

Index

Page numbers in *italics* refer to Figures and Tables

- Alpine Orogeny 171, 210
- andesite
 - Japan 15, 17
 - West Cumbria 144
- annular structure 64
 - see also* rib mark
- arrest line 42, 63, 79, 176
 - see also* rib mark
- Australia granodiorite roughness study 31
- auto correlation function (ACF) defined 13

- B-plane 176
- basalt discontinuity measurements 15, 17
- Bavaria 40, 41
- bedding planes 12
 - discontinuity profile 16, 18, 19, 20
- beef 196
- bending, role in failure of 89–91
- bending fracture, experimental production of 71–2
- Bohemian Massif 40, 41
- Borrowdale Volcanic Group 100, 141–4
 - see also* West Cumbria basement rock
- Botany Bay 154, 157
- burial/compaction and associated jointing 168–70
- Burnham chalk study 201

- C-fracture 176
- C-joint 63
- calcite
 - mineralization 115, 117, 122
 - veins 196
- Calder Sandstone 99
- cataclasite 127, 161, 165
- centre–line average height (CLAH)
 - defined 12
 - effect of profile length on 20
 - effect of sampling interval on 18, 19
 - relation to ratio of profile length 24
 - relation to weighted asperity inclination 23
- Chalk joint features 168–70
 - method of analysis 199
 - results 200–6
 - results discussed 209–11
 - significance of spatial changes 208–9
 - stress implications 206–8
 - setting 197–9
- Chausuyama hornfels discontinuity study 15, 17
 - chert
 - discontinuity measurements 15, 17
 - jointing study 229, 230
 - Chita mudstone discontinuity study 15, 17
 - compaction/burial and associated jointing 168–70
 - compressional tectonics 171
 - compressive strength in Chalk 209
 - Continental Superdeep Borehole *see* KTB
 - cooling discontinuity 12
 - core diskings surface (CDS) 46–7, 48, 53
 - transitional forms 47
 - crack branching, role in failure of 91–3
 - cross fracture 63
 - Cumbria *see* West Cumbria

 - density of Chalk 209
 - desiccation discontinuity 12
 - diatomite jointing study 229, 230
 - dilatant echelon crack 63
 - discontinuities
 - classification 12
 - Japan case study
 - effect of profile length 20, 21
 - effect of sampling interval 18–19
 - equipment 16–17
 - location of samples 15
 - primary v. secondary 22–4
 - role of eigen direction 21, 22
 - linear profile measurement 15–17
 - linear profile parameters 12–15
 - summary of observations 24–5
 - disparity, use in roughness measurement of 28
 - diverging plumes 41
 - drape folds 163, 168, 172
 - Dumpton Gap 158
 - dyke, sandstone 192–3

 - East Cliff 158
 - East Harling chalk study 202
 - East Irish Sea Basin 98, 99
 - Echizen tuff discontinuity study 15, 17
 - eigen direction 22
 - effect on discontinuity study 21, 22
 - eigen discontinuity 12
 - elastic moduli, effect on joint spacing of 224
 - en echelon fracture 101
 - Ennerdale granite and granodiorite 99, 134, 146
 - Epple Bay 158, 160

