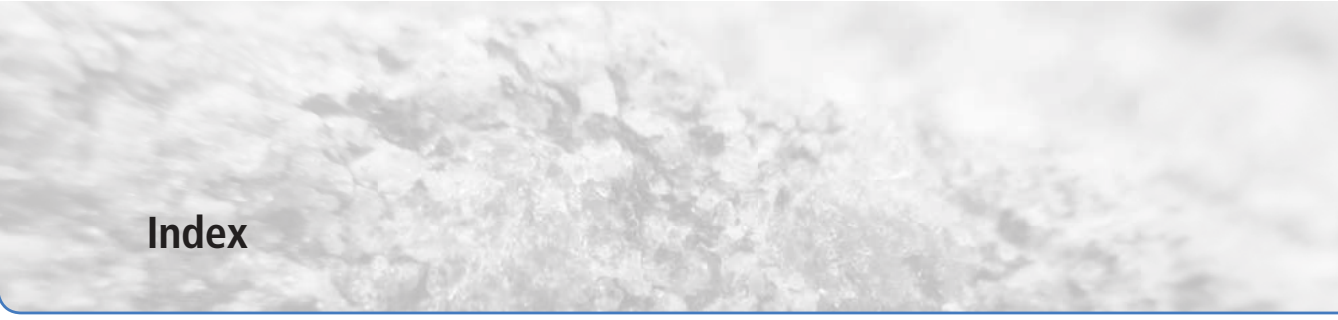




Index

Page numbers in italics indicate figures.

- accessory minerals, 12, 39, 104, 146, 251, 253–4
 - dating, 260
 - P–T* conditions of formation, 251
- accuracy and precision, 242
- actinolite, 136, 138, 145
- activity, 77–8
 - linking experimental to natural systems, 78
 - relation to composition, 78, 79
- advection, 206, *See also* fluid flow
- albite, 76, 83, 106, 117, 139, 141, 145, 158
 - breakdown, 76
- alkali feldspar, 73, 83
- Al-silicate polymorphs, 11, 40, 40, 59, 66, 109–10, 216
- Al-silicate triple point, 41
- Alta aureole, Utah, USA, 182–4
- amphibole, 137–8
 - Ca-rich, 124
 - composition, 136
 - immiscibility, 146
 - miscibility gaps, 136
 - structure, 137
 - textures, 197
 - zoned, 210
- amphibolite, 31, 31, 144
- amphibolite facies, 70, 145–7, 283
- anatexis. *See* partial melting
- andalusite, 117, 281
 - andalusite–cordierite–biotite zone, 118
 - AFM projection, 119
 - andalusite–cordierite–chlorite zone, 117
 - nucleation, 210, 236
 - vein, 237
- anthophyllite, 47, 50, 73
- antigorite, 47–8, 73
- apatite, 257, 262
- aragonite, 152, 167
- Archean metamorphism, 289
- augen gneiss. *See* gneiss
- Barrow, George, 3
- basic igneous rocks. *See* metabasic rocks
- Beinn-an-Dubhaich aureole, Scotland, 171–2
- Bergell aureole, Italy, 49, 50–1, 72
 - petrogenetic grid, 73
- biotite, 95, 99, 118, 145, 210, 236
 - biotite zone, 102
 - AFM projection, 102
 - structure, 99
- blueschist, 31, 31, 144, 150, 151, 233, 291
- blueschist facies, 71, 150–3, 277, 279
 - precursor assemblages, 150
- boiling, 156
- boiling curve, 20, 43, 243
- brucite, 73
- buffering, 56–8, 178–80, *See also* mixed-volatile fluids
 - external, 183
 - internal, 180–2
 - oxygen fugacity, 57
 - silica concentration, 56
 - water fugacity, 235
- Bugaboo aureole, Canada, 10–11, 117–20, 282
 - thermal evolution, 263
- bulk composition. *See* rock composition
- burial metamorphism, 22, 139, 141
- burial rate, 249
- calcite, 142, 167, 181
 - stability, 170
- calc-silicate rocks, 165
 - chemical changes, 189
 - zonal scheme, 187
 - zoned, 166
- carbonation–dehydration reactions, 178
- carpholite, 122
 - carpholite zone, 122
- cataclastic metamorphism. *See* dynamic metamorphism
- cathodoluminescence (CL), 190, 254
- cation exchange, 54
- cation-exchange reactions, 44–5, 75, 79, *See also* geobarometry and geothermometry
 - garnet–biotite, 46
- chemical equilibrium, 34–6, 39, 46–50, 214
 - application, 3
 - defined, 66, 68
 - deviations from, 196
 - limitations, 58–60
 - volume of equilibration, 87
- chemical potential, 65, 306
- gradient, 204, 206
- chert nodules, 171
 - reaction with dolomitic limestone, 172
- chloride salts, 53, 55
- chlorite, 93, 100, 108, 121–2, 141, 145, 158
 - chlorite zone, 101
 - chlorite–pyrophyllite zone, 122
 - structure, 100
- chloritoid, 106, 108, 123, 214
 - chloritoid zone, 123
- clay minerals, 93, 121, 141, 156
- cleavage. *See* deformation fabrics
- clinopyroxene, 148, *See also* diopside, jadeite, omphacite

- closure temperature, 256
 for helium loss, 256
 garnet, 257
 mica, 256
 rutile, 257
 CO₂, 55
 coesite, 23, 154, 215, 260, 285
 inclusion in garnet, 154
 compatible assemblages, 41
 component, 36–7, 39, 41, 47, 65
 inert, 306
 minor elements, 39
 oxide, 38
 perfectly mobile, 306
 concentration gradient, 209
 conditions of metamorphism.
