

# Index

- Accretion, lunar  
  geochemical constraints, 4
- Age, lunar, 120-123
- Ages, exposure  
  *see* exposure ages
- Agglutinates, 41, 71, 169, 230, 236, 237  
  241, 248, 249, 252, 261-269  
  chemistry, 263-267  
  and darkening of crater rays, 169  
  defined, 261, 263  
  grain size, 230, 267-269, 272, 274  
  origin, 263, 264, 269,  
  shape, 263
- Agglutination dominated stage  
  of soil development, 280
- Alpes Formation, 182
- Al/Si orbital data, 144, 219, 220, 260  
  and mare-highlands boundary, 238, 240
- Altimetry, laser, 119, 120, 135
- Ancient meteoritic component  
  characteristics, 37
- Annular mountains, 145
- Antidunes  
  *see* base surge, antidunes
- Apennine Bench  
  Formation, 142-144
- Apennine Front, 47, 48, 207, 208, 257, 260,  
  261
- Apennine Mountains, 123, 128, 184, 198
- Apenninian Series, 209
- Apollo 11, 42, 181, 245, 251, 271
- Apollo 12, 24, 42, 163, 181, 231, 232, 260  
  262, 263, 270, 271
- Apollo 14, 136, 137, 140, 181, 182, 184, 185,  
  186, 241, 243, 245, 246, 251, 257, 258,  
  259, 260, 261, 272
- Apollo 15, 47, 48, 50, 56, 119, 147, 153,  
  164, 170, 181, 184, 198, 208, 231, 233,  
  234, 237, 245, 246, 255, 257, 258, 259,  
  260, 273, 278
- Apollo 16, 119, 136, 142, 143, 144, 181, 209,  
  210, 211, 212, 213, 214, 221, 232, 255,  
  256, 266, 268, 272, 278
- Apollo 17, 56, 58, 119, 136, 170, 171, 181,  
  255, 256, 260
- Archimedes, 142
- Ariel satellites, 23
- Aristarchus Plateau, 153, 172
- Asteroids, 22, 23, 25, 26, 40
- Asthenosphere, earth's, 7
- Asthenosphere, lunar  
  *see* lower mantle
- Authigenic overgrowths  
  on plagioclase grains, 195, 215  
  on pyroxene grains, 196
- Autolycus, 261
- Ballistic ejecta  
  *see* ejecta, ballistic
- Basalt, Fra Mauro  
  *see* Fra Mauro basalts
- Basalts, continental  
  and mare basalts, 147
- Basalts, Mare, 4, 7  
  ages, 128, 160-164  
  classification of, 166-167  
  clasts in Fra Mauro Formation,  
  186-188  
  composition of, 164-168  
  and degree of partial melting, 7  
  depth of source, 5  
  distribution of, 148  
  flow fronts, 147, 149  
  in Hadley Rille, 51, 52  
  major element composition, 168  
  modal mineralogy, 164  
  olivine in, 165-166  
  origin of, 166  
  plagioclase in, 164-165  
  pyroxene in, 164  
  seismic velocity, 3  
  and soils, 258-260  
  stratigraphy of, 147-167  
  and terrestrial analogues, 147  
  texture of, 166-167

- young flows of 147-148, 150
- Base surge, 88, 95-114
  - and antidunes, 103, 104, 105, 106, 107, 110, 142, 144, 145, 208
  - and Cayley Formation, 219
  - definition, 95-96
  - distance of travel, 97, 106
  - evolution of gas by hot particles, 98, 99
  - fluidization of, 99, 100-101, 219, 232
  - and the Fra Mauro Formation, 141-142
  - and the Hevelius Formation, 144, 145
  - lubrication by gas, 98, 99, 100, 106, 233
  - and lunar soil, 232-233, 271
  - morphology, 96-101
  - and nuclear explosions, 95-96
  - and soil breccias, 242-244
  - sorting of detrital materials in, 101-102, 271
  - supercritical flow in, 103, 104, 142, 144, 203, 208
  - velocity of, 97, 142, 208
- Base surge sediments, 106-112
  - grain size of, 107-109, 204-205
