

Index

a

Aamot pendulum probe 287
 abrasion 165, 166, 561, 565, 579, 583, 589, 637
 accessing the bed 297, 298
 acid mine drainage (AMD), 530
 acid treatment 716
 adaptive wedge 595
 aerial platforms 632–636
 aerobots 622, 635, 636
 airships 622
 albeit clean 733
 ALIAS 676
 alkaline cleaners 716
 alpha backscatter spectrometer 679, 680
 alpha particle X-ray spectrometer (APXS) 627, 628, 653–655, 666, 679–682
 analytical instruments (deck-mounted) 652
 anchoring module 488, 489
 anorthosites 426
 Antarctic 221, 223, 226, 238–240, 251, 282, 286, 287, 293, 301, 302
 Antarctic Dry Valleys 533, 534
 Anti-torque 227, 228, 230–232, 234, 236, 238–240, 247, 249, 259
 Anti-torque system 227, 230, 232, 234, 236, 239, 240
 Apollo drive tube 493, 497
 Apollo Lunar Surface Drill (ALSD) 7, 23, 24, 348, 495
 Arbitrary Lagrange Eulerean (ALE) algorithm 204
 Arctic sites 529–531
 aromatic 293
 asteroid surface sampling device (ASSD) 504
 asymmetric waveform ion mobility spectrometry (FAIMS) 693, 694
 at launch 722, 723

Atacama Desert 532
 attrition 571, 579, 585–589, 595, 597, 611
 – machines 585–589
 – mill 571, 572, 586, 597, 603, 611
 auger flights 227, 231, 245
 Aurora program 510, 511
 Australian National Antarctic Research Expeditions (ANARE) 287, 302
 autogenous mills 584, 591, 593
 autogenous self-cleaning 599
 autogenous tumbling mills 599
 autonomous ice-melting drills 286–291
 autonomous operation 535, 541
 autonomous tethered corer (ATC) 488, 489
 Axel Heiberg Island 530, 531

b

back drill 275
 backward contamination 711
 backward (sample return) planetary protection 725
 bailer 228, 230, 541
 ball mills 572, 581, 583–585
 ball penetrometer testing (BPT) 313, 330
 barrel 224, 226, 227, 228, 231, 235, 236, 238–242, 245, 247, 249–251, 253–259, 261, 262, 299, 300
 Barringer Crater 532
 basic working model 542
 bearing capacity theory 203–205
 bed 223, 230, 234, 236, 238, 240, 243, 262, 277, 278, 286, 295–300, 302
 Benthic geotech (BGT) 329, 331, 334
 Benthic multicoring system (BMS) 319–321, 323, 324, 332, 333
 Berea sandstone 58, 64, 94–96, 100, 102
 Berkner Island 238
 BHA modeling 193–196

- biobarrier 734–736
 - bioburden 718, 722–724, 729, 734, 735
 - bio-decontamination 726
 - bio-inspired drilling 512–520
 - bioload 709, 710, 720–723
 - biology 654, 655, 685–694
 - biomimetics 375, 512, 513, 516
 - bioseal 727
 - bit balling 175
 - bit chatter 541
 - bit design 167, 185, 188–191, 215
 - bits 1, 4, 5, 6, 7, 10, 11, 13, 15, 16, 17, 18, 19, 21, 22, 23, 24
 - Black Point 533
 - Black Rapids Glacier 299, 300
 - blacklight 719
 - Blake crusher 576
 - blocky material 51
 - blowout prevention equipment (BOP) 152
 - Boit's poroelastic constant 37, 67
 - borehole 222, 223, 226, 227, 240, 241, 244, 247, 249, 252–254, 256, 259, 263–268, 271, 273–277, 279, 280, 290–293, 298–300, 649, 652, 654, 660–662, 680–682, 694
 - instruments 652, 654, 662, 681, 682
 - neutron probe (BNeuP) 661
 - spectrometers 661, 681
 - stability 141, 142, 143, 188, 214
 - bottom hole assembly (BHA) 150, 156, 158, 160, 162, 185, 188, 189, 193, 197, 215, 473, 479, 480, 481
 - bottom hole pressure (BHP) 96, 99, 101, 106
 - box corer 342
 - breakage 32, 37, 89, 91, 119, 126, 128
 - breakout 69, 70
 - British Geological Society (BGS) 328, 331, 332
 - buhrstone 586, 587, 591, 593, 594
 - bulk compressibility 32, 45, 46, 126
 - bulk site mineralogy 649
 - burrowing mole integrated instruments 662
 - burs 26
 - Byrd Polar Research Center (BPRC) 244
 - Byrd station 230, 231
- c**
- cable 226–228, 230–235, 239, 243, 244, 246, 248–251, 253, 255, 256, 260, 262, 274, 284, 286, 296–299
 - cable-suspended drill 230, 249
 - cable-suspended electromechanical (EM) drills 226–228
 - cable-suspended electrothermal (ET) drills 248–257
 - cable-tool 144, 145, 146
 - drilling rigs 144–147
 - calibration chamber testing 203, 205, 206
 - Caltech drill 265, 268, 269, 272–276, 278, 279
 - camera, hand lens and microscope probe (CHAMP) 659, 660
 - cam-hammer 394
 - Camp Century 230, 234, 300
 - capillary electrochromatography (CEC) 687
 - capillary electrophoresis 686, 689
 - capillary force 37, 61, 62
 - capstan 233, 266, 273, 274
 - carbide 230, 261, 262, 296
 - carbon fiber reinforced polymer (CFRP) 372
 - carbon nanotubes 691
 - carousel 236
 - casing 226, 297, 299, 300
 - cavitation 166
 - cavity enhance spectroscopy 676, 677
 - cavity expansion theory 203, 206
 - cavity ring down spectroscopy (CRDS) 676, 677
 - cement 37, 39, 52, 53, 55, 61, 126
 - cementaceous material 143
 - Center for Marine Environmental Sciences (MARUM) 328, 331, 333
 - centering drill bits 17
 - CHAMP scannable laser spectrometer (CHAMP-SLS) 660
 - charge-coupled devices (CCD) 644, 657, 658, 663, 672–674
 - chemical reactions 146, 163–165, 214
 - chemical techniques 13
 - CheMin 672, 673
 - chemistry 654, 655, 674–685, 694
 - chemistry & camera (ChemCam) spectrometer 655
 - chemistry & mineralogy (CheMin) 505
 - chip(s) 223, 224, 226–228, 230–235, 238–241, 245, 249, 257, 259, 262, 285, 286, 291, 295, 394, 415, 434, 444, 522, 534
 - chlorofluorocarbon 294, 295
 - choking 431, 444, 467, 492
 - classification of comminution equipment 573
 - cleaning process 718
 - cleanliness level 714, 715, 718, 719, 733
 - cleanroom categorization 717
 - cleating 186
 - closure 223, 227, 249, 286
 - cohesive strength 32, 37, 39, 57, 62, 100
 - coiled tube penetrometers 342, 343
 - coiled tubing 150–154
 - coiled tubing drill for ice (CTDI) 286

