Amino acid racemization geochronology using foraminifera from the Yermak Plateau

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Introduction

Developing accurate age models for Arctic Ocean sediments has been challenging, and while amino acid racemization (AAR) geochronology has been used for dating Quaternary marine deposits across the globe, its application in the Arctic has been limited. Previous studies reported anomalous rates of AAR in foraminifera from the central Arctic, indicating that either the rate of racemization is higher in this area, or inaccurate age models were used to constrain the sediment ages.

The current study investigates racemization rates of amino acids in well-dated samples of planktic and benthic foraminifera from three Yermak Plateau sediment cores (Figure 1) taken during the 2015 TRANSSIZ Expedition on board the icebreaker *Polarstern*. Sample ages were estimated using mean D/L values and 2 previously published calibrated age equations, and then compared with independent ages.

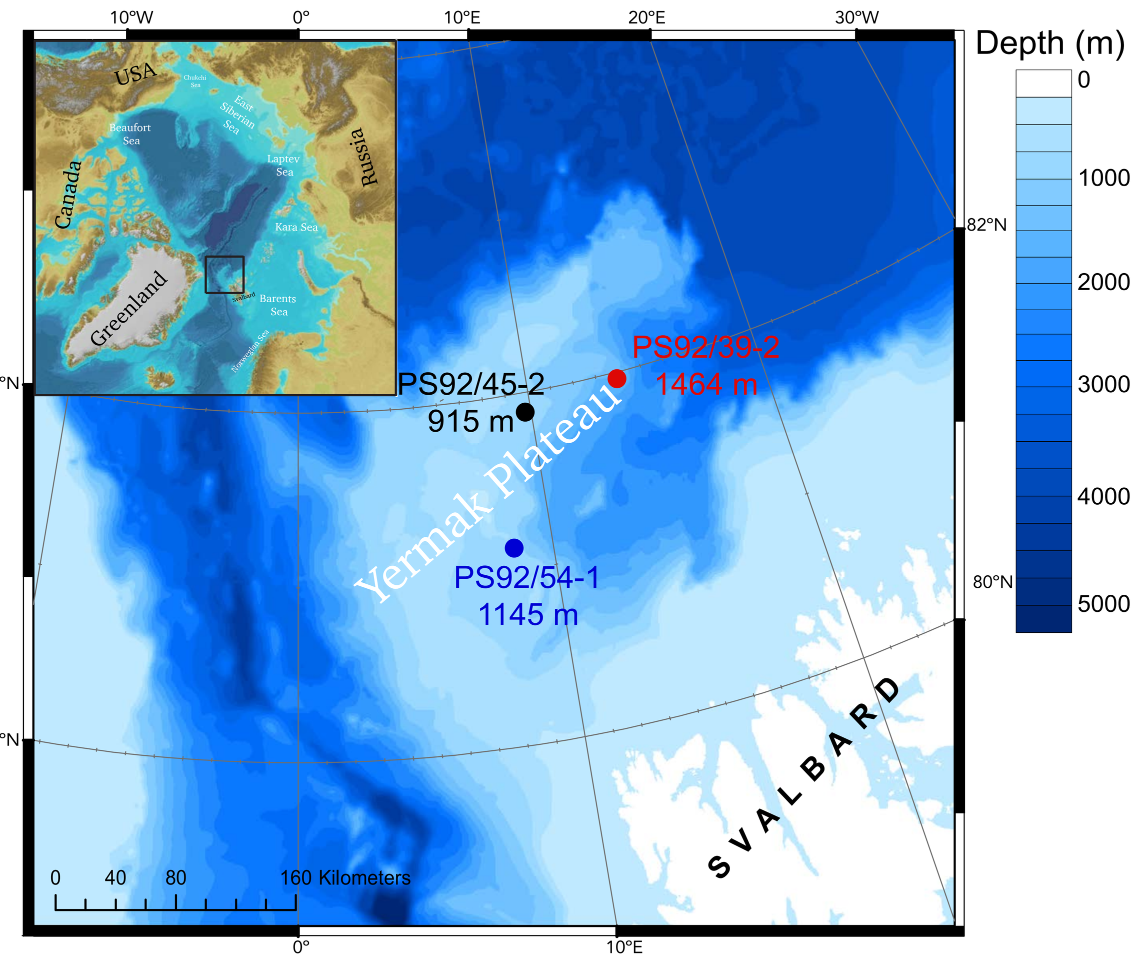

Figure 1. Locations of the studied cores and water depth at core sites (Basemap: Jakobsson et al. 2012).

