THE STRUCTURAL GEOLOGY
OF THE
RUTH-HOPE AND SILVERSMITH MINES

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ABSTRACT

The Ruth-Hope and Silversmith areas are mainly underlain by structurally-competent quartzites, sandy limestones, and thick argillites. Bedding attitudes are steep; several major and minor recumbent folds occur within the local section of bedding structures.

The strong northeasterly-trending Standard-Silversmith lode system is represented locally by the Hope, New Ruth, and Silversmith lodes. The Old Ruth-Stewart section lies about one-half mile north, and in the footwall of the main belt. Lodes strike easterly to northeasterly across the trend of bedding structures; they dip to the southeast at moderate to high angles. The most important ore minerals are argentiferous galena, sphalerite, and grey copper.

The major bedding structure of the Old Ruth-Stewart section is a recumbent anticline which is convex to the southwest. Bedding within the New Ruth-West Silversmith section dips moderately to steeply southwest.

The pattern of lode and cross-fault displacements is reasonably consistent within the mines area. From evidence provided by minor structures, the relative displacements were such that lode hanging walls moved downward to the east and
Abstract

southeast; normal displacements occurred on all cross-faults. Within the productive part of the Old Ruth Mine, mineralization apparently followed a late normal displacement within a major strand of the lode. Lode movements, at least later ones, were, to some extent, transmitted by cross-faults which join the offset segments of the lodes. Also, to a minor extent, the cross-faults contain ore minerals which probably entered by way of fault-lode linking fractures.

Apparently porphyry, alteration, and ore were emplaced consecutively, but concurrently with displacements on the lodes and cross-faults. The stronger mineralization of the northeasterly-trending fractures was probably due to a close timing of ore deposition with more intense late movements on this set of fractures. In addition, deeper "ore channels" could be expected within fractures which cross-cut, rather than parallel the bedding.

That the West Silversmith porphyry "plug" was emplaced as a separate body, and is not a faulted block from the main Silversmith Stock was proved by the study of flow structures within the "plug".

(iii)
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# TABLE OF CONTENTS

Abstract ......................................................... i
Acknowledgements .............................................. iii
Introduction ..................................................... iv

General Geology of the Mines Area ............................. 1

Details of Structural Geology
Introduction ..................................................... 10

Old Ruth-Stewart Section
General .......................................................... 12
Pattern of Major Structures ................................... 13
Silversmith Fault ............................................... 15
Stewart Fault ................................................... 17
Wall Rock Types and Structures ............................... 26
Old Ruth Lode ....................................................
   No. 1 Level .................................................. 35
   No. 2 Level .................................................. 36
   No. 3 Level .................................................. 38
   No. 4 Level .................................................. 40
   No. 5 Level .................................................. 42
Stewart Lode and Ruth Fault ...................................
   Stewart No. 4 Level ......................................... 43
   Stewart No. 5 Level ......................................... 44
Old Ruth No. 3 Level ...........................................
Old Ruth No. 4 Level ...........................................
Old Ruth No. 4150 Level ....................................... 50
Old Ruth No. 5 Level ...........................................
Summary Old Ruth-Stewart ...................................... 52

Mascot-Hope Section ............................................. 57

New Ruth Section
Introduction ..................................................... 62
Rock Types and Structures ..................................... 64
Mineralization and Orebodies ................................ 64
Silversmith Lode ............................................... 65
Ruth Fault ....................................................... 66
Lone Star Fault ................................................ 67
West Silversmith Lode ......................................... 68
Cross-Fault ...................................................... 69
West Silversmith Porphyry ..................................... 70
Minor Structures and Movement Patterns ..................... 71
   Ruth Fault .................................................. 71
   West Silversmith Lode ..................................... 72
   Lone Star Fault ............................................. 73
West Silversmith Porphyry ..................................... 76
Table of Contents - 2

Petrographic Features of the West Silversmith Plug

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Megascopic</td>
<td>78</td>
</tr>
<tr>
<td>(b) Microscopic</td>
<td>79</td>
</tr>
<tr>
<td>Essential Minerals</td>
<td>79</td>
</tr>
<tr>
<td>Accessory Minerals</td>
<td>80</td>
</tr>
<tr>
<td>Alteration</td>
<td>80</td>
</tr>
<tr>
<td>Summary</td>
<td>81</td>
</tr>
<tr>
<td>Specimen No. 4</td>
<td>83</td>
</tr>
<tr>
<td>Specimen No. 5</td>
<td>83</td>
</tr>
<tr>
<td>Specimen No. 6</td>
<td>84</td>
</tr>
<tr>
<td>Specimen No. 7</td>
<td>84</td>
</tr>
</tbody>
</table>

Sequence of Geological Events; New Ruth-Silversmith Areas 85

References 87

Maps in Pocket

<table>
<thead>
<tr>
<th>Map No. 1</th>
<th>Surface and Underground Geology of the Mascot-Hope-Ruth-Silversmith Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Map No. 2</td>
<td>Spread Composite Plan, Old Ruth Mine</td>
</tr>
<tr>
<td>Map No. 3</td>
<td>Cross-Section Details of Stewart and Old Ruth Lodes</td>
</tr>
<tr>
<td>Map No. 4</td>
<td>Underground Geology, New Ruth Area</td>
</tr>
</tbody>
</table>
INTRODUCTION

The Sandon area of the Slocan mining district lies a few miles east of New Denver, B.C., which is situated on the east shore of Slocan Lake. Descriptions of accessibility, climate, topography, history of mining, and general geology may be found in Memoir 173, by C.E. Cairnes, of the Geological Survey of Canada.

Early in 1946 the Kelowna Exploration Company started a program of surface and underground geological mapping of their large group of claims lying to the south and west of Sandon. This work has been carried on continuously to the present time under the general direction of Mr. Paul Billingsley, Consulting Geologist for the Company. The direction of field work has been the responsibility of Mr. A.E. Buller, during the 1946 season, of Dr. E.B. Mayo during the 1947 and 1948 seasons, and of the writer's, under Chief Resident Geologist Dr. E.B. Mayo, during the 1949 season.

The object of this thesis is the detailed description of the structural geology of the Ruth-Hope and Silver-smith mines. The description of minor fold and fracture
structures, with interpretations, will be emphasized. To this end, it is hoped that the maps and other illustrations accompanying this thesis will provide a maximum of assistance in following the text.
GENERAL GEOLOGY OF THE MINE AREA

The mine area including, from west to east, the Mascot, Hope, Ruth, Silversmith, and Slocan Star properties is situated immediately to the south of Sandon (Map No. 1). It lies on the steep slopes forming the south side of Carpenter Creek valley, between the east fork of Tributary Creek on the west, and Sandon Creek on the east. The most important mine workings range in elevation from 4000 feet at Ruth No.5 adit to about 5300 feet at Hope No.1 adit.

Mining activity in the area commenced in 1891 with the location of the Slocan Star claim, in what is now the easterly section of the Silversmith mine. The first locations on Ruth-Hope ground were made in 1892. Intensive mining of the various orebodies took place until the early 1930's. Little production, excepting that from intermittent small scale mining by lesers, has ensued since low metal prices forced a general shut-down at the latter date.
Geologically, the mine area straddles one of the prominent northwesterly-trending belts of quartzitic rocks, occupying a central position in the Slocan Series of highly-folded quartzites, argillites, and limestones. This belt is predominantly quartzitic for a considerable distance to the northwest, but within a short distance to the southeast the rocks become rather calcareous. This change is, in a sense, gradational, and is due to an increase in the proportion of limey beds, with a corresponding decrease of the number of quartzitic beds which normally make up the bulk of the formation to the northwest. Southeast of the mine area, the increasingly calcareous composition of the sediments, with a corresponding increase in the development of shallow-water cross-bedding within coarse sandy layers, suggests that this section of the area persistently maintained a "relatively positive" position with respect to deeper parts of the original basin of deposition.

The orebodies of the mine area lie towards the easterly end of the main through-going lode system of the district. C.E. Cairnes, on page 28 of Memoir 184, suggests the possible continuity of the Standard, Mammoth, Carnation, and Ruth-Hope lodes in a northeasterly direction across the Slocan mining area. On page 122 he points also to the possible continuity
of the Hope and Silversmith lodes. This apparently continuous system of the major lodes of the district is, in detail, a composite structure formed by the roughly-parallel development of a few strong fracture-shear zones separated by panels of country rock that are generally more deformed than the bounding formations. Individual lodes may unite to form a single structure, or split into a number of weaker shear strands separated by relatively-undeformed sections of country rock. In addition the lodes may curve in strike, or be offset abruptly, where they intersect strong northwesterly-trending faults. At such bends and offsets mineralization is sometimes continuous, although erratically distributed, through the fault-lode intersection. In such cases, it is evident that cross-faulting took place prior to mineralization, and perhaps at a time close to the development of the north-easterly-striking lodes. In general, the lodes dip south-easterly, and the stronger cross-faults dip southwesterly in the mine area. When fault-lode intersections are closely examined, the intersecting structures are often found to be linked by curved shear strands which merge with both structures at small angles. As already stated, these links are frequently mineralized.

Bedding throughout the mine area is generally folded along northwesterly- to northerly-trending axes,
except where it has been locally deformed adjacent to the walls of a lode. North of the old Ruth and Stewart workings (Map No. 1) surface exposures of hard, thinly-bedded argillites dip to the west and north, with bedding "tops" facing east and north respectively, indicating a section of up-side-down bedding. Between the outcrop of the Hope orebody and the surface over the New Ruth section, is a wide belt of calcareous argillites and quartzites dipping to the west, and with "tops" also facing westerly. To the east of this central belt, outcrops over the Silversmith and Slocan Star mines, between White and Sandon Creeks, are mainly of massive, slightly calcareous quartzites, with minor inter-bedded blocky and slaty argillites. Bedding dips are steep to the east and west, with "tops" consistently to the west. To the west of the Hope-New Ruth central belt, and to the south of the Mascot-Hope lode outcrop, is a strong section of massive, variably-calcareous quartzites. The beds dip moderately to steeply east with bedding "tops" to the west. The few short tunnels of the Mascot property lie within a westerly part of this belt. To the north across the Mascot lode, there is a marked change from the massive quartzitic hanging wall beds to thinly-bedded argillaceous rocks. Within the latter, occasional pronounced cross-folds, with northeasterly-trending axes, have developed locally. Farther north, small exposures
of up-side-down bedding show the effects of extreme over-folding. Further examples of this type of bedding deformation are afforded in the vertical section including the outer part of Ruth No. 5 level and the surface area above. Here, calcareous quartzites and thin, slaty argillites are buckled from a westerly-dipping, right-side-up attitude to westerly-dipping up-side-down attitudes within a few feet of vertical distance. Immediately below, in the adit, bedding is intricately folded, about vertical axial planes, into gentle and tight rolls superimposed upon a generally slight dip to the east.

The most significant feature of the larger bedding structures within the mines area is the development of complex folds with essentially horizontal axes. An east-west vertical section through the hill between the long southerly crosscut from Ruth No. 5 drift and the surface area immediately above would bring out this feature. On the surface the majority of beds dip, right-side-up, to the west; at crosscut level the bedding dips, up-side-down, to the east. Correlation of these exposures is most easily accomplished by the assumption of one or more recumbent folds with an approximately horizontal axis, or axes. Minor recumbent folds mapped on the surface and underground lend support to the assumption that similar major structures do exist. One excellent example was mapped
in a cut-bank a short distance west of Sandon on the Silver Ridge mine road. Later in the text, in describing the geology of the Old Ruth mine, the relationship of higher westerly-dipping beds and underlying easterly-dipping beds to a well-defined recumbent fold will be discussed in detail.

