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Comment to: Detecting upland glaciation in Earth's pre-pleistocene record

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Introduction

Soreghan et al. (2022) conducted field research to find evidence of ancient upland glaciation "in the absence or near-absence of icecontact indicators", and as an example they presented a case study mainly from the Late Paleozoic palaeoequatorial Cutler Formation (Colorado, United States). This is a good aim, because upland areas are subject to much higher rates of erosion than lowland or marine environments, the latter which more often exhibit deposition. Even today there are glaciers close to or even at the equator, on e.g., Mount Kenya (Mahaney, 1990).

As Soreghan et al. (2022) describe, the problems of identifying ancient upland glaciation are substantial. A large part of the paper is used to try to explain how fluvial deposits can be interpreted as glaciofluvial. The work is diligent, but there is no definite answer to the origin based on the appearance of the deposits themselves.

Discussion—General

Most of the pictures presented by Soreghan et al. (2022) of geologic features, which would be the more decisive ones for influence from cold weather, are from other areas than the Cutler Formation. Features interpreted to be pseudomorphs from ice-crystals may be chemical, from e.g., salt mineralization, as Soreghan et al. (2022) mention. However, occasional snowfalls may take place on lower land surfaces close to the equator (Knight, 2022), and the ice-crystal pseudomorphs pictured appear to be perfectly similar to recent ones (Pfeifer et al., 2021; Voigt et al., 2021). However, none of these ice-crystals are from the Cutler Formation.

"Frozen ground phenomena" described and pictured are not from the Cutler Formation, but from the Pennsylvanian Fountain Formation, Colorado. Soreghan et al. (2022) refer to a paper by Sweet and Soreghan (2008), which describe these fractures and polygons to "range from 3 cm to 55 cm to 13 cm–>220 cm in width and depth, respectively". The patterned ground documented appears to display a network of squeezed sediments (Sweet and Soreghan, 2008; Soreghan et al., 2022, their fig. 5), like what may be induced by gravity from soft sediment tectonics (e.g., Eyles and Clark, 1985), but more seldom from freeze-thaw cycles. Freeze and thaw polygons may be straighter and more vertical, but not displaying an underground network of sediments. The size and appearance of the polygons described by Soreghan et al. (2022) are not much similar to polygons which are made by freeze-thaw-cycles. The latter commonly are more regular and in sizes often many times larger (Eyles and Clark, 1985), while the interiors documented by Soreghan et al. (2022) are displayed as an irregular "condensed" network.

Slices and balls of soft non-cohesive sediment, i.e., rip-up clasts, are incorporated in the deposits, and are interpreted to have been in a frozen condition. The only reference by Soreghan et al. (2022) to sediments "which appear analogous to rip-ups of frozen bank material" is a paper by Diffendal (1984). Diffendal (1984) wrote "It is possible that the sand megaclasts were transported to the site in a frozen condition." Any material inside and especially at the bottom of a glacier is heavily molded, and clasts are quickly rounded. Any frozen sediment would be more prone to such molding. At the other end, soft non-cohesive sediments are commonly transported with mass flows (e.g., Cardona et al., 2020; Dufresne et al., 2021), which takes place regularly and so often that such sediments actually may be used as an indication of sediment gravity flows. In conclusion, soft non-cohesive sediments, either mud balls covered with sand or gravel giving them an appearance of sandstone (Diffendal, 1984; Strat and Móga, 2020), or balls or slices of non-cohesive sediments, are common constituents of sediment gravity flows and flash flood sediments (Molén, 2017; 2021; Strat and Móga, 2020). The evidence from incorporated soft sediments therefore is better explained by sediment gravity flows than glaciation.

Discussion—Surface microtextures

A major shortcoming in the paper by Soreghan et al. (2022) is their interpretation of surface microtextures on quartz grains. Papers and books by e.g., Mahaney (2002), Molén (2014), Kalińska-Nartiša et al. (2017) and Kalińska et al. (2022), even if different methods are used, show how and when surface microtextures originate and change during transport.

Soreghan et al. (2022) wrote "More recent work has argued that only large-scale fractures that cover at least one-quarter of the grain surface can be considered glaciogenic, as smallerscale fractures can be produced in a wide variety of environments (Molen, 2014)." This statement is in part almost opposite to the quoted work of Molén (2014). Fractures by themselves indicate almost nothing. They commonly originate during release from bedrock or in any high-stress environment (Mahaney, 2002; Molén, 2014). It is the combination and appearance of surface microtextures which is important. The conclusion in the paper by Molén (2014) is: "1 A glacigenic grain typically exhibits largescale fractures (F1) and irregular abrasion (A1)," Later work has further specified this combination of surface microtextures, i.e., fresh fractures that are irregularly abraded (e.g., Molén and Smit, 2022).

Soreghan et al. (2022) refer to a paper by Sweet and Brannan (2016) to indicate that surface microtextures can be preserved during long fluvial transport. However, the sand grains pictured by Sweet and Brannan (2016), their fig. 3 display different fractures, or actually fractured grains, and not any abrasion, neither regular abrasion from fluvial transport nor irregular abrasion from glacial grinding (e.g., Mahaney, 2002; Molén, 2014; Molén and Smit, 2022). Their pictured grains are all similar to grains that have only been fractured, by any high-stress process (e.g., this also occur in strong rivers displaying clasts that are tumbling around) and these grains are also similar to the Late Paleozoic grains pictured by Soreghan et al. (2022, their fig. 1). Molén (2014) documented how surface microtextures are transformed, from the typical glaciogenic irregularly abraded fractures, to regularly abraded grains, from transport by water. Only in a sample transported less than 1,000 m, maybe only c. 100 m, there were no difference compared to tills from the same area, but sand grains that had been transported longer distances were more regularly abraded and therefore also displayed less large scale fractures. Soreghan et al. (2022) also wrote "no systematic study exists to assess quartz-grain microtextural variation due to thickness of ice in alpine settings", and have missed the documentation in Molén (2014). This paper (Molén, 2014) also presented a method to avoid operator bias or variance, as was not recognized by Soreghan et al. (2022).