 See geobarometry and geothermometry
 conduction, 243
 Connemara, Ireland, 112, 192, 234, 234, 282
 contact aureole. See metamorphic aureole
 contact metamorphism, 2, 11, 243–4, 282
 timescale, 247, 263–4
 continental collision. See tectonic settings
 continuous reaction, 76–9, 108, 123, 146
 controls on metamorphism, 13–21
 convection, 243
 coordination
 octahedral, 98
 tetrahedral, 98
 cordierite, 116–17, 281
 cordierite–garnet–K-feldspar zone, 115
 cordierite–anthophyllite rocks, 159
 corona texture, 149
 critical point, 20
 critical pressure, 20
 critical temperature, 21

 Danba dome, China, 265
 decarbonation reactions, 167, 169, 176
 transient porosity, 190
 decompression. See exhumation
 deformation
 brittle, 225, 238
 ductile, 225, 229

 enhanced metamorphic reactions, 236
 intercrystalline, 225
 intracrystalline, 225
 superplastic flow, 239
 timing relative to metamorphic peak, 234
 deformation and metamorphism
 feedbacks, 234–9
 relative timing, 231–4
 deformation fabrics, 21, 227
 cleavage, 25, 227
 crenulation, 228
 crystallographic-preferred orientation, 225
 gneissic layering, 26
 lattice-preferred orientations, 227–8
 lineation, 198
 mineral alignment, 227
 mylonitic, 29, 229
 P, Q domains, 228
 penetrative, 227
 planar, 25
 preferred orientations, 227–8
 preserved as inclusion trails, 231
 pressure shadow, 232
 rotation, 227
 schistosity, 26, 228
 internal, 231
 segregation layering, 228–9
 deformation mechanisms, 225–7
 dislocation creep, 225, 226, 228
 dissolution–precipitation creep, 225
 polyminerale rocks, 226
 grain-boundary sliding, 226, 238
 pressure solution, 225, 226, 228, 233
 deformation textures, 196, 227–30
 mortar texture, 229, 230
 pressure shadow, 233
 ribbon texture, 230
 degrees of freedom, 37, 39–40, 47, 56, 104
 independent, 40
 dehydration melting, 148
 dehydration metamorphism, 141

 dehydration reactions, 53, 169, 177, 226
 dehydration–decarbonation reactions, 177, 180
 density
 Al-silicates, 11, 66
 crust, 16
 water, 21
 deviatoric stress. See stress
 devolatilisation reactions, 53, 69, 75
 diagenesis, 93
 diamond, 154, 215
 microdiamonds, 154
 diffusion, 253. See transport
 diopside, 47, 73, 172, 175, 192
 discontinuous reactions, 43, 107, 110
 in marbles, 180
 disequilibrium textures, 211–15
 dislocations, 200, 201. See also real crystals
 distribution coefficient, 46, 61, 79, 103, 213
 divariant assemblage, 50
 divariant field, 40–1, 299
 dynamic metamorphism, 23

 eclogite, 31, 31, 144, 153, 239
 lawsonite-bearing, 153
 eclogite facies, 71, 153–5, 277, 279, 287, 290
 pressures of formation, 154
 effective pressure. See pressure
 element substitution, 13
 endothermic reaction, 68, 220, 244
 enstatite, 47
 enthalpy, 68, 247
 entropy, 67, 75
 epidote, 145, 158–9, 237
 epidote amphibolite facies, 69
 equation
 equilibrium, 44
 reaction, 44
 equilibrium. See chemical equilibrium
 equilibrium curve, 68
 erosion, 249, 250
 rates, 249
 Eskola, Pentti, 3, 69

- European Alps, 120, *See also*
 Bergell aureole
 Alpine orogen, 286–7
 Central, 265
 Western, 120–4, 281, 286
 exhumation, 12, 250, 285,
 288–9
 balance of forces, 288
 isothermal, 278
 mechanisms, 288
 P–T–t paths, 268
 rates, 259, 267, 288
 timing, 256
 two-stage, 288
 exothermic reaction, 68
 extensive property, 65
- facies series, 70, 277–8, 283
 feldspar, 76, 253, *See also*
