



Index

Bold = key term; italics = figure or map; * = mineral described in the appendix

- aa, **9**, *10*
 abbreviation, mineral, *264*
 Abitibi belt, Canada, *256*, *257*
 Absaroka Mountains, Wyoming, USA, *102*
 absarokaite, *102*
 accessory mineral, *99*, *182*, *281–282*
 accretionary prism, *257*
 ACF diagram. *See* chemographic projection
 acmite*, *272*
 actinolite*, *273*
 activity coefficient, *194*
 adiabat, *68*
 adiabatic decompression. *See* decompression
 melting
 aegirine*, *272*
 aeromagnetic survey, *15*, *145*
 AFC (assimilation with fractionation
 crystallization), *44*
 AFM diagram
 igneous, *100*
 metamorphic, *223–224*, *223*, *224*, *226*, *227*,
 228, *230*, *231*
 Ajo, Arizona, *244*
 albite*, *263*, *264*
 albite thermal barrier. *See* phase diagram,
 thermal barrier
 albite-epidote hornfels, *182*, **186**
 Aleutian island arc, Alaska, USA., *89*, *92–93*, *97*,
 101, *103*
 alkali lime index. *See* modified alkali lime index
 (MALI)
 alkaline
 gneiss, *161*
 intrusion, *124*, *138–141*, *161*
 volcanism, *116*, *116–121*, *117*
 alkalinity index (AI), *56*, *117–119*, *146*
 peralkaline, **56**
 allanite, *99*
 almandine*, *278*
 Alpe Arami, Switzerland, *211*
 alphabet classification. *See* granite
 Alpine orogeny, *107*, *185*, *216*, *252–253*, *254*
 Alps Mountains, Europe, *158*, *201*, *211*, *215*,
 252, *253*
 Alta stock, Utah, USA, *240–242*, *241*
 aluminosilicate, *21*, *149*, *160*, *161*, *277*
 P-T diagram, *19*
 triple point, *19*
 aluminum saturation index (ASI), *55*, *55–56*, *81*,
 114, *137*, *146*, *153*
 metaluminous, **55**, *80*, *115*, *145*
 peraluminous, **55**, *114*, *136*, *145*, *146*, *155*
 aluminum-excess minerals, *277–279*
 amphibole*, *272–274*
 hornblende*, *274*
 quadrilateral, *272*, *273*, *275*
 sodic, *182*, *184*, *273–274*, *274*
 amphibolite, *186*, *199*
 amphibolite facies, *131*, *163*, *181*, *182*, *183*, *198*,
 211, *212*, *214*, *224*, *238*, *250*, *254*
 correlation to Barrovian zone, *229*
 amygdale, *163*, **164**, *279*
 a-normal method, *265–266*
 analcime, *187*, *198*
 anatexis, **158**. *See* partial melting
 ancylite, *139*
 andalusite*, *277*
 Andes Mountains, South America, *89*
 andesine*, *264*, *264*
 andesite, *6*, *7*, *8*, *40*, *51*, *91*, *95*, *98*, *99*, *103*,
 105, *145*
 andradite*, *278*
 anhedral grain, *7*, *9*, *43*, *263*
 ankerite*, *268*
 annite*, *276*
 anorogenic granite. *See* granite
 anorthite*, *263*, *264*
 anorthite-diopside, *22–23*
 anorthoclase*, *267*
 anorthosite, *3*, *5*, *41*, *59*, *124*, *127*, *131*, *134*
 anorthosite complex, *132*, *134*
 Archean, *124*, *131*, *132*
 massif, *124*, **131**, *131*, *131–132*, *135*, *136*
 anthophyllite*, *273*
 anticline, *215*, *216*
 antigorite, **205**, *206*, *207*, *275*
 apatite*, *281–282*
 Appalachian Mountains, USA, *233*
 Apulian plate, *252*
 aragonite*, *268*
 arc, *129*
 batholith, continental, *95–97*, *148*
 K₂O variability, *100–101*, *101*
 magmatism, *104–105*
 paired metamorphic belt, in, *250*
 petrography, *97–99*
 plutonic complex, *91*, *93–94*, *102–103*
 relation to large mafic intrusions, *129*
 structure, *91*, *92*
 volcano, continental, *94–95*
 arfvedsonite, *116*, *140*, *274*
 argillic alteration, *245*, **246**
 ash, volcanic, **11**, *12*, *90*, *113*
 assemblage, mineral, **162**, *170*, *171*, *197*,
 220, *252*
 Barrovian metamorphic, *225–228*
 calcareous, *238–242*, *239*, *240*, *241*, *242*
 granulite facies, *185*, *230*, *255*
 mafic, *181–185*, *187–189*
 opaque, *243–244*
 pelitic, *224–233*
 ultramafic, *204–214*
 astrobleme, *130*
 A-type granite. *See* granite, alphabetic
 classification
 augite*, *269*, *272*
 sub-calcic, *271*
 aureole, *165*, *215*, *216*, *230*, *232*, *238*, *240–242*,
 241, *242*
 autolith, *9*, *15*, *105*
 Azores, *83*
 back-arc, *70*, *74*, *92*
 Baikal rift, Siberia, Russia, *108*
 Baltica, *150*
 Bandolier, New Mexico, USA, *12*
 Barrovian metamorphism, *224–228*, *251–252*
 basalt, *10*, *39*, *54*, *79*, *94*, *98*, *109*, *163*, *181*
 alkali, **66**, *83*, *115*, *121*, *155*
 chemistry and petrography, *66–67*
 classification, *66*
 differentiation, *48–49*, *110–111*, *129*
 ferro-, *80*, *100*, *116*
 from hot spot volcanism, *81*
 nepheline, *8*, *115*
 pressure effect on melting, *69*
 tetrahedron, *66*
 tholeiitic, *83*, *99*, *108*, *112*, *134*
 tholeiitic versus alkali, *66*, *69–70*
 basanite, **66**, *115*
 base metal deposit, *133*
 Basin and Range province, USA, *107*
 bathograd, **231**, *231*, *231–233*
 batholith, *8*, **14**, *91*, *95*, *102*, *134*, *217*, *251*