  - sedimentary structures in, 104, 107, 109-112, 184, 232
- Binary Planet Hypothesis
  - of lunar origin, 11, 15
- Booming sand, 53, 54
- Boulder trails, 45, 47, 50
- Breccias, crystalline
  - Apollo 16,
    - see* Cayley Formation
  - classification of, 184-186, 209-214
  - clasts in soil, 239, 241
  - Fra Mauro, 39, 140, 181-209, 239
  - lenses beneath craters, 79
  - metamorphism in, 140
  - partial melting in, 220-222
  - thermal metamorphism in, 140, 193-201, 212, 218, 219
  - vugs in, 198
- Breccias, soil
  - and base surge, 242
  - clasts in soil, 241-248
  - density, 241
  - grain size of, 245-246
  - lapilli in, 242, 243
  - layering in, 242
  - maturity of, 244-245, 246, 247
  - origin, 241, 242-244
  - porosity, 241
  - roundness of grains, 246-248
  - sintering of, 242, 244
- Bulk ejecta
  - see* ejecta, bulk
- Capture Hypothesis
  - of lunar origin, 11, 14
- Carpathian Mountains, 128
- Cataclysm,
  - lunar, 40, 129, 134
- Cavalerius Formation, 172
- Cayley Formation, 137, 141, 142-144, 181
  - classification of lithologies, 209-214
  - contribution to soils, 239
  - definition, 209
  - distribution of, 143
  - lithic clasts in, 215-218
  - lithology of, 209-218
  - matrix of, 214-215
  - metamorphism of, 212, 218, 219
  - origin of, 218-220
  - petrology, 142, 144, 214-218
  - stratigraphy of, 142-144
- Cayley plains, 209
- Center of mass, lunar, 119
- Chalcophile elements
  - in lunar core, 9
  - in mare basalts, 9
  - as meteoritic index,
    - (*see* volatile elements)
- Chondrules, lunar, 187, 188
- Cinder cones, 56
- Comets, 21, 28, 39, 40
- Comminution by meteoroid impact, 81, 82-87, 244, 267, 277-281
- Compaction by meteoroid impact, 80, 82
- Composition, lunar, 3, 5
- Conductivity, lunar,
  - see* electrical conductivity
- Cone Crater, 181, 182, 183, 184, 204, 205, 245, 246, 272
- Copernican System, 124, 128, 129, 130, 168-173
- Copernicus, 40, 55, 123, 125, 126, 127, 128, 130, 168, 169, 182, 261, 270
  - age, 129
- Cordillera Mountains, 146
- Core, lunar, 8-9
- Cosmic rays, 267
- Crater counting ages, 25
- Crater shape, 31, 32, 70-79
  - macrocraters, 73-79
  - megacraters, 77-79

- microcraters, 71-73
- Cratering rates, 26
- Cratering, secondary, 90-92, 144
- Cratering mechanics, 66-79
  - compression stage, 66-68
  - excavation stage, 69-70
  - jetting, 67, 68, 69, 80, 90
  - modification stage, 70
  - terminal engulfment, 67
- Craters, lunar
  - impact origin of, 19, 65
  - volcanic origin of, 19, 65
- Craters, named lunar
  - Archimedes, 142
  - Aristillus, 261
  - Autolycus, 261
  - Cavalerius, 172
  - Cone, 181, 182, 183, 184, 204, 105, 245, 246, 272
  - Copernicus, 40, 55, 123, 125, 126, 127, 128, 130, 168, 169, 182, 261, 270
  - Dune, 246
  - Elbow, 245, 246
  - Eratosthenes, 124, 125, 126, 168, 182
  - Euler, 150
  - Fra Mauro, 139
  - Marius, 173
  - Mösting C, 106
  - North Ray, 210
  - Prinz, 153
  - Reinhold, 124
  - Shorty, 56
  - South Ray, 210
  - Tycho, 40, 82, 84
- Creep of lunar soil, 52-55
- Crust, lunar, 3-5, 7, 257
  - age of, 121-123
  - rate of formation, 121
  - stratigraphy of, 119-180
  - thickness, 3
  - upper 1 km, 3
