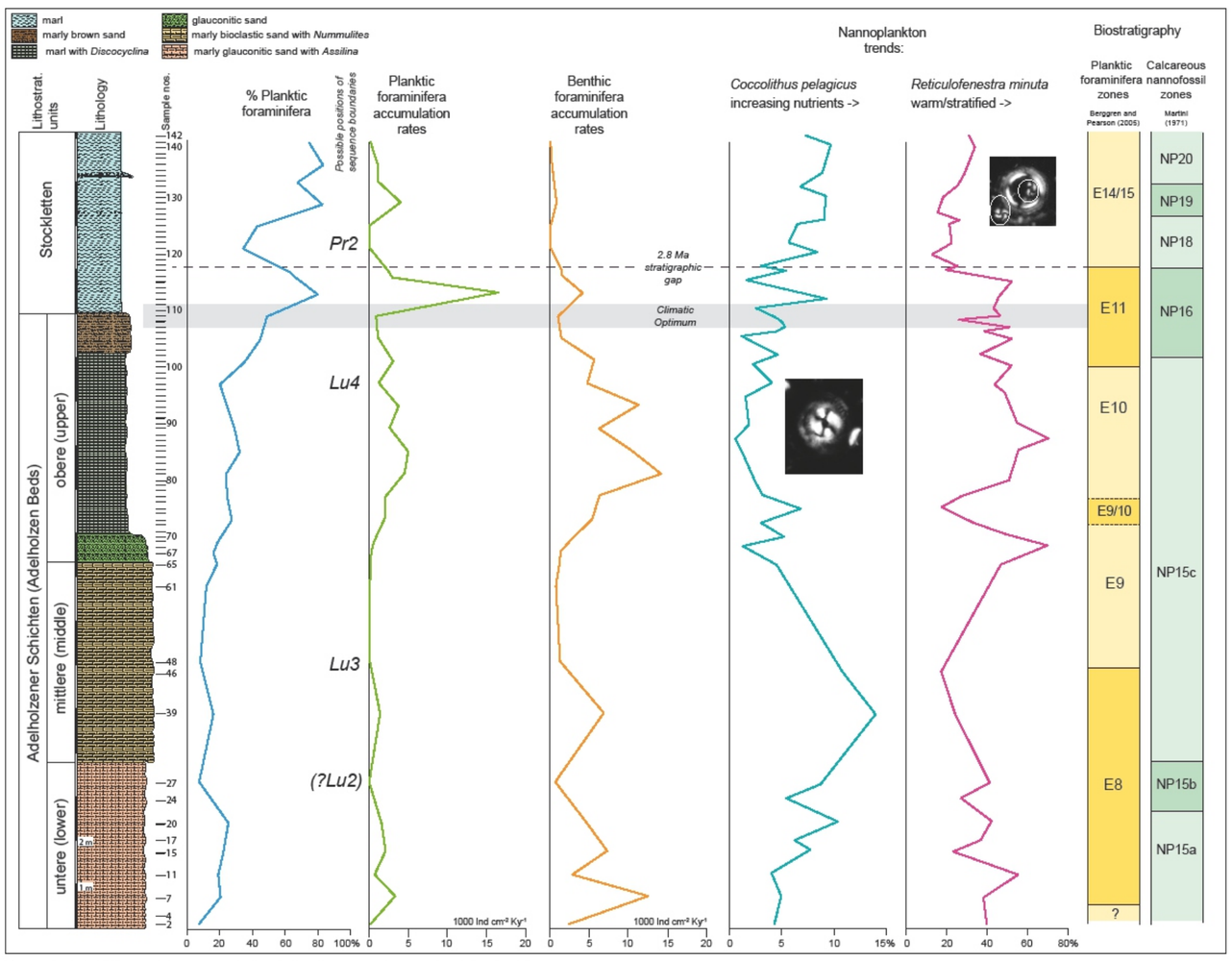
Changing paleo-environments of the Lutetian to Priabonian beds of Adelholzen (Helvetic Unit, Bavaria, Germany)

Holger Gebhardt, Stjepan Ćorić, Bettina Schenk, Geologische Bundesanstalt, Neulinggasse 38, A-1030 Vienna, Austria

