

# Index

Note: Page numbers in *italics* refer to Figures. Page numbers in **bold** refer to Tables.

- Acarinina bullbrookii* 63, 67, 68
- acorn barnacle *see Semibalanus balanoides*
- Acropora* spp., chemistry **39**, 49–51
- Alabaminella weddellensis* 108
- alkalinity, relation to stable isotopes in
  - foraminifera 137–138, *139*
- alkenones 15–16, 77
  - U<sub>K</sub><sup>37</sup> (alkenone unsaturation index) 15
- Allogromia laticollaris* 109
- Ammonia* spp.
  - A. batavus* 158, 166
  - A. beccarii* 109, **161**, *163*, *165*, *166*, *167*
- Antarctica, first ice 10
- aragonite
  - biological controls on 36
  - in corals 37, 87, 88, 90
- Arboraminna hilaryae* 110
- Archohelia* 95
- ARENA 114
- Aschemonella ramuliformis* 109
- Atlantic Ocean (North), foraminifera diversity **102**, **103**, *104*
- atomic emission spectrometry (AES) 22
- Bathysiphon capillare* 108
- benthic foraminifera
  - distribution in deep ocean 110–111
    - biogeochemical cycles 112
    - phylogeny 112–113
  - diversity 97
  - ecology 97–98
  - effect of water depth on
    - large species 98–99
    - small species 99–101
  - factors affecting  $\delta^{13}\text{C}$  122
    - carbonate ion 126–129
    - isotope disequilibrium 123–124
    - methane 124–126
    - microhabitat 122–123
    - nutrients 121
    - ontogeny 126
    - organic matter flux 124
  - $\delta^{18}\text{O}$ 
    - effect of salinity 155–156
    - effect of temperature 156–157
    - vital effects 157–158
  - $\delta^{18}\text{O}$  seasonality in Scottish fjord 155
  - culturing experiments 135–136
    - interspecies variation 143
    - ontogenetic trends 143–144
    - yearly  $\delta^{18}\text{O}$  offset 143
  - trophic biology
    - $\delta^{13}\text{C}$  labelled food experiments 101, 104–106, *107*
    - diets 106–108
      - bacterivores 109–110
      - herbivores 108
      - omnivores 108–109
      - stercomata-bearing 109
      - suspension feeders 110
- Benthic Foraminiferal Accumulation Rate (BFAR) 111
- biogenic minerals 3
- biogeochemical cycling 112
- biological proxies
  - coccolithophores 6, 7
  - corals 8–9
  - diatoms 6, 8
  - foraminifera 5–6
  - molluscs 9
- biological pump 5
- biomineral, defined 3–4
- biomineralization
  - biological controls 35–36
    - bones **42**, 44
    - cell level 36–37
    - coccolithophores 37–42
    - corals 37
    - foraminifera 42–44
    - genetic level 44
  - defined 3
  - experimental observations 34–35
  - factors affecting 33–34
  - modelling the vital effects of boron in foraminifera
    - biological controls 49–51
    - chemistry 48
    - fractionation 46–48
    - isotopes 48–49
  - process 4
  - protistan promoted 4–5
- black corals 9
- Bolivina* spp.
  - B. pacifica* 104, 108
  - B. spathulata* 108
  - B. spissa* 108
- bones and biomineralization 42, 44
- boron in foraminifera
  - fractionation 46–48
    - biological controls 49–51
    - inorganic chemistry 48
    - isotopes 48–49
- Bulimina* spp.
