An age model for the Lutetian to Priabonian beds of Adelholzen (Helvetic Unit, Bavaria, Germany)

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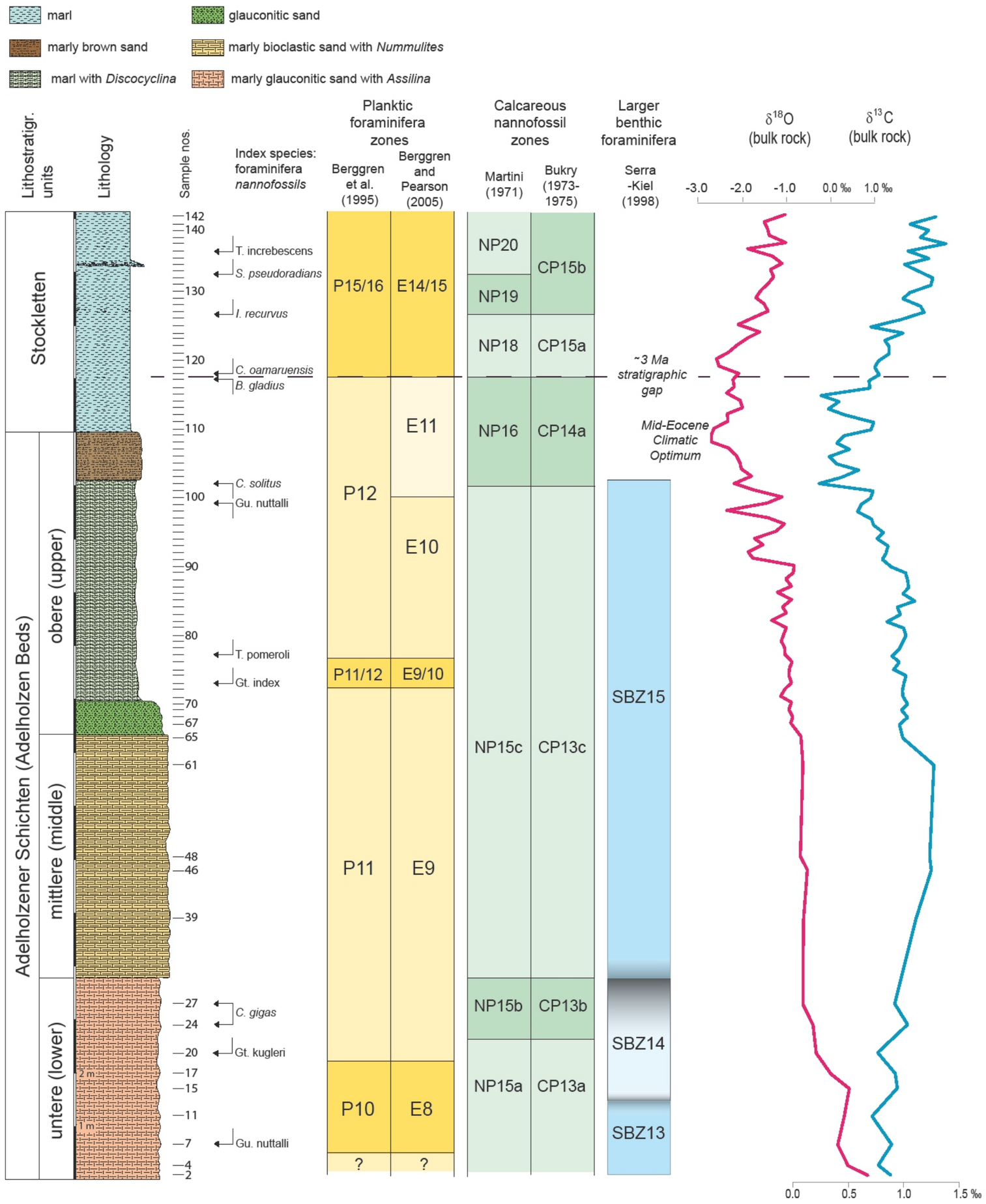
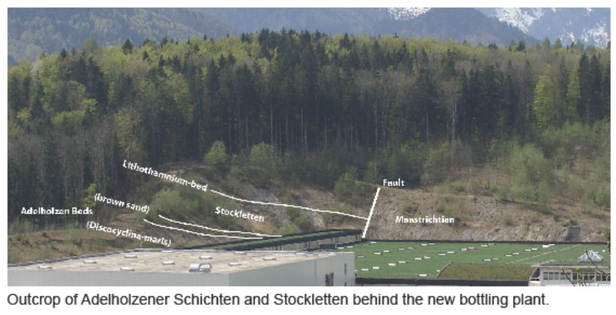


