

# Index

Page numbers in *italic* denote figures. Page numbers in **bold** denote tables. Letters a, b, or f following a page number indicate references to appendices, textboxes and foldouts respectively.

- abrasion, effect on construction materials 55, 57
- Abu Dhabi, sabkha 83
- Abu Sueir, subgrade moisture content 361, **363**
- acid, excretion by lichen 36
- admixtures, concrete 328, 332, 334b
- adobe 336, 388
- adsorption 272
- aeolian bedforms 49–50
  - classification 50–51
- aeolian hazards 55, 57–58
- aeolian processes 4, 7, 20, 25b, 45–50, 148
  - see also* wind erosion
- aeolian soils **147**, 149
- aerosol index method 57–58
- aerosols, salt 77
- aggregate 301
  - concrete and mortar 328–331
  - crushed rock 316–317, 320–321
    - extraction and processing 320–321, 322b
  - properties **314**, **316**
  - in road building 323, 324
  - salts 313–316, *318*, *319*
  - sampling 211–212, 313–314
  - sand and gravel 310–316
    - evaluation 313–314, **318**
    - processing *313*, 314–316
  - sources 101, *103*, **103**, 226
    - sampling 216, 217–218b, 313–314
  - storage 312–313, 335
- air-masses, global 46–47
- albedo 12
  - and wind variation 47
- alcrete 150
- algae, weathering 36–37
- algal mats 79, 81
- Alice Springs, Australia, climate data **19**
- alkali aggregate reactions (AAR) 328, 329b, 330b
- alkali-carbonate reaction (ACR) 312b, 330b
- alkali-silica reaction (ASR) 330b, *331*
- allogenic rivers 58–59, 60
- alluvium, groundwater calcrete 43–44
- Almanzora River Dam 80
- alveoles 40
- amphitheatres, valley head 39–40
- anhydrite 76
  - dissolution 285–286
  - hydration 64, 68, 82, 284–285
  - sabkha 82
- Antofagasta, Chile, climate data **20**
- aquifers 340
- Arabian Desert *If*, **3**, 10
  - landforms **14**
- arid deserts 10, *11*
  - rainfall variability 18
  - soil and rock types *145*
- aridisols 148
- aridity 61–62
  - causes 11–12
  - classification **3**, 8–9
  - definition 8
- Aridity Index (AI) **3**, **9**, 61
- armourstone 307–310, 311b, 369
- arsenic, pollution 29
- asphalt 325–328, 326b, 365
- ASTER
  - DEM 178
  - imagery **173**, 176, *177*
- Atacama Desert *If*, **3**, 8, 10
  - fog and dew 12, 17, *21*
  - mine pollution 29
  - nitrate enrichment 44–45
  - origin 24
  - rainfall *13*
- atmosphere, stability, and aridity 11
- attapulgitite *see* palygorskite
- Atterberg limits, testing **220**, 222, 223, 239ab, 324
- augering, rotary 202, **203**, 206, *207*
- Australia
  - palaeoclimate 25
  - silcrete 44
- AVHRR imagery **173**, 176b, 177
- Awash River 59, *131*
- backing wind shift 46
- badlands 4, 65, 67, **70**, 72, *119*
- Bahrain Surface Materials Resources Survey *186*, 187–188
  - field mapping *180*, 188
- bajada 68, **100**
- ballistic impact, grains 47, 49, 55, 57
- bankfull discharge *63*, *67*
- Barcelona model *274*, *275*, *277*
- barchans 51, **53**, *54*, *55*
- basalt plateau *109*
- baseflow *63*
- basin, enclosed *see* bolson
- basin and range model 101, *102*
- beach stone 149, 302, 302b, 367, 368
- bedforms, aeolian 49–50
  - classification 50–51
- bedload, mobile 62–63, *65*
- Benguela Current 12
- bentonite, drilling fluid 208b
- bitumen, in road building 322, 323, 325–328, 364–365
- Blackhawk landslide *137*
- blasting, aggregate production 320, 321b
- blowouts 52–53, *56*, **56**
- bolson *133*
- bonding
  - partially saturated soils 276
  - sand and gravel 288b, 289–290

- bores 62
- boring  
 cable percussion **203**, 206, 207, 208, 230  
 rotary wash **203**, 208  
 soft-ground 202, **203**, 206, 208
- breakwaters 308, 309, 310b, 310
- bricks  
 adobe 338, 388  
 fired 336, 338  
 materials 338–339  
 sand-lime 332, 334, 336
- bridges  
 channel migration 71–72  
 channel scour 63, 66, 372
- Bryce Canyon, Utah, gullies 126
- building materials *see* engineering, natural materials
- building stone 303–307  
 standards 305, **306**  
 technical assessment 305–306
- buttes 117, 123  
 soil types **146–147**, 149
- Cairo, climate data **16**
- calcarenite  
 bonding 289–290  
 excavation 349
- calcite 76  
 concretions 88, 89
- calcium carbonate 35, 87–88  
 and soil strength 292, 294
- calcium sulphate 35  
 dissolution 285–286  
 hydration 284–285  
 sea water 87  
 and soil strength 292, 294  
 and swell potential 281–282
- calcrete 4, 22, 42–44, 88, 112, 149–150  
 as aggregate 319, 320  
 as building material 302  
 engineering characterization and classification,  
 existing schemes **154**, 155  
 floodwater 43  
 groundwater 43  
 road building 324, 326b, 364–365
- caliche, sodium nitrate 44
- California bearing ratio (CBR) **203**, **220**, 222, **235**, **238**,  
 242ab, 243ab, 244ab  
 gypsiferous soils 302, 362, 364  
 road building 323, 324, 361
- canker, duricrust 150, **154**
- canyon and scarp model 101, 102
- capillary fringe 34, 43, 64, 75, 270  
 engineering impact **22**, **374**  
 evaporites 34–35
- capillary rise 22, 64, 270, 375
- carbonation, concrete 387
- case hardening 41, 111, **146**, 148  
 tafoni 39
- caves 37, 38, 113  
*see also* tafoni
- celestine 76, 82
- cement  
 Portland 328, 329b, 331–332, **333**  
 standards 331, 332, **333**  
 storage 335
- cementation 226, 276  
 alluvial fan deposits 287b  
 beach stone 302  
 road building materials 324  
 salt precipitation and dissolution 285  
 sand 286b  
 and slope stability 348  
 soil, mechanics 289–294  
 terminology **151**  
*see also* bonding
- Central Arizona Long-term Ecological Research  
 Project (CALERP), GIS and remote  
 sensing 185
- Chalbi Desert *If*, **3**
- channels, stream 73  
 braided 67, 73  
 ephemeral 8, 67, 372, 373  
 migration 71–72, 78, 79  
 meandering 67, 73
- chemical weathering 36  
 salt 35, 387
- Chihuahuan Desert *If*, **3**, 10
- chloride 7  
 in aggregate 319, **324**, 327b  
 concrete mix water **341**  
 effect on reinforced concrete 359  
 influence on test results **219**, 222  
 in reclamation fill 370b
- chloride content, testing 244ab, 245ab
- chlorite 4, 36  
 brick-making **338**
- Cholistan Desert *If*, **3**
- Chott el Gharsa salt lake 8
- chromatography 89
- cladding stone 303–304b, 303–307, 307b
- clay  
 natural piping 64  
 slaking 34  
 swelling potential 280–282  
 Oman 355, 356b
- clay minerals, shrink/swell cycles 34, 36
- climate  
 control on environment 13–22  
 engineering significance of 7  
 influence on hydrology 60–62
- climate change 28, 29  
*see also* palaeoclimate change
- coastal development 367–370  
 marine environment 369–370
- coastal environment, sabkha 79, 81–83
- coastlines  
 armourstone 307–310, 311b, 369  
 sabkha 79, 81–83  
 soil types **146**, 148–149
- collapse  
 desert soils 72–73, 231, 274, 278–280, 353–355  
 salt dissolution 222–223
- Colorado Desert *If*, **3**
- comminution, salt weathering 36, 81
- compaction, low moisture content 350–352
- compaction tests **220**, 222, **235**, 242ab

