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LETTER TO THE EDITOR

Another perspective on the age and origin of the Berelyokh mammoth site: response to Pitulko et al.

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The comments by Pitulko, Pavlova, Basilyan, and Nikolskiy (2018) concerning the origin and age of the Berelyokh mammoth site underscore the challenges for interpreting the complex sediment stratigraphy of the massive valley exposures that form the basis for much of the understanding of Late Quaternary environments of northern Siberia. The purpose of our paper is to explore this complexity by: (1) presenting permafrost processes as an alternative cause for the accumulation of large numbers of mammoth bones at Berelyokh; (2) providing counter arguments to ideas that the genesis of the bone horizon was the result of catastrophic floods as initially postulated by Vereschagin (1977) and later developed by Nikolskiy et al. (2010, 2011) and Pitulko et al. (2014); and (3) limiting the age of the bone horizon to a time prior to post-glacial amelioration (i.e., older than ~12,500 ^{14}C yr BP). Our paper is not meant to denigrate the extensive research done ~40 yr after the original field work (note: the more recent work did not include the original locale, which was destroyed during excavation and subsequently covered by hillside erosion). Rather, our alternative hypothesis is intended to emphasize the importance of permafrost processes, which are often give secondary consideration in paleogeographic reconstructions.

Pitulko et al. (2018) assert that we have manufactured data to support what they consider to be an *ad hoc* argument. We want to emphasize that the data presented in our paper were gathered by an experienced, interdisciplinary team (including permafrost specialists) during the original 1970 field season—these data are not a fantasy. We see no need to repeat the arguments presented in detail in our paper. We will take the opportunity, however, to correct some statements by Pitulko et al. (2018).

Figure 2 (Lozhkin and Anderson, 2018) is not a hypothetical reconstruction, but is based on data collected from sections at the original site. Exposures were described and samples collected from freshly cleaned surfaces of *in situ* sections, not from "erosional" material, as speculated by Pitulko et al. (2018). Because much of our paper involves paleovegetation, we provided a more detailed description of the section where the palynological data were collected.

We are unsure what Pitulko et al. (2018) mean by "thermokarst trap lake," but our hypothesis does not involve the formation of a thermokarst lake. The underground accumulation of water caused by subaerial melting is not equivalent to a thermokarst lake, which is a surface feature that migrates across the landscape; thus, a thermokarst trap does not have the same stratigraphic "signature" as a thermokarst lake (Hopkins and Kidd, 1988). Furthermore, a thermocirque, a slump deposit caused by subaerial permafrost activity, is not related to thermokarst lakes.

Permafrost features, which were documented at the original Berelyokh site, did not begin ~13,000 ^{14}C yr BP, as asserted by Pitulko et al. (2018). Permafrost landscapes were active across northern Siberia during glacial and interglacial times, dating to at least the middle Pleistocene (see Hopkins, 1982). While the most recent postglacial warming might alter the number or characteristics of permafrost features, this point has little relevance to our argument, as permafrost has been active at Berelyokh prior to the late-glaciation. In terms of the Yana region, the long-term importance of permafrost has been established most dramatically at Batagaika, where a detailed permafrost record is described from a mega-slump dating to at least Marine Oxygen Isotope Stage (MIS) 5 (Murton et al., 2017). It seems as if Pitulko et al. (2018) are not familiar either with the history of permafrost landscapes in northern Siberia and/or have confused processes that relate to the formation of thermokarst lakes, thermokarst traps, and thermocirques.

We remain unclear as to how the stratigraphy from the more recent research (Fig. 1 in Pitulko et al. 2018) correlates with the bone horizon. The subsequent work in the Berelyokh valley does, however, demonstrate that landscape features and ages vary across the second terrace. Such spatial variability and clear presence of other permafrost features does not preclude the local formation of a thermocirque at the original site.

Pitulko et al. (2018) ask why were the bones not articulated if Berelyokh represents a catastrophic burial. The bone bed was excavated by power washing (i.e., use of a high-velocity stream of pumped water), and bones collected as they were freed from the frozen sediments. This method is not especially useful in recovering articulated material. As described in our paper (Table 1), however, the published material indicates a diversity and number of mammoth bones sufficient to suggest whole animals were present. We, in turn, would ask Pitulko et al. why the Berelyokh assemblage consists of 99.3% mammoth bones if bones are being periodically washed into a side channel or marsh, as they suggest.

Our chronological interpretation is based on data from the original site. The radiocarbon data obtained during the later research may reflect temporal limitations for the original site, but do not necessarily provide accurate ages for the bone bed proper. We think that the date from the mammoth leg ($13{,}700 \pm 80$; MAG-114) is the most reasonable age for the bone bed, because it is directly associated with the bone horizon, is not based on problematic bone collagen, nor does it rely on spatial extrapolation to a deposit that no longer exists.

Our proposed chronology is supported by the palynological data. Unfortunately, similar analyses were not done during the subsequent work by Pitulko et al. (2014). This omission is rather surprising, given that palynological analysis is fairly standard for interdisciplinary studies of Siberian river exposures. Paleobotanical data not only present key information on past environments but they also are a check of ^{14}C-based age models, a factor that is particularly important when dealing with ancient thermokarst deposits where organic material is mixed. The herb-dominated spectra documented from the bone bed is characteristic of MIS 2, which would be consistent with the earlier ^{14}C dates noted by Pitulko et al. (2018; e.g., older than ~12,500 ^{14}C yr BP) but not with the younger range of dates (note: the discussion in our paper is based on an age of 12,600–12,200 ^{14}C yr BP proposed by Pitulko et al. [2014] and Nikolskiy et al. [2010] not the 13,700–11,800 ^{14}C yr BP used in their letter).

We maintain, based on work at the original site, that the occurrence of hillside instability caused by permafrost processes and the subsequent formation of a thermocirque is a viable hypothesis for the creation of the Berelyokh bone horizon. The importance of landscape instability in the formation of large mammoth "cemeteries" is not a new idea; it also has been proposed by Lavrushin et al. (2015) for more temperate areas in eastern Europe. In sum, permafrost should not necessarily be considered secondary to other landscape processes when interpreting the potential impact on ancient fauna (e.g., Lozhkin and Anderson, 2016). This exchange of ideas concerning the Berelyokh mammoth site underscores the difficulty in unraveling environmental histories from the river exposures of northern Siberia in particular and the strengths of interdisciplinary research in Quaternary studies in general.

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