- Cold Regions Research and Engineering Laboratory (CRREL) 230, 257
 collectable volatile condensable material (CVCM) 714
 collection and handling for *in-situ* martian rock analysis (CHIMRA) 628
 collisionally induced dissociation (CID) 688
 colloid mill 588
 colorimetric assays 690
 comet nucleus sample return (CNSR) 422, 451, 452
 – mission 422, 451, 452
 cometary analogue material (CAM) 422
 commercial, off-the-shelf (COTS) 389, 564, 574, 609
 comminution 179, 180, 427, 428, 433, 488, 559, 564–573, 575, 579, 581, 584, 587, 589–591, 594, 595, 602–605, 618, 619, 636, 637
 comminution circuit 565, 637
 comminution processes 562, 566, 568, 573–575, 604, 605
 comminution requirements 562–564
 commutator motor 232
 compressional tectonics foreland basin 80–81
 compressive failure 97, 128
 compressive forces 585, 598, 603
 compressive strength 32, 37, 38, 40, 47, 54, 55, 58, 59, 99, 103
 conchoidal chip 92, 104
 cone offset angle 170
 cone resistance 200, 203, 204, 206, 212, 213
 confining stress 36, 38, 43, 44, 47, 55–58, 95, 102, 108
 construction and resource utilization explorer (CRUX) 453–455, 661
 contact instruments (arm-mounted) 652
 contact X-ray diffraction 673
 contamination 244, 263, 267, 286, 290, 563, 605, 620, 633
 contamination control (CC) 652, 686–688, 707, 708, 712–714, 716–719, 731, 736
 continental margin basin 72, 79, 80
 control software 613, 615
 conventional continuous wave (cw)-CRDS 676, 677
 core 223, 224, 226–228, 230–236, 238–262, 279, 280, 294, 295, 300, 301, 302
 core barrel 224, 226–228, 231, 235, 236, 238–242, 245, 247, 249–251, 253–258, 261, 262, 299, 300
 core catcher 250, 255, 279, 280
 core diameter 226, 227, 231, 234
 core dogs 227, 228, 234, 236, 239, 241, 249, 257, 258, 261
 core length 234, 240
 corer and abrader tool (CAT) 354, 407–411
 core samples 41, 42, 51
 coring bit 6, 7, 10, 11, 23, 225, 261, 348, 354, 379, 382, 383, 406, 409–410, 453, 454, 469, 473–475, 485
 Cosmic Vision program 416, 510–512
 CO₂ snow 716, 718
 COSPAR 708, 709, 711, 725, 729, 731, 734, 737
 craters 170
 creep tests 44
 cross-contamination 563, 591, 593, 594, 722
 CRREL electromechanical drill 228
 crusher 571, 572, 574–579, 587, 589–591, 593–600, 604, 611, 613, 617, 637
 crusher system 595, 599, 611, 613
 crushing 162, 167, 170–182, 210, 559, 562–564, 567, 568, 571, 573, 575–578, 580, 589, 593, 595, 599–604, 610, 612, 613, 617–620
 crushing and grinding 559, 562, 563, 567, 568, 603
 cryo grinding 572
 cryobot 287, 288, 289, 291
 cryogenic/magnetic hammer mill 582
 cut per revolution 542
 cutter head 227, 241, 242
 cutters 164, 167, 170, 223, 227, 228, 230, 234, 236, 240–242, 245, 261, 262, 285, 295, 296
 cutting machines 585
 cutting process 106, 111, 113
 cuttings 142, 145, 146, 148–150, 158–160, 168, 170–172, 174–181, 185, 197, 348, 352–354, 358, 363, 381–383, 385, 409, 423, 426, 428–433, 441, 464, 473–475, 479, 480, 482–484, 488, 491, 493, 500, 517–519, 522
 – disposal 175
 – frictional contact processes 105
 – removal 159, 160, 177, 178, 352, 382, 423, 431, 441, 442, 444, 470, 473, 475, 493, 498, 517, 519
 – transport 150, 174, 175, 177, 185, 197, 214
- d**
 D47 251
 Danish tipping (shallow) drill 228, 233, 234, 236, 238
 debris 259, 262, 267
 – laden ice 259, 267
 DeeDri drill 509
 deep drills 423, 476–493, 540