- compression  
 partially saturated soil behaviour 273–275  
 sand 260–261, 262
- concrete  
 admixtures 332, 334b, 385  
 aggregate 328–331  
 alkali aggregate reactions (AAR) 312b, 328, 329b, 330b  
 carbonation 387  
 curing 341, 385–386  
 durability 387  
 engineering design and construction 384–387  
   mixing and placing 385–386  
 environmental problems 7, 384–385, 387  
 production 320b  
 reinforcement 332  
   salt attack 35, 38, 328, 332  
 salt attack 328, 329b, 358–359, 387  
 salt weathering 69, 73, 86, 387  
 standards 328  
 storage 335, 385  
 water quality 341
- concretions, and groundwater flow rate 88, 89
- conductivity, hydraulic, testing 253ab
- cone penetration testing (CPT) 205, 209, 212, 237  
 sand 267, 268  
 zone III 228  
*see also* soil assessment cone penetrometer (SACP)
- consequences, hazard and risk 169b
- consolidation tests 235
- construction 347–390  
 desert ground model 97  
 ground investigation methods 201–211, 232, 233  
 hazards 97–99  
   fluvial 68–73  
   geochemical 75–76, 82, 201  
   wind-related 55, 57–58  
 natural materials *see* engineering, natural materials  
 traditional 387–388  
 waste 339–340  
 continental margins 12  
 active 12, 14  
 passive 12, 14
- continentality, and aridity 11, 12
- continuous dynamic probing 238
- copper, pollution 29
- coral 149  
 dredging 368
- Corona imagery 173, 177
- cratons 12, 14
- creep, surface 48, 49, 375
- critical state line (CSL) 261, 262, 263–264, 266, 267–268
- critical states, sand 261, 263–267
- croûte de nappe* 44
- crystallization, salts 35, 75–76
- currents *see* ocean currents
- dams, sediment loading 72, 80
- Danakil Desert *I*f, 3
- Darb el Arba'in Desert *I*f, 3
- dayas 37
- Death Valley  
 alluvial fan 36, 135  
 bolson 133
- diurnal wind variation 47  
 dune field 52  
 evaporites 82, 85, 134
- debris flows 68, 74  
 soil types 146, 148
- deflation 53, 55  
 sabkha 81
- deflation hollows 54–55, 121
- deforestation, and groundwater salinity 29
- degradation  
 aggregate 312  
 armourstone 311b  
 by vehicles 58, 390  
 salt weathering 348–349, 350
- demolition, waste 339–340
- density, tests 234, 243ab, 244ab
- deposition, grain 49  
*see also* landforms, depositional
- desalination 28, 341
- desert glaze 145, 146, 148
- desert landscape classification, Earth systems model  
 104, 105–141
- desert models 78, 97, 99, 100–105, 231, 393f  
 Cooke 101, 103  
 Fookes and Knill 12, 78, 99, 100–101  
 Goudie and Wilkinson 101, 102  
 landscape development model 104  
 rock and soil types 143–144, 146–147, 393f
- 'desert roses' 81–82
- Desert Working Party (DWP) 1, 2b, 5
- desert zones 13, 78, 99, 100, 101, 103, 393f  
 investigation techniques 223–231  
   Zone I 13, 78, 100, 223, 224, 226–227  
   Zone II 13, 78, 100, 224, 227–228  
   Zone III 13, 78, 100, 224–225, 228–229  
   Zone IV 13, 78, 100, 225, 229–231  
 soil and rock types 144, 145, 146–147
- desertification 29
- deserts  
 definition 1–2, 8–10  
 distribution *I*f, 3, 10, 11  
 environments 7–29  
   controls on diversity 12–24  
 extent and location 7  
 past climate change 24–25  
 stoney *see* pavements, desert
- design  
 engineering 267–268, 347–390  
*see also* front-end engineering design (FEED)
- desk study 159, 167–170  
 benefits table 168, 171  
 field validation 179  
 geological model 170, 179  
 planning and undertaking 168–169, 171  
 reporting 169–170, 185–186  
 sources of information 169  
 uncertainties 167
- dewfall 16, 17, 36
- diagrapy probing 209, 210, 211
- digital elevation models (DEM) 177, 178, 182
- digital surface model (DSM) 183, 184
- dimension stone 303–304b, 303–307  
 technical assessment 305–306

