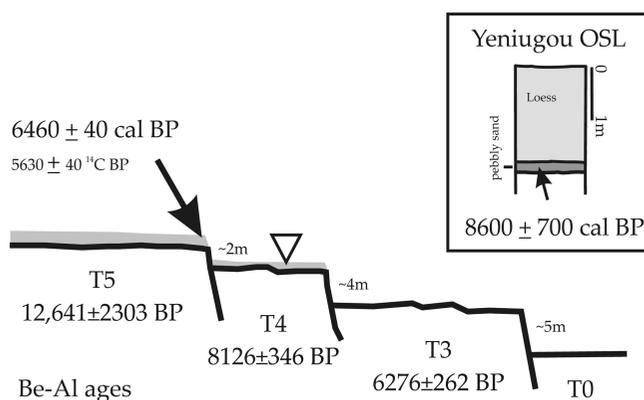


Fig. 6. Be–Al cosmogenic surface exposure, radiocarbon, and OSL ages from the xidatan 2 site and the adjacent yeniugou valley. Be–Al ages determined from terrace gravels by Van Der Woerd et al. (2002). The OSL date is from a pebbly sand unit underlying a loess cap in the yeniugou valley was determined by Owen et al. (in press). The age of the archeological site on T4 (open triangle) is constrained to be younger than ca. 8200 cal yr BP and older than ca. 6400 cal yr BP with a probable age assuming constant loess sedimentation rate of ca. 7800 Cal yr BP (redrawn following Van Der Woerd et al., 2002 and Owen et al., 2006).

2 lithic assemblage is constrained by cosmogenic surface exposure (CSE) dates (Van Der Woerd et al., 2002), one OSL date (Owen et al., 2006) and one AMS radiocarbon date (Brantingham et al., in prep). Be–Al CSE ages for each of the three terraces at Xidatan 2 were determined as part of a geological study of slip rates along the Kunlun Fault, which runs through part of the site (Table 4) (Gosse and Phillips; Van Der Woerd et al., 2002). T5, the highest terrace, yielded a Be–Al age of 12614 ± 2303 Cal yr BP. T4, which holds the Xidatan 2 site, yielded an age of 8126 ± 346 Cal yr BP. The lowest terrace, T3, returned an age of 6276 ± 262 Cal yr BP. These ages date the transition between periods of fan aggradation and periods of renewed terrace down cutting. They also provide limiting ages for the Xidatan 2 archeological site. The materials on T4 can be no older than ca. 8.1 ka. The absence of materials on T5 suggests that there was no occupation at the site between 12.6 and 8.1 ka, while the absence of materials on T3 also suggests that the site on T4 is older than ca. 6.3 ka. Owen et al. (in press) report an OSL date of 8.6 ± 0.6 ka on pond sediments immediately underlying a surface loess cap the

adjacent Yeniugou valley (see Table 2). This provides confirmation for the maximum age of the loess at Xidatan 2. We identified a possible hearth feature 16 cm below the surface on T5, 100 m up stream from the main concentration of artifacts on T4. An AMS radiocarbon date of 6460 ± 40 Cal yr BP provides a minimum age for the loess deposits on T4 and T5 as well as the archeological site on T4 (Table 3). Assuming a constant rate of deposition between the onset of loess sedimentation around 8.1 ka and termination around 6.5 ka, the buried materials on T4 date to ca. 7800 Cal yr BP.

We correlate other sites known on the high Plateau with Xidatan 2 on the basis of shared stone raw material types, including a compositionally unique obsidian, and the techno-typological characteristics of the assemblages (see below). We hypothesize that the surface sites from the Chang Tang, previously described by Brantingham, Olsen et al. (2001b) as LGM in age, are in fact no older than Xidatan 2. Similarly, a number of other sites in the high elevation Kekexili Reserve (e.g., Police Station 1 and 2, Erdaogou 1) and several on the middle-elevation step (e.g. Da Qaidam and Sogo Nur) are also assigned to the Early Holocene based on the same criteria. None of these sites have independent age determinations, however.

Finally, we note that the first evidence for nonforaging adaptations on the middle-elevation step of the northern Plateau probably postdates 6000 Cal yr BP. The site of Jiangxigou 2 (N36.59, E100.33310 m.a.s.l.) has yielded thick, undecorated and thin cord marked ceramics, as well as abundant fragmentary faunal remains, from a stratified section with radiocarbon dates ranging between 9140–5580 Cal yr BP (Table 3). The oldest of three OSL dated ceramic sherds, at 6.8 ± 0.6 ka, suggests that ceramic technologies appear in the middle part of the sequence. If these date withstands further scrutiny, then the Neolithic component at Jiangxigou 2 may be as old as, or older than the well-known Neolithic site of Karou, located near Qamdo (N31.09, E97.10, 3307 m), nearly 700 km to the southwest (CPAM, 1985; Aldenderfer and Zhang, 2004). The earliest occupations at Karou date to ca. 5758 ± 109 Cal yr BP.

5. Archeological Characteristics of the Metapopulation

The Late Pleistocene archeological sequence in the low-elevation areas surrounding the northern Tibet Plateau is reasonably well known, especially following H4 (ca. 38.8 ka). The Early Upper Paleolithic is first recognized in

Table 4. Be–Al Cosmogenic Surface Exposure Ages.

Site	Terrace Number	N	E	Be–Al mean age Cal yr BP	Cal yr SD	Reference
Xidatan 2	T3	35.71	94.26	6,276	262	Van Der Woerd et al. (2002)
Xidatan 2	T4	35.71	94.26	8,126	346	Van Der Woerd et al. (2002)
Xidatan 2	T5	35.71	94.26	12,614	2,303	Van Der Woerd et al. (2002)

northwest China 34.8–28.7 ka and may be linked to populations moving south from Siberia through Mongolia beginning 45 ka (Brantingham *et al.*, 2001a). At Shuidonggou Locality 1, flat-faced cores, technologically equivalent to a Levallois core reduction strategy, were used to produce large, flat blades that were subsequently retouched along one or both edges (Ningxia Institute of Archaeology, 2003). Stone raw material usage at Shuidonggou appears to be focused on moderate-quality materials that were readily available in alluvial deposits at the site. Retouched tools are generic in character, dominated by types that are considered diagnostic of the Middle Paleolithic including many side scrapers, denticulates, and notches. The later part of the sequence at Shuidonggou Locality 2 may show a trend towards reduction in the sizes of cores and tools, including a turn to bipolar reduction of small chert and quartz pebbles (Madsen *et al.*, 2001). Numerous other sites within reach of the low-elevation areas surrounding the Plateau are coeval with Shuidonggou (e.g., Guyuan 3, Tongxin 3 and Tongxin 8 at 29–30 ka) (Barton, Brantingham, and Ji, this volume; Bettinger *et al.*, this volume) (Ji *et al.*, 2005). These show a similar focus on moderate-quality raw materials and broadly Middle Paleolithic retouched tool types. Levallois-like flat-faced blade technologies too may have featured at these sites (Gao *et al.*, 2004).

