

Index

Page numbers in *italics* indicate illustration of the topic.

- A horizon soil, 265, *265*
- Aa flow, *92*, 95
- Ablation, 380
- Abrasion
 - glacial, 381
 - stream channel, 310
 - wind, 459
- Abyssal floor, *17*, 21
- Abyssal hills, 21, 561
- Abyssal plains, 21
- Accreted terranes, 627, *627*
- Accretion
 - lunar, 730
 - of North America, 627, *628*
- Accretionary wedges, 606, *607*
- Acid hydrolysis, 254–55
- Aegean Sea, 520–21, *520*
- Age correlations, 198
- Alaska
 - Earthquake 1964, 516
 - terranes, *626*
- Alcoves, 673
- Algae, 122
- Alluvial fans, 130, *131*, 326, *327*, *328*
- Alluvial slope, 327
- Alluvial valleys, 321
- Alpine transform, New Zealand, 588–89, *590*
- Alps, *386*, 608, *610*, 612, 624
- Amorphous solids, 57
- Amphiboles, 76, *76*
- Amphibolite, 157
- Amphibolite facies, 160
- Andesite, *90*, 91
- Andes Mountains, 608, *608*, *609*
- Angle of repose, 276
- Angular unconformity, 192, *192*
- Antarctica, *232*, *233*, 234–35, 239, 244, *376*, 389, 392, *393*
- Anticlines, 178, *180*
- Aphanitic textures, *86*, 86–88, *90*, 91
- Apollo Program, 733
- Appalachian Mountains, *677*, 678
- Aquifers, 340, *342*
- Arches, 673, *675*
- Arêtes, *385*, 388
- Artesian-pressure surface, 346
- Artesian water, *346*, 346–47
- Artificial discharge, 345
- Ash, 94
- Ash flows, 98, *101*, 102
- Ash-flow tuff, 94
- Assimilation, *108*, 109
- Asteroids, 751–52, *752*
- Asthenosphere, 14
- Aswan High Dam, 306–307
- Atmosphere, 10–11
 - atmospheric pressure, 223
 - composition of, 220–21, *221*
 - energy and motion of, 224–29
 - global circulation of, 226–27, *228*
 - thermal structure of, 221–22
 - water vapor in, 223–24, *224*
- Atolls, 440–42, *441*
- Atomic mass, 55
- Atomic number, 55, *57*
- Atoms, 54–55, *55*
- Australia, *439*, 457, 470, 694, *698*
- Avulsion, 323, *325*
- Axis of plate rotation, 500
- B horizon soil, 265
- Backarcs, 599
- Backarc spreading, 612
- Backswamps, 319
- Backwash, 423
- Baffin Island, Canada, *391*, 402
- Bajadas, 679, *681*
- Banded iron formations, 697–98, *698*
- Barchan dunes, 468, *468*
- Barnes Ice Cap, Canada, *390*, 390–92
- Bar Harbor, Maine, *105*
- Barrier islands, 130, 433, *434*, *435*
- Barrier reefs, 440
- Basal drag, 505
- Basalt, *90*, 91, 259
- Basaltic eruptions, products of, 97–98
- Basaltic plains, 681–83, *681*, *684*
- Base level, 304–5
- Basement complex, 16
- Basin and Range Province, 174, 562–64, *563*, 679–80, *681*, *682*
- Basins, *183*, 183–185, 672
- Batholiths, 103, *105*, *106*, *107*
- Baymouth bars, 432
- Bays, 432
- Beach drift, 425
- Beaches, 130, 432
- Bedding planes, 117
- Bed load, 303
- Beds, 125
- Big Lost River, Idaho, *344*, 345
- Bingham copper mine, Utah, *696*
- Biochemical sedimentary rocks, 122, 125
- Biomass, 703
- Biosphere, 10–11, *12*
- Biotite, 74
- Bird-foot deltas, 325
- Blackhawk slide, California, 288, *288*
- Black smokers, 561, *561*
- Blowout dunes, 470, *470*
- Blueschist facies, 161, *161*, 624, *625*
- Blyde River, South Africa, *311*
- Bonding, 56–57, *58*
- Borah Peak, Idaho, *166*–67
- Bracketed intrusions, 210–211
- Braided streams, 320, *320*
- Breakers, 423, *424*
- Brines, 698, *699*
- Brittle deformation, 168, *169*
- Bryce Canyon, Utah, *248*–49, 260, 672, *674*
- Buttes, *672*, 672
- Bylot Island, Canada, *383*
- Calcite, *77*
- Calderas, *97*, *98*
- Callisto, *728*, *744*, 746
- Canadian Rockies, *254*, *287*–88, *290*, *610*
- Canadian shield, *18*, 147, *147*, *668*, 669, *669*
- Capacity, stream, 304
- Carbon-14 clock, 205–7, *206*
- Cascade volcanic chain, 685, *685*
- Catastrophism, 191
- Caves, 352, *353*
- Cementation, 130
- Cenozoic Era, 199
- Chalk, 122
- Channeled Scablands, Washington, *409*, 409–10, *410*
- Charon, 749–50, *751*
- Chatham, Massachusetts, 433, *436*
- Chemical precipitates, 122, 697–99
- Chemical sedimentary rocks, 122–24
- Chemical weathering, 253–57, *256*
 - by acid hydrolysis, 254–56
 - by dissolution, 253–54
 - by oxidation, 256
- Chert, 123–24
- Cinder cones, 96, *96*
- Cirques, 388
- Clastic sedimentary rocks, 118–122
- Clastic sediments, 697, *698*
- Clay minerals, 76
- Claystone, 120
- Cleavage planes, 61, 64, *64*
- Climate
 - deserts, 270
 - landscape development and, 662, *663*
 - polar, 270
 - river systems and, 331–332
 - temperate, 270
 - tropical, 269
 - weathering and, 268–270, *270*
- Climate change, 242–43
 - continental drift and, 242–43, *243*
 - global, 243, *243*
 - greenhouse gases and, 244, *246*
 - mass spectrometry and, 415
- Climate zones, *240*, 240–41
- Clipperton fracture zone, 581, *581*
- Closed systems, 31
- Coal, 706–9, *707*, *708*, *709*
- Coastal upwelling, 236, *237*
- Coasts,
 - local geologic processes and, 445–447
 - plate tectonics and, 443–445
- “Cold Wall,” 583, *583*
- Collecting system, 299, *300*

