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Comment & Reply — Stratigraphy, Sedimentology

Traces of fire in a 560,000-year-old occupation soil at Caune de l'Arago: response to the article by Professor Henry de Lumley

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Abstract. This note is a reply to the comment "Did the first inhabitants of the Caune de l'Arago between 700,000 and 400,000 years BP have domesticated fire? Did they know how to light the fire at will?" by H. de Lumley, published in *Comptes Rendus Géoscience* in Volume 354, 2022, pages 41-45, https://doi.org/10.5802/crgeos.113. The comment in question concerns the article "Search for early traces of fire in the Caune de l'Arago at Tautavel (Eastern Pyrenees, France), combining magnetic susceptibility measurements, microscopic observations, and Raman analysis" by Deldicque et al., published online on July 29, 2021, in *Comptes Rendus Géoscience* in Volume 353, 2021, pages 247-264, https://doi.org/10.5802/crgeos.66.

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Our paper Deldicque et al. [2021] presents a new archaeometric method that reveals traces of heating associated with charcoal and vitrified charcoal at the prestigious site of the Caune de l'Arago. This evidence is found in sediments older than 400,000 years BP where no charcoal has previously been reported. Guided by a strong magnetic susceptibility signal in Ensemble I of the Middle Complex, we use Raman spectrometry and scanning electron microscopy to characterize charcoals and closely associated magnetic minerals in the Q4 level of the cave, where the age of the sediments is estimated at between 580,000 and 560,000 years BP. The strong magnetic susceptibility signal is due to the presence of maghemite and magnetite. The charcoals and associated magnetic minerals are found precisely at the F/G band boundary in zone 15, 1040 cm below the zero level (Figure 1 (a)). According to our observations, some charcoal fragments are up to 1 mm long ([Deldicque et al., 2021, Figure 3 and Figure 7]).

We also show that it is possible to produce the same magnetic minerals and reach the same susceptibility values by heating cave sediments – which are a priori unheated – sampled in proximity to the charcoals and magnetic minerals. The temperatures required for the formation of such minerals can be attained in the topmost few centimetres under a wood fire, at around 500°C Aldeias et al. [2016].

Concerning the interpretation of our results, we do not claim at any point that the inhabitants of the Arago Cave knew how to make fire and use it as they wished; these criteria would need to be met before we could speak of fire domestication stricto sensu. We have been extremely cautious and have carefully considered and studied two hypotheses: an external origin and an in situ origin. Both possibilities have very interesting implications. An ex situ origin is compatible with the existence of paleo wildfires, which would therefore characterize the paleoenvironments of the first occupants of the Caune de l'Arago. In the case of in situ origin, the presence of charcoals provides evidence of an anthropic input into the cave 560,000 years ago.

The article does not in any way question the age of fire domestication around 400,000 years ago, which is currently the consensus. There is increasing evidence for fire domestication in Europe between 400,000 and 300,000 years ago (Roebroeks and Villa [2011], Shimelmitz et al. [2014]). Sites showing evidence of fire use are rare in the first half of the Middle Pleistocene (between 800,000 and 400,000 years BP and its anthropogenic origin is systematically debated, with good reason: the traces are often altered and the association of charcoal, burnt bone and thermally altered lithic objects is not always present. Such is the case, for example, at Menez-Dregan 1 in Brittany, France, dated at around 500,000 years BP (layer 9 - Monnier et al. [2016]) and at the Gesher Benot Ya'aqov site in Israel (800,000 years BP) (Goren-Inbar et al. [2004]).

At Caune de l'Arago, questions arise about the close association of charcoal and magnetic minerals in the same level. In particular, we need to explain why these different combustion products are found together at the same location, 30 m away from the original entrance. If the charcoal and magnetic minerals had been formed from a natural fire outside the cave, it would be necessary to invoke transport by wind or run-off water. However, the highly contrasted densities and surface properties of the charcoal and mineral phases (chars are hydrophobic, unlike minerals) would probably have led to their separation during transport, which is not what we observe.

To date, no burnt bones have been found associated with the charcoal and magnetic minerals. However, it should be noted that sample CA 1040 is located in the "Terres Noires" (Figure 1 (a)), an organic-rich zone within the cave, whose sediments have undergone significant geochemical alteration, notably decarbonation. Volume III of the monograph on the Caune de l'Arago [de Lumley et al., 2020, p. 549, paragraph "Palaeontology"], presented in Figure 1 (b), mentions a scarcity of bones and limestone lithic objects, although they are abundant in the same stratigraphic horizon outside the "Terres Noires" zone. The continuation of the excavation would allow to go further on this point.

The discovery of charcoal associated with magnetic minerals that can be formed by heating, in a level estimated to be 560,000 years old, leads to consider and examine some exciting new hypotheses.