Materials and methods

The age-depth models for cores PS92/39-2, 45-2 and 54-1 were developed by Wiers et al. (2018, in review) using a correlation of environmental magnetic parameters (κARM/κ) with the global δ[18]O record (Figure 2), and provided a robust chronological framework. Sedimentation rate in core PS92/39-2 prior to MIS 3 is approximately three times higher than in the other two cores.

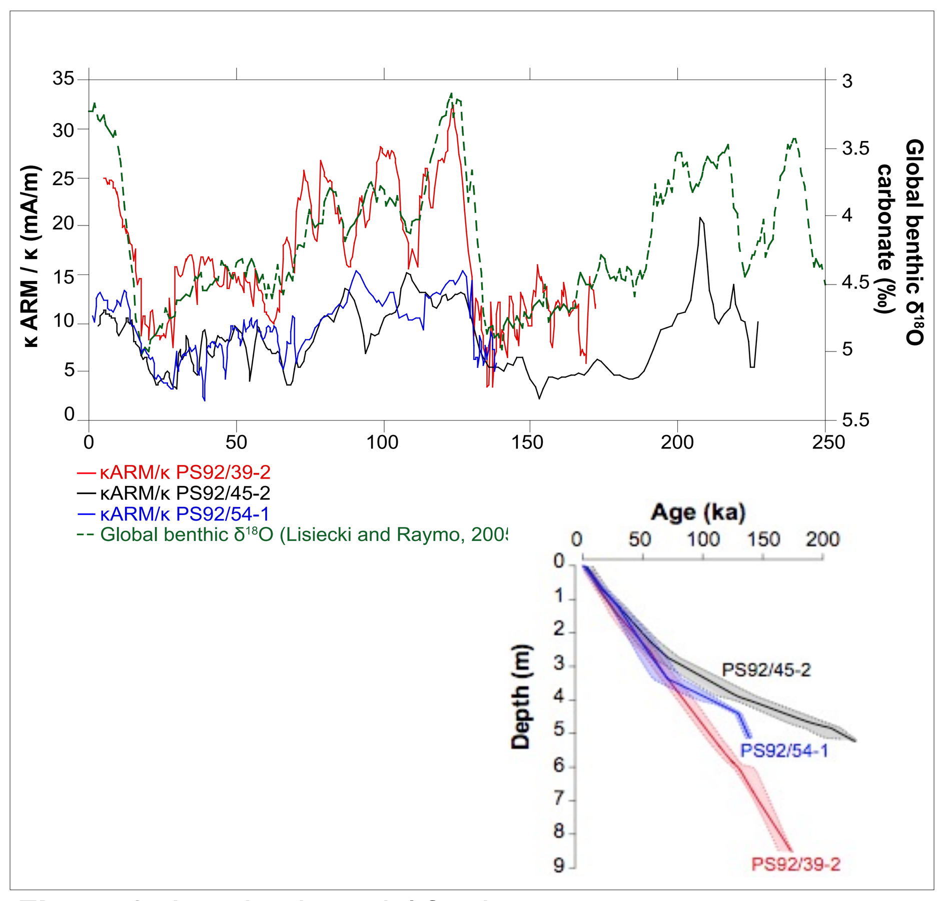

Figure 2. Age depth model for the cores.

Figure 3. Umbilical view of specimens of *Neogloboquadrina pachyderma* (left) and *Cassidulina neoteretis* (right) (Hesemann, 2019).

High-performance liquid chromatography was used to separate D and L isomers of the amino acids, aspartic (Asp) and glutamic (Glu) acid in samples of the planktic foraminifera, *Neogloboquadrina pachyderma* and the benthic species, *Cassidulina neoteretis* (Figure 3) to quantify the extent of racemization. In total, 241 subsamples were analysed, extending back to MIS 7.

