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Speculation on the timing and nature of Late Pleistocene hunter-gatherer colonization of the Tibetan Plateau

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Abstract **Hunter-gatherer populations in greater northeast Asia experienced dramatic range expansions during the early Upper Paleolithic (45—22 ka) and the late Upper Paleolithic (18—10 ka), both of which led to intensive occupations of cold desert environments including the Mongolian Gobi and northwest China. Range contractions under the cold, arid extremes of the Last Glacial Maximum (LGM, 22—18 ka) may have entailed widespread population extirpations. The high elevation Qinghai-Tibetan Plateau is significantly more extreme in both climate and environment than either the Gobi or the Siberian taiga forests, and provides an ideal setting to test fundamental models of human biogeography in the context of regional population fluctuations. The area is presently occupied primarily by nomadic pastoralists, but it is clear that these complex middle Holocene (<6 ka) economic adaptations were not a necessary prerequisite for successful colonization of the high elevation Plateau. Exploratory field-work in 2000—2001 has established that Upper Paleolithic hunter-gatherers were present on the Qinghai-Tibetan Plateau by at least 12 ka and possibly much earlier. A speculative model for the colonization process is developed and preliminary archaeological data in support of the model are presented.**

Keywords: Upper Paleolithic, late Pleistocene, climate change, China.

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1 Human biogeography on the edge

The Qinghai-Tibetan Plateau occupies nearly 1.25 million km^2 of the Asian continent and reaches an average elevation of more than 4000 m a.s.l. (Fig. 1). In addition to playing a critical role in global climate systems[1,2], the plateau is distinguished as the largest continuous high elevation ecosystem on the planet. This harsh, barren landscape is characterized by extremes of climate and environment and a biotic community specially adapted these extremes[3].

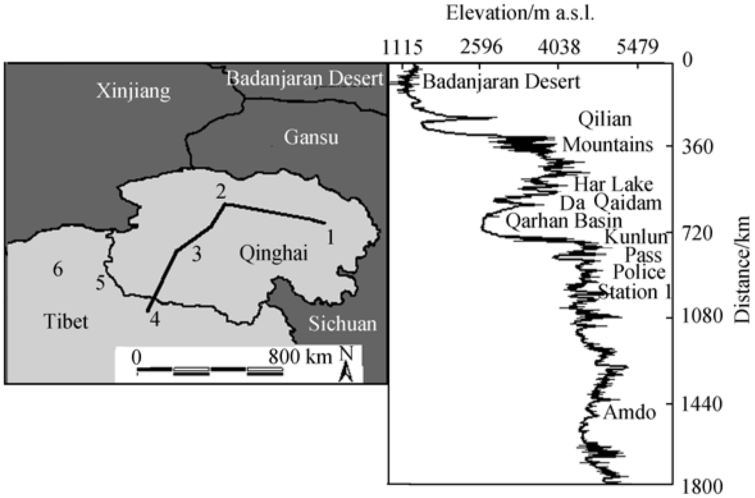

Fig. 1. Map of the Qinghai-Tibetan Plateau (left) and an elevation cross-section from the Badanjaran Desert in the northeast to south-central Tibet near Amdo (right). Left panel: 1, Qinghai Lake; 2, Xiao Qiadam and Da Qaidam; 3, Obsidian finds at Police Station 1; 4, Amdo; 5, Obsidian finds at Dogai Coring; 6, Chang Thang Sites. Right panel: Low elevation step represented by the Badanjaran Desert in the northeast; middle elevation step from the Qilian Moutains to the Qarhan Basin including Xiao Qaidam and Da Qaidam; high elevation step from the Kunlun Pass to Police Station 1 and Amdo.