 alkali feldspar,
 K-feldspar, plagioclase
 ferromagnesian minerals, 44–5
 fluid. *See* metamorphic fluids
 fluid flow, 53, 156, 159, 208,
 307
 in carbonate rocks, 190
 fluid flux, 190
 fluid inclusions, 3, 19, 54–5
 fluid pressure. *See* pressure
 fluid-absent reactions, 178, 216
 Focussed Ion Beam (FIB), 205
 foliation. *See* deformation
 fabrics
 formula weight, 65
 forsterite, 47–8, 50, 172, 175,
 219
 fractionation, 45, 104, *See also*
 distribution coefficient
 fugacity, 57
 oxygen, 57
- garnet, 8, 77, 111, 123, 148,
 192, 232, 253, 255, 262
 acting as a pressure vessel,
 154
 appearance in metabasic
 rocks, 145
 dating, 258–9
 garnet zone, 103
 photomicrographs, 104
 garnet–kyanite zone, 123
 garnet–talc zone, 123
 Lu concentrations, 261
 volume diffusion, 214
- zonation, 209, 212, 213
 dating, 258
 Rayleigh Fractionation, 213
 garnet–kyanite schist, 109
 geobarometers. *See*
 geobarometry and
 geothermometry
 geobarometry and
 geothermometry, 71–88
 alkali feldspars, 83
 applied to disequilibrium
 textures, 215
 applied to metabasic rocks,
 159–62
 applied to metapelites, 127–9
 calcite–dolomite, 83
 calcite–dolomite
 geothermometer, 186
 carbonate rocks, 186
 cation-exchange
 thermometers, 79–81
 garnet–biotite, 80
 garnet–hornblende, 161
 chlorite crystallinity, 88
 chlorite geothermometer, 84,
 161
 computational methods, 86
 multiple equilibria, 84–5, 86
 predicting assemblages,
 85–7, 86
 software. *See* software
 packages
 directly-calibrated
 thermobarometers, 76
 garnet–orthopyroxene, 83,
 162
 hornblende–plagioclase, 161
 illite crystallinity, 88, 88
 isochemical phase diagram,
 146
 jadeite geobarometers, 161
 linked to deformation fabrics,
 233
 markedly continuous
 reactions, 76–9
 mutual solid solution
 geothermometers, 82–3
 oxygen isotope
 geothermometer, 81–2,
 160, 186
 principles, 75
 Raman spectroscopy of
 carbonaceous material,
 89
- skarns and calc-silicate rocks,
 193
 trace-element
 geothermometers, 84
 two-pyroxene, 83, 162
 when meaningless, 72
 geochronology. *See* radiometric
 dating
 geochronometers, 241, 251,
 254–5, *See also*
 radiometric dating
 as inclusions, 260
 containing inclusions, 260
 trace element partitioning
 with index minerals,
 261–3
 geotherm, 14, 281
 apparent. *See* metamorphic
 field gradient
 transient, 265
 geothermal fields. *See*
 geothermal systems
 geothermal gradient, 14, 157,
 248, 274
 geothermal systems, 6, 23, 84,
 133, 139, 156–7, 215,
 243, 281
 geothermometers. *See*
 geobarometry and
 geothermometry
 Gibbs free energy, 65–6, 68, 75
 bulk, 202
 effect of pressure, 66
 effect of temperature, 67
 net free-energy change, 202,
 203
 real crystals, 199
 surface contribution, 200,
 236
 surface energy, 202
 variation with *P* and *T*, 67
 glaucophane, 136, 138, 150,
 152
 substitution of Fe for Al, 152
 gneiss, 26, 27
 augen gneiss, 28
 orthogneiss, 28
 paragneiss, 28
 Goldschmidt, Victor, 3, 36
 grain boundary, 201, 205–6
 fluid, 205
 low-angle, 201
 porosity, 206
 SEM imaging, 205

- transport, 205
- water saturation, 205
- grain-boundary network, 59
- grain growth, 204
 - anisotropic, 211
 - rate, 204
 - textures, 211
- grain size, 199, 207, 229
 - nucleation and growth rates, 204
- granoblastic texture, 197
- granulite, 27, 28, 144
 - high-pressure, 150
 - low-pressure, 149
 - moderate-pressure, 134
