

**Reply to Schmidt et al.**

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**DOI**

[10.1073/pnas.1920933117](https://doi.org/10.1073/pnas.1920933117)

**Publication date**

2020

**Document Version**

Final published version

**Published in**

Proceedings of the National Academy of Sciences of the United States of America

**Citation (APA)**

Kozowyk, P. R. B., Langejans, G. H. J., Dusseldorp, G. L., & Niekus, M. J. L. T. (2020). Reply to Schmidt et al. Interpretation of Paleolithic adhesive production: Combining experimental and paleoenvironmental information. *Proceedings of the National Academy of Sciences of the United States of America*, 117(9), 4458-4459. <https://doi.org/10.1073/pnas.1920933117>

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REPLY TO SCHMIDT ET AL.:

# Interpretation of Paleolithic adhesive production: Combining experimental and paleoenvironmental information

Paul R. B. Kozowyk<sup>a,1</sup>, Geeske H. J. Langejans<sup>b,c,1</sup>, Gerrit L. Dusseldorp<sup>a,c,1</sup>, and Marcel J. L. Th. Niekus<sup>d,1</sup>

We agree with Schmidt et al. (1) that simple tar manufacturing processes exist. Tar could have been (re)discovered accidentally (2), and we do not exclude the use of condensation (3) by Neandertals. However, we think it is not the most parsimonious interpretation of all tar finds. Based on (regional) archeological and paleoenvironmental data, we suggest more efficient methods of tar production were used in the Zandmotor case (4). We will further address our reasoning.

## Efficiency

Schmidt et al. (1) suggest that simultaneously repeating the condensation process reduces the production time, yet this can also be done with distillation methods. Having more people work simultaneously requires the same number of man-hours and may add a degree of social sophistication. This also does not change the amount of birch bark required. Birch forests provide plenty of bark (1); however, the Zandmotor environment was primarily steppe-tundra and largely treeless (5, 6). Therefore, raw material constraints and efficiency cannot be disregarded.

## Composition

Koller et al. (7) analyzed the Königsauve piece and stated tar was produced at temperatures below 400 °C. This was generally accepted until Kozowyk et al. (2) produced tar at higher temperatures. The presence of certain fatty acids and diacids indicate a production method similar to a raised structure (8). These are visible in the Zandmotor tar, shown in the long-chain diacids plot of  $m/z$  98 (ref. 4, figure S4). High ratios of betulin and lupeol to degradation markers with the condensation method (ref. 3, figure 2D) are remarkable, with temperatures in the flames being much higher than

what Koller et al. (7) initially stated. More compositional analysis (cf. ref. 6) will no doubt be a tremendous aid to future research. The importance of uniform methods of analysis to establish diagnostic criteria for different production methods is also clear.

Birch tar is well suited for reuse (9). However, curation similar to Neolithic finds (6) cannot be posited on current evidence and intuitively a large amount of logistical complexity on the part of Neandertals. Furthermore, the thermoplastic properties making birch tar ideal for reuse also mean that it does not need to become liquid, as this hampers the application. Ethnographic examples show adhesives were only warmed until soft and then pushed onto flakes (10). Complete homogenization of contaminants, found in the Zandmotor tar, is unlikely to result from reuse.

## Prehistoric Analogies

Schmidt et al. (1) state that birch tar was kept and transported long distances in the Neolithic and that harvesting significant quantities of bark was not an issue. However, at that time, people used highly efficient and complex methods of tar production and still may have needed to consider the seasonality of bark harvesting and the qualities of different ages and types of bark (8). If these considerations were necessary when birch was plentiful, they become more significant for the Zandmotor tar produced by highly mobile societies in a largely treeless landscape.

## Conclusion

We agree that intuition cannot solve debates about Paleolithic tar production. Only through rigorous experimentation (3), uniform methods of analysis (8), and consideration of contextual information (4) can we get a better handle on the past.

<sup>a</sup>Faculty of Archeology, Leiden University, 2333 CC Leiden, The Netherlands; <sup>b</sup>Faculty of Mechanical, Maritime and Materials Engineering, Delft University of Technology, 2628 CD Delft, The Netherlands; <sup>c</sup>Palaeo-Research Institute, University of Johannesburg, Johannesburg 2092, South Africa; and <sup>d</sup>Stichting STONE/Foundation for Stone Age Research in The Netherlands, 9741 KW Groningen, The Netherlands

Author contributions: P.R.B.K. designed research; P.R.B.K., G.H.J.L., G.L.D., and M.J.L.Th.N. performed research; and P.R.B.K., G.H.J.L., G.L.D., and M.J.L.Th.N. wrote the paper.

The authors declare no competing interest.

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<sup>1</sup>To whom correspondence may be addressed. Email: p.r.b.kozowyk@arch.leidenuniv.nl, g.langejans@tudelft.nl, g.l.dusseldorp@arch.leidenuniv.nl, or marcelniekus@gmail.com.

First published February 11, 2020.

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