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

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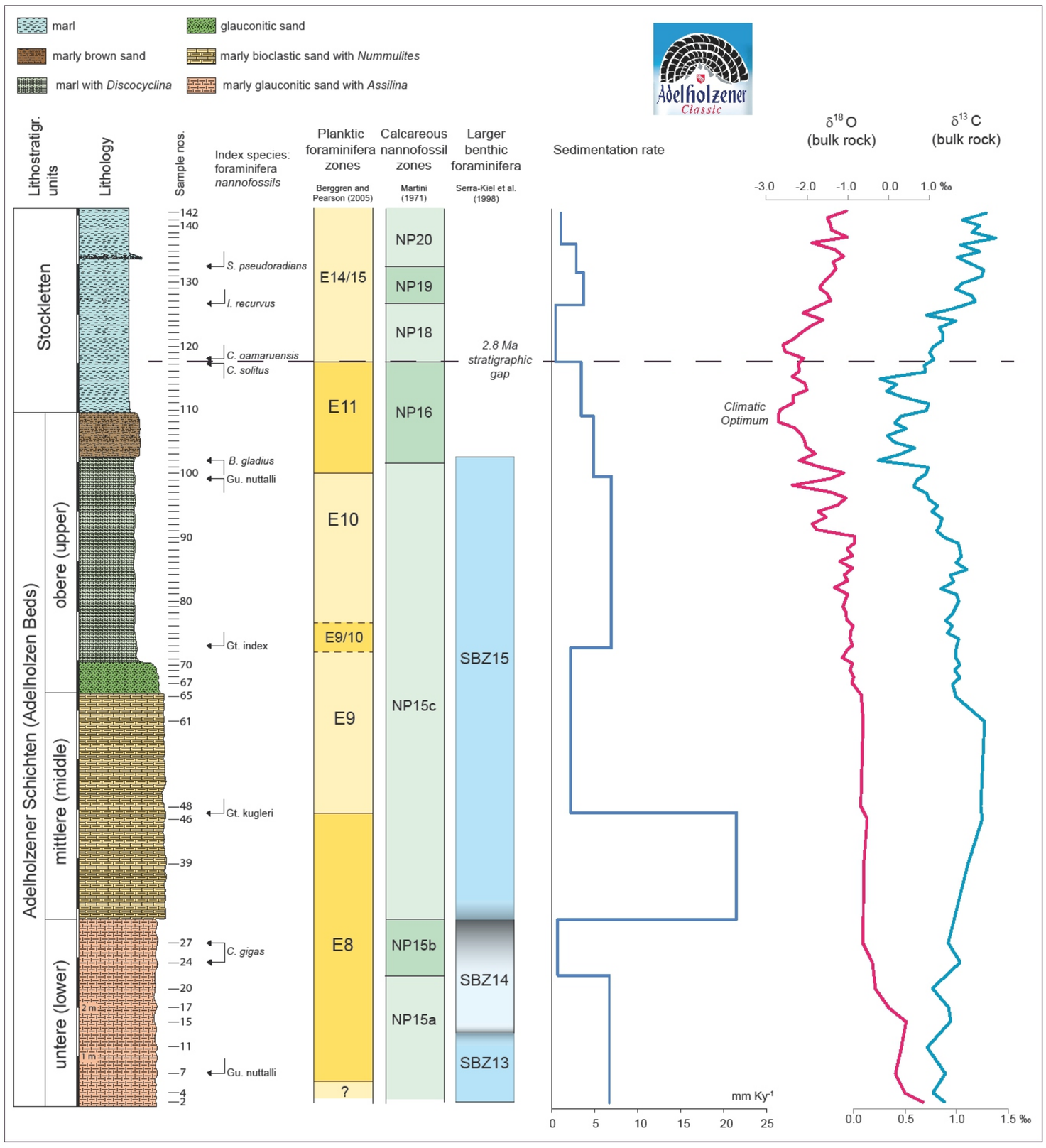
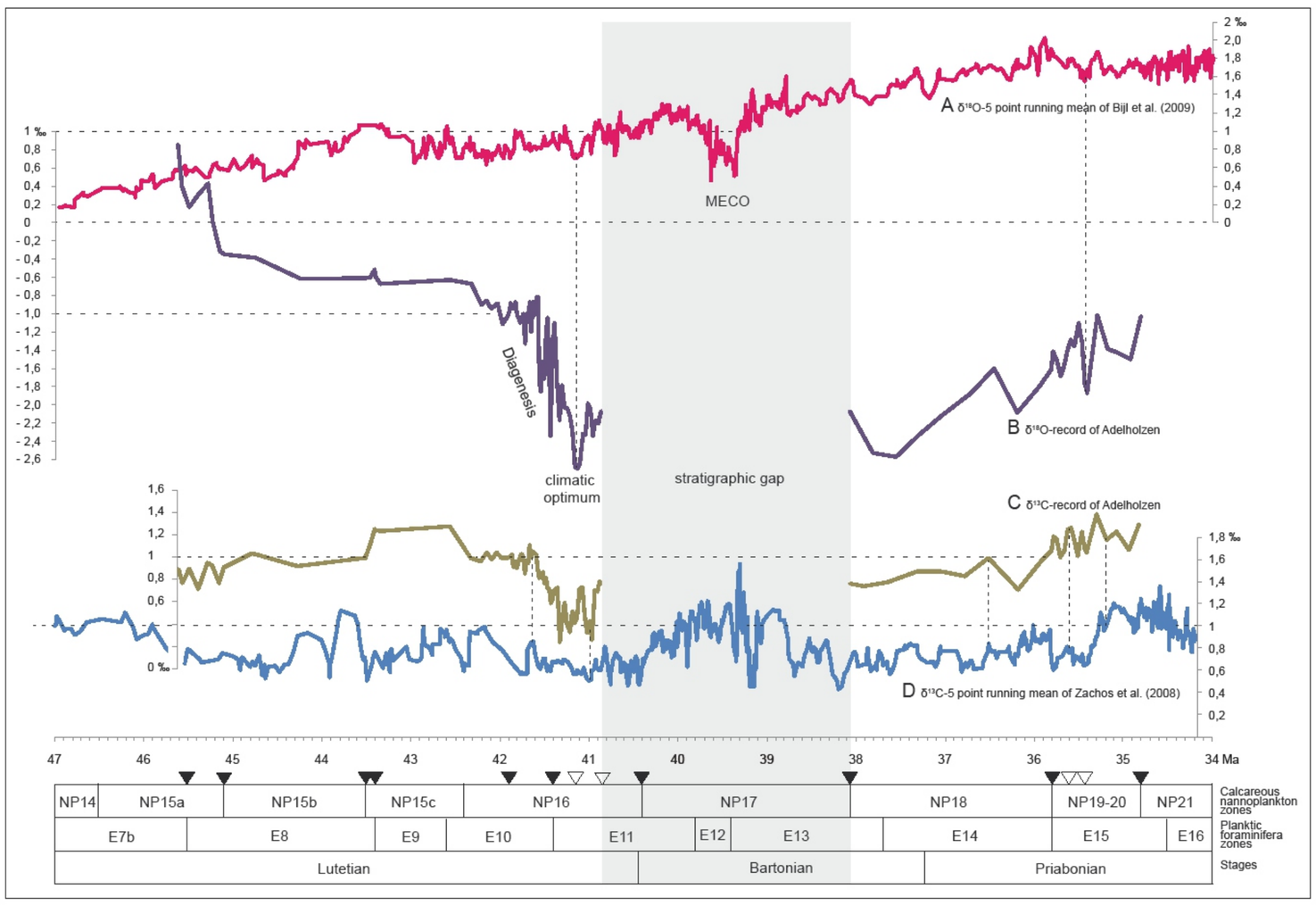