I-2 Index

- Collision zones, 525
Colorado Plateau, 172, 659, 661, 672, 673
Columbia Plateau, Washington, 85, 95, 652–53
Columnar joints, 92, 95
Columns, 672, 674
Comets, 752–53, 753
Compaction, 130
Competence, sediment load, 303–4
Composite volcanoes, 97, 100
Compound, 56
Compressing flow, 378–79, 378
Compression, 170, 170
 in continental collision zones, 609–12, 611
 at subduction zones, 606–9
 in transform fault systems, 582–83, 583
Compressional waves, 511
Conchoidal fractures, 64
Cone of depression, 345, 345
Confined aquifers, 340, 346
Confining pressure, 152
Conglomerate, 119, 120, 121
Consequent streams, 674
Constancy of interfacial angles, law of, 61
Contact metamorphism, 150, 150, 697
Continental accretion, 625, 627
Continental arc magmatism, 614–15
Continental drift, 482–87
 climate change and, 242–43, 243
 glaciation evidence for, 485–86, 486
 paleoclimatic evidence for, 486–87, 487
 paleontological evidence for, 483–84, 484
 structure and rock type evidence for, 484–85, 485
 See also Plate tectonics
Continental glacier systems, 375–76, 376, 388–98
 landforms created by, 395–96
Continental margins, 21, 22–24
Continental rifts, 562–70, 568, 569
 landscape development and, 678–83
 mantle plumes and, 654–56
Continental shelf, 22
Continental slope, 22–23
Continents
 crust, 14, 15
 major features, 15–20, 17
Contraction, 170, 170
Convection, 41, 43, 506
 inside Earth, 531–32
Convergence coasts, 443–44, 444
Convergent plate boundaries, 44–45, 497, 498, 499, 596–631
 continent-continent, 600, 601
 deformation at, 606–14
 factors influencing nature of, 601–4
 generation of magma at, 110–11
 mineral resources and, 716–17, 717
 ocean-continent, 599–600, 600
 ocean-ocean, 598–99, 600
 seismicity at, 604, 604–6
 types of, 598–600
 volcanic eruptions at, 618–23
Coral reefs, 439, 442
Core, 13–14, 14
 convection in, 531
Coriolis effect, 227, 456
Correlations, age, 198, 199
Covalent bond, 56–57
Crater Lake, Oregon, 98, 101
Craters, 97
Craton, 16
Creep, 281, 281–82, 282, 283
Cretaceous-Tertiary (KT) boundary, 758
Crevasses, 322, 377, 379–80
Cross-bedding, 125, 126, 466, 467
Crosscutting relations principle, 196, 197
Crust, 13
 formation of, 625–29
Crystallization, 67
Crystals, 61
 destruction of, 68–69
 faces, 64
 forms, 64
 growth of, 67, 67–68, 68
Crystal structures, 57
Cuestas, 672

Darwin, Charles, 442–43
Daughter isotopes, 202
Dead Sea transform system, 587–88, 588
Death Valley, California, 268, 327
Debris flows, 280, 284–85, 283
Decompression melting, 557, 559, 640
Deep-focus earthquakes, 511–12
Deep-marine sediment, 136
Deep water of oceans, 231
Deflation, 458
Deflation basins, 458, 458
Deformation
 at convergent plate boundaries, 606–14
 rock, 168–187
Dehydration, 616
Deltaic coasts, 446, 446
Deltas/delta systems, 130, 133, 322–26
Dendritic drainages, 299, 300, 314, 671
Density
 circulation of ocean and, 234–35
 of minerals, 65
 planetary, 5
Deposition
 coastal, 431–33
 by groundwater, 359–62
 river systems and, 317–26
 sedimentary systems and, 129–30
Desert climates, 241, 270
Desertification, 474–75
Desert pavement, 459, 459, 460
Deserts, 456–57, 457
Devil's Postpile, California, 261
Diamond, 61, 61, 65–66, 73, 152, 697–98
Diapirs, 185, 185, 638
Diatom, 122, 124, 139, 549
Differential erosion
 evolution of columns by, 674
 of folded mountain belts, 675–77, 677
 landscape development and, 662–63, 664
 stable platforms and, 672–74
Differential stress, 153
Differential weathering, 260
Differentiated planet, 13, 755
Differentiation of magma, 106–9
Dikes, 103, 105, 106
Dike swarms, 652
Diorite, 90, 91
Dip, 171, 171
Disappearing streams, 354–55
Discharge, 302
Disconformity, 194, 194
Dispersing system, 301
Dissolution, 253–54
Dissolved load, 303–4
Distributaries, 301, 322, 323
Divergent plate boundaries, 42, 42–43, 496–97, 497, 536–73
 earthquakes and, 524
 generation of magma at, 109–10
 mineral resources and, 715–16
Dolomite, 77
Dolostone, 123
Domes, 183, 183, 672
Downcutting, 310–311
Drainage basins, 299
Drainage patterns, 311–314
Drumlins, 396, 397
Ductile deformation, 168, 169
Dunes, 126, 132
Dust, 462–64, 463, 464

Earth, 7–9, 8
 internal structure, 13, 13–14
 as natural system, 31
 outer layers, 10–13, 15
Earthquakes
 Alaskan, 516, 516
 continental collision and, 605–6
 elastic-rebound theory and, 510, 511
 Hawaiian, 646, 647
 hazards of, 43, 514–21
 intensity of, 512–13, 513
 Izmit, Turkey, 518, 520
 Kobe, Japan, 517–18, 518
 locations of, 511–12
 magnitude of, 514
 plate tectonics and, 524–25
 prediction of, 521–23
 preparation for, 523–24
 radar interferometry and, 519
 San Francisco, 514, 516
 seismic waves and, 510–11, 511
 subduction zones and, 604–5, 605
 at transform boundaries, 590–91, 591
East African rift, 564, 565–66
Easter Island, 719–21, 721
Eccentricity, 413, 414
Echo sounding, 23
Eclogite facies, 161
Ecosphere, 24–25
Ejecta blanket, 729, 730
Elastic limit, 510
Electrons, 55
Element, 54–55
El Niño, 236, 237
Enceladus, 728, 746, 747, 748
End moraines, 388
Energy resources, 700–15
 fossil fuels, 706–712
 geothermal, 704–6
 hydroelectric, 703
 nuclear, 713–15
 renewable, 692, 700–6
 solar, 701–3
 tidal, 706
 wind, 703–4
Eolian (wind) systems. *See* Wind