 bathozone, *231–233*
 Bay of Islands, Canada, *73*
 Bear Lodge alkaline complex, Wyoming,
 USA, *139*
 bedding, sedimentary, *162*, *163*, *165*
 Benioff zone, *88*, *91*, *92*, *101*
 Bergell tonalite, European Alps, *215*, *217*
 Bering peninsula, Alaska, *230*
 beryl, *154*
 beryllium, *155*
 bimodal volcanism, *112–115*
 Bingham mine, Utah, USA, *91*, *245*, *246*
 biotite*, *276*
 biotite zone, *226*
 Bishop Tuff, *43*
 Black Hills, South Dakota, USA, *55*, *148*, *154*
 black smoker, *84*, *254*
 blackwall zone, *214*, *215*
 block, volcanic, **10**, *96*
 Blue Mountains, Oregon, USA, *9*
 blueschist belt, *250*
 blueschist facies, *182*, *198*, *212*, *230*, *250*, *251*
 Boina volcano, Afar region, Africa, *116*, *117*
 bomb, volcanic, **10**
 Bonanza-type gold deposit. *See* gold deposits
 boundary layer fractionation, **43**, *44*
 Bouvet Island, South Atlantic, *109*
 Bowen's reaction series, *282*
 brecciation, breccia, *93*, *120*, *130*
 brine, *213*
 Brittany leucogranites, France, *148*

- bulk assimilation, **44**
 bulk distribution coefficient, **57**
 buoyancy fracturing, **41**
 Bushveld intrusion, South Africa, **126, 127, 128, 129, 130**
 bytownite*, **264**
- caerinite*, **267**
 calcite*, **268**
 calcite-dolomite thermometer, **195, 195**
 calcium-aluminum silicate, **279–280**
 calc-silicate rocks, **181, 241**
 caldera, **38, 92, 94, 112, 113**
 Caledonian Granites-see Granites
 Caledonian orogeny, **149–151, 201, 225, 254**
 Caledonide belt, Europe, **252**
 Cameroon volcanic line, Africa, **107, 108**
 carbonate alteration, **246**
 carbonates, **104, 120, 148, 160, 171, 194, 212, 213, 238–242, 268**
 carbonatite, **5, 116**
 Caribbean plateau, **81**
 Casa Parigia, Italy, **230**
 Cascade Mountains, North America, **94, 95, 100, 206, 216, 217**
 Cascade trend. *See* iron enrichment index (Fe-index)
 cassiterite, **148**
 celestine, **139**
 cesium, **155**
 charnockite, **2, 5, 199, 256**
 terrane, **256**
 chemical gradient, **214**
 chemographic projection, **170, 171–176, 205, 220**
 ACF diagram, **175, 176, 181, 182, 183, 184, 185**
 AFM projection, *see* AFM diagram
 continuous reaction, **221–223**
 discontinuous reaction, **223**
 four-component, **175**
 pseudobinary, **175**
 pseudoternary, **175**
 ternary, **238**
 chert, **73, 160, 163**
 Cheyenne belt, Wyoming, USA, **132**
 chialstolite*, **277**
 chilled margin, **9, 14**
 chlorite*, **276**
 chlorite zone, **226**
 chloritic, alteration, **246**
 chloritoid, **229, 230, *279**
 chondritic meteorite, **58, 67**
 chromite, **126, 127, 128, *280**
 podiform, **84, 125**
 stratiform, **84, 125**
 chrysotile, **205, 275**
 CIPW norm, **48**
 Clausius-Clapeyron equation, **192**
 cleavage, **165, 166**
 clinozoisite*, **279**
 clockwise P-T-t (pressure-temperature-time) path, **251–252**
- CO₂
 effect on melting temperature, **38–39, 68**
 effect on polymerization and viscosity, **38–39**
 and ferroan granite, **135**
 and melt evolution, **38–39, 120, 255–256**
 in metamorphism, **171, 198, 199, 212–214, 237, 239–242, 255–256**
 solubility in H₂O, **213**
 Coast Range batholith, Canada, **91**
 coesite. *See* UHP rocks
 Columbia River basalts, USA, **108, 109–111**
 chemistry, **110–111**
 relation to Snake River Plain-Yellowstone, **108, 109**
 units, **109**
 columnar jointing, **9, 10**
 comendite, **56**
 compatible trace element, **48, 57, 58**
 component, thermodynamic, **19, 172, 221**
 composite volcano, **92**
 Comstock Lode, Nevada, USA, **147, 148**
 conchoidal fracture, **165, 263, 279**
 conglomerate, **163**
 congruent melting, **24**
 constructive plate margin, **70**
 contact aureole. *See* aureole
 continental arc magmatism, **89–91, 105**
 continental collision, **185, 201, 251–253**
 continental overthrusting, **67, 72, 251, 254**
 continental rifting, **107, 108, 130, 140, 148, 254**
 continuous reaction, **221–223**
 convergent margin, **75**
 magmatism, **88–105**
 metamorphism, **250–251**
 copper deposits. *See* porphyry copper deposit, volcanogenic massive sulfide (VMS)
 cordierite, **210, 223–224, 229–230, *278**
 Cordilleran batholith, **91, 95–98, 102–103, 134, 146**
 cotectic. *See* phase diagram
 Craters of the Moon, Idaho. *See* Snake River Plain, Idaho, USA
 critical point, **212**
 cross bedding, **162**
 crossite, **182, *273–274**
 crustal cross-section, **256**
 crustal delamination, **146, 151–152**
 cummingtonite*, **273**
 cumulate, **7, 9, 93, 99, 126, 128, 131, 141**
 Curaçao, Netherlands Antilles, **10**
- dacite, **8, 50, 51, 54, 94–95, 98, 104, 148**
 Dalradian Supergroup, Scotland, UK, **225**
