



When empirical data challenge entrenched interpretations: Revisiting the “hyaenid metanarrative” at Fuente Nueva 3 archaeological site (Orce, Granada, Spain)

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Scientific debates are not only about data, but also about how existing interpretations are maintained, challenged, or resisted in light of new evidence. In our original paper (Yravedra et al., 2024), we claimed that: (1) the nearly complete *Mammuthus meridionalis* skeleton from the Fuente Nueva 3 site (Orce, Granada, Spain) was deposited in a pseudogleyed sandy clay facies of the highly complex stratigraphic level 5 (FN3-5), and (2) certain modifications on the cortical surface that are consistent with large felid tooth marks and anthropogenic cut marks. Both claims have been criticized in a comment by Espigares et al. (2026), which raises several empirical, methodological, and interpretative issues that warrant clarification. To provide clarity, our response is structured in two complementary parts. First, we address the claims directly, focusing on stratigraphy, taphonomy, experimental analogues, and lithic technology. Second, we examine the broader epistemological implications of the arguments presented, particularly regarding interpretative frameworks and scientific practice.

1. Direct empirical and methodological response to Espigares et al. (2026)

1.1. Stratigraphy and contextual association

The commentators' insistence on deriving a direct behavioural association between the mammoth carcass, coprolites and lithic industry from their occurrence within Level 5 lacks rigor. As shown by Yravedra et al. (2024), specimen FN3-5-MPS belongs to Level 5B, and its depositional context was assigned to Microfacies Unit 4 (MF-U4), a pseudogleyed sandy clay deposited under waterlogged, shallow-water conditions. This attribution is based on sediment attached to bones and thin sections from the site's stratigraphy. As shown in Yravedra et al. (2024), Level 5 comprises different microfacies formed through distinct processes in different sedimentary environments. Thus, inferring direct behavioural association without considering the empirical microstratigraphic evidence provided in Yravedra et al. (2024) disregards the limits of archaeological resolution and reproduces the 'Pompeii Premise'.

Moreover, Fig. 1B in Espigares et al. (2026), which shows the presence of coprolites in MF-U4 (pseudogleyed sandy clays), contradicts their own previous claims, where they explicitly stated that coprolites surrounded the carcass, which was included in a thick layer of fine greenish sands (Espigares et al., 2013, 2023; Palmqvist et al., 2024). Such selective omission of their own published data to force an association constitutes an over-interpretation that disregards stratigraphic reality. Ultimately, accepting the commentators' current reasoning would require the physically impossible assumption that specimen FN3-5-MPS was deposited simultaneously in two different sedimentary contexts. This would effectively imply a 'Schrödinger-like' scenario.

1.2. Taphonomic evidence and the periosteum paradox

While Espigares et al. (2023) previously attributed the appearance of cutmarks at FN3 to periosteum removal, they subsequently argued (2026) that the thickness of the proboscidean periosteum would prevent such marks from forming. However, following the logical principle of

modus tollendo tollens: if a thick periosteum precluded mark formation, no such traces should be observed. Given that we have documented clear cut marks and tooth marks on three bones of a mammoth individual, their 2026 premise is refuted. The periosteum did not mask the biotic activities.

1.3. Biological plausibility of hyena attribution

Attributing the marks to immature hyenas to avoid recognizing other predators lacks parsimony. It is biologically implausible that marks from juvenile hyenas simultaneously mimic those of canids (Palmqvist et al., 2023b) and felids (Espigares et al., 2026). Furthermore, according to Arribas and Palmqvist (1998), infant individuals remain near the dens, not in open foraging areas. Invoking their presence in this context therefore constitutes an *ad hoc* hypothesis lacking empirical support.

1.4. Taphonomic independence: the fallacy of the analogous model

The criticism regarding the use of pig bones in our experimentation is taken to an extreme when stating that "pigs are absent from FN3" (Martínez-Navarro et al., 2015). This observation confuses the taxonomic composition of a site with the validity of an experimental model. As demonstrated by Maté-González et al. (2019)—a work not cited by the commentators—cut mark morphology does not depend on the species or the size of the bone, but on the physical properties of the cortical surface and the modifying agent. The use of suids is a methodological standard; suggesting that an experiment is invalid because the taxon or the exact conditions are not present at the site equates to invalidating a large part of experimental taphonomy (e.g., Binford, 1981; Behrensmeier, 1978).

1.5. Institutional reports and the "silicone hypothesis"

It is difficult to reconcile the recent introduction of the idea that a silicone mold damaged the fossil with the absence of such observations in earlier documentation. Neither the official 2010 monograph (Toro-Moyano et al., 2010) nor the mandatory reports of the Junta de Andalucía (Toro-Moyano et al., 2006) (both signed by three of the commentators) mention such damage. Invoking a supposed degradation only when marks appear that contradict their metanarrative raises doubts about the objectivity of the criticism. If the damage were real, the absence of their documentation in official publications over the past two decades would be inconsistent with standard scientific reporting practices.

1.6. Lithic technology: functional reductionism and mechanical efficiency

The criticism of the FN3 lithic industry incurs a double conceptual error. First, the authors reductively assume that all lithic elements were intended for dismemberment or cutting, ignoring that not all knapped elements identified are flakes. In the assemblage, there are pieces—such as the three (one on flint and two on limestone)—that lack an active edge and whose morphology and functionality respond to other phases of the *chaîne opératoire* or activities.