- Epicenter, earthquake, 510, *511*, *513*
 Equilibrium, 32
 glacial, 380–81
 river systems and, 305–8, *306*
 Ergs, 470
 Eros, *752*
 Erosion
 coastal, 427–31, *436*
 by glacier systems, 381–82
 by groundwater systems, 349–59
 headward, 311–14
 by river systems, 309–16
 by wind, 458–61
 See also Differential erosion
 Erratics, 397, 397–98
 Eskers, 398, 397
 Europa, *724*, *725*, 724–25, 728, 742–45, *743*, *744*, *745*
 Evaporation, 228, 228–29
 Evaporation-precipitation balance, 229
 Evaporites, 124, 268, *268*, 698
 Everglades, Florida, *367*, 367–68
 Exfoliation, *261*, 263
 Extending flows, 378–79, *378*
 Extension, 170, *170*
 at convergent boundaries, 612–14, *613*
 in transform fault systems, 582–83, *583*
 Extrusive rocks, 83, 88–89
- Faceted spurs, 679, *680*
 Facies, 130
 Faults, *173*, 173–77, *175*, *176*, *177*
 normal, *174*, *175*
 observed movement on, *177*
 reverse, *174*
 San Andreas, 43, 45, *177*
 strike-slip, *174*–77
 thrust, *174*
 Fault scarps, 678
 Faunal succession, 195–96
 Feldspars, *72*
 Felsic minerals, 72–74
 Fissures, *93*, 95, 543, *544*
 Flash floods, 330
 Flood basalts, *95*, 95–96, 638, 680–83, *683*, *684*
 mantle plumes and, 654–55
 Floodplains, *318*, 317–20
 flooding on, 328–330
 Floods, 327–30, *328*
 Fluvial systems, 130, *131*
 Focus, earthquake, 510, *511*
 Folded mountain belts, 15, 16–17, *19*, 180, 599
 differential erosion of, 675–77, *677*
 Folds, 178–85
 anticlines, *178*, 180
 belts of, 180
 hinge line, 180
 hinge plane, 180, *180*
 limbs, 180
 monoclines, *178*, 180
 overturned, *178*, 181
 plunging, 180, *180*, *181*
 synclines, *178*, 180
 Foliated rocks, 155–57
 Foliated textures, 153–54, *154*
 Foliation, 153
 Footwall, *173*, 174
 Forearc ridge forms, 599
- Formations, 116–17, *117*, 125
 Fossil fuels, 706–12
 Fossils, 117, *118*, 128
 Fractional crystallization, 108, *109*
 Fractures, 168
 Fracture zones, 540, 576
 Frank slide, Alberta, *287*
 Friction, 505
 Fringing reefs, 440
- Gabbro, *90*, 91
 in ophiolites, 553
 Ganges River, India, *329*, 330–31
 Ganymede, *728*, *743*, *744*, 745–46
 Gas, 58
 Gas giants, 726–27
 Geodes, 362
 Geographic Information Systems (GIS), 289
 Geologic column, 198–200, *199*
 Geologic maps, 179
 Geologic systems, 28–51, *34*–35
 Geologic time, 188–215
 calibration of, 209–11
 dating methods, 201–9
 discovery of, 190–92
 geologic column for, 198–200, *199*
 magnitude of, 214
 relative ages, 195–97
 Geology, 4
 Geothermal energy, 349, 704–6, *705*
 Geothermal gradient, 46
 Geysers, 347, 349, *350*, *351*
 Giant's Causeway, Ireland, *92*
 Glacial erosion coasts, 446, *446*
 Glacial plucking, 381
 Glacial striations, 382, *383*
 Glacier systems, 39–40, 372–419, *375*
 causes of, 412–416
 continental, 388–98
 equilibrium, 380–81
 erosion by, 381–82
 glacial ice, 374–75
 glacier flow, 376–79, *377*
 Pleistocene, 398–411
 pre-Pleistocene, 411–12
 sedimentary rocks and, 129–30, *132*
 valley, 382–88
 Glassy texture, 85, *86*
 Global climate change, 243–45
 Global positioning system (GPS), 592
 Gneiss, *156*, 157
 Gneissic foliation, 153
 Graben, *174*, *175*
 Graded bedding, *126*, 126–27
 Graded streams, 305
 Gradient, 302
 Grand Canyon, Arizona 116–17, *117*, *212*–13, *316*, *316*
 Grand Teton Mountains, Wyoming, *251*
 Granite, 74, *74*, 258–59
 Granular disintegration, *261*, 261
 Granulite, 158
 Granulite facies, 160
 Gravimeters, 569
 Gravity, 48–49
 slope processes and, 276
 variations, hidden continental rift and, 569
 Gravity anomaly, *547*, 547–48
- Great Lakes, United States, 403, *404*
 Greenhouse effect, 223
 Greenhouse gases, 245
 Greenland, 389–90, 628, 650
 Ice Sheet, *391*, *392*
 Greenschist facies, 160, *161*
 Greenstones, 158
 Groundmass, 88
 Ground moraines, 397
 Groundwater processes, 699–700
 Groundwater systems, 39, *40*, 336–71
 alteration of, 363–69
 aquifers and, 340
 artesian water/confined aquifers and, 346–47
 deposition by, 359–62
 erosion by, 349–359
 flowing, computer models of, 366
 groundwater movement, *341*, 341–42
 groundwater resources, *341*, 341–42
 natural discharge of, 342–45
 porosity/permeability and, 338–39
 thermal springs/geysers and, 347–49
 water table and, 340, *340*
 Guilin, China, *322*–23, *358*
 Gulf of California transform system, 586–87
 Gulf Stream, *235*
 Gypsum, 77, *121*, 124
- Hale-Bopp comet, *752*, *753*
 Half-dikes, 550, *552*
 Half-life, 202
 Halite, 77
 Halls Harbor, Nova Scotia, *449*
 Hanging valleys, 388, 428
 Hanging wall, *173*, 174
 Hardness, 65, *65*
 Hawaiian Islands, 45, 96, *635*, 643–49, *644*
 earthquakes, 646, *647*
 Hawaiian plume, 643–45
 volcanism, 646–47
 Headland, 424
 Headward erosion, 311–13, *312*, *313*
 Heat balance, 224–26, *226*
 Heat flow, *547*, 547–48
 plate tectonics and, 46
 Heat, internal, 9
 Hess, H. H., 488
 High-grade metamorphism, 152
 Himalaya Mountains, *480*–81, 498, 609–12, *611*
 Hinge line, 180
 Hinge plane, 180, *180*
 Hogbacks, *664*, 672, *673*, *678*
 Hoover Dam, 49
 Hornfels, 158
 Horns, 388
 Horst, *174*, *175*
 Hotspots, 632, *635*
 characteristics of, 636–38
 Hawaiian, 643–47
 Iceland, *636*, 649–51, *651*
 Yellowstone, *633*
 Hotspot track, 643
 Humidity, 221
 Hutton, James, 190–92
 Hydraulic head, 341
 Hydrocarbon traps, 709–10
 Hydroelectric power, 703, *703*
 Hydrologic system, 33, 33–40