- deformation properties 43
 - degree of fineness 571, 572
 - degree of freedom (DOF) 410
 - densifiers 293–295
 - dental drills 25–26
 - Department of Defense Characterization and Analysis Penetrometer System (SCAPS) 682
 - deployable jackstands 485
 - depth-of-field (DOF) 670, 674
 - descending system 516
 - descent mechanism 513, 516, 517
 - detergents 716
 - DFA 256
 - D-HYDRA 661
 - DI water spray cleaning 718
 - diamond bit 167, 230, 261
 - diamond impregnated cutters 542
 - diesel 264, 293
 - differential comminution 603–605
 - differential mobility spectrometry (DMS) 693
 - differential scanning calorimetry (DSC) 669
 - diffuse reflectance/Fourier transform infrared (DRIFT/FTIR) 714
 - directional drilling 162, 183–199
 - DISC drill 227, 236, 241, 242, 243
 - disk attrition mills 586
 - disk mill 586, 588
 - DNA chips 689
 - Dodge crusher 576
 - Dome C 239, 251
 - Dome Fuji 240, 241
 - double-acting duplex pump 159
 - double stage comminution 594
 - down the hole hammer (DTHH) 147
 - down-hole drilling 300
 - downhole motors 162
 - drawworks 156–158
 - dredge sampling 337
 - drill-ahead model 193, 195, 196
 - drill bits 224, 742, 743, 744, 745, 746, 747, 748, 749
 - drill ships 310–313, 315–319, 333, 343
 - drill string 353, 385, 394, 421, 423, 429, 431, 433, 437–440, 444, 452, 454, 456, 458, 459, 463–465, 467, 469, 471, 472, 473, 475, 496, 509
 - integrated instruments 661, 662
 - drill testing facility 525–527
 - drill wandering 543
 - drill with hammering mechanism (DHM) 392–399
 - drilling and sampling subsystem (DSS) 452
 - drilling automation 464–469
 - drilling automation for Mars exploration (DAME) 464–469
 - drilling efficiency 110, 112, 113, 119, 120, 129
 - drilling fluid 68, 74, 87, 88, 89, 124, 125, 128, 129, 223, 224, 227, 230, 236, 238–241, 244, 249–251, 253–254, 263, 286, 291–296, 301
 - drilling power 478
 - drilling process 243, 244, 276, 277, 293, 297, 299
 - historical perspective 1–9
 - drilling rigs 144–162
 - drilling theories 128
 - drilling tools 749
 - drilling, observation and sampling of the Earth's continental crust (DOSECC) 313–315
 - drillpipe 161, 162
 - drillstring 161, 162, 166, 172, 191, 193, 198
 - dry drilling 423, 426–430, 432, 441–443, 471, 473, 475, 482, 483, 488, 491
 - dry heat 722, 724, 726, 727
 - dry heat microbial reduction (DHMR), 722, 723, 728, 732, 735, 737
 - dry-hole core drilling 223
 - ductile shales 44, 75
 - duricrust 507, 534
 - D* value 721, 723
 - dye-3 234, 235
 - dynamic albedo of neutrons (DAN) 655
 - dynamic parameters 120, 122–124
 - dynamic positioning system (DPS) 310
- e**
- Earth boreholes 143
 - ECORD Science Operator (ESO) 315, 318
 - effect of environment 129
 - elastic properties 32–36, 46
 - elastic stresses around a borehole 83–86
 - elastic zone 206, 207, 208
 - electric conductivity (EC) 678
 - electric hot points 284
 - electrical comminution 590
 - electrochaude 284–285
 - electrodrill 227–230
 - electromechanical 226, 228, 234, 244, 245, 249, 255, 256, 300, 301
 - drill 226, 228, 234, 244, 245, 249, 300, 301
 - electrospray ionization (ESI) 751
 - electrostatic discharge (ESD) 712, 735
 - control 724
 - electrothermal 228, 248–251, 253, 254, 293, 295, 296
 - drill 248–251, 253, 254, 293, 295, 296
 - Ellesmere Island 486, 529

encapsulated microbial density 721
 end-effector of drills 15–19
 energy in drilling 65–89
 engineering model (EM) 405–407, 503
 enhanced hot water drill (EHWD) 264, 280, 282
 environmental test 618
 EPICA 238, 239
 – NGRIP drill 238, 239
 equilibrium model 193
 erosion 10, 11, 12, 24
 ethanol 244, 253, 255, 279, 293
 ethanol-thermal-electric drill (ETED) 253–257
 ethanol-water solution (EWS) 253
 European Consortium for Ocean Research Drilling (ECORD) 315
 European planetary protection policy 725
Expéditions Polaire Française 223
 explosion 590, 591
 explosive excavation 11–12
 explosive shattering 568, 574
 extraterrestrial rocks 48–65

f

far-field stresses 68, 87, 128
 feed 563, 571, 576–578, 580, 581, 589, 594, 598, 637
 field-of-view (FOV) 657, 659, 660, 673
 filter 238–240, 267, 268, 270, 271, 276, 290, 295
 filtration 267, 268, 270, 271
 fines 491, 561, 563, 571, 579, 587, 591, 594, 603, 607–610, 612, 618, 619, 637
 firn 222, 223, 225, 226, 228, 232, 234, 257, 259, 262, 266, 268, 271, 276–278, 284–286
 – ice transition 222
 – penetration 276
 fishtail bits 167
 flagship missions 647
 flame-jet drill 283
 flights 227, 231, 238, 240, 245, 257–259, 428, 430–433, 434, 441
 flow rates 159, 160, 174, 175, 178
 fluid saturation 45, 47, 59–63
 fluorescence assays 690
 flutes 383, 403, 404, 464, 497
 forward (outbound) planetary protection 719–724
 forward contamination 708, 711, 721
 Fourier transform infrared (FTIR) spectroscopy 663, 668, 690
 frictional contact process 104, 105, 107–109
 full-faced bit 542