  - B. aculeata* 104
  - B. exilis* 109
  - B. marginata* **162**, *163*, *165*
  - B. mexicana* *123*, *124*
- $\delta^{13}\text{C}$ 
  - of cultured foraminifera 135–136
  - factors affecting  $\delta^{13}\text{C}$  in foraminifera 122
    - carbonate ions 126–129
    - methane 124–126
    - microhabitat 122–123
    - nutrients 121
    - ontogeny 126
    - organic matter flux 124
    - relation to micro-environment 45, 51–52
    - size 73
  - in *S. balanoides* 175–181

- $\delta^{13}\text{C}$  (*Continued*)  
 use in food experiments for foraminifera 101,  
 104–106, 107
- $^{14}\text{C}$  in corals 17, 18
- $\delta^{44}\text{Ca}$   
 in  $\text{CaCO}_3$  35  
 in corals 17, **39**, **40**, **41**, **42**  
 in foraminiferal 42–44  
 in molluscs 19
- calcification 48, 74
- calcite  
 dissolution in foraminifera 60  
 factors affecting precipitation 33–34  
 gametogenic 75, 76, 78  
 overgrowths in foraminifera 60–61  
 recrystallization in foraminifera 61
- calcium carbonate  
 biological precipitation 4–5  
 coccolithophores and marine production 6  
 export to deep ocean 5  
 physical precipitation 4
- Cambrian explosion 5
- Cape Verde Abyssal Plain, foraminifera  
 diversity 101
- carbon cycle (oceanic) 5
- carbon dioxide  
 relation to isotopes in foraminifera 45–46, 53  
 sequestration 5  
 solubility in sea water 79
- carbonate compensation depth (CCD), relation to  
 foraminifera diversity 101
- carbonate ion concentration  
 effect on  $\delta^{13}\text{C}$  in foraminifera 126–129  
 effect on stable isotopes in shells 138, 140
- carbonate pumps 5
- Cassidulina* spp.  
*C. carinata* 108  
*C. neoteretis* 125  
*C. reniforme* 125
- Cd/Ca, foraminifera 22
- cells, effect on biomineralization 36–37
- Chilostomella* spp.  
*C. oolina* 109  
*C. ovoidea* 104, 109, 110
- Cibicides* spp.  
*C. lobatulus* 159  
 Loch Sunart **161–162**, 163, 165, 166, 167  
*C. wuellerstorfi* 157
- Cibicidoides* spp.  
*C. pachyderma* 123, 124  
*C. wuellerstorfi* **41**
- clay, role in foraminifera test preservation 59, 69
- CLIMAP 3, 4
- coccolithophores  
 as biological proxy 6, 7  
 biomineralization 37–38, 42  
 as geochemical proxies 14–16
- corals  
 Ca and Mg ion concentrations **39–41**  
 biomineralization 37  
 as geochemical proxies 17–18  
 skeletogenesis 87–88  
 skeleton composition studies 88–95
- Cyclammina cancellata* 104
- dark/light (day/night) cycles, relation to foraminifera  
 chemistry 51–52
- deep water renewal events (DWRE) 158
- deer bones, biomineralization 42
- diagenesis  
 foraminifera tests 59, 60–62  
 problems of 19–21
- diatoms  
 as geochemical proxies 16
- DIC *see* dissolved inorganic carbon
- dinoflagellates, impact on microenvironment 77
- dissolution, problems of 21
- dissolved inorganic carbon (DIC) and isotopes in  
 foraminifera 48, 137–138, 139
- DNA, studies in foraminifera 25–26
- DWRE *see* deep water renewal events
- Early Eocene Climatic Optimum (EECO) 10  
*see also* Palaeocene/Eocene Thermal Maximum  
 (PETM)
- El Niño (ENSO) 17
- Eocene  
 (early) climatic optimum (EECO) 10  
*see also* Palaeocene/Eocene Thermal Maximum  
 (PETM)
- Epistominella exigua* 108
- Eponides pusillus* 108
- equilibrium constant, for  $\text{CaCO}_3$  precipitation 33
- ESONET 114
- Favia* 88, 93
- fixed biological indicator (FBI) 174  
*see also Semibalanus balanoides*
- Fontbotia wuellerstorfi* 123, 124, 125
- foraminifera  
 Ca and Mg ion concentration **39–41**  
 biomineralization 42–44  
 as used in CLIMAP 3, 4  
 as geochemical proxies  
 Mg/Ca ratio 12–14  
 oxygen isotope record 9–12  
 impact on chemical micro-environment 51–53  
 Mg/Ca ratio 54–55  
 pH record 53–54  
 species  
*Acarinina bullbrooki* 63, 67, 68  
*Acropora* spp. 49–51  
*Alabaminella weddellensis* 108  
*Allogromia laticollaris* 109  
*Ammonia* spp.  
