

University of Wollongong - Research Online

Thesis Collection

Title: Jointing and fracturing of flat-lying rock masses, Illawarra Coal Measures, southeastern Sydney Basin
New South Wales, Australia

Author: Hossein Memarian

Year: 1994

Repository DOI:

Copyright Warning

You may print or download ONE copy of this document for the purpose of your own research or study. The University does not authorise you to copy, communicate or otherwise make available electronically to any other person any copyright material contained on this site.

You are reminded of the following: This work is copyright. Apart from any use permitted under the Copyright Act 1968, no part of this work may be reproduced by any process, nor may any other exclusive right be exercised, without the permission of the author. Copyright owners are entitled to take legal action against persons who infringe their copyright. A reproduction of material that is protected by copyright may be a copyright infringement. A court may impose penalties and award damages in relation to offences and infringements relating to copyright material.

Higher penalties may apply, and higher damages may be awarded, for offences and infringements involving the conversion of material into digital or electronic form.

Unless otherwise indicated, the views expressed in this thesis are those of the author and do not necessarily represent the views of the University of Wollongong.

Research Online is the open access repository for the University of Wollongong. For further information contact the UOW Library: research-pubs@uow.edu.au

1994

Jointing and fracturing of flat-lying rock masses, Illawarra Coal Measures, southeastern Sydney Basin New South Wales, Australia

Hossein Memarian
University of Wollongong

Follow this and additional works at: <https://ro.uow.edu.au/theses>

University of Wollongong

Copyright Warning

You may print or download ONE copy of this document for the purpose of your own research or study. The University does not authorise you to copy, communicate or otherwise make available electronically to any other person any copyright material contained on this site.

You are reminded of the following: This work is copyright. Apart from any use permitted under the Copyright Act 1968, no part of this work may be reproduced by any process, nor may any other exclusive right be exercised, without the permission of the author. Copyright owners are entitled to take legal action against persons who infringe their copyright. A reproduction of material that is protected by copyright may be a copyright infringement. A court may impose penalties and award damages in relation to offences and infringements relating to copyright material.

Higher penalties may apply, and higher damages may be awarded, for offences and infringements involving the conversion of material into digital or electronic form.

Unless otherwise indicated, the views expressed in this thesis are those of the author and do not necessarily represent the views of the University of Wollongong.

Recommended Citation

Memarian, Hossein, Jointing and fracturing of flat-lying rock masses, Illawarra Coal Measures, southeastern Sydney Basin New South Wales, Australia, Doctor of Philosophy thesis, Department of Geology, University of Wollongong, 1994. <https://ro.uow.edu.au/theses/1395>

NOTE

This online version of the thesis may have different page formatting and pagination from the paper copy held in the University of Wollongong Library.

UNIVERSITY OF WOLLONGONG

COPYRIGHT WARNING

You may print or download ONE copy of this document for the purpose of your own research or study. The University does not authorise you to copy, communicate or otherwise make available electronically to any other person any copyright material contained on this site. You are reminded of the following:

Copyright owners are entitled to take legal action against persons who infringe their copyright. A reproduction of material that is protected by copyright may be a copyright infringement. A court may impose penalties and award damages in relation to offences and infringements relating to copyright material. Higher penalties may apply, and higher damages may be awarded, for offences and infringements involving the conversion of material into digital or electronic form.

**JOINTING AND FRACTURING OF FLAT-LYING ROCK MASSES,
ILLAWARRA COAL MEASURES, SOUTHEASTERN SYDNEY BASIN,
NEW SOUTH WALES, AUSTRALIA.**

A thesis submitted in fulfilment of the
requirement for award of the degree of

DOCTOR OF PHILOSOPHY

from

THE UNIVERSITY OF WOLLONGONG

by

HOSSEIN MEMARIAN

(M.Sc. University of Waterloo, Canada)

Department of Geology

1994

The content of this thesis are the result of original research by the author and material contained herein has not been submitted to any other university or similar institution for a higher degree.

H. Memarian
Please see print copy for
image.

This thesis is dedicated to my wife.

ABSTRACT

Fracture mapping of the Late Permian Illawarra Coal Measures, between Coalcliff and Wollongong, shows that joints developed originally in extension (mode I) and were faulted in subsequent events. Conjugate joint sets are a consequence of two separate fracturing events. Extension joints developed in joint units of different size and shape, with boundaries at changes in mechanical properties. The fracture pattern of extension joints in a joint unit is related to the mechanical properties of the rock mass and loading history. Joints with regional distribution fall into two, early and late formed, groups. Group I regional joints strike N-NNE, NE and SE. These joints propagated horizontally and never interfered with each other. All the existing interactions are the result of succeeding events.