Lithology of the section investigated, first and last occurrences of calcareous nannofossil and planktic foraminiferal index species, biostratigraphic zonations for planktic foraminifera, calcareous nannofossils and larger benthic foraminifera, and δ13C- and δ18O-isotope curves. The position of a c. 3 Ma stratigraphic gap and the Mid-Eocene Climatic Optimum are indicated.

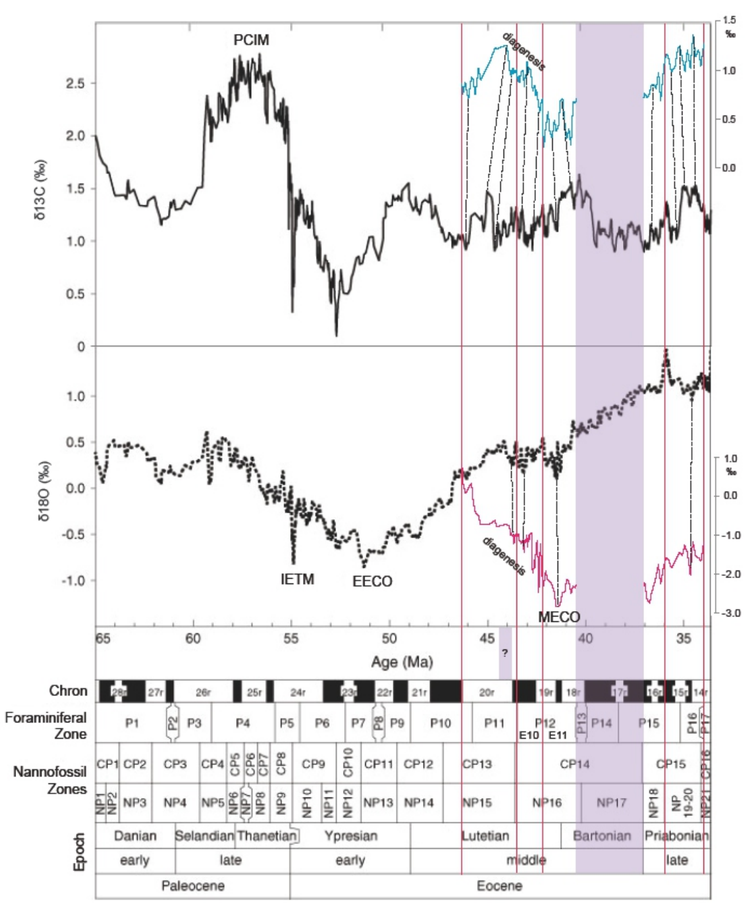
Location of section at Adelholzen near Siegsdorf.

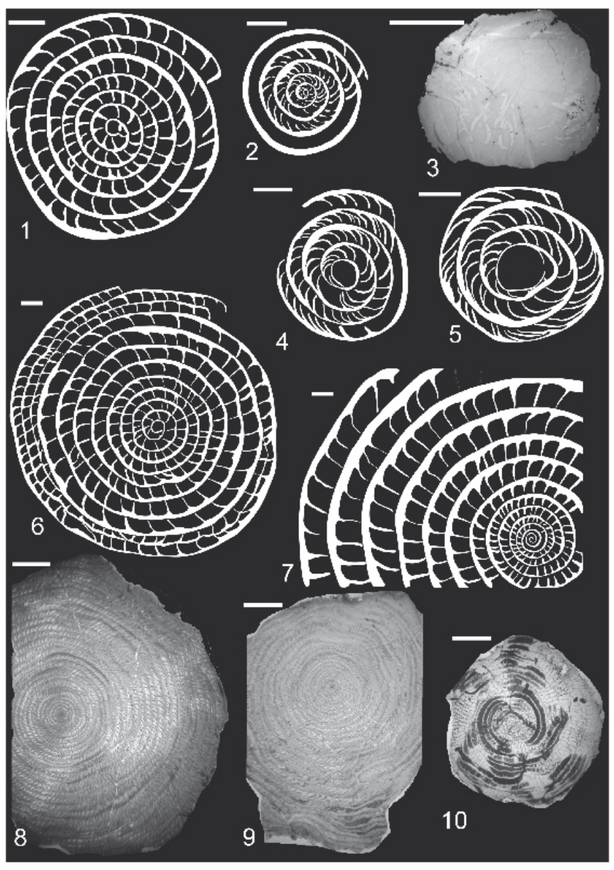


Outcrop of Adelholzener Schichten and Stockletten behind the new bottling plant.