Results

Variation of D/L values with depth

There are noticeable differences between the cores in that the racemization of Asp and Glu in *N. pachyderma* samples is lower in PS92/39-2 below 3 m core depth than in the other two cores (Figure 3). The primary cause of this is likely the higher sedimentation rates in PS92/39-2 below this depth.

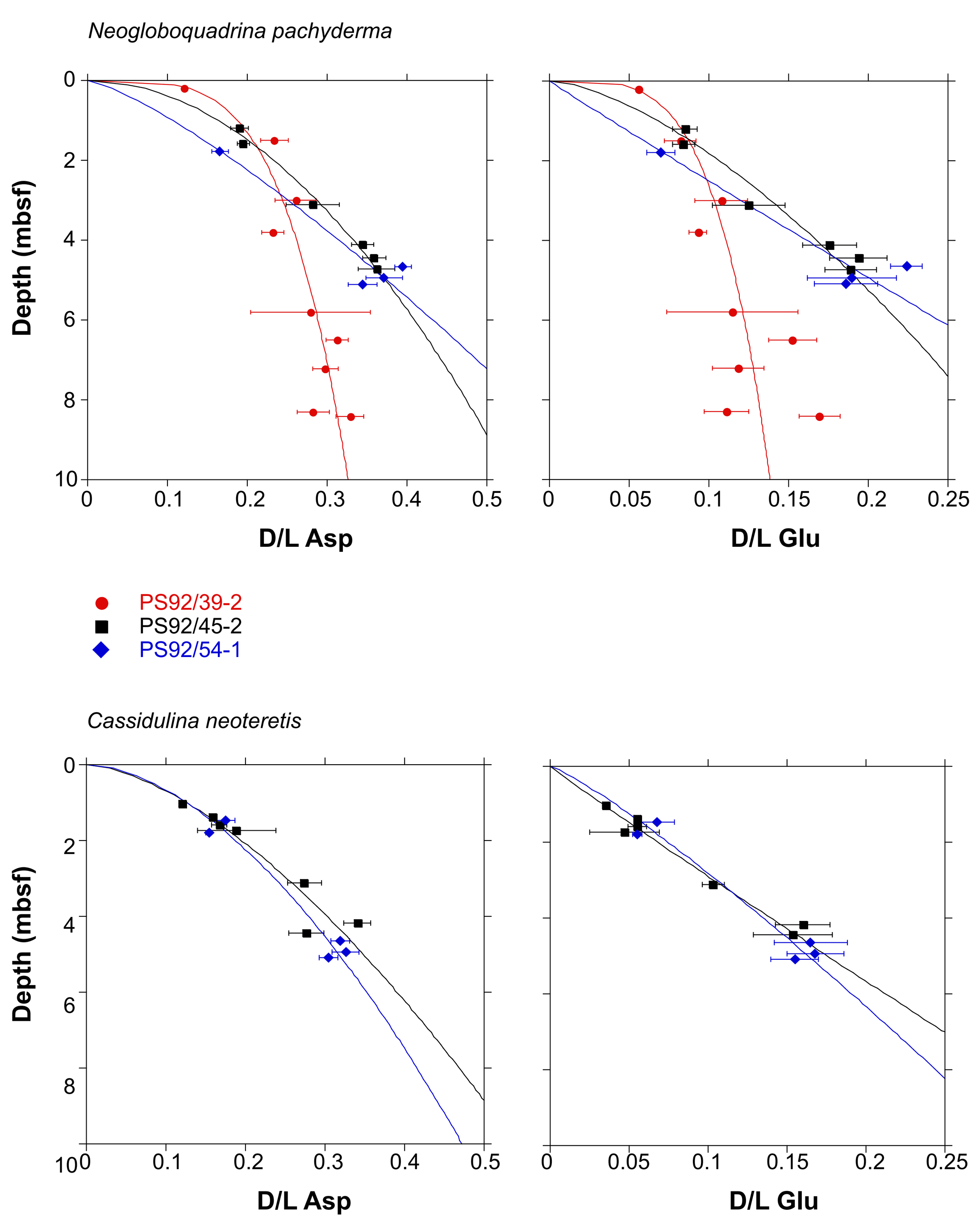

Figure 4. Extent of racemization (mean D/L in aspartic acid and glutamic acid) in samples of *N. pachyderma* and *C. neoteretis* plotted against depth in sediment cores PS92/39-2, PS92/45-2 and PS92/54-1. Error bars represent ±1σ deviation from the sample mean. Least square regression lines (power fit) are shown for all cores.

