Forum Reply

https://doi.org/10.1130/G52152Y.1

Ice-rafted dropstones at midlatitudes in the Cretaceous of continental, Iberia

Juan Pedro Rodríguez-López[1,2], Carlos L. Liesa[3,*], Aránzazu Luzón[3], Arsenio Muñoz[3], María J. Mayayo[3], Julian B. Murton[2], and Ana R. Soria[3]

[1]Department of Geology, Faculty of Science and Technology, University of the Basque Country (UPV/EHU), Ap. 644, E-48080 Bilbao, Spain
[2]Permafrost Laboratory, Department of Geography, University of Sussex, Brighton BN1 9QJ, UK
[3]Departamento de Ciencias de la Tierra-Instituto de Ciencias Ambientales (IUCA), Facultad de Ciencias, Universidad de Zaragoza, Pedro Cerbuna 12, E-50009 Zaragoza, Spain
*carluis@unizar.es

We recently reported glacial dropstones in a glacial–deglacial succession in the Cretaceous of continental Iberia (Rodríguez-López et al., 2024), and here we reply to the Comment by Benito et al. (2024).

The dropstones occur within deposits located at meter 986 of the 1.3-km thick Navalsaz section (Enciso Group, Cameros Basin, Spain). The age of the group is Hauterivian–lower Barremian based on ostracods (Schudack and Schudack, 2009), charophytes (Moreno-Azanza et al., 2016), and cyclostratigraphy analysis, both at the studied section (Liesa et al., 2023), and on the magnetic survey in the Cidacos section (5 km to the west of the Navalsaz section) anchored by astrochronological methods (Casas et al., 2024). The physical correlation of both sections yields a time span of ~7.5 m.y. for the Navalsaz section and a Hauterivian age for the glacial deposits. The apparent contradiction with the uncertain Barremian–early Aptian age proposed by Suárez-González et al. (2013), based on foraminifers (Berriasian–Aptian distribution of cf. *Istriloculina*) and dasycladales (Barremian–Albian distribution of *Salpingoporella urladansi*) from the upper part of the Leza Formation, can be resolved by considering that the dated part of this unit could have a lower Barremian age and that it correlates with the upper Enciso Group, above the glacial sequence.

Benito et al. argued that a flat-lying architecture provided evidence of shallow paleodepths and homogeneity in terms of processes; these are dubious assumptions. We have not observed root traces or other evidence of subaerial exposure (e.g., infilled mudcracks) in the lacustrine succession. Moreover, the Enciso Group is characterized by organic-rich facies deposited under an extensional context in an extensive lake (>20 km). It contains black and dark shale that deposited under favorable conditions for organic matter accumulation; in fact, the Cameros Basin is a well-known paleo-petroleum system (Omodeo-Salé et al., 2016). High productivity anoxic lakes, with a certain depth, and not shallow lakes, show these favorable conditions for organic matter preservation and source-rock generation.

Detailed field observations allowed us to differentiate between glacial dropstones (e.g., Rodríguez-López et al., 2016; Xia et al., 2023) and dinosaur track infills (e.g., Navarrete et al., 2014). Unfortunately, Benito et al. (2024) appear to have conflated stratification planes inherited in the dropstone clasts (S_0 in Fig. 1E of Rodríguez-López et al., 2024) with adjacent calcite veins; the discrete calcite veins are clearly parallel to the yellow-marked lines (Fig. 1E of Rodríguez-López et al., 2024) and can be easily seen by zooming in on the provided high-definition photographs. Our study in the Navalsaz section yielded a total of 14 discrete horizons containing dinosaur tracks and casts at meters 10, 14, 275, 277, 368, 371, 492, 815, 910, 967 (Cuesta de Andorra tracksite), 1197, 1198, 1199, and 1302 of the logged section. These tracks cluster into nine stratigraphic intervals, with a mean distance (thickness) between intervals of ~161 m (standard deviation: 95.7 m; range: 57–318 m; mode: ~100 m), which involves ~880 k.y. (550 k.y. for the recurrence mode of 100 m). The Cuesta de Andorra tracksite indicated by Benito et al. is not at 10 m below the glacial–deglacial succession, but at 19 m; that is, it preceded it by ~142 k.y. (for comparison, the Last Glacial Maximum of the Pleistocene occurred from 26.5 to 19 ka; Clark et al. 2009). Dinosaurs have been adapting well to extreme cold environments at least since the Late Triassic, and dinosaur tracks have reported to be found along with abundant lacustrine ice-rafted debris in the Triassic–Jurassic of China (Olsen et al., 2022). Similar to our results, one of the dinosaur track levels is 24.2 m below one of the ice-rafted debris intervals. The conclusions of Olsen et al. (2022) are interesting and profound: "dinosaurs were already well adapted to cold temperatures, and not only survived but also underwent a rapid adaptive radiation and ecological expansion…" Which was the effect of this glacial event on Cretaceous dinosaurs? Is this the only record of Cretaceous glaciation in Iberia?

