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DEPARTMENT OF MINES AND PETROLEUM RESOURCES

BULLETIN No. 57

The Jordan River Area Near REVELSTOKE, BRITISH COLUMBIA

A Preliminary Study of Lead-zinc Deposits in the Shuswap Metamorphic Complex

by

JAMES T. FYLES

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SUMMARY

1. This bulletin describes the structure and lithology of rocks associated with conformable lead-zinc deposits in the Shuswap Metamorphic Complex northwest of Revelstoke.

2. This type of deposit contains large reserves of lead and zinc, but none of the deposits has been mined. The most important properties include the Big Ledge northwest of Nakusp, the Wigwam 20 miles southeast of Revelstoke, the Cottonbelt 30 miles northwest of Revelstoke, the Ruddock Creek property 60 miles north of Revelstoke, and the King Fissure in the Jordan River area.

3. The Jordan River area is about 15 miles northwest of Revelstoke on the southeastern flank of the Frenchman Cap gneiss dome (*see* Fig. 1, p. 11).

4. Rocks within the area include quartzite, mica schist, quartz-feldspar, and calc-silicate gneiss, and minor amounts of marble in the amphibolite facies of regional metamorphism. The lithological succession is given in Table I, page 14. Nepheline-syenite gneiss and syenite gneiss form concordant layers within calc-silicate gneiss. Granitic gneiss intrudes the metasedimentary rocks and undeformed lamprophyre dykes follow a system of northerly trending fractures.

5. Granitic gneiss of uncertain origin forming the core of the Frenchman Cap dome occurs along the northern edge of the area. Schist, quartzite, marble, and paragneiss lie above the granitic gneiss, and these metasedimentary rocks contain the lead-zinc deposits.

6. Rocks of the Jordan River area are complexly folded. Three phases of deformation are recognized. The oldest or Phase 1 folds are isoclinal, recumbent, similar folds with warped axial planes and axes which plunge at various angles dominantly to the southwest, west, and east. Phase 2 folds are overturned with axial planes dipping southwest and south. The style and plunge of the folds varies in relation to the position of the folds on the curving flank of the Frenchman Cap dome. A broad curvature of the foliation around the southeastern corner of the dome is referred to as a Phase 3 fold. The lead-zinc layer and the nepheline-syenite gneiss have been deformed by all three phases of folding.

7. The lead-zinc sulphide layer occurs in a group of rocks known as the lead-zinc sequence which consists of a quartzitic part lying structurally beneath a calcareous part. The calcareous part contains mica schist, calcareous mica schist, calc-silicate gneiss, and at least three distinct layers of marble, each a few feet thick. The sulphide layer is a few tens of feet from the quartzitic part of the sequence. It is very closely confined stratigraphically, and ranges from less than an inch to 25 feet thick and is normally less than 10 feet thick. It consists of fine-grained

pyrrhotite, sphalerite, galena, and pyrite with lenses of quartz and locally barite and marble in a calc-silicate gneiss.

8. The sulphide layer occurs on the King Fissure property where reserves are estimated to be more than 3 million tons having an average grade of approximately 1 ounce per ton silver, 5 per cent lead, and 5 per cent zinc. The layer is also present on the eastern slope of Frisby Ridge, where it is less than 1 foot thick.

9. Molybdenite associated with syenite gneiss and syenite pegmatite is found near the margins of a mass of nepheline-syenite gneiss west of the King Fissure property. This molybdenite is currently being mined.

10. The Ruddock Creek area 60 miles north of Revelstoke is on the northwestern flank of the Frenchman Cap dome. Rocks in the area are mica schist, sillimanite, and calc-silicate schist and gneiss with intercalated layers of marble. These rocks form highly folded discontinuous layers and lenses engulfed in granite-pegmatite.

11. The dominant folds in the Ruddock Creek area plunge 20 to 30 degrees to the west and are of two ages. The later or Phase 2 folds are recumbent, having rounded hinges and a modified concentric style varying from sub-isoclinal in the east to relatively open in the west. One older, or Phase 1 fold, has been mapped with axis almost parallel to the axes of the Phase 2 folds. This fold described as a syncline is shown diagrammatically on Figure 8, page 49.