Between H2 and H1, 24.2–15.8 ka, Levallois-like large blade technologies disappear and we see a shift towards expedient lithic technologies and the (possibly selective) use of poor quality raw materials. Zhuang Lang 5, dated between 24 and 19.7 ka, for example, appears to represent small scale, occupation centered on bipolar reduction of quartz and fine grained quartzite cobbles (Barton, Brantingham, and Ji, this volume; Brantingham *et al.*, 2004c). We have suggested elsewhere (Madsen *et al.*, 2001) that bipolar reduction yields large quantities of small, sharp debitage that can be easily picked through to find suitable small blanks for use in inset tools, much like formal microblade insets, but without all of the associated stone procurement and production costs (Elston and Brantingham, 2003).

Following H1, at 15.8 ka, we see the intensification of foraging strategies throughout northeast Asia, although there is considerable variability in the local character of archeological assemblages. Intensification is signaled most clearly by the appearance of formal microblade technologies based on pebble, flake and, very occasionally, biface blanks. Evidence from Siberia suggests that these core technologies were used to produce microblades that would be segmented and used as insets in composite point armatures. There is no conclusive evidence for the use of composite points in north or northwest China beyond the prevalence of microblades at most sites of this age, however. It is also unclear exactly when microblades first appear in the Chinese sequence. The site of Xiachuan is often cited as providing the earliest evidence (ca. 19–25 ka) for both the use of microblades and ground stone (Chen and Wang, 1989; Lu, 1999; Chung, 2000). Yet, there is some uncertainty about the association between specific archeological finds and radiocarbon dates across the many Xiachuan localities. The

“smash-and-bash” bipolar technology seen at Shuidonggou Locality 2 (Madsen *et al.*, 2001) and Zhuanglang 5 may be an appropriate precursor to a formal microblade technology, suggesting an origin around the end of H1 (15.8 ka) (Barton, Brantingham, and Ji, this volume; Bettinger *et al.*, this volume). But it may also be the case that formal microblade technology did not become an important part of the Late Pleistocene foraging adaptations until the Younger Dryas ca. 12.8–11.5 ka, or shortly before (Elston and Brantingham, 2003). The Pigeon Mountain localities, for example, suggest that the period following H1, ca. 15.8 ka, in the desert margins of the Plateau, is characterized by heavy-duty macrolithic tools as well as simple unifacial and bifacial points (Elston *et al.*, 1997; Zhang, 1999). Microblade technology increases dramatically in frequency in the stratified Pigeon Mountain sequence between 13,510 ± 136 (Beta 86731) 11,608 ± 183 (Beta 86732), coinciding with the Younger Dryas (Elston *et al.*, 1997; Madsen *et al.*, 1998).

There is a gap in the archeological record of northwest China between the end of the Younger Dryas (ca. 11.5 ka) and the emergence of agricultural adaptations on the western Loess Plateau, shortly after the Holocene climatic optimum at 8200 Cal yr BP (Bettinger *et al.*, this volume). Initial low-level agricultural activities at sites such as Dadiwan (N35.01, E105.91, 1,500 m.a.s.l., 7800 Cal yr BP) are, within a millennium, converted into intensive agricultural adaptations focused around large, complex permanent settlements associated with Yangshao (6900–5300 Cal yr BP) and Majiayao (5300–4200 Cal yr BP) Cultures (An *et al.*, 2004). The rapid transition from warm–semi-arid to warm–arid conditions around 4000 Cal yr BP may have driven a reduction in the total number and distribution of agricultural settlements over the western Loess Plateau (An *et al.*, 2005). Nomadic pastoralism appears to have become a viable alternative to rain-fed agriculture sometime during the Qijia (ca. 4300–3900 Cal yr BP) (Flad *et al.*, this volume).

6. Archeological Characteristics of the Colonizers

Lenghu locality 1 is the only site for which there is any reliable geochronological evidence for a pre-H2 occupation of the middle-elevation step of the Plateau. There is no evidence for an occupation of this age on the high-elevation step. The very small archeological assemblage, consisting of two cores and a large blade, is minimally consistent with the character of the Early Upper Paleolithic in the source area. On the basis of a fine-grained green–gray quartzite, the two cores show a flat-faced geometry with emphasis on linear blade production. The single blade, also on the same raw material, is large flat and slightly convergent (Fig. 7). It has a faceted platform and retouch along both edges. The Lenghu specimens are typologically linked to the Levallois-like blade technology seen Shuidonggou and other Early Upper Paleolithic occurrences in northeast Asia (Brantingham *et al.*, 2001a; Gao *et al.*, 2004). By contrast, Xiao Qaidam, the other middle elevation site for which a pre-H2 date has been suggested, presents a generic quartzite core-and-flake



Fig. 7. An Early Upper Paleolithic levallois-like blade from Lenghu locality 1.

technology that is not chronologically diagnostic. We regard these tools as possibly Late Holocene in age based on an association with Han Dynasty age ceramics seen in the nearby Iqe (Yucha) river valley (unpublished field observations). No additional evidence is available to try and characterize the subsistence, mobility and settlement strategies of pre-H2 foragers on the Plateau.

Beyond the site of Chusang (Quesang), far to the south, there are no other candidate archeological occurrences on either the middle- or high-elevation step of the Plateau that can be assigned to the period between H2 and H1 (ca. 24.2–15.8 ka). Aside from the several hand and footprints, Chusang has produced a single probable hearth feature, but no associated stone technology or other cultural materials. Putting aside the concerns about the dating of Chusang, the site is of limited utility for discerning the possible archeological characteristics of a LGM occupation. If evidence from the low-elevation source areas of the Plateau is used as a guide, at this time we would expect to see an emphasis on simple bipolar technologies based on moderate to low quality raw materials and possibly a reduction of mobility (Barton, Brantingham, and Ji, this volume). Such technological characteristics are, of course, not chronologically diagnostic, making accurate geochronology and stratigraphic control essential for identifying any H2–H1 occupations on the Plateau.

Postglacial, Late Upper Paleolithic sites on the middle-elevation step of the Plateau are characterized by both formal microblade technologies and a heavy-duty flaked stone component (Madsen *et al.*, 2006). Indeed, this association is as firmly established here as at sites in low-elevation source area contexts (Elston *et al.*, 1997; Madsen *et al.*, 1998). It is also in this context that we have our first direct evidence from the Plateau of both subsistence activities and within-settlement patterning of activities. Jiangxigou 1, ca. 14.7 ka, on the southern shore of Qinghai Lake, preserves at least two simple, unprepared hearths or hearth-related features with associated cultural debris. The first feature is a 50 cm long, 2 cm thick lens of charcoal-stained sand with no

underlying fire-reddening. What is preserved may represent a secondary concentration of debris raked from a true hearth that may have eroded away. Two pieces of microdebitage related to microblade production were recovered from within the concentration of debris. A complete microblade and two mid-section fragments of long bones from a gazelle-sized animal were recovered from the face of the aeolian sand 5 m east of the hearth.