Inter-species differences

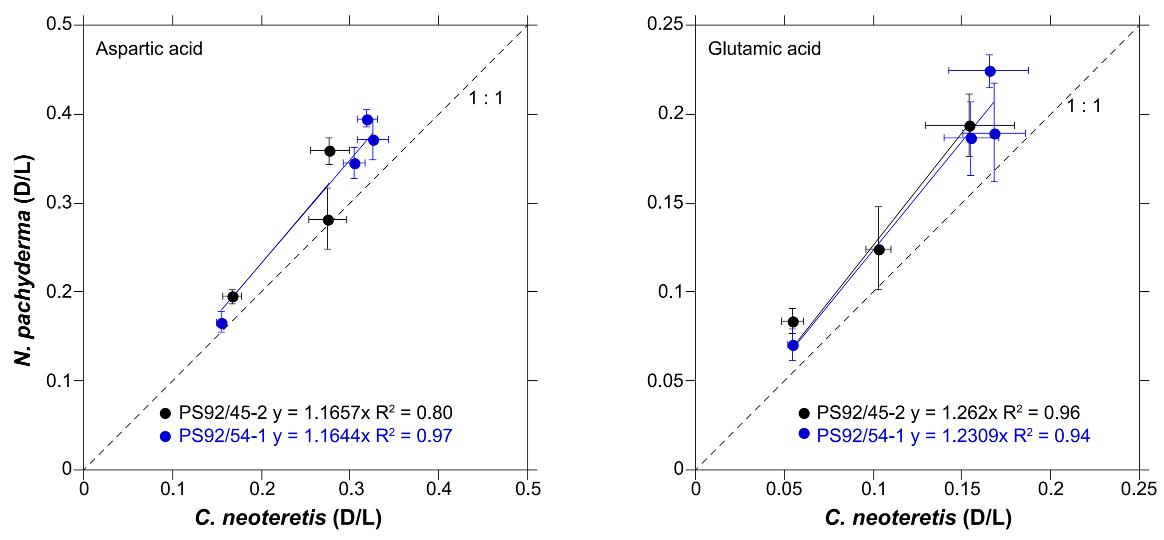

Figure 5. Extent of racemization for Asp and Glu in *N. pachyderma* and *C. neoteretis* samples from cores PS92/45-2 and PS92/54-1.

Taxon-dependent differences can be observed in the rates of AAR (16% for Asp and 23-26% for Glu) measured in *N. pachyderma* and *C. neoteretis* (Figure 5). Little is known about the extent and causes of the differences in racemization rates in these two common Arctic species.

Comparing proposed AAR age calibration models

In order to assess the validity of the Arctic-specific (Kaufman et al., 2008) and global calibrated (Kaufman et al., 2013) age equations at the Yermak Plateau, ages predicted by the two models were generated using the mean D/L Asp and Glu values obtained during the AAR analysis of the *N. pachyderma* and *C. neoteretis* tests. The calibrated ages were then compared with the independent sample ages (Figure 6).