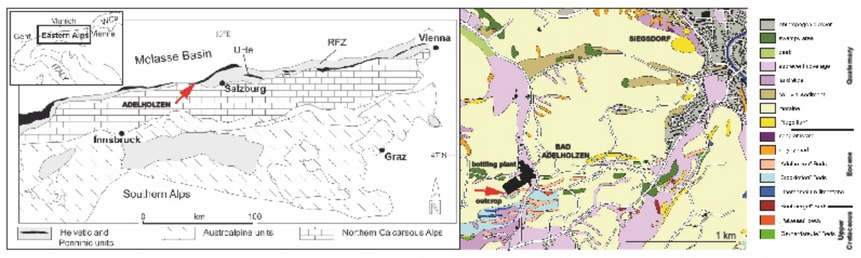
Robert Darga, Naturkundemuseum Siegsdorf, Auenstr. 2, D-83313 Siegsdorf, Germany

Antonino Briguglio, Erik Wolfgring, Universität Wien, Althanstraße 14, A-1090 Vienna, Austria

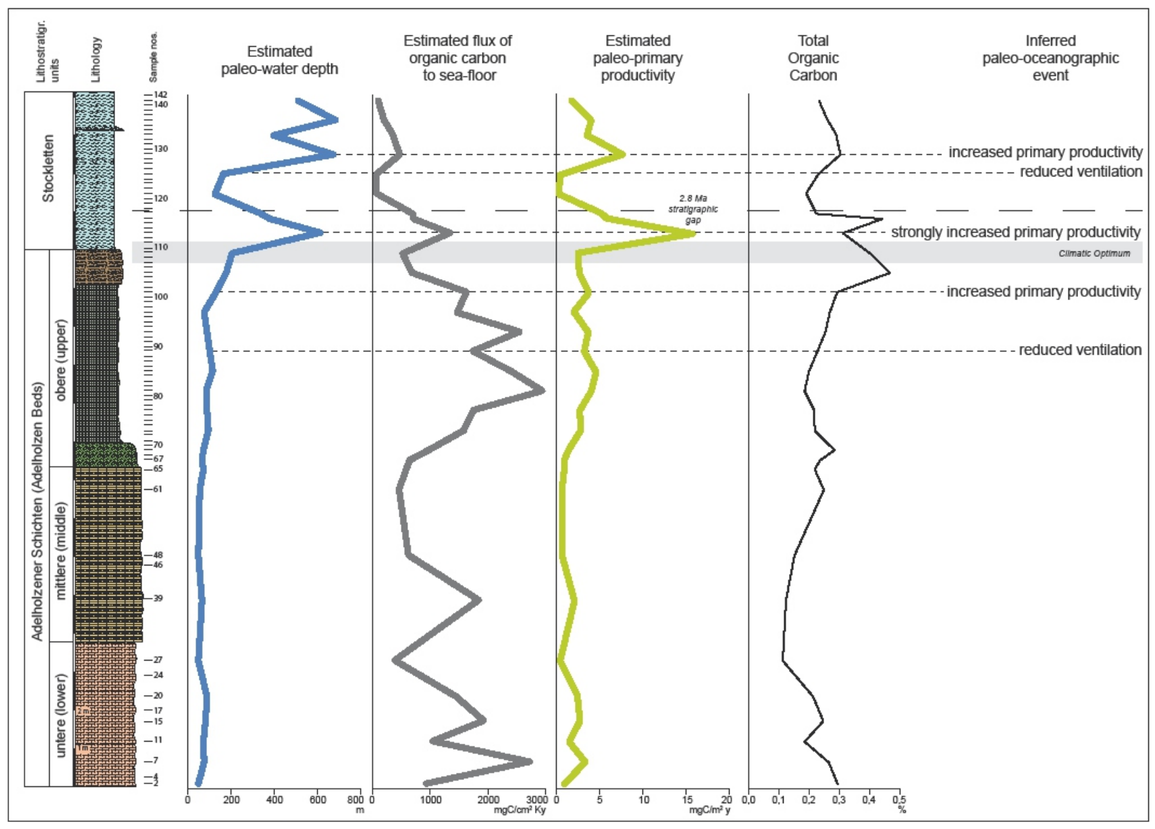
Winfried Werner, Bayerische Staatssammlung für Paläontologie und Geologie, Richard-Wagner-Str. 10, D-80333 München, Germany