- Eskdale granite 99, 134, 145
 experimental production of fractographic features
 methods 64–6
 results
 bending fracture 71–2
 fracture forking 68
 fracture hooking 68
 origin of fracture 66–8
 point load fracture 70
 thermal fracture 71
 torsion fracture 68–70
 results discussed
 forking 77
 inclusion hackle 77–9
 origins 73–4
 rib marks 79–80, 81
 speed of propagation effect 72–3
 twist hackle 77–9
 Wallner lines 75–7
 extensional tectonics 170–1
- F-joint 63, 176
 failure mode 83
 experimental testing 84–5
 failure area analysis 89
 bending 89–91
 crack branching 91–3
 microscope analysis 86–8
 fast Fourier transform (FFT) images 35, 36
 faulting, role in discontinuity of 12
 faults 100
 West Cumbria study 104–7, 125–6
 feather fracture border plane 63
 flow plane 12
 fluidization 192–3
 focal point 62
 see also origin
 folding, role in discontinuity of 12
 forced folds 163, 168, 172
 forking 48, 54
 see also fracture forking
 fractal defined 27
 fractal dimension defined 13
 fractographic features classified 100
 fractography
 defined 1, 99–100, 152
 evolution of studies 1–2
 first use of term 59
 relation to fracture analysis 2–3
 research
 future 9
 past 3–8
 fracture defined 99–100
 fracture face 176
 fracture forking 63, 66, 68, 74, 77
 fracture hooking 68
 fracture plume 176
 fracture processes 52–4
 fracture propagation 52
 fracture spacing index (FSI) 229
 fracture spacing ratio (FSR) 229
 fracture surface studies (markings, morphology and patterns)
 classification 27, 41–2, 176
 interpretation of stress patterns 43
 photogrammetric measurement
 principles 28
 quantitation 31–2
 regional studies
 KTB analysis
 core diskings surfaces (CDS) 46–7, 48, 53, 54
 drilling-induced centre-line fractures 46
 transitional forms 47, 52
 usual fractographic surface structures (UFS) 46–7, 49, 50, 51
 Mt Alexandra Quarry 32–6
 St Mary's Well Bay 176–7
 methods of analysis 180–1
 results 181–3
 results discussed 183–5
 setting 177–9
 West Cumbria 108, 115, 133
 symmetry 42
 fracture trace
 defined 100
 West Cumbria study 101, 108, 109, 110, 111, 112, 133
 Franconian Line 39, 40
 freezing discontinuity 12
 fringe 176
 fringe face 63
 fringe step 63
- Germany 40, 41
 glaciation, overburden effects of 211
 gouge 127, 161, 165
 grain plane, role in discontinuities of 12
 granite
 Japan 15, 17
 West Cumbria 100, 133, 145, 146
 granodiorite
 Mt Alexandra 31
 West Cumbria 145
 Griffith criteria 187
 gull wing 72, 75, 76
 gypsum veins 196
- hackle face 158
 hackle (hackly) fractures 63
 hackle plume 79, 101
 KTB study 41

- Lavernock Point 181, 183, 184
 Thanet monocline 158, 159, 163
 West Cumbria study 118, 121
- hackle step 158
 haematite mineralization 127
 Harcourt roughness measurements 31
 hardway plane, role in discontinuity of 12
 hesitation line 64
 see also rib mark
 hooking 3, 101, 125
 hoop test for failure 84–5
 hornblende, role in discontinuity of 12
 hornfels discontinuity measurements 15, 17
 hydraulic fracturing 191
- igneous rocks, discontinuities in 12
 inclusion hackle 63, 77–9
 inclusion hackle tail 72
 iron oxide mineralization 115, 117, 163
 Italian marble, failure testing of 85, 87, 88
- Japan discontinuity morphology study
 effect of profile length 20, 21
 effect of sampling interval 18, 19
 equipment 16–17
 location of samples 15
 primary *v.* secondary features 22–4
 role of eigen direction 21, 22
- joint
 defined 62, 99, 197
 regional studies
 Eastern England 168–70, 197–9
 method of analysis 199
 results 200–6
 results discussed 209–11
 significance of spatial changes 208–9
 stress implications 206–8
 West Cumbria 104–7
- joint face 101, 176
- joint spacing
 bed thickness effects 218–20
 history of research 215–17
 mathematical modelling
 1-D Hobbs model 220–2
 finite element model 222–4
 models compared 224–5
 testing of models 225–8
 Monterey Formation study 229–31
 stress field effects 217–18
- Kingsgate Bay 154, 156
 Kitamatado shale discontinuity study 15, 17
- KTB study
 drill core fractures
 fracture processes 52
 fracture types
 core diskings surfaces (CDS) 46–7, 48, 53, 54
 drilling-induced centre-line fractures 46
 transitional forms 47, 52
 usual fractographic surface structures (UFS) 46–7, 49, 50, 51
 stress field analysis
 methods 54–6
 results 56–7
 location 39, 40, 41
- Lake District Block 98, 99
 Lavernock Point 176, 177
 fracture surface marking study
 methods of analysis 180–1
 results 181–3
 results discussed 183–5
 setting 177–9
 limestone
- Japan discontinuity measurement 15, 17
 St Mary's Well Bay Formation 176–7
 methods of analysis 180–1
 results 181–3
 results discussed 183–5
 setting 177–9
- lithology, effect on joint spacing of 229
- London-Brabant Massif 152–4
- macrofracture and macrofault
 defined 100
 West Cumbria study 125–8, 137
- marble, failure testing of 85, 87, 88
- mathematical modelling of joint spacing
 1-D Hobbs model 220–2
 finite element model 222–4
 models compared 224–5
 testing of models 225–8
- mean standard variation of height (MSVH)
 defined 13
- mean standard variation of inclination (MSVI)
 defined 13
- megafracture defined 100
- Mercia Mudstone 193, 194
- mesofracture
 defined 100
 West Cumbria study
 mesofracture study in basement rock 131–3, 141–6
 dynamic significance 133–7
 surface features 133
 fracture traces 133
 surface patterns 133
- mesofracture study in cover rock
 chronology 115–7
 layering control 117