- dissection, of terrain 4  
*see also* etchplains
- dissolution, salts 285–287, 289, 356, 357b
- Dog's Bay Sand  
 compression 260, 261, 262  
 critical states 261, 263, 265, 266
- dolines 37, 42
- dolocrete 42, 43, 88, 149
- dolomite 82, 312b
- draa *see* megadunes
- dredging 367–368  
 impact on marine environment 369–370
- dreikanter 53
- drift potential (DP) 20, 25b  
*see also* sand, drifting
- drilling  
 rotary **204**, 208–209, 210  
   carriers 209, 210  
   core **204–205**, 208–209  
   fluids 208–209b, 349  
   open-hole **204**, 208  
   percussion **204**, 208  
   zone I 226–227  
   zone II 228  
   zone III 228
- drilling fluid 208–209b, 349  
 and geotechnical samples 212
- drought 61
- dry sub-humid deserts 2, 9, 11  
 rainfall variability 18
- drying  
 influence on test results 221  
 of soil 272
- Dubai Dry Dock  
 sabkha 83, **85**  
 settlement due to gypsum solution 201, 357b
- dune fields 132, 144  
 Death Valley 52
- dunes 48, 50, 140  
 barchan 51, **53**, 54, 55  
 blowouts 52–53, 56, **56**  
 climbing 53, 56, **56**  
 dissipation of 382  
 dome 51, **53**, 54  
 echo 53, 56, **56**  
 engineering significance 3–4, 164  
 falling 53, 56, **56**  
 fore 53, 56, **56**  
 free 51–52, **53**, 54  
 GIS assessment 183  
 ground investigation 230  
 immobilization of 384  
 impeded 51, 52–53, 56, **56**  
 lee 53, 56, **56**  
 LiDAR DEM 182  
 linear 8, 51, 52, **53**, 54  
 lunette 53, 56, **56**  
 movement 58, 232, 382–384  
 nebkha 53, 56, **56**, 164  
 parabolic 53, 56, **56**  
 remote sensing 177  
 removal of 382  
 reversing 51, **53**, 54  
 seif 164  
 soil types 145, **147**, 149  
 star 51, **53**, 54, 55, 164  
 topographically influenced 53  
 transverse 8, 51, **53**, 54, 55  
 wind variability and sand availability 52, 55  
 zibar **53**
- duricrusts 4, 41–45, 112, 145, **147**, 149–151, 289  
 as aggregate 320  
 cementation 151  
 construction problems 232, 353  
 engineering characterization and classification, 154–155  
 excavation 347, 348  
 and groundwater 22  
 incision 42  
 pedogenesis 42, 43, 149–151  
 in road building 324–325
- dust  
 atmospheric, and remote sensing 176b  
 Sahara Desert 48, 55  
 wind-blown hazard 55, 57–58, 312, 313, 375, 384, 385, 386b  
*see also* sand-dust system
- dust devils 47, 55
- dust plumes 57
- dust storms 50, 55, 376
- Dzungarian Desert *If*, **3**
- earth, rammed 336, 388
- Earth Resource Satellite **173**, 178
- Earth systems model, desert landscape classification 104, 105–141
- earthworks 347–352
- Eastern Desert *If*, **3**  
 calcrete 4
- efflorescence 34
- El Arish flood 71
- El Niño-Southern Oscillation (ENSO) 14
- electricity, static 57
- electromagnetic surveys **205**, 210–211, 213b
- endogenic rivers 58–59, 60
- endoreic basins 12, 15
- endoreic rivers 59  
 floodplain 131
- engineering  
 aggressive ground conditions 73, 201  
 desert ground model 97  
 design and construction 267–268, 347–390  
*see also* front-end engineering design (FEED)  
 ground investigation, methods 201–211  
 hazards 97–99  
   fluvial 68–73, **98**  
   geochemical 75–76, 82, **98**  
   wind-related 55, 57–58, **98**  
 impact on ground conditions 73  
 natural materials 301–341  
   effects of desert environment 301–302, 312–313  
   storage 335–336, 385  
   traditional 336–339  
 waste 339–340
- engineering geological model 161, 165, 170, 179  
 route corridors 164–165
- entisols 148
- entrapment, grain 48–49

- environment
  - marine 369–370
  - protection of 388, 390
- episodic change model 58, 60
- Equatorial Trough *see* Intertropical Convergence Zone (ITCZ)
- ergs *see* sand seas
- erosion
  - flooding 372
    - see also* scour, channel
  - sand 4
    - protection against 380–381
  - wind 4, 7, 20, 47–48
    - features 53–55
    - see also* landforms, erosional
- escarpments 116
- Esna Shales, shrink/swell cycles 34
- etchplains 4, 68, 120
- Ethiopian Highlands, flood basalts 109
- ettringite 35
  - formation in concrete 358
- evaporation 7, 75, 76, 268, 270
- evaporites
  - capillary zone 34–35
  - engineering behaviour 294–296
  - GIS assessment 183
  - see also* salts
- evapotranspiration 8, 9
  - ratio to precipitation (PE) 9
- excavation 347
- Exchangable Sodium Percentage (ESP) 34
- exfoliation 33–34, 38–39
- exoreic rivers 59
- exposure, hazard and risk 169b
  
- faceted surface 53
- falaj *see* qanats
- fans, alluvial 67–68, 74, 75, 135
  - as cement 287b
  - soil types 146, 148, 149
  - see also* footslopes and fans, zone II
- fences, sand 377–378, 379, 380, 384
- ferricrete 4, 44, 88, 150
- Fezzan sands, ground investigation 229b
- field evaluation 159, 178–181
  - reporting 185–186
  - uncertainties 167
- field mapping 159, 179–181
- field reconnaissance 159, 178–179
- fills 349–352
  - coastal reclamation 368–369
  - presence of salts 352
- filterpaper suction tests 251–252ab, 280
- fire, rock spalling 34
- flaking 38, 39
- flash floods 62
  - hazards 69–71, 226, 231b
  - GIS assessment 183
- flatiron 42, 128
- Flood Insurance Rate Maps 183
- flood risk, zone II: footslopes and fans 228
- flooding 4, 19–20, 62–63, 69–71
  - and erosion 371–372, 373
  - hazard estimation 231b
  - hazard mitigation 372
- fluvial deposits 226
- fluvial geomorphology 58–73
- fluvial processes, hazards 68–73
- fluvial soils 146, 148
- fog moisture 12, 17, 21
- foggara *see* qanats
- fold mountains 106
- footslopes and fans, zone II 101
  - ground investigation 203–205, 224, 227–228
  - soil and rock types 144
- foundations 352–359
  - pile 358
- front-end engineering design (FEED) 188, 193
- frost weathering 34
- Fryberger technique 20, 25b, 26
  
- gara 36
- geochemistry
  - ground and groundwater, sampling 212–213
  - salt, engineering hazards 75–76
- GeoEye 173, 178
- geographical information systems (GIS) 181–185
  - applications 182–185
    - corridor selection 183, 185
    - geohazard assessment 183
    - land-cover changes 185
    - thematic mapping 182–183
    - unstable ground 183
    - water resources 183, 340
  - data 181–182
- geohazards 97–99
  - GIS assessment 183, 185
- geology
  - control on desert environment 12–13
  - engineering geological model 161, 164, 165, 170, 179
- geomodels 97, 138–139
  - see also* desert models
- geophysics, ground investigation techniques 205, 209–211
- Oman dam sites 213
  - zone I 227
- geotechnical investigation, staged 161b, 162, 163
- gibber *see* pavements, desert
- Gibson Desert *If*, 3
- global positioning systems (GPS) 177, 178
- gnammas 40
- Gobi Desert *If*, 3, 10
  - drift potential 20
- gold, pollution 29
- Google Earth 177, 178
- grain-fall 49
- grains
  - accretion 49
  - ballistic impact 47, 49, 55
  - deposition 49
  - entrapment 48–49
  - size and transportation 48–49
- granite, as building stone 304b
- gravel
  - bonding 288b
  - as building material 312–316
  - roads 366–367