Lithology of the section investigated, first and last occurrences of calcareous nannofossil and planktic foraminiferal **index species**, biostratigraphic **zonations** for planktic foraminifera, calcareous nannofossils and larger benthic foraminifera, **Sedimentation rates**, and δ13C- and δ18O-**isotope curves**. The position of a 2.8 Ma stratigraphic gap and the climatic optimum are indicated.

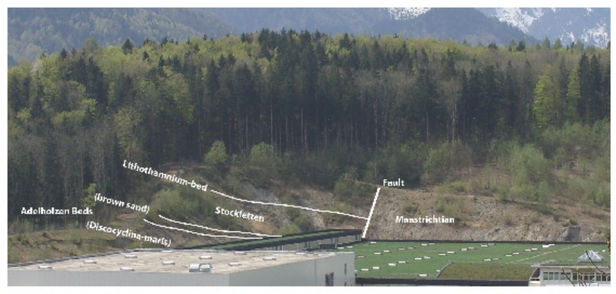


We tuned the Adelholzen **stable isotope records** to the global stack of Bijl et al. (2009, Nature 461, 776-779) and Zachos et al. (2008, Nature 451, 279-283) in order to deliminate the apparent stratigraphic gap in the lower part of the Stockletten (entire Zone NP17 is missing). Oxygen isotopes are strongly biased by diagenesis but prominent lows can be easily identified (e.g., climatic optimum). Age fix points for calculation of sedimentation rates are indicated (closed triangles - biostratigraphic, open triangles - isotopic).

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). Our age model is based on calcareous nannofossils, planktic foraminifera, and nummulitid zones. Prominent highs and lows in $\delta^{13}C$- and $\delta^{18}O$-curves allow a correlation with global isotope stacks for the Paleogene.

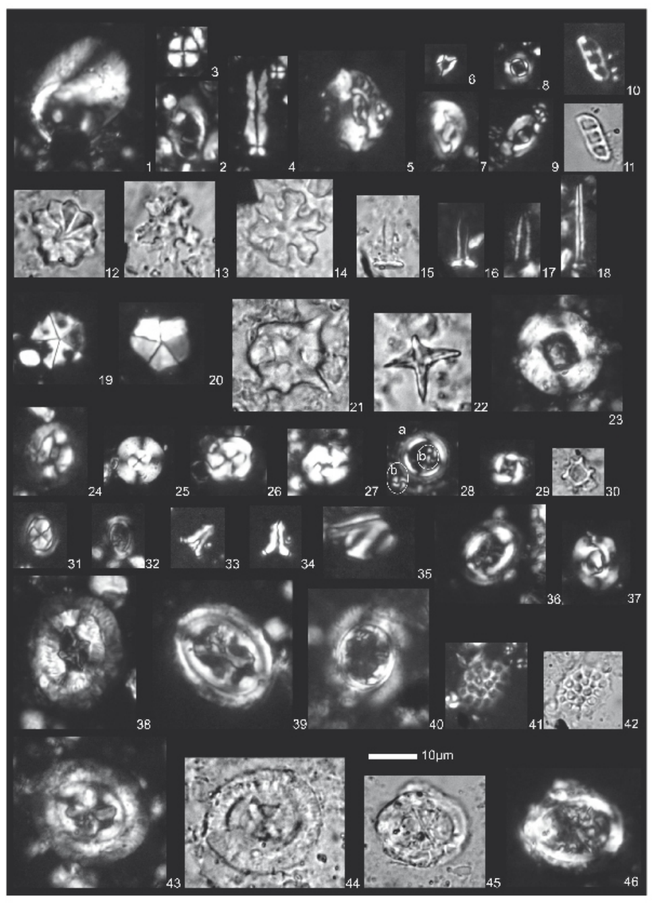
Our analysis shows the presence of six nannoplankton zones (NP15a to NP19-20). Zone NP17 is completely missing and therfore most of the Bartonian Stage, including the Mid Eocene Climatic Optimum (MECO). In combination with the tuned isotope records, the duration of the stratigraphic gap was deliminated to 2.8 My. Four Lutetian planktic foraminiferal zones were identified (E8 to E11), the assemblages above the stratigraphic gap are in agreement with the nannofossil zones. Shallow Benthic Zones based on nummulitids confirm our age assignments. In total, 14 age fix points for the calculation of sedimentation rates and further parameters (e.g., accumulation rates for benthic and planktic foraminifera) were determined.

Location of section at Adelholzen near Siegsdorf.

