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Comment on: "Extinction chronology of the woolly rhinoceros *Coelodonta antiquitatis* in the context of late Quaternary megafaunal extinctions in northern Eurasia" by A.J. Stuart and A.M. Lister [Quat. Sci. Rev. 51 (2012), 1–17]

In their invited review, Stuart and Lister (2012) present a spatio-temporal model for the extinction of one of the most important representatives of Late Pleistocene megafauna in Eurasia, the woolly rhinoceros (*Coelodonta antiquitatis* Blum.). Although they achieve definite progress compared to previous studies (e.g., Orlova et al., 2004a), some comments are necessary in order to make the picture of extinction patterns for woolly rhinoceros more objective.

It is crucial to conduct rigorous evaluations of the existing corpus of ^{14}C dates run on woolly rhinoceros remains. This was performed by Stuart and Lister (2012); however, their evaluation seems to be biased to some extent, and this affects their conclusions. Several important ^{14}C values from localities in Western Siberia and the Urals were rejected due to "Specimen ID unknown" (Stuart and Lister, 2012, Supplementary Table 2). The explanation for this is: "Dates are excluded from the study if identification could not be corroborated – this includes cases where the sampled skeletal element is unknown from published data or our requests for information from laboratories." (Stuart and Lister, 2012:9). However, this cannot be confirmed because for the ^{14}C dates mentioned (see Orlova et al., 2008) the skeletal element or at least an indication of the material as "bone" is given: for Lugovskoe, bone (Pavlov et al., 2002:165); for Zlatouskovka, teeth (Latypova and Yakheemovich, 1993:443; see also Kosintsev, 2007:115); and for the Orda River, calcaneus (SOAN-6385) and femur (SOAN-6386) (Vasiliev et al., 2007:30). Some of these sources are in Russian, but to the best of my knowledge no requests were made to the authors of the original reports to clarify the details. More than 20 samples from other Siberian localities labeled simply as "bone" are nevertheless accepted by Stuart and Lister (2012, Supplementary Table 1). Therefore, the rejection of the above mentioned sites in Western Siberia and the Urals is not fully justified, and their ^{14}C ages should still be taken into account. Furthermore, among the rejected values the very late ^{14}C date of ca 10,690 BP from the Hutouliang locality in Northeast China is missing, although it is cited in Kuzmin (2010:256).

The Lugovskoe locality on the central West Siberian Plain deserves special attention. If the ^{14}C date of the woolly rhinoceros bone of ca 10,770 BP (Orlova et al., 2008; Kuzmin, 2010) is valid, this is the youngest individual in the world known so far. However, this value was rejected by Stuart and Lister (2012:12, see also Supplementary Table 2) without an apparent reason. It should be mentioned that several other ^{14}C dates in the same range (ca 13,700–10,210 BP) were generated on woolly mammoth bones from this site (Orlova et al., 2004b). Paleoenvironmental data (Leshchinskiy et al., 2006) show a vegetation of forest tundra with a small amount of birch forests, typical for the West Siberian Plain in the Lateglacial (e.g., Kuzmin and Orlova, 2004:152–153; see also Velichko et al., 2002:78); these landscapes were generally suitable for woolly rhinoceros.

Another important issue is the focus by Stuart and Lister (2012:9) on "ultrafiltrated" ^{14}C dates produced mainly at the Oxford and Aarhus laboratories (223 values) versus dates obtained by non-ultrafiltered protocols (50 values). This seems to be an exaggeration of the existing situation. First, ultrafiltration does not always give better results; for example, the dating of the Kostenki 1 human skeleton with almost identical ages—ca 32,600–32,000 BP, overlap with ±2 sigma—obtained on both ultrafiltered and non-ultrafiltered collagen (Higham et al., 2006) is a case in point. Second, the reliability of ^{14}C dates produced in Russian laboratories (Moscow, St. Petersburg, and Novosibirsk), using slow dissolution of bone in hydrochloric acid as developed by L.D. Sulerzhitsky (e.g., Kuzmin and Orlova, 2004:144–145) and employed since the 1970s by most of the Soviet and (later) Russian facilities, was repeatedly proven by parallel measurements of the same sample in European and U.S. laboratories (e.g., Arslanov et al., 1998; Vasil'chuk et al., 2000; Kuzmin and Orlova, 2004). Notable is the case study of the Lugovskoe locality where two pairs of ^{14}C dates were obtained in Novosibirsk and Oxford, with negligible differences (Orlova et al., 2004b:366). Thus, "non-ultrafiltered" ^{14}C dates should be taken into consideration unless they are clear outliers like the IPAE-93 value of ca 9500 BP from the Urals (see Stuart and Lister, 2012:9).