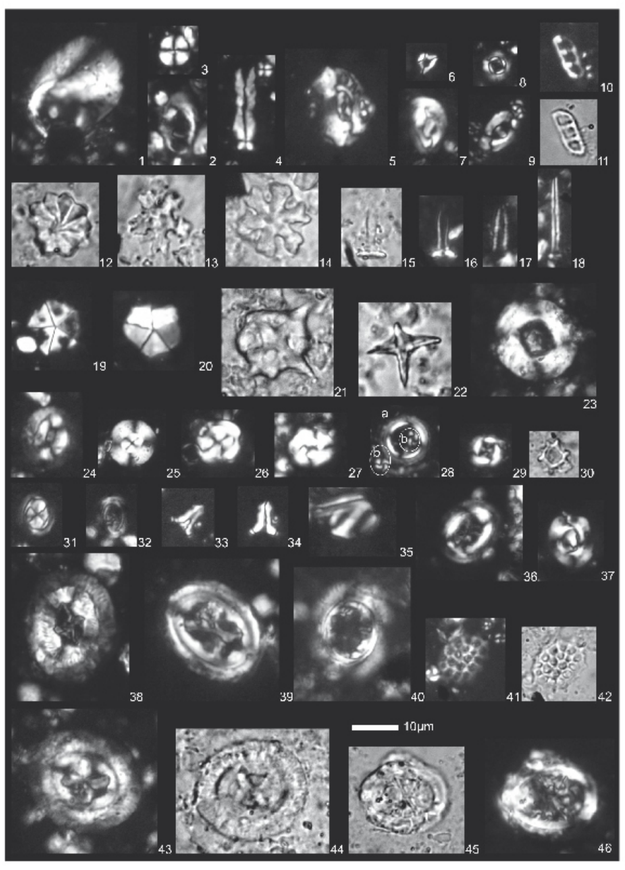
The 18 m thick Adelholzen Section, located southwest of Siegsdorf in southern Bavaria, Germany, is part of the Helvetic (tectonic) Unit and comprises six lithologic units: 1) marly, glauconitic sands with predominantly *Assilina*, 2) marly bioclastic sands with predominantly *Nummulites*, 3) glauconitic sands, 4) marls with *Discocyclina*, 5) marly brown sand (units 1-5 "Adelholzener Schichten"), and 6) Stockletten (marls without established formal name). The Adelholzen-Section is rich in planktic (and benthic) foraminifera. Reworked specimens from older deposits commonly occur, whereas most zonal markers were not found within the investigated samples; other potential index species show a rather sporadic occurrence instead of a continuous record. Consequently, our age model is based mainly on calcareous nannofossils and nummulitids and one zonal boundary only is based on planktic foraminifera. All investigated sediments contain very rich and well preserved calcareous nannoplankton assemblages, dominated by reticulofenestrids. All samples are characterized by low percentages of reworked nannofossil taxa. Zone NP 17 is missing and we therefore assume a stratigraphic gap (at least 3 Ma) in the lower part of the exposed Stockletten. This assumption is supported by the almost complete disappearance of acarinids (planktic foraminifera) in the overlying strata, pointing to a strong change in paleoceanography. A prominent decrease in bulk rock δ18O-values indicates the Mid-Eocene Climatic Optimum-Event around the brown sand (unit 5) and confirms our biostratigraphic zonation. The overall sediment-accumulation rate was at least 1.8 mm/Ky. Lack of first and last occurrences, evidence of stratigraphic gaps, and reworked planktic foraminifera specimens complicate the construction of a consistent biostratigraphic framework. As reported from other sections elsewhere, planktic foraminifera, calcareous nannoplankton and larger benthic zonations did not always correlate well with established zonal schemes. Application of independent approaches however enabled us to overcome these difficulties.