 daughter isotope, **60**
 Deccan traps, India, **108**
 decompression melting, **68, 70, 79, 81, 146, 229**
 decompression reaction, **183, 189**
 Deep Sea Drilling Project (DSDP). *See* ocean drilling
 degrees of freedom. *See* variance
 dehydration melting, **146, 149, 229**
 dehydration reaction, **192, 195, 199, 204, 205, 212, 228, 238**
 delamination. *See* crustal delamination
- Denver International Airport, Colorado, USA, **15**
 destructive plate margin, **70**
 diabase, **163**
 diagenesis, **158, 198**
 diamond, **120, 120–121**
 diatreme, **120**
 differentiation, **51–59, 67, 99**
 dihedral angle, **165**
 dike, **8, 9, 13, 14, 15, 41, 93–94, 111, 120**
 sheeted, **73, 74, 254**
 swarm, **14, 15, 41**
 diopside*, **270**
 diorite, **9, 54, 91, 99**
 ferro-, **132**
 monzo-, **155**
 discontinuous reaction, **222, 223**
 discrimination diagram, **59**
 distribution coefficient. *See* bulk distribution coefficient
 divariant, **19, 172**
 dolomite*, **268**
 drusy quartz, **263**
 Ducktown, Tennessee, USA, **242–244**
 Dufek intrusion, Antarctica, **127, 130**
 Duke Island, Alaska, USA, **99, 129**
 Duluth intrusion, Minnesota, USA, **125, 125**
 See also Keweenaw basalts, North America
 dunite, **5, 25, 93, 131, 132, 165**
- Earth structure, **67**
 asthenosphere, **67, 104, 151, 253**
 core-mantle boundary, **81**
 crust, thickness of oceanic and continental, **67, 82**
 geophysical evidence, **67, 74, 78, 82, 91, 92, 217–218**
 lithosphere, **82, 88, 104, 120**
 lithospheric mantle, **67, 104**
 lower mantle, **68**
 mesosphere, **67, 68**
 upper mantle, **67, 68, 81, 104**
 earthquake, **82, 88, 91, 92, 95, 204**
 East African rift, **69, 107, 108, 116–118, 117, 121**
 East Pacific Rise (EPR). *See* Mid-ocean ridge
 Eastern Goldfields sub-province, Australia, **259**
 eclogite, **186**
 eclogite facies, **182, 185, 189, 198, 199, 201, 212, 229, 231, 251, 252**
 edenite*, **274, 275**
 El Teniente mine, Chile, **91**
 electron microprobe, **171, 191, 264**
 enclave, **15, 51, 86, 134**
 English River – Uchi belt, Canada, **257, 258**
 enstatite*, **270–271**
 enthalpy, **192**
 entropy, **192**
 Eoalpine metamorphism, **252**
 epidote*, **279**
 epidotization, **163**
 epithermal ores, **147–148**
 epizone, **171**
 equilibrium constant, **192–193, 195, 243**
 equilibrium crystallization, **21, 42**

- albite-silica, 26
anorthite-diopside, 23
forsterite-fayalite, 27–28
forsterite-silica, 24–26
olivine-anorthite-diopside, 30–31
equilibrium melting, 21, 42
 anorthite-diopside, 23
 forsterite-fayalite, 28–29
 forsterite-silica, 25
equilibrium, thermodynamic, 162, 192, 195, 196
escape tectonics, 107
Eskola classification. *See* metamorphic, facies, grade
Etendeka flood basalt, Namibia and Angola, 108, 109
Etive granite, Scotland, UK, 150–152, 152
Etta mine, South Dakota, USA, 154
eudialyte, 139, 140, 141
euhedral grain, 7, 9, 140, 154, 165
eutectic. *See* phase diagram
evaporite, 160
exhumation, 200, 255
experimental petrology, 2, 133, 171, 211
exsolution texture, 99, 264, 267, 271
 anitperthite, 264
 perthite, 264
 in pyroxene, 271
extensional faulting, 75
extinction angle, 265–266, 271, 273
Eyjafjallajökull volcano, Iceland, 85, 90
- facies, grade. *See* metamorphic facies, grade
FAMOUS valley, 79–80, 80, *See also* Mid-Atlantic Ridge (MAR)
fayalite*, 268–269
feldspar*, 263–267
 alkali*, 266–267, 267
 plagioclase*, 264–266, 265, 266
feldspathoid*, 267–268
feldspathoid silica saturation index (FSSI), 56, 117, 118, 119
Fennoscandia, 132
ferroaugite*, 270
ferromagnesian silicates, 31, 98, 99, 181, 187, 268–277
ferrosilite*, 270
Fe-Ti oxides (magnetite and ilmenite), 76, 78, 99, 100, 103, 133, 145, 186, *280
fiamme, 12
fibrolite, 277
Fiji, 98
filter pressing, 21, 42
Fiskenæsset anorthosite complex, Greenland, 131–132, 131, 132
flood basalt, 108–112, 108, *See also* large igneous province (LIP)
 petrography and chemistry, 111
flow segregation, 42
fluid
 igneous, 91, 104, 121
 metamorphic, 212–214
 externally controlled (infiltrated), 214, 240–241
 internally controlled, 240–242
 supercritical, 212
 fluid inclusion, 263
 fluid-rock ratio, 240
 fluorine poisoning, 85
 foliation, 164, 165, 165, 217, 258
 fore-arc, 91, 92
 forsterite*, 268–269
 fractional crystallization, 21, 31, 42, 51, 57–58, 58, 74, 103–104, 110, 119, 124, 141
 anorthite-diopside, 22–23
 forsterite-fayalite, 27–28, 28
 forsterite-silica, 25
 olivine-anorthite-diopside, 30–31
 fractional melting, 21, 42
 anorthite-diopside, 23
 forsterite-fayalite, 28
 forsterite-silica, 25
Franciscan complex, California, USA, 250
free energy (Gibbs), 192, 243
freezing point, depression, 21–22, 30
