Stable isotope age constraint on a Pliocene sediment borehole from the Netherlands

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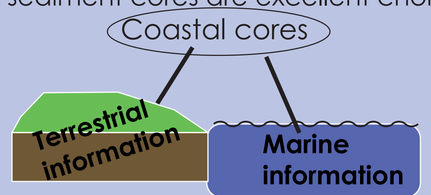
INTRODUCTION

- The Pliocene is the most recent period in time that bears a resemblance to future climate projections (IPCC)
- Thus, multi-proxy records of Pliocene climate are *crucial* input data for climate models
- Coastal sediment cores are excellent choices:



- Studies on the Hank borehole (TNO, Fig. 1) have generated an excellent dataset:
  1) Terrestrial: mean air temperatures (MAT) and pollen records
  2) Marine: sea surface temperature (SST) and dinocyst records

However, current age model is not precise enough!

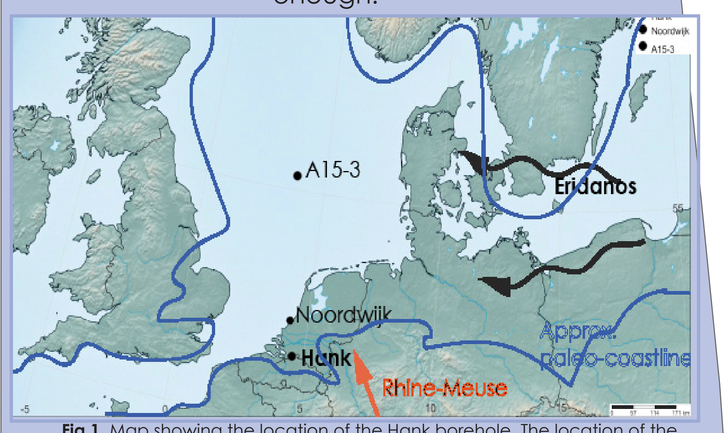


Fig 1. Map showing the location of the Hank borehole. The location of the Pleistocene boreholes from Noordwijk and A15-3 are also shown. The paleo coastline during the early Pliocene is modified after Gibbard and Lewin (2003) and Knox et al. (2010). Both the Eridanos and Rhine-Meuse river systems are represented by coloured arrows.

APPROACH

- The current age model is only based on 9 age-tying points, and shows large changes in sedimentation rate, particularly for Plio-Pleistocene transition.

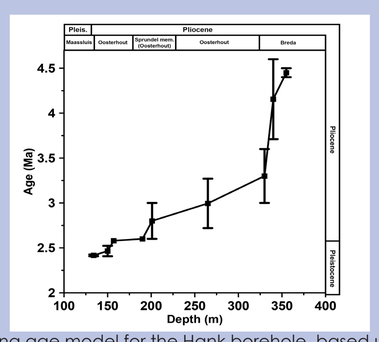


Fig 2. The working age model for the Hank borehole, based upon FODs and LODs of dinoflagellate cysts. Briefly, the events are: the LOD of Reticulatosphaera actinocoronata (355 m), the LOD of Operculodinium tegillatum (340 m), the LOD of Melitasphaeridium choanophorum (330 m), the LOD of Invertocysta lacrymosa (265 m), the LOD of Operculodinium? eirikianum (201 m), the LOD of Barssidinium pliocenicum (190 m), the LOD of Barssidinium spp. (157 m), the acme of Impagidinium multiplexum (150 m), and the acme of Operculodinium israelianum (133-136 m).

Goal:
Better age constraint through stable isotope stratigraphy to identify key Pliocene climate events: the M2 gla cial (3.3 Ma) and the Mid-Pliocene Warm Period (MPWP; 3.3-3.0 Ma)

Challenge:
It is very difficult to obtain good age constraint by measuring $\delta^{18}O$ on foraminifera in coastal cores due to complex sedimentary processes and mixed signals...

- Endobenthic foraminiferas *Cassidulina laevigata* and *Bulimina aculeata* were picked.
- As such, they may reflect pore waters in the sediment more than the overlying water column.
- However, the isotope content of the foraminferas shell is less likely to be disturbed by the effect of salinity through freshwater input.
- This approach was used succesfully by Noorbergen et al. (2015) for a Pleistocene-dated borehole from Noordwijk.