Prominent highs and lows in δ13C- and δ18O-curves allow a correlation with global isotope curves for the Paleogene (here with curves published in Hancock and Dickens 2005, Proc. ODP Sci. Results 198). Oxygen isotopes are strongly biased by diagenesis but prominent lows can be easily identified (e.g., MECO). The Carbon curve shows both, lows as well as highs and allow the detection of futher (minor) stratigraphic gaps and is less influenced by diagenesis. Stratigraphic gaps ar indicated by purple bars.

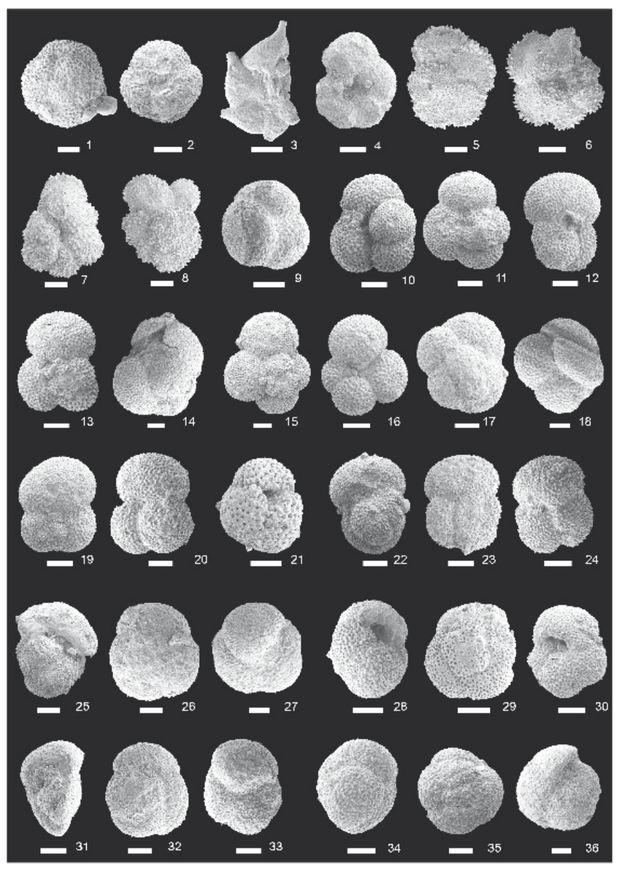




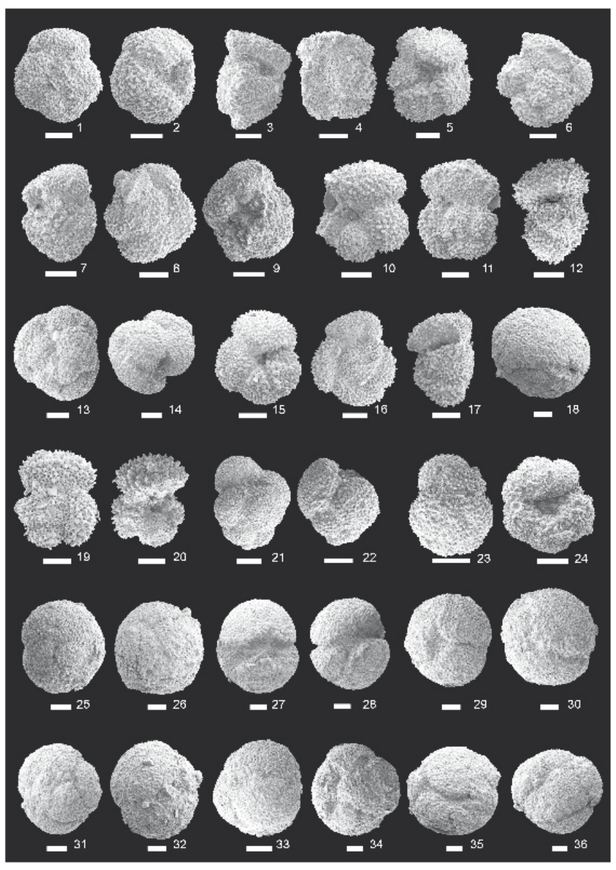
Stratigraphically important **nummulitids**. 1. *Assilina cuvillieri*, A-form, scale bar; 1 mm (sample AH-2). 2. *Nummulites alponensis*, A-form, scale bar; 1 mm (sample AH-15). 3. *Discocyclina* sp. with bioturbation, scale bar; 10 mm (sample AH-11). 4. *Nummulites millecaput* A-form, scale bar; 1 mm (sample AH-27). 5. *Nummulites millecaput* A-form, scale bar; 1 mm (sample AH-61). 6. *Assilina exponens* (larger specimen), A-form, scale bar; 1 mm (sample AH-24). 7. *Assilina tenuimarginata*, B-form, scale bar; 1 mm (sample AH-7). 8. *Nummulites millecaput*, B-form, scale bar; 5 mm (sample AH-39). 9. *Nummulites millecaput*, B-form, scale bar; 5 mm (sample AH-65). 10. *Assilina exponens*, B-form, scale bar; 5 mm (sample AH-65).