Frost pyroxenite, 127
fugacity, 243, 244, 280
- gabbro, 4, 9, 54, 99, 126, 127, 131, 161, 163, 181, 254, 255, 256
 classification, 5
 leuco-, 4, 131, 132, 133, 135
 mela-, 4, 93
 monzo-, 155
 in ophiolite, 73, 74
 oxide, 76, 78
Gakkel ridge, Arctic Ocean, 74, 75
Galapagos Islands, 79, 81, 99, 100, 109
Gardar province, 138
Garhwal Himalaya, India, 149
garnet*, 278
garnet zone, 226–227, 227
garnet-biotite thermometer, 194
GASP barometer, 195
gedrite*, 273
geobarometry, 171, 195
geochemistry
 isotope, 2, 59–60, 100
 major element, 2, 47, 79–80, 111, 114, 145–146, 153, 157
 trace element, 2, 47, 56–59
geochronology, 60, 171, 281–282
geothermal gradient, 68, 198
 fossil, 251–252
geothermal heat, 245
geothermometry, 171, 194–195, 197
 ion exchange, 194
 solvus, 194–195
Gibbs free energy. *See* free energy (Gibbs)
glass
 manufacturing, 154
 volcanic texture, 7, 8, 12, 79
glaucophanite*, 273–274
Glomar Challenger, 77
gneiss, 162, 163
 ortho-, 163
 para-, 163
 quartzo-feldspathic, 257
 terrane, 258–259
- gneissosity, 166
gold deposits, 147, 147–148
Gondwana, 108, 130
graded bedding, 163
 reverse, 162
grandite garnets*, 278
granite, 4, 9, 52, 54, 99, 102, 163, 198
 alphabet classification, 145
 Caledonian-type, 149–152, 153, 155
 Cordilleran-type, 95–97, 98, 146, 152, 153, 155, 251
 dehydration melting, 146, 229
 ferroan, 124, 129, 134–138, 152, 153, 155
 hypersolvus, 266, 267
 magnetite and ilmenite, 145
 in metamorphism, 200, 250
 mineralogical classification, 145
 minimum melt, 38, 199
 peralkaline, 55–56, 141, 146
 peraluminous leucogranite (Himalayan-type), 146, 148–149, 150, 151, 152, 153, 155
 subsolvus, 266, 267
 tin, 148
 volcanic arc (VAG), 59
 within plate (WPG), 59
granoblastic texture, 165
granodiorite, 4, 9, 15, 54, 91, 95, 98, 99, 102
granophyre, 99, 129
granulite, 199, 254
granulite facies, 131, 164, 185, 188–189, 197, 198–199, 212, 229, 230, 238, 255–257, 256
 granulite terrain, 249, 254, 255–257, 257
graphite, 145, 148, 224, *281
Great Dyke, South Africa, 125, 130
green spinel*, 280
greenalite*, 275
greenschist, 186
greenschist facies, 163, 181–182, 187, 198, 212, 214, 225
greenstone belt, 257, 258
Grenada, Lesser Antilles, 98, 101
Grenville anorthosite complexes, North America, 131, 132
Grenville province, Ontario, Canada, 232
greywacke, 145, 162, 250, 258
grossular garnet*, 278
groundwater, 245
grunerite*, 273
guyot. *See* seamount
- H₂O, 12, 38, 96, 154
 effect on melting temperature, 37–38, 38, 68, 128, 146
 effect on polymerization and viscosity, 37 and melt evolution, 37–38, 99, 104, 149
 in metamorphism, 171, 175, 176, 192, 237, 255
 phase diagram, 212
 in serpentinization, 204
 solubility of CO₂ in, 212–213, 213
Harker diagram, 49–51, 53, 58
Harney Peak granite. *See* Black Hills, South Dakota, USA

- harzburgite, 5, 68–69
Hawaii-Emperor chain, 82–83, 107
Kilauea, 10, 82, 85, 90
Loihi, 81, 82, 83
Mauna Kea and Mauna Loa, 82
relation to hot spot, 82, 107
heat capacity, 39
heat of fusion, 39, 44
hedenbergite*, 269–270
Helena dolomite, 241
Hercynian granulites, 254
hercynite, 224
high pressure belt. *See* paired metamorphic belt
Highland Boundary fault, Scotland, UK, 225
Himalaya Mountains, 158, 201
Himalayan leucogranite, 148–150, 199–200
Himalayan orogeny, 107
Honshu, Japan, 250
hornblende*, 274–275
hornfels, 164, 165, 230
 albite-epidote, 182, 186
 hornblende, 182, 186
 pyroxene, 182, 186
Hortavær complex, Norway, 44
hot spot, plume, 68, 70, 79, 81, 108, 109, 112, 115
Hudson Bay, Canada, 15
hyaloclastite, 11
hydration reaction, 204, 254
hydrofracturing, 91
hydrothermal alteration, 244–246, 254
hydrothermal fluid, 84, 141, 148, 159, 244–246
- Iceland, 79, 99, 109
icelandite, 100
iddingsite, 120, 269
ideal gas, 243
ideal solution, 193
idioblastic texture, 165, 268
igneous
 classification, plutonic, 3–5, 145
 classification, preliminary, 3
 classification, volcanic and hyperabyssal, 5, 6, 7, 10–12, 11, 12
 petrogenesis, 2
 petrography, 2
 petrology, 1, 2
 structures, 8–15, 126–128, 148
 textures, 5–8, 9, 124, 162–164, 163
Ilimaussaq intrusion, Greenland, 127, 128, 138–141
ilmenite*, 280, 282
ilmenite granite, 145
immiscible fluid, 43
incompatible trace element, 48, 57, 66, 69, 79, 125, 147
incongruent melting, 24
industrial minerals, 124, 138, 154
Ingalls peridotite, Washington, USA, 216, 217
Integrated Ocean Drilling Program (IODP), *See* ocean drilling
International Union of Geological Sciences (IUGS), 1, 2–5, 6, 7, 48
intrusions, 15
ion-exchange reaction, 194, 196
ion-exchange thermometry, 194–195
iron enrichment index (Fe-index), 54–55, 79, 81, 99, 100–103, 111, 114, 116–117, 119, 137, 146, 148, 153