I-4 Index

- Hydrolysis, 254–55
Hydrosphere, 11, 12, 37
Hydrothermal alteration, 153, 558–60, 695
Hydrothermal fluid, 695, 695
Hydrothermal ore deposits, 696, 696
- Ice Ages, 398–417
Iceland, 394, 504, 537, 553–555, 555, 556
 mantle plume beneath, 635, 636, 649–51, 650
Ice layers, 208, 209
Ice wedging, 251, 125–52
Icy planetary bodies, 727, 742–50
Ida, 751–52, 752
Igneous rocks, 80–113
 classification of, 89
 extrusive, 91–99
 intrusive, 102–106
 nature of, 82–85
 in North America, 84
 plate tectonics and, 109–111, 111
 textures of, 85–88, 86
 types of, 88–94
Iguazu Falls, South America, 296–97
Impact craters, 9, 10, 728–30, 729
Inclined seismic zone, 604, 605
Inclusion principle, 196–98, 198
Inclusions, 106
Index minerals, 159–60
Industrial minerals, 696
Inner core, 14
Inner planets, 5, 9, 26, 531, 727, 727–41
 See also specific planets
Intermediate-focus earthquakes, 511
Internal heat, 9
Intraplate seismicity, 525, 525
Intraplate settings, mineral resources and, 717
Intrusions, magmatic, 102–4, 105
Intrusive rocks, 83, 87, 102–6
Inverted valleys, 682, 683
Io, 742, 745
Ionic bond, 56–57
Ionic substitution, 62
Ions in solution, 268
Island arc magmatism, 614, 615
Island arcs, 22, 600, 605
Isostasy, 48–49, 50
Isotopes, 56
Izmit, Turkey earthquake, 518, 520
- Jet stream, 228–29
Joint-block separation, 260, 261
Joints, 172, 172–73
Jupiter, 5, 6, 742, 743
 satellites of, 742–46, 743–45
- Karst topography, 354–58, 355, 356
Kettles, 395, 397
Kilauea volcano, Hawaii, 97, 643–47, 644
Kobe, Japan earthquake, 517, 518
Komatiite, 89, 90, 91–92
Krakatau, Indonesia eruption, 619, 619–20
- Laccoliths, 104, 106
Lag deposits, 457, 459, 459
Lagoons/lagoon systems, 134, 134
Lahar, 284, 285
Lake Agassiz, Canada, 405
Lake Bonneville, United States, 49, 405–6, 407
- Lake Chad, 475
Lake Okeechobee, Florida, 367, 368
Lakes, Pleistocene glaciation and, 403, 403–6
Laki eruption, Iceland, 553–55, 556
Laminae, 120
Land degradation, 474–75, 475
Landscapes
 continental, factors influencing, 660–63
 continental rifts and, 678–80
 flood basalts and, 680–83
 folded mountain belts and, 675–77
 magmatic arcs and, 684–85
 plate tectonics and, 658–87
 shield evolution and, 664–69, 665
 stable platforms and, 670–75
 succession in development of, 196, 198
Landslides, 285–88, 288
 hazard maps for, 289
Lateral moraines, 370, 370
Lateral slip, 384, 384
Lava, 83
Lava domes, 97, 100
Lava tubes, 92, 95
Layered gabbro, 550, 553
Leached, 253, 364
Leaky transform systems, 580
Lechugilla Cave, New Mexico, 360–62, 367
Lee slope, 467
Lift, 461
Limbs, 180
Limestone, 121, 122, 259
Linear dunes, 469, 468
Liquefaction, 518
Liquids, 57
Lithosphere, 14
 See also Oceanic lithosphere; Plate tectonics
Loess, 407, 471–74, 471, 473
Longitudinal profile, 302
Longshore currents, 425
Longshore drift, 425–27
Low-grade metamorphism, 152
Luster, 65
Lyell, Sr., Charles, 191, 201
- Madagascar slope failures, 277, 278
Mafic, 74–76
Magma, 82, 83
 generation of
 in continental collision zones, 617
 at convergent plate boundaries, 110–11, 615
 at divergent plate boundaries, 109–10
 in mantle plumes, 111
 in subduction zones, 615–17, 616
 mafic, 83
 origin and differentiation of, 106–9
 silicic, 83–84
Magma mixing, 108, 109
Magmatic arcs, 684, 684–85, 685
Magmatic differentiation, 107, 108
Magmatic segregation, 694
Magnetic anomalies, 490
Magnetic mapping, 626
Magnetic reversals, 489–93
Magnetism, 66
Magnetosphere, 223
Mammoth Cave, Kentucky, 344, 354, 354
Mammoth Hot Springs, Wyoming, 362, 363
- Mantle, 13
 convection in, 531–32
 seismic tomography of, 533
Mantle plumes, 41, 45, 632–57
 beneath continents, 651–55
 beneath ocean floors, 642–51
 characteristics of, 636–38
 climate change and, 656
 continental rifting and, 654–55
 evidence for, 634–36, 636
 evolution of, 638, 638–39
 flood basalts and, 654–55
 generation of magma in, 110–11, 639–42
 Hawaiian, 643–45
 Iceland, 636, 636, 649–51, 651
 mass extinctions and, 656
 at midocean ridges, 649–51
 Yellowstone, 652–54
Mantle resistance, 505
Marble, 156, 158
Marginal sea coasts, 444, 445
Maria, 730, 731
Marine deposition coasts, 446, 447
Mars, 5, 8, 9, 734–38
 crust, 18
 landslides, 737
 life on, 737–38, 738
 stream channels, 737
 surface, 735, 736
 volcanoes, 736
Mass extinction, 758
Massive gabbro, 550
Mass movements
 factors influencing, 276–77
 slope systems and, 294, 294
 types of, 280–93
Mass spectrometry, 415
Matrix, 88
Matter, 54–59
 states of, 57–58
Meanders, 317, 318
Medial moraines, 384, 384
Mekong Delta, Vietnam, 325, 326
Mélange, 141, 162, 606
Melt, 68
Mercury, 5, 8, 9, 18, 732–34, 734
Mesas, 671, 672
Mesosphere, 14, 222, 223
Mesozoic Era, 200
Metabasalt, 560
Metaconglomerate, 156, 158
Metallic bond, 57
Metamorphic rocks, 145–65
 facies, 160
 kinds of, 155–59
 nature of, 146–48, 147
 origin of, 148–55
 plate tectonics and, 161–63
 source material for, 159
Metamorphic zones, 159–161
 in Japan, 624
Metamorphism, 146
 chemically active fluids and, 152–53
 contact, 150
 at convergent margins, 624, 623–25,
 high-grade, 152
 low-grade, 152
 ore deposit, 696–97