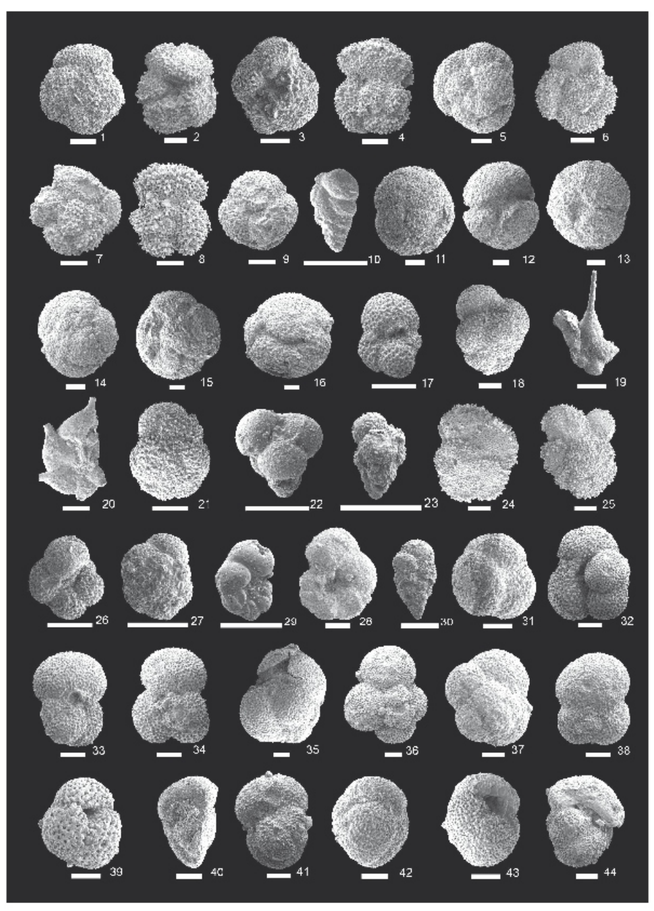


Outcrop of Adelholzener Schichten and Stockletten behind the new bottling plant.

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.



Planktic foraminiferal species identified in the Adelholzen Section. 1. *Acarinina boudreauxi*, sample AH-95. 2. *Acarinina bullbrooki*, sample AH-101. 3. *Acarinina collactea*, sample AH-97. 4. *Acarinina praetopilensis*, sample AH-101. 5. *Acarinina pseudosubsphaerica*, sample AH-77.6. *Acarinina punctocarinata*, sample AH-116. 7. *Acarinina rohri*, sample AH-117. 8. *Acarinina topilensis*, sample AH-116. 9. *Catapsydrax unicavus*, sample AH-75. 10. *Chiloguembelina ototara*, sample AH-77 11. *Globigerinatheka euganea*, sample AH-133. 12. *Globigerinatheka index*, sample AH-129 13. *Globigerinatheka korotkovi*, sample AH-129. 14. *Globigerinatheka kugleri*, sample AH-127 15. *Globigerinatheka luterbacheri*, sample 133. 16. *Globigerinatheka subconglobata*, sample AH-129. 17. *Globorotaloides quadrocameratus*, sample AH-7 18. *Guembelitroides nutalli*, sample AH-77. 19. *Hantkenina* cf. *compressa*, sample AH-129. 20. *Hantkenina liebusi*, sample AH-93. 21. *Igorina broedermanni*, sample AH-95. 22. *Jenkinsina columbiana*, sample AH-85. 23. *Jenkinsina triseriata*, sample AH-105. 24. *Morozovelloides coronatus*, sample AH-77. 25. *Morozovelloides lehneri*, sample AH-89. 26. *Parasubbotina pseudowilsoni*, sample AH-7. 27. *Planorotalites capdevilensis*, sample AH-133. 28. *Pseudohastigerina micra*, sample AH-105. 29. *Pseudohastigerina wilcoxensis*, sample AH-101. 30. *Streptochilus martini*, sample AH-129. 31. *Subbotina angiporoides*, sample AH-139. 32. *Subbotina corpulenta*, sample AH-101. 33. *Subbotina crociapertura*, sample AH-97. 34. *Subbotina eocaena* , sample AH-115. 35. *Subbotina gortanii*, sample AH-142. 36. *Subbotina hagni*, sample AH-115. 37. *Subbotina jacksonensis*, sample AH-141. 38. *Subbotina linaperta*, sample AH-139. 39. *Subbotina senni*, sample AH-2. 40. *Turborotalia cerroazulensis*, sample AH-135. 41. *Turborotalia frontosa*, sample AH-97. 42. *Turborotalia increbescens*, sample AH-139. 43. *Turborotalia pomeroli*, sample AH-116. 44. *Turborotalia possagnoensis*, sample AH-113. Length of scale bars: 0.1 mm.



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).