 ferroan, 54, 100
 magnesian, 54, 100
iron formation, 160, 258, 259
island arc, 89, 91–94
 magmatism, 89, 100–102, 104–105
 volcano, 92–93
isograd, 162, 215–217, 231, 240–242, 241, 250
 second sillimanite, 228
isostasy, 251
isotope geochemistry, 59–61, 83, 103–104, 105, 114, 115, 118
Iszu – Bonin subduction zone, western Pacific, 218
- jack-straw texture, 206
jadeite, 182, 185, *271–272
Joides Resolution, 77
Juan de Fuca plate, 109
- Kaiserstuhl, Germany, 8
kakortokite, 140, 141
Kalapana Gardens subdivision, Hawaii, USA, 85
Kangerdluarssuk fjord, Greenland, 140, 141
Kapusking block, Canada, 256, 257
Karmusten volcanics, Vancouver Island, Canada, 186
Karoo basalts, South Africa, 108–109
katazone, 171
Katmai, Alaska, USA, 96
Kerguelen plateau, 81, 82
Keweenaw basalts, North America, 108, 130
Kiglapait intrusion, Canada, 129
kimberlite, 41, 119–121, 120
kinetics, 206
Kola peninsula, Russia, 138
komatiite, 5
Krakatoa, Indonesia, 96
KREEP basalt (lunar), 57–59
Kurile island arc, 89
kyanite zone, 224, 227–228, 227, 228
- labradorite*, 264
Lake Owen complex, Wyoming, USA, 99
lamellae, 271
lamproite, 119–121, 120
lamprophyre, 5
lapilli, 11
Laramide orogeny, 133
Laramie anorthosite complex, Wyoming, USA, 15, 41, 43, 132–134, 136, 164, 230, 232
 Chugwater intrusion, 132
 Maloin Ranch pluton, 133
 Poe Mountain anorthosite, 132
 Red Mountain pluton, 50–51, 50, 51, 53, 54, 58, 133, 139
 Snow Creek Anorthosite, 132
 Sybille monzosyenite, 133
Laramie Mountains, Wyoming, USA, 50, 59, 163, 186, 232
large igneous province (LIP), 81, 108
laser ablation, 171
- laumontite*, 280
Laurentia, 150
lava dome, 12, 13, 14, 95, 96
lava flow, 8, 85, 90, 92, 95, 108
lava tube, 95
law of mass action, 192
lawsonite*, 280
lawsonite-albite-chlorite facies, 182, 185
layered mafic intrusion (LMI), 99, 124, 126–130
 mineralogical variability, 126, 128–129
 stratigraphy, 128–130
 tectonic environment, 130
Le Chatelier's principle, 208
Lesser Antilles, Caribbean, 89, 98, 101
leucite*, 267–268
Leucite Hills, Wyoming, USA, 116, 120
leucocratic minerals*, 263–268
leucosome, 200
lever rule, 20–21
lherzolite, 5, 67, 68, 69, 78
 depleted, 68
 fertile, 68, 104
Ligurian Alps, Italy, 186
limestone, 238–239
lineation, 165
liquidus, 22, 27, 29, 39, 103, 158
lithium, 154–155
lizardite, 204, 205, 206, *275
Long Valley caldera, California, USA, 43
low-pressure belt. *See* paired metamorphic belt
lujavrite, 140, 141
- Macquarie Island, South Pacific, 73, 74
mafic minerals*, 268–277
mafic selvage, 200
magma, 36
 ascent, 40–41, 79, 99, 120
 assimilation and contamination, 41, 44, 52, 104, 105, 110, 124, 141
 chamber, 41, 82, 99, 104, 111, 113, 128
 density, 40, 141
 differentiation, 48
 environment of magmagenesis, 70, 104–105, 111–112, 146
 exsolution of aqueous fluid, 37–38, 91, 96, 148
 mixing, 44, 51, 52, 103, 119, 124
 in paired metamorphic belts, 251
 temperature, 39
 viscosity, 39–40, 95, 96
magmatic differentiation, 42–44, 67, 79, 99–100, 100, 112, 126–128
 continental arc, 100–103, 103
 oceanic tholeiites, 78–80, 100
magnetic anomaly, 255
magnetite*, 280, 282
magnetite granite, 145
major elements (oxides), 3, 47
Malenco serpentinite, European Alps, 215–217, 215
manganese (Mn) formation, 160
mantle, 78, 88, 120
 composition, 67, 121
 convection, 68
 isotopic composition, 105

- melting, 68–70, 86, 104, 111, 121
olivine fabric, 217
peridotite, 204
plume. *See* (hot spot)
xenocryst, 98
xenolith, 121
- marble, 238–242, 250, 259
Marianas island arc, 89
marl, 160
Marysville stock, Montana, USA, 241–242, 242
mass extinction, 86
mass fractionation, 60
massive sulfide deposit. *See* volcanogenic
massive sulfide (VMS)
mass-transfer reaction, 196
Matterhorn, Switzerland, 252
McKenzie Mountains, Yukon-Northwest
Territory, Canada, 148
megacryst, 131
mélange, 250
melanosome, 200
mesozone, 171
metabasite, 161, 181–189, 272
metabasalt, 163, 164, 186, 187
metadiabase, 163, 186, 187
metagabbro, 187, 215
metaconglomerate, 162, 163
metamorphic
conditions, 161–162, 180, 197–200
facies, grade, 171, 181–186, 182, 211–212,
226, 238, 259
field gradient, 252
fluid, 171, 238–246
nomenclature, 166–167
petrology, 157
textures and fabric, 159, 162–166, 186–187,
206, 211
metamorphism, 158
in Archean terranes, 257–259
burial, 158–159
contact, 158, 185–186, 215–217, 238–239,
240–242
in continental collision, 185, 251–253
dynamic, 159
in granulite terranes, 255–257
hydrothermal, 159
isochemical, 159
prograde, 203, 204–208
regional, 158, 181–185, 233, 249–259
retrograde, 159, 197, 253
in rifting terranes, 253–254
seafloor, 254–255
metaperidotite, 203–217
role of aluminum, 210–211
role of iron, 208–210. *See also* serpentinite