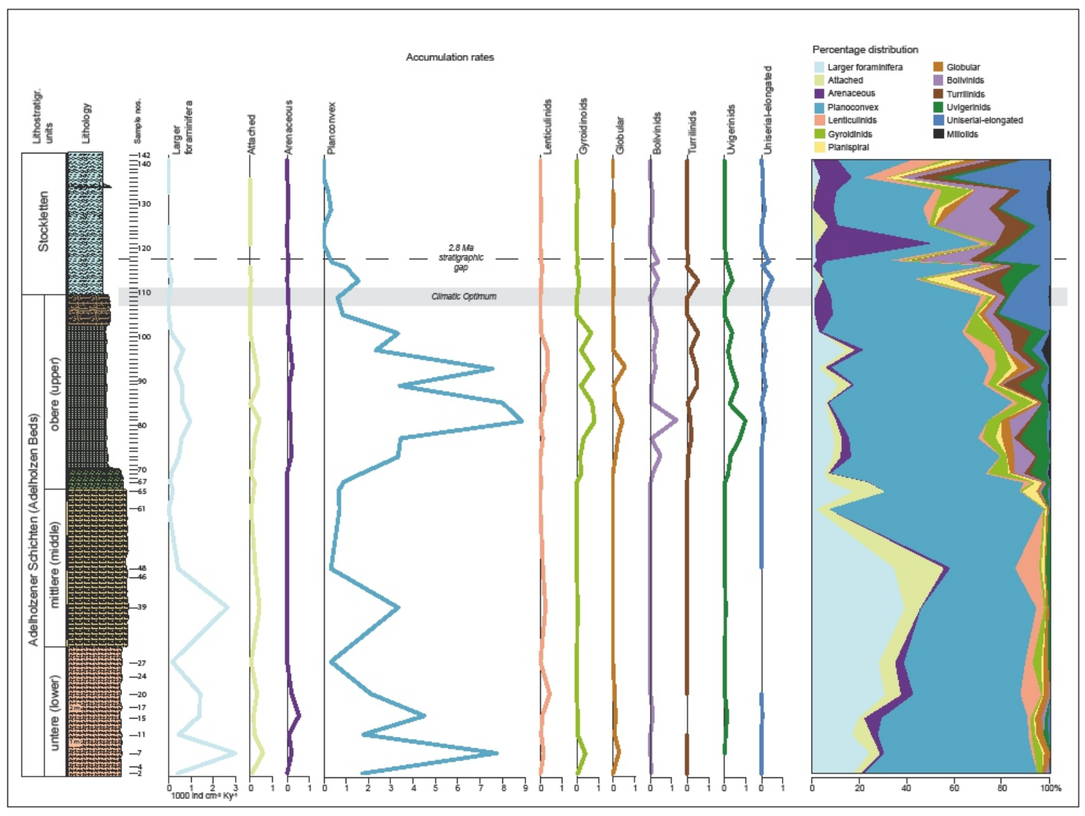
Percent planktic foraminifera, foraminiferal abundance, and nannoplankton trends:
Water depth estimates are based on the percentage of planktic foraminifera (relative to the total assemblage, transfer function of Van der Zwaan et al. 1990, Mar. Geol. 95, 1-16), and show generally increasing water depths from base to top of the investigated section (see Fig. to the right). Several cycles are indicated by possible positions of sequence boundaries (*Lu, Pr*). Paleo-water depths range from inner shelf to upper bathyal environments. While in the Adelholzen Beds the benthic foraminifera form the majority of the assemblages, the planktic forms prevail in the Stockletten.
Very prominent peaks of planktic and benthic foraminiferal accumulation rates (AR) after a climatic optimum point to increased food supply for foraminifera. These peaks are paralleled by peaks in *Coccolithus pelagicus*-percentage, a nutrient indicator, pointing to a moderate nutrient increase for these intervals. Increased vertical mixing of the water column took place in the upper part of the Stockletten (higher ARs of cold-water/mesotrophic planktic foraminifera and percentages of *Coccolithus pelagicus*, lower percentages of *Reticulofenestra minuta*).