REFERENCES CITED

Benito, M.I., Quijada, I.E., García-Martín, M., Pertuz, A., Suárez-González, P., Toricez, A., and Campos-Soto, S., 2024, Ice-rafted dropstones at midlatitudes in the Cretaceous of continental Iberia: Comment: Geology, v. 52, p. e574, https://doi.org/10.1130/G52006C.1.

Casas, A.M., Muñoz, A., Tella, A., and Liesa, C.L., 2024, Magnetic surveying as a proxy for defining cyclicity in thick sedimentary fillings: Application to the Cretaceous Cameros Basin (N Spain): Cretaceous Research, v. 154, https://doi.org/10.1016/j.cretres.2023.105736.

Clark, P.U., Dyke, A.S., Shakun, J.D., Carlson, A.E., Clark, J., Wohlfarth, B., Mitrovica, J.X., Hostetler, S.W., and McCabe, A.M., 2009, The Last Glacial Maximum: Science, v. 325, p. 710–714, https://doi.org/10.1126/science.1172873.

Liesa, C.L., Soria, A.R., Luzón, A., Mayayo, M.J., Yuste, A., Angulo, A., Illueca, N., Rodríguez-López, J.P., Pérez, A., and Muñoz, A., 2023, Orbitally induced climate signal in the Lower Cretaceous synrift lacustrine sediments of the Enciso Group (eastern Cameros Basin, N Spain), *in* Vlahovic, I., and Matesic, D., eds., 36th IAS Meeting of Sedimentology, Dubrovnik (Croacia) Abstract Book: Croatian Geological Society (HGD), p. 498, https://iasdubrovnik2023.org/Abstracts-Book.pdf.

Moreno-Azanza, M., Gasca, J.M., Díaz-Martínez, I., Bauluz Lázaro, B., Canudo Sanagustín, J.I., Fernández, A., and Pérez-Lorente, F., 2016, A multi-ootaxic assemblage from the Lower Cretaceous of the Cameros Basin (La Rioja; Northern Spain): Spanish Journal of Palaeontology, v. 31, p. 305–320, https://doi.org/10.7203/sjp.31.2.17158.

Navarrete, R., Liesa, C.L., Castanera, D., Soria, A.R., Rodríguez-López, J.P., and Canudo, I., 2014, A thick Tethyan multi-bed tsunami deposit preserving a dinosaur megatracksite within a coastal lagoon (Barremian, eastern Spain): Sedimentary Geology, v. 313, p. 105–127, https://doi.org/10.1016/j.sedgeo.2014.09.007.

Olsen, P., Sha, J., Fang, Y., Chang, C., Whiteside, J.H., Kinney, S., Sues, H.-D., Kent, D., Schaller, M., and Vajda, V., 2022, Arctic ice and the ecological rise of the dinosaurs: Science Advances, v. 8, https://doi.org/10.1126/sciadv.abo6342.

Omodeo-Salé, S., Suárez-Ruiz, I., Arribas, J., Mas, R., Martínez, L., and Herrero, M.J., 2016, Characterization of the source rocks of a paleo-petroleum system (Cameros Basin) based on organic matter petrology and geochemical analyses: Marine and Petroleum Geology, v. 71, p. 271–287, https://doi.org/10.1016/j.marpetgeo.2016.01.002.

Rodríguez-López, J.P., Liesa, C.L., Pardo, G., Melendez, N., Soria, A.R., and Skilling, I., 2016, Glacial dropstones in the western Tethys during the late Aptian-early Albian cold snap: Palaeoclimate and palaeogeographic implications for the mid-Cretaceous: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 452, p. 11–27, https://doi.org/10.1016/j.palaeo.2016.04.004.

Rodríguez-López, J.P., Liesa, C.L., Luzón, A., Muñoz, A., Mayayo, M.J., Murton, J.B., and Soria, A.R., 2024, Ice-rafted dropstones at midlatitudes in the Cretaceous of continental Iberia: Geology, v. 52, p. 33–38, https://doi.org/10.1130/G51725.1.

Schudack, U., and Schudack, M., 2009, Ostracod biostratigraphy in the Lower Cretaceous of the Iberian chain (Eastern Spain): Journal of Iberian Geology, v. 35, p. 141–168.

Suárez-González, P., Quijada, I.E., Benito, M.I., and Mas, R., 2013, Eustatic versus tectonic control in an intraplate rift basin (Leza Fm., Cameros Basin): Chronostratigraphic and paleogeographic implications for the Aptian of Iberia: Journal of Iberian Geology, v. 39, p. 285–312, https://doi.org/10.5209/rev_JIGE.2013.v39.n2.42502.

Xia, G., Wu, C., Mansour, A., Jin, X., Yi, H., Li, G., Fan, Q., Shi, Z., Murton, J.B., Pei, J., and Rodríguez-López, J.P., 2023, Eocene–Oligocene glaciation on a high central Tibetan Plateau: Geology, v. 51, p. 559–564, https://doi.org/10.1130/G51104.1.