metasedimentary belt, 257
metasedimentary rock, 104, 200, 212, 250
metasomatism, 121, 159, 214–215, 214,
215, 256
mica*, 276–277
Mica Dam, British Columbia, Canada, 184
microcline*, 266–267
Mid-Ocean Ridge 74–76, 109
East Pacific Rise (EPR), 74, 75
Mid-Atlantic Ridge (MAR), 74–76, 79–80
Mid-Ocean Ridge Basalt (MORB), 67, 78, 83,
104, 111
composition, 59, 78–80
E-MORB, 80, 111
interaction with mantle, 77, 79
N-MORB, 80, 111
pressure effect on melting, 78, 79
migmatite, 200
minnesotaite*, 276
minor elements, 47
modal mineralogy, 4, 5, 6, 48, 204
mode, 3, 48
modified alkali lime index (MALI), 53–54, 81,
102, 114, 116–118, 119, 137, 148–149,
151, 152, 153
alkalic, 54, 80, 91, 98, 102, 114, 117, 136, 153
alkali-calcic, 54, 59, 66, 80, 98, 100, 101, 114,
136, 151, 153
calc-alkalic, 54, 66, 80, 91, 98, 100, 101, 102,
121, 130, 151, 153
calcic, 54, 66, 97, 98, 100, 102, 151, 153
Moho, 67, 74
monazite*, 282
Mont Pelée, Martinique, 12
monzonite, 4, 50, 54, 134, 155
Mount Pinatubo, Philippines, 90, 96
Mount Saint Helens, Washington, USA, 12, 14,
90, 94–95, 96–97, 100, 101, 103, 105
Mount Somma caldera, Italy, 119
Mount Stuart batholith, Washington, USA, 217
Mount Vesuvius, Italy, 11, 118–119, 119
Mullen Creek complex, Wyoming, USA, 99
muscovite*, 276–277
myrmekite, 99
Nain anorthosite complex, Canada, 133
naujaite, 140–141, 141
Nebo granite, South Africa, 136–137
nepheline*, 267
network-forming ions, 36, 37, 40
network-modifying ions, 36, 37, 40
Neuberg Peak, Antarctica, 127
neutralization reaction, 244
Nevado del Ruiz, Columbia, 90
New Caledonia, 73, 193
New Hebrides island arc, 89
norite, 4, 5
Norm (CIPW Norm), 48
Normative mineralogy, 66, 83, 115, 119,
See also CIPW norm
normal zoning, 265
nucleation, 6, 165
Nyambeni, Kenya, 116, 117
Nyriragongo, Congo, 90, 116, 117
ocean drilling
Deep Sea Drilling Program (DSDP), 72, 77
Integrated Ocean Drilling Program
(IODP), 75, 76, 77, 79, 254–255
Ocean Drilling Program (ODP), 77, 254
ocean plateau, 81, 82. *See* large igneous province
oceanic spreading center, 68
fast, 74, 75, 78, 254
slow, 74, 75, 254
ultra-slow, 74, 75
off-ridge magmatism, 78, 80–81
Ok Tedi mine, Papua New Guinea, 91
Ol Doinyo Lengai, Tanzania, 116
Old Faithful geyser, Wyoming, USA, 147
olivine*, 268–269
Oman ophiolite, 73, 74
omphacite*, 272
Ontong-Java plateau, 83, 86
opaque mineral, 280
ophiolite, 67, 72–78, 84, 254
optical mineralogy, 2, 187
Ore Deposits
association with hydrothermal alteration,
157, 245–246
occurrence in
alkaline rocks, 138–139
anorthosite, 133
granitic rocks, 147–148
layered mafic intrusions, 125, 130
Oceanic crust and ophiolites, 84
pegmatites, 154–155
porphyry deposits, 91
Oregon plateau. *See* Columbia River
basalts, USA
orthoclase*, 263, 264, 266–267
orthogneiss, 163
orthopyroxene*, 269–271
Otago belt, New Zealand, 250
oxide minerals*, 280
Paddy-Go-Easy pass, Washington, USA, 206,
215, 216–217, 216
pahoehoe, 9, 10
paired metamorphic belt, 250
high-pressure, 250
low-pressure, 250
pantellerite, 56
paragneiss, 163, 200
paragonite*, 277
Paraná plateau, Brazil, 108
parent isotope, 60
pargasite*, 274, 275
parisite, 139
partial melting, 31, 42, 57, 67, 74, 78, 79, 86,
115, 121, 145
assimilation of, 44, 158
partition coefficient, 57, 138
Peacock classification. *See* modified alkali lime
index (MALI)
pegmatite, 7, 57, 141, 154–155
Pele, 85
pelite, pelitic rocks, 160, 220–234
chemographic projection, 221–224
pendant, 251
penetrative deformation, 159
Peninsular Ranges batholith, North America, 91
Penrose Conference, 73
peralkaline, 55, 56, 115, 141, 146
periclase zone, 240, 241
peridotite, 5, 67, 76, 120, 128, 131
garnet, 201, 211
metamorphic protolith, 161, 203
in ophiolite, 73
refertilized, 210–211
peritectic. *See* phase diagram

- petrogenetic grid, **171**
petrographic microscope, 48
pH
 alkaline (basic) fluids, 204
 buffering, 244
phase diagram, 18–32, 170–176
 binary, 21–29
 cotectic, **30**, 78
 divariant, 19, 20, 22
 eutectic, 21–23, 25, 29, 30, 68, 69, 78, 79
 invariant, 19
 peritectic, **24**, 24–26, 30
 pseudoternary, **30**, 69, 78
P-T diagram, 19, 38, 39, 149, 192, 195, 196,
 198, 199, 207, 209, 210, 211, 212, 229,
 231, 251, 251–252, 277
solidus, **27**, 39, 68, 112, 135
 dry, 37, 39
 solvus, **28**, **29**, 195, 213, 266–267, 267, 270
 ternary, 29–31, 68–69
 thermal barrier, **26–27**, 31, 67, 118
T-X diagram, 22, 23, 24, 25, 26, 27, 28, 209, 213,
 214, 221, 239, 240, 241, 242, 267, 270
 univariant line, 19, 22
phase rule, 19–20, 209
phase, thermodynamic, **19**, 172
 equilibria, 191
phengite*, 276
phenocryst, 7, 8, 9, 78, 97, 99, 111, 163
Philippine Institute of Volcanology and
 Seismology, 96