The other simple feature at Jiangxigou 1 consists of a concentration of stream cobbles, broken and burned bone, and charcoal centered on a ~3.5 m diameter use surface ~55 cm below and ~13 m east of the first hearth remnant (Fig. 8). The feature also appears to represent materials raked from a primary hearth. Nevertheless, a comparatively large array of broken and burned bone fragments was recovered. Much of the faunal material consists of small fragments of cancellous bone suggesting it may be associated with bone boiling and degreasing activities (Madsen *et al.*, 2006). None of the lithic specimens from the feature is typologically diagnostic of a specialized core reduction strategy, such as a formal microblade core technology, and no formal retouch tools were recovered. However, that the distribution of flake and flake shatter sizes is strongly suggestive of either preparation of small cores and/or retouching of flake tools. The absence of formal microblades or debitage characteristic of core rejuvenation argues against later stage core reduction directly associated with the exposed portion of the site.

Heimahe 1 (ca. 13.3–12.6 ka) is very similar to Jiangxigou 1 in both site structure and contents, but has yielded more examples of formal microblades. The primary cultural feature is an isolated hearth with a surrounding ash- and charcoal-stained use surface (Fig. 9). Artifacts on this use surface are restricted to an area within 1.8 m of the fire hearth. These include a concentration of possible bifacial thinning flakes, a quartzite core, microblade fragments, a bifacially worked slate scraper, and a possible ground stone cobble. Numerous bone specimens were collected from in and around the hearth. The majority of these are small and fragmentary, and many are burned. Most of the bone fragments are attributable to a medium-sized ungulate, possibly gazelle. Eggshell fragments from hen/duck-sized eggs were also recovered from the

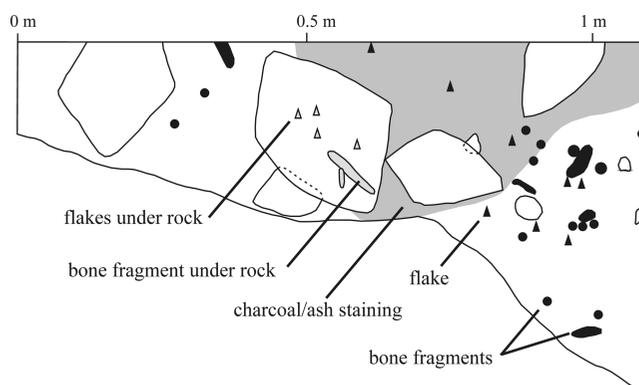


Fig. 8. Plan view of the secondary hearth feature (feature 3) at Jiangxigou 1. The occupation dates to ca. 14,700 Cal yr BP.

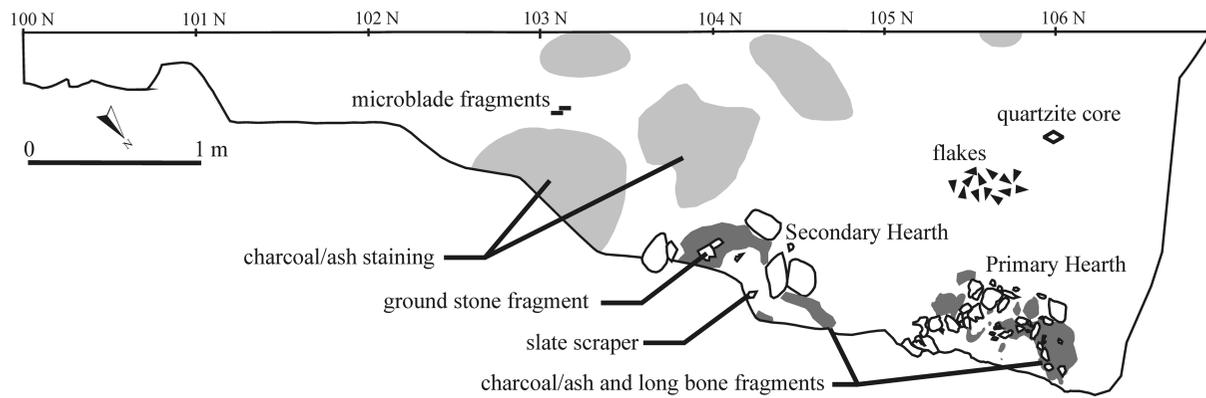


Fig. 9. Plan view of the cultural surface at Heimahe 1. The occupation dates to ca. 13,000 Cal yr BP.

occupational surface. Overall, the simple, unprepared cultural features and small number and diversity of artifacts suggest that Jiangxigou 1 and Heimahe 1 each represent short-term, single-visit foraging camps occupied by a small foraging parties. Subsistence focus seems to have been on the procurement and intensive processing of a gazelle-sized ungulate and possibly on egg collecting (at Heimahe 1).

The Early Holocene sites that are known on the middle- and high-elevation steps of the Plateau are broadly characteristic of the northeast Asian Late Upper Paleolithic or Epi-Paleolithic. These sites contain both a microblade and generalized flaked stone component, but in high elevation contexts we see the addition of a specialized large blade and bladelet technology that appears to be unique to the area (Brantingham *et al.*, 2001b). In the Qinghai Lake basin, the site of Heimahe 3 (N36.71, E99.78, 3202 m.a.s.l.) is virtually identical to Jiangxigou 1 and Heimahe 1 in the structure of the site and included cultural materials, despite its Early Holocene age of 8450 ± 50 Cal yr BP. A single, unprepared hearth is associated with fragmentary bone and generalized flaked stone tools (Fig. 10). Formal microblades are present in very small numbers. It would appear that short-term foraging camps focused on procurement and processing of a gazelle-sized ungulates remained part of the settlement system of populations on the middle step of the Plateau until at least the Holocene cold-dry event at ca. 8200 Cal yr BP.

We lack specific information about the subsistence strategies of populations on the high-elevation step of the Plateau at this time. However, the lithic assemblages attributed to the

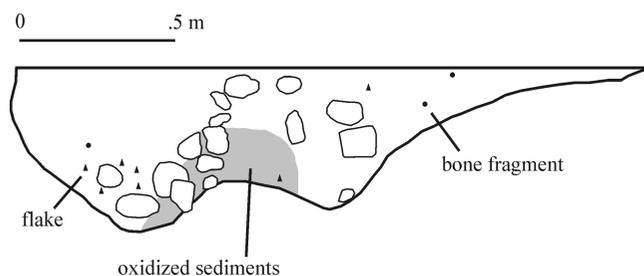


Fig. 10. Plan view of the cultural surface at Heimahe 3. The hearth and associated materials are dated to ca. 8450 Cal yr BP.