*A. batavus* 158, 166  
*A. beccarii* 109, **161**, 163, 165, 166, 167  
*Arborammina hilaryae* 110  
*Aschemonella ramuliformis* 109  
*Bathysiphon capillare* 108  
*Bolivina* spp.  
*B. pacifica* 104, 108  
*B. spathulata* 108  
*B. spissa* 108  
*Bulimina* spp.  
*B. aculeata* 104  
 stable isotope culture experiment  
 135–151  
*B. exilis* 109

- B. marginata* **162**, 163, 165  
*B. mexicana* 123, 124  
*Cassidulina* spp.  
   *C. carinata* 108  
   *C. neoteretis* 125  
   *C. reniforme* 125  
*Chilostomella* spp.  
   *C. oolina* 109  
   *C. ovoidea* 104, 109, 110  
*Cibicides* spp.  
   *C. lobatulus* 159  
     Loch Sunart **161–162**, 163, 165, 166, 167  
   *C. wuellerstorfi* 157  
*Cibicidoides* spp.  
   *C. pachyderma* 123, 124  
   *C. wuellerstorfi* **41**  
*Cyclamina cancellata* 104  
*Epistominella exigua* 108  
*Eponides pusillus* 108  
*Fontbotia wuellerstorfi* 123, 124, 125  
*Fursenkoina mexicana* 123, 124  
*Gaudryina siphonifera* **41**  
*Globigerina bulloides* 47  
   chemistry **39**  
   controls on growth 78, 79, 80, 81  
*Globigerinatheka index* 63, 66  
*Globigerinoides* spp. 60  
   *G. conglobatus* **39**  
   *G. ruber*  
     chemistry **40**  
     controls on growth 75, 76, 79  
   *G. sacculifer*  
     chemistry **40, 41**, 49–51  
     controls on growth 75, 76, 79  
*Globobulimina* spp.  
   *G. affinis* 104, 123, 124  
   *G. pacifica* 108  
*Globocassidulina subglobosa* 108  
*Globopelorhiza sublittoralis* 110  
*Globoquadrina conglomerata* 20  
*Globorotalia* spp. 60  
   *G. hirsuta* **39**  
   *G. inflata*  
     chemistry **39**  
     controls on growth 79  
   *G. menardii*  
     chemistry **39, 40**  
     controls on growth 78, 79, 80  
   *G. truncatulinoides* 80  
     test composition **40, 76**  
     test size 79  
     test structure 75, 77  
   *G. tumida*, controls on growth 79  
*Globoturbotalita* spp. 63, 65, 68  
*Hantkenina australis* 62  
*Hastigerina pelagica* **40**  
*Lobatula lobatula* 123, 124  
*Neogloboquadrina* spp.  
   *N. dutertrei* **39**  
   *N. pachyderma* 127  
     controls on growth 79, 80  
     DNA studies 25–26  
   *Orbulina universa* 20, 47, 75, 77, 79, 168  
     boron chemistry 49–51  
     Mg/Ca ratio **41** 74, 78  
   *Planulina wuellerstorfi* 157  
   *Porites cylindrica*, boron chemistry 49–51  
   *Pulleniatina obliquiloculata* 41  
   *Pyrgo* 157  
   *Quinqueloculina seminulum* 158, 159  
   *Rosalina vilardeboana*  
     stable isotope culture experiment 135–144  
   *Rhizammina algaeformis* 109  
   *Saccorhiza ramosa* 110  
   *Sphaeroidinella dehiscens* **41**  
   *Subbotina linaperta* 63, 64, 68  
   *Syringammina* spp.  
