

THE STRATIGRAPHY, STRUCTURAL GEOLOGY AND GEOCHEMISTRY
OF THE FOX LAKE MASSIVE SULFIDE DEPOSIT

A Thesis
Presented to
The Faculty of Graduate Studies
University of Manitoba

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

by

Philip Eugene Olson

August 1987 ©

Permission has been granted to the National Library of Canada to microfilm this thesis and to lend or sell copies of the film.

The author (copyright owner) has reserved other publication rights, and neither the thesis nor extensive extracts from it may be printed or otherwise reproduced without his/her written permission.

L'autorisation a été accordée à la Bibliothèque nationale du Canada de microfilmer cette thèse et de prêter ou de vendre des exemplaires du film.

L'auteur (titulaire du droit d'auteur) se réserve les autres droits de publication; ni la thèse ni de longs extraits de celle-ci ne doivent être imprimés ou autrement reproduits sans son autorisation écrite.

ISBN 0-315-37430-6

THE STRATIGRAPHY, STRUCTURAL GEOLOGY AND GEOCHEMISTRY
OF THE FOX LAKE MASSIVE SULFIDE DEPOSIT

BY

PHILIP EUGENE OLSON

A thesis submitted to the Faculty of Graduate Studies of
the University of Manitoba in partial fulfillment of the requirements
of the degree of

MASTER OF SCIENCE

© 1987

Permission has been granted to the LIBRARY OF THE UNIVERSITY OF MANITOBA to lend or sell copies of this thesis, to the NATIONAL LIBRARY OF CANADA to microfilm this thesis and to lend or sell copies of the film, and UNIVERSITY MICROFILMS to publish an abstract of this thesis.

The author reserves other publication rights, and neither the thesis nor extensive extracts from it may be printed or otherwise reproduced without the author's written permission.

ABSTRACT

The Fox Mine was a Proterozoic copper-zinc, volcanogenic massive sulfide deposit located in northwestern Manitoba. It was hosted by tholeiitic and calc-alkaline, sodic series volcanic and associated sedimentary rocks. The area has undergone middle amphibolite grade metamorphism.

The deposit comprised two major massive sulfide lenses, produced by separate hydrothermal vents. Both displayed typical metal zonation with lowermost copper-rich stringer ore, central massive copper-rich ore and uppermost stratified zinc rich ore. The lenses were laterally continuous with altered felsic metavolcanic rocks. The western extension is obscured by thick accumulations of siltstones and pyritic mudstones. A thin horizon of iron formation coincides with the eastern extension.

The structural evolution of the Fox Mine area involved subvolcanic plutonism, early isoclinal folding (F1), tight E-trending shear folding (F2) followed by a period of faulting and shearing (D3) that segmented and offset the sequence of strata.

The orebody occurred on the overturned limb of an early, sub-horizontally plunging, isoclinal fold. Altered felsic metavolcanic rocks 800 meters south of the mine constitute a similar geological environment. They represent a detached, folded (F2) repetition of the favorable stratigraphy.

TABLE OF CONTENTS

| | |
|------------------------|------|
| ABSTRACT..... | i |
| TABLE OF CONTENTS..... | ii |
| IN MEMORIAM..... | vii |
| ACKNOWLEDGEMENTS..... | viii |
| LIST OF FIGURES..... | x |
| LIST OF TABLES..... | xii |
| LIST OF PLATES..... | xiii |
| LIST OF MAPS..... | xix |

CHAPTER I

INTRODUCTION

| | |
|--|---|
| 1.1 BACKGROUND, LOCATION AND ACCESS..... | 1 |
| 1.2 PREVIOUS WORK..... | 3 |
| 1.3 SCOPE OF THE PRESENT STUDY..... | 6 |