- ocean-ridge, *163, 588–61*
- pressure changes and, *152*
- regional, *159–61, 696*
- temperature changes and, *148–50, 153, 149*
- at transform plate boundaries, *591–93*
- Metasomatism, *152*
- Metastable
 - mineral, *66, 150*
 - position, *33*
- Meteorite, *26, 728*
- Methane hydrate, *713, 714*
- Mexico City, Mexico, *368, 369, 515*
- Mica, *72, 74*
- Midocean ridge, *538–48, 539, 541, 542, 543*
 - cooling and subsidence of, *540–42*
 - gravity and, *547–48, 547*
 - heat flow and, *547, 547–48*
 - magmatism at, *557–58*
 - magnetic anomalies and, *546–47*
 - seismicity of, *545–46*
 - topography of, *520*
- Migmatite, *157, 157*
- Milankovitch climate cycle, *413–14, 414*
- Mineral resource, *692–700*
 - plate tectonic controls on, *715–718, 717*
 - processes forming, *693–700*
- Mineral, *52–79*
 - common, *73*
 - composition of, *62*
 - destruction of, *68–69*
 - growth of, *67–68, 67, 68*
 - nature of, *59–66*
 - nonsilicate, *77*
 - physical properties of, *62–66*
 - rock-forming, *71–77*
 - silicate, *70–76*
 - stability range, *66*
 - structure of, *59–62, 61*
 - X-ray diffraction and, *60*
- Mississippi River, *302, 304, 319–320, 328–29, 329*
 - Delta, *324, 325–326*
- Mohorovičić discontinuity, *529*
- Mohs hardness scale, *65*
- Moment magnitude, *514*
- Monocline, *178, 180*
- Mont Pelée, West Indies eruption, *618, 620, 623*
- Moon, *5–9, 6, 8, 18, 727–32, 731*
 - history, *730, 732*
 - impact processes, *728–30, 755, 755*
 - surface, *730, 731*
- Moraine, *384, 384*
- Mount Kilimanjaro, Kenya, *565*
- Mount Rainier, Washington, *100*
- Mount St. Helens, Washington State, *620–23, 621, 622*
- Mount Vesuvius, Italy eruption, *618–619, 618*
- Mud crack, *118, 127–28*
- Mudflow, *284–85*
- Mudrock, *120*
- Multiring basin, *730*
- Muscovite, *74*
- Mylonite, *157, 578*
- Mylonitic texture, *155–159, 155*
- Nappe, *608–09*
- Natural arches, *673, 675*
- Natural gas, *709–13*
- Natural levee, *319, 319*
- Natural system, *31–32*
- Nebula, *753, 754*
- Neck, volcanic, *104, 106*
- Neptune, *5*
 - satellites of, *748, 750*
- Neutron, *55*
- New Madrid, Missouri, earthquake, *525*
- New Zealand, *99, 101, 588–89, 590*
- Niagara Falls, New York, *312*
- Niger Delta, Nigeria, *326, 325*
- Nile River, Africa
 - delta, *34, 38, 325–26*
 - river equilibrium and, *307, 306–308*
- Nonconformity, *193, 194*
- Nonfoliated metamorphic rock, *157–58*
- Nonrenewable resource, *692*
- Nonsilicate mineral, *77–78*
- Normal fault, *174, 175*
- Normal polarity, *489, 491*
- Northridge, California earthquake, *515, 516–17, 517*
- Nuclear energy, *713–15*
- Nucleus, atomic, *54*
- Nuclides, chart of, *201*
- Numerical age, *190*
- Ocean basins
 - crust, *13–14, 15, 17*
 - major features, *13, 21–24*
 - mapping from space, *23*
- Ocean Drilling Program, *140*
- Ocean floor
 - cooling and subsidence of, *540, 542*
 - geology of, *487–88*
 - magnetic fabric of, *504*
 - metamorphism, *163, 558–61*
 - methods of studying, *539–40*
 - sediment on, *493–94*
 - spreading, *488*
- Oceanic lithosphere, *548–62*
 - abyssal hills and, *561*
 - deep submersible observation of, *552–53*
 - Iceland, *553–55*
 - ophiolite, *548–52, 549*
 - origin and evolution of, *556–62*
 - seismic studies of, *548*
 - visualizing, *555–56, 557*
- Oceanic plateau, *635, 642*
- Oceanic ridge, *17, 21, 538–553, 542, 543*
- Oceanic trenches, *17, 21–22*
- Oceans
 - coastal upwelling of, *236, 236*
 - composition of, *230–31*
 - energy and motion of, *232–39*
 - global circulation of, *236–39, 239*
 - Pleistocene glaciation and, *407–408*
 - thermal structure of, *231, 230–31*
- Oil, *700–701, 709–10, 712, 710*
- Oil shale, *712*
- Olivine, *75, 75*
- Oman ophiolite, *549, 549–50, 550, 551*
- Ontong-Java Plateau, *642, 643*
- Oolite, *122*
- Open system, *31*
- Ophiolite, *548–52*
 - transform fault zones in, *582*
- Optical microscope, *87*
- Ore deposits. *See* Mineral resources; Minerals
- Orogenic belt, *608*
- Outer core, *14*
- Outer planet, *5, 6, 726–7, 742–50*
 - See also* specific planets
- Outer swell, *599*
- Outlet glacier, *392, 392*
- Outwash plain, *375, 387, 388, 396*
- Overtaken fold, *181–183, 181*
- Oxbow lake, *317, 318*
- Oxidation, *256–7*
- Oxide mineral, *77*
- Ozone, *221–22*
- Ozone hole, *244, 244*
- Ozone layer, *222, 244*
- P-wave, *511, 527–8*
- Pahoehoe flow, *92, 93, 95*
- Paired metamorphic belt, *624, 623–4*
- Paleomagnetism, *488–93, 489, 490*
- Paleozoic Era, *200*
- Pangaea, *483*
- Parabolic dune, *470, 468*
- Parent isotope, *202*
- Partial melting, *107–8*
- Passive continental margin, *562, 568*
- Passive-margin coast, *444, 444–5*
- Peat, *706–707*
- Pecos River, New Mexico, *313, 314*
- Pediment, *679, 681*
- Pegmatite, *88, 695*
- Perched water table, *340*
- Peridotite, *90, 97*
- Periodic table, *57*
- Permafrost, *282*
- Permeability, *258, 339*
- Peru earthquake, *520–521*
- Petrified Forest National Park, Arizona, *348, 361–2, 362*
- Petroleum, *709–10, 712*
- Phaneritic texture, rocks with, *86, 88–91*
- Phanerozoic Eon, *200*
- Phenocryst, *88*
- Photovoltaic cell, *702–3, 702*
- Phyllite, *155*
- Physical weathering, *251, 251–3, 252*
- Pillar, *672, 672*
- Pillow lava, *97, 99, 543, 544, 549–551, 551*
- Pinnacle, *672, 672*
- Placer deposit, *697, 698*
- Plagioclase, *72*
- Planetsimal, *754*
- Planet, *724–59*
 - impact processes in origin of, *755–56*
 - physical characteristics, *728*
- Plastic deformation, *148*
- Plateau basalt, *652*
- Plateau, *671, 672*
- Plate motion, *43–47, 500–503, 501*
 - in last 200 million years, *570–71, 550, 552*
 - rates of, *40–41, 480–87, 502–503*
- Plate tectonics
 - development of theory, *487–94*
 - driving mechanisms for, *503, 505–506*
 - earthquakes and, *524–25*
 - igneous rocks and, *161–63*
 - metamorphic rocks and, *161–63*
 - mineral resources and, *715–18, 717*