- Crystallization
  - of mare basalts, 164-166
- Dark mantle, 56, 169-172, 182
- Deep drill cores,
  - Apollo 15, 231, 233, 234, 273, 274
  - Apollo 16, 232, 256, 268
  - Apollo 17, 256
- Descartes Mountains, 209
  - (see also Apollo 16)
- Differentiation, lunar, 9, 10
- Domes, 172, 173
- Doppelmayr Formation, 170, 172
- Eclogite, 7
- Ejecta
  - ballistic, 89-93, 101, 102
  - bulk, 88, 95
  - fall-back, 85, 147, 219
  - grain size of, 85-87
  - stratigraphy of, 93-95
  - thickness of, 114
  - velocity of, 89-91
- Electrical conductivity
  - in lunar interior, 7
- Electrostatic transport
  - of lunar soil, 19, 43, 59
- Emerald green glass, 257, 258
  - origin of, 56, 57, 170, 258
- Energy
  - meteoritic, 24, 41-42, 79-114
  - solar, 19, 42-45, 59
- Equilibrium soils, lunar, 281
- Eratosthenes, 124, 125, 126, 168, 182
- Eratosthenian System, 124, 128, 129, 147, 168-173
- Escape velocity
  - of earth, 30, 31
  - of moon, 30, 31
  - of solar system, 30, 31
- Erosion rates, 53
- Euler, 150
- Evolution
  - of lunar soil, 277-281
- Explorer satellites, 23, 28
- Exposure ages, lunar
  - and agglutinates, 268, 275, 282
  - from track data, 267
- Facies, 124, 139
- Faults, 150, 160
- Fire fountain
  - origin for dark glass, 170-171
- Fission Hypothesis
  - of lunar origin, 11-14
- Fluidization
  - see base surge, fluidization of
- Folds, 160
- Formations, by name
  - Alpes, 182
  - Apennine Bench, 137
  - Cavalerius, 172
  - Cayley, 137, 141, 142-144, 147, 181, 239
  - Doppelmayr, 169, 170, 172
  - Fra Mauro, 39, 101, 128, 135, 137, 138-142, 144, 147, 163, 171,

- 181-209, 239, 246
- Harbinger, 172
- Hevelius, 144, 147
- Montes Rook, 146
- Reiner Gamma, 172
- Sulpicius Gallus, 169, 170, 171, 172
- Vallis Schroteri, 172
- Fractionation, 14, 15
- Fra Mauro basalts, 4, 5, 259, 260, 262, 270, 271
- Fra Mauro breccias,
  - see* Fra Mauro Formation
- Fra Mauro Crater, 139
- Fra Mauro Formation, 39, 101, 128, 135, 137, 138-142, 171
  - ancient basalt clasts in, 163, 187
  - base surge origin, 142, 198, 203, 204, 206, 208-209
  - and Cayley Formation, 214, 215
  - chondrules in, 187, 188
  - classification of lithologies, 184-186
  - composition of, 186-193
  - contribution to soils, 239
  - definition, 138, 181
  - distribution of, 181, 182
  - grading of, 204
  - grain size of, 140, 204-205
  - and Hevelius Formation, 144
  - hummocky facies, 139, 141
  - jointing in, 183
  - lithic clasts in, 186-191, 201-204
  - lithology of, 140, 181-209, 210, 261
  - matrix, 193-201
  - metamorphism of, 140, 193-201
  - mineralogy of, 186-193
  - and penecomtemporaneous erosion, 203, 205
  - roundness of detrital particles, 188, 190, 203, 205-206, 246
  - smooth facies, 139, 141
  - stratification in, 183-184
  - texture of, 201-206
  - thickness of, 140, 141, 181
  - vapor phase minerals, 198, 199, 200, 208
- Fra Mauro landing site, 40
- Froud numbers, 103
- Galaxy, 41, 283
- Gamma-ray orbital data, 1
  - and Cayley Formation, 144
- Gegenschein, 23
- Geochemical model
  - of lunar evolution, 3-9
- Glasses, lunar, 252-269
  - (*see also* agglutinates)
  - chemical composition, 257-261
  - color, 255-257