The costs of living at high elevation are both severe and numerous, placing stringent constraints on hunter-gatherer colonization of the plateau environment. For example, nutritional requirements to maintain normal metabolic function at 4500 m a.s.l. exceed sea-level requirements by more than a factor of two[4], while work capacity is greatly reduced[5,6]. These nutritional constraints are exacerbated by hypoxia, which reduces the ability to absorb certain nutrients and concomitantly stimulates diuresis[4]. Acute and chronic cold exposures are constant risks and low biological productivity implies a low environmental carrying capacity[3,7]. Finally, populations at high elevation experience significant declines in infant birth weights and parallel increases in infant mortality[6,8]. The implications of these constraints are that high elevation hunter-gatherers would have been faced with greater nutritional demands, as well as greater capture costs and a reduced physiological capacity to benefit from resources successfully procured. More importantly, colonizing hunter-gatherer groups would have been demographically limited by reduced total fertility and possibly higher mortality rates across all age groups. Theory would suggest that (1) sustained high rates of immigration from source areas around the plateau, and/or (2) specialized adaptations to increase local intrinsic population growth would have been necessary to stave off local extinction of the colonizing groups. Establishing how Upper Paleolithic hunter-gatherer groups overcame these biological and physiological barriers, and whether the adaptive mechanisms were largely biological or behavioral, is of great significance for understanding the fundamental biogeographic capacities of human populations.

This paper develops a general model of the stages of colonization of the Qinghai-Tibetan Plateau and speculates on the behavioral adaptations that may have been involved at each stage. Preliminary archaeological data from exploratory field research conducted in 2000—2001 are presented. While consistent with the colonization model developed, the available archaeological data are too limited in chronological, spatial and behavioral resolution to provide a definitive test.

2 Environmental and climatic parameters

We hypothesize that the colonization of the Qinghai-Tibetan Plateau occurred in several discrete stages coinciding with major fluctuations in regional paleoclimate over the past 50 ka1). Moreover, we hypothesize that each discrete stage of colonization involved very different forms of hunter-gatherer foraging organization, suggesting that there is more than one set of behavioral strategies that can be successfully deployed for dealing with extreme environments.

Pleistocene climatic conditions are complex for China and northeast Asia as a whole. While proxy records for the early glacial (δ^{18}O Stage 4, 90—50 ka) are limited, regional climatic conditions were at least as extreme as during the LGM (see below). Between about 45—25 ka

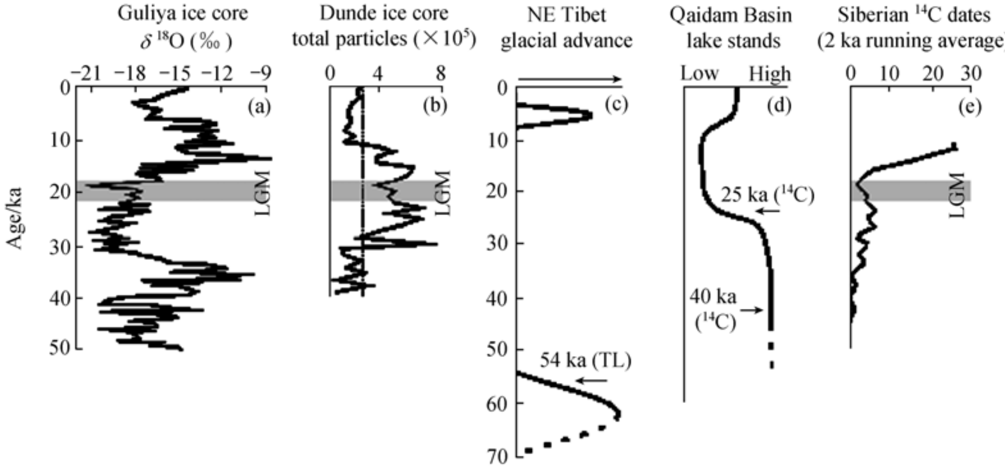

Fig. 2. Paleoclimatic records from the Qinghai-Tibetan Plateau and the frequency of archaeological radiocarbon dates from Siberian Paleolithic sites. From left to right, curve (a) to (e). (a) δ^{18}O record from the Guliya ice core indicates dramatic temperature fluctuations over the past 50 ka (more negative δ^{18}O values correspond to colder temperatures); (b) total particle ($\geqslant 2$ μm) content of the Dunde ice core reflects the magnitude of sediment mobilization from northwest Chinese deserts and dry lake basins and serves as a proxy of desert expansion and contraction; (c) glaciations on the northeastern Qinghai-Tibetan Plateau were limited to δ^{18}O Stage 4 (>50 ka) and the Holocene (<10 ka); (d) high lake stands occurred in the Qaidam and other basins during δ^{18}O Stage 3; (e) the frequency distribution of radiocarbon dates (2 ka running average) from Siberian Paleolithic sites is highly correlated with regional paleoclimatic fluctuations and is indicative of population range expansion during relatively cool-wet periods (δ^{18}O Stage 3 and post-LGM), and range contraction during the height of the LGM (22—18 ka). After Benn and Owen[1], Thompson et al.[2,33].