- granulite facies, 70, 148–9, 283
 - direct transformation from an igneous assemblage, 149
 - transition from amphibolite facies, 148
- greenschist, 31, 31
- greenschist facies, 70, 144, 144–5, 157, 279, 287
 - upper limit, 139
- greywacke, 139
- H₂O, 47–8, 50
- heat flow, 13–14, 243, 275, 276
- heat of reaction. *See* enthalpy
- heat sources, 22, 244, 247
 - frictional heating, 244
 - magmas, 244
 - mantle, 244
 - radioactive decay, 244
- heating rate, 241, 244–9
 - overthrust continental crust, 248
 - vicinity of a sheet-like intrusion, 245
- helium, 256
- high-grade basement terranes, 236
- high-pressure granulite, 291
- high-pressure-high-temperature rocks, 124
- high-pressure metamorphism, 22, 120–5
 - AFM projection, 122
 - dating, 266–9
 - fault-bounded blocks, 155
 - field relations, 155
 - metamorphic history, 277–80
- high-temperature metamorphism, 111–16
 - dating, 267–9
- Himalayan orogen, 284–6
 - cross-section, 285
- hornblende, 136, 138, 145–6, 148
 - blue-green, 145
- hornfels, 22, 28, 118
- Hutton, James, 2
- hydration reactions, 132, 238
- hydration–decarbonation reactions, 178
- hydraulic fracturing, 20, 53
- hydrostatic pressure. *See* pressure
- hydrothermal metamorphism, 23, 133, 139, 144, 243, 306
- ice cream, 17
- Ile de Groix, France, 31, 150, 153, 280
- illite, 88, 121
 - illite–chlorite zone, 121
- immiscibility, 78
- impact metamorphism. *See* shock metamorphism
- inclusions, 10, 59, 60, 108, 154, 198, 260
- incongruent melting, 114
 - peritectic phase, 114
- index minerals, 8–9, 283
 - dating, 258–9
- intensive property, 65
- invariant point, 41, 299
- inverted metamorphic sequence, 286
- isobaric invariant point, 181
- isobaric univariant curve, 170
- isochemical metamorphism, 12
- isochemical phase diagram. *See* phase diagram
- isochore, 20
- isograd, 9, 47, 103, 107, 181
 - mineral appearance, 9, 171, 173
 - mineral assemblage, 9
- isotherm, 15
- isotopes, 251
 - daughter, 251, 254
 - loss, 256
 - parent, 251
 - potassium, 251
 - uranium, 251
- jadeite, 76, 152
- kaolinite, 121
- K_D. *See* distribution coefficient
- K-feldspar, 83, 111
 - adularia, 141
- Korzhinskii, D. S., 306
- Kübler Index, 88
- kyanite, 77, 123
 - breakdown, 216–17
 - kyanite zone, 108, 285
 - AFM projection, 109
- lawsonite, 124, 142, 150, 152–3
 - pseudomorphs, 151
- Le Chatelier's Principle, 53
- leucosome. *See* migmatite
- lithostatic pressure. *See* pressure
- low-grade metamorphism, 88, 139, 279
 - sporadic absence, 142
- low-pressure metamorphism, 117–20, 281–3
 - AFM projection, 118
- magmatic arc. *See* tectonic settings
- major elements, 12
- mantle wedge, 280
- marble, 29, 99
 - calcite, 166, 167–8
 - dolomite, 171–6
 - ophicalcite, 184
 - tremolite, 166
- marbles
 - dolomite
 - reactions, 172–6
- mélange, 155, 279
- melanosome. *See* migmatite
- metabasic rocks, 69
 - amphibolite, 145
 - breakdown of primary assemblages, 133–4
 - fabric, 233
 - high-pressure metamorphism, 150–3
 - isochemical phase diagram, 147
 - low-grade metamorphism, 139–44
 - low- to moderate-pressure metamorphism, 144–9
 - partial metamorphism, 134
 - petrogenetic grid, 160

- metagreywacke, 124, 140
 metamorphic aureole, 10, 22, 47, 171, 243, 245, 246,
See also named examples in Contents
 metamorphic belt, 70
 metamorphic core complex, 276
 metamorphic cycle, 2, 241, 249, 251
