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STRUCTURAL AND METAMORPHIC GEOLOGY OF A  
CRITICAL AREA ADJACENT TO THE BROKEN HILL  
OREBODY, WILLYAMA COMPLEX, AUSTRALIA

by

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TABLE OF CONTENTS

	<u>Page</u>
LIST OF ABBREVIATIONS	i-ii
LIST OF TABLES	iii
LIST OF APPENDICES	iv
SUMMARY	v-vi
STATEMENT OF ORIGINALITY	vii
ACKNOWLEDGEMENTS	viii
<u>Chapter 1. INTRODUCTION</u>	1
1.1 <u>BACKGROUND OF THE STUDY</u>	1
1.2 <u>LOCATION OF THE AREA</u>	2
1.3 <u>LOCAL ENVIRONMENT</u>	3
1.4 <u>PREVIOUS WORK</u>	4
1.4.1 Structural studies	4
1.4.2 Origin of the orebody	10
1.4.3 General studies	13
1.5 <u>AIMS OF THE STUDY</u>	16
1.6 <u>ORGANISATION</u>	16
<u>Chapter 2. LITHOLOGIES, STRATIGRAPHY AND SEDIMENTARY ENVIRONMENT</u>	18
2.1 <u>SCOPE OF THE DISCUSSION</u>	18
2.2 <u>LITHOLOGY OF INDIVIDUAL BEDDING LAYERS IN THE PELITIC METASEDIMENTS</u>	19
2.2.1 Geometry	19
2.2.2 Composition	20
2.2.3 Graded bedding	24
2.3 <u>NOTES ON THE NON-PELITIC UNITS</u>	26
2.3.1 Granite gneiss	26
2.3.2 Garnetiferous granite (Potosi) gneiss	27
2.3.3 Amphibolite (basic gneiss)	27
2.3.4 Lode Horizon	27
2.4 <u>STRATIGRAPHY</u>	28

TABLE OF CONTENTS (cont'd)

	<u>Page</u>
2.5 <u>DISCUSSION</u>	29
2.5.1 Original rock-types	29
2.5.2 Sedimentary environment	30
<u>Chapter 3. MESOSCOPIC STRUCTURES</u>	33
3.0 <u>SCOPE OF THE DISCUSSION</u>	33
3.1 <u>LAYERING, LAYER-PARALLEL SCHISTOSITY AND THE FIRST DEFORMATION</u>	34
3.1.1 Layering, bedding, and the earliest schistosity	34
3.1.2 Graded bedding as sedimentary younging	37
3.1.3 Significance of the bedding-parallel $S_1$ schistosity: has mesoscopic $D_1$ transposition occurred?	38
3.2 <u><math>D_2</math> STRUCTURES</u>	41
3.2.1 $F_2$ folds and $S_2$ schistosity	41
3.2.2 Relation between $F_2$ folds and the mineral lineations $L_1$ and $L_2$	45
Outcrops containing a single lineation	46
Outcrops containing two lineations	47
3.2.3 Has mesoscopic transposition occurred during $D_2$ ?	48
3.3 <u><math>D_3</math> STRUCTURES</u>	49
3.3.1 Description	49
General	49
$D_3$ structures adjacent to retrograde schist zones	51
3.4 <u>STRUCTURES WITHIN RETROGRADE SCHIST ZONES</u>	52
3.5 <u><math>D_4</math> STRUCTURES</u>	54
3.5.1 Description	54
3.5.2 Age of $D_4$ structures	55
3.6 <u>SYNTHESIS</u>	57
A note on fold correlation	57





TABLE OF CONTENTS (cont'd)