12. The sulphide member on the Ruddock Creek property consists of calc-silicate gneiss, quartzite, marble, and sulphides, and ranges from 5 to 15 feet thick without structural repetitions. At the main (E) showing it is repeated by folding and is more than twice this thickness. The sulphide layers contain sphalerite, pyrrhotite, galena, pyrite, and minor chalcopyrite with quartz, calcite, and locally barite and fluorite. Much of the sulphide layer is very fine grained with rounded knots of quartz. Other mineralization is medium grained and massive. The deposit is estimated to contain several million tons of material grading approximately 10 per cent combined lead and zinc and less than 1 ounce per ton silver.

13. The conformable lead-zinc deposits in the Shuswap Metamorphic Complex have several parallel and some contrasting features. They are closely confined stratigraphically, but are not in the same lithological succession and probably not in the same time-stratigraphic unit. The mineralogy, textures of the sulphides, and mineral associations are similar at all the deposits. All the deposits have been deformed and metamorphosed. Locally they are replaced by pegmatite.

THE JORDAN RIVER AREA

CHAPTER I

Introduction

Conformable lead-zinc deposits in the Shuswap Metamorphic Complex constitute the largest known potential of these metals in British Columbia. None of the deposits has been mined but several have been actively explored, particularly during the last 10 years. The Shuswap Metamorphic Complex forms an extensive structural belt in southeastern British Columbia lying west of the Kootenay Arc (*see* Fyles, 1967, Fig. 12), which itself contains important lead-zinc mines. The complex consists of a series of gneiss domes having cores of granitic gneiss and flanking envelopes of metasedimentary rocks in a high grade of regional metamorphism. The deposits are folded layers of sulphides conformable with the enclosing metasedimentary rocks. They include the Big Ledge northwest of Nakusp, and the Wigwam 20 miles south-east of Revelstoke, both of which are on the flanks of the Thor-Odin dome (*see* Reesor, 1969). Also included are the King Fissure deposit in the Jordan River area 10 miles northwest of Revelstoke, the It and In claim groups, known as the Ruddock Creek property, 60 miles north of Revelstoke, and the Cottonbelt property, 30 miles northwest of Revelstoke. These are on the flanks of the Frenchman Cap dome (*see* Fig. 1). Several other concordant lead-zinc deposits are known in the area of the same two domes but have not been explored extensively.

The purpose of this study has been to define the structure of individual layers as an aid to detailed exploration and to determine the stratigraphy and structure near the deposits as an aid to regional prospecting. The King Fissure deposit in the Jordan River area was studied first (1964–1966) because of the active exploration there at that time and because the lithologic succession contains good marker beds and few pegmatites. The Ruddock Creek deposit, which is complicated by many pegmatites, was studied in detail in August, 1968. The Wigwam, Big Ledge, and Cottonbelt, though visited briefly, have not been carefully studied and are not included in this report. It is expected that the other deposits will be studied as time permits.

This bulletin is principally concerned with the Jordan River area in which the sulphide layer and enclosing rocks have been mapped over an area of about

50 square miles. The Ruddock Creek study did not extend far beyond the deposit itself and is included in the bulletin (pp. 48–57) for comparative purposes.

The Jordan River area is in the Monashee Mountains west of the Columbia River and a few miles northwest of Revelstoke (*see* Fig. 1). It is in the Revelstoke Mining Division and contains one known major lead-zinc deposit, the King Fissure property, and several showings of lead and zinc as well as copper and molybdenum.

The main stream within the area, the Jordan River, flows eastward from the heart of the Monashee Mountains, curves southward for 15 miles, and joins the Columbia at Revelstoke. It is separated from the Columbia, which also flows south by a flat-topped ridge known as Frisby Ridge. Three main tributaries from the west are Copeland, Hiren, and Kirkup Creeks. Jordan River and tributary creeks have very steep walls rising from the valleys to elevations of about 6,000 feet above sea-level. Alplands above 6,000 feet are generally rounded with summits up to 8,500 feet. Most of the mining exploration has been on Mount Copeland and the ridge to the west between Hiren and Copeland Creeks. Logging roads extend up the Jordan to Hiren Creek and a mining-road continues up Hiren Creek for more than 10 miles to the south camp on the Knox property north of the creek. An old trail follows Copeland Creek, but is overgrown. Access for exploration and for this mapping project has been mainly by helicopter from Revelstoke.