g

gas chromatograph (GC) 751
 gas chromatograph/mass spectrometer (GC/MS) 361, 505, 650, 682–685
 generator 231, 233, 253, 259, 262, 275, 277, 284
 geological studies 19–20
 geologic context 654, 656–665
 geologic formation 512, 542
 geotechnical drilling 312, 313, 315, 344
 GISP 234
 GISP2 236, 294
 glaciers 221, 222, 226, 244, 249, 259, 263, 297–302
 glass fiber reinforced polymer (GFRP) 378
 glycol 230, 276, 279
 gopher 25, 380, 382, 475, 476, 513
 grab sampling 337
 gravity coring 338–340
 gravity piston coring 338
 Greenland 221–223, 225, 230, 234, 236, 238, 249, 250, 259, 261, 285, 287, 291, 292, 294, 296, 300, 301
 Griffith criterion 38
 grinder(s) 355, 564, 571, 586, 587, 589, 593, 605, 637
 grinding 559, 563, 567, 568, 571–574, 581–589, 591, 593, 594, 598, 603, 611, 630, 637
 – mills 574, 584–586
 GRIP 238–239
 ground mole demonstrator (GMD) 477, 478
 gun drill 16–17
 gyratory and cone crushers 576

h

hammer drill 4, 14, 15
 hand augers 257–259
 Hans Tausen drill 236–238
 Hansen/Nebraska probe 287
 hardies 721
 hardness 121
 – scleroscope 121
 – shore 121
 hardy organisms 722
 Haughton Crater 465–467, 529
 heating and cooling the borehole 87–89
 heating system 271
 HEPA/ULPA filter 724
 high performance liquid chromatography (HPLC) 688, 689, 751
 high temperature drilling 743–746
 highside of the borehole 184
 hoisting subsystem 156–160

hole-only drills 262–286
 hollow waveguide (HWG) 676
 hollow waveguide cavity ringdown spectroscopy (HWG-CRDS) 676
 hose 262, 265–267, 270, 272–275, 277, 278, 284, 285, 297
 hot water drilling systems 262–283, 296, 297, 299
 hot-water ice coring 264, 279
 HP3 372, 373, 510
 huygens penetrometer 501
 hybrid coiled tubing 154
 hydraulic drills 5
 hydraulic fracture data 73, 74
 hydraulic issues 178
 hydraulic piston core (HPC) assembly 341, 342
 hydrocarbon 293, 294
 hydrochlorofluorocarbons 295
 hydrocyclones 160
 hydrogen peroxide vapor 726
 hydrolysis 60

i

ice core production rate (ICPR) 244, 247
 ice coring 222, 223, 225, 226, 227, 239, 244, 245, 257, 261, 264, 279, 297, 300, 301
 ice drilling 25
 IceCube 263, 264, 268, 272, 273, 274, 275, 279, 302
 Icelandic temperate glacier drill 231
 icy soil acquisition device (ISAD) 362–364
 IF factor 120
 imaging and spectroscopic instruments 657–665
 imaging spectrometers 659
 impacting machines 578
 impactor 580, 633
 IMS/MS 693
 inchworm deep drilling system (IDDS) 489, 491
 index testing 41
 Indiana Princeton Tennessee Astrobiology Initiative (IPTAI) 677
 inelastic stresses around a borehole with fluid flow 86–87
 influence factors 52–65
 InPhotote spectrometer 371
in situ instruments 644, 645, 651, 656, 694
in-situ resource utilization (ISRU) 24, 352, 353, 515, 541
 instrument categories 652–656
 instrumented mole system (IMS) 372, 373, 510

internal friction angle 32, 37, 47, 108, 113
 International Continental Scientific Drilling Project (ICDP) 144
 International Ocean Drilling Program (IODP) 315–318
 intragranular porosity 400
 ion chromatography (IC) 687, 688, 691
 ionizing irradiation 726
 ion mobility spectroscopy (IMS) 692–694, 751
 ion selective electrodes (ISE) 677, 678
 ISRU 646
 ISTUK drill 234–236, 238, 240

j

jackhammer 3, 5
 jack-up drills 311, 312
 James Ross Island 238
 Japanese Antarctic Research Expedition (JARE) 239, 293
 Japan Oil, Gas and Metals National Corporation (JOGMEC) 328, 331, 332
 JARE deep ice coring drill 239–241
 jaw crusher 571, 572, 575–577, 591, 593–595, 597
 JOIDES resolution 315
 Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES) 144
 jumbo sampler 338
 Juneau Icefield Research Project 223

k

KAGUYA 373, 523
 KEMS drill 227, 239, 240
 kerf 164, 172, 245, 247, 253, 264, 427, 429, 430, 431, 433, 435, 482
 Keweenawan basalt 409
 kick 146, 150, 156, 179
 knives, shears, and wedges 585
 Koci drill 259–262
 Kola Peninsula 144, 744
 Kola-SG3 drill-rig 8
 Kola Superdeep Borehole project 7, 8
 Kovacs auger 257, 258
 Kugluktuk 529–530

l

large strain model 204
 laser induced breakdown spectrometers (LIBS) 654, 655, 659, 660
 laser induced native fluorescence detector (LINFED) 751
 laser spectroscopy 675–677
 – for volatiles 649

- leak-off tests (LOT) 73, 74, 127
- level wind 244, 273
- Lexan sampler 340
- life detection 711, 734
- limit equilibrium analysis 203
- Limulus Amebocyte Lysate (LAL) reagent 690
- liquid chromatography 687–689
- liquid nitrogen (LN₂) 422, 426, 428
- lithic fragments 31, 48
- lithological history 186, 187
- logger 475
- logging 222, 228, 249, 301
- logging-while-drilling (LWD) 162
- loose regolith capture 534
- loose regolith ejection 535
- low force sample acquisition system (LSAS) 402–405
- low temperature drilling 742–743
- lowside 184
- lunar drill core samples 48–51