CHAPTER II

ROCK TYPES OF THE FOX MINE AREA

| | |
|--|----|
| 2.1 REGIONAL SETTING..... | 9 |
| 2.2 LOCAL SETTING..... | 11 |
| 2.3 WASEKWAN GROUP..... | 14 |
| 2.3.1 PORPHYRITIC MAFIC METAVOLCANIC ROCKS (UNIT 1)... | 14 |
| 2.3.1.1 Massive basalt (1a)..... | 18 |

| | |
|---|----|
| 2.3.1.2 Pillowed basalt (1b)..... | 18 |
| 2.3.1.3 Aphyric basalt (1c)..... | 23 |
| 2.3.1.4 Aphyric andesite (1d)..... | 26 |
| 2.3.1.5 Autoclastic breccia (1e)..... | 32 |
| 2.3.1.6 Iron formation (1f)..... | 35 |
| 2.3.1.7 Volcaniclastic and derived sedimentary rock (1g)..... | 36 |
| 2.3.1.8 Altered porphyritic mafic metavolcanic rocks (1h)..... | 37 |
| 2.3.2 FELSIC METAVOLCANIC ROCKS (UNIT 2)..... | 40 |
| 2.3.2.1 Massive porphyritic dacite (2a)..... | 41 |
| 2.3.2.2 Massive aphyric dacite (2b)..... | 47 |
| 2.3.2.3 Massive porphyritic rhyolite (2c)..... | 47 |
| 2.3.2.4 Dacitic tuff (2d)..... | 49 |
| 2.3.2.5 Altered dacite (2e)..... | 52 |
| 2.3.2.6 Sulfides (2f)..... | 54 |
| 2.3.3 METASEDIMENTARY ROCKS (UNIT 3)..... | 55 |
| 2.3.4 APHYRIC MAFIC METAVOLCANIC ROCKS (UNIT 4)..... | 58 |
| 2.4 SICKLE GROUP..... | 60 |
| 2.4.1 ARKOSIC META-SANDSTONE (UNIT 5)..... | 60 |
| 2.5 INTRUSIVE ROCKS..... | 63 |
| 2.5.1 GABBRO, DIABASE (UNIT 6)..... | 63 |
| 2.5.2 QUARTZ-EYE PORPHYRY (UNIT 7)..... | 64 |
| 2.5.3 HORNBLLENDE TONALITE - QUARTZ DIORITE (UNIT 8)... | 65 |
| 2.5.4 BIOTITE LEUCOGRANITE (UNIT 9)..... | 66 |

CHAPTER III

THE ALTERATION ZONE

| | | |
|-------|--|----|
| 3.1 | LOCATION AND EXTENT..... | 67 |
| 3.2 | LITHOLOGICAL DESCRIPTIONS..... | 67 |
| 3.2.1 | Quartz-sericite schist (2eQSS)..... | 67 |
| 3.2.2 | Quartz-biotite gneiss (2eQBG)..... | 68 |
| 3.2.3 | Cordierite-anthophyllite gneiss (2eCAG)..... | 70 |
| 3.2.4 | Coarse mica schist (2eCMS)..... | 73 |
| 3.2.5 | Other constituents of the alteration envelope... | 76 |
| 3.3 | ZONING OF ALTERATION ROCK TYPES..... | 77 |
| 3.4 | ALTERED ROCK TYPES EXTERNAL TO THE ALTERATION ENVELOPE..... | 79 |

CHAPTER IV

THE ORE ZONE

| | | |
|-----|---|----|
| 4.1 | LOCATION AND EXTENT..... | 81 |
| 4.2 | ORE TYPES AND DISTRIBUTION..... | 83 |
| 4.3 | SULFIDE RECRYSTALLIZATION AND MOBILITY..... | 85 |
| 4.4 | LATERAL FACIES EQUIVALENTS..... | 85 |

CHAPTER V

STRUCTURAL GEOLOGY, METAMORPHISM AND INTRUSIVE SEQUENCE

| | | |
|-------|--------------------------|----|
| 5.1 | GENERAL STATEMENT..... | 87 |
| 5.2 | STRUCTURAL ELEMENTS..... | 87 |
| 5.2.1 | Primary structures..... | 89 |
| 5.2.2 | Foliations..... | 90 |