     *S. fragilis* 110  
     *S. corbicula* 109  
   *Texularia kattegatensis* 104, 108, 110  
   *Thurammina albicans* 108  
   *Uvigerina* ssp. **41**  
     *U. akitaensis* 104, 108, 126  
     *U. mediterranea* 126  
     *U. peregrina* 108, 157, 168  
        $\delta^{13}\text{C}$  124, 126  
     see also benthic foraminifera also planktonic foraminifera  
   Forth, Firth of see *Semibalanus balanoides* experiment  
   *Fursenkoina mexicana* 123, 124  
  
   gametogenic calcite, in foraminifera 75, 76, 78  
   gas chromatography-mass spectroscopy (GCMS) 25  
   gas hydrates,  $\delta^{13}\text{C}$  in foraminifera 124–126  
   *Gaudryina siphonifera* **41**  
   Ge/Si ratio, diatoms 16  
   genetics  
     biomineralization 44  
     use in foraminifera research 114  
   geochemical proxies  
     coccolithophores 15–16  
     corals 17–18  
     diatoms 16–17  
     foraminifera 9–15  
     molluscs 19  
     problems of measurement  
       calibration 21  
       contaminants 19  
       element abundance 22  
       isotope analysis 22–25  
       organic matter 25  
       preservation 19–21  
   germanium (Ge) in diatoms 16–17  
   glacial-interglacial cycles, effect on foraminifera size 79–81  
   *Globigerina bulloides* 47  
     chemistry **39**  
     controls on growth 78, 79, 80, 81  
   *Globigerinatheka index* 63, 66  
   *Globigerinoides* spp. 60  
     *G. conglobatus* **39**  
     *G. ruber*  
       chemistry **40**  
       controls on growth 75, 76, 79  
   *G. sacculifer*  
     chemistry **40, 41**, 49–51  
     controls on growth 75, 76, 79

- Globobulimina* spp.  
*G. affinis* 104, 123, 124  
*G. pacifica* 108  
*Globobulimina affinis* 104, 123, 124  
*Globocassidulina subglobosa* 108  
*Globopelorhiza sublittoralis* 110  
*Globoquadrina conglomerata* 20  
*Globorotalia* spp. 60  
*G. hirsuta* **39**  
*G. inflata*  
 chemistry **39**  
 controls on growth 79  
*G. menardii*  
 chemistry **39, 40**  
 controls on growth 78, 79, 80  
*G. truncatulinoidea* 80  
 test composition **40, 41, 76**  
 test size 79  
 test structure 75, 77  
*G. tumida*, controls on growth 79  
*Globoturbotalita* spp. 63, 65, 68  
*Goniastrea*, skeletal composition 88–90  
 greenhouse climate, early Eocene 10
- Håkon Mosby Mud Volcano 125  
 Hampden Beach, New Zealand 59  
 foraminifera test texture study 63, 64, 65,  
 66, 67, 69  
*Hantkenina australis* 62  
*Hastigerina pelagica* **40**  
 heterococcoliths 6  
 Hexacoralla *see* corals  
 holococcoliths 6  
 hydrocorals 9
- icehouse climate, first Antarctic ice 10  
 Indian Ocean, foraminifera diversity **103**  
 inductively coupled plasma-mass spectrometry  
 (ICP-MS) 22  
 intertidal organisms as sea-level indicators  
*see Semibalanus balanoides*  
 isotope analysis  
 methods 22–25  
 precision 24  
 isotope dilution thermal ionization mass spectrometry  
 (ID-TIMS) 22
- Kerguelen Plateau 59, 69  
 foraminifera test texture study 63, 64, 65,  
 66, 67, 68  
 Kolmogorov scale 51  
 Komokiacea 99, 100
- Labrador Sea ODP site 59  
 foraminifera test texture study 62, 68, 69  
 laser ablation (LA) ICP-MS 22  
 Last Glacial Maximum (LGM), sea surface  
 temperature 3, 4  
 Late Palaeocene Thermal Maximum (LPTM) 11–12  
 light/dark cycles, relation to foraminifera chemistry  
 51–52  
 lithium, isotope ratio 24  
*Lobatula lobatula* 123, 124  
 lunar cycle, effect on foraminifera growth 78
- Madeira Abyssal Plain, foraminifera diversity 99  