- m**
- macro-geology 185
- Mancos shale 94–96, 112–113
- manipulator 624–631
- manual cleaning 718
- Mars analog 408, 465, 532
- Mars astrobiology research and technology experiment (MARTE) 354, 362, 662
- Mars borehole spectrometer (MBS) 661
- Mars environmental compatibility assessment (MECA) 677, 678
- Mars exploration program analysis group (MEPAG) 666, 674, 685
- Mars exploration rovers (MERs) 355, 410, 411, 461, 464, 505, 512, 562, 620, 621, 627–631, 647, 657, 658, 667, 670, 680–682
- Mars Express 711, 732
- Mars Global Surveyor 711
- Mars hand lens imager (MAHLI) 628, 658, 659
- Mars instrument development program (MIDP) 368
- Mars integrated drilling and sampling (MIDAS) 384, 387
- Mars multispectral imager for subsurface (MaMiss) 507
- Mars multispectral imager for subsurface science (MA-MISS) 507, 662
- Mars Odyssey 711
- Mars Pathfinder (MPF) 621
- Mars Reconnaissance Orbiter 711
- Mars sample return (MSR) 353, 405, 510
- Mars Science Laboratory (MSL) 353, 355, 410, 421, 504, 505, 618, 627, 628, 747, 751
- Mars Science Laboratory Rover drill 504–506
- Mars underground mole (MUM) 662
- Mars/Arctic Deep Drill 354, 479
- material properties 48, 127
- mean time between failures (MTBF) 323
- measured depth (MD) 184, 310
- measurement while drilling (MWD) 20, 162, 197
- MeBo 328, 333, 334
- mechanical advantage 157
- mechanical breakage 141, 162, 163, 165, 214
- mechanical drills 1, 3, 14, 15
- mechanized sample handler (MeSH) 587, 595, 600–620
- mechanized shaker 570
- Meeresboden–Bohrgerät 333
- melting and vaporization 9, 12, 13
- MER Instrument Deployment Device (IDD) 627, 630
- MeSH sample distribution (MeSH-SD) 600, 602
- MeSH sample hand-off (MeSH-SHO) 600, 601
- Mesh sample separation & preparation (MeSH-SSP) 600, 601
- metal matrix composite (MMC) 378
- metamorphic rocks 31, 126
- microarrays 689
- micro-capillary electrochromatography (Micro-CEC) 687, 691
- micro end effector (MEE) 364, 365
- micro imager 649, 657
- Micro Robots for Scientific Applications 2 (MRoSA2) 538
- MicroRoSA 452, 453
- microscopic imager (MI) 562, 650, 653, 655, 657, 658, 668, 690
- microseismic mapping 73
- microwave comminution 590
- microwave drill 13, 14
- mill 572, 574, 579–589, 591, 593, 594, 597, 599, 603, 611, 637
- mineral identification and composition analyzer (MICA) 673, 674
- mineral processing techniques 637
- mineralogy 649, 650, 654, 655, 666, 667, 670, 672–674, 685
- identification 666–674
- miniaturized Mössbauer spectrometers (MIMOS) 666
- Mini-Corer (MC) 405, 406

- mining and tunneling 20
 - mining drilling 143
 - mission compliance constraint 708
 - mission specific platforms (MSP) 315, 318
 - mobile operational platforms 621
 - mobile penetrometer (Mole) 366, 367, 372
 - mobile platforms 746
 - mobile rover-based drilling 485
 - modular planetary drill system (MPDS) 491–493
 - modulus of toughness 39, 126
 - Mohole 8
 - Mohr–Coulomb failure criteria 38
 - Mohr–Coulomb failure model 169
 - Mohr failure criterion 168
 - Mohr's circle 47
 - Mohr's hardness values 573
 - Moineau motors 159, 162
 - moist heat 726
 - Mojave Mars Simulant (MMS) 386
 - molecular contaminants 713, 714
 - level 713
 - Moles 366–377
 - Monterey Bay Aquarium Research Institute (MBARI) 331, 334, 335, 336
 - Montgolfiere balloon 636
 - Moon 51, 62, 127
 - Moon/Mars Underground Mole (MMUM) 368–372
 - mortar and pestle mill 587
 - Moses lake 533
 - Mössbauer 654, 655, 657, 666, 667
 - Mössbauer spectrometer (MB) 627
 - MPF 621
 - multi-corer 343
 - multispectral images 662
 - multispectral microscopic imager (MMI) 668
- n**
- NASA Office of Exploration Systems (OExS) 661
 - NASA PP specifications 720, 722, 728
 - National deep submergence facility (NDSF) 329, 335
 - National Research Council Decadal studies 647
 - native induce fluorescence spectrometer 649
 - n*-butyl acetate 240, 292, 293, 294
 - near-earth asteroids (NEA) 416
 - near-earth objects (NEO) 416
 - NGRIP bore hole 256
 - Nip angle 574, 637
 - Nipping (compression) machines 574–578
 - non-rotary sampling 336–343
 - non-tectonic classical basin and diagenetic effects 76
 - non-volatile residue (NVR) 713, 714
 - NorthGRIP 238
 - numerical wave methods 205
- o**
- ocean and seafloor drilling 23
 - ocean sediments 647
 - offshore drilling 309–312
 - optical probe for regolith analysis (OPRA) 663
 - optical sensors 690
 - organic geochemistry/gas analysis package (GAP) 733
 - oxygen plasma 718
- p**
- packing 149, 179, 189
 - paleoenvironmental studies 222
 - paleomagnetic analysis 331
 - panoramic imagers 654
 - parametric bioload 722
 - particle size distribution 563, 569–572
 - PCL 714–716, 727
 - Peary land 238
 - pendular stability 287
 - pendulum probe 287
 - penetrometer 181, 200, 201
 - data 51
 - testing 313
 - percussion drilling 89–103, 118, 120, 122, 128
 - percussive drill 7, 23
 - percussive drilling 2, 7, 23, 391, 434, 453, 497, 517
 - rigs 144–149, 214
 - percussive dynamic cone penetrometer 399, 401
 - percussive regolith penetrometer 399, 401
 - percussive scoop 365–366
 - permafrost piling 210
 - permeability 32, 39, 40, 41, 44, 53, 58, 62, 65, 68, 77, 117, 126
 - permenur plate core 165
 - Petit Pulverizer 589
 - petroleum 293, 294
 - petroleum and gas drilling 21–23
 - Philae platform 499, 501
 - Philberth probe 286, 287
 - Phoenix 2007 Scoop 361–364
 - Phoenix Scout 752
 - Phoenix spacecraft 751
 - photomultiplier tube (PMT) 670, 691