Conclusion

In conclusion, the paper by Soreghan et al. (2022), is an attempt to fill in a gap in our knowledge, but it fails to show the evidence that is needed. In particular the section concerning surface microtextures is superficial and faulty, and the presented data do not show evidence of any former glaciation.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

Conflict of interest

MM was employed by Umea FoU AB.

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References

Cardona, S., Wood, L. J., Dugan, B., Jobe, Z., and Strachan, L. J. (2020). Characterization of the Rapanui mass-transport deposit and the basal shear zone: Mount Messenger Formation, Taranaki Basin, New Zealand. *Sedimentology* 67, 2111–2148. https://doi.org.10.1111/sed.12697.

Diffendal, R. F. (1984). Armored mud balls and friable sand megaclasts from a complex Early Pleistocene alluvial fill, southwestern Morrill County, Nebraska. *J. Geol.* 92, 325–330. doi:10.1086/628863

Dufresne, A., Zernack, A., Bernard, K., Thouret, J.-C., and Roverato, M. (2021). "Sedimentology of volcanic debris avalanche deposits," in *Volcanic debris avalanches. Advances in volcanology*. Editors M. Roverato, A. Dufresne, and J. Procter (Cham: Springer), 175–210. doi:10.1007/978-3-030-57411-6_8

Eyles, N., and Clark, B. M. (1985). Gravity-induced soft-sediment deformation in glaciomarine sequences of the Upper Proterozoic Port Askaig Formation, Scotland. *Sedimentology* 32, 789–814. doi:10.1111/j.1365-3091.1985.tb00734.x

Kalińska-Nartiša, E., Woronko, B., and Ning, W. (2017). Microtextural inheritance on quartz sand grains from Pleistocene periglacial environments of the Mazovian Lowland, Central Poland. *Permafr. Periglac. Process.* 28, 741–756. doi:10.1002/ppp.1943

Kalińska, E., Lamsters, K., Karušs, J., Krievāns, M., Rečs, A., and Ješkins, J. (2022). Does glacial environment produce glacial mineral grains? Pro- and supra-glacial Icelandic sediments in microtextural study. *Quat. Int.* 617, 101–111. doi:10.1016/j.quaint.2021.03.029

Knight, J. (2022). The Conversation. https://theconversation.com/snowfall-in-the-sahara-desert-an-unusual-weather-phenomenon-176037. *Snowfall in the Sahara desert: an unusual weather phenomenon*.

Mahaney, W. C. (1990). *Ice on the Equator: Quaternary Geology of Mount Kenya, East Africa*. Ellison Bay: Wm Caxton Ltd., 386.

Mahaney, W. C. (2002). *Atlas of Sand Grain Surface Textures and Applications*. New York, NY, USA: Oxford University Press, 237.

Molén, M. O. (2014). A simple method to classify diamicts by scanning electron microscope from surface microtextures. *Sedimentology* 61, 2020–2041. doi:10.1111/sed.12127

Molén, M. O. (2017). The origin of Upper Precambrian diamictites; Northern Norway: A case study applicable to diamictites in general. *Geologos* 23, 163–181. doi:10.1515/logos-2017-0019

Molén, M. O. (2021). Field evidence suggests that the Palaeoproterozoic Gowganda Formation in Canada is non-glacial in origin. *Geologos* 27, 73–91. doi:10.2478/logos-2021-0009

Molén, M. O., and Smit, J. J. (2022). Reconsidering the glaciogenic origin of Gondwana diamictites of the Dwyka Group, South Africa. *Geologos* 28, 83–113. doi:10.2478/logos-2022-0008

Pfeifer, L. S., Birkett, B. A., Van Den Driessche, J., Pochat, S., and Soreghan, G. S. (2021). Ice-crystal traces imply ephemeral freezing in early Permian equatorial Pangea. *Geology* 49, 1397–1401. doi:10.1130/G49011.1

Soreghan, G. S., Pfeifer, L. S., Sweet, D. E., and Heavens, N. G. (2022). Detecting upland glaciation in Earth's pre-Pleistocene record. *Front. Earth Sci.* 10, 904787. doi:10.3389/feart.2022.904787

Strat, D., and Móga, J. (2020). The occurrence of the armored mud balls during the flash flood phases of the streams from the Meledic Plateau – the Curvature Subcarpathians, Romania. *Forum Geogr.* 19, 18–28. doi:10.5775/fg.2020.028.i

Sweet, D., and Brannan, D. K. (2016). Proportion of Glacially To Fluvially Induced Quartz Grain Microtextures Along the Chitina River, SE Alaska, U.S.A. *U.S.A. J. Sediment. Res.* 86, 749–761. doi:10.2110/jsr.2016.49

Sweet, D. E., and Soreghan, G. S. (2008). Polygonal cracking in coarse clastics records cold temperatures in the equatorial Fountain Formation (Pennsylvanian–Permian, Colorado). *Palaeogeogr. Palaeoclimatol. Palaeoecol.* 268, 193–204. doi:10.1016/j.palaeo.2008.03.046

Voigt, S., Oliver, K., and Small, B. J. (2021). Potential ice crystal marks from Pennsylvanian–Permian equatorial red-beds of Northwest Colorado, U.S.A. *Palaios* 36, 377–392. doi:10.2110/palo.2021.024