| | | |
|-------|--|-----|
| 5.2.3 | Lineations..... | 92 |
| 5.2.4 | Folds..... | 94 |
| 5.2.5 | Faults and shear zones..... | 95 |
| 5.3 | DEFORMATIONAL EVENTS AND INTRUSIVE SEQUENCE..... | 101 |
| 5.3.1 | Early intrusions (I1)..... | 101 |
| 5.3.2 | First deformational event - D1..... | 102 |
| 5.3.3 | Second deformational event - D2..... | 102 |
| 5.3.4 | Third deformational event - D3..... | 103 |
| 5.3.5 | Late intrusions (I2)..... | 104 |
| 5.3.6 | Fourth deformational event - D4..... | 104 |
| 5.4 | METAMORPHISM..... | 105 |
| 5.4.1 | Hydrothermal Alteration | 105 |
| 5.4.2 | Early Middle Amphibolite Grade Metamorphism (M1)..... | 105 |
| 5.4.3 | Late Middle Amphibolite Grade Metamorphism (M2)..... | 106 |
| 5.4.4 | Retrograde Metamorphism (M3)..... | 109 |
| 5.4.5 | Metamorphic Temperature and Pressure Conditions..... | 109 |

CHAPTER VI

STRATIGRAPHIC MODEL OF THE FOX MINE AREA

| | | |
|-----|---|-----|
| 6.1 | GENERAL STATEMENT..... | 114 |
| 6.2 | STRATIGRAPHIC DEVELOPMENT OF THE FOX MINE AREA..... | 117 |

CHAPTER VII

GEOCHEMISTRY

| | | |
|-------|---|-----|
| 7.1 | GENERAL STATEMENT..... | 121 |
| 7.2 | MAJOR ELEMENT INVESTIGATIONS..... | 123 |
| 7.2.1 | Alkalies-Silica Diagram..... | 124 |
| 7.2.2 | AFM Diagram..... | 125 |
| 7.2.3 | Alumina versus NPC Diagram..... | 132 |
| 7.2.4 | NCI versus NPC Diagram..... | 132 |
| 7.2.5 | An-Ab'-Or Diagram..... | 133 |
| 7.2.6 | Alkali Ratio Diagram..... | 133 |
| 7.3 | TRACE ELEMENT INVESTIGATIONS..... | 134 |
| 7.3.1 | Zr/TiO ₂ versus Nb/Y Diagram..... | 135 |
| 7.3.2 | TiO ₂ versus Zr Diagram (logarithmic)..... | 136 |
| 7.3.3 | TiO ₂ versus Zr Diagram..... | 137 |
| 7.4 | GEOCHEMICAL SUMMARY..... | 137 |

CHAPTER VIII

DISCUSSIONS AND CONCLUSIONS

| | | |
|-----|-------------------|-----|
| 8.1 | DISCUSSION..... | 142 |
| 8.2 | CONCLUSIONS..... | 146 |
| | REFERENCES..... | 149 |
| | APPENDIX I..... | 154 |
| | APPENDIX II..... | 164 |
| | APPENDIX III..... | 201 |
| | APPENDIX IV..... | 211 |
| | APPENDIX V..... | 214 |

IN MEMORIAM

FOX MINE (1970-1985)

On the 29th of November, 1985, milling operations at the Fox Mine ceased. Ore milled to closure totalled 11,958,182 tonnes grading 1.82% copper and 1.78% zinc. With many fond memories, I bid adieu to an old 'friend' and respectfully submit this thesis.

ACKNOWLEDGEMENTS

This study of the Fox Lake massive sulfide deposit was a co-operative venture undertaken by the author in conjunction with the University of Manitoba. The project was funded by Sherritt Gordon Mines Limited and the Manitoba Department of Energy and Mines, Mineral Resources Division. Implementation of this program was facilitated through the efforts of Mr. I. M. Plummer, Dr. W.D. McRitchie and Dr. W.C. Brisbin.

The author wishes to acknowledge the significant contribution Sherritt Gordon Mines has made to the fruition of this project. Financial assistance, logistical support, access to information and computing facilities, meaningful discussions and moral support were provided by the management and staff of Sherritt Gordon Mines. Over a period of ten years, discussions with I.M. Plummer, R.G. Fernandez, R.F. Sawyer, J.M. Plecash, W.A. Jealous, A. Prus, R. Morin, B.R. King, and Dr. S. Amor enabled the author to formulate this interpretation of the Fox Mine area. Very capable assistance was provided during the 1984 field season by Mr. T. Giles.