- pickling 279
 PICO auger 257–259
 PICO drill 236, 237
 pile driving formulas 201–203
 pin mill 580, 581, 594
 pipelines under the ocean (PLUTO) 151
 piston 238, 239, 253, 254, 255, 274, 280, 299
 – coring 274, 280, 299
 piston-die press (PDP) mode 611
 planetary drilling and sampling 23–25
 planetary instrument definition and development program (PIDDP) 663, 670, 673, 674, 677, 695
 planetary mill 582, 594
 planetary protection (PP) 652, 671, 686, 690, 707–709, 711, 712, 718–731, 733, 736, 737
 – categories I to IV 708
 planetary underground tool (PLUTO) 662
 planning 196
 plant inspired space probe 514, 515
 plastic zone 207
 PLUTO 356, 368, 369, 371, 372, 502–504
 pneumatic drill 3, 4
 pneumatic sample return 448
 polycrystalline diamond (PCD) 18, 19, 22, 148, 422, 453, 483, 485, 745
 polycrystalline diamond compact (PDC) 104, 109, 112, 117, 122, 167, 483, 542
 pond water kits 690
 pore pressures 37, 42, 43, 66, 67, 72, 76, 78–81, 83, 85, 99, 101–103, 106, 115, 117, 118, 127
 porosity 32, 39, 40, 41, 45, 46, 47, 48, 53, 55, 58, 61, 65, 77, 88, 91, 95, 117, 126
 portable drills 5, 14
 portable remotely operated drill (PROD) 334, 335
 powder acquisition drill system (PADS) 628
 powdered cuttings sampler 381, 382
 powder sample capture 534
 powder sample ejection 535
 powder X-ray diffraction 672
 powerdrive 190
 Prairie dog 258, 259
 precharging 160
 precision cleaning 716, 718, 735
 preload 353, 363, 364, 385, 390, 403, 415, 442, 491
 pressure bubble 209, 210
 primary crusher 574, 575, 598
 processing and distribution assembly (PDA) 361
 project PLUTO 151
 protein chips 689
 pseudoplastic craters 170
 pulverize 590
 pump 227, 228, 234–236, 238–240, 242, 243, 249–253, 266–268, 270, 271, 274–277, 285–291, 297
 push coring 341–343
- q**
 quantum cascade (QC) laser 676, 677
 Queen Maud Land 223
- r**
 radioisotope thermoelectric generator (RTG) 645
 Raman spectrometer 562, 563, 593, 600, 649, 654, 659, 660, 662, 663, 670, 691
 Raman spectroscopy 668–671
 rapid air movement (RAM) drill 285, 286
 rate independent interface laws 104
 rate of penetration (ROP) 90, 99, 102–104, 114, 115, 118, 120, 124, 129, 163, 166, 170, 172–175, 177, 188, 211, 383, 397, 398, 444, 454, 460, 465, 468, 479, 488, 498, 525
 reamer 265, 274, 275, 279
 reaming 249, 265, 278, 279, 293
 recirculation 266–268
 recompaction of cuttings 179–181
 recontamination prevention 719
 redox meters 677
 reduction ratio 563, 565, 567, 577–579, 637
 reference systems 183–185
 refreezing 265
 Regolith and Environment Science and Oxygen and Lunar Volatile Extraction (RESOLVE) 660
 Regolith cores 494, 564
 remote instruments (mast-mounted) 652
 remotely controlled robotic seafloor drilling 318–336
 remotely operated vehicles (ROV) 328, 333–335, 339
 remote sensing 649, 654
 remote spectrometers 654
 reservoir 268, 270, 272, 276, 277, 288, 290
 reservoir stresses 81
 residual strength 39, 126
 resistance 38, 43, 52, 104, 119, 121, 122
 RESOLVE 423, 424, 437, 439
 resonant sonic drilling rigs 148, 149
 Rio Tinto analog site 532
 riser drilling 316–318
 riserless drilling 315, 316
 robot 286
 robotic arm (RA) 621, 626–628, 635, 734, 735