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1) All ages are reported in thousands of radiocarbon years before present (ka), or radiocarbon years before present (BP), unless otherwise indicated.

(roughly δ^{18}O Stage 3), the combination of cool summer temperatures and relatively high precipitation levels generated high lake stands in the Junggar Basin[9], Tengger Desert[10], Mongolian Altai[11], Mongolian Gobi[12] and various locations on the Qinghai-Tibetan Plateau (Fig. 2(a), (d))[13—15]. Regional lake expansions are correlated with increased alluviation in the southern Gobi and the desert margins in North China[16] and the expansion of steppe at the expense of desert environments (Fig. 2(b))[17].

Increased aridity and temperature declines during the LGM (22—18 ka) led to desiccation of the δ^{18}O Stage 3 lakes both on the Qinghai-Tibetan Plateau and in the surrounding regions (Fig. 2(d)). Maher and Thompson[18] reconstruct LGM precipitation levels on the Loess Plateau 50% below modern, a value generally consistent with other proxy records[19]. OSL-dated ice wedge casts in the Mongolian Gobi suggest mean annual temperatures during the LGM below −6℃[20], consistent both with general Global Climate Models[21] and temperature estimates based on ice core δ^{18}O records from the Qinghai-Tibetan Plateau (Fig. 2(a))[2]. However, it would appear that there was not a major glacial advance on the Qinghai-Tibetan Plateau during the LGM (Fig. 2(c))[1,22—24]. Deserts expanded dramatically at the expense of steppe environments and it is at this time that the Malan loess accumulated at various sections on the Loess Plateau.

In the post-LGM period (< 17 ka), some lakes reentered an expansion phase driven by increased precipitation levels[14]. This pattern, however, is locally variable given higher temperatures and accompanying increases in evaporation rates[15,25]. Apparently, few of the lakes in northwest China, or on the Qinghai-Tibetan Plateau surpassed their pre-LGM sizes (Fig. 2(d)). Similarly, the northeast Asian deserts did not retreat to their pre-LGM extents. The Holocene (<10 ka) is characterized by a general trend towards increasing aridity marked by brief periods of lake expansion and much longer periods of contraction[10].

Initial occupation of the Qinghai-Tibetan Plateau could have coincided with any one of these periods. Importantly, very different evolutionary consequences are implied by each of these alternatives. For example, initial occupation of the plateau environment during δ^{18}O Stage 4 (> 50 ka) would seem to imply that a pre-modern human species successfully answered the adaptive challenges of a high elevation ecosystem. This is not entirely unlikely given that there is some evidence for pre-modern human occupations of the central Gobi Desert[26,27]. In contrast, initial occupation during either δ^{18}O Stage 3 or 2 could signal the earliest expansion of anatomically modern human populations. This may imply that the evolution of "modern behavioral package" may have greatly expanded upon pre-modern biogeographic capacities. Finally, if initial occupation of the plateau occurred in the post-LGM period, then the success of colonization of the plateau environment may correlate with the dramatic intensification of hunter-gatherer foraging strategies recognized on a global scale towards the end of the Pleistocene.

3 A "three-step" model for the Qinghai-Tibetan Plateau

A general chronological model for the colonization of the Qinghai-Tibetan Plateau over the past 50 ka concentrates on the three elevation steps of the Qinghai-Tibetan Plateau: (1) the low elevation source areas of the northern plateau below 3000 m a.s.l., which consist primarily of Gansu Province, the Inner Mongolian Region and Xinjiang Uygur Autonomous Region; (2) the intermediate step between 3000—4000 m a.s.l., which includes the large internal lake basins of Qinghai Province; and (3) the extreme elevation step above 4000 m, which encompasses portions of Qinghai Province and all of the Tibetan Autonomous Region (see Fig. 1).