The author also wishes to acknowledge the guidance and instruction offered by the Department of Geological Sciences staff at the University of Manitoba. Comments and criticisms by advisors, Drs. W.C. Brisbin and N.M. Halden always proved constructive. The enthusiasm for petrography demonstrated by Dr. A.C. Turnock proved a constant source of inspiration.

The author would like to thank the entire staff at the Manitoba Department of Energy and Mines and in particular, Drs. H.V. Zwanzig, G.H. Gale and D.A. Baldwin, for their un-failing patience, understanding and advice during numerous field visits and discussions.

Finally, I wish to express my sincerest appreciation to my wife, Catherine, and children, Justin and Laura, for their sacrifices of a personal nature.

LIST OF FIGURES

| | | |
|-----------|--|-----|
| FIGURE 1: | LOCATION MAP WITH SIMPLIFIED GEOLOGY (modified from Gilbert et al., 1980)..... | 4 |
| FIGURE 2: | ROCK UNITS ENCOUNTERED IN THE FOX MINE AREA ARRANGED IN STRATIGRAPHIC ORDER..... | 13 |
| FIGURE 3: | SIMPLIFIED GEOLOGY OF 2100 LEVEL..... | 25 |
| FIGURE 4: | (A). SIMPLIFIED CROSS-SECTION THROUGH THE MAIN ORE ZONE. PRESENT DISPOSITION OF ALTERATION, STOCKWORK AND MASSIVE SULFIDES IS CONSISTENT WITH AN OVERTURNED DEPOSIT ATTENUATED DOWN DIP. (B) CONCEPTUAL MODEL FOR THE TWO ORE LENSES THAT COMPOSED THE FOX LAKE DEPOSIT. THE WEST LENS HAD A SEPARATE STOCKWORKS AND WAS STRATIGRAPHICALLY HIGHER THAN THE MAIN ZONE..... | 78 |
| FIGURE 5: | Cu/(Cu+Zn) RATIOS FOR THE FOX LAKE MASSIVE SULFIDE DEPOSIT..... | 82 |
| FIGURE 6: | STRUCTURAL EVOLUTION OF THE FOX MINE AREA..... | 88 |
| FIGURE 7: | EQUAL AREA DIAGRAMS FOR STRUCTURAL ELEMENTS OF THE FOX MINE AREA..... | 93 |
| FIGURE 8: | PRESSURE-TEMPERATURE CONDITIONS EFFECTED DURING METAMORPHISM OF THE FOX MINE AREA..... | 111 |
| FIGURE 9: | SIMPLIFIED CROSS-SECTION OF THE FOX MINE AREA, SHOWING STRATIGRAPHIC REPETITIONS OF AN OVERTURNED F2 FOLD LIMB..... | 115 |

| | |
|--|-----|
| FIGURE 10: STRATIGRAPHIC MODEL OF THE FOX MINE AREA..... | 116 |
| FIGURE 11: ALKALIES-SILICA DIAGRAM..... | 126 |
| FIGURE 12: AFM DIAGRAM..... | 127 |
| FIGURE 13: Al ₂ O ₃ vs. NPC DIAGRAM..... | 128 |
| FIGURE 14: NCI VS. NPC DIAGRAM..... | 129 |
| FIGURE 15: An-Ab'-Or DIAGRAM..... | 130 |
| FIGURE 16: ALKALI RATIO DIAGRAM..... | 131 |
| FIGURE 17: (Zr/TiO ₂) vs. (Nb/Y) DIAGRAM..... | 139 |
| FIGURE 18: TiO ₂ /Zr LOGARITHMIC DIAGRAM..... | 140 |
| FIGURE 19: TiO ₂ /Zr DIAGRAM..... | 141 |

LIST OF TABLES

| | |
|--|-----|
| TABLE 1: SUBUNIT COMPARISON OF THE PORPHYRITIC MAFIC META- VOLCANIC ROCKS BY SUBAREA..... | 17 |
| TABLE 2: COMPARISON OF PILLOWED BASALTS (1b) BY SUBAREA... | 19 |
| TABLE 3: METAMORPHIC MINERALS RELATED TO DEFORMATIONAL EVENTS..... | 113 |

