How to drain a megalake: Comments on a study by Palcu et al. (2021) Scientific Reports 11, Art. Nr.: 11471.

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Abstract

In a recent paper by Palcu et al.[1], the Cape Panagia section on the Taman peninsula (Russian Black Sea) was dated using magnetostratigraphy, in order to calibrate the timing of previously published regressions of the Paratethys megalake. The authors of the paper claim that this “largest megalake in the geological record” experienced four major desiccation episodes in the period between 9.75 and 7.65 million years ago. In our opinion, the conclusions drawn in this contribution are not always fully justified, and reflect a somewhat selective approach to existing data. The sedimentological and biostratigraphic record of Cape Panagia does not lend itself to interpretation as reflecting major lake-level drops. The observed changes in the depositional record might be explained by other factors, such as regression due to filling of the accommodation space, or local uplift of the area. None of these, however, were considered, being simply excluded from the options. The lack of convincing evidence for the high-resolution events described in the region, compounded by inconsistencies in the paleogeographic reconstructions, give rise to concern about the reliability of the model presented in the paper.

Introduction

Large-scale paleogeographic re-arrangements, such as continental drift, subaerial exposure of the continental shelves during glacial maxima, or the (hypothetical) desiccation of the Mediterranean at the end of the Miocene, are intriguing not only to students of earth history, but the wider public as well. In a recent, highly stimulating paper, Palcu et al.[1] proposed a model for the repeated partial desiccation of the “largest megalake in the geological record” in Eurasia during the middle late Miocene (late Tortonian, 9.5–7.5 Ma). This lake was the relict of the Paratethys Sea, which had covered the Black Sea basin and adjacent foreland and back-arc depressions from the Alps to Central Asia since the Oligocene. Repetitive fragmentation of the Paratethys into restricted marine and lacustrine basins subjected the marine biota to recurrent extermination, and nurtured endemic radiation. The paleontological record of these basins does, thus, reflect environmental turnovers, but does not give much support to biostratigraphic age determinations. The temporal context of the evolution of the Paratethyan area has been gradually unravelled by a series of magnetostratigraphic studies from Germany to Azerbaijan, all performed recently in the Paleomagnetic Laboratory Fort Hoofddijk, Utrecht University, in the Netherlands, under the guidance of Wout Krijgsman (e.g., [2–6]).

The paleogeographic model proposed by Palcu et al.[1] is also founded on magnetostratigraphy: using it, they investigated and successfully dated a ~650 m thick upper Miocene sedimentary succession at Cape Panagia, on the Taman Peninsula, Russian Black Sea. The succession consists of offshore clays with four intervals (each 10–50 m thick) in which multiple layers of organogenic carbonate buildups occur. Palcu et al. infer that the appearance of these obviously shallow-water carbonates reflects large (100 to 250 m) lake-level drops, identifiable throughout the Paratethys, which led to the severe fragmentation of the Paratethyan megalake.

As grandiose as this model is, we think that the paper suffers from a lack of distinction between, on the one hand, hypotheses supported by facts, and on the other, unsubstantiated tentative estimates, and from a selective approach to existing data. Our reservations can be summarised as follows: (1) The authors fail to present compelling evidence for base-level drops of 100–250 m magnitude in the studied depositional record; in fact, the sedimentological and biostratigraphic proxies published from the Cape Panagia section[7] contradict their claims. (2) The regional context of the sedimentary processes that shaped the depositional record, like possible changes in sediment supply or tectonics, was not assessed. (3) Estimation of the extent of the megalake was performed on the basis of middle Miocene paleogeography (before 11.6 Ma), while the declared attributes of the lake refer to the late Miocene configuration (after 11.6 Ma). (4) Lake Pannon is inconsistently either included or excluded from the late Miocene Paratethys megalake, although its isolation from the rest of the Paratethys is warranted during the late Miocene. (5) The claim that the high-resolution events explored can be correlated across the region is not justified.

Vague water-level drop estimates

The calculation of water-level drop magnitudes is not explicitly explained by Palcu et al.[1], although it is fundamental to the subsequent paleogeographic modelling. The facies association representing the deepest environment (FA1) in the Cape Panagia section is considered to have been deposited below the wave-base, which might well represent not more than a few tens of meters' depth even in a basin of megalake dimensions[8,9]. The paleontological evidence[7], and primarily shallow-water benthic diatoms, excludes a profundal depositional environment for the Cape Panagia section in between the first three suggested water level drops. As signs of subaerial exposure were not observed in the succession, the lithofacies and paleoenvironmental proxies imply that it is not possible to interpret the evidence as showing water level drops reaching ~100–230 m in the Cape Panagia section, at least between 9.75–8.5 Ma.

The authors themselves implicitly admit this by drawing a bizarre, appendix-like embayment to connect the lowstand lake with Cape Panagia in the paleogeographic reconstruction of Fig.