- non-systematic fractures 108, 112
- systematic fractures 100–1
 - dynamic significance 117, 125
 - fracture traces 101, 108, 109, 110, 111, 112
 - surface patterns 108, 112
- mesofracture/macrofault relations in basement rock 137
- mesofracture/macrofault relations in cover rocks 126–8
 - regional stress patterns 128
- metamorphic rocks, discontinuities in 12
- micas, role in discontinuity of 12
- microfracture defined 100
- Mill Hill chalk study 201
- mineralization 3
 - West Cumbria 115–7, 122
- mineralogy, effect on discontinuities of 12
- Minnis Bay 158
- mirror region
 - defined 62
 - experimental production of 74, 66, 71, 72
- mist region
 - characterized 62
 - experimental production of 66, 72, 74
- mode I (tensile) fractures 188, 190
 - Thanet monocline 170, 172
 - West Cumbria 117–9
- modes of failure 83
 - experimental testing 84–5
 - failure area analysis 89
 - bending 89–91
 - crack branching 91–3
 - microscope analysis 86–8
 - mode I (tensile) failure 83, 176
 - effect of tensile strength 193–4
 - relation to stress 187
 - role of fluid pressure 190–1
 - mode II (sliding) failure 83
 - mode III (tearing) failure 83, 176
- Mohr circles 187, 188
 - chalk stress field 207
- Monterey Formation joint spacing study 216, 217, 219–20, 229–31
- Mt Alexandra Quarry roughness measurements 31
- mudstone discontinuity measurements 15, 17
- Navatsukawa granite discontinuity study 15, 17
- Navier–Coulomb criteria 187
- non-systematic fractures
 - defined 100
 - West Cumbria study occurrences 101, 117, 123
- North Cliff 158, 165
- Okumino discontinuity studies 15, 17
- origin 62, 70, 72, 101
 - action in experiments of 66
 - role in chalk failure 158
- Otake andesite and basalt discontinuity study 15, 17
- overburden, stress effects of 196, 210–11
- Palm Bay 154, 156, 159
- Pegwell Bay 166, 167
- Pegwell Bay–Minnis Bay Transpression Zone 158, 168, 171
- Penrith Sandstone failure testing 85, 86, 87
- photogrammetry
 - Mt Alexandra Quarry tests 32–6
 - use in roughness measurement
 - methods 31–2
 - principles 28
- pit 62
 - see also* origin
- plume axis 101
- plumose structure 63, 176
- plumose–coarse twist hackle boundary 176
- point load fracture 70
- point sources 181
- porosity in Chalk 209
- power spectral density (PSD) plots 36
- pressure solution features 64
- profile length, effect on discontinuity study of 20, 21
- profilometer 14, 17, 31
- radient 63
- ratio of profile length (RPL)
 - defined 13
 - effect of profile length on 20
 - effect of sampling interval on 18, 19
 - relation to centre–line average height 24
 - relation to weighted asperity inclination 25
- rhyolite discontinuity measurements 15, 17
- rib mark 63, 71, 78, 79–80, 81, 101
 - Lavernock Point 181
 - Thanet monocline 158, 159, 163
 - West Cumbria study 118, 120, 121
- Richborough syncline 173
- ripple mark 62–3
 - see also* Wallner line
- river line 63
- root mean-square of height (RMSH) defined 13
- root mean-square of inclination (RMSI) defined 13
- roughness measurement 27–8
 - method 28–30
 - quantitation 31–2
 - regional study 32–6