LIST OF PLATES

- Plate 1: The Fox Mine as viewed from the south, with milling complex on the left and headframe on the right.....2
- Plate 2: Ellipsoidal pillow with massive core and coarsely recrystallized rim. From pillowed basalt (1b) of subarea 1. Location - 71260E x 6680N.....22
- Plate 3: Loaf-like pillows with altered, vesiculated cores and thin selvages. From pillowed basalt (1b) of subarea 2. Location - 69920E x 9720N.....22
- Plate 4: Porphyritic seriate texture in pillowed basalt (1b). Felted groundmass of cummingtonite and plagioclase enclosed cummingtonite clot. Cross nicols. From DDH UF-1886 @ 2413' (736m).....24
- Plate 5: Hornblende- and plagioclase-phyric pillowed basalt (1b). Groundmass is fine-grained amphibole and plagioclase. Plane polars. From UF-1886 @ 113' (35m).....24
- Plate 6: One complete flow unit within the aphyric andesite (1d) from subarea 1. Flow comprises massive andesite at the base (top left), pillowed andesite in the centre and andesite pillow breccia at the top (bottom right). Pillow size decreases and amount of hyaloclastite increases upwards. Location - 71060E x 5940N.....27
- Plate 7: Elongate pillows with well-defined selvages, conspicuous interpillow sediment and raised amygdules. Blunt pillow terminations indicate facing direction (to left in photo). From aphyric andesite (1d) in subarea 1. Location - 71060E x 5890N...28
- Plate 8: Small amygdules concentrated near pillow margins. From aphyric andesite (1d) in subarea 2. Note also tightly folded quartz vein below lens cap. Location - 72350E x 8500N.....28
- Plate 9: Internal shelf showing secondary epidote replacement in a large, subspheroidal pillow. In aphyric andesite (1d) from subarea 2. Location - 72150E x 8970N.....30
- Plate 10: Pale white, cummingtonite-rich, pillow fragments in a recrystallized [garnet-biotite schist] hyaloclastite matrix. In aphyric andesite (1d) from subarea 2. Location - 72600E x 8890N.....30

- Plate 11: Zoned amphibole poikiloblasts overprinting foliation defined by biotite laths. In aphyric andesite (ld) from subarea 2. Plane polarized light. DDH FS-35 @ 508' (155m).....31
- Plate 12: Knife-sharp contact between autoclastic breccia (le) and aphyric basalt (lc). Fragment curvature indicates sinistral component of movement on structurally discontinuous surface. Location 71415E x 8675N.....33
- Plate 13: Elongate, pale grey flow fragments in a mica schist matrix. From autoclastic breccia (le) Location - 72410E x 8545N.....33
- Plate 14: Aphyric, pale greyish fragments enclosed in a garnet-mica schist matrix. Large fragment above lens cap appears folded. In autoclastic breccia (le). Location - 72410E x 8545N.....34
- Plate 15: Pale grey, angular fragments in garnet-mica schist matrix. Note late, low angle fault surfaces. In autoclastic flow breccia (le). Location: 2100 Level - 70910E x 10150N.....34
- Plate 16: Discontinuous, isoclinally folded layers of chert in magnetiferous iron formation (lf). Location - 71210E x 10205N.....36
- Plate 17: Weakly altered pillow breccia of the aphyric andesite (ld-h). Clast/matrix boundaries are more diffuse and coarser grained than in unaltered samples. Location - 72090E x 9095N.....38
- Plate 18: Aphyric basalt (lc) with crosscutting alteration. Reconstituted host rock is a coarse-grained anthophyllite schist (lh). Location - 71195E x 10105N.38
- Plate 19: Massive porphyritic dacite (2a) polygonized by fracture network. Near upper flow contact where garnet porphyroblasts and disseminated magnetite grains are evident, but feldspar phenocrysts are indistinguishable from matrix. Location - 70930E x 6980N.....43
- Plate 20: Basal portion of massive porphyritic dacite (2a). Large angular blocks separated by fine-grained reworked material. Location - 71275E x 7170N.....43