Early Holocene are particularly rich, allowing us to draw a number of important inferences about the nature of high elevation adaptations at this time. The Xidatan 2 lithic assemblage is diverse both in terms of raw material types and technologies represented. Seven broad classes of raw material are present in the assemblage, including a chemically distinctive true obsidian glass (Brantingham *et al.*, in prep). Raw material source locations are known for two of these materials. A light yellowish brown to grayish brown mudstone originates from deposits around active springs at the Police Station 1 and 2 archeological sites in the Kekexili nature reserve (N35.43 and E93.61), approximately 66 km away. Obsidian artifacts chemically identical to that from Xidatan 2 have been identified at four other archeological sites on the Plateau. Three of these sites are on the high Plateau, south of Xidatan 2, but one (Jiangxigou 2) is on the south shore of Qinghai Lake. The geological source of this material is known to be centered around Migriqgyangzham Co (N33.42, E90.30, 5240 m.a.s.l.) (Brantingham *et al.*, 2001b).

The Xidatan 2 lithic assemblage includes pieces representative of core reduction, but very few specimens recognized as formal retouched tools (Fig. 11). Cores are classified as either generalized flake technology or classic northeast Asian microblade cores (see Elston and Brantingham, 2003). One exception to this pattern is a series of bifacial discoid cores that were prepared to produce circular flakes that were then retouched around all or part of the margin (Brantingham *et al.*, in prep). These cores were not organized around a Levallois geometry, but nevertheless were designed to produce flakes of standardized size and shape.² Generalized flakes and microblades are the two most common flake types at Xidatan 2. However, bipolar technology makes up a small, but distinctive component of both the flake assemblage and flake shatter and it is not unlike that seen in low elevation

² A core refit from Xidatan 2 shows that core reduction begins with preparation of a bifacial discoid which is then struck parallel to the plane of intersection between the faces to detach tablet-like, circular flakes. This technology shares much in common with the technique for microblade core platform rejuvenation and we suspect that the origin of this discoidal prepared core reduction process is derived from Northeast Asian microblade technologies, though it is applied to a large flake-core substrate.

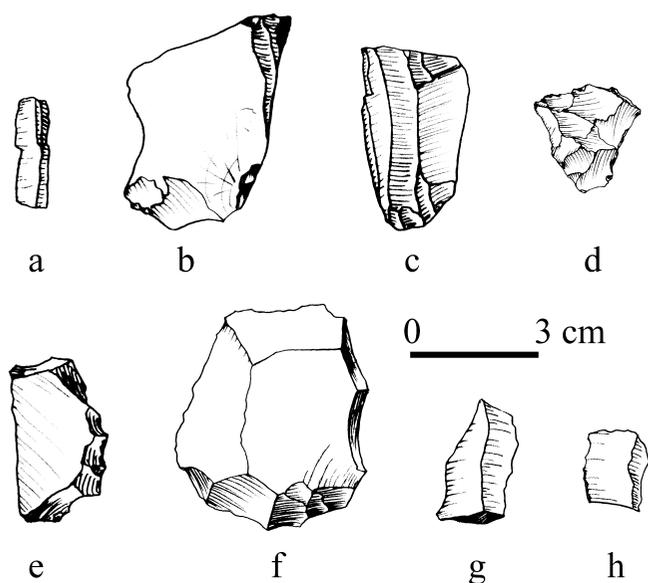


Fig. 11. Lithic specimens from Xidatan 2 (a–e) and the Police Station 1 site in the Kekexili nature reserve (f–h). a, microblade; b, microblade core perform on fined-grained gray quartzite; c, microblade core on cream-colored mudstone from the Police Station 1 spring deposits; d, heavily retouched flake made on Chang Tang obsidian; e and f, flat, tablet-like flakes removed from the face prepared discoidal cores made on gray–green quartzite and Police Station mudstone; g and h, distal and medial bladelet segments.

contexts during the LGM (Madsen *et al.*, 2001) (Barton, Brantingham, and Ji, this volume). Only 3 percent of the total assemblage preserve evidence of formal retouch and two of the specimens are based on Plateau obsidian. Two remaining retouched specimens should technically be classified as debitage; these are burin-like spalls that preserve scraper-like retouch along one side and are most likely byproducts of tool resharpening. Overall, Xidatan 2 provides good evidence for the continued use of a formal microblade technology, most probably as part of composite points, well into the Early Holocene. The distribution of debitage size classes at the site suggests that retooling activities were taking place here, while the topographic position of the site in a steep cut canyon would have been an ideal setting for game drives.

Equally important is the link that Xidatan 2 provides with other undated sites present on the high Plateau, most notably the numerous surface assemblages from the Chang Tang reported by Brantingham, Olsen *et al.* (2001b) and several sites in the Kekexili nature reserve. These sites preserve the same formal microblade technology seen at Xidatan 2 made on a similarly diverse range of raw material types. At least one of the Chang Tang sites (Tsatsang) also contains an example of the unique discoid prepared core technology seen at Xidatan 2. The Chang Tang assemblages are unique, however, in preserving a specialized large blade and bladelet technology (Fig. 12). The blades are extremely flat, have very straight or gradually convergent edges and

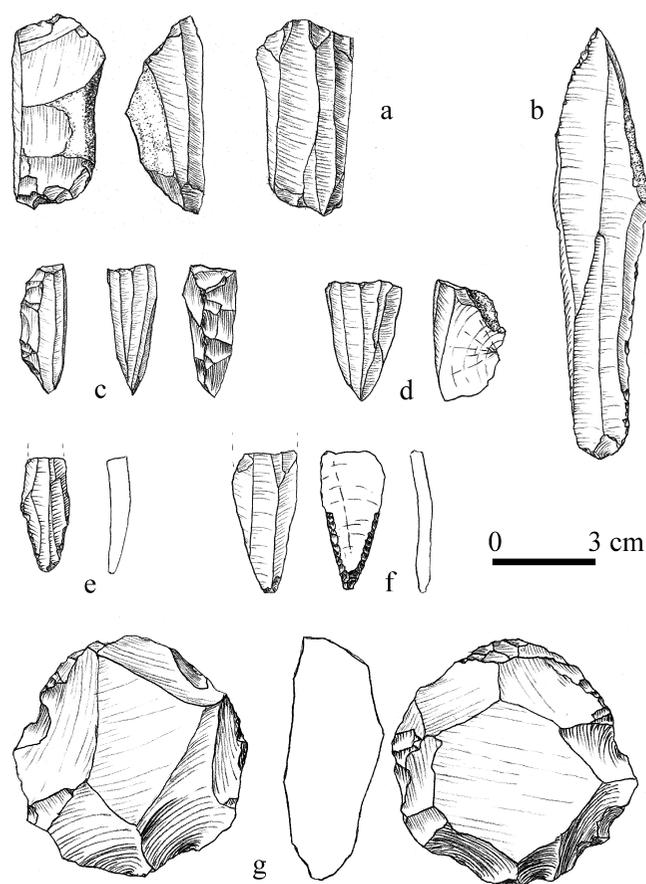


Fig. 12. Lithic specimens from the Chang Tang nature reserve. a, bladelet core; b, pointed prismatic blade; c and d, flake-based microblade cores; e and f, proximal bladelets with retouched hafting accommodations; prepared discoidal core used for producing tablet-like circular flakes.