  - compositional groupings, 258, 259
  - emerald green, 56, 57, 170, 257, 258
  - and fire fountains, 170, 258
  - form, 253-255
  - impact origin, 253
  - orange, 56, 170-171, 258, 260
  - origin, 261
  - pyroclastic, 255, 256, 257, 258, 260
  - and parent composition, 257
  - refractive index, 255-257
  - spheres, 253-255, 256, 258
- Graded bedding
  - in lunar soil, 232
- Grain flow, 112-114, 232-233
- Granite, in highlands, 259, 261
- Gravitational energy, 45-55, 59
- Gravity, lunar, 122
  - anomalies, 123
  - and mascons, 7, 123
- Green glass
  - see* emerald green glass
- Hadley Rille, 47, 49, 50, 51, 147, 149, 153, 154, 156
- Harbinger Formation, 172
- Heat flow, lunar, 77
- Hevelius Formation, 144, 147
- Highlands breccias
  - see* breccias, crystalline
- Highlands, lunar
  - layering in, 183-184
  - rock types in, 261
- Horizontal glow, 43, 90
- Imbrian System, 47, 124, 125, 136, 137, 138-168, 171, 172
- Impact glasses
  - see* agglutinates
  - see* glasses
- Impact fusion, 24, 80-82, 83, 93, 221, 239, 244, 263, 266, 268, 269, 282
- Impact metamorphism, 133, 140, 193-201, 212, 218, 219
- Interior, lunar
  - internal structure of, 3-9
  - model compositions, 6
  - molten zones in, 7
  - zones of, 3-9
- Jetting
  - see* cratering mechanics
- Jupiter, 21, 22, 25

- Kant Plateau, 209
- Kilaton, definition, 97
- KREEP, 4, 5, 260, 262, 270
- Lampson scaling effects, 77
- Lava channels 150-151, 156, 158
- Lava flows, 158
  - in Mare Imbrium, 147, 149
  - and wrinkle ridges, 161
- Lava lake, 157
- Lava, mare
  - see mare basalts
- Lava tubes, 157, 158
- Lava viscosity, 151
- Layering
  - in highlands, 183-184
- Light plains material units, 138, 141, 142, 181
- Lineations
  - highlands, 45
- Lunar cataclysm
  - see cataclysm, lunar
- Lunar chondrules
  - see chondrules
- Lunar crust
  - see crust
- Lunar interior
  - see interior, lunar
- Lunar material unit
  - definition, 127
- Lunar Orbiter missions, 23
- Lunar soil,
  - see soil, lunar
- Lunar time stratigraphic units, 130
- Magnetic field, lunar
  - intensity, 10
  - origin, 10-11
- Magnetic properties
  - of breccias, 10-11
  - of soils, 10-11, 233
- Mantle, dark
  - see dark mantle
- Mantle
  - lower, 7
  - middle, 7
  - upper, 5
- Mare
  - Cognitum, 182
  - Crisium, 119
  - Fecunditatis, 163, 260
  - Humorum, 162, 169
  - Imbrium, 65, 77, 123, 125, 126, 135, 136, 137, 140, 141, 147, 149, 150, 160, 161, 162, 181, 182, 184, 187, 204, 207, 208, 259, 261
  - Nubium, 182
  - Oriente, 39, 82, 123, 135, 136, 144-147
  - Procellarum, 40, 119, 125, 160, 163, 173, 182
  - Serenitatis, 56, 125, 162, 163, 169, 170, 184, 204, 207, 208, 209, 259
  - Smythii, 119
  - Tranquillitatis, 40, 142, 163, 260
  - Vaporum, 169, 259
- Mare basalts
  - see basalts, mare
- Mare filling, 160-164
- Mare surface features, 151-160
- Marius Group, 172
- Marius Hills, 40, 163, 173
- Marius Hills Rille, 152, 156
- Mars, 25
- Mascons, lunar,
  - and source of mare basalts, 7, 123
  - theories of origin, 7
- Mass wasting, 45-55
- Material units, lunar
  - see lunar material units
- Maturity
  - of crystalline breccias, 206-208
  - of lunar soils, 170, 230, 248, 277, 281-283