Furthermore, the mechanical features of the raw materials (flint and limestone) expose the flaw in the interpretation by the commentators. Activities such as disarticulation provoke high flake edge attrition; consequently, the number of flakes required should be higher than for tasks such as defleshing (Braun et al., 2008). Compared to flint, the mechanical properties of limestone preclude low durability (Braun et al., 2009). Experiments show that defleshing leads to an 8.35% loss of edge sharpness in limestone versus 1.88% in flint. This attrition increases considerably during skin processing: 25.48% for limestone compared to 3.22% for flint. In practice, this means that between four and eight limestone flakes—perhaps those found at archaeological sites—would be required to perform the same task as a single flint flake. Furthermore, the claim that limestone flakes were used for disarticulation is not supported by Espigares et al. by any experimental work, nor has a referential framework been established to confirm their suitability for such tasks.

2. Synthesis of empirical conclusions

To conclude, we reiterate our original findings.

1. The nearly complete skeleton of the *M. meridionalis* female FN3-5-MPS was deposited in the microfacies MF-U4, as defined within level 5 of FN3, and not in the green sands (MF-U2) as claimed by the commentators.
2. The tooth pits identified on the pelvis and one rib of the FN3-5-MPS specimen and morphometrically analyzed are highly consistent with those of a large felid; hence, we propose they should be attributed to *Homotherium*.
3. There is no direct evidence of hyena activity on the specimen FN3-5-MPS.

These results are based on careful analyses of the available evidence. Thus, any claim of overinterpretation from our side is contrary to the evidence. Additionally, it is worth noting that the observations related to FN3-5-MPS reflect circumstances which are particular to this case and cannot be extrapolated to other processes that occurred at FN3.

3. Epistemological and historiographical implications

3.1. Progressive science vs. degenerating programmes

The comment by Espigares et al. (2026) on our original paper (Yravedra et al., 2024) provides an exceptional opportunity to reflect on scientific methodology in the study of the Early Pleistocene. Following the distinction established by Lakatos (1978), science progresses through research programmes that lead to the discovery of “novel facts”. Conversely, a programme becomes degenerative when its production is limited to protecting “hard core” through *ad hoc* hypotheses, verbiage, and systematic resistance to any data that threatens the established paradigm. Our interpretation of the FN3-5-MPS specimen is based on direct evidence. Contrastingly, the comments in Espigares et al. (2026) prioritize reiterating their previous hypotheses (Espigares et al., 2013) without taking into account new scientific data obtained after more than 10 years of excavations and interdisciplinary research at the Fuente Nueva 3 site and without providing new data to support their claims.

In this context, we consider that our new characterization of cut marks and carnivore tooth marks, obtained by combining experimental taphonomy, 3D geometric morphometrics, and artificial intelligence algorithms, provides an alternative hypothesis achieved thanks to progressive research methodologies currently being applied by international experts (e.g., Boschín and Crezzini, 2012; Courtenay et al., 2023a; Domínguez-Rodrigo et al., 2024; Keevil et al., 2026; Souron et al., 2019).

3.2. The hyena metanarrative and bibliographical circularity

The high number of citations in the comment by Espigares et al. (2026) referring to their own publications is noteworthy. This pattern of circular self-referencing suggests a tautological model wherein the archaeological context is invariably interpreted under the influence of hyaenids, in support of their own previous works (Espigares et al., 2013, 2023; Palmqvist et al., 2011, 2023a, 2023b, 2024; Toro-Moyano et al., 2006, 2010). A metanarrative (Lyotard, 1979) appears to have developed in which the hyena is the absolute protagonist in Orce. We do not deny the importance of hyaenids in the Fuente Nueva 3 site (Courtenay et al., 2026). However, we argue that imposing a single interpretative model prevents the exploration of multi-causal scenarios where, from the morphometrical analyses of the teeth marks, the Orce's hyenas could be a relevant biotic agent (Courtenay et al., 2026; Yravedra et al., 2022) or otherwise (Courtenay et al., 2023a, 2023b; Yravedra et al., 2024). Moreover, staunch defense of ideas that clearly ignore the most recently obtained evidence simply because it is in contradiction to them is counterproductive to the advancement of science.

The attempt to shield their model has led the commentators to incur insurmountable logical contradictions, already discussed in the empirical sections above (Sections 2.1–2.3). Taken together, these inconsistencies reflect internal tensions within the proposed interpretative framework, suggesting that the model is being maintained through assumptions that are not mutually compatible.

4. A final reflection: comments-replies as a debate, not a metric

While this reply focuses on specific empirical and methodological issues, we consider it appropriate to reflect on the broader context in which post-publication exchanges are conducted and evaluated. Such exchanges should primarily serve the advancement of knowledge. However, they may also reinforce existing citation patterns, particularly when they rely heavily on previously published work by the same authors.

In this context, a significant proportion of the arguments in Espigares et al. (2026) have already been addressed in previous commentary (Courtenay et al., 2023b), and revisiting them here would only perpetuate an unproductive cycle. For this reason, it is more appropriate to consider Comments and Replies primarily in terms of their contribution to scientific debate, rather than their potential to generate additional citations, as redundancy does not necessarily equate to rigor. Ultimately, science advances by testing interpretations against new data, and the present debate underscores a broader principle: that the identification and definition of fresh research questions, the application of novel methodologies and techniques, and the inclusion of new empirical evidence must provide the basis for developing and progressive interpretative frameworks that allow science to evolve in accordance to current states of knowledge.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

All data and/or code is contained within the submission.

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