“punctiforme” striking platforms. Several specimens preserve lateral retouch along the margins and ventral retouch at the base, which appears to represent a special accommodation for end hafting of the blades possibly as spear points. Importantly, these blades are technologically very different from the Levallois-like flat-faced blade technology seen at Shuidonggou and other northeast Asian Early Upper Paleolithic sites. The uniqueness of this technology led Brantingham, Olsen *et al.* (2001b) to speculate that they were LGM in age. However, the striking technological similarity of the entire collection of Chang Tang materials to the Xidatan 2 assemblage, as well as the presence of Chang Tang obsidian at Xidatan 2, two of the Kekexili sites and one of the Chang Tang sites, leads us now to conclude that the Chang Tang assemblages are all Early Holocene in age, contemporaneous with Xidatan 2.

The distribution of Chang Tang obsidian on the Tibetan Plateau also reveals something important about the organization of high-elevation habitat exploitation during the Early Holocene. Xidatan 2 is approximately 416 km from the source of the obsidian at Migriggyangzham Co. The

Dogai Coring, Erdaogou and Police Station 1 sites are 171, 243, and 350 km from the source and are 495, 177, and 66 km away from Xidatan 2, respectively. Amazingly, this same obsidian has been recovered from the Jiangxigou 2 site, on the southern shore of Qinghai Lake, 551 km from Xidatan 2 and 951 km from the known source. It is presently unclear whether the obsidian from Jiangxigou 2 is associated with the 9 or 5 ka date there. However, the correlation with Xidatan 2 argues for the earlier age. In any case, the presence of this raw material on the middle-elevation step suggests that movement of populations between high- and mid-elevation areas was established as early as 8 ka, but perhaps not earlier. On these grounds, we now favor assigning Early Holocene ages to one other middle-elevation step bladelet- and/or microblade-dominated surface assemblages. The Da Qaidam surface locality is located on a well-formed beach ridge in the Da Qaidam basin (N37.76, E95.26, 3110 m.a.s.l.). Previously, we had speculated that the beach represented a high stand of the Da Qaidam during MIS 3, possibly corresponding to the warm-wet event following H3 (ca. 30.5 ka) (Brantingham *et al.*, 2003). The technological character of the Da Qaidam lithic assemblage is identical to that seen at Xidatan 2 as well as the Chang Tang and Kekexili localities. The assemblage is similarly diverse in terms of raw material types. If this age assignment withstands further scrutiny, then Da Qaidam would further support the conclusion that regular movement between the middle- and high-elevation steps of the Plateau was established by the Early Holocene. However, we cannot yet conclusively trace any of the Da Qaidam stone raw materials to a high-elevation step source, unlike at Jiangxigou 2.

The earliest evidence for nonforaging adaptations on the Tibetan Plateau is found at the site of Karou and dated to ca. 5758 ± 109 Cal yr BP (CPAM, 1985; Aldenderfer and Zhang, 2004). Formal architecture consisting of several semisubterranean buildings with central hearth features, storage pits and an incredibly rich assemblage of ceramic, chipped stone, and ground stone technologies is recognized, even in the earliest occupations at Karou. Cultivated millet has been identified at the site as well as possibly domesticated pigs. A range of hunted animals (e.g., red deer and roe deer) and gathered plant foods are also recognized (see Aldenderfer and Zhang, 2004). While an Early or Middle Holocene site of this size and complexity has yet to be identified on the northern Plateau, the site of Jiangxigou 2 (ca. 9–6 ka) preserves thick midden deposits with abundant charcoal, ash, fragmentary bone, chipped stone technologies, and at least two varieties of ceramics (a thick plain ware and a thick cord marked ware). The highly fragmentary faunal assemblage includes deciduous dentition attributed to sheep as well as a small gazelle and small cervid. While it is presently uncertain whether the sheep remains represent wild or domesticated animals, the presence of gazelle and cervid remains suggests that hunting of wild game remained important through the Early Holocene. With a minimum age of 5587 ± 60 and maximum of 9140 ± 90 ka, these materials are nearly as old if not older than that seen at Karou.

7. Evaluating Colonization Models

The available archeological evidence from the Tibetan Plateau and surrounding low-elevation source areas is sufficient to provide a preliminary evaluation of the three alternative colonization models outlined at the beginning of this chapter. We propose that colonization can be driven by a process of (1) adaptive radiation, where the appearance of new adaptations in low-elevation source areas drops the hard biogeographic barrier preventing movement into high-elevation regions and low-elevation adaptive traits are sufficient to ensure survival in the high-elevation area; (2) directional selection, where initial forays into high-elevation areas are supported by low-elevation adaptations, but it is selection within the high-elevation environment that drives the appearance of unique adaptive characteristics that ensure survival; and (3) competitive exclusion, where the evolution of superior adaptive strategies in low-elevation environments pushes populations retaining ancestral adaptations into suboptimal high-elevation habitats.

All three colonization models require that there be a metapopulation present in the low-elevation areas surrounding the Tibetan Plateau to serve as a source of potential colonists. This seems like a trivial observation. However, several research groups have argued for massive depopulation of northeast Asia, including north China, during Pleistocene glacial events (Goebel, 2004; Brantingham *et al.*, 2004a). Barton *et al.* (this volume) use radiocarbon evidence from north China to show that occupation intensity in the low-elevation source areas of the middle- and high-elevation step of the Plateau fluctuated, but also that the area was never completely abandoned, at least over the last 40 ka (Fig. 13). The aggregate radiocarbon record for north China shows, in fact, that increases in the summed probability density distribution of calibrated radiocarbon dates tends to coincide with extreme climatic events, particularly H3 (ca. 30.5 ka), H1 (ca. 15.8 ka) and the Younger Dryas (ca. 12.8–11.5 ka). While the interpretation of such data is not unproblematic, it may provide a rough guide as to the intensity of archeological site formation at different times.

Present evidence supports the adaptive radiation of populations onto the Tibetan Plateau during three distinct periods, before H2, between H1, and the Younger Dryas and again in the Middle Holocene around 6000 Cal yr BP (Fig. 14). Occupation of the high-elevation step during the Early Holocene displays characteristics consistent with both competitive exclusion and directional selection, possibly in that sequence.