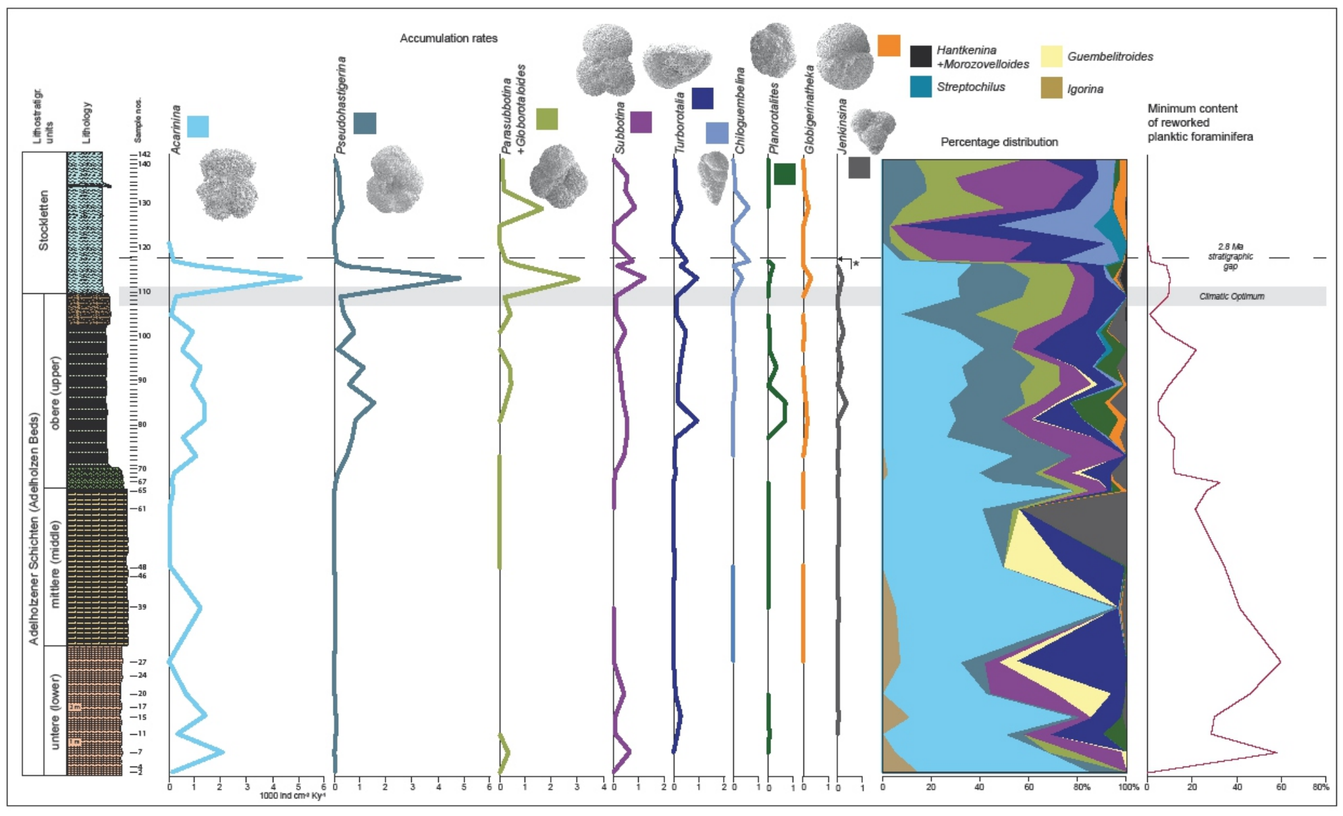
Tectonic map of the Eastern Alps and geological map of the Adelholzen area, changed after BIS (Bayerisches Landesamt für Umwelt).