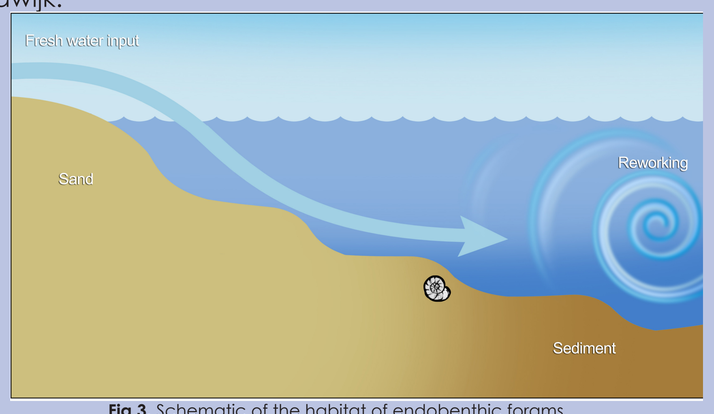
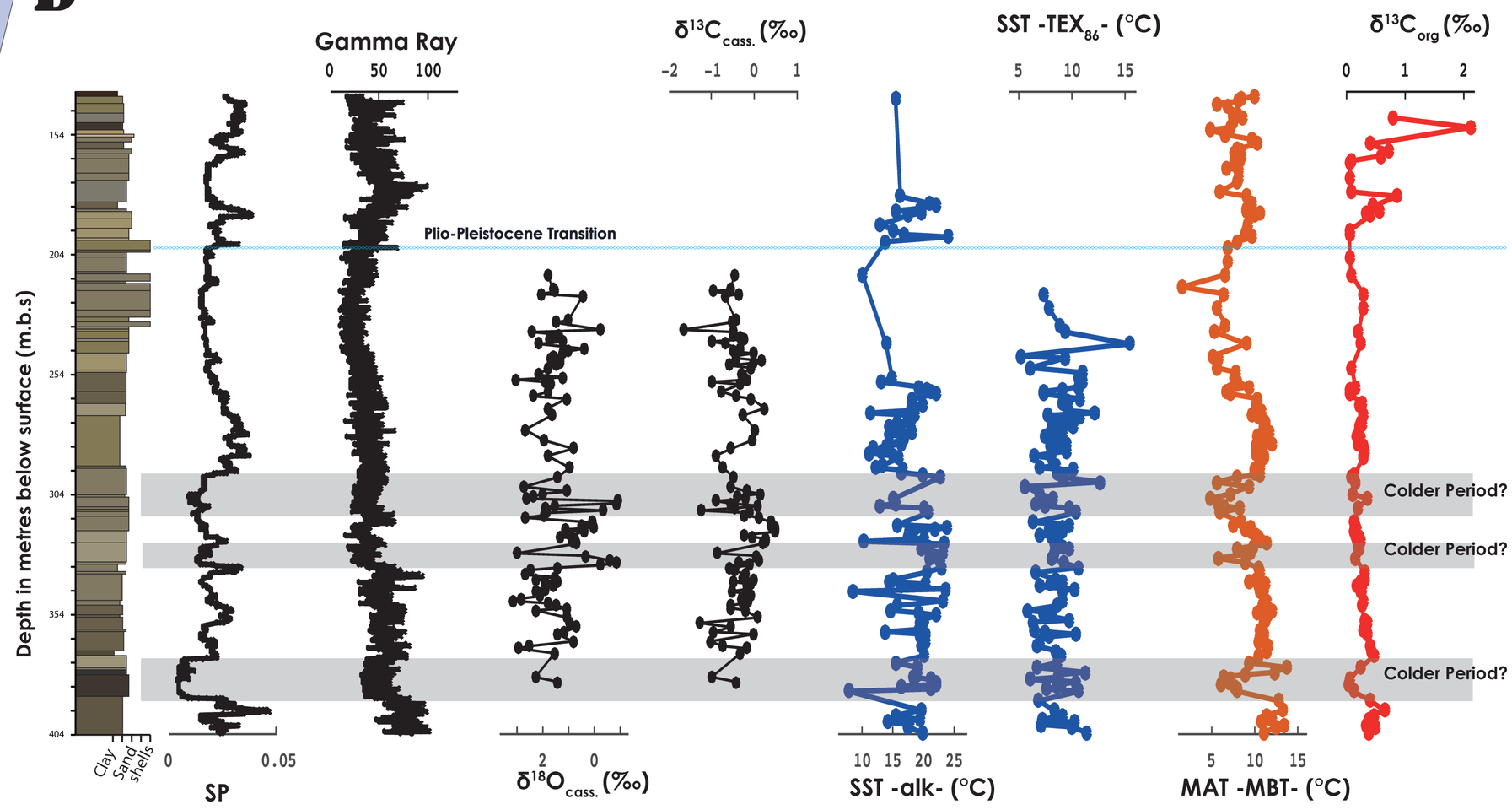