The mapping of these complex recumbent folds would be impossible without an adequate number of primary bedding structures of the type required to distinguish between right-side-up and overturned sections of bedding. Of these primary structures truncated cross-bedding provides the most conclusive determinations. Second in usefulness are secondary structures in the form of minor drag-folds within the bedding. These structures, used in conjunction with occasional "top" determinations by the study of cross-bedding, enable the geologist to map wider normal or overturned sections of bedding. The principle on which their application is based is that these structures are overturned in the direction of the axes of major folds. They are best developed where the folded section is composed of inter-bedded firm, hard and soft, plastic rock types, thus allowing a maximum of inter-bed movement and the consequent development of drag-folds in the more plastic layers. In this type of folding beds farther from the center of curvature move towards an anticlinal axis
with respect to those closer to the center. Folding also involves simple flexure of the more competent rock layers, and differential movements, accompanied by the plastic flowage of material within less-competent layers. An ideal assemblage for the development of minor drag-folds is one of interbedded quartzites and soft argillites. The reasoning by which these drag-folds are used to extend "tops" determination over a wider section is as follows: Westerly-dipping sections of Slocan sediments are, with very local exceptions, right-side-up. Consequently, minor drag-folds in these westerly-dipping sections are overturned to the west towards a major recumbent anticlinal fold axis. Thus, if a drag-fold is seen to be overturned to the west, the section of bedding involved is probably part of a major westerly-dipping, right-side-up section of bedding. A similar line of reasoning applies to the interpretation of drag-folds overturned to the east as lying within a section of essentially easterly-dipping, up-side-down bedding. Thus, a large part of the solution of major bedding folds resolves itself into the piecing-together of right-side-up and up-side-down bedding. At this point it may be said that the displacements on bedding faults are generally associated with inter-bed adjustments within the enclosing strata. Similarly, the occurrence of drag-folds, shear cleavage, and "gash-fractures" is useful in determining relative displacements.
The main orebodies of the mines area (Map No.1) lie within three major lodes, each striking generally to the north-east and dipping to the southeast. The strongest lodes are those that contained the Hope orebodies in the westerly part of the area, and the New Ruth, Silversmith, and Slocan Star orebodies in the southern and eastern parts. Recent investigations confirm C.E. Cairnes opinion that the Hope and Silversmith lodes are continuous structures, linked by the strong southwesterly-dipping Ruth and Lone Star faults. A weaker lode strand, the West Silversmith lode, continues along the hanging wall of the West Silversmith porphyry "plug", and probably parallels the Hope lode, which appears to be close to the footwall of the "plug" in the vicinity of the Ruth 501 lateral (Map No.4).

The Old Ruth orebodies are situated within a fracture zone parallel to, but 2500 feet north of the Silversmith lode. With respect to a line representing the northeasterly projection of the Mascot-Hope lode, they would lie approximately 2000 feet north. Occupying a fracture-shear zone situated between the Hope and Old Ruth lodes, is the Stewart orebody. Possibly the Hope-Stewart lodes are linked through a northwesterly-trending fault zone, much as the Stewart and Old Ruth lodes are, as will be pointed out in another section of the text.
A number of northwesterly-trending fault zones split the mine area into rather distinct panels within which lode and bedding structures may be correlated between the steep southwesterly-dipping fault-boundaries of each individual panel. However, the effect of displacements which have occurred on these fault-boundaries should be considered when correlating similar sections of bedding that lie within different panels. Generally, lodes are interrupted, within intervals of a few hundred feet of strike-length, by these zones of cross-faults. As was pointed out in the discussion of inter-bed motion related to flexural-slip folding within recumbent folds, most of these cross-faults which are roughly parallel to the bedding show normal displacements. Consequently, when a southeasterly-dipping lode is interrupted by a southwesterly-dipping cross-fault, the effect is an apparent right-hand displacement of the lode. Also, as these intersections are frequently characterized by curved shear-links, on which displacements, locally, represent a compromise between the typical fault and lode movements, it appears that the development of lodes and cross-faults was rather closely timed. From past experience in mapping these structures, one would not necessarily expect a similar lode structure on both sides of a cross-fault. It is safer to assume that sections of a through-going lode may have a characteristic development that varies within different panels separated by cross-faults.
INTRODUCTION

Detailed underground mapping, particularly of minor structures within the lode and wall rock, involved the use of the "Sander Method" — a technique devised by the Austrian geologist, Dr. Bruno Sander. This method saves much time in recording those structures in the field and, at the same time, emphasizes the fundamental relationship between different structures resulting from the same stress and movement. The method was introduced, probably for the first time in this country, by Dr. E.B. Mayo in mapping the new section of the Ruth Mine. The "Sander Method" employs a system of axes, as illustrated in the following three-dimensional diagram.
"b" - the direction of the fold axes; axes of rotation; any lineation developed by differential movement and which lies normal to the line of movement. An arrowhead and number gives the direction and plunge.

"a" - a direction at right angles to "b" and lying in the movement plane. This axis, representing a direction, is shown as an arrow with a number giving the direction and inclination of the line of movement. "a" is taken as the direction of overturning of minor folds on fault surfaces and in fault zones, and as the attitudes of movement striae (slickensides) on fault surfaces.

"c" - a reference axis perpendicular to "a" and "b"; it does not appear on the maps or figures, but is used solely to refer to features lying in, or of, the three principal planes defined by the coordinates "a", "b", and "c".

Mapping by this method will present a clearer pattern of the movement in related faults and lodes and the adjacent wall rocks, provided that sufficient minor structures are present. In order to group the lineations related to distinctive classes of displacement an additional refinement was added:

a₁ and b₁ - those lineations related to interbed or bedding-fault movements.

a₂ and b₂ - those lineations related to predominantly strike-slip displacements on lodes.

a₃ and b₃ - those lineations related to predominantly normal displacements on lodes.
OLD RUTH-STEWARD SECTION

General

The following description of the workings in this section of the area may be followed on Maps No.1 and No.2. As both the Old Ruth and Stewart workings lie within steeply-dipping lodes, several levels of the mine would appear one over the other on a conventional composite plan. Consequently Map No.2 was designed to show the geology of each level without confusing overlaps of details from other levels. This "spread composite plan" is actually the projection of a true composite plan upon a plane that dips at 45 degrees, with the dip-line bearing at about south 30 degrees east. To obtain the actual plan relationship of all levels they would have to be shifted so that all the green-dashed lines, which are numbered from 1 to 5, would be superimposed. The cross-sections shown on Map No.3 were derived from a true composite plan.

The Old Ruth lode was explored and developed on five levels, with connecting raises, over a vertical distance of about 600 feet. No's. 1, 2, and 3 Levels are, in their easterly parts, drifts which were driven southwestward from the
outcrop. To the southwest, beyond the Stewart fault zone, each level becomes a system of exploratory crosscuts, laterals, and drifts. No's. 4 and 5 Levels start as acute crosscuts, but continue mainly as drifts, with frequent crosscuts, to the Stewart fault zone. In this area crosscuts were driven southward to, and on the downward extension of the Stewart lode. No. 5 was the main haulage level, and drew on both the Old Ruth stopes above, and the New Ruth section to the south. No. 2 Level, which extends farthest to the southwest, reached a position below and in the footwall of the Hope orebodies. On the southwest side of the Stewart fault zone, a long crosscut was driven south on No. 2 Level to intersect the Stewart lode. The subsequent drift on the Stewart lode is the lowest level within the main Stewart ore shoot.

Pattern of Major Structures

The Old Ruth and Stewart lodes (Map No. 2) lie to the northeast and southwest, respectively, of the Stewart fault; the individual parts forming the Ruth and the Stewart "segments". The northwest-southeast separation of these segments, across the southwesterly-dipping Stewart fault, is roughly 100 feet, as measured on No. 2 Level. On approaching the Stewart fault from the northeast, strands of the Ruth lode turn gently and sharply south to join strands of the Stewart fault. South-
ward, strands of the Stewart fault curve westward to join strands of the southeasterly-dipping Stewart lode. Although strands of the lode segments do not appear to continue directly through bounding faults, these major cross-faults do, in part, appear to continue to the northwest and southeast of their intersections with the lodes. As was stated earlier, evidence of the continuity of mineralization from lodes to cross-faults, suggests that the cross-faults are of pre-mineral age, and perhaps lodes and cross-faults were developed contemporaneously.

The southwesterly course of the Stewart lode is interrupted by the southwesterly-dipping Ruth fault. This intersection is marked by a northerly bend of the lode into the footwall of the Ruth fault. This pattern suggests that the lode was "dragged" by a late normal displacement on the fault or by a northerly component of hanging wall movement along the fault. The southwesterly continuation of the Ruth-Stewart lode system beyond the Ruth fault may be represented by the Dorothy vein which outcrops on the westerly slope of Ruth Ridge. As the 4800-foot contour of the Dorothy vein would lie at least 300 feet south of the southwesterly projection of the Stewart lode at this elevation, there is probably another southerly offset within the lode system similar to that at the Stewart
fault, but apparently opposed to that at the Ruth fault.

To the northeast, the Ruth segment is rather sharply bounded by the so-called Silversmith fault. This southwesterly-dipping fault correlates approximately with the Silversmith fault mapped on No.10 level of that mine. Within the Old Ruth it appears on No's. 4 and 5 levels, and projects upward to a position near, but probably east of, No.3 level. Following this general description of the structure pattern, the following pages will deal with specific details of the component structures as shown in plan, longitudinal vertical projection, and cross-section on Maps No. 2, No.2A, No.2B and No.3.

Silversmith Fault

This structure was mapped on No. 4 Level, by A.E. Buller, before the main zone was tightly timbered. At sta.408 two strands, each including several feet of broken- to sheared graphitic wall rock and gouge, dip to the southwest at 60 degrees. Fifty feet to the southwest, smaller hanging wall strands provide fair evidence of the nature of the displacement across the fault zone. Map No.2A shows the structure of the hanging wall strands in cross-section. Minor drag folds, with axes plunging flatly southeast, lie in $b_1$. Rotation about $b_1$ is counter-clockwise; hence the relative hanging wall motion was down to the southwest. In the hanging wall of this
strand closely-spaced fractures, resembling slaty cleavage, parallel the fault plane. With reference to the local axes of movement they would parallel the $a_1 - b_1$ plane. A few feet east of sta. 404 is a tightly timbered section through what appears to have been a strong footwall strand of the fault. Locally, though poorly exposed, the easterly lode segment appears to have been displaced to the south across the fault. This right-hand displacement is in accord with a normal displacement on a southwesterly-dipping normal fault, or like that on the hanging wall strand.

On No.5 Level the most distinctive strand of the Silversmith fault cuts the adit 85 feet east of sta.503. It includes about 18 inches of fine breccia and gouge between sharply-defined walls dipping at 80 degrees to the west. Shear cleavage within the gouge dips southwesterly, indicating a normal displacement. Close by, a parallel fracture has minor "gash" fractures dipping to the southwest, logically developed by a normal displacement on the parent fracture. At 150 feet west of 503 a pair of strong faults, dipping at 40 degrees to the west, contains minor drag folds and shear cleavage so oriented as to suggest that these faults are thrusts. This would imply a displacement opposed to that already deduced. However, it appears that these thrusts are
more closely related to late interbed motion than to a late movement associated with the development of the Silversmith fault. The Silversmith fault, in summary, is actually a wide zone of approximately parallel fault strands, dipping moderately to steeply westward on the upper levels, but steepening below No. 4 Level to a dip of 80 degrees west on No. 5 Level. Below No. 5 a reversal to an easterly dip may actually occur. Mainly from evidence obtained on No. 4 Level, it is considered to be a normal fault.

**Stewart Fault**

This fault zone, bounding the Ruth segment on the west, is composed, generally, of several strong, closely-spaced bedding faults. As the major bedding structure is a recumbent fold convex to the southwest, the Stewart fault reverses from a westerly dip on and above No. 3 Level to an easterly dip through No's. 4 and 5 Levels (Map 2-B). Where the zone is most compact, that is on No's. 2-, 4-, and 5 Levels, it is composed of intensely-sheared graphitic material. As it apparently represents a zone of localized inter-bed adjustments between firm hard beds of the Ruth segment and soft plastic beds of the Stewart segment, it most naturally developed in the latter. Consequently minor movement structures such as drag-folds, shear cleavage, and fault striae are exceptionally well
developed. Locally, several feet of gouge or breccia have been produced where it involves relatively brittle beds, and fracturing occurred in preference to folding.