  - of soil breccias, 244-245, 246, 247
- Melting, impact
  - see impact fusion
- Metamorphism, impact
  - see impact metamorphism
- Meteor Crater, Arizona, 93, 95, 184
- Meteoroid flux
  - history of, 39-41
  - on lunar surface, 19-41, 54
  - into earth's atmosphere, 28
- Meteoroids
  - composition, 33-35
  - density, 30-32
  - distribution in space, 20-22
  - shape, 32-33
  - velocity, 30, 42
- Meteoritic component
  - ancient, 36, 37
  - in highlands, 36
  - in soils, 33, 36, 42
  - in ocean sediments, 24, 33, 42
  - in polar ice, 24, 33

- Meteoritic energy, 41-42, 59
- Meteors  
 photographic, 28, 29  
 radio, 22, 24, 25, 28  
 shower, 20, 21  
 sporadic, 20, 21, 39
- Microcraters, 35  
 size, 71  
 morphology, 31, 71-73  
 on rock surface, 24, 31
- Micrometeoroids  
 composition, 33-35  
 density, 30-32  
 shape, 32-33
- Mixing models  
*see* soils, lunar
- Moment of Inertia  
 lunar, 9
- Montes Rook Formation, 146
- Moonquakes  
 and the Mantle, 7  
 periodicity, 53  
 thermal, 53, 54
- Mount Hadley, 48
- Oceanus Procellarum, 3, 40, 119, 160
- Olivine, 7, 8  
 in Cayley Formation, 214-218  
 in Fra Mauro Formation, 191-197  
 in mare basalts, 165-166  
 in soils, 249-251
- Orange glass  
 age, 171  
 composition, 171  
 origin, 56, 170-171  
 and Sulpicius Gallus Formation, 171
- Orbital Al/Si ratios,  
 and Cayley Formation, 144, 219, 220  
 and highlands composition, 260  
 and lunar soil composition, 238
- Orbital gamma-ray data,  
 and Cayley Formation, 144, 219
- Oriente Basin,  
 age of, 147  
 stratigraphy, 144-147
- Origin, lunar,  
 binary planet hypothesis, 11, 15  
 capture hypothesis, 11, 14  
 fission hypothesis, 11-14  
 precipitation hypothesis, 11, 14-15  
 sediment ring hypothesis, 11, 15
- Palus Putredinus, 259
- Partial melting,  
 in agglutinates, 266-267  
 in breccias, 220-222  
 and highland petrogenesis, 262  
 origin for Fra Mauro basalts, 5
- Patterned ground, 45
- Pegasus missions, 23, 28
- Pioneer missions, 21, 23, 28
- Plagioclase  
 in Cayley Formation, 214-218  
 in Fra Mauro Formation, 186-198  
 in highland lithologies, 5  
 in mare basalts, 164-175  
 in soils, 249, 250  
 in soil breccias, 246
- Plains forming units  
 relation to ringed basins, 209, 219
- Planetesimals, 15, 33, 35-38, 39
- Plato II, 156
- Precipitation Hypothesis  
 of lunar origin, 11, 14-15
- Pre-Imbrian, stratigraphy, 124, 128, 135-138,  
 140, 163, 209, 260
- Prinz Rilles, 152, 156
- Procellarian System, 124, 128
- Pyroclastic materials,  
 lunar, 55-56, 57, 59, 170-172, 227, 255,  
 256, 257, 258
- Pyroxenes  
 in Cayley Formation, 214-218  
 in Fra Mauro Formation, 191-198  
 in soils, 249  
 in soil breccias, 246  
 in mare basalts, 164
- Pyroxenite, 7, 258
- Rays, lunar crater, 70, 168, 169
- Regolith, lunar,  
*see* Soil, lunar
- Reiner Gamma Formation, 172
- Rima  
*see* Rilles
- Rille, Hadley  
*see* Hadley Rille
- Rilles, 49, 50, 151-158, 163  
 arcuate, 151-152, 161  
 sinuous, 151, 152-158, 172, 173  
 straight, 151-152, 161
- Ringed basins, lunar,  
 ages, 129-135  
 ancient, 129, 135  
 ejecta thickness, 114  
 impacts and mare basalts, 162-163  
 origin, 65-66