Early Upper Paleolithic hunter-gatherer groups, identified by a unique type of stone technology based on large stone blades, first ventured into the desert regions surrounding the Qinghai-Tibetan Plateau during δ^{18}O Stage 3, when lakes were at their highest stands of the late Pleistocene and steppe environments supported large wild ungulate populations[28]. These groups arrived in northwest China at sites such as Shuidonggou, by 29—25 ka[29], and perhaps as early as 40 ka (2001 field data). These early Upper Paleolithic hunter-gatherers engaged in a high mobility foraging strategy that specialized on medium- and large-sized game. As a result of the relatively uniform abundance of resources on these steppe landscapes, early Upper Paleolithic hunter-gatherers were able to move frequently from one lake basin to another as high-ranked resources became locally depressed. Simulation models of these foraging strategies suggest that landscape colonization may have proceeded much like a "random walk". Early Upper Paleolithic populations placed on the threshold of the Qinghai-Tibetan Plateau thus may have first colonized the middle elevation step (3000—4000 m a.s.l.) "accidentally" around 25 ka.

Changes in the fundamental character of resource distributions in the transition from δ^{18}O Stage 3 to the LGM (δ^{18}O Stage 2) may have had a dramatic impact on the organization of early Upper Paleolithic hunter-gatherer adaptations. Around 24—23 ka, δ^{18}O Stage 3 lakes started to retreat and desert environments began to replace steppe environments on the Qinghai-Tibetan Plateau and in the surrounding source areas of the plateau. Both vegetation and game likely concentrated around the receding lakes in each basin, producing a patchy distribution of resources. Simulation models indicate that a high-mobility, "random walk" foraging strategy becomes increasingly untenable as the patchiness of resource distributions increases and correlations in the quality of adjacent resource patches decrease. Theory would suggest that small hunter-gatherer groups, stranded on the middle elevation step of the plateau under increasingly patchy landscape conditions, would have to (1) increase their diet breadth to incorporate lower ranked resources concentrated around the receding lakes such as small, fast game or plant resources with higher processing costs[30,31], and/or (2) engage in more systematic seasonal strategies of landscape use (i.e., non-random walk).

The degree to which such changes in foraging behavior were accomplished may have determined whether hunter-gatherer populations managed to survive the LGM (22—18 ka) on the Qinghai-Tibetan Plateau. While archaeological evidence from greater northeast Asia leads us to hypothesize that the onset of the LGM ultimately led to the extirpation of early Upper Paleolithic hunter-gatherer groups on the Qinghai-Tibetan Plateau (see Fig. 2(e)), it is also reasonable to suggest that the first incursions of hunter-gatherers onto the high elevation step of the plateau (> 4000 m a.s.l.) may have directly preceded this event. Even during the height of the LGM, water availability, and consequently biological productivity, would have been somewhat greater on the high elevation step of the Qinghai-Tibetan Plateau compared with both the middle elevation step represented by the Qarhan, Qaidam and Qinghai Lake basins and the low elevation source areas represented by the deserts of northwest China. These middle elevation basins and low elevation deserts are all within the rain shadow of the high plateau and receive limited precipitation from the Indian and Southeast Asian summer monsoon[1,19,32]. Hunter-gatherer groups confronted with receding middle elevation lake basins at the onset of the LGM (23—22 ka) may have been forced to exploit the high elevation step of the Qinghai-Tibetan Plateau first seasonally, and then permanently with the complete desiccation of many lakes during the height of the LGM (20—18 ka).

Post-LGM environments in greater northeast Asia remained patchy in terms of both food and water resource distributions, suggesting that when late Upper Paleolithic hunter-gatherer groups re-colonized the Qinghai-Tibetan Plateau after the LGM (< 18 ka) they would not have been able to adopt the high mobility, "random walk" foraging strategy employed by early Upper Paleolithic groups. Rather, structured seasonal exploitation of different patches with longer residence times on the various elevation steps may have been a prerequisite of successful occupation.