On No.2 Level, about 10 feet west of sta.212, the fault includes up to four feet of brecciated siliceous argillite. Within the stub crosscut, minor drag-folds on the footwall plunge at 15 degrees south. The counter-clockwise rotation about b1 points to a downward and slightly northward movement of the hanging wall. Southward, 50 feet from sta.212, a fault strand curves from the footwall of the Ruth lode to join the fault zone in the crosscut. Small drag-folds within this strand again have their axes plunging southward at a small angle; rotation about b1 is also counter-clockwise, substantiating the inference of a downward hanging wall movement. In addition, these minor drag-folds have been filled with quartz and sphalerite - thereby providing excellent evidence of the continuity of mineralization from lode to cross-fault, and of the pre-mineral development of the Stewart fault. The Stewart fault zone may be followed southward to its intersection with a footwall strand of the Stewart lode near the end of the crosscut marked R-2. Paralleling drag-folds within this section of the fault, drag-folds within the enclosing bedding are also overturned to the west and southwest about axes plunging.
slightly to the south. A hanging wall strand of the Stewart Fault zone may be seen in the main crosscut to the Stewart No. 5 Level. Here, the pattern of minor fault- and bedding structures is much the same as before. In addition, striae on fault surfaces plunge westward, and being related to counterclockwise rotations on related drag-folds, confirm the downward and slight northerly hanging wall movement on strands of the Stewart fault.

On No.3 Level, west of sta. 317, strong elements of the Stewart fault cut off the Ruth lode to the southwest. In particular a strong shear-fracture, cutting squarely across the drift and curving westward to the south of it, appears to be the footwall member of the fault zone. Farther to the southwest, this shear apparently curves back into the crosscut on a more westerly strand of the zone to continue its sinuous southerly course out of the workings. Along its course it warps from a westerly-to easterly-to westerly dip in paralleling the bedding planes of the intensely-folded bedding in this easterly section of the Stewart segment. Within the stubs west of sta. 318 soft argillites are intensely folded, evidently lying between strong fault strands. In section, the bedding is seen to be completely involved in closely-packed drag-folds. In the more westerly of these, fold axes parallel the strike of
the Stewart fault zone with no apparent plunge. About these axes, lying in \( b_1 \), rotation is counter-clockwise, in accord with the normal displacement on the Stewart fault and the inferred inter-bed motion within the westerly-dipping beds forming this part of the major recumbent fold. Within the greater part of the crosscut southwest of sta. 318, this westerly and downward movement of upper-over-lower beds and the corresponding displacement on strands of the Stewart fault is evident. Locally, however, a conflicting movement pattern is suggested by the contrasting behaviour of minor drag-folds at, and southwest of, sta. 318. Here, drag-folds are overturned to the southeast and lie adjacent to a narrow fault dipping at 45 degrees southeast. Fold axes plunge at 10 degrees southwest, rotation about \( b_1 \) is clockwise; hence the displacement on the fault is essentially normal. This fracture may be considered as a minor lode segment within the Stewart fault. Drag-folds with a similar orientation and symmetry appear in the stub north of sta. 318. Possibly these inter-bed displacements, paralleling that of the lode segment, are related to another lode segment to the north of this stub. Locally, because the southwesterly-plunging drag-fold pattern is superimposed on the more general pattern of southerly-plunging folds, it appears that the final increments of movement occurred on the minor lode segments and, perhaps also the main Ruth segment.
Although the lode-fault intersection appears rather abrupt at the westerly end of the Ruth segment, mineralization has penetrated to a distance well within the fault zone. Also, to maintain the apparent fault-lode continuity, southeasterly-dipping mineralized shear-fractures, which appear to be "links" from the hanging wall of the Ruth lode, enter the long cross-cut from a northeasterly direction. Near sta. 320, a mineralized strand of the Stewart fault produced a fair tonnage of ore. In this area on No.3 Level distinct segments of the Stewart lode do not appear. However, the cross-section (Map No.3) shows it to be to the north of the "lateral" running west of sta. 321. A few feet north of sta. 320, a fault strand with a curve concave to the northwest, and dipping from 65- to 35 degrees northwest, may be a shear-link from the Stewart fault to the Stewart lode. Along it from the southwest the consecutive appearance of drag-folds in the b2 and b1 directions, showing clockwise to counter-clockwise rotation respectively, suggest a blending of the lode- and fault movements along this strand. In other words, along it there is a transition from an easterly motion in the ground south of the lode to an upward motion, around the curve, in the footwall of the Stewart fault zone. On No.3 Level, there appears to be a more harmonious movement from the Stewart lode to fault than there is from the fault to the Ruth segment.
On No. 4 Level, the mineralization and old stopes within the westerly part of the workings are on the lower productive section of the Stewart lode. To the northeast of the old stopes west of sta. 415, there is no trace of the wide, westerly-dipping fault zone seen on the above levels. The only prominent structure, trending across the northeasterly extension of the Stewart lode, is a cross-fault that dips 43 degrees eastward, and which cuts the southwesterly crosscut from the Ruth lode near sta. 412. This fault, and minor fractures to the west, represents the Stewart fault zone on No. 4 Level. Locally, rather gently east-dipping beds with minor steep easterly "rolls", duplicate the symmetry of drag-folds that are overturned eastward and downward. Closer mapping, in bedding such as this, would probably bring out significant minor structures. The corresponding inter-bed motion then, displaces beds to the east relatively down and over adjacent beds to the west - affecting normal inter-bed displacement. Logically then, the Stewart fault which has consistently proved to be a "bedding fault" on higher levels was also developed as a normal fault within this section of easterly-dipping bedding. On this level, and within a corresponding part of the major recumbent fold, several smaller easterly-dipping faults are of the "normal" variety. Similarly, they have developed through inter-bed motion and are closely associated with minor bedding drag folds that are overturned to the east and northeast (Map 2-A).
The structural connection between the Stewart fault and Ruth lode is not clearly apparent on No. 4 Level. However, a mineralized branch that leaves the lode near Sec. B - B follows a curving westerly course towards the fault and probably bends south to join it a short distance west of the cross-cut.

The continuity of hanging wall movements from the Stewart lode - to fault - to Ruth lode is evident from the pattern of minor structures. On parallel strands of the Stewart lode southerly-plunging drag folds, in b2 with clockwise rotation, together with horizontal striae in a2, indicate that the lode hanging wall has moved eastward with almost no downward component. At sta. 413, drag folds within the lode, lying in b2 with clockwise rotation, fan out to the southeast. Lying close to the lode-fault "corner", they strongly suggest a continuous easterly to northerly hanging wall motion from the lode to the fault. The crumpling within footwall beds that arch symmetrically around this corner seems in accord with the local "swing" in ground movement. Evidence of the continuous easterly movement of the hanging wall is provided again by the pattern of minor structures. At 50 feet southwest of sta. 411, drag folds plunging 35 degrees southeast in b2, indicate a local upward and eastward hanging wall movement out of the
fault-lode "corner". Farther west, both drag folds and fault striae, in b2 with clockwise rotation and in a2 plunging eastward, suggest the resumption of the eastward and downward hanging wall movement that is usual within lodes of the mine area.

On No. 5 Level at sta. 573, a narrow zone of fracturing and shearing, striking nearly north-south, cuts off the main Ruth lode to the west. Southward from this intersection, footwall strands of the Stewart fault bend westward to parallel the strike of crumpled bedding lying in the lode trend. Throughout the length of the crosscut to the southwest a wide belt of folded east-west striking shear-fractures and sharply-crumpled bedding forms the Stewart lode panel on No. 5 Level. Maps No's. 2 and 3 provide plan- and cross-sectional views of the widely-stranded pattern of the lode at this level.

The curving pattern of easterly movements of the hanging wall "ground" on No. 4 Level is faithfully duplicated within the Stewart-Ruth transition on No. 5 Level. Within the buckled strands of the Stewart lode, numerous southerly and southeasterly-plunging drag folds, in b2 with clockwise rotation, plus fault striae plunging mildly eastward in a2, provide adequate proof of the easterly- and slightly-downward movement of the hanging wall. Between sta's. 576 and 571 within the "corner" of fault-lode intersections, similar minor structures
show the easterly - to northerly - to easterly course of the "hanging wall" motion into, and out of the Stewart fault. As on No. 4 Level, the resumption of the easterly movement on the Ruth lode is attended by a small thrust component; proof of this being supplied by the southeasterly-plunging drag folds at sta. 572.

In summarizing the above analysis of ground movements through the Stewart-Ruth linking structures, it seems necessary to qualify some impressions of the exact nature of the component movements. First, it seems unlikely that the total hanging wall movement, perhaps amounting to a few hundreds of feet, could be entirely transmitted around the tight "corners" of these fault-lode intersections. However, in the text, the frequent occurrence of linking-shears that cut across these intersections has been called to the attention. These generally appeared during the course of detailed mapping, but where they do not appear on the map, logic almost demands that they be assumed present. Assuming their existence, it is easy to see that they must have transmitted the greater part of the strike-slip displacement from one lode segment to another or, in this case, from the Stewart- to the Ruth segment. The lesser part of the movement, or the part that continuously followed the course outlined by the cross-fault and lode segments, was evidently "in sympathy" with the major movement.
Wall Rock Types and Structures

Throughout the Ruth and Stewart segments, bedding on both sides of the lodes, but not in close proximity to them, strikes with fair regularity between north and north 30 degrees west. However, bedding dips vary greatly in degree and direction between the upper and lower levels. On Ruth No. 2 Level dips are slightly westward, interrupted only by gentle waves or restricted sections with frequent large and small drag folds. Towards No. 3 Level the beds generally steepen and, locally, dip vertically or roll over to steep easterly up-side-down. On No. 4 Level the bedding dips, on the average, rather flatly to the east, but is complicated by strong faults which roughly parallel the bedding. Frequent discordant panels, blocks, and wedges of bedding have been produced where these bedding faults have traversed sections of irregular bedding structure. The bedding structures mapped on No. 5 Level have been so complicated by east- and west-dipping faults that only a general approximation of the un-fractured pattern is possible. However, the few fairly extensive sections that were not seriously disturbed by complex faulting, suggest a section of gently east-dipping up-side-down beds that were rather closely folded and crumpled about steep axial planes. In softer beds intra-bed motion associated with differential inter-bed movements has developed drag folds that are generally overturned to the east.
At several places within the upper and lower levels the rocks contain a sufficient number of minor structures to allow conclusive bedding "top" determinations. Within the lateral in the footwall of the Stewart workings, sandy sections of bedding provide a few truncated cross-beds. In this working, and throughout Ruth No's 2 and 3 Levels, cross-bedding within these westerly-dipping sections shows that these beds are right-side-up. Where drag folds have developed in softer beds of this section, they are overturned to the west, thus substantiating the more conclusive evidence provided by the few occurrences of cross-bedding. Drag folds within the generally east-dipping section of beds below No. 3 Level are invariably overturned to the east and, with the positive evidence provided by a few overturned truncated cross-beds, show this major part of the bedding section to be upside-down.

The correlation of the separate sections of bedding mapped on each level, shows the large bedding structure to be a recumbent fold. The existence of this recumbent anticlinal fold, overturned to the west was deduced by Mr. Paul Billingsley as early as 1946, from the mapping of A.E. Buller and R.S. Moehlman. This structure is convex, or anticlinal to the west, with a generalized axial plane dipping at only a few
degrees in this direction, and lying generally a few feet below No. 3 Level of the Ruth segment (Map No.'s. 2A and 2B and 3). Superposition of the Hanging Wall Projection (2A) over the Footwall Projection (2B) shows a marked similarity of bedding structures on both walls of the lode, particularly in those sections above No. 4 Level. In addition, the trace of the axial plane of the hanging wall structure lies only a few feet below that of the footwall structure. This suggests that the apparent displacement on the Ruth lode, even though accompanied by a large component of strike-slip motion, could not have been greatly over 100 feet.

Broadly described, the wall rocks of the Ruth lode are rather thickly-bedded, hard, locally siliceous argillites with minor thickly-bedded quartzites and thin, soft to cherty argillites. Beds are considered thin if only an inch or two in thickness; thick, if about two feet or over; and medium, between six and eighteen inches. The apparent silicification, or simple thermal alteration of wall rocks, particularly above No. 4 Level within the productive part of the lode, renders the distinction between true quartzites and silicified argillites rather difficult. Generally, typical quartzites have a characteristically granular texture and medium- to dark gray color; silicified argillites, as a rule, appear fine-grained to porcellaneous, are often uniformly pale, or pale-striped
where they contain cherty layers.

To the west of the Ruth segment, and forming the easterly cross-section of beds of the Stewart segment, is a belt of relatively soft, thinly-bedded argillites. Major inter-bed adjustments, accompanying the development of the recumbent bedding fold, produced the concordant fracture zone which is the Stewart fault.