Group I regional joints were recracked subsequently. Recracking commenced with jointing and continued with lateral slip. All the faulted joints are classified as hybrid fractures. Faulted joints grew horizontally by the connection of recracked segments. En echelon arrays are the result of vertical propagation of faulted joints into intact rock. Recracking of rock also formed a set of secondary joints parallel to σ_1 . The sense of movement along conjugate faulted joints and orientation of sets of secondary joints, are related to 3 compressional stress fields namely: NNE-SSW, E-W and SSE-NNW. The intensity of recracking and the amount of lateral slip is mostly related to the strength of infilling materials, the angle between the fracture and the maximum compression direction, and the number of compressional events imposed on the fracture.

In the southeastern Sydney Basin, some of the northwesterly trending normal faults were active during Late Permian deposition. Slip along these listric faults formed northwesterly trending gentle folds. A quasi-extensional regime, related to the forebulge of the Sydney Basin, reactivated appropriately oriented basement faults, which in turn, generated grabens in the cover. Group I regional joints formed after lithification and are classified as burial joints. Normal faults and dykes also developed during the Mesozoic. It is considered that the later part this episode was related to rifting that predated the opening of the Tasman Sea and its subsequent extensional history. The youngest deformational events were compressional. Group II regional joints and reactivation of pre-existing fractures occurred during these post-Early Tertiary events. Anticlockwise motion of the Australian crust, relative to the rest of the enclosing plate,

caused by the collision between the Indo-Australian and Pacific Plates, may have been responsible for the NNE-SSW compression in the eastern part of the Southern Coalfield. The E-W compression most probably postdated the NNE-SSW event.

Rock fracturing controlled the present configuration of the coastal platforms. Fractures in bedrock also governed the location of many landslips in talus along the Illawarra Escarpment. A method is presented for predicting the presence of dykes in underground coal mines, using adjacent joints.

CONTENTS

CHAPTER 1 INTRODUCTION	1
1.1 OBJECTIVES	1
1.2 DATABASE	2
Presentation of field data	4
1.3 STRUCTURAL SETTING	5
Sydney Basin	5
Southern Coalfield	6
Folds	6
Faults	7
Joints	7
Igneous activity	8
Deformational events	8
1.4 STRATIGRAPHY	9
Shoalhaven Group	9
Illawarra Coal Measures	10
Cumberland Subgroup	10
Sydney Subgroup	11
Narrabeen Group	14
 CHAPTER 2 DEVELOPMENT OF SYSTEMATIC JOINTS	 17
2.1 INTRODUCTION	17
Definitions	17
Objectives	18
2.2 ORIENTATION AND DISTRIBUTION OF JOINTS	19

Previous work	19
General characteristics	20
Major orientations	21
N-NNE joints	21
NE joints	21
SE joints	22
Other systematic joints	22
Nonsystematic joints	22
Discussion	23
2.3 ORIGIN OF JOINTS	25
Mode of formation	25
Infilling	25
Lateral displacement	26
Surface marking	26
Conjugate pattern	27
Discussion	28
2.4 ROCK TYPE AND JOINTING	29
Coarse-grained rock	29
Fine-grained rock	30
Horizontal variation of jointing	30
Vertical variation of jointing	31
Coal	32
Plant fragments and clasts	32
Discussion	33
2.5 EFFECTS OF BED THICKNESS	34
Curving strike	34
Joint spacing	34
Discussion	37
2.6 AGE OF JOINTING	38
Relative age of joints	39

Discussion	40
2.7 DEVELOPMENT OF JOINT PATTERN	41
Jointing units	42
Relation between jointing units	44
2.8 CONCLUSIONS	45
 CHAPTER 3 DYKE INJECTION AND DYKE RELATED JOINTS	 49
3.1 INTRODUCTION	49
3.2 GENERAL CHARACTERISTICS OF DYKES	50
Dyke orientation	50
Structures associated with dykes	52
3.3 DISCUSSION	54
Dyke induced fractures	54
Relative age of dykes	57
Dykes and stress field	58
3.4 CONCLUSIONS	59
 CHAPTER 4 FAULTS AND RELATED STRUCTURES	 61
4.1 INTRODUCTION	61
4.2 ESE-SE NORMAL FAULTS	62
Relative age	64
4.3 N-NNE NORMAL FAULTS	65
Relative age	66

