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Review of the doctoral dissertation by Dhanushka Devendra, M.Sc.

The present review has been prepared in accordance with the provisions of the law on higher education and science of the Republic of Poland, passed on 20 July 2018.

The doctoral dissertation in question is a collection of coauthored scientific publications under a common theme, entitled "Late-glacial and Holocene paleoceanographic changes in the European Arctic based on a multiproxy approach". Two of its constituent articles have been published before submitting the dissertation for review. The third and final publication included in the dissertation has been submitted to the journal "Climate of the Past". In addition to the articles themselves, the dissertation includes:

1. A preface in English;
2. Acknowledgements in English;
3. A table of contents;
4. An English summary of the key research findings along with conclusions;
5. A Polish summary of the key research findings along with conclusions;
6. References for points 4 and 5;
7. Information on funding in English;
8. Statements from coauthors, also in English.

Together, the dissertation is about 130 pages long; its logical structure is clear, the content that represents the addition to the original research papers is concise, well-written, and reflects well the contents of the articles that make up the most important part of Mr. Devendra's dissertation.

Article I has been published in 2022 in the prestigious, international journal *Global and Planetary Change* (2023 Impact Factor: 4.0). Mr. Devendra is the lead author, and there are 5 coauthors listed. The article deals with reconstructing the impact of the Atlantic Water influx on the climate and environments of the NE Greenland shelf, based on a sediment core collected from the continental slope of Greenland. The temporal span of the sediments studied is ~35 to 4 kyr BP, with age control based on radiocarbon dating. The methods used included: micropaleontology, sedimentology, stable isotope geochemistry and organic geochemistry. The main finding of Article I is that the presence of Atlantic Water has been a persistent feature of the NW Greenland Sea through the study interval, but also that the strength of its inflow has been variable. Article I also documents a series of profound climatic changes, and associated changes in sea-ice cover, in the NW Greenland Sea through the Late Glacial and the Holocene.

Article II has been published in *Global and Planetary Change* in 2023, again with Mr. Devendra as the lead author, with eight additional coauthors. The article investigates changes in sea ice cover on the western Spitsbergen shelf through the Holocene, based on a sediment core retrieved from near the Hornsund mouth. Age control is again based on radiocarbon dating, and the performed analyses include: XRF and magnetic susceptibility scanning, stable isotope geochemistry, Mg/Ca paleothermometry, micropaleontology, and organic geochemistry, including an examination of pigments and biomarkers preserved in sediments. This publication offers a reconstruction of dynamic cryospheric conditions and variable ocean circulation in the Svalbard region over the past ~11.7 kyrs, with alternating periods of extensive and reduced ice cover, and periods of enhanced bottom sediment erosion, linked to the intensity of Atlantic Water export from lower latitudes.

Article III has been submitted to an equally respected journal, *Climate of the Past* (2023 IF: 3.8, 5-year IF: 3.9) in August 2024. Mr. Devendra is the lead author, and the manuscript lists six additional coauthors. Based on a sediment core taken from the NW Barents Sea, the research team interprets a record of four successive meltwater events spanning ~14.2 through 8.2 cal kyrs BP. These are interpreted in a broad regional context, considering tectonics and sedimentology. The core was dated by means of radiocarbon analyses, and additional methods included micropaleontology, stable isotope and organic geochemistry, sedimentology, and XRF spectrometry.

Climate of the Past has an entirely transparent peer-review process, in which the manuscript, in its original form, is made available for public discussion online, open to anyone willing to express their comments and questions. Also the reviewer and editor comments, as well as the (co)author responses, are made public. The journal website reveals that the reviews for the manuscript by Mr. Devendra and six co-authors have been received on 21 August (reviewer recommendation: reject) and 9 October (recommendation: major revision), respectively, and that the handling editor has made a decision in October 2024, choosing to reject the manuscript and close the public discussion. The reviewers were especially critical of the age model used in the study, but also of the dataset resolution and biomarker application. I find the decision of the editor surprisingly harsh, as the authors have not been given a chance to rectify the highlighted issues.

Overall, the articles comprised in Mr. Devendra's doctoral dissertation testify to his extensive knowledge of the Arctic oceanography and paleoceanography, Late Glacial and Holocene climate change, and methods that are broadly applied in modern paleoceanographic studies. His position as the lead author on all three publications indicates that he is a capable team leader, and that he feels confident managing the various inputs from multiple colleagues working in different institutions located in various countries. Most importantly, however (especially considering the author contributions indicated in each article), this indicates that

Mr. Devendra is capable of conducting scientific research independently, on his own, which is one of the key requirements for awarding a doctoral degree.

The articles included in Mr. Devendra's doctoral thesis are based on research involving an impressive array of methods. These include micropaleontology, sedimentology, stable isotope geochemistry, organic geochemistry, radiometric dating, X-ray fluorescence spectrometry, and others. The doctoral work of Mr. Devendra follows good practices in that the raw data are made available via the PANGAEA repository (Articles I and II). No data are made available for Article III.

The research topic – reconstructing the Late Glacial and Holocene paleoceanography of the Arctic, with a special focus on the variations in the influx and distribution of the Atlantic Water, is very timely, given the disturbing rate of the present-day warming observed in the northern high latitudes. The articles present new, important data, they have been published (in the case of Article III – still yet to be published) in internationally recognized journals, which ensures their high visibility in the paleoceanographic community. The research problems undertaken in the three articles are remarkably consistent, and represent different, but clearly related aspects of the Late Cenozoic Arctic paleoceanography, and thus represent an original solution to a scientific problem.