4 Results of pilot projects

Pilot projects undertaken in 2000 and 2001 provide some preliminary results in support of the above colonization model. Surveys of the Xiao Qaidam Basin (37º27′23.0″N, 95º31′06.0″E, 3100 m a.s.l.) suggest that the posited age for the first colonization of the Qinghai-Tibetan Plateau of around 30 ka[34,35] may be in error. Archaeological materials recovered from the surface of a wave deposited beach in the Da Qaidam Basin (37º45′40.0″N, 95º15′19.0″E, 3110 m a.s.l.) are more consistent with an age of 25—23 ka for initial occupation. Yu et al.[15] suggest that dated sediment cores from Da Qaidam, collected by Huang et al.[36] and Zheng et al.[37], indicate a maximally high lake in the basin dates to 32—26 ka and possibly earlier. By 21 ka, lake levels had fallen below this elevation, but Da Qaidam remained a freshwater lake. Shortly thereafter (ca. 19 ka), evaporates indicate that the lake was much reduced, and has remained so, with some fluctuations until the present. We think the shoreline identified in 2001, which is minimally 20—25 m above the current basin bottom, may be related to the 30 ka mega-lake. Assuming that traces of any occupations chronologically coincident with the formation of the beach would have been obliterated by wave action, we are led to propose that the identified Upper Paleolithic materials may date to the intermediate-sized, lower-elevation freshwater lake phase (ca. 23—21 ka). Unfortunately, this reconstruction remains tentative. On the basis of present evidence, the sequences in the lake's two sub-basins appear to be out of phase[15]. However, we acknowledge that the radiocarbon dates from the available sediment cores appear to be on bulk organics (thus providing only approximate ages). Moreover, plant macrofossils collected from sodium-rich lake clays exposed in an alluvial drainage at the western end of the town of Da Qaidam (37º51′0.0″N, 95º20′16.0″E) dated to 1420 ± 140 BP (Beta-162260). This date suggests a Holocene high-stand in the basin that is not represented in the earlier cores.

Archaeological materials on the beach consist primarily of a specialized large blade and bladelet technology reminiscent of the early Upper Paleolithic in greater northeast Asia. Other examples of this specialized blade technology are known from earlier surveys of the Chang Thang Reserve on the high plateau (> 4000 m a.s.l.)[38]. We identified a similar, but somewhat more generalized early Upper Paleolithic large blade technology in the Kunlun Pass (3º38′19.0″N, 94º03′57.0″E) at an elevation of 4800 m a.s.l. If correlated with the materials from Da Qaidam, the materials from the Chang Thang and Kunlun Pass may reflect an early incursion onto the high plateau just preceding the height of the LGM.

Re-colonization of the Qinghai-Tibetan Plateau following the LGM is marked by the widespread occurrence of microblade technologies[35,38—40], dated in North China primarily to the terminal Pleistocene period[41,42]. While most of the known microlithic sites on the plateau are of unknown age, we identified and AMS radiocarbon dated two stratified archaeological sites on the southern rim of Qinghai Lake that are unequivocally terminal Pleistocene in age. A single, unprepared hearth identified along the small drainage at Jiangxigou yielded a charcoal date of 12420 ± 50 (Beta-149997). A second, much larger site at Heimahe yielded at date on hearth charcoal of 11070 ±40 (Beta-149998). These sites demonstrate that late Upper Paleolithic hunter-gatherers were present on the middle elevation step of the plateau before the end of the Pleistocene.

Presently, we can only offer informed conjectures about the organization of foraging adaptation on the Tibetan Plateau prior to the LGM, in large part because we require much greater chronological control over assemblages thought to date to this time period. The formal blade tools recovered from the Da Qaidam beach, and similar materials from the high plateau, are consistent with the hypothesized specialized hunting adaptation[38]. Moreover, the diversity of raw materials found on the Da Qaidam beach and the intensive pattern of tool recycling seen in similar assemblages from the high plateau are consistent with the model presented above of high-mobility, "random walk" foraging. The surface sites of putative pre-LGM age thus identified appear to be short-term occupations, though this conclusion demands further investigation. We expect, however, that stratified archaeological sites when finally identified will resemble Shuidonggou (29—25 ka), a site within the low elevation source area of the plateau, with simple, unprepared hearths and small assemblages of materials indicative of single family groups moving frequently in pursuit of high-ranked resources (Fig. 3(a))[29]. In contrast, at least five large, prepared hearths or roasting pits, each approximately 1 m in diameter, have been identified at Heimahe, one of the Qinghai Lake sites (Fig. 3(b)). Fragmentary bone material recovered from Hearth 4 at Heimahe represent a small- or medium-sized ungulate such as a goitered gazelle (*Gazella subguttarosa*). Such large archaeological features suggest a very different type of social and foraging organization involving multiple family groups occupying the location for an extended period of time, and a shift away from "random walk" foraging organizations towards more systematic seasonal use of given catchments as proposed in the above model.