4.4	STRIKE-SLIP DISPLACEMENTS	67
4.5	FAULT-RELATED MONOCLINES	67
	Discussion	68
4.6	FAULT-BOUND ANTICLINES	71
	Discussion	73
4.7	CONCLUSIONS	74
	CHAPTER 5 RECRACKING OF JOINTED ROCK MASSES	77
5.1	INTRODUCTION	77
5.2	CONJUGATE FRACTURE PATTERN AT COALCLIFF	78
	Conjugate faulted joints	80
5.3	RECRACKING AND JOINTING	81
	Horizontal re cracking	81
	Vertical re cracking	82
5.4	FORMATION OF SECONDARY JOINTS	83
	Horizontally grown secondary cracks	84
	Vertically grown secondary cracks	86
	Interactive secondary cracks	87
	Summary	88
5.5	FAULTED JOINTS WITH MULTIPLE DISPLACEMENTS	88
5.6	EPISODES OF RECRACKING	90
	NNE-SSW compressional event	91
	E-W compressional event	91

SSE-NNW compressional event	92
Relative age of compressional events	93
Regional joints	93
Normal faults	93
Dykes	94
Monoclines	94
Compressional events	95
5.7 MECHANISM OF RECRACKING	96
Mode of fracturing	96
Sequence of recracking	98
Recracking and deviatoric stress	100
5.8 CONCLUSIONS	101
 CHAPTER 6 TECTONIC DEVELOPMENT OF THE SOUTHEASTERN SYDNEY BASIN	 105
6.1 INTRODUCTION	105
6.2 PERMIAN-TRIASSIC TECTONIC HISTORY OF THE SYDNEY BASIN	105
6.3 POST-TRIASSIC TECTONIC HISTORY OF THE SYDNEY BASIN	107
Uplift	109
6.4 SYNDEPOSITIONAL STRUCTURAL MODEL FOR THE SOUTHERN COALFIELD	111
Quasi-extensional model	112
Origin of extensional stress	113
The effect of basement structures	114
6.5 POST-DEPOSITIONAL STRUCTURAL MODELS FOR THE SOUTHERN COALFIELD	116

Mesozoic-Early Tertiary extensional episodes	116
Late-stage compressional events	119
Origin of compressional stress	120
6.6 DEFORMATION HISTORY	121
6.7 CONCLUSIONS	121
 CHAPTER 7. SOME GEOMORPHOLOGICAL AND ENGINEERING IMPLICATIONS OF ROCK FRACTURING	 123
7.1 INTRODUCTION	123
7.2 THE FORMATION AND RECESSION OF ROCK PLATFORMS	123
Development of rock platforms	124
Platform recession	125
Surfacial erosion	126
Recession of low tide cliff	127
Erosion of headlands	128
Age of rock platform	128
7.3 BEDROCK FRACTURES AND UNSTABLE TALUS SLOPES	129
Illawarra Escarpment	129
Factors affecting slope instability	130
Contemporary stress	131
Major recent landslips	133
Bedrock fractures and talus failure	136
7.4 DYKE PREDICTION IN UNDERGROUND MINING	137
Adjacent joints and dyke prediction	138
7.5 CONCLUSIONS	140

CHAPTER 8. SUMMARY OF CONCLUSIONS	143
8.1 JOINTS	143
8.2 FAULTS AND DYKES	144
8.3 FAULT-FORCED FOLDS	145
8.4 FAULTED JOINTS	145
8.5 RELATIVE AGE OF STRUCTURES	147
8.6 TECTONIC HISTORY	149
Early quasi-extensional regime	149
Intermediate regime	149
Late compressional regime	150
8.7 IMPLICATIONS OF ROCK FRACTURING	150
REFERENCES	153
ACKNOWLEDGEMENTS	171
FIGURES OF CHAPTER 1	173
FIGURES OF CHAPTER 2	182
FIGURES OF CHAPTER 3	214
FIGURES OF CHAPTER 4	224
FIGURES OF CHAPTER 5	237