Wall rocks forming the footwall of the Stewart lode, and which are well exposed in the cross-section provided by the footwall lateral on No. 2 Level (Map No.2), are thin- to medium-bedded hard and soft argillites with lesser thick quartzite. Several rather strong bedding faults and zones of intense drag folding are present in sections of softer beds. This footwall section maintains a rather uniform character to the lowest levels of the mine.

Hanging wall rocks of the Stewart segment, particularly below Stewart No. 5 Level, appear to be much softer and less competent than their footwall counterparts. They are generally thinly-bedded dark argillites with only minor quartzitic sections. Locally, these beds are highly contorted and sheared and, within the lower levels, the Stewart lode appears to have flattened largely by branching into parallelism with
the weak hanging wall bedding. Possibly the hanging wall beds above Stewart No. 5 Level, and adjacent to the steeper section of the lode, were comparatively more competent.

Numerous sheets, sills and dykes of quartz-feldspar porphyry are present within the wall rocks adjacent to the lode. It is evident that the majority of these small intrusions occur within the Ruth segment, and are practically absent in rocks adjacent to the Stewart lode. Possibly, the more brittle, competent character of the wall rocks adjacent to the Ruth lode permitted the development of deep, open fissures which would allow relatively easy intrusion of the melts. Numerous strong porphyry sheets, approximately paralleling the bedding of the thick hard argillites, lie within the hanging wall beds exposed in the outer part of No. 4 Level. On Map 2A these sheets are seen to thicken considerably within the axial region of the mine fold, indicating that this section of the structure provided a maximum of open space. This feature, in itself, provides fair evidence for the location of the axial plane of the mine fold. On No. 4 Level, bedding faults parallel the two major sheets. Movement has caused some brecciation, and locally the development of cross-joints in the porphyry, indicating that folding and inter-bed movements continued for some time after the intrusion and solidification of the porphyry melts.
By the method outlined earlier in the text, the symmetry and spatial distribution of bedding drag folds were closely studied with the object of proving or disproving the bedding structure inferred. Drag folds of anomalous symmetry; namely, those overturned up-dip, were rare, and were found to be in accord with local inter-bed movements once the position of these beds within the structure was established. At this point, it should be mentioned that Slocan drag folds provide reliable indications of normal or inverted sections of bedding and, possibly, of the plunge of the major fold axes, but do not provide consistent indications of the attitudes of major axial planes. The heterogeneous composition of Slocan sedimentary formations, and the consequent dissimilarity in the development of bedding drag folds, prevents their use in this connection. Possibly, drag folds in assemblages of thinly-bedded, soft argillites lying between thick, relatively competent quartzitic beds, would be best suited; but a good number of drag folds should be distributed throughout the bedding section in order to provide an accurate average of the varied attitudes of their axial planes.

Lineation symbols for bedding drag fold axes ($b_1$) and the corresponding striae produced by inter-bed motion ($a_1$) are plotted on Map No. 2. The association of the drag fold patterns
characteristic of the major easterly- and westerly-dipping sections of bedding forming the mine fold is best seen on Maps 2A and 2B.

In and above No. 3 Level of the Ruth workings, and in the Stewart workings within this vertical range, drag folds occurring in westerly-dipping beds are universally overturned to the west, showing that higher beds have moved westward and downward with respect to relatively lower beds, or towards the overturned anticlinal axis. This is the movement pattern associated with the right-side-up, westerly-dipping limb of a major recumbent fold developed by flexure-slip folding. Hence all sections of beds containing $b_1$ lineations, with counterclockwise rotation, belong to the major westerly-dipping section of upright bedding above the axial plane of the mine fold. As such drag folds were found within No. 3 Level bedding the axial plane must lie somewhat below this level.

The pattern of bedding drag-folds within a section of hanging wall beds exposed in the easterly part of No. 4 Level is shown on Map 2-A. Without exception folds are overturned eastward and down-dip, with clockwise rotation about axes in $b_1$. In addition, bent ends of bedding contacting bedding faults, drag folded schistosity, and gently-dipping shear cleavage in these bedding faults, all suggest that
structurally-lower beds moved westward toward the major fold axis with respect to higher adjacent beds. This section of beds, then, belongs to the larger, overturned easterly-dipping section forming the under limb of the recumbent mine fold. Drag folds of this symmetry are to be found in the westerly part of No.4 Level and throughout No. 5 Level, showing that these workings lie within the under limb of the mine fold, and that the major axial plane is certainly between No's 3 and 4 Levels of the Ruth workings.

The average plunge of all b1-lineations shown on Map No. 2 would appear to be about 5 degrees southerly. Slick-snsides on bedding faults, or a1-lineations, pitch within 10 degrees north of the respective dip-lines. Hence, it appears that the axis of the recumbent mine fold plunges very gently to the south.

Old Ruth Lode

The productive part of the lode, from a short distance below No. 3 Level to the outcrop, is a steep fissure striking about north 75 degrees east and dipping steeply, almost vertically, to the south. The structure, here, is a regular fracture with rather smooth and distinct walls; having a filling of broken- to crushed wall rocks or, formerly, banded veins of galena and sphalerite. Appreciable amounts of soft
graphitic gouge and schistose material, which are usually associated with shear-lodes, are conspicuously absent within the upper section of the vein. Below the productive section, from the first sub-level above No. 4, the lode flattens rather suddenly to a dip of about 60 degrees south, which it holds through No. 5 Level. The lode becomes a zone of sub-parallel shear-fractures, forming a braided structure in which one strand is most clearly-defined and best mineralized. The lode filling is usually one of schistose, sheared wall rocks, black graphitic- to pale bleached gouge with lesser amounts of cleanly-brecciated wall rocks in quartz-carbonate gangue. Veining and disseminated ore minerals are generally associated with the latter type of lode filling.

From a description in Mem. 184 by C.E. Cairnes, and the writer's own notes, the main strand of the lode pinches and swells from an average width of about 4 feet. Minor strands locally widen the lode. Above No. 3 Level the vein filling was largely clean galena and minor sphalerite with associated quartz-carbonate gangue. From No. 3 Level to a short distance below No. 4 Level, the ore reportedly contained more zinc blende and less clean galena. The lode where it is now exposed on No. 5 Level, contains a small amount of zinc blende in a gangue of brecciated wall rocks cemented by an abundance of gangue minerals. The gangue is principally
yellow carbonates with stringers and lenses of medium-grained white quartz containing much pyrite. The unmineralized sections on No. 5 Level are frequently nothing more than a single "tight" shear or zone of sinuous shear strands, which contrast strongly with the wide, well-defined fissure of the upper levels. The following level-by-level descriptions of the detailed geology of the Old Ruth Lode are based on Maps No. 2, -2A, -2B, and -3, and supplemented by the writer's field notes.

No. 1 Level

Throughout this level the lode has a regular, but locally-sinuous trend and dips vertically. Ore was mined above and below the level from the portal to the Stewart fault. According to Mr. J.C. Black of Sandon, a minor vein within the portal area diverged down-dip from the hanging wall of the lode. Its approximate position is shown on Map No. 2. Little is known about the downward extension of this vein; possibly it exists as a simple hanging wall "split" with little displacement of its walls, or as a link-vein between the main lode and an undiscovered steeper lode strand lying to the south of it. Within the main raise between No's 1 and -2 Levels, gently south-dipping fractures, according to Mr. Black, pass through the vein and effect small normal displacements. These would appear to be genetically related to similar fractures mapped below the second sub-level above No. 4, as shown.
on Sec. B-B of Map No. 3. The consecutive small normal dis-
placements of the vein across this upper zone of fractures
may be responsible for its apparent steep northerly dip above
No. 2 Level.

No. 2 Level

On this level the lode has a broad, gently-sinuous
trend and dips between 60 degrees south and vertical. Smaller,
less steeply-dipping hanging wall strands apparently di-
verge from the lode above the level and, down-dip, tend to
bend into parallelism with the local flat-lying wall rocks.
The main strand of the lode, at this level, intersects gently-
dipping thickly-bedded argillites, siliceous argillites, and
minor quartzites and porphyry. Both walls of the lode are
cleanly-defined, and the adjacent wall rocks show few signs
of deformation which might be related to an early intense
shearing stress which might have produced major displacements
of the lode walls. Near sta. 211, footwall beds dipping gent-
ly to the east are bent to steep southerly dips at the lode
footwall, suggesting that the hanging wall moved down with
respect to the footwall. At other places on the level steeply
southerly-dipping bedding-warps adjacent to both walls of the
lode also suggest a prominent component of normal displacement.
Within the southerly crosscut between 209 and 210, a minor
hanging-wall strand of the lode provides excellent evidence of a normal displacement. Both the hanging wall, and cleavage parallel to it, are involved in a drag fold overturned down-dip to the south about a horizontal axis; this fold constitutes a b3-lineation having clockwise rotation, looking east.

The lode, within this gently wavy, westerly-dipping section of thick beds, could owe its steep dip to a tendency of the initial fractures to cut squarely across hard, brittle beds. The other tendency, that is towards a deflection into the plane of weaker, less coherent sections of bedding is shown by a hanging wall strand dipping at 30 degrees to the south. Where the downward extension was located in a cross-cut 40 feet below No. 2 Level, it had, at least locally, decreased in dip to become essentially a bedding fault. Up-dip, it blankets a steeper lode strand, but both structures have been mineralized. Consequently, both the gently- and steeply-dipping fractures may have been developed under the same set of stresses. Between No's 2 and 3 Levels, in the main raise, up-turned beds and several vertically-dipping gash fractures over the hanging wall of the lode, locally confirm previous evidence of the normal displacement (Sec. B-B). Another illustration of the tendency for lode strands to branch off into the hanging wall is shown by Sec. C-C, in the main raise 40 feet above No. 3 Level. Here, the hanging wall branch is
is formed by a continuation of a southerly-dipping section of the lode below No. 2 Level; the local steepening of the other fracture, however, is probably due to the presence of a section of thick, brittle siliceous argillites forming the wall rocks at this section of the lode.

**No. 3 Level**

Throughout No. 3 Level the trend of the lode is markedly consistent. However, there is a gentle bend between 308 and 314 which shows up on higher levels and in the 2nd sub-level below. Reportedly, the strongest part of the ore-body was located on this gentle nose in the lode. Practically no evidence of the character of the lode matter remains within this level. However, the walls and wall rocks of the lode could be observed in untimbered sections.

Again, minor structures all point to a normal displacement. On the hanging wall and footwall, bedding, for the most part, squarely intersects the walls, thus indicating that strong shearing stresses and large displacements were absent during the formation of the lode. At 310, where a westerly warping of the hanging wall beds might be construed as evidence of a strong easterly movement of the hanging wall, well defined striae plunge directly down-dip. These lie in the a3 direction, and in conjunction with a local up-warping of beds
into parallelism with the lode, point to a relatively downward movement of the hanging wall. Similar footwall striae at 311 support this inference. Within upwarped hanging wall beds at 314, small drag folds plunge westerly at 15 degrees; rotation about b3 is clockwise, looking east, and the hanging wall bedding has evidently moved differentially in accordance with the normal displacement on the lode.

Silicification of the wall rocks is frequent. The porphyry bodies intersected between 308 and 310 have been bleached and softened by hydrothermal solutions. More intense alteration of the bleached porphyry at 316 has produced abundant disseminated pale brown sericite, which, in turn, has been strongly silicified where the porphyry is closely veined by quartz. In the crosscut near 314, thick argillites are similarly sericitized and silicified.

Below No. 3 Level the lode maintains its steep dip through a section of thick hard beds within the axial region of the mine fold. However, at the 1st Sub-Level in the main raise, a part of the lode branches into the hanging wall beds (Sec. B-B), while the other part continues with a steep dip to No. 4 Level. Within this latter branch, drag folds with horizontal axes lie in b3, about which clockwise rotation, looking eastward, has taken place. The folds, along with the
lode filling, have been mineralized by sphalerite, sparse galena, and pyrite. Within the vertical raise shown on C-C, the productive steep section of the lode, is apparently deflected, or cut off, by less steeply-dipping lode strands. These strands were observed within both crosscuts below the 2nd Sub Level and possibly correlate rather closely with the strong branch dipping 60 degrees south in the No. 4 Level crosscut. Comparison of B-B and C-C suggests that the less steeply-dipping lode strands are closely related in attitude and in their effect of restricting mineralization on the Ruth lode at depth. The relationship between certain groups of fractures forming the Ruth lode will be pointed out in the following section.