- gravity surveys **205**, 211, 213b  
 Great Basin Desert *If*, **3**, 10  
 Great Man Made River Project 229b, 360  
 Great Sand Sea 50  
 Great Sandy Desert *If*, **3**  
 Great Vistoria Desert *If*, **3**  
 grooves, wind eroded 53–54  
 ground conditions  
   aggressive 73, **87**  
     investigation 201, 230, 232  
     Suez, Egypt 192, 193  
   desert model 97  
   GIS assessment 183  
   unstable, investigation 201  
 ground investigation 201–255  
   during construction 232, 238  
   interpretation and reporting 231–232  
   methods 201–211  
     planning 201–202  
     soft-ground boring 202, **203**  
     trial pits and trenches 202, **203**  
   research bodies 243a, 255a  
   sampling 202, **203–205**, 211–216  
   standards 202, 216, 231, 238a, 240a, 243a  
   techniques 223  
     Zone I **204–205**, **224**, 226–227  
     Zone II **203–205**, **224**, 227–228  
     Zone III **203–205**, **224–225**, 228–229  
     Zone IV **203–205**, **225**, 229–231  
   testing 216, **219–220**, 221, 222–223, **234–238**, 238–240ab  
   Wadi Siji Groundwater Recharge Dam 227b, 228  
 groundwater  
   calcrete formation 43  
   coastal, chemistry 85–89  
   controls on landscape 22–24  
   flow rate, concretion growth 88, 89  
   mining 28–29  
   rising 374–375  
   saline 36  
     engineering issues **87**, 302, 375  
     intrusion 29  
   sapping 39  
   soil moisture zones 232  
   transport above water table 75  
   and urbanization 372, 374–375  
   wastewater pollution 29  
   water supply 28–29  
   weathering 23  
 groyne 308  
 Gulf State sand processing plant, ground investigation  
   217–218b  
 gullies 62, 65, **70**, 71, 72, 74, 126  
 gypcrete 4, 22, 44, 88, 149, 150, 286b  
   as aggregate 320  
   road building 325b, 364–365  
 gypcrust 44, 149, 150  
   tension polygons 217b, 218b  
 gypsum 35, 73, 76  
   as building material 302  
   comminution 81  
   concretions 89  
   ‘desert roses’ 81–82  
   dissolution 285–286, 356, 357b  
   enrichment 44  
   field identification test 254ab  
   hydration 284–285  
   karst 64, 67, 68, 113  
   near-surface crusts 73  
   playas 83  
   precipitation 283  
   sabkha 81–83  
   solubility in saltwater 86, 88  
 halite  
   comminution 81  
   near-surface crusts 73, 76, 82  
   playas 83  
   precipitation 283  
   sabkha 35, 79, 82  
 haloturbation *see* salt heave  
 Ham River Sand  
   compression 260, 262  
   critical state line 262  
 hardpans 42, 88, 89, 150, **154**  
 Harmattan wind 47  
 hazards 97–99, 169b  
   fluvial processes 68–73  
   geochemical 75–76  
   wind-related 55, 57–58, 312, 313, 325, 327,  
     375–384, 385, 386b  
 heave  
   clay soils 282  
   due to ground conditions 73, 76, 82, 375  
   salt 36, 356, 357b, 358  
 herringbone sampling 216  
 high-pressure belts, subtropical 11, 12, 46  
 Hofuf sands and gravels, ground investigation  
   217–218b  
 honeycomb duricrust 150, **154**  
 honeycomb weathering 40, 72, 111  
 hoodoos 72  
 hot deserts 2–3  
   engineering significance 3–4  
 Humboldt Current 12  
 humidity 14–16  
 hydration, salts 35, 39, 64, 68, 82, 284–285  
 hydrocompaction 72–73  
 hydrograph, flood 62–63  
 hydrology 60–64, 98  
 HyMap 176, 177  
 hyper-arid deserts 2, 8–9, 10, 11, 12, 13  
   rainfall variability 18  
 Hyperion sensor **173**, 174  
 hysteresis 272, 275, 277  
  
*Ikonos* imagery **173**, 178  
 illite 36, 40, 282  
   brick-making **338**  
 In Salah Gas Project, Algeria  
   facility sites 193–195  
   geological model 161, 164–165, 179  
   pipeline route selection 187, 188, 192–193  
 incision, duricrust 42  
 Index of Moisture Availability 1, 8–9  
 India, quarrying 304b  
 induration *see* duricrusts

- infiltration 62, 268, 270, 271, 372  
 and urbanization 374b
- infra-red (IR) photography 171, **173**
- insect infestation 338b, 388
- inselberg and pediment model 101, *102*
- inselbergs *125*  
 soil types **146–147**, 149
- insolation weathering 33–34
- inter-cratonic zones 12, **14**
- inter-orogenic zones 12, 13, **14**
- Intertropical Convergence Zone (ITCZ) 11, 46, 47
- iron oxide 40, 88
- irrigation 340  
 and salinization 29
- Jeddah, sand and gravel extraction *315*
- Kalahari Desert *If*, **3**, 10  
 amphitheatres 39  
 calcrete, as building material 302, 326b  
 climate change 24  
 drift potential 20  
 evapotranspiration 9  
 lunette dunes 53
- kamenitza 40
- Kandahar, Afghanistan, climate data **18**
- kaolinite 36, 282  
 brick-making **338**  
 case hardening 41
- Karakum Desert *If*, **3**  
 drift potential 20
- Karnak, salt weathering 69
- Karoo Desert *If*, **3**, 10
- karst 4, 37–38, 64, 67, *113*, 353  
*see also* pseudo-karst
- Khartoum, subgrade moisture content 361, **363**
- kilns, brick 336, 338
- Kretchba gas field  
 facility sites 193–194  
 terrain evaluation *195*, *196*
- Kuwait, climate data **17**
- Kuwait Desert, sand movement 58
- Kyzylkum Desert *If*, **3**  
 drift potential 20
- lag deposits 48, 53, 55  
 soil types **146**, 148
- lagoons 79, 83  
 ground investigation 230
- Lake Chad 48, 55
- Land Systems mapping 177
- land-cover  
 GIS analysis 185  
 remote sensing 172, *174*
- landforms  
 azonal 114  
 depositional 133, 138, *141*  
 macro-/mesoscale  
 dunes *140*  
 landslides *137*  
 sabkha *136*  
 macroscale, alluvial fan *135*  
 mega-/macroscale  
 endoreic river floodplain *131*  
 salinas *134*
- meqascale  
 bolson and playa lake *133*  
 dune fields *132*  
 sand seas *132*
- mesoscale  
 river terraces *139*  
 scree *138*
- erosional 128–129, *141*  
 macro-/mesoscale, inselberg *125*
- macroscale  
 badlands *119*  
 wadis *122*
- mega-/macroscale  
 deflation hollows *121*  
 escarpment *116*  
 pediments *118*  
 tableland and mesas *117*
- meqascale, palaeosurface *120*
- meso-/microscale, desert pavements *130*
- mesoscale  
 butte *123*  
 flatiron *128*  
 gullies *126*  
 strath terrace *127*  
 yardangs *124*  
 microscale, ventifacts *129*
- fluvial 64–68
- scale **105**, 114, 118, *141*
- structural 121–124, *141*
- meqascale  
 fold mountains *106*  
 rift valleys *107*
- variety of 12–13, **14**
- volcanic 121–124, *141*
- meqascale  
 basalt plateau *109*  
 volcanoes *108*
- weathering 38–45, 124, 127, *141*
- meso-/microscale  
 case hardening *111*  
 duricrusts *112*  
 honeycomb weathering *111*  
 karst *113*
- mesoscale  
 pseudokarst *115*  
 zeugen *114*  
 microscale, rinds *110*  
 rock varnish *110*
- zonal 109, 114
- Landsat  
 ETM 177, 178, 183  
 TM 172, **173**, *174*, 175, 176, 177–178
- landscape classification *104*, 105–141
- landslides *137*
- Las Vegas, Nevada, climate data **19**
- laterite, road building 325
- leaching 289, 302
- ledge rock *see* beach stone
- Libyan Desert *If*, **3**  
 aeolian landforms 13, **14**  
 drift potential 20