The evidence for the presence of human groups on the middle-elevation step of the Plateau before H2 (ca. 24.2 ka) is arguably limited. Only Lenghu locality 1 is found in a date-constrained surface setting with a minimum age greater than H2 (ca. 24.2 ka), maximum age of less than H4 (ca. 38.8 ka) and a probable age of 28–30 ka, immediately after H3 (Fig. 13). The Lenghu materials may thus be the same age as or slightly younger than the oldest Early Upper Paleolithic assemblages known in northwest China (Madsen *et al.*, 2001; Brantingham *et al.*, 2001a) (Barton, Brantingham, and Ji, this volume). The fact that the Lenghu materials

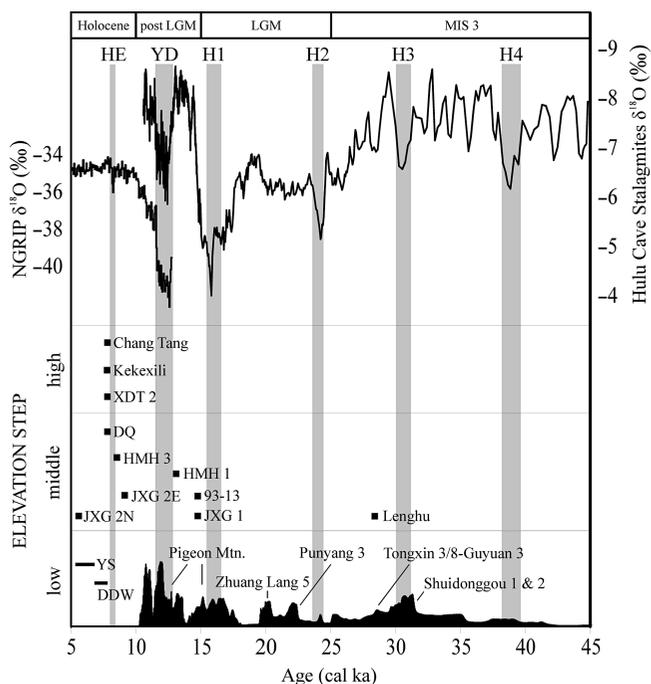


Fig. 13. Ages of sites and their positions within the low-, middle-, and high-elevation steps of the Tibetan Plateau. Individual radiocarbon sites from within the low-elevation step source area are shown against the summed probability density function for all known radiocarbon dated sites in North China (see Barton, Brantingham and Ji, this volume). Sites/Culture groups: DDW, Dadiwan Neolithic; YS, Yangshao Neolithic; JXG 1, Jiangxigou Locality 1; HMH 1 and 3; Heimahe 1 and 3; JXG 2E, earliest occupation at Jiangxigou 2; JXG 2N, Neolithic occupation at Jiangxigou 2; DQ, Da Qaidam; XDT 2, Xidatan 2. Kekexili includes the Police Station 1 and 2 and Erdaogou sites. Chang Tang includes all of the sites described in Brantingham, Olsen et al. (2001).

consist of stone technologies that are identical to the Levallois-like flat-faced blade technologies seen at Shuidonggou and other Early Upper Paleolithic sites in the region lends support to a 28–30 ka age assignment. Overall, the appearance of Early Upper Paleolithic blade technologies on the middle-elevation step of the Plateau is consistent with an adaptive radiation model for colonization: specialized large blade technologies appear first in low-elevation source areas and subsequently in high-elevation recipient areas with no apparent modification. The emergence of the Early Upper Paleolithic appears to have lowered, at least partially, the biogeographic barrier to human movements onto the middle-elevation step of the Tibetan Plateau. Selective pressures operating within low-elevation environments are thus responsible for changes in human biogeographic capacities at this time.

While there is no reliable evidence for human occupation anywhere on the Plateau between H2 and H1 (ca. 24.2–15.8 ka), there is growing evidence for a significant presence of human groups on the middle-elevation step

during the postglacial period. These groups appear to have made use of specialized microblade technologies, like those seen over a wide area of northeast Asia, as well as more generic, heavy-duty chipped stone tools and simple hand-held grinding equipment (Madsen et al., 2006). Sites in the middle-elevation step Qinghai Lake basin, which predate the Younger Dryas (Fig. 13), represent short-term foraging camps where intensive processing of medium- and small-sized game took place around simple hearth features (Madsen et al., 2006). The appearance of Late Upper Paleolithic adaptations on the middle-elevation step of the Plateau with little or no apparent modification, shortly after their emergence in greater northeast Asia, is strongly suggestive of a process of adaptive radiation. Low elevation selective pressures drove the emergence of the Late Upper Paleolithic and these adaptations (further) lowered the barrier to population movements onto the Tibetan Plateau.

The situation may have been quite different during the Early Holocene. At this time we see the first unequivocal evidence for exploitation of the high-elevation step of the Plateau. Buried archeological materials at Xidatan 2 are dated between ca. 8.2–6.4 ka and have a probable age of ca. 7.8 ka. The Xidatan 2 assemblage is broadly similar to the Late Upper Paleolithic in low-elevation environments. Shared technological attributes and stone raw material types link sites in the Kekexili and Chang Tang to Xidatan 2. We now believe that the Kekexili and Chang Tang surface assemblages are all also Early Holocene in age (contra Brantingham et al., 2001b).

If these high-elevation sites are linked to dedicated, full-time foragers, then it is possible to invoke a model of competitive exclusion to explain some of their archeological characteristics and temporal-spatial pattern of distribution (Fig. 14). Xidatan 2 was occupied at a time when early agricultural adaptations were coming to dominate landscapes within the low-elevation source areas around the Plateau. The Dadiwan Neolithic appears on the western Loess Plateau abruptly around 7800 Cal yr BP, but the initial steps towards a fully fledged agricultural adaptation should precede this date by several centuries, if not several millennia (Bettinger et al., this volume). By 6800 Cal yr BP intensive settled agricultural communities are found over a widespread area of north and northwest China, all of which are generally assigned to the early Yangshao (early Banpo) (Chang, 1986; Underhill, 1997; Lu, 1999; An et al., 2004; An et al., 2005). We believe that the emergence of agricultural adaptations in the low-elevation areas surrounding the northern Tibet Plateau and appearance of the first well-dated examples of human exploitation of the high-elevation step of the Plateau at the same time is not coincidental. Both events follow the Holocene cold-dry event (ca. 8200 Cal yr BP) falling within the regional climatic optimum. In low-elevation environments, warm-wet conditions during the Early Holocene were good for seasonal plant productivity, specifically on river floodplains, and may have contributed to the feasibility of agricultural specialization (Bettinger et al., this volume; Richerson et al., 2001). In high-elevation environments, these same warm-wet conditions may have stimulated the expansion of mesic (as opposed to arid) steppe-grasslands