The survival of woolly rhinoceros in Northeastern Siberia until ca 12,200–12,500 BP as presented by Stuart and Lister (2012; see also Lorenzen et al., 2011) is based on solid new information previously unavailable (e.g., Kuzmin, 2010). Northeastern Siberia now has a record of about 100 finite ^{14}C dates on woolly rhinoceros remains, the best in Eurasia.

If the 'late' ^{14}C dates on woolly rhinoceros from Western Siberia (Lugovskoe and Orda River) and the Cis-Urals (Zlatoustovka) were to be accepted, the extinction patterns would be different compared to Stuart and Lister's (2012), although some similarity

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remains. Small populations of woolly rhinoceros survived in Central Europe until at least ca 13,700 BP (ca 16,800 cal BP), in Eastern Europe until ca 12,800 BP (ca 15,100 cal BP), in the Urals until ca 12,300 BP (ca 14,200 cal BP), in Western Siberia until ca 10,800 BP (ca 12,600 cal BP), and in Northeastern Siberia until ca 12,200 BP (ca 14,000 cal BP). Another possible late survival of woolly rhinoceros in Eastern Siberia near the Lake Baikal shore is the Verkholenskaya Gora 1 site in the city of Irkutsk (^{14}C-dated to ca 12,570 BP, or ca 14,700 cal BP); here its bones were found in the early twentieth century (Birula, 1929).

It appears that before the extinction the habitat (range) of woolly rhinoceros was represented by isolated "pockets" with suitable environmental conditions, first of all steppe-like vegetation with sparse forest formations, and with a lack of large bogs and other water-enriched ecosystems (like modern tundra in Northeastern Siberia, for example). The final extinction of woolly rhinoceros in Eastern Europe and Siberia occurred within a few thousand years, at ca 12,800–10,800 BP (ca 15,100–12,600 cal BP, median values). Within Siberia proper, populations of woolly rhinoceros persisted in different regions until ca 12,200 BP (ca 14,000 cal BP) contra Stuart and Lister (2012, Fig. 1, *I–K*) who conclude that habitat "…contraction [was] toward the east" (Stuart and Lister, 2012:12), finally going extinct in Western Siberia and the Urals at ca 10,800 BP (e.g., Orlova et al., 2008; Kuzmin, 2010) or even later (ca 10,000 BP; see Markova et al., 2011:59). Therefore, Northeastern Siberia was not the "last stronghold" of woolly rhinoceros as concluded by Stuart and Lister (2012:9–12), and before the terminal extinction its fragmented habitat (sensu Lister and Stuart, 2008:619) covered most of the Siberian terrain and adjacent regions in the west (Urals and Eastern Europe). At that time, corresponding to the Lateglacial, the major part of this vast territory was covered by mostly treeless landscapes (e.g., Kuzmin, 2010:252–254), and the woolly rhinoceros populations were able to survive.

I agree with Stuart and Lister (2012:12): "The radiocarbon record of *C. antiquitatis* is still poor in some potentially important areas, and further work will corroborate or reject the hypotheses of regional 'gaps' in occurrence' noted above, and might possibly reveal currently unsuspected later survival." Nevertheless, existing data should be taken into account without bias, in my opinion. In this case, the extinction patterns for woolly rhinoceros would be quite different from the conclusions given in Stuart and Lister (2012).

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