- Plate 21: Plagioclase phenocryst in matrix of polygonized plagioclase and quartz with muscovite laths defining foliation. In massive porphyritic dacite (2a). Cross nicols. Location - UF-1886 @ 1428' (435m).....44
- Plate 22: Strained quartz phenocrysts and plagioclase aggregates replacing original phenocrysts in massive porphyritic dacite (2a). Cross nicols. Location - FS-34 @ 515' (157m).....44
- Plate 23: Cored segment near upper contact of massive porphyritic dacite (2a), showing fibrolite porphyroblasts (top), garnet and staurolite porphyroblasts (bottom). Location - UF-1886 @ 1319' (402m)....45
- Plate 24: Replacement of fibrolite porphyroblast by muscovite. In massive porphyritic dacite (2a). Cross nicols. Location - UF-1886 @ 1319' (402m).....45
- Plate 25: Anthophyllite prisms overprinting weak biotite foliation in massive porphyritic rhyolite (2c). Plane polarized light. Location - FS-35 @ 1020' (311m).....49
- Plate 26: Weathered surface of the dacitic tuff (2d) showing late (S_2) foliation crosscutting the (S_1) foliation and layering. Location - 72410E x 9160N..51
- Plate 27: Photomicrograph of the dacitic tuff (2d), showing two penetrative foliations (S_1 and S_2) defined by aligned biotite laths. Trains of garnet porphyroblasts are aligned in the early foliations. Location: UF-1886 @ 1319' (402m).....51
- Plate 28: Photomicrograph of cummingtonite rhombs and prisms overprinting early foliation (S_1) in the dacitic tuff (2d). Plane polarized light. Location - DDH FS-34 @ 94' (29m).....53
- Plate 29: Photomicrograph of cordierite-anthophyllite schist. In altered dacite (2e). Plane polarized light. Location - DDH UF-1886 @ 662' (202m)....53
- Plate 30: Intercalated feldspathic siltstone (3a) and mudstone (3b) layers in folded, laminated metasedimentary rocks (3). Location - 71060E x 11610N..57

- Plate 31: Porphyroblasts of staurolite and garnet in a fine-grained feldspathic siltstone (3a). Staurolite internal surfaces are discordant with external surfaces. Opaque minerals outline minor folds. Plane polarized light. Location - FS-28 @742' (226m).57
- Plate 32: Highly deformed pillows with epidotized cores and cross-cutting calcite veins. In aphyric mafic metavolcanic rocks (4). Location - 70880E x 10600N.....59
- Plate 33: Medium-grained, dark-green, well-foliated aphyric basalt (4) cut by carbonate-filled veins and late fractures. Location - 71200E x 10500N.....59
- Plate 34: Photomicrograph of the massive basalt (4a), containing folded, subidioblastic hornblende and xenoblastic plagioclase. In aphyric mafic metavolcanic rocks (4). Plane polarized light. Location - 71250E x 10500N.....60
- Plate 35: Cross-bedding that yields a south-facing direction for the Sickie Group arkosic meta-sandstone (Unit 5). Location - 71170E x 10400N.....62
- Plate 36: Photomicrograph of mylonitized south contact of the Sickie Group arkosic meta-sandstone (Unit 5). Dextral movement is indicated by the S-C fabric. Cross nicols. Location: DDH UF-1911 @ 168' (51m).....62
- Plate 37: Photomicrograph of the quartz-sericite schist (2eQSS). Grain size differences reflect varying degrees of recrystallization. Cross nicols. Location: 2800 Level - 70875E x 10520N.....70
- Plate 38: Large poikiloblasts of cordierite in underground exposure of quartz-biotite gneiss. Scale is in tenths of inches. Location: 2800 Level - 70875E x 10520N.....72
- Plate 39: Large acicular blades of anthophyllite with phlogopite and cordierite. In cordierite-anthophyllite gneiss. Cross nicols. Location: 2800 Level - 70928E x 10640N.....72
- Plate 40: Very coarse-grained, interpenetrative biotite laths in the coarse mica schist (2eCMS). Location: 2800 Level - 70960E x 10620N.....74