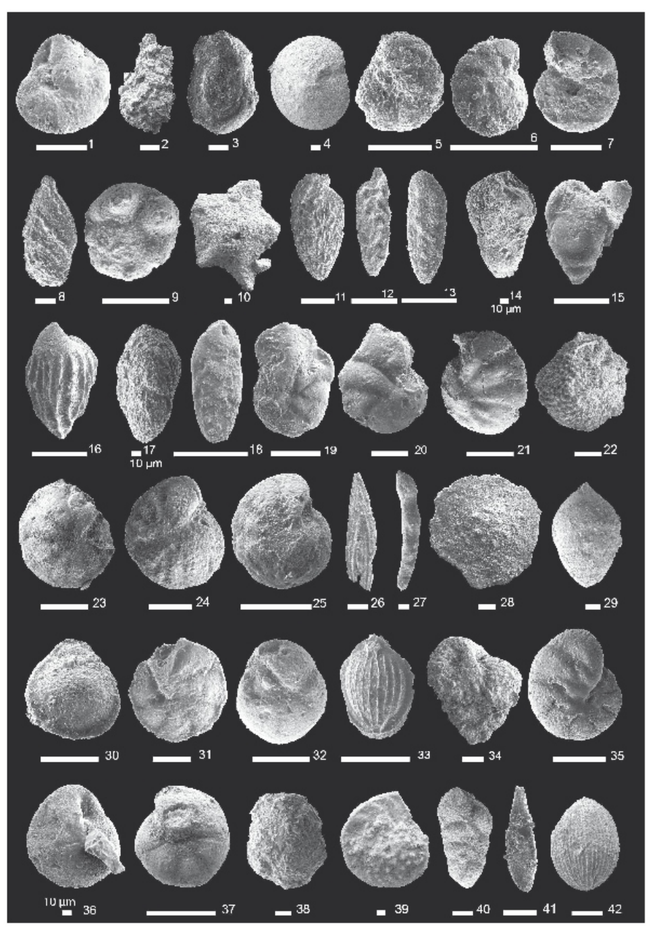
Estimated paleo-water depths, organic carbon flux, primary productivity, and inferred paleo-oceanic events
We estimated flux of organic carbon to the sea-floor (food for benthic foraminifera) and paleo-primary productivity on the base of transfer funktions of Herguera (2000, Mar. Micropal. 40, 259-275) that concider water depth in order to account organic matter decay during sinking. TOC content largely reflects paleo-primary productivity (pPP). Inferred paleo-oceanic events were identified by combination of pPP estimates, accumulation rates of benthic and planktic foraminifera, percentage distributions of opportunistic high productivity / low oxygenation index taxa, and nannoplankton trends.



Accumulation rates (AR) of benthic foraminifera morphogroups:
Deaceasing AR of larger foraminifera within the < 1 mm-fraction and Attached group taxa indicate the increasing paleo-water depth. Most prominent are the high numbers of planoconvex morphotypes (*Alabamina, Anomalinoides, Cibicides, Cibicdoides, Gavelinella....*) within the marls with *Discocyclina*, pointing to well oxigenated bottom waters. High productivity or oxygen deficiency indicators (Bolivinids, Turrilinids, Uvigerinids) occur always with moderate numbers but show distinct increases in percentage distribution during periods of increased paleo-primary productivity. Increasing numbers of uniserial calcareous taxa (*Dentalina, Stilostomella*) reflect the decreasing water energy and indicate the general deepening.



Accumulation rates (AR) of planktic foraminifera genera (morphogroups):
The highest AR show Acarinids, inhabiting the lower mixed layer. These symbiont bearing taxa prefer oligotrophic conditions. Increasing numbers of *Subbotina, Turborotalia*, and *Planorotalites* indicate the successive deepening at this site and the presence of cold waters and possibly higher nutrient levels. *Globigerinatheka* and *Jenkinsina* inhabit the shallow and warm surface waters. The prominent abundance peaks after the climatic optimum in most planktic foraminifera (*Acarinia, Pseudohatigerina, Parasubbotina* etc.) indicate the presence of abundant food recources after a decrease during the climatic optimum. However, eutrophic conditions were not reached (see also nannoplankton trends above). Reworked species reach up to 60% of the planktic taxa. These are species that were reworked from lower Eocene rocks (mostly *Acarinina* and some *Morozovella*). The * indicates the extinction level of *Jenkinsina*.