- St Bees Sandstone 99
 fracture pole diagrams 102, 103
 macro faults 127, 130
- St Mary's Well Bay Formation 176–7
 fracture surface marking study
 methods of analysis 180–1
 results 181–3
 results discussed 183–5
 setting 177–9
- sampling intervals, effect on discontinuity study
 of 18, 19
- sandstone
 discontinuity measurements 15, 17
 failure testing 85, 86, 87
see also West Cumbria study cover rock
- satin spar 196
- schistosity planes 12
- sedimentary rocks, discontinuities in 12
- shale, discontinuity measurements in 15, 17
- shear failure and relation to stress 187
- shear planes
 discontinuity profile 16, 18, 19, 20
 role in discontinuity of 12
- shearing 3
- sheeting planes
 discontinuity profile 21, 22
 role in discontinuities of 12
- Sherwood Sandstone Group 100
see also West Cumbria study cover rock
- shoulder 176
- slickenlines 3, 52, 54
 KTB study 52, 54
 Thanet monocline 155, 161, 164, 167
 West Cumbria study 113, 127
- sliding (mode II) failure 83
- Solway Basin 98, 99
- South Cliff 165
- spatial frequency (SF) plots 36
- stereographic projection 155
- stress 187
 KTB stress field analysis 39, 40, 41
 drill core fracture evidence 46
 core diskling surfaces (CDS) 46–7, 48, 53, 54
 drilling-induced centre-line fractures 46
 transitional forms 47, 52
 usual fractographic structures (UFS) 46–7, 49, 50, 51
 West Cumbria study 112, 124, 125, 128–9
- striations 63
- structure function defined 13
- stylolites defined 100
- stylolitization 3
- surface features *see* fracture surface studies
 systematic fractures 99–100
 West Cumbria study
 dynamic significance 117, 125
 fracture traces 101, 108, 109, 110, 111, 112
 surface patterns 108, 115
- tearing (mode III) failure 83, 176
- tectonic discontinuity 12
- tectonic features of Thanet monocline 170–1
- tectonic stress field study
 drill core fracture evidence 46
 fracture types
 core diskling surfaces (CDS) 46–7, 48, 53, 54
 drilling-induced centre-line fractures 46
 transitional forms 47, 52
 usual fractographic structures (UFS) 46–7, 49, 50, 51
 location 39, 40, 41
- tendential fractographic features 62, 67, 69
- tendential penetration 176
- tensile (mode I) failure 83, 176
 effect of tensile strength 193–4
 failure area analysis 89
 bending 89–91
 crack branching 91–3
 hoop test 84–5
 microscope analysis 86–8
 relation to stress 187
 role of fluid pressure 190–1
- tensile (mode I) fracture 188, 190
 Thanet monocline 170, 172
 West Cumbria 117–9
- tensile strength 209
- tensile stress analysis
 application to joints
 finite element model 222–4
 Hobbs model 220–2
- tension planes
 discontinuity profile 16, 18, 19, 20
 role in discontinuity 12
- texture, effect on fracture of 72, 73
- Thanet monocline
 fracture characterization
 hinge area 161–3
 NE area 154–8
 NW area 158
 SE area 158–61
 fracture origin 168–71
 origin 163–8
 seismic section 169
 setting 149, 150
 stratigraphy 151
 structure 152
 synthesis 172–3
- thermal fractures, experimental production of
 71, 74
- torsion fractures 68–70
 experimental production of 68–70
- tourmaline, role in discontinuity of 12
- trace 176

- transient fractographic features 59, 70, 72
 transpression in Thanet monocline 171
 Tsuge granite discontinuity study 15, 17
 tuff discontinuity measurements 15, 17
 twist angle 125
 twist hackle 63, 66, 77–9, 158
 twist-hackle face 78
 defined 101, 176
 twist-hackle fringe 68, 69, 70, 79
 defined 101, 176
 KTB study 41–2
 Thanet monocline 158
 West Cumbria study 118, 120, 125
 twist-hackle plane 182–3
 twist-hackle step 54, 72, 78
 defined 101, 176
- uplift/unloading, associated jointing 171
 usual fractographic surface (UFS) structures
 46–7
 transitional forms 47
- veins
 defined 100
 West Cumbria study 104–7
- velocity hackle 62, 70, 72
 experimental production of 66, 68, 71, 74
- Wallner line 62, 62–3, 70, 72
 experimental production of 66, 71, 71–2, 75–7
- Walpole Bay 154, 156, 157
 Watchet 193, 194
- weighted asperity inclination
 defined 13
 effect of profile length on 20
 effect of sampling interval on 18, 19
 relation to centre-line average height 23
 relation to ratio of profile length 25
- West Cumbria
 basement and cover rocks compared 137–9
 macrofault study in cover rock 125–6
 mesofracture study in basement rock 131–3,
 141–6
 dynamic significance 133–7
 surface features 133
 fracture traces 133
 surface patterns 133
 mesofracture study in cover rock
 chronology 115–7
 layering control 108–12
 non-systematic fractures 101, 117
 systematic fractures 100–7
 dynamic significance 117, 125
 fracture traces 101, 108, 109, 110, 111,
 112
 surface patterns 108, 115
 mesofracture/macrofault relations in base-
 ment rock 137
 mesofracture/macrofault relations in cover
 rocks 126–8
 regional stress patterns 128
 setting 97, 98
 West Runton chalk study 203
 Westgate Bay 158, 160
- Young's modulus 229