TECHNICAL RESPONSE

ARCHAEOLOGY

Response to Comment on "Permanent human occupation of the central Tibetan Plateau in the early Holocene"

W. R. Haas,[1]* M. S. Aldenderfer,[2]* M. C. Meyer[3]*

Zhang *et al*. contest that Chusang was part of an annual mobility round that "more likely" included seasonal use of high-elevation environments than permanent use. We show that their probabilistic statement hinges on indefensible claims about hunter-gatherer mobility. In the context of quantitative data from hunter-gatherer ethnography, our travel model shows that seasonal-use models are highly unlikely to explain Chusang.

Drawing on a travel-cost analysis and comparisons with ethnographic hunter-gatherer data, we argued that the site of Chusang likely indicates permanent use of the interior Tibetan Plateau by at least 8000 years ago (*1*). In their Comment, Zhang *et al*. (*2*) contend that "It is more likely that Chusang was part of a series of seasonally occupied camps produced by a group of foragers moving from place to place between lower-elevation margins and the high TP during the year." They base this claim on two points: (i) the lack of certain archaeological features at Chusang indicates that it cannot be considered as having a permanent occupation, and (ii) aspects of the travel model we employ are flawed.

As to the first claim, Zhang *et al*. state "Demonstrating permanent human occupation requires archaeological data including intense fire use, highly efficient tool kits, living structures, and a diverse array of plant or animal remains" and argue that because none of these are found at Chusang, it was not permanently occupied. This is a fundamental misunderstanding of our argument. We never stated that Chusang itself was the locus of a permanent habitation but instead hypothesized that it was used for "seasonal, short-term task pursuits" and that it was part of a settlement system that reflected an "annual, permanent, preagricultural occupation of the central plateau." This activity pattern does not require the construction of more permanent facilities.

Second, they claim that our model requirement of a minimum contiguous territory size of 25 km^2 is flawed, citing (i) Tibetan cities that have persisted in smaller areas for millennia and (ii) small territory sizes among ethnographic hunter-gatherers. Both of their analogies are flawed. Regarding the city analogy, scholars have long recognized that village sedentism—the reduction of per capita land-use area—is an unequivocal outcome of agricultural and market economies [e.g., (*3*)]. Cities, therefore, do not offer an acceptable analog for hunter-gatherer territory sizes.

For a more appropriate comparison, we consult hunter-gatherer ethnography. Indeed, the very review that Zhang *et al*. cite (*4*) supports our model's territory size threshold. The minimum territory size observed among 70 ethnographic hunter-gatherer groups is 25 km^2, and the average is 566 km^2 (*4*) (Fig. 1, A and B). A mere 3% of a maximum likelihood lognormal probability model fit to the ethnographic data [Kolmogorov-Smirnov (KS) test, D = 0.07, P = 0.81] is less than 25 km^2. The highly incised, geographically constrained interior valleys that Zhang *et al*. consider likely low-elevation source areas are therefore too small in areal extent to have comprised substantial portions of an annual round in the Tibetan Plateau interior.

Given the extreme travel distances indicated by our analysis, Zhang *et al*. and "other [uncited] researchers" furthermore suggest that travel distance would have been an "unlikely...factor in determining permanent occupation." We again refer to hunter-gatherer ethnography to generate empirically anchored, quantitative statements about the relationship between travel distance and the permanent use of a given location. Kelly's (*4*) compilation of annual residential move distances among 25 ethnographically documented hunter-gatherer societies serves as our baseline (see Fig. 1, C and D). A one-sample KS test indicates that a maximum likelihood lognormal model with a log mean of 4.88 + 0.20 log km (133 km) and a log

[1]Department of Anthropology, University of California, Davis, CA 95616, USA. [2]School of Social Sciences, Humanities, and Arts, University of California, Merced, CA 95343, USA. [3]University of Innsbruck, Institute for Geology, A-6020 Innsbruck, Austria.
*Corresponding author. Email: wrhaas@ucdavis.edu (W.R.H.); maldenderfer@ucmerced.edu (M.S.A.); michael.meyer@uibk.ac.at (M.C.M.)

