REPLY TO VAN PEER:

Direct radiocarbon dating and ancient genomic analysis reveal the true age of the Neanderthals at Spy Cave

Thibaut Devièse[a,b,1], Grégory Abrams[c,d,1], Mateja Hajdinjak[e], Stéphane Pirson[f], Isabelle De Groote[g,h], Kévin Di Modica[c], Michel Toussaint[i], Valentin Fischer[j], Dan Comeskey[a], Luke Spindler[a], Matthias Meyer[e], Patrick Semal[k], and Tom Higham[a]

Van Peer (1) contests the conclusions of our article on Neanderthal disappearance in Northwest Europe (2), but we think his argument may reflect a misunderstanding of the stratigraphy at Spy Cave and/or incomplete reading of our article. We provide here a response to his arguments.

The idea that the discovery time of the Neanderthal bones impacts the results is not scientifically valid and indicates an incomplete review of the literature. Among the oldest radiocarbon dates obtained on the Spy Neanderthals are those measured on collagen from material collected on the slope: Spy 737a (OxA-10560) and Spy 94a (GrA-32623) (3, 4). In addition, although found on the slope, the maxillary fragment and the attached molar refit with the maxilla from the original collection excavated in 1886 as described and illustrated in figure 2B of ref. 2.

Van Peer argues that we rejected the young dates on the scapula Spy 572a "on the grounds of probable contamination." However, we demonstrated, using genomic analysis, that all dates on Spy 572a are younger than those of the other Neanderthal specimens because a modern collagenous glue made from bovid was applied on this specimen. Therefore, all the radiocarbon dates of Spy 572a are inaccurate, even those made on hydroxyproline (HYP).

The attribution of the remains to Spy I or Spy II is not the subject of our article. These attributions, discussed since the discovery of the bones in 1886, are the subject of ongoing research by Rougier and colleagues. Given the high level of uncertainty for assigning the bones to any individual, it is not reasonable to raise any stratigraphic argument for Spy I and Spy II. The only data we have, so far, to discuss their contemporaneity are the dates obtained on collagen extracted from teeth of each individual (Spy 92b and Spy 94a). These dates suggest the contemporaneity of both individuals (3, 4). Redating of these specimens with the HYP method (5) would be ideal, but this would require resampling.

A reworked position of Spy I is probable and unfortunately unverifiable. The argument proposed by Van Peer that mentions the presence of an erosive facies on the terrace is a misunderstanding of the literature. Indeed, the reworked sediment that Van Peer attributes to a natural erosive process (3? in figure 1A of ref. 1) is in fact the backfill from previous excavations, as de Loë and Rahir state in their publication (6). The stratigraphic units and their succession that Van Peer refers to in his letter vary greatly from one publication to another (7). These approximations raise questions on their relevance to the present discussion.

Finally, Van Peer argues that Neanderthals possibly lived more recently in the Meuse Valley than the individuals from Spy, Fonds-de-Forêt, and Engis. The discovery of more recent Neanderthal fossils may indeed, in the future, challenge the conclusions of our study. In addition to human remains, bone tools and/or faunal remains bearing anthropogenic

[a]Oxford Radiocarbon Unit, Research Laboratory for Archaeology and the History of Art, University of Oxford, Oxford OX1 3QY, United Kingdom; [b]Centre de Recherche et d'Enseignement de Géosciences de l'Environnement, Aix-Marseille University, CNRS, Institut de Recherche pour le Développement, Institut National de la Recherche Agronomique, Collège de France, Technopôle de l'Arbois, 13545 Aix-en-Provence, France; [c]Scladina Cave Archaeological Centre, 5300 Andenne, Belgium; [d]Faculty of Archaeology, Leiden University, 2311 EZ Leiden, The Netherlands; [e]Department of Evolutionary Genetics, Max Planck Institute for Evolutionary Anthropology, 04103 Leipzig, Germany; [f]Direction Scientifique et Technique, Agence Wallonne du Patrimoine, 5100 Namur, Belgium; [g]Department of Archaeology, Ghent University, 9000 Ghent, Belgium; [h]School of Biological and Environmental Sciences, Liverpool John Moores University, Liverpool L2 2QP, United Kingdom; [i]Association Wallonne d'Études Mégalithiques, 4000 Liège, Belgium; [j]Evolution & Diversity Dynamics Lab, University of Liège, 4000 Liège, Belgium; and [k]Scientific Heritage Service, Royal Belgian Institute of Natural Sciences, 1000 Brussels, Belgium

Author contributions: T.D., G.A., M.H., S.P., I.D.G., K.D.M., M.T., V.F., D.C., L.S., M.M., P.S., and T.H. wrote the paper.

The authors declare no competing interest.

[1]To whom correspondence may be addressed. Email: deviese@cerege.fr or gregory.abrams@scladina.be.

Published June 21, 2021.

modifications are the only elements that can be validly dated as they can be associated with archaeological material. We are currently dating these cultural witnesses, and more particularly bone tools.

1 P. Van Peer, The stratigraphic context of Spy Cave and the timing of Neanderthal disappearance in Northwest Europe. *Proc. Natl. Acad. Sci. U.S.A.*, 10.1073/pnas.2106335118 (2021).

2 T. Devièse *et al.*, Reevaluating the timing of Neanderthal disappearance in Northwest Europe. *Proc. Natl. Acad. Sci. U.S.A.* **118**, e2022466118 (2021).

3 P. Semal *et al.*, "Radiocarbon dating of human remains and associated archaeological material" in *Spy Cave. 125 Years of Multidisciplinary Research at the Betche aux Roches (Jemeppe-sur-Sambre, Province of Namur, Belgium), Volume 1, The Spy Cave Context*, H. Rougier, P. Semal, Eds. (Bull. Soc. Roy. Belge Anthrop. Préhist., 2013), vol. 123/2012, pp. 331–356.

4 P. Semal *et al.*, New data on the late Neandertals: Direct dating of the Belgian Spy fossils. *Am. J. Phys. Anthropol.* **138**, 421–428 (2009).

5 T. Devièse, D. Comeskey, J. McCullagh, C. Bronk Ramsey, T. Higham, New protocol for compound-specific radiocarbon analysis of archaeological bones. *Rapid Commun. Mass Spectrom.* **32**, 373–379 (2018).

6 A. de Loë, E. Rahir, Nouvelles fouilles à Spy, grotte de la Betche-aux-Rotches. *Bull. Soc. Anthropol. Brux.* **30**, 40–58 (1911).

7 S. Pirson *et al.*, "The stratigraphy of Spy Cave: A review of the available lithostratigraphic and archaeostratigraphic information" in *Spy Cave. 125 Years of Multidisciplinary Research at the Betche aux Roches (Jemeppe-sur-Sambre, Province of Namur, Belgium), Volume 1, The Spy Cave Context*, H. Rougier, P. Semal, Eds. (Bull. Soc. Roy. Belge Anthrop. Préhist., 2013), vol. 123/2012, pp. 91–131.