- lichen
  - manganese fixation 41
  - weathering 36–37
- LiDAR (Light Direction And Ranging) 174, 178, 197a
  - DEM 182
- limestone 312b
  - as armourstone 311b
  - as building stone 303–304b
  - dolomitic 312b
  - weathering
    - biological 36–37
    - solution 37–38
    - see also* karst
- liquid limit, tests **233**, 239ab
- loading collapse curve (LCC) 274–275
- loess 48
- logging, downhole geophysical **204–205**, 211
- Lut Desert *If*, **3**
  
- magnesite 82
- magnesium sulphate 35
- manganese, rock varnish 40–41
- mapping
  - geological, remote sensing 175–176
  - geomorphological field 159, 179–181
  - hazard, GIS 183
  - thematic, GIS 182–183
- marble
  - as building stone 304b
  - thermal degradation 34
- megadunes 50
  - movement 58
  - Namib Desert 52
- megaripples 50
- mercury, pollution 29
- mesas 117
  - soil types **146–147**, 149
- methylene blue staining test 255ab
- micro-gravity surveys **205**, 211
- Microsoft Virtual Earth 177
- Mina Jebel Ali
  - chemical changes in fill 201
  - reclamation fill contamination 370b
- minerals
  - precipitation and solution 75–76, 79, 86–89
  - remote sensing 177
  - solubility in saltwater 85–89
- mining, pollution 29
- mirabilite 35, **284**
- MODIS imagery **173**, 176b
- moisture
  - and building stones 307b
  - influence on test results **219**, 221, 223
  - variability 9
  - see also* groundwater; soil, moisture
- Moisture Availability Index 1, 8–9
- moisture content
  - subgrade 361
  - testing **233**, 238ab
- moisture equilibrium 268
- moisture zones 75, 81, **82**, 232
- Mojave Desert **3**
  
- monsoon 11
  - and palaeoclimate change 24
- Monte Desert *If*, **3**
- montmorillonite 36, 40, 64
  - brick-making **338**
  - swelling potential 281–282, 357b
- Monument Valley, Utah 117
  - buttes 123
  - high intensity rainfall 24
- monuments, salt weathering 36, 37, 64, 69
- mortar
  - aggregate 328–331
  - production 320b
  - standards 330, **332**
- Mostap sleeve sampler **205**, 209, 212
- mountain ranges 8
  - precipitation reduction 11–12, 14
  - see also* orogenic belts
- mudflow 68, 76
- mudrocks, slaking 34
- mushroom rock *see* zeugen
- Mustard Canyon, pediment 118
  
- Namib Desert *If*, **3**, 8, 10
  - drift potential 20
  - dust storms 50
  - fog and dew 12, 17
  - linear dunes 51
  - megadunes 52
  - origin 24
  - ripples 51
  - salt attack 34
  - sand sea 52
- Namibia, climate data **16**
- nebkha 53, 56, **56**
- Negev Desert *If*, **3**
  - dewfall 17
- Nile River, source 58
- Nile Valley, secondary salinization 29
- nitrate enrichment 44–45
- normal compression line (NCL) 260–261, 262, 263–264, 267, 290
- Nubian Desert *If*, **3**
  
- ocean currents, cold, and aridity 12
- oedometer tests 231, 245ab, 246ab, 247–249ab, 273–274, 279–280, 291
- Ogaden Desert *If*, **3**
- Ogallala calcrete cap rock 42
- Oman
  - coastal defences 309, 310
  - swelling clays 355, 357b
- onion-skin weathering 38
- Ordos Desert *If*, **3**
- orogenic belts 12, **14**
  - see also* mountain ranges
- overland flow 19, 62, **70**
  
- palaeoclimate change 24–25, 59
- palaeosurfaces 120
- palygorskite 4, 36
  - swelling potential 282
- pans, and deflation 55