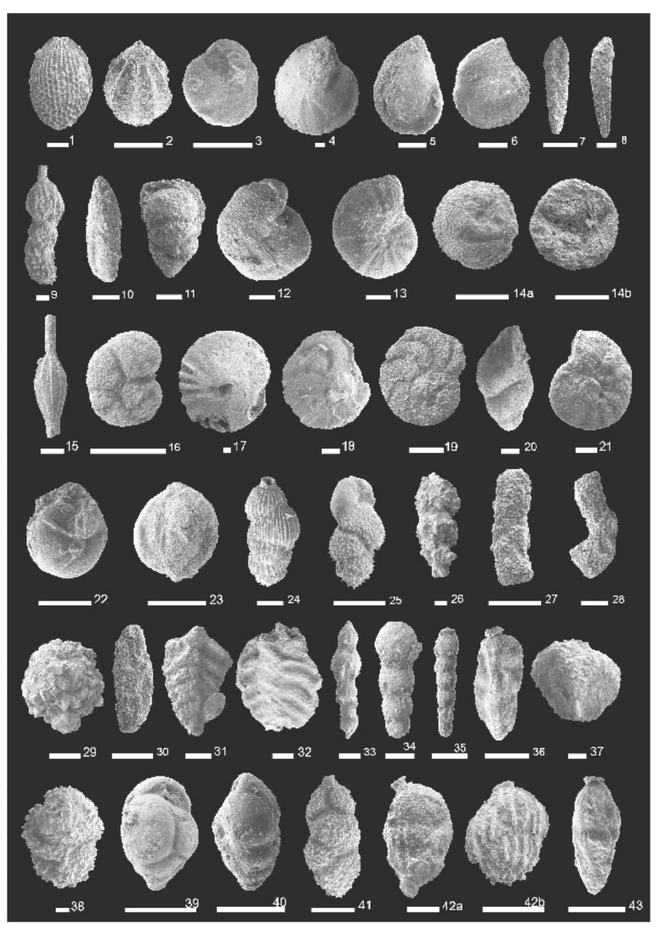


Benthic foraminiferal species identified in the Adelholzen Section
1. *Alabamina dissonata*, sample AH-27. 2. *Ammobaculites* sp., sample AH-141. 3. *Ammodiscus cretaceus*, sample AH-129. 4. *Amphistegina* sp., sample AH-65. 5. *Anomalinoides capitatus*, sample AH-141. 6. *Anomalinoides darwini*, sample AH-141. 7. *Anomalinoides nobilis*, sample AH-07. 8. *Astacolus crepidulus*, sample AH-101. 9. *Asterigerinata(?) pustulosa*, sample AH-69. 10. *Asterocyclina* sp., sample AH-20. 11. *Bolivina vaceki* subsp. *glabra*, 1954, sample AH-97. 12. *Bolivina* sp. 1, sample AH-77 13. *Bolivina* sp. 2, sample AH-77. 14. *Bolivinoides oedumi*, sample AH-129. 15. *Bulimina coprolithoides*, sample AH-77. 16. *Bulimina subtruncana*, sample AH-141. 17. *Bulimina tuxpamensis*, sample AH-85. 18. ?*Cassidella* sp., sample AH-77. 19. *Cibicides lobatulus*, sample AH-93. 20. *Cibicides ribbingi*, sample AH-65. 21. *Cibicides simplex*, Brotzen, sample AH-85. 22. *Cibicides subspirata*, sample AH-07. 23. *Cibicidoides grimsdalei*, sample AH-15. 24. *Cibicidoides incrassatus*, sample AH-101. 25. *Cibicidoides pachyderma*, sample AH-69. 26. *Citarinella* cf. *watersi*, sample AH-101. 27. *Dentalina consobrina*, sample AH-77. 28. *Discocyclina* sp., sample AH-89. 29. *Ellipsoglandulina labiata*, sample AH-137. 30. *Entosolenia crebra*, sample AH-141. 31. *Epistominella minuta*, sample AH-077. 32. *Epistominella vitrea*, sample AH-109. 33. *Fissurina* cf. *formosa*, sample AH-101. 34. *Gaudryina mcleani*, sample AH-27. 35. *Gavelinella* sp., sample AH-07. 36. ?*Globocassidulina* cf. *subglobosa*, sample AH-137. 37. *Gyroidinoides* sp., sample AH-07. 38. ?*Haplophragmoides* sp., sample AH-141. 39. *Heterostegina costata*, sample AH-85. 40. *Karreriella subglabra*, sample AH-137. 41. *Lagena clavata*, sample AH-141. 42. *Lagena gracilicosta*, sample AH-101. Lengths of scale bars 0.1 mm, unless stated otherwise