phlogopite*, 276
phonolite, 6, 40, 67, 116, 119
phyllite, 166, 225
phyllosilicate*, 275–277
pigeonite*, 269–271
Pikes Peak batholith, Colorado, USA,
 135–136, 137
Pikwitonei block, Canada, 256, 257
Pilbara craton, Australia, 258
pillow basalt, **9**, 10, 73, 74, 163, 164, 254
plagioclase effect, 117–118
plane of critical silica undersaturation, **66**
plane of silica saturation, **66**
plate tectonic revolution, 201
platinum group elements (PGEs), 125, 133
pleochroism, 66, 183, 189, 210
Pliny the Younger, 11, 119
plume, *See* hot-spot
pluton, plutonic, 8, **14**, 91, 95, 141, 150
 charnockitic, 256
 epizonal, 171
point-counting, 48
polymerization, polymers, 36, 37, 38, 40
 aqueous fluids, 104
polythermal projection, **29**, 30, 31
Pompeii, Italy, 11, 119
porphyroblast, porphyroblastic, 164, **165**
porphyry, **8**, 9
 copper deposit, 91, 147, 244, 245
potassic alteration, 245, **246**
Precambrian shield, 249, 257
precious metal, 258
preferred orientation, 164, **165**, 166, 217–218
prehnite*, 279–280
prehnite-pumpellyite facies, 181, 182, 184–185,
 186, 187, 198, 211–212, 229, 254
primary texture, 162–164
propylitic alteration, 245, **246**
protolith, 157, 159–161, 167
 calcareous, 160, 237–242
 igneous, 161
 mafic, 161, 163, 164, 180–189
 pelitic, **160**, 220–233
 quartzite, 160, 165, 250
 quartzo-feldspathic, 161
 sedimentary, 159, 160, 161, 162
 semi-pelite (psammite), **160**, 200, 227
 ultramafic, 161, 208–218
pseudomorphs, 206
pumice, **11**, 12
pumpellyite*, 280
pumpellyite-actinolite facies, 182
pyralspite garnets*, 278
Pyre Peak, Alaska, USA, 92
Pyrenees, Europe, 254
pyrite*, 280
pyroclastic deposits, 10–12, 90, 93, 96–97
 air fall, **11**, 13, 90, 113
 pyroclastic flow, **11–12**, 13, 14, 94–97
pyroclastic rocks, **5**, **8**
pyrometer, 39
pyrope*, 278
pyroxene*, 269–272
 clino-, 270
 ortho-, 270
 quadrilateral, 269, 270, 271
 sodic, 269, 271–272
pyroxene-hornfels, **182**, **186**
pyroxenite, 5, 9, 93, 127, 128, 131, 204
pyrrhotite*, 280
QAPF diagram, classification, 3, 4, 6, 102, 145,
 153, 155
quartz*, 263
quartzite, 160, 165, 166, 250
Quetico belt, Canada, 257
Raft River Mountains, Utah, USA, 163
rapakivi texture, 43, 52
rare earth elements (REEs), 56, 58–59, 138, 155
 in alkaline intrusions, 138–139
 diagram, **58**, 59
 in garnet, 211
 in lunar samples, 59
Rayleigh fractionation, 58
reaction rim, 43, 99, 164, 183, 184, 211, 228
Red Sea, 107, 116
refertilization, 210–211
residual melt, 26
resorbed crystal, 43, **44**, 66
restitute, **158**, 200
retrogressive reactions, 44, 251
reverse zoning, **44**, 265
rheology, 204
Rhine graben, Europe, 107, 108
rhyolite, 6, 7, 39, 40, 51, 54, 79, 99, 100, 112, 148
 melt viscosity, 40
 peralkaline, 56, 116
riebeckite, 116, 140, *274
Rio Grande rift, North America, 107, 108
Rocas Verdes, Chile, 73, 74
Rocky Mountains, North America, 158
rodingite, **204**, 215
Rogaland anorthosite complex, Norway, 131,
 133, 134
Roman province, Italy, 69, 118, 119, 121
Rum intrusion, Scotland, UK, 126, 127, 130
rutile*, 281
Ryoke belt, Japan, 250
Ryuku island arc, 89
San Miguel Regla, Hidalgo, Mexico, 10
sanidine*, 266–267
Scandinavian shield, 254
scanning electron microscope (SEM), 224
schist, 164, 225, 243
schistosity, **165**
scoria, **11**
Scotia island arc, South Atlantic, 89
seamount, **80**
seawater, 104, 164, 254
sedimentary texture, 162, 163
Seguam. *See* Aleutian island arc, Alaska, USA
seismic anisotropy, **217–218**
seismograph, 96
sericite, sericitization, 224, 244, 245, **246**
serpentine*, 275
serpentine polymorphs, 204–205, 275
serpentinite, serpentinization, 73, 120, 175,
 204–206, 250
Sesia zone, Italy, 186
shale, 2, 149, 220, 224
shatter cone, 130
shear zone, 149, 159
Sherman batholith, Wyoming, USA, 43, 49,
 50–51, 52, 54, 59
 Lincoln granite, 51, 52, 59
 Sherman granite, 51, 52, 59
Shiprock, New Mexico, USA, 14
Shuksan belt, Cascade Mountains, North
 America, 250
Siberian traps, Russia, 108, 109
Sierra Nevada batholith, California, USA, 14,
 91, 95, 98, 102, 105, 150
 Tuolumne pluton, 53, 54, 55, 95–97, 98, 101,
 102, 150
silicate structure
 octahedral site, 36, 37, 204
 tetrahedral site, 36, 37, 204, 225
silicic alteration, **246**
sill, **8**, 14, 149
sillimanite*, 277
sillimanite zone, 228
Skaergaard intrusion, Greenland, 9, 128
Skaergaard trend. *See* iron enrichment index
 (Fe-Index)
skarn, **148**, 241
slate, 166
Smartville ophiolite, California, USA, 99, 163
Smoky Buttes, Montana, USA, 120
Snake River Plain, Idaho, USA, 10, 107,
 109–110, 112, 114–115, 117,
 See also Yellowstone hot spot, USA
soapstone. *See* steatite

- sodalite*, 140–141, 267–268