1. However, such a paleogeographic feature would serve as an important gateway for routing of clastic sediment, with high sediment supply caused by erosion of subaerially exposed sedimentary successions. Monotonous fine-grained depositional record at Cape Panagia is incompatible with this scenario.

The authors also fail to evaluate alternative explanations for the observed lithological changes. A normal regression would not influence the base level but might produce facies stacking pattern comparable to the Cape Panagia section. In contrary, the forced regressions claimed by the authors would cause increased sediment supply, which was not observed (Fig. S5, Palcu et al.[1]). The modification of sediment supply by climatic changes or autogenic switching of depositional systems commonly causes a change in lithology/facies. The Crimean Peninsula and adjoining Black Sea are known to have experienced major compressional events during the late Miocene[10,11], which might also have affected sedimentation at Cape Panagia. None of these possibilities was considered as a factor that could have shaped the Cape Panagia depositional record. Even if the sole objective of the authors was to date the water-level drops suggested earlier by Popov et al.[12], evidence for a link between the published base-level changes and the Cape Panagia section remains questionable.

Inconsistency in paleogeography

Palcu et al.[1] calculated and depicted the maximum expansion of the megalake using the late Serravalian (middle Miocene, >11.6 Ma) paleogeographic reconstruction of Popov et al.[12] In contrast, the text says that the megalake originated at the beginning of the late Miocene due to orogenic uplift taking place after 11.6 Ma. The statement that the "disconnection of Lake Pannon in the western periphery led to increased sensitivity to drought for the remaining Paratethys", together with Figs. 1 and 4a depicting Lake Pannon as part of the early megalake, suggest that this disconnection was the immediate trigger of subsequent megalake hydrological crises. It is widely accepted (and convincingly proven in a series of papers from Utrecht University[13–15]), however, that the isolation of Lake Pannon from the rest of the Paratethys took place 11.6 Ma ago. Lake Pannon remained isolated for its entire life through the late Miocene and early Pliocene, and was not affected by hydrological and biological crises such as those described by Palcu et al.[1] for the coeval Paratethys megalake[16]. The isolation and relative environmental stability of Lake Pannon is evidenced by the normal regressive clinothems with rising shelf-edge trajectory[17,18] that fill its basin and by its unique endemic biota[16,19]. Some of the endemic species migrated to the Paratethys during its lowstands[20] (e.g., ~6.05 Ma), but there is no evidence for migration in the opposite direction, i.e., from the Paratethys to Lake Pannon. The illustration of Lake Pannon as part of the Paratethys megalake on Figs. 1 and 4a might cause confusion to a wider public audience.

"Four major water-level regressions identified throughout the Paratethys"

The authors claim that the four regressions inferred from the Cape Panagia section can be identified throughout the Paratethys. If true, this statement would lend substantial support to their case. In the paper, however, there are no data or references that could be considered as justifying this statement. The sea-level curve of Popov et al.[7] referred to includes three lake level-drops in the Khersonian: a 230 m drop at its beginning, an 80 m drop in its middle part, and a 250 m drop at its end. Popov et al. [7] claim that "… at the base of the upper Sarmatian deposits, … incisions had an amplitude of 200 m". However, the attached cross sections and seismic profiles indicate such deep incisions only for the Pontian, thus it remains unclear how the magnitude of the two earlier base-level drops was calculated.

Another paper referred to, by Böhme et al.[21], indicates a substantial drop in mean annual precipitation as reflected by the herpetofauna of the Black Sea region 9.7–9.8 million years ago. The pattern is based on the fossils of four localities, two with ca. 1400 mm MAP and two with 200–280 mm, but with a strong overlap between their stratigraphic ranges within the interval of 10.0–9.3 Ma. After a recovery interval, another drop is indicated about 8 Ma ago. Even if these data reflect a real trend of recurring aridity, their stratigraphic resolution does not allow correlation with four distinct water-level regressions within the 9.8–7.6 Ma interval.

Megalake regression: a trigger or a consequence of climate change?

Palcu et al.[1] conclude that their results "raise questions about whether the Paratethys crises were trigger, contributor or mere expressions of dry climatic episodes in Europe and central Asia." Because increasing aridity and seasonality, expansion of grasslands with C_4 grasses at the expense of C_3 forests, and a consequent change in the land faunas through the late Miocene are globally known phenomena, commonly attributed to the expansion of the Antarctic ice-sheet[22–26], it seems reasonable that hydrological changes in the endorheic Paratethys megalake were consequences of the climate change rather than its trigger. From the paper by Palcu et al.[1] we get a hypothesis about the nature, magnitude, timing and paleogeographical consequences of these hydrological changes in the Paratethys, but this hypothesis remains highly disputable in view of the lack of published supporting data and convincing data interpretations.

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Author contributions statement

MŠ, NH and IM conceived, wrote and edited the manuscript. All authors reviewed the manuscript.

Competing interests

The authors declare no competing interests.