 duration, 241, 257, 264
 stages, 257
 metamorphic fabrics. *See* deformation fabrics
 metamorphic facies, 68–71, 135–9
 characteristic mineral associations, 136
 defining mineralogical changes, 135–9
 high-*P*, 71
 low- to moderate-*P*, 70
 low-*T*, 71
 P–*T* diagram, 70
 scheme, 69
 metamorphic field gradient, 265
 central Alps, 266
 metamorphic fluids, 18–21, 47, 52–5, 156, 216, 236, *See also* mixed-volatile fluids, buffering
 and deformation, 53, 225
 composition, 53, 56, 168, 176–84
 grain-edge fluid, 206
 infiltration, 155, 168, 173, 178, 180, 182, 190
 oxygen isotopes, 155
 significance for diffusion, 207
 source for wet melting, 112, 120
 metamorphic grade, 8
 textures, 211
 metamorphic history, 257–8
 metamorphic map
 Alta aureole, Utah, USA, 183
 Bergell aureole, Italy, 48
 Bugaboo aureole, Canada, 10
 Central European Alps, 173
 SE Highlands, Scotland, 7
 South Island, New Zealand, 140
 Vassalboro Formation, Maine, USA, 188
 Western European Alps, 121
 metamorphic reactions, 11, 36, 39, 66
 deduced from phase diagrams, 42, 49–50, 52, 95, 172
 degenerate, 300
 energy change, 202, 203
 enhanced by deformation, 236–8
 incomplete, 216, 219
 ionic reaction, 216
 overstepped, 202, 202, 210, 221
 effect on rates, 221
 retrograde, 235
 siliceous dolomites, 181
 terminal, 49
 thermodynamic principles, 65–8
 tie-line flip, 50, 52, 108, 127
 volume change, 190
 metamorphic rocks, 1
 metamorphic terranes, 277, 284
 metamorphic textures, 260, *See also* deformation textures, reaction textures
 acicular, 197, 211
 anhedral, 197
 corona textures, 219
 corroded, 211
 euhedral, 197, 204
 granoblastic polygonal, 206
 growth and dissolution, 210–11
 growth rate, 204, 210
 idioblastic, 197
 influence of nucleation, 209–10
 overgrowth, 209
 reaction rims, 219, 220
 retrograde metamorphism, 219
 sub-grains, 201
 subhedral, 197
 symplectite, 219
 metamorphic zones, 7, 9–10, 47, 50, 72
 burial metamorphism, 142
 geothermal system, 142
 metamorphism and
 deformation, 224
 deformation as a cause of metamorphism, 224
 metamorphism as a driver for deformation, 224
 pressure solution, 226
 metamorphism through Earth history, 289–91
 metapelitic rocks, 6, 10, 38
 assemblages of the SE Scottish Highlands, 97
 defined, 93
 effect of pressure on metamorphic zoning, 125–7
 moderate *P* and *T*, 96
 petrogenetic grid, 128
 P–*T* diagram, 126
 metasomatic rocks, 12, 307
 metasomatism, 12, 140–1, 156, 158, 165, 208, 236
 mica, 253–5, *See also* biotite, muscovite, paragonite, phengite, phyllosilicate
 microthermometry, 56
 micro-X-ray tomography, 219
 mid-ocean ridge. *See* tectonic settings
 migmatite, 12, 27, 113, 261
 leucosome, 28, 113
 melanosome, 28
 restite, 28
 migmatite zone, 120
 mineral assemblages, 3, 196
 diagnostic of facies, 69
 non-equilibrium, 215
 stable, 35, 66
 mineral dissolution, 211
 minor elements, 12, 39
 miscibility gap, 78
 mixed-volatile fluids, 168
 buffering, 179
 externally-buffered, 176
 internally-buffered, 176
 miscibility, 169, 193
 mixed-volatile reactions, 177
 Miyashiro, Akiho, 3
 moderate-pressure metamorphism, 277, 283–4
 molar volume, 65–6, 75

- mole, 65
- mole fraction, 45
- molecular proportions, 49
- monazite, 107, 251, 253, 255, 264, 268
 - growth with garnet, 262
- Morey–Schreinemakers rule, 301
- muscovite, 73, 88, 95, 99
 - breakdown, 73, 111, 114