- Plate 41: Large cordierite poikiloblasts overprinting kinked phlogopite laths. In coarse mica schist (2eCMS). Cross nicols. Location: 2800 Level - 70893E x 10550N.....74
- Plate 42: Photomicrograph of staurolite and fibrolite inclusions in a cordierite poikiloblast. From the coarse mica schist (2eCMS). Cross nicols. Location: 2800 Level - 70900E x 10660N.....75
- Plate 43: Altered diabase sill or dike margin (Unit 6). Anthophyllite asterisms in matrix of cummingtonite and plagioclase. Location: 2800 Level - 70670E x 10690N.....76
- Plate 44: Minor folds (F2) in the feldspathic siltstone (subunit 3a) with Z-shaped asymmetry. Location - 71030E x 11625N.....96
- Plate 45: Photomicrograph of a minor F2 fold defined by segmented layer of opaque minerals (pyrrhotite) and biotite. In feldspathic siltstones (subunit 3a). Plane polarized light. Location: DDH FS-28 @ 742' (226m).....96
- Plate 46: Minor fold (F2) in the autoclastic breccia (subunit 1e) with Z-shaped asymmetry. Note discontinuity parallel to axial trace. Location - 71400E x 8750N.....97
- Plate 47: Open folding (F2) of an epidote layer in the aphyric basalt (subunit 1c). Location - 71250E x 8755N.....97
- Plate 48: Photomicrograph of protomylonite from a D2 fault in aphyric andesite (subunit 1d). Plane polarized light. In DDH FS-28 @ 431' (131m).....100
- Plate 49: Fault surface defining southern ore contact. Slickensides indicate downward movement of the hangingwall block (left in photo). Viewed from northwest. Location - 70800E x 9600N.....100
- Plate 50: Fibrolite mass or knot partially replaced by muscovite. Lepidoblastic schistosity is defined by biotite laths. In the felsic metavolcanics (Unit 2). Cross nicols. Location - DDH UF-1886 @ 1319' (402m).....108

- Plate 51: Zoned amphibole with hornblende core and cumingtonite rim aligned in a nematoblastic schistosity (S_2). Note also the late garnet porphyroblast. From the autoclastic breccia (subunit 2e). Plane polarized light. Location - DDH FS-35 @ 508' (155m).....108
- Plate 52: Fascicular anthophyllite aggregate and pinnitized cordierite overprinting the S_2 lepidoblastic schistosity. In altered felsic metavolcanic rocks (subunit 2e). Plane polarized light. From UF-1886 @ 662' (202m).....110
- Plate 53: Augen mylonite with large strained quartz porphyroclast with finer matrix grains of penninite and sericite. From quartz-eye porphyry. Cross polars. From FS-28 @ 1193' (364m).....110

LIST OF MAPS

Map 1: Fox Mine Geology - Surface

Map 2: Fox Mine Geology - 2800 Level

Map 3: Diamond Drill Holes UF-1886 and UF-2039 (plan view)
- 2000 Level (south)

Map 4: Geological Cross-section A-B

**Maps contained in back jacket.

CHAPTER I
INTRODUCTION

1.1 BACKGROUND, LOCATION AND ACCESS

In his economic assessment of the Dunphy Lakes area, M. S. Stanton (1949) made the following innocuous statement in the final paragraph of his report:

"About 1,000 feet northwest of Fox Lake, a sparse dissemination of fine pyrrhotite occurs in a small exposure of recrystallized dark-grey very impure garnetiferous quartzite. A magnetic anomaly was also noted in the immediate vicinity. No surface workings were observed" (p. 34).

Twelve years later, exploration crews in the employment of Sherritt Gordon Mines Limited confirmed the existence of a massive sulfide deposit approximately 300 meters northwest of Fox Lake. By July of 1965, diamond drill crews had outlined 11,153,636 tonnes of ore grading 1.74% copper and 2.35% zinc. Feasibility studies based on these drill results culminated in a production decision and in May of 1970, the first ore was shipped at Sherritt Gordon's Fox Mine.

For the next fifteen years, production levels at the Fox Mine were maintained near its design capacity of 2,750 tonnes per day. Published mining reserves dated December 31, 1984, included 632,893 tonnes averaging 1.802% copper and 2.418% zinc.

These reserves were exhausted by routine mine production during 1985. The final ore was processed on November 29th. Tonnage milled to closure totalled 11,958,182 tonnes grading

1.82% copper and 1.78% zinc.