- relation to Cayley Formation, 218-220
- Roche's limit, 15
- Root-mean-square velocity of meteoroids, 30, 31, 268
- Rook Mountains, 146
- Scaled depth-of-burst, 77
- Schroeters Valley, 155, 156
- Secondary cratering, 144, 219, 220
- Sediment Ring hypothesis
  - of lunar origin, 11, 15
- Sediment flux, lunar, 283
- Seismicity
  - lunar, 7
- Seismic properties
  - regolith, 3, 229
- Seismic signals
  - lunar, 25, 29, 53
  - velocity, 7, 79
- Seismometers,
  - lunar, 25
- Selenopetal structure,
  - in lunar soil, 235-236
- Shock waves and cratering, 67, 69
- Shorty Crater
  - and orange glass, 56
- Siderophile elements
  - depletion in moon, 38
  - in mare basalts, 14
  - as meteoritic index, 33
  - in lunar soils, 34, 36, 37
- Silver Spur, 184
- Sinuuous Rilles
  - see* Rilles, sinuous
- Sinus Aestuum, 169
- Slumping of crater walls, 45
- Soil, lunar
  - ages of 173-174, 229
  - agglutinates in, *see* agglutinates
  - chemical composition of, 237-238, 240
  - and crater morphology, 76, 77, 227, 228
  - cycling of, 275, 276, 280-281
  - and deep drill cores, 231
  - definition, 227
  - density, 236-237
  - evolution of, 277-281
  - exotic component, 238
  - graded beds in, 232
  - grain size, 271-275
  - interclastic soil chip breccias, 235
  - layers in, 227, 231-236
  - local component, 239
  - magnetic properties, 233
  - maturity of, 170, 230, 248, 277, 281-283
  - metallic particles in, 252
  - meteoritic component, 36, 37
  - mixing models, 269-271
  - petrography of, 238-269
  - pyroclastic component, 170-171, 227
  - rate of accumulation, 76, 77, 227-231, 272
  - rate of turnover, 236
  - reworking of, 235, 236, 276, 277, 280-281
  - seismic properties, 3, 229
  - selenopetal structures, 235-236
  - shape of particles, 233, 234, 275-277, 278
  - stratigraphy of, 231-236
  - stratigraphic inversions in, 233, 235
  - thickness, 76, 77, 227-231, 281
- Solar energy, 19, 42-45, 59
- Solar nebula
  - and lunar origin, 11, 12, 13
- Solar wind,
  - sputtering, 44-45
- South Imbrium basin, 163
- Spallation and microcraters, 71
- Stratigraphy, lunar, 123-126
  - of soil, 231-236
  - units defined, 127-129
- Steady state soils, lunar, 281
- Sulfur,
  - in lunar core, 8-9
- Sulpicius Gallus Formation, 169, 170, 171, 172
- Surveyor spacecraft, 24, 43
- Talus slopes, lunar, 50-52
- Taurus-Littrow site,
  - see* Apollo 17
- Terminal engulfment, 67
- Thermal erosion, 43-44
- Thermal moonquakes, 44
- Tides, lunar, 12, 15
- Time-stratigraphic units, lunar
  - see* lunar time stratigraphic units
- Tobias Meyer, 156
- Topography, lunar 119, 120
- Troctolite, 215, 218, 262
- Tycho, 40, 82, 84
- Upper mantle, 5-7
- Vallis Schröteri Formation, 172
- Vapor phase transfer
  - see* Fra Mauro Formation
- Volatile elements,

- in highland rocks, 5
  - in lunar soils, 34, 36
  - in mare basalts, 8
  - and meteoritic contribution, 33, 37
  - in planetesimals, 38
- Volcanism, lunar, 19, 55-56
- Vugs
- in breccias, 198
  - crystals in, 198
- Winnowing of lunar soil, 50
- Wrinkle ridges, 151, 152, 158-160, 161, 173
- in Mare Humorum, 162
- XRF orbital data, 1, 144, 219, 220, 238, 260
- Zodiacal cloud, 22, 23