solid solution, 20, 27–29, 185, 195, 221–223, 263, 267, 270, 272, 274, 275
 partial, 29
solidus, 27, 68, 112, 135, 149
Solomon Islands, 81, 89
solvus, 28, 29, 195, 213, 266–267
solvus thermometry, 194
Soufrière volcano, St. Vincent, 8
Southwest Indian ridge, 76
spessartine*, 278
sphene*, 281
St. Helena, 83
St. Kitts and Nevis, 100, 101
static texture, 164–165
staurolite*, 278
staurolite zone, 226, 227
steatite, 214
Stillwater intrusion, Montana, USA, 9, 125, 126, 130
stilpnomelane, 182, 226, 229
Stokes law, 41
stopping, 41
strontianite, 139
structural geology, 157, 166, 253
sub-arc intrusion, 99
subduction zone, 68, 89, 91, 92, 104, 121, 185, 201, 250, 251
 cold, 185, 198
 serpentinites in, 204
 suprasubduction-zone ophiolite, 74
Sudbury intrusion, Canada, 125, 129, 130
sulfide minerals*, 280–281
sulfide ore body, 242–244, *See also* ore deposits
sulfide melt, 125
sulfur-bearing fluid, 171, 242–244, 281
Sunda-Banda island arc, 89, 98
Super High Resolution Ion Microprobe (SHRIMP), 171
supercritical fluid, 212
Superior province, Canada, 256, 257
supracrustal rocks, 257
Suswa volcano, Kenya, 116–118, 117
syenite, 4, 50, 54, 56, 91, 140
 monzo-, 43, 133
 nepheline, 4, 127, 140
synchysite, 139
syncline, 215, 216
system, thermodynamic, 19, 172
- tabular feldspar, 7, 8, 9, 133, 162–163, 186–187
Taconic orogeny, 233
talca*, 275
Tambora, Indonesia, 90
tantalum, 155
Taos, New Mexico, USA, 164
TAS diagram, classification, 5, 7
tectonic texture, 165–166
tectonic thickening, 148, 151
tectosilicate, 184
Tellnes Ti-deposit, Norway, 133
tephrite, 6, 7, 115, 119
- terminal reaction, 174, 222, 223
Tethys sea, 216, 252
Teton Range, Wyoming, USA, 200
thermal anomaly, 254
thermobarometry, 158, 162, 171, 191, 194–197, 199
thermocouple, 39
thermodynamic database, 162, 205
thermodynamics, 19, 171
thermometry, *.See* geothermometry
tholeiite, 40, 57, 58, 66, 83, 100, 108,
 See also basalt
 melt viscosity, 40
 olivine, 8, 66, 112, 116
 quartz, 66
thrust fault, 185
Tibetan plateau, 151
tie line flip reaction, 174, 222, 223, 228
tiltmeter, 96
tin ore, 147
titanite. *See* sphene
Toba, Indonesia, 90
Tobago, West Indies, 89, 93–94, 99, 102
tonalite, 4, 93, 97, 98, 99, 102, 155, 200
Tonga-Kermadec island arc, 89
topaz, 154
topology, 172, 173, 174
Toutle River, Washington, USA, 94, 95
trachyte, 6, 54, 100, 115
Trans-Hudson orogeny, 256
transition metals, 56, 91, 254
tremolite*, 273
trench, 88, 91, 92, 101, 218
Tristan da Cunha, 83, 109
troctolite, 4, 5, 77, 78
Troodos, Cyprus, 73, 74, 84
tschermakite*, 274
tuff, 11, 12, 114
tungsten ore, 148
Tuolumne pluton, California, USA. *See* Sierra Nevada batholith, California, USA
turbidite, 163
Turino, Italy, 253
twinning, 264, 266, 273, 279
 albite, 264, 265, 266
 Carlsbad, 264, 265
 pericline, 265
 polysynthetic, 265, 273
 tartan, 267
- ultrahigh pressure (UHP) metamorphism, 198, 200
ultrahigh temperature (UHT) metamorphism, 198, 199–200
ultramafic rock, 5, 93, 99, 102, 111, 119, 126, 174, *See also* peridotite, pyroxenite
ulvöspinel*, 280
undulatory extinction, 263
- Val Malenco. *See* Malenco serpentinite, European Alps
variance, 19, 183, 209, 221, 240
- variation diagram, 58, 80, 103, 111,
 See also Harker diagram
vein, 121, 141, 148, 244, 254
vesicle, 10, 66, 164
viscosity, 39–40, 41
Voisey's Bay deposit, Canada, 133
volatile, 7, 11, 37–39, 99, 139, 154, 158, 239, 255
volcanic eruption type
 fissure, 85, 108, 110
 phreatomagmatic, 11
 plinian, 11, 13
 strombolian, 11, 13
Volcanic Explosivity Index (VEI), 90, 96–97
volcanic gas, 96, 97
volcanic hazard prediction, 96–97, 113
volcanic hazards, occurrence
 convergent margin, 90, 96–97
 intracontinental, 113
 oceanic, 85
volcanic neck, 13, 14
volcanic winter, 90
volcanogenic massive sulfide (VMS), 84
- wairakite, 184
Wasatch Mountains, Utah, USA, 240
wehrlite, 5, 93
welding, 12
Wenatchee Mountains, Washington, USA, 217
whiteschist, 201, 229–230, 231, 275
Willow Creek pass, Colorado, USA, 9
Wind River Range, Wyoming, USA, 114, 199
Windimurra anorthosite complex, Australia, 131, 133
Wyoming province, 132
- xenocryst, 36, 43, 44, 98, 120, 134
xenolith, 15, 67, 83, 120, 256
X-ray diffraction, 206, 224
- Yellowknife, Northwest Territories, Canada, 163
Yellowstone hot spot, USA, 12, 109, 112–115, 112, 113, 147, 148, 159
Yilgarn province, Australia, 258, 259
Yosemite National Park, California, USA, 95
- Zarza, Baja, Mexico, 53, 54
zeolite, 164
zeolite facies, 184, 187, 198, 225, 229, 250, 254, 255
Zermatt-Saas ophiolite, Switzerland, 201, 206, 252
zircon, *281, 58, 139, 140
zoisite*, 279
zonation, zoning
 in granite, 97, 150
 in plagioclase
 normal, 265
 reverse, 44, 265
 in ultramafic rocks, 214