The Adelholzen-Section is rich in planktic and benthic foraminifera. The percentages of planktic foraminifera in the assemblages point to depth ranges from 50 m (middle neritic) at the base of the section to a maximum of c. 650 m (upper bathyal) in the Stockletten. Nummulitids and macrofossil assemblages (oysters, spondylids, sea urchins, serpulids, crabs, bryozoans, shark teeth) point to shallower paleo-water depths (middle to outer neritic) for the basal and middle lithologic units.

The accumulation rates of heterotrophic planktic and benthic foraminifera are largely coupled to primary surface productivity as these groups either feed directly on diatoms, coccolithophores or other algae (planktic foraminifera) or depend on the organic rain that reaches the seafloor (benthic foraminifera). Foraminiferal ARs are therefore a good estimator for paleo-productivity of ancient ecosystems.

All samples contain very rich calcareous nannoplankton floras with dominance of small reticulofenestrids. High amounts of *Reticulofenestra minuta* can be interpreted as indicator of warm, well stratified water column. Low percentages of *Coccolithus pelagicus* point to oligotrophic paleo-environments. We are therefore able to distinguish several paleo-primary productivity events and phases of reduced bottom water ventilation.



Benthic foraminiferal species identified in the Adelholzen Section (continuation)
1. *Lagena gracilicosta* var., sample AH-101. 2. *Lagena sulcata*, sample AH-101. 3. *Lenticulina inornata*, sample AH-69. 4. *Lenticulina limbosa*, sample AH-141. 5. *Lenticulina* sp. 1, sample AH-137. 6. *Lenticulina* sp. 2, sample AH-85. 7. *Loxostoma plummerae*, sample AH-93. 8. *Loxostomoides applinae*, sample AH-129. 9. *Marginulina hirsuta*, sample AH-109. 10. *Marginulina similis*, sample AH-141. 11. *Marsonella oxycona*, sample AH-141. 12. *Melonis affinis*, sample AH-27. 13. *Melonis pompilioides*, sample AH-141. 14a,b. *Neoconorbina ystadiensis*, sample AH-48. 15. *Nodosaria* sp., sample AH-137. 16. *Nonionella robusta*, sample AH-85. 17. *Nummulites* sp., sample AH-137. 18. *Operculina* sp., sample AH-109. 19. *Planulina austriaca*, sample AH-69. 20. *Pleurostomella incrassata*, sample AH-137. 21. *Porosononion* sp., sample AH-77. 22. *Pullenia bulloides*, sample AH-137. 23. *Quinqueloculina brevidentata*, sample AH-101. 24. *Rectuvigerina multicostata*, sample AH-11. 25. *Rectuvigerina* sp., sample AH-116. 26. *Reophax nodulosa* var. *brevior*, sample AH-129. 27. *Rhabdammina* sp., sample AH-141. 28. *Rhizammina* sp., sample AH-141. 29. *Saccammina globosa*, sample AH-109. 30. *Spiroloculina canaliculata*, sample AH-129. 31. *Spiroplectammina dentata*, sample AH-93. 32. *Spiroplectammina* sp., sample AH-48. 33. *Stilostomella adolphina*, sample AH-129. 34. *Stilostomella paleocenica*, sample AH-137. 35. *Stilostomella plummerae*, sample AH-141. 36. *Trifarina bradyi*, sample AH-69. 37. *Tristrix excavatus*, sample AH-105. 38. *Trochammina* sp., sample AH-105. 39. *Turrilina brevispira*, sample AH-137. 40. *Turrilina robertsi*, sample AH-77. 41. *Uvigerina hispida* Schwager, sample AH-77. 42. *Uvigerina moravia*, a: sample AH-93, b: sample AH-85. 43. *Uvigerina* cf. *semiornata*, sample AH-069. Lengths of scale bars 0.1 mm, unless stated otherwise.