No. 4 Level

Throughout No. 4 Level the lode remains within the thick hard argillites, quartzites, and thin siliceous argillites dipping eastward below No. 3 Level. However, the lode is a more widely-stranded zone of sinuous shear-fractures, and intervening and bounding wall rocks have been largely warped into the lode trend. The deformation of the wall rock bedding, and the sheared character of the material filling lode strands, suggest higher shearing stresses and greater displacements than in the steep upper section of the lode. Evidence of the eastward and slightly downward movement of the hanging wall is
plentiful. Between the main raise and 411 the footwall strand of the lode has a well-developed shear cleavage which angles easterly across the lode from footwall to hanging wall. The trace of cleavage planes upon the lode walls constitute a b2-lineation plunging with the walls at south 30 degrees west; rotation about b2 is counter-clockwise and is related to an easterly and downward hanging wall movement. Closer to the raise, fine striae on the footwall, and lying in a2, plunge at 34 degrees easterly, thus confirming the inferred hanging wall motion. A few feet east of the main raise strong grooves plunge at 10 degrees to the east, and are also a2-lineations. Corresponding to these, the intersection of strong, closed shear fractures with both walls plunges almost directly down-dip. These lie in b2, and the cleavage planes are oriented to conform again with the easterly and slightly downward movement of the hanging wall. Within the crosscut north of 410, is the apparent continuation of the strong lode strand observed at the foot of the main raise. Comparison of the minor lode structures at both places, suggests that a strong strike-slip displacement has been succeeded by a milder downward movement of the hanging wall. Although normal faulting appears to favour only the steeper fractures of a composite lode, it appears that it may be superimposed upon strands developed primarily by strike-slip shearing, and probably obliterates minor structures related to the earlier motion.
From the portal to the footwall of the "Silversmith" fault zone, individual segments of the lode show evidence of an eastward and very slightly downward hanging wall movement. With this, it appears that the major component of displacement on the Ruth lode was that which involved the apparent easterly and downward hanging wall movement.

No. 5 Level

The geology of this level of the old Ruth mine is taken from maps by E.B. Mayo, J.Lamb, A.E. Buller and R.S. Moehlman. Within the short section of the lode that is exposed, the pattern of minor drag folds and movement striae point to an eastward and slightly downward apparent displacement of the hanging wall. Steep, southerly-plunging crumples, within the thickly-bedded argillites that trend roughly parallel with the lode, also may be related to a strong easterly movement of the hanging wall. The lode on this level has a markedly sinuous trend through the folded wall rocks. The lode filling of soft gouge and wall rock breccia contained only small lenses of ore. In general, the "hanging wall motion" is similar to that deduced on No. 4 Level, without the presence of lode strands which show evidence of normal displacements. Within the soft, crumpled beds of No. 5 Level, the lode zone has probably widened to include thicker sections of less-sheared wall rock between weaker lode strands.
Stewart Lode and Ruth Fault

The detailed geology in all presently-accessible workings is shown on Map No. 2. Fortunately the general pattern of the faults and lode within the productive upper levels was available from an old plan compiled by H.A. Rose. The geology of Stewart No. 5 Level and the Stewart segment of Ruth No. 5 Level was mapped by E.B. Mayo and J.Lamb. That of 4150 Level, and other inaccessible sections, was taken from mapping by A.E. Buller and R.S. Moehlman. The presently-accessible sections were re-studied by the writer.

The Stewart lode, lying between the Stewart and Ruth faults, forms a mildly-crumpled nose with a general southerly plunge. This nose is most pronounced where it contains the main ore shoot between the outcrop and Stewart No. 4 Level. With depth, the dip of the lode sharply decreases from about 65 degrees south, above No. 2 Level, to an average of 45 degrees south through all the workings below No. 2 Level (Map No. 3). Where the lode intersects thinner and more plastic beds in the lower workings, it is a much wider zone of weak lode strands, separated by considerable thicknesses of contorted, but unfractured wall rocks. Between these rather flat and barren shear-fractures occasional steeply-dipping fractures are mineralized and, locally, formed workable ore shoots. Within the steep nose formed by the lode in the upper levels, the
westerly limb was the more intensely mineralized. This ore shoot has been described as an aggregate of small overlapping lenses of clean galena and minor zinc blende contained in sheared beds within which accompanying quartz-carbonate gangue mineralization was relatively sparse. The lode, with its generally graphitic- to gougy filling, apparently was developed mainly by folding and shearing rather than by fracturing and brecciation. The soft, incompetent Stewart wall rocks would lend themselves to the former type of failure rather than to the latter, which is very apparent within the relatively brittle wall rocks of the Old Ruth Lode.

Stewart No. 4 Level

Within this level only a central section of the lode may be studied. The westerly section, which bends northerly to join the Ruth fault, is now inaccessible; towards the east, underground exploration was stopped at least 100 feet short of its intersection with the Stewart fault. The approximate strike of the lode on No. 4 Level is east-west and the dip about 45 degrees to the south. Within the exposed section, mineralization is strongest where the lode arches to the south before assuming a final northwesterly strike to join the Ruth fault. Here, a zone of closely-spaced shear-fractures containing from a few inches to several feet of highly-sheared, folded and crushed graphitic wall rocks forms the lode. Bedding, in both
the footwall and hanging wall, has been deflected from its usual northwesterly trend into close parallelism with the lode. Drag-folded shear cleavage within the lode, and grooves or striae on shear surfaces are sufficiently well developed to provide a movement pattern. At two separate sections minor drag folds plunge southwesterly and are overturned to the southeast; related movement striae plunge southeasterly between 30 and 40 degrees. This is the usual pattern of b2 and a2 lineations so related as to provide conclusive evidence of the eastward and downward hanging wall motion. Within a small lode strand lying in the footwall of the main structure minor drag folds are overturned directly down-dip, so that fold axes lie in b3 with clockwise rotation, looking eastward. This single observation of drag folds related to normal displacement on the Stewart lode indicates that local, late normal displacements followed the strike slip component of displacement which was mainly responsible for the development of the structure.

A clue to the character of the footwall bedding within the upper productive section of the lode is provided by exposures within the footwall crosscut. Here, a small section of westerly-dipping argillites should, in part, suggest the presence of brittle beds within the upper workings. From their similarity to rocks within the Ruth segment, it is likely that the upward steepening and, possibly, greater shattering of the
wall rocks produced more favourable conditions for mineral deposition within the upper section of the lode.

On Stewart No. 3 Level the lode is apparently offset to the left on a northerly-striking fault lying to the west of the raise. Two strands of the displaced lode cuts across the top of the raise. The absence of lode structures within the southerly part of No. 4 Level and the presence of a distinct strand traversing the raise at this level, suggests a similar displacement to the west of the raise. Apparently the cross-fault flattens in dip below No. 3 Level and intersects No. 4 Level at a closely-timbered section within the crosscuts to the south of the westerly part of the lode.

Stewart No. 5 Level

Only small pockets of ore have been mined in raises above the level. On this level the lode follows a sinuous east-west trend that contrasts with its arcuate course in the levels above. As on No. 4 Level, the lode traverses rather soft argillites in which shear strands split and converge with rolling attitudes, to form a pattern of closely-sinuous shears lacing a gougy- to fragmental graphitic filling. Quartz-carbonate gangue mineralization is even sparser than on the level above.
At 70 feet west of the main raise, minor drag folds within beds adjacent to the hanging wall of the lode plunge at 25 degrees to the southwest. Rotation about these axes in \( b_2 \) is clockwise, suggesting downward and eastward relative hanging wall displacement. Within the lode, close to the Ruth fault, \( b_2 \) lineations were developed under the same clockwise rotation stress; nearby striae in \( a_2 \) complete the pattern of lineations produced by an eastward and downward hanging wall movement. Southwesterly-dipping footwall beds turn sharply eastward with southerly dips at the footwall of the lode. The symmetry of this drag pattern is completed by hanging wall beds which bend to a westerly strike and southerly dip at the hanging wall of the lode. The general axes of bedding curvature plunges to the southwest or, like the minor drag fold axes, in \( b_2 \). Similarly, rotation is clockwise. Consequently minor structures provide conclusive evidence of the eastward and downward "hanging wall motion".

At its west end, the lode bends sharply northward to join the Ruth fault. Undoubtedly, the Ruth fault, like the Stewart fault, developed from a localized intense inter-bed adjustment to large scale folding. Consequently it should be, mainly, a normal fault on which the hanging wall has moved down-dip to the west. This motion is confirmed by the pattern of minor slickensides on fault surfaces close to its intersection
with the lode. These, plunging directly down the dip, are clearly lineations in $a_1$, and which have developed under a normal displacement. Close by, however, the axes of drag folds within the schistose filling plunge at 48 degrees to the northwest. With counter-clockwise rotation about their axes these lineations suggest a southerly component of movement on at least some elements of the fault zone. This movement, in turn, was probably influenced by movements on the nearby lode, and suggests that strike-slip components of movement were continuous from south to east around the intersection. As on other fault-lode intersections late easterly hanging wall movements on the lode apparently continued after cross faulting was essentially completed.

Old Ruth No. 3 Level

As was pointed out in the section describing the Stewart fault, no recognizable strand of the Stewart lode could be traced far on No. 3 Level. Also, it appears, from cross-sectional projections on Map No. 3, and the presence of fault strands curving westerly from the Stewart fault several feet north of sta. 320 (Map No. 2), that the lode should lie only a few feet to the north of the lateral driven at south 75 degrees west from sta. 321.
Old Ruth No. 4 Level

Cross-section A-A indicates how the lode zone may widen below Old Ruth No. 3 Level. Accompanying this downward splitting of the lode into wider-spaced shear-fractures, there is a tendency for the through-going strands to flatten within the soft hanging wall argillites of the lower levels. However, concurrent with this spreading-out and flattening of the lode zone, is the tendency for steep open veins to develop between individual strands. It was these fractures, having an apparent "gash" relationship to the main zone, that carried the bulk of the ore below Old Ruth No. 2 Level. Naturally the vertical extent of these ore shoots would be closely limited between flatter lode strands. On Old Ruth No. 4 Level the two main ore shoots (Map No. 2) developed on such steep veins lying towards the footwall of the lode zone.

From what evidence of relative displacements that is supplied by minor structures, it appears that the hanging walls of individual lode strands moved eastward with little, if any, normal component of displacement. Most distant from the Stewart fault zone, footwall grooves at sta. 416 trend almost horizontally eastward. These represent a2 lineations and indicate a pure strike-slip, eastward displacement of the hanging wall of this relatively steep strand of the lode. Eastward, and close to the intersection of the lode with the Stewart fault,
drag-fold axes in b plunge to the south and southeast consecutively, indicating that a part of the general eastward hanging wall movement has curved northeasterly around the "corner" towards the Old Ruth Lode, via the Stewart fault zone.

Throughout the length of the lode on this level there is a marked swing of the hanging wall bedding from its usual northwesterly trends to an east-west trend where it approaches the lode. This counter-clockwise drag pattern offers additional confirmation of the relative eastward movement of the hanging wall ground.

At the west end of No. 4 Level, the workings encountered a broad zone of intensely-fractured and sheared sediments. This fault zone, which is evidently the only intersection of the Ruth fault made below No. 2 Level, forms the westerly limit of the Stewart lode in No's 4 and 5 Levels. The lode-fault intersection is now inaccessible.

Old Ruth 4150 Level

No data pertaining to minor structures, which would supply evidence of lode displacements, are available from geological plans of this level. However, the pattern of counter-clockwise bedding drag close to the lode zone confirms the inference of an easterly movement of the hanging wall ground. As on No. 4 Level, mineralization definitely favours the steeper, restricted strands of the lode. The "hanging wall drift"
emphasizes the spread of the lode zone at this level.