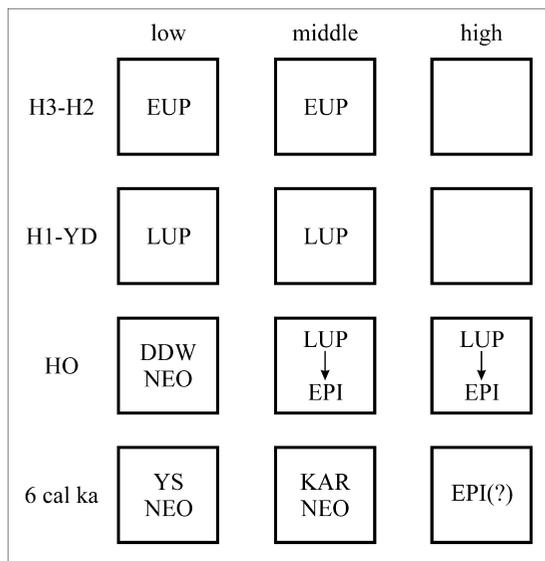


Fig. 14. Repeated colonization of the Plateau between H3 and H2, between H1 and the Younger Dryas and again approximately 6 Cal ka are each consistent with adaptive radiations based on largely unmodified low-elevation adaptations. The appearance of epi-Paleolithic groups on the middle- and high-elevation step are more consistent with an iterated process of colonization beginning with competitive exclusion of Late Upper Paleolithic from low-elevation environments and followed by directional selection leading to a unique high-elevation adaptive complex. The adaptive radiation of agricultural populations onto the middle-elevation step of the plateau ca. 6 ka MAY have eliminated epi-Paleolithic populations from the plateau. Abbreviations: YD, Younger Dryas; HO, Holocene optimum; EUP, Early Upper Paleolithic; LUP, Late Upper Paleolithic; EPI, epi-Paleolithic; DDW NEO, Dadiwan Neolithic; YS NEO, Yangshao Neolithic; KAR NEO, Karou Neolithic.

and game populations would have flourished. Climatic, environmental and regional population conditions thus may have favored the displacement of foragers onto the Plateau. Filling of low-elevation environments with agricultural populations may have pushed foragers up onto the Plateau, with the pull of a reasonably rich faunal community during the Holocene optimum also playing some measured causal role. Ethnohistoric evidence suggests that foragers who, for whatever reason, decide not to adopt new subsistence and social strategies are likely to be pushed into increasingly marginal environments (Spielmann and Eder, 1994). While these “relict” foragers may come to establish resource-exchange relationships with agriculturalists and/or pastoralists who occupy prime habitat, these relationships tend to be highly asymmetric and it is clearly the foragers who suffer the far more severe conditions (e.g., Howell, 2000). In sum, Late Upper Paleolithic adaptations prevalent in low-elevation environments surrounding the Plateau, during and immediately after the Younger Dryas (ca. 12.8–11.4 ka), may have provided some entrance into high-elevation environments.

However, competitive exclusion from low-elevation environments by early farming populations may have been responsible for making occupations on the high Plateau more permanent.

Several features of the assemblages seen on the high-elevation step of the Plateau suggest, however, that competitive exclusion was not the only process at play in driving Early Holocene colonization. Large, flat blade and bladelet technologies of the Chang Tang are derived from a Late Upper Paleolithic substrate, but present attributes that are unknown in the low-elevation environments that surround the Plateau. First, although these blade products tend to be quite large, they appear to have been produced by either indirect percussion or pressure flaking; a method used in northeast Asia for the manufacturing of microblades, but not regularly for large blades. Second, retouch patterns on some of the Chang Tang specimens seem to suggest that large blades and bladelets were sometimes end-hafted as spear points, also a pattern unseen in the Early or Late Upper Paleolithic of northeast Asia. Finally, stone raw material transport patterns appear to represent stone procurement distances that are at least an order of magnitude farther than anything previously documented in the Paleolithic of northeast Asia. Most instance of stone raw material procurement seen in the Early and Late Upper Paleolithic of north and northwest China are of low- to moderate-quality raw materials that are usually available in the immediate vicinity of the sites where they were worked and discarded. On the northern Tibetan Plateau, during the Early Holocene, we can demonstrate the transport of obsidian tool stone over distances as large as 951 km – between the source locality along the Kekexili–Chang Tang frontier and the Qinghai Lake site Jiangxigou 2. All of these features lead us to suggest that the Early Holocene lithic assemblages from Xidatan 2, Kekexili and the Chang Tang represent uniquely evolved strategies linked to the extreme selective pressures of high-elevation environments. Why these selective pressures did not appear to impact earlier incursions onto the middle-elevation step of the Plateau remains an open question. The answer may lie, however, in the observation that directional selection during the Early Holocene may have followed immediately on the heels of a period of competitive exclusion that necessitated more permanent occupation of the Plateau (Fig. 14).

Finally, we note that the appearance of fully fledged agricultural settlements on the Plateau after 6000 Cal yr BP appears to reflect another period of adaptive radiation from low-elevation source areas to middle-elevation sites. In this case, however, the evidence clearly points to the successful establishment of full-time, year round occupations. Karou, for example, shows the use of permanent architecture, storage features and domesticated plants and animals. Less is known about Jiangxigou 2 at Qinghai Lake, but the presence of large accumulations of debris (ash, rock, and animal bones) and the use ceramic vessels suggests lengthy, if not permanent occupation. The impact of this adaptive radiation on resident populations, if they were present, is unknown.

8. Seasonal Exploitation or Year-Round Occupation?

Each of the biogeographic models examined here has the requirement that dispersal leads to an established population on the Plateau. Otherwise we must acknowledge that a biogeographic barrier to colonization remains in place. From an archeological standpoint, we are presented with the difficult task of assessing whether archeological sites found on the Plateau represent continuous, year-round occupation, or merely seasonal exploitation of high-elevation habitats (see Derevianko *et al.*, 2004).

Human populations are recognized on the middle-elevation step of the Plateau at ca. 28–30 ka and 13–14.5 ka shortly after the initial appearances of Early and Late Upper Paleolithic in low-elevation source areas, respectively (see Fig. 13). However, we cannot be certain that the sites on the Plateau at these two different times represent anything more than specialized seasonal foraging forays. The Late Upper Paleolithic Qinghai Lake sites (14.5–13 ka) have simple hearth features, but there is no evidence for formal architecture, storage features, or large quantities of accumulated debris that would indicate long-term utilization of the area. The Qinghai Lake sites seem to represent short-term encampments that were used for at most only a few days. We note also that Lenghu (ca. 28–30 ka) and Qinghai Lake sites are close to the margins of the Plateau and near major mountain passes leading between the low- and middle-elevation steps. The linear distance from Lenghu to low-elevation areas below 2500 m.a.s.l. is less than 65 km, while it is less than 100 km in the case of the Qinghai Lake sites. Such distances were easily traversed by Holocene and more recent foragers in the Great Basin as part of seasonal foraging activities (e.g., Zeanah, 2004). The most parsimonious explanation is that the Early and Late Upper Paleolithic sites on the middle-elevation step of the Tibetan Plateau represent seasonal exploitation only. On technical grounds, therefore, we must qualify our conclusions that Early Upper Paleolithic and Late Upper Paleolithic human presence on the Plateau represents a process of adaptive radiation. Certainly, these adaptations allowed for seasonal exploitation, but perhaps no more. This is an important distinction since seasonal exploitation is unlikely to entail the severe demographic costs of year-round occupation and selection – both in terms of strict natural selection as well as within a cultural evolutionary framework (Boyd and Richerson, 1985) – is therefore unlikely to have had much scope for operation.