<u>Chapter 4 (cont'd)</u>	<u>Page</u>
<u>New minerals of the M<sub>3</sub> assemblage</u>	129
(a) Muscovite	130
(b) Staurolite	130
(c) Chlorite	133
(d) Accessory minerals	134
4.3.2 <u>CHARACTERIZATION OF THE M<sub>3</sub> METAMORPHISM</u>	134
<u>Downgrade sequence of metamorphism</u>	134
<u>Estimate of P, T and p<sub>H2O</sub></u>	135
<u>The mobility of components</u>	136
4.3.3 <u>SYNTHESIS</u>	136
4.4 <u>RELATIONSHIP BETWEEN S<sub>3</sub> AND S<sub>R</sub></u>	139
4.4.1 <u>NATURE OF THE PROBLEM</u>	139
4.4.2 <u>MICROFABRIC TRANSITION FROM S<sub>3</sub> TO S<sub>R</sub></u>	140
<u>The microfabric of S<sub>R</sub></u>	140
<u>Development of segregation banding</u>	141
<u>Quartz recrystallization completed</u>	141
<u>Obliteration of coarse relict phases</u>	141
<u>Garnet cataclasis</u>	142
<u>Metamorphic conditions</u>	142
4.4.3 <u>SYNTHESIS</u>	143
<u>Chapter 5. MACROSCOPIC STRUCTURES</u>	144
5.0 <u>INTRODUCTION</u>	144
5.0.1 <u>Method and scope of the analysis</u>	144
5.0.2 <u>Presentation of data</u>	146
5.1 <u>STRUCTURES SOUTHEAST OF THE GLOBE-VAUXHALL SHEAR</u>	146
5.1.1 <u>North Mine area</u>	146
Evidence for the major structures	146
Complexities in the Broken Hill Antiform	150
Structure of the North Mine orebody	155
A note on correlation of orebody folds across the British Shear.	156

TABLE OF CONTENTS (cont'd)

	<u>Page</u>
<u>Chapter 5 (cont'd)</u>	
5.1.2 <u>Imperial Ridge - Round Hill</u>	158
5.1.3 <u>The Highway area</u>	163
Evidence concerning the large-scale geometry of $F_2$ folds - has macroscopic transposition occurred during $D_2$ ?	163
Structure of the Highway area - evidence for the Broken Hill Antiform	166
5.2 <u>STRUCTURES NORTHWEST OF THE GLOBE-VAUXHALL SHEAR</u>	168
5.2.1 <u>Gross macrostructure from stratigraphic evidence</u>	168
5.2.2 <u>Detailed macrostructure - the problem of interpreting the mesoscopic structural evidence</u>	169
5.2.3 <u>Detailed macrostructure - summary of subareas</u>	175
5.2.4 <u>Summary and interpretation</u>	183
5.3 <u>THE HIGH-GRADE LINEATIONS</u>	187
5.3.1 <u>Macroscopic relations between lineations and <math>F_2</math> fold axes</u>	187
5.3.2 <u>Interpretation of lineation/fold axis relations</u>	189
5.4 <u>RETROGRADE SHEAR ZONES</u>	192
Terminology	192
5.4.1 <u>Geometry of the zones</u>	192
Pattern of shear zones	192
Geometry of the retrograde schistosity and lineation	194
5.4.2 <u>Kinematic interpretation</u>	196
Observed displacements across retrograde shear zones	196
(a) British and De Bavay Shears	196
(b) Globe-Vauxhall and Western Shears	196
Strain estimates from retrograde schistosity and lineation	201
British and Globe-Vauxhall Shears - a conjugate set?	203
5.4.3 <u>Model of development of the shear zones</u>	205
5.5 <u>FAULTS</u>	208

TABLE OF CONTENTS (cont'd)

	<u>Page</u>
<u>Chapter 6. SYNTHESIS</u>	210
6.1 <u>STRUCTURAL ANALYSIS IN THE HIGH-GRADE ROCKS OF THE WILLYAMA COMPLEX</u>	210
6.1.1 <u>General approach</u>	210
6.1.2 <u>Mesosopic analysis</u>	211
6.1.3 <u>Microscopic analysis</u>	212
6.1.4 <u>Macroscopic analysis</u>	213
6.2 <u>THE OLARIAN OROGENY</u>	214
6.3 <u>THE NORTH MINE OREBODY</u>	218
6.3.1 <u>Review of earlier work-conformability of the orebody</u>	218
6.3.2 <u>Structural and stratigraphic reconstruction</u>	220
6.3.3 <u>Factors in future exploration</u>	222
6.4 <u>SUMMARY OF THE GEOLOGICAL HISTORY OF THE OREBODY</u>	223
6.5 <u>GENERAL SUMMARY</u>	230

REFERENCES



SUMMARY

The Willyama Complex in the area of North Mine and the adjacent Northern Leases comprises a sequence of pelitic metasediments and lesser acid and basic gneisses which have been strongly deformed and metamorphosed to upper amphibolite/lower granulite facies. Conformably within the sequence lies a horizon carrying sulphide mineralization (the Lode Horizon) and in North Mine this horizon contains a high-grade lead-zinc-silver orebody.