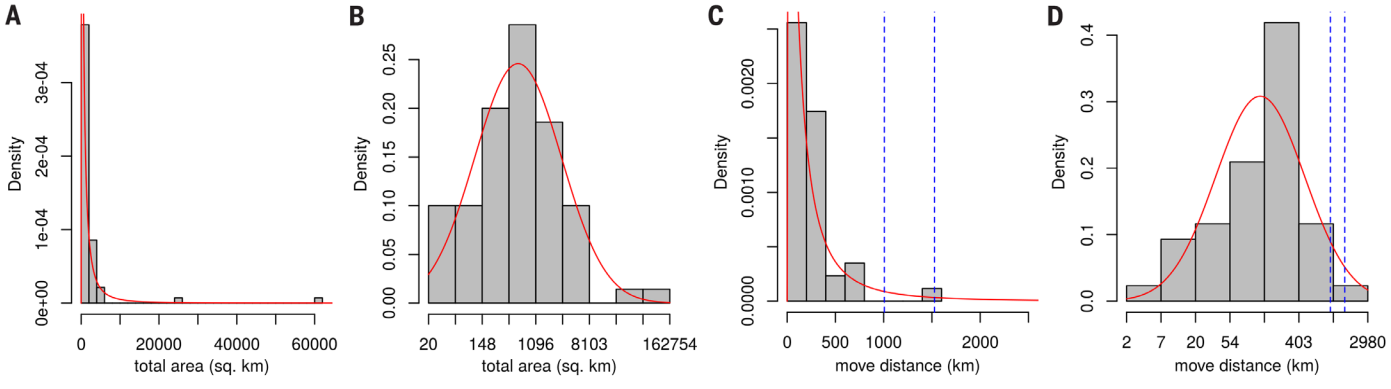

Fig. 1. Territory sizes (A and B) and annual move distances (C and D) observed among ethnographic hunter-gatherer groups, as compiled by (3). Data presented on linear (left) and logarithmic (right) axes. Solid red curves indicate maximum likelihood lognormal models. The territory size data indicate that hunter-gatherer territory sizes of less than 25 km^2 are extremely rare and entirely absent from the ethnographic sample. Dashed blue lines indicate minimum round-trip travel estimates between Chusang and the nearest low-elevation sources areas, given southern and eastern routes and assuming that at least 25% of the annual round was spent at low elevation. Such annual travel distances are certainly underestimates and yet are extremely rare among ethnographic hunter-gatherers.

standard deviation of 1.29 + 0.14 km offers a plausible fit to the data (D = 0.13, P = 0.39). Ninety percent of these modeled annual move distances fall below 688 km, and 95% fall below 1099 km. If the round-trip travel distances between Chusang and the nearest plausible low-elevation source regions are less than those values, then it would seem reasonable to conclude that Chusang could have been part of an annual round that included low-elevation environments.

Our travel-cost model (*1*) shows that a southern route could have minimally been traversed in 28 to 47 days of round-trip travel over 755 km—a distance that exceeds 91% of the ethnographically modeled annual travel distances. We emphasize that the 755-km estimate is a minimal estimate that ignores at least three important realities of hunter-gatherer mobility on the Tibetan Plateau. First, the nearest potential low-elevation source area, south of Chusang, would have entailed traversal of the Himalayan Arc, which would have been impassable much of the year. An eastern entry would have been more accessible and could have minimally been traversed in 41 to 70 days of round-trip travel over 1145 km. Such an annual move distance is greater than 95% of the values observed in the ethnographic model and thus highly unlikely.

A second simplification in our travel-cost model relates to how we identify the potential source area. The model identifies the nearest points on the low-elevation landscape. Yet, if low-elevation environments played an appreciable role in the annual round of residentially mobile foragers, then at least one season—~25% of the annual round—would have occurred in the low-elevation environment. We can therefore solve for an adjusted minimum annual travel distance, t, as follows: $t = d/(1 - 0.25)$, where d is the estimated least-cost, round-trip travel distance between Chusang and the nearest low-elevation source area. Inserting the southern entry distance estimate of 755 km into d gives a minimum annual travel distance of t = 1007 km—a distance greater than 94% of the values observed in the ethnographic model. Inserting the eastern entry estimate gives a value of t = 1527 km—a distance greater than 97% of the values observed in the ethnographic model. Again, such annual travel distances are highly unlikely.

Third, our model assumes a simple out-and-back scenario. Hunter-gatherer annual rounds were almost certainly more circuitous and reticulated. Although we could further model such path complexity, it would only belabor the already apparent point that the annual move distances that Zhang *et al.* consider "likely" are in fact highly unlikely.

As stated in our original manuscript, we cannot entirely rule out the possibility of nonpermanent use of the highlands. We acknowledge the pitfalls of using hunter-gatherer ethnography in the interpretation of archaeological data (*5*). Nonetheless, not all models are equal in light of empirical evidence, and likely explanations should be elevated over those that are remotely possible (*6*–*9*). Our travel analysis, in light of the best available data from hunter-gatherer ethnography, suggests that Chusang was highly unlikely to have been part of an annual round that included low-elevation environments. The onus therefore falls on proponents of seasonal-use models to demonstrate why we should accept the proposition that prehistoric populations engaged in extraordinary behavior that has rarely, if ever, been observed among other hunter-gatherer populations.

REFERENCES

1. M. C. Meyer *et al.*, *Science* **355**, 64–67 (2017).
2. D. Zhang *et al.*, *Science* **357**, eaam8273 (2017).
3. R. J. Braidwood, *Sci. Am.* **203**, 131–148 (1960).
4. R. L. Kelly, *The Foraging Spectrum: Diversity in Hunter-Gatherer Lifeways* (Percheron Press, New York, 1995).
5. H. M. Wobst, *Am. Antiq.* **43**, 303–309 (1978).
6. T. C. Chamberlin, *Sci. Mon.* **59**, 356–362 (1944).
7. L. Fogelin, *Am. Antiq.* **72**, 603–626 (2007).
8. P. A. Marquet *et al.*, *Bioscience* **64**, 701–710 (2014).
9. R. McElreath, *Statistical Rethinking: A Bayesian Course with Examples in R and Stan* (CRC Press, 2016).

16 March 2017; accepted 16 June 2017
10.1126/science.aam9444

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Science **357** (6351), eaam9444.
DOI: 10.1126/science.aam9444