I-6 Index

- plate boundaries and, 496, 496–97
- plate geography and, 495–96
- plate motion and, 45, 47, 500–502
- river systems and, 330–33
- sedimentary systems and, 139–41, 141
- shoreline classification and, 444, 443–45
- See also Tectonic system
- Platform reef, 440, 442
- Playa lake, 679, 681
- Pleistocene Epoch, 399
- Pleistocene glaciation, 398–411, 398
 - drainage system modification, 402–403
 - isostatic adjustment, 407
 - lake creation, 403, 403–405
 - ocean, 407–409
 - pluvial lake, 405–406, 406
 - sea level change, 405
 - wind effects, 407
- Plucking, glacial, 378, 381, 382, 384
- Plume head, 638, 638
- Plume, mantle. See Mantle plumes
- Plume tail, 638, 688
- Plunge, 180, 180
- Plunging fold, 180–81, 181
- Pluto, 728, 749, 751
- Pluton, 103
- Pluvial lake, 405–406, 406
- Point bar, 317, 318
- Polar climate, 241, 270
- Polarity chron, 490, 491
- Polar wandering, 488–89
- Pole of rotation, 500
- Polymorphism, 62
- Population growth, limits to, 718–719
- Pore space, 338, 339
- Porosity, 258, 338
- Porphyritic texture, 85–88, 86
- Porphyry copper deposit, 696, 696
- Potassium-argon (K-Ar) clock, 205
- Pothole, 310, 311
- Precambrian Eon, 200
- Precession, 413, 414
- Precipitation, 224, 225
- Pressure, 58, 59, 152
- Pressure ridge, 92, 95
- Primary (P) wave, 511
- Proton, 55
- Proterozoic, 198–200
- Pull-apart basin, 583
- Pumice, 94
- P-wave, 511
- Pyroclastic-fall tuff, 94
- Pyroclastic texture, 86, 88, 94
- Pyroxenes 75