 - intergrown with sillimanite, 217
 - structure, 100
- mylonite, 23, 29, 205, 230
 - protomylonite, 229
- naming metamorphic rocks, 24–32
- nucleation, 202–4, 236
 - controlling factors, 204
 - critical radius, 202
 - effect of overstepping, 220
 - epitaxial, 203
 - garnet, 218
 - heterogeneous, 202, 217
 - on fractures, 236
 - rate, 204
 - stable nucleus, 202, 203
- oceanic crust, 274
 - subducted, 287
 - subduction, 279
- oligoclase, 139, 145
- olivine, 47
- omphacite, 17, 77, 153, 162
- orogen
 - accretionary, 276
 - continental collision, 276
 - magmatic, 276
 - non-magmatic, 277
- orogenesis, 276
- orogenic belts, 276–7, 284
- orthogneiss. *See* gneiss
- orthopyroxene, 116, 148
- overprinted assemblages, 277, 283, *See also* retrograde metamorphism
- overprinting
 - Alpine, 286
- paired metamorphic belts, 3
- paragenesis. *See* mineral assemblages
- paragneiss. *See* gneiss
- paragonite, 73, 100, 117, 124
 - breakdown, 73
- partial melting, 12, 111–14, 148
 - dehydration melting, 113
 - impact on rock strength, 239
 - wet melting, 112
- partitioning. *See* fractionation
- pelitic schist. *See* metapelitic rocks
- peritectic reactions. *See* incongruent melting
- permeability, 133, 208
- petrogenetic grid, 72–4, 85
 - amphibolite–granulite transition, 149
 - melting of metapelites, 114
 - metabasic rocks, 151
 - metapelites, 127–8
 - mica–feldspar equilibrium, 74
 - siliceous dolomitic marble, 185
- phase, 35, 37, 41, 47, 66
 - effect of impurities on stability, 76, 78, 152
- phase diagram, 39, 299
 - AFM diagram, 110
 - limitations, 110
 - AKFM tetrahedron, 94
 - AKFM tetrahedron and projection, 95
 - compositional, 41, 47, 50, 171
 - construction from first principles, 299–305
 - isobaric T – X_{CO_2} diagrams, 170
 - isochemical phase diagram, 87
 - limitations, 42
 - multisystems, 300
 - projection, 50–2
 - AFM projection, 94–6, 103, 105
 - plotting coordinates for an AFM diagram, 96
 - P – T diagram, 40, 72, 84
 - calcite stability, 168
 - T – X_{CO_2} diagram, 181, 185
- phase rule, 36–7, 56, 59, 68
 - application to natural rocks, 38–9
 - applied to dolomitic marbles, 175
- applied to mixed-volatile fluids, 169
- Korzhinskii, for open systems, 306–7
- phengite, 124, 237
- phengite substitution, 102
- phyllite, 25, 118, 121, 232
- phyllosilicate, 25, 88, 122
 - dioctahedral, 98
 - structure, 98
 - substitutions, 98–101
 - trioctahedral, 98
- pillow lavas, 5, 145
- plagioclase, 77, 79, 106, 145, 148, 214
 - absence in eclogite, 153
 - breakdown at high-pressure, 139
 - gap, 106, 145
 - melting, 115
 - oligoclase, 106
- poikiloblast, 8, 198, *See also* porphyroblast
- origins, 205
- porosity, 19, 179, 190, 197–8, 208
- porphyroblast, 8, 8, 197
 - depleted halo, 207
 - extended growth, 233
 - helicitic texture, 231
 - inclusion trails, 231
 - internal schistosity, 231
 - post-tectonic, 231, 232
 - pre-tectonic, 232
 - snowball texture, 232
 - syn-tectonic, 233
- porphyroclast, 230
- precision. *See* accuracy and precision
- preferred orientation, 25
- prehnite, 141
- prehnite–pumpellyite facies, 71, 141–2, 279
 - transition to blueschist facies, 142
- pressure, 16
 - and deformation, 17
 - effective, 19
 - fluid, 19, 53, 167, 208, 235
 - hydrostatic, 19, 208
 - lithostatic, 16, 19, 53, 249
 - on solids, 169
 - partial fluid, 169
 - relationship to depth, 16, 18

- pressure (cont.)