FIGURES OF CHAPTER 6	265
FIGURES OF CHAPTER 7	273
TABLES	285
APPENDICES	A1
1. Symbols used in maps and scanline charts	A3
2. Location map for studied outcrops and scanlines	A4
3. Examples of fracture maps	A7
4. Scanlines	A22

LIST OF FIGURES

- Figure 1.1 Simplified structural elements of the Sydney Basin.
- Figure 1.2 Simplified geological map of the southeastern Sydney Basin.
- Figure 1.3 Lease boundaries of coal mines of the Southern Coalfield.
- Figure 1.4 Location map of the studied outcrops.
- Figure 1.5 Distribution of the orientation of 57 surveyed scanlines.
- Figure 1.6 Scanline chart of rock fractures, for scanline 14-II'.
- Figure 1.7 Major structural elements of the southeastern Sydney Basin.
- Figure 1.8 Simplified stratigraphic column of the Sydney Subgroup.
-
- Figure 2.1 Vertical propagation of joints in one or more beds.
- Figure 2.2 Vertical extent of NNE striking joints.
- Figure 2.3 Joint pattern at Coalcliff (Outcrop 2)
- Figure 2.4 Fracture pattern of a 1 cm thick sideritic mudstone.
- Figure 2.5 Horizontal and vertical traces of the SE joints.
- Figure 2.6 Orientation of systematic joints.
- Figure 2.7 Orientation of joints in the northern zone (Outcrops 1-9).
- Figure 2.8 Orientation of joints in the central zone (Outcrops 10-19).
- Figure 2.9 Orientation of joints in the southern zone (Outcrops 20-30).
- Figure 2.10 Histograms of joint orientation in the study area.
- Figure 2.11 Nonsystematic cross joints.
- Figure 2.12 Joint cuts pebbles of a conglomerate at Coalcliff.
- Figure 2.13 Surface marking on a 032° striking joint.
- Figure 2.14 Surface marking on a 005° striking joint.
- Figure 2.15 Fracture pattern resulting from a dynamite explosion.
- Figure 2.16 Relation between rock type and fracture pattern.
- Figure 2.17 Influence of rock type on frequency of joints.
- Figure 2.18 Fracture pattern of the Bulli Coal.
- Figure 2.19 Fractures in the Tongarra Coal.
- Figure 2.20 Fracture pattern of a silicified plant fragment.
- Figure 2.21 The effect of bed thickness and rock type on jointing.
- Figure 2.22 Gradual change in strike, due to an increase in bed thickness.
- Figure 2.23 Scanline charts showing frequency and strike of joint sets.
- Figure 2.24 The effect of bed thickness on frequency of joints.

- Figure 2.25 Hobbs (1967) model for spacing of joints in sedimentary rocks.
- Figure 2.26 Orientation of fractures in ironstone intraclasts.
- Figure 2.27 Cross cutting relationships between 4 sets of joints.
- Figure 2.28 Cross-cutting relationships between 6 sets of joints.
- Figure 2.29 Joint orientation in two adjoining mechanical units.
-
- Figure 3.1 Adjacent joints parallel to a 110° striking dyke.
- Figure 3.2 Dyke parallel adjacent joints.
- Figure 3.3 Distribution of dykes in the Southern Coalfield.
- Figure 3.4 Orientation of dykes at the level of coal mining.
- Figure 3.5 Adjacent joints along a scanline at Austinmer.
- Figure 3.6 Scanline charts showing adjacent joints.
- Figure 3.7 A NNE striking vertical dyke at Coledale.
- Figure 3.8 A SE dyke at Red Point (Port Kembla).
- Figure 3.9 Development of adjacent joints.
- Figure 3.10 Process of magma injection into a sequence.
-
- Figure 4.1 Rose diagrams of fault orientations.
- Figure 4.2 Map of the ESE faults in the northern part of the study area.
- Figure 4.3 Post-depositional normal slip on the Harbour Fault.
- Figure 4.4 Syndepositional faulting in the Coal Cliff Sandstone.
- Figure 4.5. Normal faults at Bell Point Austinmer (Outcrop 18).
- Figure 4.6 NNE striking normal faults at Coalcliff Adit.
- Figure 4.7 A 020° striking normal fault at Coalcliff Adit.
- Figure 4.8 Distribution of N-S fractures along a scanline at Wombarra.
- Figure 4.9 A fault related monocline at Coledale (Outcrop 16).
- Figure 4.10 Relationship between a monocline and underlying normal fault.
- Figure 4.11 Cross section along the coast between Coalcliff and Woonona.
- Figure 4.12 Variation in dip of ESE growth faults due to compaction.
-
- Figure 5.1 Fracture pattern of Coalcliff Sandstone at Coalcliff.
- Figure 5.2 A 2 mm dextral movement along a 010° faulted joint.
- Figure 5.3 Structure of a long re-cracked 120° striking joint at Bulli.
- Figure 5.4 Abutting of a 045° fracture against a 013° fracture.