 magnesium (Mg)  
 biological controls on 36, 37, 38  
 in corals and foraminifera 37, **39, 40, 41**, 42–44  
 in fixed biological indicator species 174  
 in foraminifera 46  
 in seawater 35, 36  
 effect on CaCO<sub>3</sub> precipitation 33–34  
 Mg/Ca ratio *see* Mg/Ca ratio  
 manganese (Mn)  
 in fixed biological indicator species 174  
 oxide coatings 19  
 Mn/Ca ratio in foraminifera 20  
 Maud Rise 59, 69  
 foraminifera test texture study 62–63, 64, 66, 68  
 May, Isle of 174–175  
*see also Semibalanus balanoides* experiment  
 MC-ICP-MS 25  
*Merulina* 88, 90  
 metal binding capacity, foraminifera 6  
 methane, effect on δ<sup>13</sup>C in foraminifera 121, 124–126  
 methane release 12  
 Mg/Ca ratio  
 in corals 85  
 in foraminifera 20, 46, 54–55, 74, 76, 78  
 intralab precision of measurement 22  
 thermometry  
 corals 17  
 foraminifera 12–15, 20  
 molluscs 19  
 micropalaeontology 5  
 Milankovitch cycles 10  
 Mn/Ca ratio in foraminifera 20  
 modelling  
 boron in foraminifera  
 biological controls 49–51  
 chemistry 48  
 fractionation 46–48  
 isotopes 48–49  
 molluscs  
 as geochemical proxies 19
- δ<sup>15</sup>N  
 coral 93  
 diatoms 16–17  
 nanoSIMS 25  
 neodymium (Nd) isotopes, in coral 18  
*Neogloboquadrina* spp.  
*N. dutertrei* **39**  
*N. pachyderma* 127  
 controls on growth 79, 80  
 DNA studies 25–26  
 neomorphism *see* recrystallization  
 New Zealand, Hampden Beach 59  
 foraminifera test texture study 63, 64, 65, 66, 67, 68  
 night/day cycles, relation to foraminifer  
 a chemistry 51–52  
*Nonionella turgida* **162, 163, 165**  
 North Atlantic Deep Water (NADW) 18  
 nucleation, CaCO<sub>3</sub> precipitation 34  
 δ<sup>18</sup>O  
 of cultured foraminifera 135–136  
 O and C isotope correlation 142–143  
 ontogenetic trends 143–144

- in corals 88–169
- factors affecting
  - in corals 17
  - in diatoms 16–17
  - in foraminifera 9–12, 45
  - in molluscs 19
- first measured 9
- in *S. balanoides* 174–181
- Ocean Drilling Program (ODP) sites *see* Kerguelen Plateau; Labrador Sea; Maud Rise
- ontogeny, effect on  $\delta^{13}\text{C}$  in foraminifera 126
- optical emission spectrometry (OES) 22
- Orbulina universa* 20, 47, 75, 77, 79, 168
  - boron chemistry 49–51
  - Mg/Ca ratio 41, 74, 78
- organic matter
  - effect on  $\delta^{13}\text{C}$  in foraminifera 124
  - export to deep ocean 5
- Pachythecalia* 92, 93, 94, 95
- Pacific Ocean, foraminifera diversity 103, 106
- Palaeocene, (Late) thermal maximum (LPTM) 10–11
- Palaeocene/Eocene Thermal Maximum (PETM) 121
  - see also* Eocene, (early) climatic optimum (EECO)
- palyнологy 5
- pH
  - effect on stable isotopes in shells 138, 140, 180
  - record in foraminifera 46, 53–54
- phylogeny, foraminifera 112–113
- planktonic foraminifera
  - calcification and growth 74
  - pH record compared with benthic 53–54
  - test arrangement 59–60
  - test diagenesis 59
    - dissolution 60
    - overgrowth 60–61
    - recrystallization 61
  - test preservation 61
  - test size and composition 73–74
  - test textural study 62–70
  - test trace elements 74–77
    - effect of environment 78–79
    - effect of glacial-interglacial cycle 79–81
    - effect on growth rate 77–78
    - effect of test size 78
    - photosynthesis 48
- Planulina wuellerstorfi* 157
- Pocillopora* sp., chemistry 39
- Porcupine Abyssal Plain, foraminifera diversity 99
- Porcupine Seabight, foraminifera diversity 101