Notably, the three articles included in the doctoral dissertation constitute only a part of Mr. Devendra's scientific achievements. As listed in the Web of Knowledge (WoK), Mr. Devendra is a coauthor of a total of seven published peer-reviewed papers. He is the lead author of four of those. All these publications consistently deal with paleoceanography (with no exclusive focus on the Arctic), and are based on a variety of novel proxies. As of this writing, Mr. Devendra's papers have been cited 28 times (according to WoK). GoogleScholar lists a higher number of publications (15) and citations (46). Both databases calculate the same h-

index of 4. Given the early stage of Mr. Devendra's scientific career, these results look very promising for the Candidate's future in academia, if he chooses to pursue one.

Critical Remarks

Below, I focus mostly on stratigraphic aspects of the articles included in Mr. Devendra's doctoral dissertation.

It drew my attention that Articles I and III, and the summary, state that the sediment cores studied in the respective papers were continuous and revealed no reworking. In each case this is stated before any mention is made of stratigraphy or age model, and determining whether or not sedimentation was continuous and/or if reworking had occurred macroscopically is very risky at best. Also, at least two of the articles encountered dating issues, with foraminifer shells yielding ages conflicting with the age of the shallower or deeper sample. In both cases, reworking is invoked as a possible explanation for the dating discrepancies. Have biostratigraphic methods been employed to determine the possible discontinuity and/or reworking in the studied cores?

There are several recurring issues concerning the age models used in the studies, and the associated reconstructions of linear sedimentation rates (LSR) and fluxes, expressed – for instance in the case of foraminifera – as the number of shells per unit area (cm^2) per unit time (kyr). In addition to the sedimentary component in question, sediment flux calculations require also LSR estimates and a measure of sediment density or porosity and water content. Articles I-III mention that flux calculations were based on dry bulk density (DBD) measurements. None of the papers, however, reveal how DBD values were obtained. No such information is provided in the summary, either.

An issue that is highlighted on numerous occasions in the publications is that the age models constructed for the studies yield extremely low sedimentation rates over some of the crucial intervals examined. Given that foraminiferal assemblages were examined anyway, I

find it unclear why the age models are based exclusively on radiocarbon dates. The research papers do mention scarcity of planktic foraminifera over some intervals. Did this preclude biostratigraphic correlation? I believe even partial success in applying other techniques in addition to radiocarbon dating may have positively contributed to age model construction.

I am also at a loss as to why the authors made no effort to apply smoothing techniques to their age-depth curves, as this may have resolved some of the issues they encountered with extremely low LSRs and – as a consequence – with data point density through some of the critical intervals investigated. In Articles I and III, LSRs vary over two orders of magnitude; in Article II – over three orders of magnitude. Some authors question whether – taken at face value – LSRs are a realistic representation of the actual sedimentation rates, and deem the rapid shifts is LSRs at age-model tiepoints as unrealistic (see Piela et al. (2023), Paleoceanography 27: PA2204, https://doi.org/10.1029/2011PA002236). Fitting a polynomial expression to the age-depth curve and adjusting the sample depths accordingly is one possible solution to the problem, as it generally makes LSRs "flatter". There are also geochemical approaches to reconstructing sedimentation rates, for instance involving ^{230}Th normalization. I strongly believe an application of one of these methods may have been beneficial. One other feature of the LSR records considered by the Candidate is puzzling: Figure 2 in Article III shows fine-scale variability in sediment accumulation rates. How were these calculated, if the plot is based on a total of eight age model tiepoints?

The final stratigraphic/geochronological issue is the question of the temporal resolution of the datasets used in the respective papers. On geological timescales, the events that the presented articles deal with are rapid, as they have unfolded on the timescales of hundreds to thousands of years. Yet, the age model resolution is often on the same order of magnitude as the events that the respective studies attempt to tackle. This is best exemplified in Article III, where the average sampling resolution amounts to about 200 years (about – since the manuscript fails to indicate a clear number of samples examined for each proxy). Such dataset

is then used to interpret meltwater events lasting up to 700 years, which results in single datapoints spanning each of the three interpreted events. While this does not invalidate the entire interpretation, it makes it considerably less credible. How does one make sure such sparse datapoints represent trends and not artifacts? These issues have also been highlighted in the reviewer and editor comments posted on the *Climate of the Past* website, and ultimately contributed to the rejection of the manuscript.

An important related issue is the sampling resolution itself. It is a tenet of paleoceanography that one should work at a resolution sufficient to answer one's questions. In all three cores studied by Mr. Devendra, the sampling resolution could be doubled, if not tripled – especially that, according to the materials & methods sections in the respective papers (and in the summary), cores were sliced at 0.5 to 1 cm intervals. If so, why were they subsequently sampled at lower resolution? Why was the sampling resolution not increased once the critical intervals were identified? Even in the intervals characterized by the lowest sedimentation rates, there is usually some way to collect additional samples, and toothpick sampling is commonly employed for such precise analyses. Would the material yielded in such way be insufficient for the analyses? Sticking to the example used above – the meltwater events reconstructed in Article III – having, for instance, 9 or 15 data points through a critical interval instead of, say, 3 to 5 data points, as in the current form of the manuscript, would somewhat increase the credibility of the interpretations.

Recapitulation

A doctoral dissertation is legally required to (1) present the overall knowledge of the candidate in their chosen scientific discipline; (2) present the candidate's capability of conducting scientific research on their own; and (3) represent an original solution to a scientific problem. Despite the reservations expressed above, I believe the thesis submitted by Mr. Devendra satisfies all these requirements. Accordingly, my recommendation to the Scientific

Board of the Institute of Oceanology, Polish Academy of Sciences, to qualify Mr. Devendra for further proceedings on his doctoral dissertation.