- particle density **220**
  - tests **234**, 239ab, 240ab
- particle size analysis 221, 222
- particle size distribution, tests **234–235**, 240ab
- Patagonian Desert *If*, **3**, 10
- patina, rock 145, **146**, 148
  - see also* desert glaze; rock varnish
- pavements, desert 4, 53, 130, 148, 388, 389
- pavers 303–304b, 306–307, 307b
- pediments 68, 76, 77, 118
  - soil types **146**, 149
- pediplain 120
- pedogenesis, duricrust 42, 43, 149–151
- peneplain 120
- penetration testing *see* cone penetration testing;
  - standard penetration testing
- Penman's formula 9
- per ascensum model 22, 43, 268
  - calcrete formation 22, 43
- per descensum model 22, 42, 268
- permeability, and suction 270, 271
- permeability tests **236**
- Peruvian Current 12
- Peruvian Desert *If*, **3**, 10
  - ENSO 14
- photogrammetry 171, **173**
- photography
  - aerial 171, **173**, 196a
    - sources 177
  - digital 171, **173**
  - infra-red (IR) 171, **173**
- pile foundations 358
- pipelines 367
  - Great Man Made River Project 360, 367
- pipes, natural subsurface 63–64, 66, 113, 115
- piping, natural subsurface 63–64, 72, 115
- pisé see* earth, rammed
- pisolite 150, **154**
- pits
  - solution 36, 40
  - wind erosion 53
- plains, base level, zone IV **100**
  - ground investigation **203–205**, **225**, 229–231
  - soil and rock types 144, 151
- plains, zone III **100**
  - ground investigation **203–205**, **224–225**, 228–229
  - soil and rock types 144, 151
- planation 120
  - etch 4, 68, 120
- planning, ground investigation 201–202
- plastic limit, tests **234**, 239ab
- plasticity index 280–281
  - tests **234**, 239ab
- plasticizers 332, 334b
- plate-bearing test **238**, 249ab, 280, 281, 354
- playa lakes 12, 77, 78, 84, 133, **146–147**
  - engineering issues **86**
  - lunette dunes 53
  - soil types **146–147**, 148, 151
- playas
  - salt **14**, 68, 81, 83–85, 84
    - engineering issues **86**
- plinthite 324
- pluvial periods 59, 68
- poljes 42
- polygons, salt-pressure 79, 82, 217b, 218b
- polymers
  - in drilling fluid 208–209b
  - soil reinforcement 352
- population, impact on desert environment 25, 27–29
- precipitation **15**, 16–20
  - flooding 4, 371–372
  - lack of 11
  - ratio to evapotranspiration (PE) 9
  - variability 9
    - see also* dewfall; fog; rainfall; snow
- pressuremeter test **203**, **238**, 250–251ab, 280, 281
- prewetting 353, **354**
- pseudo-karst 64, 115
- qanats 28
- Qattara Basin 55
- Qattara Depression 121
- quarrying 303–304b, 305, 320, 322b
- Quickbird* imagery 171, **173**, 177, 178
- quickflow 63
- radar, ground penetrating (GPR) 211
- Radar (Radio Direction And Ranging) **173**, 174, 196a
- Radarsat **173**, 178
- rain-shadow effect 11–12, 13
- rainfall 17, 371
  - areal reduction factors 371
    - Atacama Desert 13
    - intensity 18–19, 24
    - localized 60, 61
    - variability 17–19, **22**, 23
      - see also* precipitation
  - rainfall stations 61–62
- Rambla Seca, bore 62
- raster model, GIS 181
- recharge 374b
- reclamation, coastal 368–369
- recycling
  - building materials 336, 338, 339–340
  - water 341
- Red Sea rift valley 107
- Registan Desert *If*, **3**
- Relative Dilatancy Index 264
- remote sensing 58, 171–178
  - applications 175–177
    - costs 177–178
    - geocological surveys 177
    - geological mapping 175–176
    - geomorphological surveys 176–177
    - image processing and mapping 174–175
    - problems in deserts 175, 176b
    - sources 177
    - wavelength 171, 172, **173**, 174
- resistivity measurement, ground investigation **205**, 210, 213b, **235**
- resultant drift potential (RDP) 20, 25b
- reverse osmosis 341
- ridges
  - barchanoid 51, **53**, 54
    - transverse 51, **53**, 54
- rift valleys 107

- rills 62, 65, **70**, 72  
rinds, weathering *110*  
rip-rap, coastal defences 308, 369  
ripples 49–50, *51*  
risk 169b  
risk assessment, health and safety 202  
risk registers 167, 168b, 170  
rivers  
  allogenic 58–59, 60  
  endogenic 58–59, 60  
  endoreic 59  
  ephemeral 8  
  exoreic 59  
  *see also* stream channels; stream flow  
Riyadh, Saudi Arabia  
  climate data **17**  
  groundwater 374b  
roads  
  construction 321–328, 327b  
  duricrusts and marginal materials 324–325  
  layers and materials 321–323  
  unpaved roads 323–324, 366–367  
  water supply 350  
  design and construction 359–367  
  pavements  
    design and construction 362, 364–365  
    salt damage 365–366  
  salt damage *350*  
  subgrade 360–362, **363**  
  wind-blown sand 325, *327*, 378–379  
rock  
  crushed, as aggregate 316–317, 320–321, 322b  
  disintegration, temperature response 33–34  
  engineering characterization and classification  
    existing schemes 154–155  
    recommended method 155–156  
  local  
    as engineering material 301, 302–310  
    location, extraction and processing 302–303  
  types  
    bare and/or patinated 144–145, **146**, 148  
    desert model 143–144, *145*, **146–147**  
    weathered *in situ* *145*, **146**, 148  
rock cycle *104*, 105  
rock pedestals 36  
rock varnish 40–41, *110*, 144, 145, 148  
  and remote sensing 176b  
route corridor selection 359–360  
  engineering geological model *164–165*  
  GIS *182*, 183, *184*, 185  
Rub' Al Khali *If*, **3**, 8  
  drift potential 20  
  sand sea 50  
rubble, coastal defences 308, *309*, 310b, *310*  
runoff 19, 62, *64*  
  impact on engineering 372, **373**  
  prediction of 371–372  
sabkha 35, 79, 81–83, *84*, **85**, *136*  
  cable percussion boring 207, 208  
  chemistry **88**  
  engineering issues **86**, **87**  
  ground investigation 229–230  
  leaching 289  
  soil behaviour 294–296  
  soil characterization and classification *152*, 156  
  soil types **147**, 151  
  trial pitting 202, *206*  
Sahara Desert *If*, **3**, 10  
  climate change 24  
  drift potential 20  
  dust 48, 55  
  escarpments *116*  
  flood damage *361*  
  landforms **14**  
  localized storms 60  
  palaeoclimate  
    karst features 38  
    silcrete 44  
  salt heave and blistering 366  
  sand sheets 50  
  temperature 14  
  wadis *122*  
  wind systems 47  
Salah, Algeria, climate data **15**  
Salima Sand Sheet 50  
salinas *81*, 84–85, *119*, *134*  
  engineering issues **86**, **87**  
  ground investigation 229–230  
  soil behaviour 294–296  
  soil types **146–147**, 148, 151  
salinity 4–5, 7, 22  
salinization, irrigation 29, 151, 232  
salt  
  accumulation 76–77, 79, 82  
  in aggregate sources 216, 313–315, *318*, *319*  
  as cementation 285  
  changes in hydration 284–285  
  in concrete 328, 358–359, 387  
  in construction materials 302, 313–315, *318*  
  crystallization and hydration properties 35, 283  
  dissolution 285–287, 289  
  effect on engineering 73, 75, 201, 356  
    drilling fluids 208–209b  
  effect on testing 216, **219**, *221*, *222*  
  engineering behaviour 282–289  
  expansion 35  
  groundwater 73  
  near-surface crusts 73, 76, 82  
  precipitation and solution 76, 79, 283–284, 285  
  in road building 323, 365–366  
  total soluble, testing 254ab  
  types and occurrence 35  
  wind-blown 77  
  salt enrichment, soils *145*, **147**, 151, **152**  
  salt heave 36, 356, *357b*, 358  
  salt jacking 283, 353  
  salt pans  
    ground investigation 229–230  
    *see also* salinas  
  salt weathering 4–5, 14, 34–36, 37, 64, *69*, 81  
  chemical 35, 387  
  engineering issues 35, 36, 38  
  mechanical 35  
  products and rates 35–36, 39  
  and slope stability 348–349, 350