The study to which this thesis pertains, was initiated in 1984 as a geological and geochemical assessment of the Fox Lake massive sulfide deposit prior to the cessation of mining operations. Although the final draft of this thesis was not available prior to closure, preliminary results were released in the Manitoba Department of Energy and Mines, 1984 Report of Activities.

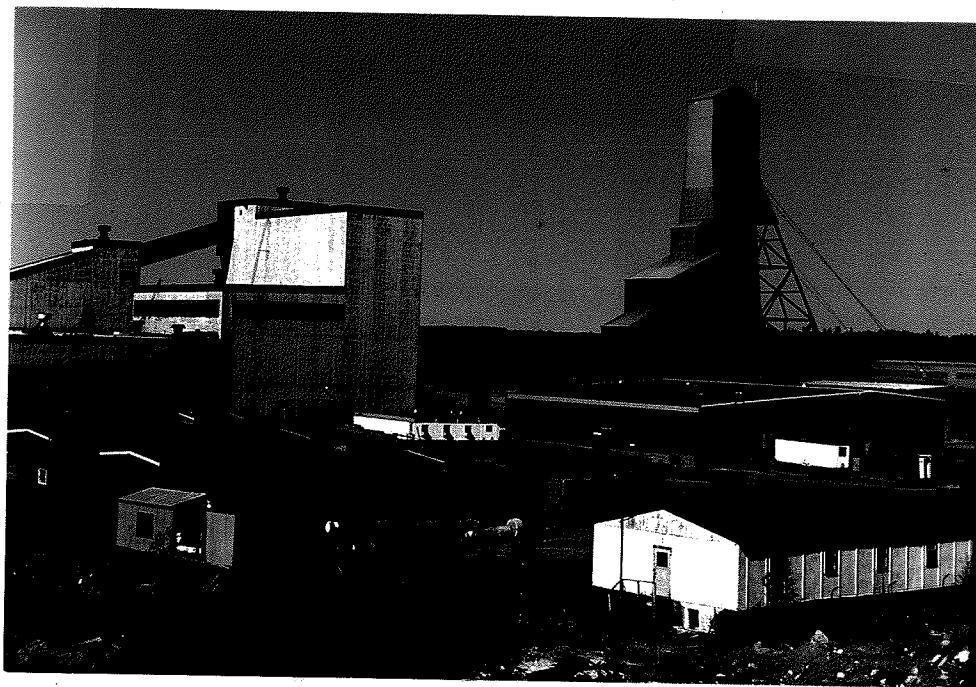


Plate 1: The Fox Mine as viewed from the south, with milling complex on the left and headframe on the right.

Fox Mine (Plate 1) is located in northwestern Manitoba, 20 kilometers east of the Saskatchewan provincial boundary, 45 kilometers southwest of the Lynn Lake townsite and 800 air kilometers northwest of Winnipeg (Figure 1). All weather access to the mine from Lynn Lake is possible via Provincial Highway #396. Lynn Lake is accessible by scheduled aircraft

service and Provincial Highway #396 by way of Thompson and by a branch-line of the Canadian National Railway via Cranberry Portage.

1.2 PREVIOUS WORK

The earliest geological map to include the Fox Mine area was the work of D. L. Downie in 1935. It was published as Geological Survey of Canada Map #343A covering the Granville Lake Map Sheet (West Half) on a scale of one inch equals four miles.

The next published geological work providing coverage of the Fox Mine area was by M. S. Stanton. It was released in 1949 as Manitoba Department of Mines and Natural Resources Report #48-4. This publication included the first detailed map (inch to half mile) for the Dunphy Lakes segment of the Granville Lake Mining District. In this report, Stanton separated the rocks of the Dunphy Lakes area into the Wasekwan and Sickle Series, consistent with the nomenclature of Norman (1933) and Bateman (1945). Meta-volcanic and volcanoclastic rocks composed the former group; immature, presumably younger metasedimentary rocks composed the latter. Significantly, Stanton noted several occurrences of coarse garnet-actinolite-cordierite-chlorite rock that he interpreted as hybrids resulting from impregnation by granitic material. Stanton did not elaborate on the structure of the Dunphy Lakes area. He cited the paucity of minor structures and facing direction indicators as limiting factors.