- Porites cylindrica*, boron chemistry 49–51
- pressure, effect on  $\text{CaCO}_3$  precipitation 33
- primary organic membrane (POM) 60, 74
- protists, role in biomineralization 4–5
- proxies, defined 1
- proxy methods 3
- proxy records
  - biological
    - coccolithophores 6, 7
    - corals 8–9
    - diatoms 6, 8
    - foraminifera 5–6
    - molluscs 9
  - geochemical
    - methods of measurement 19–25
    - useful species
      - coccolithophores 15–16
      - corals 17–18
      - diatoms 16–17
      - foraminifera 9–15
      - molluscs 19
  - proxy variables 1, 3
  - Pulleniatina obliquiloculata* 41
  - Pyrgo* 157
  - Quinqueloculina seminulum* 158, 159
  - reductive cleaning methods 19
  - respiration 48
  - Retiophyllia* 92
  - Rhizammina algaeformis* 109
  - Rosalina vilardeboana*
    - stable isotope culture experiment 135–144
  - Saccorhiza ramosa* 110
  - Sagami Bay (Japan), foraminifera diversity 104, 106
  - salinity, relation to stable isotopes in foraminifera 137, 138, 155–156
  - satellite telemetry, use in foraminifera studies 114
  - Scleractinia *see* corals
  - sclerochronology 5
  - Scotland *see Semibalanus balanoides* experiment; Sunart, Loch
  - sea surface temperature *see* temperature
  - sea-level change
    - Holocene 173
    - use of fixed biological indicator 174
    - use of *S. balanoides* as indicator 175–181
  - seasonality
    - foraminifera in Scottish fjord 155–157
    - fjord hydrography 158–159
  - seawater chemistry 34–35, 48, 53
  - secondary ion mass spectrometry (SIMS) 22, 25
  - Semibalanus balanoides*
    - ecology 174
    - experiments on isotope composition 175–181
  - $\delta^{30}\text{Si}$  in diatoms 16–17
  - silica
    - in diatoms 8
    - physical precipitation 4
  - silicate weathering 5
  - skeletal evolution, Cambrian explosion 5
  - soft corals 9
  - Sphaeroidinella dehiscens* 41
  - stable isotopes *see* boron;  $\delta^{13}\text{C}$ ;  $\delta^{44}\text{Ca}$ ;  $\delta^{15}\text{N}$ ;  $\delta^{18}\text{O}$ ;  $\delta^{30}\text{Si}$
  - stony corals 8
  - stromatolites 4
  - strontium (Sr)
    - in fixed biological indicator species 174
    - in foraminifera 74, 76, 78, 79–80
  - Sr/Ca ratio
    - coccolithophores 15–16
    - corals 17–18, 95
    - foraminifera 20
    - interlab precision of measurement 22
    - molluscs 19

- Subbotina linaperta* 63, 64, 68
- Sunart, Loch  
 hydrography 158–159  
 $\delta^{18}\text{O}$  in foraminifera experiment 159–169
- Syringammina* spp.  
*S. corbicula* 109  
*S. fragilis* 110
- temperature  
 effect on  $\text{CaCO}_3$  precipitation 33, 36  
 effect on foraminifera growth 79, 80  
 Last Glacial Maximum 3, 4  
 relation to  $\delta^{18}\text{O}$  in foraminifera 156–157  
 shelf seas of NW Europe 158
- Texularia kattegatensis* 104, 110
- Thurammina albicans* 108
- trace elements  
 in fixed biological indicator species 174  
 in foraminifera 73, 74–77  
 effect of environment 78–79
- effect of glacial-interglacial cycle 79–81  
 effect on growth rate 77–78  
 effect of test size 78  
 role in foraminifera test  
 neomorphism 61
- Triassic, coral composition 88, 90–91
- U/Ca ratio, in corals 17, 18
- $\text{U}_K^{37}$  (alkenone unsaturation index) 15
- Uvigerina* ssp. **41**  
*U. akitaensis* 104, 108, 126  
*U. mediterranea* 126  
*U. peregrina* 108, 157, 168  
 $\delta^{13}\text{C}$  124, 126
- Weddell Sea, foraminifera diversity **103**, 105
- X-ray absorption spectroscopy (XAS) 25
- zinc (Zn) in diatoms 16