- Quartz, 72
- Quartzite, 156, 158

- Radar interferometry, earthquake deformation and, 519
- Radioactive decay, 9, 202, 202
- Radioactivity, 9, 202
- Radiogenic heat, 9
- Radiometric dating, 201–207
 - problems in, 207
- Rain forest, 225, 228, 241
- Rain-shadow desert, 241, 454, 456
- Rays, impact crater, 730
- Recessional moraine, 388
- Recharged aquifer, 326, 340
- Recrystallization, 69
- Recycle, 692
- Red Sea Rift, 35, 42–43, 566, 568
- Reefs/reef system, 129–30, 135, 441
 - ecology of, 440
 - types of, 440
- Regional metamorphism, 150, 152, 159–61, 161, 624, 696–97
- Regolith, 263, 264
 - removal of, 309–10
- Regression, 137
- Relative dating, 195–97, 197
- Relief, 16
- Renewable resource, 692
- Reservoir rock, 709
- Resources
 - depletion of, population growth and, 718–19
 - energy, 700–15
 - mineral, 692–700
 - plate tectonics and, 715–718
- Reverse fault, 174
- Reverse magnetic polarity, 490, 491
- Rhyolite, 86, 89, 90, 91, 554–555, 562, 618, 650–51
- Richter Scale, 514
- Ridge and Valley Province, 677, 678
- Ridge jump, 651
- Ridge offset, 584–85
- Ridge-push, 505
- Ridge-ridge transform fault, 578, 579
- Ridge-trench transform, 578, 578
- Rifts
 - Basin and Range province, 174, 562–64, 563
 - East African, 565, 566, 565–66
 - Red Sea, 566
- Rift system, East Africa, 9
- Rift valley, 21, 488
 - of midocean ridge, 540, 541
- Rift zone, 643–644
- Ring of fire, 603, 604
- Rip current, 425
- Ripple mark, 118, 127–28
- River flow, rainfall sources for, 229
- River system, 38, 38, 296–335
 - age of, 332
 - characteristics of, 298–302
 - climate and, 330–331
 - equilibrium gradients in, 305–308
 - erosion by, 309–316
 - flood, 327–30
 - geologic importance of, 298, 299, 300
 - order in, 301–302
 - plate tectonics and, 331–32
 - stream deposition processes, 317–26
 - stream flow dynamics, 302–305
- Roches moutonnées, 381–382, 382
- Rock avalanches, 287, 288–90
- Rock deformation, 166–87
 - principles of, 168–70
 - rock structure geometry and, 171–85
- Rockfall, 280, 287, 288
- Rock-forming mineral, 71–76
- Rock glacier, 290, 290
- Rock salt, 124
- Rockslide, 280, 287
- Romanche fracture zone, 580, 580–81
- S-wave, 511, 527
- Sahara desert, Africa, 456, 460, 464, 470, 475
- Sahel, Africa, 474–75
- Salinity, 230
- Saltation, 303, 462
- Salt dome, 185, 185
- Saltwater encroachment, 365, 365
- San Andreas fault system, 43, 45, 177, 574–75, 576–86
- San Clemente Island, California, 439
- Sand dune, 465, 465–70, 466
 - types of, 467–70
- Sand sea, 469, 470–71, 470
- Sand sheet, 465, 469
- Sandstone, 119–20, 121, 259
- San Francisco earthquake, 514, 516
- Santa Barbara, longshore drift at, 426–27, 427
- Satellite sensor, 238
- Saturn, 5, 747
 - satellites of, 746–747
- Scarp, 174
- Schist, 156, 157
- Schistosity, 157
- Sea arches, 428, 430
- Sea cave, 428, 430
- Sea cliff, 428, 431
- Seafloor. See Ocean floor
- Seafloor metamorphism, 163, 163, 558–61, 697
- Seafloor spreading, 488, 490, 492
- Sea ice, 231, 232, 233
- Seamount, 22, 21, 22
 - evolution of, 647–49, 648
- Sea stack, 428, 429, 430
- Secondary (S) wave, 511
- Sedimentary fluid, 699
- Sedimentary processes, 693, 697–99
- Sedimentary rock, 114–43
 - plate tectonics and, 139, 141, 141
 - sedimentary systems and, 129–37
 - stratigraphic sequence, 137–39
 - structures in, 125–28
 - types of, 118–24
- Sediment load, 303, 303–304, 306
- Seep, 343, 344
- Seif dune, 468, 469
- Seismic imaging, three dimensional, 711
- Seismicity, 508–535, 525
 - at convergent plate boundaries, 604–606
 - global patterns of, 524–5
 - intraplate, 525
- Seismic ray, 526
- Seismic risk map, 516, 523
- Seismic tomography, 533
- Seismic wave, 510–11, 526–30
 - velocity discontinuities, 529–31
- Seismograph, 510
- Sensitive High Resolution Ion Microprobe (SHRIMP), 204
- Sequence stratigraphy, 137–39, 139
- Serpentine, 553
- Serpentinite ridge, 584
- Shadow zone, 527, 527, 528
- Shale, 120, 121, 259
- Shallow-focus earthquake, 511, 545–546
- Shallow-marine system, 130, 135
- Shattering, 261
- Shear, 169, 576
- Shear wave, 511

- Sheeted dike complex, 550, 552
 Sheeting, 252, 253
 Shield
 continental, 16–18, 18, 662
 evolution of, 628, 664–69, 665
 Shield volcano, 96, 634
 Shoemaker-Levy comet, 756, 756, 757
 Shoreline system, 39–40, 133, 426–53
 coastal classification, 442–47
 coastal deposition, 431–33
 coastal erosion, 427–31, 436
 evolution of, 434–38
 longshore drift, 425–27
 reef, 439–42
 tide, 448, 447–48, 449
 tsunami, 448–51, 450, 451
 waves, 422–25
 Siccar Point, Scotland, 192
 Sierra Nevada, California, 103, 105, 253, 327
 Silicate mineral, 70–72
 clay, 76
 felsic, 72–74
 mafic, 74–76
 Silicic eruptions, products of, 97–102
 Silicic magma, 82–83
 Silicon-oxygen tetrahedron, 70, 71
 Sill, 105, 106
 Siltstone, 120
 Sinkhole, 351
 Slab-pull, 505
 Slate, 155, 156
 Slaty cleavage, 155
 Slip face, 467
 Slope retreat, 321
 Slope system, 274–95
 Slump block, 280, 287, 286
 Snake River Plain, Idaho, 344, 652, 653, 652–53, 668, 684
 Snow line, 374
 Soil, 265–68
 Soil profile, 265, 265
 Solar energy, 702, 701–703
 Solar radiation, 224–26, 226
 Solar system, 5, 6, 726–59
 origin of, 753–57
 See also Inner planets; Outer planets
 Solid, 57
 Solifluction, 282, 283
 Solution valley, 354
 Sorting, 119, 120, 129
 Source rock, 107, 709
 Spatter cone, 92, 95
 Speleothem, 359
 Spheroidal weathering, 263–64, 262, 263
 Spit, 432, 433, 434
 Splay, 322, 323
 Spreading rate, 540, 541, 584–85
 Spring, 343, 344–345
 Stable platform, 16, 18, 19, 662, 671, 670–675
 differential erosion and, 672–73
 landscape development and, 670–75
 of North America, 673–74
 Stalactite, 359–360, 359
 Stalagmite, 359
 Star dune, 468, 470
 Starting plume, 638, 639
 oceanic plateaus/flood basalts and, 642–43
 Stock, 107
 Storm surge, 438, 439
 Strain, 168
 Strata, 116
 Stratification, 125
 Stratosphere, 221–22, 223
 Stratovolcano, 97, 100
 Streak, 66
 Stream deposition coast, 446, 446
 Stream erosion coast, 446, 446
 Stream piracy, 312–313, 313, 314
 Stream terrace, 321, 322
 Strength, 168
 Stress, 168
 Striation, glacial, 382, 383
 Strike, 171, 171
 Strike-slip fault, 174–77, 175, 498
 Strike valley, 671–72, 672
 Strip mining, 708
 Subaqueous mass movement, 290–91, 291, 293
 Subduction, 44
 Subduction zone, 497, 598–99
 compression at, 606–608
 earthquakes and, 524–25, 604–605, 605
 extension at, 612
 generation of magma in, 515–17, 616
 thermal structure of, 602–603, 602
 Submarine fan, 130
 Subsequent stream, 674
 Subsidence, 292–293, 292, 542
 groundwater and, 368–69, 368
 Sun, 5, 6, 222
 Superposed stream, 313
 Superposition principle, 195
 Surface water of oceans, 231
 density-driven circulation of, 235–36, 235
 wind-driven circulation of, 232–33, 234
 Surface wave, 511
 Suspended load, 303
 Suspension, 463
 Swash, 423
 Systems, 32–38
 Syncline, 180, 178