 relative, 69
 units, 14
 pressure solution, 53
 prograde metamorphism, 11, 53, 234
 relation to deformation, 234
 tectonic settings, 274
 progressive metamorphism, 9
 protolith, 3–4, 24, 197
 pseudomorph, 17, 59, 141, 150
 pseudosection. *See* isochemical phase diagram
 pseudotachylite, 23, 29
P–T conditions of metamorphism. *See* geobarometry and geothermometry
P–T history, 214–15, 257
P–T path, 265
 anti-clockwise, 282
 clockwise, 278, 283
 rifting, 281
P–T–t path, 281, 283, 288
 absolute, 257
 Dangba region, China, 266
 exhumation from ultra-high-pressures, 268
 low-pressure metamorphism, 282
 subduction zone, 278
 pumpellyite, 141
 pumpellyite–actinolite zone, 141
 stability, 160
 pumpellyite metabasalt, 144
 pyrope, 123–4, 153
 pyrophyllite, 122–3, 128
 pyroxene, 76, *See also* clinopyroxene, orthopyroxene
 quartz
 solubility, 54, 56, 56
 water weakening, 225
 quartzite, 29, 112
 radioactive decay, 251–3
 radiometric dating, 241
 apparent age, 256
 argon loss, 256
 common decay schemes, 252
 equation, 252
 example age calculation, 252
 fission tracks, 257
 garnet zones, 259
 half-life, 251
 K–Ar dating, 255
 Lu–Hf dating, 255, 258
 monazite inclusions, 260, 261
 Rb–Sr dating, 255
 Sm–Nd dating, 255, 258
 thermochronometers, 254–7
 Th–Pb dating, 255
 uncertainty, 264
 U–Pb dating, 251, 254–5
 Raman spectrometry, 88
 rates of metamorphism, 257, *See also* reaction rate
 reaction mechanisms
 chemical redistribution, 218
 heat-flow-controlled growth, 220–1
 heating rate, 221
 interface-controlled growth, 219–21
 kyanite to sillimanite, 218
 reaction cycles, 216–17
 solution–reprecipitation, 216
 transport-controlled growth, 218–20
 reaction rate, 221, 244
 reaction rim, 149
 reaction textures, 196
 real crystals
 adsorbed atoms, 200
 defects, 200–1
 strength, 201
 surface energy, 200, 202
 recrystallisation, 11, 196, 225, 227
 surface energy, 206
 syn-tectonic, 229
 refractory minerals, 116
 regional metamorphism, 2, 21–2, 144, 241, 264–6
 heating rate, 264
 timescales, 264–9
 relic, 198
 relics, 59, 108, 138, 214, 283
 restite. *See* migmatite
 retrograde metamorphism, 11, 11, 59, 60, 60, 144, 155, 235
 grain boundaries, 206
 rock composition, 8, 41, 46, 117, 153
 control on blueschist formation, 155
 effective bulk composition, 87
 representative, 207
 rock strength, 234
 effect of metamorphic reactions, 238
 influence of water, 235
 rutile, 251, 255
 Scanning Electron Microscopy (SEM), 25, 205
 schist, 26, 118, 121
 schistosity, 197, *See also* deformation fabrics
 external, 233
 internal, 233
 Schreinemakers bundle, 299
 SE Highlands, Scotland, 6–8, 96
 sea-floor metamorphism, 23, 133, 157–9
 hydrothermal circulation, 157
 sericite, 59, 93
 serpentine
 in marble, 184
 serpentinite, 29, 31, 47, 280
 shear zones, 229, 236
 chemical change, 237
 eclogite, 238
 infiltration of water, 237
 link to faulting, 238
 retrograde, 236
 sheet silicate. *See* phyllosilicate
 shock metamorphism, 23
 sillimanite
 fibrolite, 60, 109, 210, 232, 234
 growth, 217
 second sillimanite isograd, 127
 sillimanite zone, 109
 AFM projection, 109
 syn-tectonic, 234
 upper sillimanite zone, 111
 skarn, 166, 191–3, 198