- Figure 5.5 Termination by branching of a vertical NE joint.
- Figure 5.6 An open vertical fracture, developed parallel to a closed joint.
- Figure 5.7 Secondary crack formed at the end of a faulted joint.
- Figure 5.8 NNE striking horse-tail fractures at Clifton (Outcrop 4).
- Figure 5.9 100° striking secondary cracks along open fractures.
- Figure 5.10 A secondary crack, connecting two segments of a faulted joint.
- Figure 5.11 Recracking and horizontal enlargement of a segmented NE joint.
- Figure 5.12 En echelon arrays above 175° fractures.
- Figure 5.13 Development of an array of echelon fractures.
- Figure 5.14 A complex zone of secondary fractures.
- Figure 5.15 Interaction between two conjugate faulted joints.
- Figure 5.16 Secondary crack formed due to the rotation of stress field.
- Figure 5.17 Classification of secondary cracks.
- Figure 5.18 Vertical growth of re-cracked fractures.
- Figure 5.19 Multiple slip along faulted joints.
- Figure 5.20 Development of multiple sets of secondary cracks.
- Figure 5.21 Model for development of opposite senses of lateral slip.
- Figure 5.22 Dextral displacement of a vertical dyke at Bulli.
- Figure 5.23 Orientation of secondary cracks in the study area.
- Figure 5.24 The relation between secondary cracks and lateral displacement.
- Figure 5.25 A set of regional joints and normal faults with dextral slip.
- Figure 5.26 3 mm sinistral movement along a 140° striking joint.
- Figure 5.27 Sequence of deformation events at Wombarra.
- Figure 5.28 Stress conditions during the formation of fractures.
- Figure 5.29 Alternative re-cracking of three sets of vertical joints.
- Figure 5.30 Sequential development of secondary cracks.
-
- Figure 6.1 Sydney-Bowen Basin System and neighbouring fold belts.
- Figure 6.2 Schematic cross section of the Sydney Basin.
- Figure 6.3 Fault-forced anticlines at Coal Cliff and Bulli Collieries.
- Figure 6.4 Syn-depositional structural model of the Southern Coalfield.
- Figure 6.5 A model for the formation of fault forced anticlines.
- Figure 6.6 Formation of extensional forced folds and narrow grabens.
- Figure 6.7 Development of tensional forces due to formation of a forebulge.

- Figure 6.8 Major ESE lineaments in the southern Sydney Basin.
- Figure 6.9 Pattern of sea floor spreading in eastern Australia.
- Figure 6.10 Origin of the NNE compression in the southeastern Sydney Basin.
-
- Figure 7.1 Two rock platforms at Coalcliff.
- Figure 7.2 Influence of fracturing on surface weathering and erosion.
- Figure 7.3 Undermining of sandstone blocks along low tide cliff.
- Figure 7.4 Fractures controlling the geometry of platforms.
- Figure 7.5 Platforms and adjacent headlands.
- Figure 7.6 Cross section of the Illawarra Escarpment near Scarborough.
- Figure 7.7 Location map for landslips cited in the text.
- Figure 7.8 Two landslips along the Lawrence Hargrave Drive.
- Figure 7.9 The relation between landslips and bedrock fractures.
- Figure 7.10 Tension cracks in talus and their relation to fractures in bedrock.
- Figure 7.11 Dyke prediction using scanline charts.

LIST OF TABLES

Table 1.1 Studied outcrops.

Table 1.2 Scanline data.

Table 1.3 Stratigraphy of the Southern Coalfield.

Table 2.1 Mean orientation of systematic joints.

Table 2.2 Major joint sets with regional distribution.

Table 2.3 Orientation of regional joints in northern and central zones.

Table 2.4 Mean orientation of NE and SE joints in different outcrops.

Table 3.1 Dykes exposed along the coast (Stanwell Park to Port Kembla).

Table 4.1 Anticlines and normal faults in the southeastern Sydney Basin.