Old Ruth No. 5 Level

Careful detailed mapping on this level has produced much information of wall-rock structures and deformation. As may be seen by the spread, sinuous pattern of the lode strands on Map No. 2, and the cross-sectional spread of the lode shown on Map No. 3, a strong lode movement has been distributed over a much greater width of wall rocks than is usual in the higher productive sections. Consequently, the soft argillites of No. 5 Level exhibit a more intricate and less-easily deciphered pattern of folding than where the lode is a more constricted zone of fracturing and shearing. On No. 5 Level, several strands of the lode show a strong tendency to follow warped, irregular bedding planes, and to be involved in the same close bedding contortions that were developed by the relatively easterly movement of hanging wall ground.

Bedding adjacent to stations 588 and 589 is tightly crumpled with fold axes plunging slightly southward. Rotation about these axes, in bg, is clockwise. In addition, striae on the surfaces of inter-bed "slips", and most evidently in ag, indicate the easterly and slightly downward movement of hanging wall ground. At the end of the crosscut south of 587, the symmetry and attitude of minor drag folds suggests an easterly to northerly hanging wall movement on local, similarly-curved
lode strands. Within weak and strong lode strands observed between 586 and 576, numerous drag folds with axes plunging southerly in b₂, and related a₂-striae on lode- and inter-bed shear planes, all point to a general eastward and downward movement of the hanging wall ground. At sta. 576, drag folds plunging down to the southeast, and presumably lying with axes normal to the direction of differential movement, suggest that a small component of thrust has attended the easterly- to northerly swing of ground movement from the lode to the Stewart fault.

**Summary Old Ruth-Stewart**

The major bedding structure of the mine area is a rather sharply-folded recumbent anticline, convex to the southwest, and with its axial plane dipping slightly in that direction. The axial plane lies a few feet below No. 3 Level within the Old Ruth segment. Localized inter-bed adjustments accompanying folding have produced three major bedding fault zones. Bounding the Old Ruth segment are the "Silversmith" and Stewart faults, while farther to the west the Ruth fault delimits the Stewart segment in this direction. Thickly-bedded argillites, quartzitic argillites, and quartzites comprise the relatively firm, brittle assemblage of wall rocks within the Old Ruth segment. Thinner-bedded argillites below Stewart No. 4 Level, with a restricted section of quartzitic
argillites, probably in the footwall of the lode above this level, comprise the generally incompetent wall rocks of the Stewart segment.

The Stewart- and Old Ruth lodes are linked through a northerly swing of strands from the Stewart lode to the Ruth fault, followed by an easterly bend of elements of the Stewart fault to join the Old Ruth lode. Restricted sections of the fault, close to the lodes, have been veined by ore minerals, showing the pre-ore age of the fault. Also, were the Stewart fault of post-ore age, the normal displacements characterizing its upper westerly-dipping part would have caused right-hand offsets, rather than the present apparent left-hand offset. In addition, it appears that the lodes have developed rather independently on either side of the Stewart fault zone.

The Stewart lode is a broad zone of fracturing and shearing, dipping at about 45 degrees to the south; the Ruth lode is a well-defined steeply-dipping fissure filled with brecciated brittle wall rocks and, formerly, with ore minerals above the second sub-level above No. 4. Below the first sub-level above No. 4, the lode has a somewhat flatter dip and widens to a broad zone of fractures and shears, enclosing deformed softer beds in the lower levels. Important orebodies were restricted to the upper steep sections of the Stewart and Old Ruth lodes.
The attitude and symmetry of drag folds, shear cleavage, and buckled wall rocks shows that there has been a general downward and eastward relative movement along the lodes of the hanging wall ground. At least a small fraction of this movement has been continuous from the Stewart to the Old Ruth lode via the Stewart fault zone. On the Old Ruth lode the main easterly and downward hanging wall motion was apparently transmitted by the flatter fracture-shear zone below, and perhaps cutting off, the steep upper section. The productive-steep upper section may have developed as a major fracture in "gash" relationship to the lower section, as a consequence of general late normal displacements; or it may have formed originally as an oblique-slip fracture zone, followed by a strong late normal displacement which erased minor structures developed by the earlier lode movement.

Steeply-dipping sections of the lode are evidently favourable to ore-deposition. The upper section of the Old Ruth lode apparently owes its permeability to the presence of open fractures or a rather coarse breccia filling. Brecciation was apparently a consequence of the relative downward movement of the hanging wall across the ends of brittle, flat-lying, closely-folded beds over the second sub-level above No. 4. With its longest dimension along the strike of the lode, the orebody is elongate across the line of relative displacement;
or the long axis lies in the $b_3$-direction. Expansion in this
direction was apparently favoured by the greater lateral ex-
tent of the section of brittle, flatly-bedded wall rocks, and
by small variations of dip which would create open spaces of
greatest extent along the strike of the lode.

In addition to the steep dip of the upper part of
the Stewart lode, other favourable ore-forming factors are
present: A brittle section of beds occupies the footwall of
the upper section; the lode forms a pronounced southerly
plunging nose within the upper levels only; the nose is furth-
er complicated by southerly-plunging crenulations developed by
local sinuosities in the strike of the lode. It is probable
that ore channels would be held open during the period of min-
eralization, and that major plunging open spaces, as "ore
traps", would result from the easterly- and downward hanging
wall movement across the nose. Like the Old Ruth lode, the
Stewart lode contains only small ore bodies within its lower,
wider, and flatter sections. Here, mineralization was appar-ently localized to short steep "gash" fractures between the
flatter, more-continuous shear strands of the lode.

Within the Old Ruth-Stewart section of the mine area,
as elsewhere in the Slocan, structural controls of mineraliza-
tion can not be too closely typed. They exist where the most
favourable combinations of rock types, bedding attitudes,
fracturing and brecciation, and relative displacements of the lode walls coordinate to develop major controlling structures.
MASCOT-HOPE SECTION

From a point on Old Ruth No. 2 Level, 200 feet west of the Ruth fault, which cuts off the Stewart lode to the west, a long crosscut was driven 600 feet to the south. This crosscut was stopped in a wide northeasterly-trending shear zone, and which is presumably the Hope lode. The lowest productive level of the Hope mine is about 250 feet above Old Ruth No. 2 Level, or in about the same horizon as the top of the Stewart orebody. In its north-south position, the Hope lode lies between projections of the Old Ruth and Silversmith lodes.

The Hope lode was productive over 4 main levels; the lowest, No. 4, is at an elevation of about 4750 feet; the upper adit is at an elevation of 5260 feet. No. 5 Level was not successful in the search for downward extensions of the orebody. To the east, the lode is cut off, or deflected southward at the northwesterly-trending Lone Star fault. This fault lies only about 100 feet west of the Ruth fault, where is was observed on Old Ruth No. 2 Level and in the New Ruth 501 lateral. To the west, probably following small offsets on cross-faults, the Hope lode seems continuous with the Mascot lode.
The upper productive part of the Hope lode cuts a generally hard, competent assemblage of calcareous argillites and quartzites, and massive quartzites, from east to west across the sedimentary section. The few outcrops that could be found (Map No. 1) show that at least the upper sections of wall rock dip to the southwest. As the Hope workings are now inaccessible, the detailed cross-sectional bedding structure throughout the levels has not been established. Apparently no major porphyry bodies were encountered in the mine workings, but at depth the lode appears to dip towards the footwall of the West Silversmith "plug". Also, a small northeasterly-trending porphyry dike outcrops southeast of the Mascot tunnels, and about 300 feet in the hanging wall of the lode. This may be an offshoot from the West Silversmith drift (Maps No. 1 and 4). C.E. Cairnes, in the G.S.C. Mem. 184, provides an extremely good description of the underground geology of the Hope lode which is quoted in the following paragraph.

"The Hope lode differs in structure and mineralization from the Ruth lode. It is a productive zone, rather than a well-marked fissure. This zone has a general east strike, dips to the south at angles varying from 25 to 40 degrees, and in its productive parts varies in width from less than a foot to about 40 feet. It has been formed by a combination of fracturing and shearing, factors which vary in relative importance
according to the nature of the rocks traversed and the angle at which the zone encounters them. In general the steeper-dipping parts of the lode are the more regular and better defined and are coincident with the intersection of the more competent rock members, particularly where the lode cuts most abruptly across them. Where the lode dips at a low angle and tends to follow the bedding of the sediments, the rocks are much broken, the channels followed by the mineralizing solutions are irregular, and the walls of the lode are ill-defined and require much crosscutting to fully explore them. Much of the old workings have, by reason of the broken nature of the ground, caved and are accessible with difficulty if at all. The principal productive area was in the eastern section of the mine workings and extended from the surface to a little below No. 4 level. It had a maximum length on No. 2 level of about 550 feet and pitched to the east, out of the hill. The lode filling consisted of crushed rock, calcite, siderite, quartz, and ore. A feature of the lode was the large bands or lenses, up to 3-1/2 feet thick, of coarsely crystalline calcite that lay chiefly next to, or near, the hanging-wall and were underlain by ore partly cemented by calcite. The ore shoots were irregular in form, pinching, swelling, and in places abruptly terminating at their greatest thickness against a cross-fissure. They consisted of galena or blende or mixtures of the two. These lenses were strung out in line, or overlapped or were
arranged in echelon. In general they favoured the hanging-wall but also occurred on or near the foot-wall or well within the body of the lode. They varied in thickness from a fraction of an inch to 2-1/2 feet and averaged, probably, about 100 feet in length. Cross fissures were encountered in places and in part proved productive but were small, the largest being a fissure following the bedding on No. 1 level and running into the footwall."

A prominent feature of the northeasterly-striking lode holding the Hope orebody is the temporary swing to the southeast along a northwesterly-trending, west-dipping fault. This "jog" is very close to the apparent "center of gravity" of mineralization. If this local deflection of the lode is compared to that around the New Ruth orebodies (Map No. 4) some striking similarities are apparent. In both cases orebodies are adjacent to the curving intersection of the lode and a transverse fault zone. Also, in both cases, this intersection has produced trough and nose structures, plunging steeply to the southwest. In other words, foci of deformation, which are capable of producing excellent channels for rising ore solutions, have been produced.

Direct evidence of the nature of ground movement along the Hope lode is lacking, but these may be inferred as similar to those on the Old Ruth and New Ruth lodes. Some
evidence, supplied by mullions on the footwall of the structure in the Mascot workings, substantiate the inference that the hanging wall moved down and to the east. Under this displacement the tendency towards the development of southwesterly plunging drag structures should be most pronounced. Possibly it was structures of this pattern, in addition to the other structures noted by Cairnes, that localized mineralization and produced the interrupted, lenticular, discontinuous, or overlapping ore shoots on the Hope lode. It is unfortunate that the habits of individual ore shoots are not described. Some detailed knowledge of these would help to prove or disprove the above assumptions.
NEW RUTH SECTION

Introduction

The westward extension of the rich lode structures from the Silversmith mine forms the main structures of the New Ruth section (Map No. 4). Both the New Ruth "Footwall" and "Hanging Wall" lodes extend westward to the Ruth fault. Beyond the Ruth fault is a single, tightly curved structure. Following sharp bends to the northwest and southwest in going through the Ruth fault, it continues to the Lone Star fault, and is here referred to as the New Ruth West lode, or simply the West lode.

At a time when the orebodies of the Old Ruth section of the mine were nearly depleted, the Ruth-Hope Mining Company turned to the exploration of the westward extension of the Silversmith lode into their ground. At 1150 feet from the portal of Ruth No. 5 level, a crosscut was driven almost due south for a distance of about 2700 feet to intersect the extension of the Silversmith lode. The southerly part of the long crosscut and pattern of subsequent exploratory workings are shown on Map No. 4. The 501 lateral, driven by the Kelowna Exploration Company, under the geological direction of Mr. Paul Billingsley,
is also shown. It was located to test more westerly extensions of the Silversmith lode. It was thought possible that these would lie in the footwall of the West lode, or in the footwall of the West Silversmith porphyry exposed in the westerly hanging wall drift.