- robotic drilling techniques 309, 318, 320–328
 - robotic sampling and containerization
 - technology (RSCT) 442
 - rock abrasion tool (RAT) 355, 356, 357, 380, 561, 589, 627, 657–659, 680
 - rock breakage 37, 89, 91, 119, 128
 - rock breaking 565, 578
 - rock compressibility 33
 - rock corer grinder (RCG) 356, 503
 - rock dredges 337
 - rock drillability 119, 129
 - rock failure 32, 39, 47, 97–101
 - rock fatigue 100
 - rock lithology 53
 - rock properties 31, 32, 41, 45, 47, 52, 57, 58, 126, 129, 186–188
 - rod drilling 320–325, 332
 - rod mill 583, 584
 - roll crusher 577, 578, 590, 591, 593, 597–599
 - design 599
 - rolling cutter bits 169–171
 - Rosetta 499, 501
 - Rosetta lander drill 499–501
 - Rosetta–Philae SD2-Drill 499
 - Ross Ice Shelf Project (RISP) 226, 281
 - rotary active sampling package (RASP) 751
 - rotary drill 5, 6, 9, 14, 15, 22, 225–227, 257, 353, 379, 390, 393, 441, 442, 516, 535
 - rotary drilling rigs 149–162
 - rotary drilling with drag bits 104, 109
 - rotary-hammer drill 15, 745, 749
 - rotary hammers 580, 591, 593, 594
 - rotary percussion drill bits 148
 - rotary percussive hammer rigs 147–149
 - rotary-percussive drill 348, 353, 497, 505, 543
 - rotasonic drilling 148
 - rotation per minute (RPM) 112, 117, 120, 124
 - ROV drill (MBARI/WHOI) 334, 335, 336
 - rover 591, 620–622, 631
 - rover support assembly (RSA) 480, 484
 - Russian KEMS-112 (KEMS-132) drill 239
- s**
- salt diapirism 72, 80
 - SAM analytical suite 675
 - sample acquisition 707, 708, 712, 725, 733
 - sample acquisition and preprocessing
 - system 423–438
 - sample acquisition and transfer mechanism (SATM) 449, 450
 - sample acquisition system (SAS) 402, 422, 440, 451
 - sample analysis at Mars (SAM) 505, 751
 - sample analysis platforms 649
 - sample caking 571
 - sample capture device (SCaD) 437
 - sample capture techniques 436–438
 - sample distribution (MeSH-SD) 600, 602
 - sample handling and distribution system (SHADS) 733
 - sample handling tasks 559, 560
 - sample hand-off (MeSH-SHO) 600, 601
 - sample processing unit (SPU) 575, 579, 595–600
 - sampler and distribution system (SD2) 499–501
 - sample return missions 712, 725
 - sample separation & preparation (MeSH-SSP) 600, 601
 - sample transfer unit (STU) 598
 - sampling, drilling, and distribution system (SD²) 499–501
 - sampling mechanisms 748–750
 - sampling mole 368, 502, 503
 - saws 585
 - science traceability matrix 647, 648
 - scientific drilling 313–318
 - scoops 358–366
 - screens 227, 236, 267
 - sea floor drill rig 333
 - secondary crusher 574
 - sedimentary rocks 31, 39, 53, 88
 - segmented coring auger drill (SCAD) 441–444
 - seismic sounding 222
 - seismometers 663–665
 - semi autogenous mills 584
 - semi-submersibles 310, 312
 - sensor 243, 251, 262–264, 272, 274, 286, 289, 291, 300
 - shallow drilling 421, 536, 538
 - shape of particles 571
 - shear failure 36, 81, 99, 121
 - shear modulus 32, 36, 45, 46, 54, 126
 - shear strength 37, 42, 46, 82, 126
 - shear testing of interfaces 42
 - shoes 227, 228, 230, 231, 236, 241
 - shot holes 223, 262, 266
 - sidewall friction 188, 199, 200, 203, 211, 212, 215
 - sidewinder 259, 260
 - sieve screens 605–607, 609, 610, 612, 613
 - sieve vibration mechanism 608
 - sieving 569, 600, 601, 605, 606, 608–610, 612, 614, 617–619
 - silicone control rectifier (SCR) 154, 155
 - single stage comminution 591–594
 - SIPRE coring auger 231

- slip-line analysis 203, 204
 slippage 39, 73
 slipping assembly 543
 small body spacecraft 622
 small sample acquisition and distribution tool (SSA/DT) 364, 365, 411, 412, 453, 501
 small strain model 204
 Smectite-to-illite mineralogy 76
 soil penetration 200, 215
 solar powered rock crusher 595, 596
 solid core capture 534
 solid core ejection 535
 solid core stratigraphy 535
 solvent cleaning 727
 solvents 716, 718, 727
 sonde 227, 228, 232, 241, 243, 244, 248, 253
 sonic cleaning 718
 sonic drilling 175
 South Pole 221, 222, 223, 263, 272, 274, 279, 301
 Soviet Luna drill 497–498
 Soviet Venera and Vega landers 52
 space analogs 528
 spacecraft landers 621
 Spacecraft Mechanisms Corporation (SMC) 449
 specific energy 103, 106, 111, 112, 113, 118, 119, 120, 129
 spectrometers 644, 649, 653–655, 657, 659–663, 666–670, 675, 679–684, 688, 690–692
 spindletop well 146
 spinning offset mass 608, 610
 Spong 624
 spores 719, 721–723, 729, 731, 734–736
 spotting drill bits 17
 SSA/DT 364, 365, 411, 412, 453, 501
 stabilizer placement effects 191
 stamp mill 580, 581, 591, 593
 static method 41–45
 stationary platforms 621–624
 statistical permeability models 39
 steam drills 283, 284
 stereo imager 649
 sterility 718, 723, 724, 727, 728
 sterilization 718, 721–731, 733, 735, 737
 Sterrad process 729
 strength properties 32, 37–39
 strength testing 42
 stress boundary conditions 67–68
 stress orientations 66, 69–73, 127
 stress; principal, total, effective 37, 58, 65, 66, 68, 69, 73, 74, 81, 83, 84, 85, 100
 stresses in drilling 68
 strong white light 727
 subsea boreholes 310
 subsurface access testing laboratory 443, 527, 528
 subsurface corer sampling system (SCSS) 455–458
 subsurface explorer (SUBEX) 477–479
 subsurface ice probe (SIPR) 286, 287, 289–291
 Subsurface Planetary Exploration Core Extracting System (SPECES) 473–475
 Subsurface Telescoping Sampling System (STSS) 458–460
 surface acoustic wave (SAW) 751
 surface drills 402–421, 537
 surface microbial density 721
 surface removal tool (SRT) 628
 Surface Sampler Acquisition Assembly (SSAA) 360–361
 surface sterilant process 729
 surface tension 54, 61, 62
 surface-driven rotary drills 224–225
 survey techniques 197, 198
 surveyor scoop 358, 359
 Suzuki booster 238, 240
 swing mill 587, 588
 Swiss Federal Institute of Technology (ETHZ) 281
 Swiss lightweight drill 231–233, 245
- t**
- tactile feedback 628
 Taku Glacier 223, 226
 T-bar (TBT) 313
 technology readiness level (TRL) 407, 424, 449, 455, 473, 486, 488, 541, 651, 662, 691, 694
 tectonic data 65
 Tedlar film 735
 TEGA instrument 714
 tele-drilling 487
 ten-meter class drills 462–476
 tensile failure 98, 99, 103, 129
 tensile strength 32, 37–39, 42, 47, 58, 59, 61, 62, 64, 99, 103
 terrain sensing 628–632
 terrestrial rocks 31–48
 thermal and evolved gas analyzer (TEGA) 669
 thermal comminution 590
 thermal drill 118
 thermal emission spectrometer (TES) 655, 668, 669
 thermal probe 649