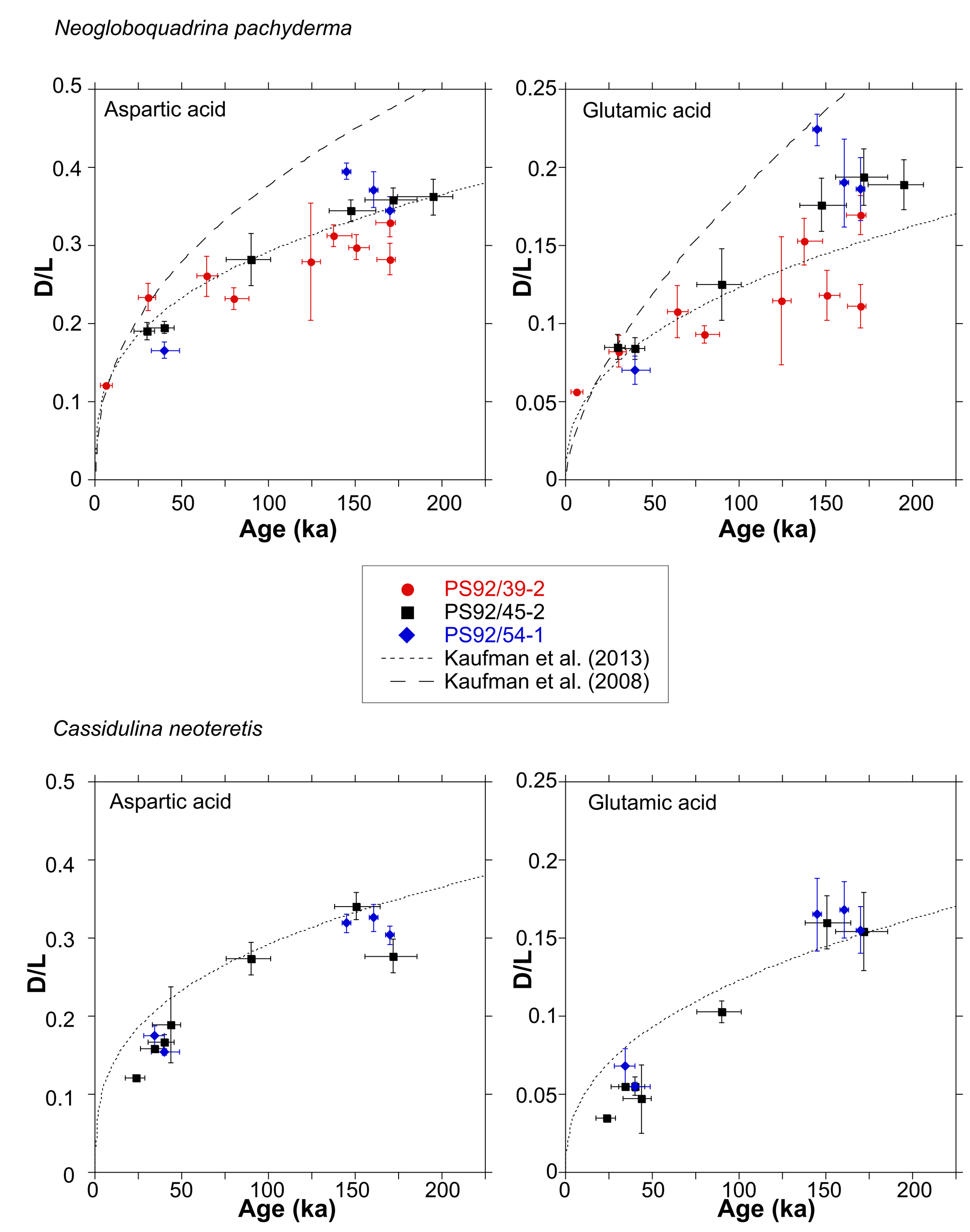

Figure 6. Mean D/L values of Asp and Glu acids plotted against the independent ages of Wiers et al. (2018) for *N. pachyderma* and *C. neoteretis* samples. Ages predicted by the calibrated age equations of Kaufman et al. (2008 and 2013) are also displayed for reference. Error bars represent ±1σ deviation from the mean D/L value of the sample, and age uncertainty respectively.

Key findings

- The extent of racemization of aspartic and glutamic acids increases with increasing sample age both in *N. pachyderma* and *C. neoteretis* samples, and it appears higher in *N. pachyderma* than in *C. neoteretis* in identical depositional environments.
- The globally calibrated age equation of Kaufman et al. (2013) provides a good chronological approximation for sediments from the Yermak Plateau. Calculated sample ages show the highest level of agreement with independent ages when D/L Asp values from *N. pachyderma* samples are used. Ages obtained using the calibrated age equation and D/L Asp values in *C. neoteretis* samples consistently appear younger (on average 18 ka) than the independent ages, consistent with the lower rate of AAR observed in this study.
- The results highlight the need for further AAR studies to test and explain the origin of the apparent rapid racemization rates in foraminifera from central Arctic sediments.

References

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- Wiers et al. (2018, submitted manuscript).