 slate, 25, 26, 101, 121, 279
 spotted, 118
 software packages, 91–2
 PerpleX, 85
 Theriak-Domino, 85

- THERMOCALC, 85
 solid solutions, 35, 38–9, 44–5,
 65, 74, 77, 82
 continuous, 78
 discontinuous, 78
 end-members, 35, 73, 76–7
 solution-reprecipitation, 53
 solvus, 82
 alkali feldspar, 82
 Southland, New Zealand, 140–1
 spilite, 158–9
 standard state, 78
 staurolite, 5, 107, 232
 staurolite zone, 107
 AFM projection, 107
 strain, 17
 stress, 16
 deviatoric stress, 17–18, 238
 mean stress, 17
 normal stress, 16
 shear stress, 16
 stretched basin. *See* tectonic
 settings
 subduction zone. *See* tectonic
 settings
 supercritical fluid, 21, 167, 169
 system, 35, 299
 Al_2SiO_5 , 40
 $\text{CaO-MgO-SiO}_2\text{-H}_2\text{O}$, 52
 $\text{CaO-MgO-SiO}_2\text{-H}_2\text{O-CO}_2$,
 171
 $\text{CaO-SiO}_2\text{-Al}_2\text{O}_3$, 42
 Gibbs free energy, 66
 H_2O , 37
 jadeite-albite-quartz, 77
 KFMASH, 110
 $\text{MgO-SiO}_2\text{-H}_2\text{O}$, 47
 open, 306–7
 talc, 47–8, 50–1, 73, 123, 172,
 181
 tectonic fabrics. *See*
 deformation fabrics
 tectonic regimes, 289
 tectonic settings, 4, 14
 accretionary wedge, 278, 280
 changes through time, 291
 continental collision, 15
 crustal extension, 281
 magmatic arc, 15, 282
 mid-ocean ridge, 15, 23,
 273–4
 plate movement rates,
 249–50
 rifting, 275–6
 stretched basin, 15
 subduction, 290
 subduction channel, 278,
 280, 288
 subduction zone, 15, 275,
 278
 volcanic areas, 275
 temperature, 13
 relative, 69
 units, 14
 thermal aureole. *See*
 metamorphic aureole
 thermal diffusivity, 245
 thermal gradient through Earth
 history, 290
 thermal models, 248
 overthrusting, 248
 thermal relaxation, 284
 thermodynamic data, 68
 internally consistent, 84
 tie-lines, 41–2, 47, 50, 52,
 103–4, 172
 trace elements, 12, 39, 261
 as a record of garnet growth,
 261
 in garnet, 262
 Transmission Electron
 Microscopy (TEM), 205
 transport, 204, 206–9, 236
 advection, 208
 diffusion, 206, 208–9, 215,
 218, 254–5
 activation energy, 207
 diffusion coefficient, 209
 distances, 207
 effect of overstepping,
 220
 Fick's first law, 209
 grain boundary, 206
 in pore fluid, 216
 interface, 207
 pathways, 207
 self-diffusion, 208
 temperature dependence,
 209
 volume, 206, 208, 214, 225
 in absence of fluid, 219
 tremolite, 47, 73, 172, 175,
 181–2
 Tschermak's substitution,
 99–100, 138
 ultra-high-pressure
 metamorphism, 154–5,
 284, 287
 dating, 260, 266–7
 ultra-high-temperature
 metamorphism, 116,
 281, 290
 dating, 267–9
 univariant assemblage, 50
 univariant curve, 40–1, 299
 univariant reaction
 metastable extension, 301
 univariant reactions. *See*
 discontinuous reactions
 uplift, 12, 250
 rates, 249
 variable, 56
 dependent, 38
 independent, 38
 Variscan orogeny, 286
 Vassalboro Formation, Maine,
 USA, 187–90
 veins, 53, 54, 192, 228, 236
 whiteschist, 127, 128
 wollastonite, 167, 192
 X-Ray Diffraction, 88
 zeolite, 141, 157
 zeolite facies, 71, 139–41, 143
 zircon, 251, 253, 255, 257, 268,
 285
 acting as a pressure vessel, 154
 zoned grains, 138, 208
 zoned minerals, 10, 59, 60, 211,
 215. *See also* garnet
 growth zoning, 213
 retrograde zoning, 214