- saltation 47, 48, 49, 375, 377–378  
 saltlands, arid 75–77, 79, 81–85  
 sample grading **219**  
 sampling  
   ground investigation 202, **203–205**, 211–216  
     aggregate sources 216, 217–218b  
     geotechnical 212–213, 216  
     quality classification 212, **213, 214–215**  
     sample disturbance 212, **214–215**  
 sand  
   bonding 288b, 289–291  
   as building material 312–316, 320b  
   burial by 58, 60, 384  
     remote imaging 176b  
   carbonate 259–260, 261, 262, 266  
     bonding 289–291  
     critical states 263, 265, 266  
     *in situ* testing 267–268  
   cementation 286b  
   compression 260–261  
   deflection of 382  
   density tests 263, 267–268  
   drift potential (DP) 20, 25b  
   drifting 20, 25b, 26, 375–382  
     road construction 325, 327  
   encroachment of 58, 325, 327, 384  
     *see also* dunes, movement  
   fencing 377–378, 379, 380, 384  
   interparticle forces 260  
   mechanics 259–268  
     design parameters, *in situ* testing 267–268  
   quartz 259, 260, 261, 262  
     bonding 289–290  
     critical states 263, 264  
   reduction of supply 380–382  
   shearing and critical states 261, 263–267, 269  
   stiffness 265–266  
   trafficability 361, 362  
   transportation of 47, 48, 375, 376  
     enhancement 378–380, 381  
     *see also* sand, drifting  
   trapping 376–378, 379, 380  
   wind-blown hazard 55, 57–58, 325, 327, 375–384  
 sand dunes *see* dunes  
 sand rose 25b, 26  
 sand seas 48, 50, 132, **147**  
   movement 58  
   Namib Desert 52  
 sand sheets 48, 50, **147**  
   and remote sensing 176b  
 sand storms, and remote sensing 176b  
 sand-blasting 57  
   *see also* abrasion  
 sand-dust system 47–48, 375–384  
   abrasion 55, 57  
   air-quality and visibility 55  
 sand-lime bricks 332, 334, 336  
 sapping, basal 72  
 satellite remote sensing 58, 171, 174, 196a  
   sources 177  
 saturation  
   degree of 272  
   partial 270–278  
 Saudi Arabia, sabkha 136  
 scour  
   channel 63, 66, 372  
     hazard estimation 231b  
   tunnel 22  
   wind 55, 57  
 scree 138  
 seawalls 308  
 Sechura Desert *If*, **3**  
 sediment load 62–63, 65, 73  
 sediment source mapping 58, 59  
 sediment transport 20, 25b, 26, 48–49  
 sedimentation, hazards 72  
 seepage 39  
 seismic profiling **205**, 210, 213b  
 semi-arid deserts 2, 8–9, 10, 11  
   rainfall variability 18  
   soil and rock types 145  
 sensors  
   hyperspectral 172, **173**, 174, 197a  
   multispectral 172, **173**, 197a  
 settlement, due to ground conditions 73, 82, 279–280,  
   353–354, 355b  
 sewage 29  
 shadow areas, weathering 16  
 shallow pad test **237**  
 Sharjah, UAE, climate data **18**  
 shear strength, partially saturated soils 276–277  
 shear-strength tests **236–237, 238**  
 shearing, and critical states 261, 263–267, 269  
 sheet flows 68  
   soil types **146**, 148  
 sheet sand  
   engineering significance 4  
   soil types **146**, 148  
 sheetflood 69, 74  
 Shibam Wadi Hadramaut, traditional buildings 388  
 shock, thermal 34  
 shore protection 369  
 shrink/swell cycles 34, 36, 64  
   GIS assessment 183  
   partially saturated soils 274  
 shrinkage, tests **234**  
 Shuttle Imaging Radar (SIR) **173**  
 Shuttle Radar Topographic Mission 177, 178, 183  
 silcrete 4, 22, 44, 149–150  
   as aggregate 320  
 Simpson Desert *If*, **3**  
   drift potential 20  
 Sind Desert *If*, **3**  
   secondary salinization 29  
 sinkholes 38, 113  
 slaking 34  
 slate, as building stone 304b  
 slip face 51  
 slope stability 347–349, 350  
 smectite 36  
   brick-making **338**  
   volume change 4  
 snow, impact on engineering 10  
 sodium carbonate 35  
 sodium chloride 35  
 sodium nitrate, enrichment 44–45

- sodium sulphate 35
- soil
- cementation, mechanics 289–294
  - collapse 72–73, 231, 274, 278–280, 353–355
  - dry 278
  - engineering behaviour 259–296
    - sabkha and salina 294–296
  - engineering characterization and classification
    - existing schemes 151–154
    - recommended method 155–156
  - excavatability 347
  - expansive 355–356
  - gap-graded 55
  - hydrocompaction 72–73
  - hydromorphic 151
  - metastable 4
  - moisture 268–270
    - equilibrium 268
  - partially saturated 270–278
    - behaviour in compression 273–275
    - shear strength and stiffness 276–277
    - stress variables 273
  - reinforcement 352
  - saline, engineering issues 86, 88
  - sampling 211–216
  - stabilization 7
  - testing
    - building suitability 337
    - chemical 235, 241ab
    - classification 234, 233ab, 239ab, 240ab
    - compaction-related 235, 242ab, 243ab, 244ab
    - consolidation 236, 245–246ab, 247–249ab
    - electrochemical 235
    - in situ* 237, 254ab
    - permeability 236
    - shear-strength 236
  - traditional buildings 336–337
    - additives 337
  - types
    - duricrusts 145, 147, 149–151
    - desert model 143–144, 145, 146–147
    - salt-enriched 145, 147, 151, 152
    - transported 145, 146, 148–149
      - aeolian 147, 149
      - fluvial/coastal 146, 148–149
      - weathered mantle 145, 146, 148
    - wetting 259, 272, 274–275
      - and collapse 279–280, 353–355
    - wind erosion 47–48
  - soil assessment cone penetrometer (SACP) 244ab
  - soil chemistry, tests 235
  - soil horizons 144, 149, 152–153
  - soil mechanics 259–268
  - soil-water retention curve 268, 272–273, 277
  - solonchaks 151
  - Sonoran Desert 3, 10
  - Spain, flash foods 70
  - spalling 38
    - response to fire 34
  - splitting 38
  - SPOT imagery 173, 176, 178
  - stability, atmospheric, and aridity 11
  - standard penetration testing (SPT) 202, 203–204, 206, 237
    - sand 267
  - standards
    - aggregates 314, 316, 318
    - building materials 301, 305, 306, 310b
    - cement 331, 332, 333
    - coastal defences 308, 311
    - concrete aggregate 328
    - geotechnical design 161
    - ground investigation 202, 216, 231, 238a, 240a, 243a
    - mortar aggregate 330, 332
    - soil classification 153, 155
  - steel, reinforcing 332
    - storage 335
  - stiffness
    - partially saturated soils 277, 278
    - sand 265–266
  - stone, salt attack 87
  - stone pavements *see* pavements, desert
  - storage, engineering materials 335–336
  - storms 18, 24
    - localized 60, 61
  - strath terrace 127
  - stream channels, ephemeral 67, 122, 372, 373
    - migration 71–72, 78, 79
  - stream flow, ephemeral channelized
    - flow regime 62, 372
    - hydrograph 62, 63
    - sediment load and channel scour 62–63, 66, 372
  - stress, effective, Bishop equation 273, 277
  - stress fatigue, thermal *see* insolation weathering
  - stress variables, partially saturated soils 273, 277
  - Strezlecki Desert *I*, 3
  - Sturt Desert *I*, 3
  - sub-humid deserts *see* dry sub-humid deserts
  - suction
    - interparticle, partially saturated soils 270–277
    - intraparticle 278
    - loss of 279, 282
    - and slope stability 348
    - testing 251–252ab, 280, 282
    - vadose zone 268, 269, 270
  - Suez, Egypt, expansion 193
    - aggressive ground conditions 192
    - geomorphological survey 189–191
  - sulphate 7
    - concrete mix water 341
    - field identification test 254ab
    - influence on test results 219, 222
  - sulphate content, testing 241ab, 316b, 319
  - sulphide, oxidation 76
  - surface lowering 55
  - suspension 47, 48, 49
    - sand and dust, effect on construction materials 57
  - Synthetic Aperture Rada (SAR) 173, 178
  - Syrian Desert *I*, 3
  - Tabernas Basin, badlands 119
  - tableland 117
  - Tabuk, sediment source mapping 58, 59
  - Tademait Plateau, Algeria 188, 192