Stratigraphically important **calcareous nannofossils**. 1. *Lophodolithus rotundus* Bukry & Percival, 1971; Sample AH-2; NP15a. 2. *Lophodolithus acutus* Bukry & Percival, 1971; Sample AH-2; NP15a. 3. *Cyclicargolithus luminis* (Sullivan, 1965) Bukry, 1971; Sample AH-2; NP15a. 4. *Sphenolithus furcatolithoides* Locker, 1967; Sample AH-7; NP15a. 5. *Helicosphaera lophota* Bramlette & Sullivan, 1961; Sample AH-27; NP15b. 6. *Lanternithus minutus* Stradner, 1962; Sample AH-140; NP20. 7. *Helicosphaera bramlettei* Müller, 1970; Sample AH-108; NP16. 8. *Calcidiscus? protoannulus* (Gartner, 1971) Loeblich & Tappan, 1978; Sample AH-80; NP15c. 9. *Helicosphaera seminulum* Bramlette & Sullivan, 1961; Sample AH-2; NP15a. 10, 11. *Isthmolithus recurvus* Deflandre, 1954; Sample AH-130; NP19. 12. *Discoaster barbadiensis* Tan, 1927; Sample AH-2; NP15a. 13. *Discoaster distinctus* Martini, 1958; Sample AH-108; NP16. 14. *Discoaster deflandrei* Bramlette & Riedel, 1954; Sample AH-27; NP15b. 15, 16. *Blackites gladius* (Locker, 1967) Varol, 1989; Sample AH-7; NP15a. 17. *Blackites virgatus* Bown, 2005; Sample AH-27; NP15b. 18. *Blackites spinosus* (Deflandre & Fert, 1954) Hay & Towe, 1962; Sample AH-108; NP16. 19. *Pemma basquensis* (Martini, 1959) Báldi-Beke, 1971; Sample AH-80; NP15c. 20. *Braarudosphaera bigelowii* (Gran & Braarud, 1935) Deflandre, 1947; Sample AH-117; NP16. 21.*Nannotetrina cristata* (Martini, 1958) Perch-Nielsen, 1971; Sample AH-77; NP15c. 22. *Nannotetrina fulgens* (Stradner, 1960) Achuthan & Stradner, 1969; Sample AH-27; NP15b. 23. *Reticulofenestra umbilica* (Levin, 1965) Martini & Ritzkowski, 1968; Sample AH-108; NP16. 24. *Coccolithus cachaoi* Bown, 2005; Sample AH-27; NP15b. 25. *Reticulofenestra bisecta* (Hay, Mohler & Wade, 1966) Roth, 1970; Sample AH-135; NP20. 26. *Reticulofenestra scripsae* (Bukry & Percival, 1971) Roth, 1973; Sample AH-135; NP20. 27. *Cyclicargolithus floridanus* (Roth & Hay, 1967) Bukry, 1971; Sample AH-80; NP15c. 28. a) *Coronocyclus bramlettei* (Hay & Towe, 1962) Bown, 2005; b) *Reticulofenestra minuta* Roth, 1970; Sample AH-115; NP16. 29. *Cribrocentrum reticulatum* (Gartner & Smith, 1967) Perch-Nielsen, 1971; Sample-AH 110; NP16. 30. *Corannulus germanicus* Stradner, 1962; Sample AH-108; NP16. 31. *Clausiococcus fenestratus* (Deflandre & Fert, 1954) Prins, 1979; Sample AH-75; NP15c. 32. *Campulosphaera dela* (Bramlette & Sullivan, 1961) Hay & Mohler, 1967; Sample-AH 90; NP15. 33, 34. *Zygrhablithus bijugatus* (Deflandre, 1954) Deflandre, 1959; Sample AH-80; NP15c. 35. *Pontosphaera exilis* (Bramlette & Sullivan, 1961) Romein, 1979; Sample AH-27; NP15b. 36. *Chiasmolithus solitus* (Bramlette & Sullivan, 1961) Locker, 1968; Sample AH-117; NP16. 37. *Reticulofenestra dictyoda* (Deflandre, 1954) Stradner, 1968; Sample AH-140; NP20. 38. *Coccolithus mutatus* (Perch-Nielsen, 1971) Bown, 2005; Sample AH-27; NP15b. 39. *Chiasmolithus grandis* (Bramlette & Riedel, 1954) Radomski, 1968; Sample AH-27; NP15b. 40. *Pontosphaera formosa* (Bukry & Bramlette, 1969) Romein, 1979; Sample AH-108; NP16. 41, 42. *Clathrolithus ellipticus* Deflandre, 1954; Sample AH-110; NP16. 43, 44. *Chiasmolithus gigas* (Bramlette & Sullivan, 1961) Radomski, 1968; Sample AH-27; NP15b. 45, 46. *Chiasmolithus oamaruensis* (Deflandre, 1954) Hay, Mohler & Wade, 1966; Sample AH-140; NP20.