Fig 3. Schematic of the habitat of endobenthic forams

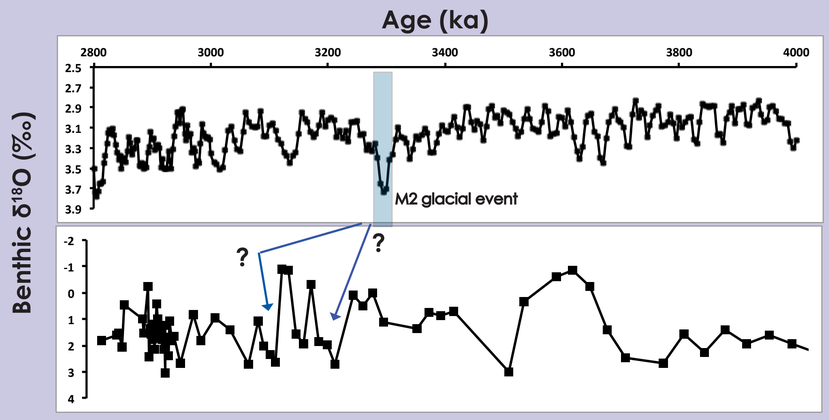
DATA



SYNTHESIS

- Initial data shows that it is challenging to 'wiggle' match to the LR04 Stack
- Waiting for the addition of new data which will fill in some of the gaps in the record.

- **$\delta^{18}O_{cass.}$ Record:**
- $\delta^{18}O_{cass}$ record is the most complete and shows a large range of values: 3.6 to -0.9 ‰
- Absolute benthic $\delta^{18}O$ values are lower in the Hank record compared to the LR04 Stack and compared to other Pliocene data from surrounding regions (could also reflect a species-specific trend):
  - ODP Hole 642B (Nordic Seas; Risebrobakken et al., 2016)
  - DSDP 610A (North Atlantic; De Schepper et al., 2013)
- Forams could not be picked in the deepest part (380 - 404 m, Breda formation) --> dissolution of carbonate in the early Pliocene section?
- Forams were not able to be picked in the Maassluis formation (< 200 m), limiting the comparison with the Pleistocene dated sections from Noordwijk (Noorbergen et al., 2015) and borehole A15-3 (Donders et al., 2017).



LRO4 Stack

Hank Borehole
- in age domain (using polynomial function derived from preliminary age model)

Climate signals?

- No clear cooling trend is seen upon the Plio-Pleistocene transition
- Difficult to identify the M2 glacial event in the $\delta^{18}O$ record - ie may possibly be a hiatus in the core. There is no clear point where the $\delta^{18}O$ values are heavier than at other periods in the record (e.g. Early Pliocene). This is similar to what has been observed in the Nordic Seas (ODP 642B, Risebrobakken et al., 2016).
- Correlation between gamma ray log and $\delta^{18}O$ is better in the older (>322 m, r^2=0.25) section of the borehole than the younger section (r^2=0.004) --> changing climate signal ?
- Correlation between the $\delta^{18}O$ and $\delta^{13}C$ records is negative (r^2=-0.11) in the older section (>312 m) and weakly positive (r^2= 0.18) in the younger section (<312 m)

CONCLUSION

- Initial stable isotope results recorded from benthic foraminifera in the Hank borehole represent a complex signal.
  - This signal is most likely not responding to one environental variable, but many.
  - There are multiple lines of evidence in the proxy data to suggest that the Pliocene climate was not stable in the North Sea, similar to the Nordic (cf. Risebrobakken et al., 2016)
- The proxy records initially indicate a substantial change in climate signal in the older and younger sections of the core (~312-322 m)
- Further work will need to unravel the local signature from Hank from the global signal in order to correlate to the LR04 stack.

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