It is similarly difficult to argue conclusively that Early Holocene (ca. 7800 Cal yr BP) occupations of the middle- and high-elevation steps of the Plateau represent more than seasonal patterns of exploitation (see Fig. 13). The primary evidence in favor of full-time, year-round occupation of the high-elevation step of the Plateau at this time relates to the sheer size of the territory exploited. In contrast to the pattern of Early and Late Upper Paleolithic sites on the middle-elevation step being situated near direct access to corridors leading to low-elevation areas, many of the Early Holocene surface archeological sites in the Kekexili and Chang Tang are hundreds of kilometers from any point of descent.

Whether or not long distances mobility reflects seasonal or year-round occupation is in large measure dependent upon what we assume about the organization of mobility and the associated costs of movement (Brantingham, 2003; Brantingham, 2006). The cumulative distance traveled by arctic foragers over an annual round of residential moves may reach 600–700 km (Kelly, 1995). Given the potentially high costs of mobility at high elevation (Aldenderfer, 1998, this volume), it is reasonable to hypothesize that the Kekexili and Chang Tang sites represent year-round occupation. However, there is also good evidence stretching back as far as the Middle Paleolithic that stone raw materials were regularly transported over distances of 300–400 km and occasionally as much as 800–1000 km (Féblot-Augustins, 1997b), presumably in single logistical foraging forays. This latter argument leaves open the possibility that long-distance moves were regularly made onto and off of the high-elevation step of the Plateau. In possible support of this alternative hypothesis we note occurrence of Chang Tang obsidian at the Qinghai Lake site of Jiangxigou 951 km away as the crow flies. Regardless of whether this long-distance transfer represents direct or indirect procurement of stone, it demonstrates that around 6–8 ka groups of people were moving between the middle- and high-elevation steps of the Plateau at least on occasion.

A more theoretically based argument for the establishment of year-round occupation around 6–8 ka would point to the unique character of the lithic technologies present at Xidatan 2 and the Kekexili and Chang Tang sites. If the specialized large blade and bladelet technologies and strategies for end hafting of large, pointed blade blanks represent a process of directional selection, then this requires sufficient exposure to selective pressures to drive change. Given the absence of such directional changes during Early and Late Upper Paleolithic incursions onto the Plateau, their presence during the Holocene suggests a much greater exposure to selection, perhaps through year-round occupation.

The only unequivocal evidence for year-round occupation of the middle-elevation step of the Plateau postdates 6000 Cal yr BP and is associated with the adaptive radiation of agricultural groups out of low-elevation areas. The site of Karou and possibly Jiangxigou 2, both at ca. 3100–3200 m.a.s.l., represent this radiation. Madsen *et al.* (in press) have hypothesized, based on this evidence, that full-time, year round occupation of even higher elevation areas in Kekexili and the Chang Tang may not have been possible without radical adaptive innovations, such as Yak domestication (Rhode, this volume), or creation of large social networks that supply resources to populations in the most marginal habitats. Although this suggestion is controversial, it is consistent with the evidence that is currently available.

Ultimately, however, additional evidence must be brought to bear on the problem of when full-time, year-round occupation of the Tibetan Plateau was finally established. If such occupations were possible through a strict foraging adaptation, likely focused on specialized large-game hunting, then one would expect to see sites with zooarcheological remains in abundances commensurate with the need for long-term

supply (especially at winter camps) and probably also more substantial architectural and for food storage features.

9. Conclusions

We favor the view that the emergence of Early and Late Upper Paleolithic adaptations during pre- and post-LGM time periods, respectively, provided a basis for a limited adaptive radiation of low elevation foragers onto the middle-, but not the high-elevation step, of the Tibetan Plateau. More permanent occupations were more likely established on both the middle- and high-elevation steps around 8200–6400 Cal yr BP, coincident with the Holocene climatic optimum. We argue that the groups moving onto the Plateau at this time were probably dedicated foragers and that the primary cause for this dispersal was competitive exclusion from low-elevation environments that were increasingly filled with settled agriculturalists. We invoke directional selection to explain the appearance of specialized large blade and bladelet technologies in high-elevation step lithic assemblages during the Early Holocene. Such adaptive shifts may have been necessary to ensure year-round survival of populations marginalized to suboptimal habitats on the Plateau. However, there is no conclusive proof that permanent occupations were established above 3000 m.a.s.l. before 6000 Cal yr BP and we have raised the possibility that permanent occupation was in fact impossible without the support of agriculture or full-time pastoralism. It should be relatively straightforward to test certain aspects of these preliminary conclusions in future archeological work. In particular, confident dating of archeological assemblages could easily establish that the adaptive radiations of Late and even Early Upper Paleolithic groups onto the middle-elevation step also entailed movement onto the high-elevation step. Determining whether such occupations were seasonal or year-round will be more difficult, however.

If the broad pattern of colonization of the Plateau presented here is even partially correct then we are confronted with a very different view of the world then presented in studies of contemporary population genetics. To wit, leading geneticists have argued that 30,000 years of occupation at high elevation may have been necessary for microevolutionary processes to generate the specialized physiological capacities seen among contemporary Tibetan populations (Moore *et al.*, 2000; Beall, 2001). The conclusion that full-time occupation was not established before 8200 Cal yr BP suggests either that (1) the populations that initially colonized the high-elevation areas of the Tibetan Plateau possessed genetic variability that predisposed them to rapid accumulation of the physiological adaptations that we see today or (2) that selection in high-elevation environments is far more severe than generally thought and these strong selective pressures drove rapid adaptation. While we favor emphasizing the second mechanism, there may be some truth to the suggestion that initial colonizing populations were genetically unique in some way. The fact that Tibetan and Andean populations appear to have evolved different

physiological strategies for dealing with the stresses of life at elevation suggests differences in initial conditions, rather than major differences in the selective pressures experienced.

Acknowledgments

This work was supported by the US National Science Foundation (INT-0214870), Santa Fe Institute, University of California, Los Angeles; Desert Research Institute, University of Nevada; University of Arizona, and A. Richard Diebold, Jr, USA and by the Qinghai Institute of Salt Lakes and the Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, PR China. Numerous individuals contributed directly to the research presented here including Robert Finkel, Steve Forman, Donald Grayson, Lewis Owen, and Zhang Xiyang.

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