For instance, the charcoal could have been introduced through fissures from a medieval charcoal kiln. However, it is difficult to prove that the charcoals from the charcoal kiln are indeed the same as those found in level Q4. Such a hypothesis could be tested by identifying the vegetal species, by dating and by soil micromorphology. Furthermore,

a

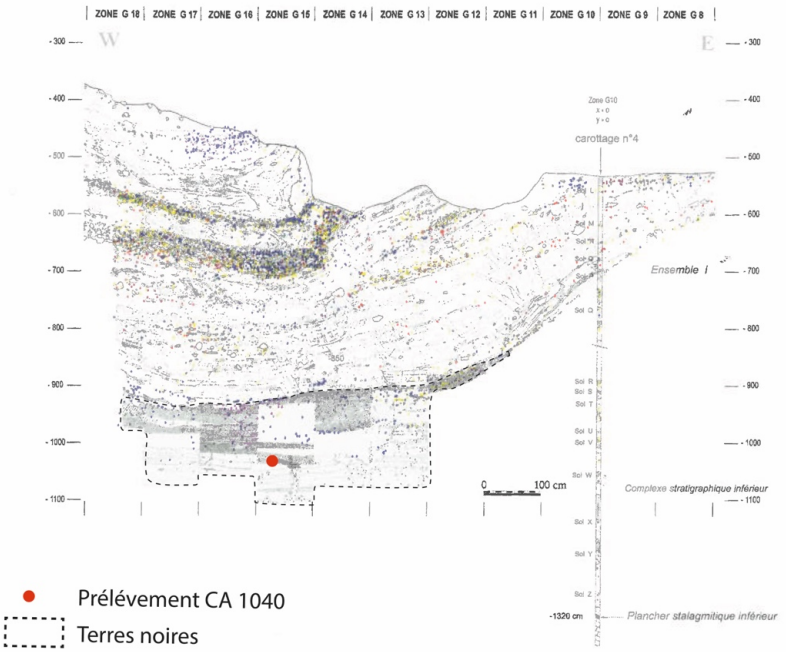

Figure 456: *Localisation des «* Terres Noires *» sur la coupe stratigraphique longitudinale F/G.*

b (Page 549)

PALYNOLOGIE

Deux coupes longitudinales F/G et E/F, en bande 16, ont été échantillonnées pour effectuer une étude palynologique. Peu de spores et de grains de pollen ont été rencontrés et, au regard des critères de validité de l'analyse palynologique, aucun spectre significatif n'a pu être établi. Cette partie du remplissage a alors été considéréc comme stérile en pollen.

PALÉONTOLOGIE

Alors que les ossements de grands mammifères sont très abondants dans les sables lités de l'ensemble stratigraphique I, au niveau des grandes unités archéostratigraphiques P et Q, ils peuvent disparaître totalement au niveau des « *Terres Noires* », alors que les lits de matériel archéologique en roche siliceuse peuvent être bien suivis en passant de l'un à l'autre et qu'aucune limite nette les sépare. Le passage latéral des sables lités jaunes des grandes unités archéostratigraphiques P et Q aux « *Terres Noires* » est toujours diffus.

Il paraît donc évident que les très nombreux ossements présents dans les grandes unités archéostratigraphiques P et Q ont, à part quelques rares exceptions, été dissous au sein des « *Terres Noires* » au cours d'une importante évolution géochimique provoquée par l'intrusion dans les dépôts d'un important réseau racinaire (fig. 488 à 490).

Il est possible que de petits vertébrés aient emprunté les cavités racinaires les plus grosses, une fois les racines dégradées, ce qui pourrait expliquer les ossements de microvertébrés recueillis dans les « *Terres Noires* » (fig. 486) ainsi qu'une petite phalangine de *Felis silvestris* (fig. 487).

Ces terriers sont certainement très anciens en raison de la présence parmi les rongeurs de *Pliomys lenki*. Néanmoins, certaines faunes de rongeurs, celles des sables lités jaunes et celles des terriers paraissent d'âge un peu différent. Si les deux ensembles se caractérisent par des proportions semblables de *Pliomys lenki*, de *Microtus (Terricola) vaufreyi* et, dans une moindre mesure, de *Microtus agrestis-arvalis* (tableau 64 et fig. 485), la surabondance de *Microtus (Stenocranius) gregalis* dans les sables lités jaunes de l'ensemble stratigraphique I du complexe moyen, comme celle de *Microtus (Iberomys) brecciensis*, plaident pour un âge un peu différent.

Figure 1. (a) Location of sample CA 1040 located 1040 cm below the zero level in zone G15, which was misplaced on the figure presented by Henry de Lumley in his comment. (b) Extract from de Lumley et al. [2020], mentioning a scarcity of bones in the "Terres Noires", in which sample CA 1040 is located.

it would be necessary to show how charcoals sometimes 1 mm long could have travelled so far from the surface kiln to reach a depth of more than 10 m. If the charcoal kiln had also produced magnetic minerals, it would be necessary to explain how magnetic minerals and charcoals could remain systematically associated together after transport over such a long distance in view of the physicochemical constraints

mentioned above. It should also be noted that these associations are located only in two levels (RFB and Q4), whereas they should be present systematically in the case of inputs from outside the cave or by migration from the charcoal kiln. Finally, these charcoals would have contaminated all the overlying sediments of level Q4, which would call into question all the data already obtained on the distribution of charcoals in the stratigraphic infilling.

In conclusion, our article clearly demonstrates the presence of traces of fire (charcoal associated with magnetic minerals) in the Arago Cave at Tautavel in sediments dated at more than 400,000 years BP. However, this result does not allow us to decide between the two hypotheses of an in situ or ex situ origin. Our article therefore invites more detailed investigations with additional observations, experiments and analyses. Further studies, including magnetic, micromorphological, anthracological, taphonomic and Raman analyses, could provide more insight into the origin of the charcoals and magnetic minerals associated together in level Q4. A great deal of multidisciplinary research is in perspective.

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