Prominent layering in the pelitic metasediments represents bedding, on the basis of composition, well-developed compositional grading in many layers, continuity, and parallelism with gross lithological boundaries. The pelitic metasediments were derived from a mature granitic or metamorphic terrain and deposited, partly as turbidites, in a distal basinal environment.

The metamorphic and structural history is characterized by three main events, with close similarities and progressive changes from one event to the next. These are categorized as the Olarian Orogeny. In all rock-types a layer-parallel schistosity  $S_1$  containing a strong mineral lineation  $L_1$  is the earliest recognizable structure, formed during the  $M_1$  high-grade metamorphism. Mesoscopic  $F_1$  folds are extremely rare, but one macroscopic example is described from the Parnell Track area northwest of Broken Hill.  $D_1$  is inferred to have involved regional nappe formation and/or large-scale thrusting. There is some evidence that a phase of folding followed  $D_1$  and preceded  $D_2$ , without development of any penetrative fabric.  $D_2$  also took place during high-grade metamorphism, and formed tight, inclined to upright  $F_2$  folds on all scales.  $F_2$  folds appear to be almost invariably developed parallel to  $L_1$ . In the pelitic metasediments a strong schistosity  $S_2$  and a strong mineral lineation  $L_2$  are commonly formed in the axial plane of  $F_2$  folds, by crenulation and recrystallization of the  $S_1/L_1$  microfabric. The  $L_2$  lineation plunges uniformly to the southwest, generally parallel to  $F_2$  fold axes and the  $L_1$  lineation, but in some areas is oblique to these structures where the latter show anomalous northeast plunges. The southwest-plunging lineation direction is inferred to represent the principal maximum axis of strain during  $D_2$  and possibly  $D_1$ . The third deformation overlapped with  $D_2$  but generally refolded  $D_2$  structures;  $D_2$  and/or  $D_3$  and their associated metamorphisms  $M_2$  and  $M_3$  were probably diachronous.  $F_3$  folds are open to tight, upright, and show variable plunge. The microfabric of the weak to strong  $S_3$  axial-plane schistosity in the pelitic metasediments is defined by various medium and low-grade assemblages which successively replace each other in a down-grade sequence,

indicating that  $D_3$  took place during waning metamorphism.  $D_3$  structures are transitional to the structures within retrograde shear zones, the initiation of which marked the cessation of regionally pervasive ductile deformation. This represents the close of the Olarian Orogeny.

Within the retrograde zones evidence from displacement of marker units and from the geometry of mesoscopic structures substantiates deformation by simple shear. Vertical displacement on the major Globe-Vauxhall Shear varies systematically along the Shear suggesting rotational movement, and is between 300 m and 1000 m, southeast-block-up. The horizontal displacement is small.

The major folds southeast of the Globe-Vauxhall Shear, including the North Mine area, are  $F_2$  structures, named the Hangingwall Synform and the Broken Hill Antiform. The Hangingwall Synform has also been recognized in the subsurface northwest of the Shear. The linear North Mine orebody occupies the hinge of a parasitic fold on the common limb of these folds, which in the North Mine area show anomalous northeast plunge. The orebody is parallel to  $F_2$  and  $L_1$  and oblique to the southwest-plunging  $L_2$  lineation. The Lode Horizon and the orebody are concordant with bedding.

Transposition of bedding into parallelism with the axial-plane schistosity of tight folds was previously thought to have created a new layering and to have destroyed stratigraphic sequence in the North Mine area. However the tight but generally not isoclinal nature of  $F_2$  and  $F_3$  folds, and consistent stratigraphic younging from graded beds over large areas show that any transposition which occurred must have been during  $D_1$  and on a macroscopic scale only. A consistent stratigraphic sequence is observed throughout most of the area; in the Mine area this sequence is inverted around the large  $F_2$  folds, which are therefore downward-facing.

Within the inverted sequence the Lode Horizon occurs stratigraphically at the top of a metasedimentary sequence which contains probable volcanogenic units (the acid and basic gneisses), and is overlain by a metasedimentary sequence lacking such units. This probably reflects a link between volcanic activity and sulphide deposition. The inverted sequence also places the lead lodes stratigraphically above the zinc lodes, thus removing an inconsistency in previous volcanogenic models.

The study confirms the unparalleled usefulness of the pelitic metasedimentary rocks in structural analysis, metamorphic investigations, and stratigraphic reconstruction. Methods of analysis of structures in drill-core are described which complement surface and underground mapping.