In 1946, R.S. Moehlman and A.E. Buller carried out the earliest 40-scale mapping done in these workings by the Kelowna Exploration Company. Later in the year the writer mapped parts of 501 lateral and the old workings along the Lone Star fault and West Silversmith lode. In 1947 Dr. E.B. Mayo mapped much of the 501 lateral to the east of, and within the porphyry, and extended his detailed studies of minor structures along the Lone Star fault and West Silversmith lode. As a result of his studies he confirmed Mr. Billingsley's inferences of the nature of lode displacements, and contributed new data of lode movements, fault displacements, and the mechanics of intrusion of the porphyry. These studies are summarized in his "Structural Study on Ruth 501 Lateral and West Silversmith Lode". The writer has drawn upon all of the above studies, particularly the latter, in writing this section of the thesis. In addition, valuable information concerning the geology of the now-inaccessible workings on the lodes was taken from old plans by H.A. Rose.
Rock Types and Structures

In 501 lateral, to the east of the porphyry, is an assemblage of rather thinly-bedded hard fissile argillites, inter-bedded by thicker argillaceous quartzites. Beds follow the normal northwesterly strike, and dip moderately to the southwest. Where they approach the footwall of the Silversmith lode zone, beds show local easterly deflections of strike; close to the footwall the bedding bends uniformly to an easterly strike and southerly dip, in sub-parallelism with the plane of the lode. This effect of drag by lode displacements is also seen within beds forming the hanging wall of the West Silversmith lode.

Mineralization and Orebodies

The mineralization of all members or extensions of the Silversmith lode is rather similar. The major ore minerals are galena, sphalerite, grey copper, and argentite. Ore minerals found in minor amounts include chalcopyrite, the ruby silvers, native silver, and "oxidation" products such as anglesite, cerargyrite, and smithsonite. The chief gangue minerals are quartz, calcite, and siderite. All, or only a few of the above minerals may occur in a single deposit.

Individual orebodies generally occur either as crude lenses, or as regular tabular bodies of ore and gangue minerals, with a brecciated, and often, roughly-banded structure.
The lens-like forms are frequently situated within folded sections of the lode. They may be strung out in line, overlapping, or en-echelon in arrangement. Where galena and sphalerite are present, masses of the latter are frequently veined by galena. Where the gangue is of the usual quartz-carbonate variety, calcite usually veins quartz, and is, in turn, veined by siderite. Where abundant "yellow and brown carbonates" are present, much disseminated pyrite will usually be found in the gangue. Minor reversals of the normal sequence of mineral deposition may be due to re-solution and consequent re-deposition, or the fracturing of "younger" minerals and mechanical flowage of "older" minerals into the open spaces. Minor cross-fractures within an orebody have differing effects on the continuity of vein structures. Most frequently, the vein or veinlet is only offset by a small amount; occasionally, the character of mineralization and the structure of the vein varies across the cross-fracture. Evidently both pre- and post-mineral minor cross-fractures occur in lodes. At several places evidence of "late" quartz indicates that more than one generation of individual gangue minerals are present.

Silversmith Lode

The Silversmith lode enters the New Ruth area as two distinct members. These are the hanging wall and footwall lodes. Each is a wide zone of shearing and slipping, separated by a
panel of relatively undeformed massive rocks, and which is over 100 feet thick on No. 5 Level. The hanging wall lode lies along the sheared footwall contact of the main Silversmith porphyry plug. The footwall lode lies in sheared argillites and quartzites and well below the footwall of the porphyry. Frequently the hanging wall of this lode lies under thin porphyry sheets which are most likely footwall leaves from the main body. Generally, the lodes that have developed adjacent to a strong body of porphyry are characterized by the development of fracture structures, with the ore minerals filling fissures and gashes or cementing a brecciated filling along with a quartz and carbonate gangue. Those sections of a lode that lie entirely within the sediments are characterized by the development of shear and fold structures, and orebodies are generally lens-shaped with sharp walls of sheared graphitic material. However, later movement and mineralization have caused some brecciation and re-cementation of these bodies.

Ruth Fault

Two main northwesterly-trending fault zones interrupt the lodes along their courses across the mine area. These are the Ruth fault and the Lone Star fault. The Ruth fault which is the stronger, strikes about north 15 degrees west and dips a little over 70 degrees southwest. It appears to be a through-going fault zone, with minor footwall or hanging wall strands
dipping at flatter angles, and which swing sharply to join the lodes at fault-lode intersections. It is filled with strongly-sheared and crumpled graphitic material, individual crumples often indicating the direction of final displacement. A few stringers and lenses of quartz are found in the fault where it crosses 501 lateral.

**Lone Star Fault**

The Lone Star fault, a weaker structure, varies from a broad zone of moderately-sheared graphitic argillite, where it follows the eastern footwall of the West Silversmith porphyry, to a narrow zone of intensely-sheared graphitic argillites and quartzites southward to its intersection with the West lode. It strikes roughly parallel to the Ruth fault but has a more irregular course where it curves to follow bumps and bays on the porphyry footwall. Under the porphyry it dips rather flatly and in sympathy with it. South of the West Silversmith lode, where it becomes a more distinctive structure, the Lone Star fault dips about 60 degrees to the southwest. Just north of the West lode a strong element of the Lone Star fault bends sharply in a tight arc through a southeasterly and, finally, a northeasterly direction to merge with the West lode. Probably only a minor strand of the Lone Star fault continues southeastward past the west end of the West lode. In the other direction, on its northwestward course, the Lone Star fault splits on the southeast corner of the West Silversmith porphyry.
A strand from the hanging wall of the fault curves, through a tight arc, to a southwesterly course, to join the West Silversmith lode on the hanging wall of the West Silversmith plug.

Along the Lone Star fault are frequent "squirts" of gangue material and porphyry (?). The porphyry, often concordantly filling drag structures in the fault zone, is closely fractured and strongly veined and replaced by quartz-carbonate vein matter. Occasionally, a little sphalerite is associated with the carbonates of this vein matter. The course of the Lone Star fault northwestward, beyond 501 lateral, is uncertain. Judging from its usual behaviour the fault could easily swing to a westerly trend to join the Hope lode in the footwall of the plug.

**West Silversmith Lode**

The West Silversmith "lode" is a rather broad, poorly-defined zone of sheared and closely-broken graphitic argillites. From the southeast nose of the porphyry, where footwall elements of it come from the Lone Star fault zone, it has been traced for 400 feet to the west. Along its course it closely follows the southward-dipping hanging wall contact of the West Silversmith porphyry. The general trend and characteristics of the structure have been deduced from data provided by diamond drill hole intersections, and the finer details from direct observations in the old mine workings. The structure contours
on Map No. 4 were sketched in by a correlation of drill hole intersections. The actual trend of the porphyry body beyond the west face of the old No. 5 Level workings has not been established. However, diamond drill holes directed from 501 lateral, and penetrating the hanging wall of the porphyry plug, have provided intersections which were plotted on both plan and section. Thus, it was possible to project the porphyry contact downward to the No. 5 Level and to infer the strike on horizons above the No. 5 Level. Carbonate veins and replacements follow the footwall for a short distance west of the Lone Star fault. Only minor amounts of dark brown sphalerite were found in the lode, closely associated with quartz-carbonate gangue.

**Cross-Fault**

One other structure is significant enough to warrant at least a brief description. This is the acutely-angling fault link between the Ruth and Lone Star faults, herein referred to as the Cross-fault. This structure follows a flatly-arcuate strike of north 45 degrees west where it departs from the hanging wall of the Ruth fault to north 30 degrees west where it approaches footwall elements of the Lone Star fault on No. 5 Level. Its presence was indicated vaguely on old plans but considerable diamond drilling was accomplished from the 501 lateral before the structure was finally established.
In its central sections it seems to consist of several closely-spaced shear strands, that may merge into one zone of crushed graphitic material. Cross-sections show that it generally dips at a flatter angle than either the Ruth or Lone Star faults, hence it forms a "roof" which would rather quickly limit the upward extensions, above No. 5 Level, of possible lode structures in the footwall of the New Ruth West lode and lying to the south of 501 lateral. A few drill-hole intersections, namely on R-1, R-2, R-4 (?), R-15 and R-16, indicate that lenses of both porphyry and quartz or quartz-carbonate with significant amounts of brown sphalerite locally fill the structure. This, and the similar occurrence of ore minerals on the Lone Star fault suggests that mineralization has again extended from the lodes into the northwesterly-trending fault zones.

West Silversmith Porphyry

This irregular body of porphyry, indicated on old plans and intersected in Ruth 501 lateral, is limited by the Hope and West Silversmith lodes in a north-south direction and by the Lone Star fault to the east. Its vertical and westerly extent are unknown. The irregular hanging wall probably dips between 45 and 60 degrees southerly. The easterly footwall, generally conforming to the Lone Star fault, dips between 20 and 30 degrees to the southwest. The shape of the northeasterly footwall and the "forced" curvature of bedding and slip planes on the hanging wall of the Lone Star fault suggests that
the body was, to some degree, forcefully intruded. The rock may be classified as a feldspar porphyry. It has the typical "birds-eye" texture of the main Silversmith stock and is most probably an offshoot from the main stock. Marginal flow layers, formed by the planar arrangement of the feldspar phenocrysts, are approximately concordant with the periphery of the porphyry body. These and other structures will be described and discussed later in the text.

Minor Structures and Movement Patterns

Ruth Fault:

The only exposure of this major fault is at its intersection with the 501 lateral (A of Map No. 4). The zone includes a width of about 60 feet of intensely-sheared graphitic argillites and quartzites. "Movement structures", such as drag folds and shear cleavage, are best developed over the sharply-defined footwall. Drag-fold axes plunge, on the average, at 40 degrees to the southwest; rotation about b1 is counterclockwise, looking north. Consequently, the relative displacement of the hanging wall is in a1, normal to b1, and is downward and slightly to the northwest. Shear cleavage, striking northeasterly and dipping northwesterly at a lesser angle than the dip of the fault, has developed in accord with this direction of movement.
West Silversmith Lode:

In the face, at the west end of the old drift, drag folds and "gash" fractures are well developed within less-sheared "ribs" of the lode. Drag fold axes plunge at a slight angle to the southwest, and are overturned to the southeast (H) for a clockwise rotation about b2. The "gashes", striking southwesterly and dipping northwesterly, lie close to the plane b-c. The attitude of these fractures, being normal to the plane and line of lode displacement, shows them to be more closely related to simple tension in a2 rather than to the type of shearing stress which develops fractures that dip into the direction of movement. By drag-fold symmetry the local hanging-wall motion was eastward and slightly downward.

Twenty feet from the face (J), on the southside of the drift, a small shear joins the lode acutely from the south-east. Drag folds in the sheared gouge have horizontal axes and are overturned to the southwest. Evidently, crowding of the hanging-wall block into the junction of the lode and Lone Star fault, has been relieved by a southwesterly slump of ground over fault-lode shear-links.

Forty-six feet from the west face (K) drag folds in the wall and back are oriented and overturned for the downward hanging-wall movement to the southeast. Fifty-eight feet from the west face (L) grooves on the hanging wall of the porphyry
plunge steeply to the southeast. Close by, drag folds plunge to the southwest, with axes oriented at right angles to the grooves. Hence both $a_2$- and $b_2$-lineations, the latter with clockwise rotation, confirm the relative southeasterly-and-downward hanging-wall movement along the West Silversmith lode.

**Lone Star Fault:**

This zone is continuously exposed for over 300 feet, except for a short section that skirts the southeast nose of the porphyry "plug". A few feet east of the porphyry body (C), the fault crosses 501 lateral as a widely-stranded structure, in which individual "shear strands" enclose wider sections of crushed and broken brittle argillites. Above the steep footwall are flatter strands which dip rather concordantly with the contact of the porphyry. Drag folds overturned to the southwest, with grooves also plunging in this direction, are oriented for a relative downward and slightly northward displacement of the hanging wall. A similar displacement on the Cross fault, exposed within 501 lateral only a few feet to the east, is recorded by minor drag folds and striae.

South of 501 lateral, where the Lone Star fault skirts the porphyry, drag folds recording anomalous lode movements probably originated from slumping of the porphyry plug. These unique variations from the general movement pattern do not appear to be of sufficient importance to warrant a detailed analysis in this thesis.
Drag folds in the fault, close to its intersection with the West Silversmith lode (Q), are irregularly squeezed within the "corner". Small bodies of porphyry (?), injected into the buckled graphitic filling have been strongly replaced by quartz and calcite. These have not been seriously deformed by lode movements. Locally drag folds within the fault have been deflected from their usual flat, northwesterly trend to plunge towards the trough formed by the fault-lode intersection. Also, their symmetry is such as to show a deflection of the downward movement of the fault hanging wall to one more nearly in the direction of that of the lode. At S, drag folds within the fault plunge at 43 degrees westward and are overturned to the south; locally these may be considered as b2-lineations with clockwise rotation. Thus, immediately south of the corner, the easterly component of movement of the lode hanging wall has turned southward to parallel the strike of the fault.