 Tahiti, 441
 Talus, 253
 Talus cone, 253, 254, 274
 Tangshan, China earthquake, 520
 Tectonic system, 40–45, 41, 495
 Tectonite, 552
 Temperate climate, 241, 270
 Temperature
 metamorphism and, 148–52, 149
 states of matter and, 57–58, 59
 Tension, 170
 Tephra, 94
 Terrace
 stream, 321, 321, 322
 wave-cut, 421, 428, 439, 443
 wave-built, 428, 428
 Terrane, accreted, 627–629, 627
 Terminal moraine, 388
 Terrestrial planet, 8, 9
 Tetrahedron, silicon-oxygen, 70
 Textures
 of igneous rocks, 85–86, 88
 of metamorphic rocks, 155–59
 of sedimentary rocks, 118–22, 121
 Thermohaline circulation, 234
 Thermosphere, 222–23, 223
 Thin section, 91
 Thousand Springs, Idaho, 344, 344–45
 Threshold velocity, 304
 Thrust fault, 174, 175
 Tibesti, Chad, 460, 462
 Tidal delta, 452, 452
 Tidal energy, 706
 Tidal flat, 130, 134
 Tidal heating, 742
 Tide, 447–48, 448, 449
 Till, 396, 397
 Time
 numerical (absolute), 201
 radiometric measurement of, 201–207
 relative, 195
 Titan, 728, 746, 747
 Tombolo, 432–433, 435
 Tonga trench, 605
 Topographic map, shuttle radar, 20, 481–482, 300
 Tower karst, 355
 of China, 358–59, 358
 Transform fault, 576
 Transform plate boundaries, 43, 43–44, 574–95
 continental, 585–89
 Dead Sea, 587–88
 earthquakes at, 524, 590–91
 magmatism at, 591–93
 map, 577
 metamorphism at, 591–93
 midocean ridges and, 540
 mineral resources and, 717
 oceanic, 579–85
 processes at, 582–85
 San Andreas, 586–89, 586, 587, 594
 thermal structure, 583–84
 types, 577–78
 Transgression, 137
 Transporting system, 300
 Transpiration, 37
 Transpression, 583
 Transtension, 583
 Transverse dune, 467–68, 468
 Tree ring dating, 207, 207–208
 Trellis drainage pattern, 313, 674
 Trench, 21, 23, 599
 Trench-trench transform, 578, 578
 Tributaries, 299
 Triton, 748, 750
 Tropical climate, 240–41, 269–271
 Troposphere, 221, 223
 Tsunami, 448–51, 451, 519
 Tuff, 91, 94, 98, 102
 Turbidite, 126
 Turbidity current, 126–27, 127, 128
 Turbulent flow, 303

 Ultramafic igneous rock, 89
 Unconfined aquifer, 340
 Unconformity, 137, 192–94
 Uniformitarianism, 190–92
 Upwelling, coastal, 236–37, 237
 Ural Mountains, Russia, 601
 Uranium deposit, 713–14, 716
 Uranus, 5, 747–748, 749
 satellites of, 723–24, 725
 Urbanization, river equilibrium and, 308, 308

I-8 Index

- Vaiont Dam, Italy, 277–78, 278
Valles caldera, New Mexico, 102
Valley and Ridge province, 183
Valley glacier systems, 375–376, 382–88
Vatnajökull glacier, Iceland, 394
Varves, 208, 397, 396
Vein, 173, 696
Velocity, stream flow, 302
Vema fracture zone, 553, 555
Ventifact, 459, 460, 461
Venus, 5, 6, 7, 8, 739, 739–40
 corona, 741
 dome, 741
 impact crater, 741
Vesicle, 87
Vesuvius, 618–619, 618
Viscosity
 of air, 461
 of ice, 376
 of magma, 83
Volatile, 84
Volcanic arc, 599
Volcanic ash, 93, 96
Volcanic bomb, 93, 96
Volcanic glass, 85, 86
Volcanic neck, 104, 106, 683
Volcanoes, 43, 97, 557–59, 591–93, 614–23

Water movement, global patterns of, 228
Water table, 340, 340
 changes in position of, 367–68

Water vapor, 223, 224
Wave base, 423
Wave-built terrace, 420, 429
Wave crest, 422, 423
Wave-cut cliff, 428, 429
Wave-cut platform, 428, 429
Wave erosion coast, 446, 447
Wave height, 422
Wavelength, 422, 423
Wave period, 423
Wave refraction, 423–4, 425
Weathering, 129, 248–73
 chemical, 253–57
 climate and, 268–70
 differential, 260
 major rock types and, 257–59
 ore deposits and, 693, 699–700
 physical, 251–53
 products of, 260–68
 rates of, 270–71
 reactions, for common minerals, 257, 259
Wegener, A., 482–84
Welded tuff, 98, 102
Well, 345–46
White smoker, 561
Wind, 40, 132, 454–77
 energy, 703–704, 704
 erosion by, 458–60
 global aspect, 456–57
 loess deposits by, 471–74
 sand deposits by, 468–71
 sediment transportation by, 461–64
Wind shadow, 456
Within-plate tectonics, 45

X-ray diffraction, structure of minerals and, 56
X-ray fluorescence spectrometry, 641

Yardang, 459–60, 461, 462
Yazoo stream, 319
Yellowstone National Park, 45, 632–33
Yellowstone plume, 652–54

Zeolite facies, 160
Zion National Park, Utah, 127, 467, 471, 673
Zone, metamorphic, 150, 159–61
Zone of ablation, 374
Zone of accumulation, 374
Zone of aeration, 340
Zone of saturation, 340