- thermal spallation 141, 214
 thermal spalling 9, 12, 162–164
 thermal spring pickaxe 595
 thermal techniques 12–13
 thermal vacuum (TV) 367, 372, 422, 528
 thermocouple 745, 746
 till 297
 tilt angle 190, 195
 time delay effect 729–731
 tipping drill 228, 234, 236
 Titan 51, 52, 127
 Titan harpoon sampler 417–421
 titanium carbon nitride (TiCN) 19
 toolface 184, 185
 top hammer (TH) 147, 148
 total drilling power 478, 542
 touch and go surface sampler (TAGSS)
 413–415
 tower 228, 231, 233–235, 244, 252,
 273, 274
 toxic gas 726
 Transmash Russian Mobile Vehicle
 Engineering Institute (VNII) 366, 367,
 502, 503
 transport properties 32, 39–41, 126
 transpressional conditions 81
 triaxial testing 36, 37, 41–44, 113, 126
 trichloroethylene 293, 294
 tricone bits 22–23
 tricon milled tooth (MT) 22
 triple point of water 742
 true vertical depth (TVD) 184, 199
 tumbling machines 583, 594
 tunable diode laser absorption spectroscopy
 (TDLAS) 675–677
 tunable diode laser spectrometer (TDLS) 669,
 675, 676
 tunable laser spectrometer (TLS) 654, 675,
 676
 tungsten carbide inserts (TCI), tricone bits 22
 twist drill bits 15, 16
- u**
- ultrasonic agitation 716
 ultrasonically assisted drilling (UAD)
 377–379, 392
 ultrasonic comminution 590
 ultrasonic drilling 165, 166
 ultrasonic drill tool (UDT) 378, 392, 393
 ultrasonic rock abrasion tool (URAT)
 356–358
 ultrasonic rock corer 390–392
 ultrasonic/sonic driller/corer (USDC)
 379–387, 743, 745, 747, 749
 ultrasonic/sonic gopher 25, 380, 382,
 475–476, 513
 ultrasonic vibration 563, 609
 ultraviolet/visible (UV/VIS) spectroscopy
 649, 655, 667
 unconfined compressive strength (UCS) 364,
 408, 543
 unconsolidated core capture 534
 underbalanced drilling 223
 uniaxial compressive strength (UCS) 34, 37,
 38, 40, 42, 46, 47, 54, 59, 61, 62, 65, 95, 108,
 117, 118, 121
 unrestricted earth return 709, 710, 712, 725
 unweathered (fresh) core 559
 US Geological Survey 221
 USDC 383, 385, 743, 745, 747, 749
 UV irradiation 709, 710, 712, 725
 UV Raman spectroscopy 671
- v**
- Van Den Berg's finite element model 205
 vapor cleaning with IPA 718
 vapor hydrogen peroxide (VHP)
 sterilization 729, 730
 vapor methods 727
 Venera drill 498, 499
 Venus 51, 52, 64, 127
 – drill 460, 462
 vertical shaft impactor 580
 vibrating mills 581
 vibratory pile driving 210–212
 vibrocoring 330, 343
 vibro-impact mechanism 378
 Viking X-ray fluorescence spectrometer 680
 vision-based terrain sensing 629–632
 volcanism 52, 72
 Vostok 239, 250, 251, 295
- w**
- water saturation 39, 59, 62, 65
 wave velocities; compressional, shear 45, 47,
 73, 100, 126
 wax corer 340
 weight on bit (WOB) 90, 92, 94, 104, 105,
 110, 112, 113, 115, 117, 120, 128, 354,
 383, 385, 388, 389, 409, 410, 451, 454,
 464, 465, 467, 469, 480, 482, 488, 523,
 527, 742, 747
 West Antarctic Ice Sheet Divide Ice Core
 (WAISCORE) 144
 wet chemistry laboratory (WCL) 677, 678
 winch 228, 231, 233, 234, 235, 238, 239, 244,
 248, 252, 253, 260, 272, 274, 285
 wireline 145, 146, 156, 747

- coring 322, 325, 328
- drill 226, 299, 300, 475, 517
- wireline system 226, 438, 440, 469, 493
- Wood wasp digging system 513, 514

x

- X-ray diffraction (XRD) 562, 654, 655, 672, 673
- X-ray emission spectroscopy 679

- X-ray fluorescence (XRF) spectroscopy 562, 649, 654, 655, 663, 672–674, 679–682

y

- Young's modulus 32, 33, 43, 45, 54, 56, 58, 59, 88, 126

z

- Z-stacking 657, 659