At U, the characteristic normal displacement of the Lone Star fault again becomes evident. Here, minor drag folds, with spotty fillings of calcite, plunge gently at about north 70 degrees west. Related grooves and striae, most probably formed in the line of displacement, plunge at 56 degrees southerly. Consequently, the hanging wall may be inferred to have moved steeply downward and southward.
Over the porphyry (?) lens forming the footwall of the fault a few feet south of R, minor drag folds have developed within the sheared graphitic filling. Axes of these plunge directly down the dip of the fault and parallel to pronounced "rolls" on the footwall. Being overturned to the south, rotation about these $b_2$-lineations is clockwise. Evidently the hanging wall of the fault, on approaching the West lode, shows evidence of strike-slip displacements comparable to those on the lodes. Very likely this motion is representative of the movement on shear-links which converge with the hanging wall of the fault from the northwest. Small bodies of porphyry (?) which conformably fill the expanded sections of minor drag folds could have been injected at approximately the same time as the footwall lens. The material forming these injected bodies has been strongly replaced by yellow calcite, with only a suggestion of the original porphyritic to granitoid texture remaining. Quartz, filling fractures in the altered porphyry, is notably undeformed, so was evidently introduced during the closing stages of ground movement.

At the intersection of the Lone Star fault and West lode the fault filling is closely buckled and drag-folded on steeply-plunging axes. The lineations in $b_2$ shows clockwise rotation. At this point it appears that "hanging wall motion" is southward and eastward around the "corner" of the fault-lode intersection. Probably, although the displacement on the
West lode cannot be determined because of the inaccessibility of the workings, the relative hanging wall displacement on the West lode was downward to the east, like that on the West Silversmith lode.

West Silversmith Porphyry

The rock comprising this body has a light- and dark-speckled appearance. Abundant feldspar, and minor quartz phenocrysts are set in a dense ground mass of purplish-brown fmic minerals. Occasional small rounded inclusions, composed almost wholly of fine-grained fmic minerals, occur throughout the body. These may represent partly-resorbed basic segregations or highly-altered inclusions of wall rock. Frequent sharp-walled dikes of cinammon-brown lamprophyre cut the main intrusive.

Phenocrysts and dark inclusions form rather obscure layers. Within these flow-layers, flow-lines have been produced by alignment of the phenocrysts and inclusions in locally preferred directions. The pattern of flow-layers and flow-lines, from detailed mapping by Dr. E.B. Mayo, is shown by conventional strike-and-dip symbols and arrows, respectively, on Map No. 4. To quote from his interpretation of the structure: "The planar structure conforms roughly with the contacts, so far as these are known. The arrangement of the layers in the western part of 501 lateral suggests a pronounced northward
bulge in the footwall of the porphyry... . The lineation indicates that the porphyry has moved upward at a low angle from the southwest.

The fact that the primary planar structure conforms roughly to the contacts and seems to reflect the shape of the intrusion... is considered conclusive proof that the porphyry is not a block, faulted off a larger mass." The main Silversmith Stock, shown on the east side of Map No. 4 might, without the benefit of information gained by the study of flow structures, be considered as the larger mass from which the West Silversmith "plug" was faulted to the north across the Ruth and Lone Star faults. Space for the West Silversmith plug may have been provided by a general opening of the ground, possibly accompanying actual fracturing as expressed by the adjacent lode and fault, and by some assimilation and thrusting aside of the wall rocks.
Petrographic Features of the West Silversmith Plug

(a) Megascopic:

The body of the porphyry, locally, is cut by small fissures. Bleaching of the porphyry adjacent to them forms the only visible type of alteration. These bleached zones, containing a few grains of pyrite, have sharply-defined margins so that they appear as thin siliceous veins. The brown lamprophyre dikes, where intersected or bordered by fissures, are similarly bleached. The most highly-altered sections of the porphyry are those marginal areas which are bordered by the West Silversmith lode or the Lone Star fault. Simple bleaching is common adjacent to both structures, but carbonate alteration favours the walls of the lode. At the southeast corner of the porphyry "plug", and in the footwall of the lode, the porphyry has been completely replaced by calcite and a little siderite over a depth of several feet. Within this carbonate shell are a few specks of brown sphalerite.

Specimens of altered porphyry were derived from the contact zones of the plug, from internally-altered sections, and from altered lenses within the faults and lodes. Specimens No's 3 and 8 represent inclusions and lamprophyric bodies.
within the porphyry. Descriptions of these slides do not appear here; the latter was examined by Mr. J.W. Young in connection with his study of the age relationships of ore and lamprophyre intrusives.

Of this suite, even apparently "fresh" specimens proved to be strongly altered when viewed by the microscope. Consequently, positive identification of many constituent minerals were impossible. However, a few less-altered areas within the slides permitted a reasonably close estimate of the composition of the original, unaltered rock.

(b) **Microscopic:**

**Specimens 1, 2, and 9:**

These are from specimens of the "fresh" porphyry, taken in 501 lateral and well within the interior of the "plug". The rock has a white-speckled appearance, with well-formed feldspar phenocrysts, up to a 1/2-inch in length, and set in a very fine-grained purplish-brown groundmass of dark minerals. The phenocrysts are, commonly, slightly rounded - perhaps through slight resorption by the cooling magma.

**Essential Minerals** -

(1) Phenocrysts (forming up to 50 percent of the slide) show: relief less than balsam; birefringence about first-order white; 2V - 50 degrees, optically negative; streaky, patchy extinction; twinning mainly Carlsbad, with
occasional polysynthetic twinning. These are evidently crystals of sodic orthoclase.

(2) Groundmass, shows: Mainly fine-grained quartz and feldspar which has a composition that is apparently similar to that of the phenocrysts.

Accessory Minerals:

Brown biotite as small bent plates; apatite as small crystals with roughly hexagonal cross-sections and marked relief; sphene, with very high relief and high birefringence, and occasional acute rhombic cross-sections.

Alteration:

Feathery chlorite has replaced the biotite. The degree of replacement varies. The alteration of patches of original biotite, which are distant from minor fissures transsecting the slides, suggests that chloritization has been effective throughout the body of the rock, and not restricted to fractures, which might appear to be responsible for limiting the extent of alteration while functioning as channels for late solutions.

The feldspar phenocrysts have been strongly altered to fine-grained aggregate of sericite, clinozoisite, and kaolin. Clinozoisite, with parallel extinction and vivid blue anomalous interference colours, frequently grows outward from
the nucleus of smaller feldspar phenocrysts. These phenocrysts show no twinning or zonal extinction.

Calcite forms as irregular patches throughout the groundmass, or fills small, discontinuous fissures that have developed as tension cracks or "checks". These fissures, with calcite fillings, transect all minerals of the slide. Patches of bordering fine-grained minerals have been replaced by calcite. In specimen No. 9 calcite forms about 20 percent of the slide.

Leucoxene, the opaque white alteration product of ilmenite, occurs marginally with respect to grains of this mineral.

Biotite, possibly the second generation, follows minor fissures and develops outward from them by replacing (?) some of the groundmass minerals. It is possible that its apparent development along these fissures is actually an illusion provided by the reverse development of fissures in elongate patches of biotite. In contrast to much of the chloritized biotite present in the slides, the "veining" biotite show little effect of alteration.

**Summary:**

The rock is probably a porphyritic, slightly sodic granite or granodiorite. From its porphyritic texture, it
appears that crystallization of super-eutectic amounts of the constituent feldspar molecule was well advanced before the magma rose to form the present "plug". After emplacement the remaining, relatively cool molten fraction crystallized to form the fine-grained groundmass of quartz, sodic orthoclase, biotite, and minor accessory minerals. The absence of perlitic cracks, the lack of evidence of marked devitrification adjacent to fissures, and the absence of glassy material, indicate that the finely-crystalline groundmass was developed by the quick solidification of the relatively cool melt containing the phenocrysts.

The alteration is of a rather complex nature and, as the true composition of original rock minerals is uncertain, can not be explained easily on the basis of the present constituents. However, strong sericitization and kaolinization of the sodic orthoclase have occurred. The clinozoisite could have developed from the alteration of plagioclase feldspar. Much of the chlorite present represents the deuteric alteration product of biotite. The unaltered veining biotite, seen in thin section No. 9, was probably introduced as an early hydrothermal mineral related to lode mineralization. The "veining" calcite is probably the youngest mineral in the rock and may be related to lode mineralization and possibly to resolution and deposition of older calcite within fissures. The
"patchy" calcite may have originated from limey wall rocks which were assimilated by the magma.

Specimen No. 4

This represents the bleached rock adjacent to a flat normal fault within the porphyry. The width of the bleached zone suggests that a considerable volume of hydrothermal solutions passed along this structure.

Microscope: The feldspar of the slide has been intensely sericitized. Much of the original fine-grained quartz has been coarsely recrystallized and augmented by siliceous solutions. In places quartz has penetrated fractures in the sericitized feldspars, and partly or wholly replaced them. The finely-felted masses of sericite are not confined to areas occupied by the former feldspars, but appear to have resulted from the diffusion of potash-rich solutions throughout the rock.

Specimen No. 5

This is a specimen of the porphyry close to the margin of the plug. It was taken at one foot from its "frozen" contact with the bordering argillites.

Microscope: The rock has a similar mineral composition as specimens from the interior of the "plug". However, coarse calcite and sericite fill the many fissures that cut
all rock-forming minerals. There is no marked increase in the intensity of sericitization and kaolinization of feldspars. Veins of late calcite form the most prominent feature of the rock.

Specimen No. 6

This slide represents the altered shell of porphyry at a point three feet below the footwall of the West Silver-smith lode.

Microscope: Nearly all of the original rock minerals have been sericitized. The original fine-grained quartz has recrystallized to form coarser-grained patches. Apatite, as rather coarse grains, is more abundant here than in central parts of the "plug". A few small calcite veinlets cut all minerals of the slide, but there is much less calcite than could be expected so close to a strongly carbonatized section of the lode. Biotite is absent. Its former presence is suggested by irregular patches of feathery chlorite which contain small shreds of magnetite.

Specimen No. 7

This slide represents a deformed lens of altered porphyry from within the Lone Star fault.

Microscope: The slide consists of a very fine-grained assemblage of quartz and sericite, containing numerous small
grains of feldspar. The feldspar, with its strong zonal ex-
tinction, is probably more calcic than that of the main "plug".

The rock has a marked schistose structure, imparted
by the flattening and elongation of the feldspars and the fol-
iation of feathery flakes of sericite. The feldspar grains
have been warped; they show irregular extinction within curved,
discontinuous twin-lamellae. The fine-grained quartz shows
similar fractures and strain shadows.

The structures and composition of the constituent
minerals indicates that the lens of porphyry was dynamically-
metamorphosed after its solidification within the fault.
Alteration by hydrothermal solutions is expressed by veinlets
of calcite containing small grains of pyrite.

Sequence of Geological Events; New Ruth-Silversmith Areas.

The history of the major bedding structures which
were, most likely, well-developed previous to the formation of
initial lode fractures, is not discussed here.
1. Strike-slip faulting along lode fractures, closely-
timed with normal displacements on the northwesterly-trending
faults. Possibly early hanging wall movements on lodes were
easterly and northeasterly.
2. Continued normal displacements on normal faults; co-
incident with, or closely followed by downward and eastward
displacements of ground above the hanging wall of the lodes.
Minor increments of this lode movement persisted and continued around "corners" of fault-lode intersections.

3. Intrusion of the porphyry (following an early stage of 2.) into major bedding structures and fracture zones. Adjacent wall rocks were baked and hardened.

4. Continued lode and fault movements, which were accompanied by brecciation of baked wall rocks and some mild deformation of porphyry intrusives. Possibly mineralization of the lodes commenced within this period. Mineralization was evidently concentrated at sections of brittle, brecciated wall rocks and crumpled sections of the lode and bordering sediments.

5. Post-ore normal faulting, producing small offsets of mineralized sections of the lodes where they are traversed by northwesterly-trending faults.
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Maps

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Reports and Printed Matter


2-A
Longitudinal Projection
Hanging Wall Geology
Old Ruth Mine
Scale 1 in = 10 ft