- tafoni 37, 39, 148  
 Taklimakan Desert *If*, **3**  
   drift potential 20  
   snow 10  
 talus cone 125, 138  
 Tanami Desert *If*, **3**  
 tectonics, control on desert environment 12–13, **14**  
 temperature, variability 9–10, 14–16  
   diurnal 14–16  
     bitumen roads 326, 364  
     building stones 307  
     salt hydration 35  
     *see also* insolation weathering  
 terraces, river 67, 127, 139  
 terrain element 166  
 terrain evaluation 165–167, 169, 179  
 terrain facet 166  
 terrain system 166  
 terrain units 165–167  
 testing 216, 222–223, **234–238**, 238–255a  
   building stone 305, **306**  
   *in situ* **237–238**, 244ab, 267–268  
   influence of arid conditions **220**  
   influence of local conditions **219**  
   sands 267–268, 291–294  
 Thal Desert *If*, **3**  
 Thar Desert *If*, **3**  
   drift potential 20  
   parabolic dunes 53  
   roads, drifting sand 327  
   sand and gravel extraction 315  
 thaumasite 35, 359  
 thenardite, hydration 35, **284**  
 thermoclasty 33–34  
 tiles 307b  
 Total Ozone Mapping Spectrometer (TOMS) 57–58  
 Toyoura Sand, critical state line 262, 264  
 tradewinds 46–47  
 travertine 38  
 trenches, sand trapping 376–377  
 trial pits and trenches 202, **203**, 206, 217b  
   zone I 227  
   zone II 228  
   zone III 228  
   zone IV 230  
 Tucson, collapsible gravel 355b  
 tufa 38  
 túmulos 64  
 tunnel scour 22  
 Turkistan Desert *If*, **3**  
  
 uncertainty, desk studies and field evaluation 167  
 Unified Soil Classification System (USCS) 153  
 uplands, zone I **101**  
   ground investigation **204–205**, 223, **224**,  
     226–227  
   soil and rock types 144  
 urbanization  
   geohazards 5  
     GIS 183, 185  
   impact on groundwater 372, 374–375  
   need for water supply 27–29  
 uvalas 38  
  
 vadose zone 268, 269, 270  
 valley head recession 39–40  
 varnish *see* rock varnish  
 vector model, GIS 181  
 veering wind shift 46  
 vegetation  
   impeded dunes 50, 53  
   influence on hydrology 29, 60  
   sand trapping 380  
 vehicles, surface degradation 58  
 ventifacts 53, 129  
 volcanoes 108  
 vulnerability, hazard and risk 169b  
  
 Wadi Hatta, gravel resource 316b, 317  
 Wadi Siji Dam, ground investigation 227b, 228  
 wadis 122  
   Eilat mountains 226  
   gravel and sand resources 315, 316b,  
     317, 320b  
   soil types **146**, 148  
 Wahiba Sands, Oman 140  
 Walnut Gulch, rainfall variability 18, 23, 371  
 wash boring, rotary **203**, 208  
 waste, construction or demolition 339–340  
 wastewater, groundwater pollution 29  
 water  
   fluvial geomorphology 58–73  
   saline, effect on engineering **87**  
   subsurface 63–64  
   waste 341  
   *see also* groundwater  
   water content 272  
   water quality 341  
   water supply 340–341  
     and desert population growth 27–29  
     GIS 183, 340  
     road building 350  
     salts **341**  
   water table  
     effect of engineering work 73  
     high  
       and duricrusts 22  
       engineering problems 73  
   wave energy  
     protection from 308, 369  
     sediment transport 148–149  
   wavelength, remote sensing 171, 172,  
     **173**, 174  
   weathering  
     building stones 304–305, 306  
     chemical 36  
       salt 35  
     frost 34  
     insolation 33–34  
     landforms 38–45  
     lichen and algae 36–37  
     mechanical, salt 35  
     onion-skin 38  
     processes 33–38  
     rock and soil types 145, **146–147**, 148  
       bare rock 144–145, **146**, 148  
       soil mantle **146**, 148

- weathering (*Continued*)
  - salt 4–5, 14, 34–36, 64, 69
    - effect on construction materials 201, 302, 307b
    - and slope stability 348–349, 350
  - shadow areas 16
  - solution 23, 37–38
  - wetting and drying 34
  - zones of 149
    - see also* landforms, weathering
- weathering rinds 110
- wells, early 27–28
- wetting 247–249ab
  - of expansive clay 280–282
  - of soil 259, 272, 274–275
    - and collapse 279–280, 353–355
  - and urbanization 374
- wetting and drying weathering 34
- wind 45–47
  - definition 46
  - engineering hazards 55, 57–58
  - flow, and sand transport 375, 377, 378–379
  - global air-masses 46–47
  - impact on environment 20
  - strength 20
  - transport 20, 25b, 26, 47–49
  - variability 20, 22
  - variation
    - diurnal 47
    - local 47
    - see also* erosion, wind
- wood, sand-blasting 57
- yardangs 53–54, 124
- Yucca Mountain Project, GIS analyses 185
- zeugen 114