Importantly, the identification on the high plateau of volcanic glass used as a type of raw material for stone tool manufacture promises to provide unparalleled resolution in discerning differences (or the lack thereof) between the behavioral strategies used in colonization of the Qinghai-Tibetan Plateau before and after the LGM. Obsidian sources can be chemically characterized to a high degree of specificity, allowing obsidian artifacts to be linked to individual sources even when found at great distances from their procurement sites[43]. Where the sources of the obsidian are known, one can reconstruct exactly the linear distances over which obsidian raw materials have been transported. Even if the geographic location of the source is not known, two archaeological sites shown to contain the same chemically characterized obsidian thus undoubtedly exploited the same raw material source and may have also been tied together into a single hunter-gatherer land use system. Obsidian artifacts have been identified at two sites in the Chang Thang Reserve (~4500 m a.s.l.), Lava Camp and Yako Hu (see Brantingham, Olsen and Schaller[38]), and at a separate site, Police Station 1, on the high plateau above Golmud (2001 field data) (see Fig. 1). Trace element analyses of the samples from Lava Camp and Police Station 1 indicate that there are two distinctive chemical varieties of obsidian represented (Richard Hughes, personal communication). The first variety is a translucent, high-Rb obsidian and is represented by two samples from the Lava Camp site in the Chang Thang Reserve[38] and one sample from the Police Station 1 site 400 km to the east (2001 field data). The second variety of obsidian is known presently only from the Lava Camp site, but is readily distinguished on the basis of its high Sr and Zr composition. While the geographic locations of the two obsidian sources have not yet been identi-

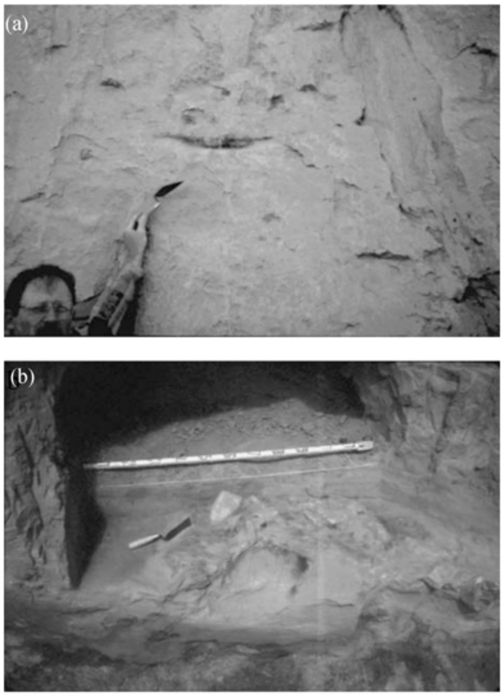

Fig. 3. Early and late Upper Paleolithic hearths from northwest China and the Qinghai-Tibetan Plateau. (a) This simple, unprepared hearth from Shuidonggou (ca. 26 ka) is indicative of a short-term occupation by a small family group using a high mobility foraging strategy; (b) a large, prepared hearth or roasting pit from a site adjacent to Qinghai Lake (ca. 11.4 ka) is one of at least five such features suggesting longer-term occupations of the site by a multiple family group involved in systematic or seasonal exploitation of the catchment area around Qinghai Lake.

fied, the fact that the Lava Camp and Police Station 1 sites contain obsidian from the same source indicates that this stone raw material was moved over a linear distance of at least 200 km. The ages of these obsidian artifacts are also unknown at present. Assuming that the materials from Lava Camp and Police Station 1 represent a single foraging system, however, it would appear that hunter-gatherer mobility distances were substantial in exploiting the plateau environment.

5 Conclusions

The evidence thus far collected provides important clues as to the timing and processes involved in colonization of the Qinghai-Tibetan Plateau. However, it is important to recognize that there are substantial empirical and theoretical questions that remain unanswered. First, the exact chronological profile of colonization needs to be resolved. Second, detailed archaeological evidence is needed for reconstructing the organization of hunter-gather adaptations deployed in the colonization of the plateau. Third, detailed reconstructions of the paleoclimatic and paleoenvironmental contexts that encouraged (or hindered) colonization are needed. Testing the general validity of different fundamental biogeographic models will be dependent upon assembling these data.

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