Stratigraphically important **planktic foraminifera**l species from the >0.250 mm-fraction (continuation). 1, 2. *Catapsydrax unicavus* (sample AH-75). 3. *Hantkenina liebusi* (sample AH-93). 4. *Pseudohastigerina wilcoxensis* (sample AH-101). 5, 6. *Morozovelloides coronatus* (5 sample AH-77, 6 sample AH-101). 7, 8. *Morozovelloides lehneri* (7 sample AH-79, 8 sample AH-89). 9. *Subbotina angiporoides* (sample AH-139). 10, 11. *Subbotina corpulenta* (sample AH-101). 12. *Subbotina cruciapertura* (sample AH-97). 13. *Subbotina eocaena* (sample AH-115). 14. *Subbotina gortanii* (sample AH-142). 15, 16. *Subbotina hagni* (15 sample AH-115, 16 sample AH-116). 17, 18. *Subbotina jacksonensis* (17 sample AH-141, 18 sample AH-137). 19, 20. *Subbotina linaperta* (19 sample AH-139, 20 sample AH-101). 21. *Subbotina senni* (sample AH-2). 22-24. *Turborotalia frontosa* (22, 24 sample AH-97, 23 sample AH-101). 25-27. *Turborotalia possagnoensis* (25 sample AH-113, 26, 27 sample AH-129). 28-30. *Turborotalia pomeroli* (sample AH-116). 31-33. *Turborotalia cerroazulensis* (sample AH-135). 34-36. *Turborotalia increbescens* (34, 35 sample AH-139, 36 sample AH-137). Length of scale bars: 0.1 mm.



Stratigraphically important **planktic foraminifera**l species from the >0.250 mm-fraction. 1, 2. *Acarinina boudreauxi* (1 sample AH-95, 2 sample AH-99). 3-5. *Acarinina bullbrooki* (sample AH-101). 6. *Acarinina rohri* (sample AH-117). 7-9. *Acarinina collactea* (7, 9 sample AH-97, 8 sample 101). 10-12. *Acarinina praetopilensis* (10, 11 sample AH-101, 12 sample AH-115). 13, 14. *Acarinina pseudosubsphaerica* (sample AH-77). 15-17. *Acarinina punctocarinata* (sample AH-116). 18. *Orbulinoides beckmanni* (reworked specimen, sample AH-132). 19, 20. *Acarinina topilensis* (sample AH-116). 21, 22. *Guembelitroides nuttali* (21 sample AH-77, 22 sample AH-99). 23, 24. *Igorina broedermanni* (sample AH-95). 25, 26. *Globigerinatheka euganea* (25 sample AH-133, 26 sample AH-132). 27, 28. *Globigerinatheka index* (sample AH-129). 29, 30. *Globigerinatheka korotkovi* (sample AH-129). 31, 32. *Globigerinatheka kugleri* (sample AH-127). 33, 34. *Globigerinatheka luterbacheri* (33 sample AH-139, 34 sample 133). 35, 36. *Globigerinatheka subconglobata* (sample AH-129). Length of scale bars: 0.1 mm.