GEOLOGICAL WORK

Prospecting in the Jordan River area has been carried out since the turn of the century (*see* p. 40). Geological work on the King Fissure property was done by J. S. Ives in 1956. The area is within the Big Bend map-area studied by J. O. Wheeler of the Geological Survey of Canada in 1962 and 1963. The present study began in August, 1964, with detailed mapping of the King Fissure deposit and continued in July and August of 1965 and 1966. Mapping the area has taken about six months of field work and has been followed by the necessary office work. Geology was plotted in the field on a special topographic map, scale 1,000 feet to the inch, prepared by the Topographic Division, Department of Lands, Forests, and Water Resources, with the aid of air photographs. Although this study is primarily of the lead-zinc deposits, it has produced results of significance in understanding the regional structure and in the exploration of the molybdenite deposit of King Resources Company.

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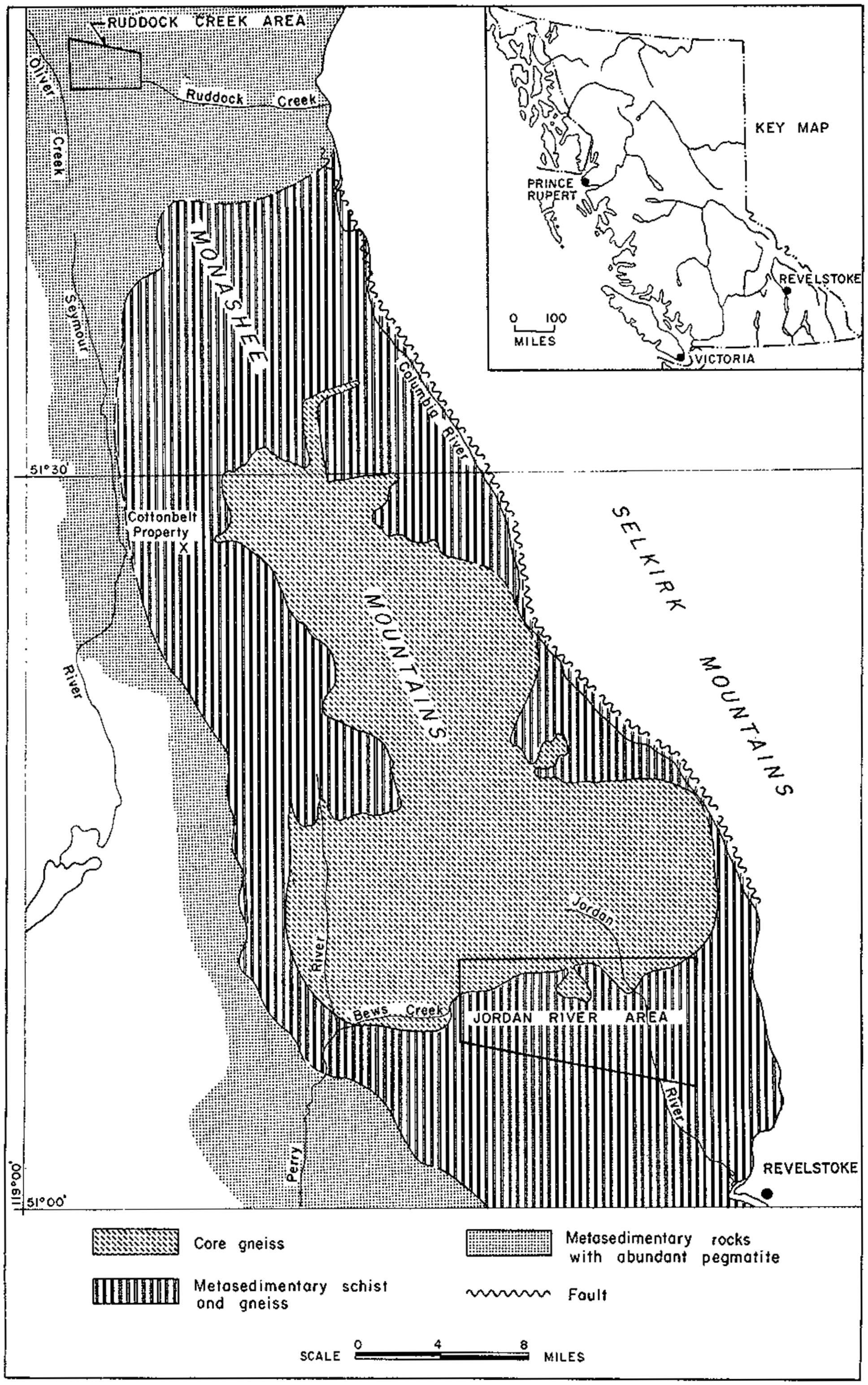

Figure 1. Index map showing the Frenchman Cap dome and the Jordan River and Ruddock Creek areas.

REFERENCES

Craig, D. B. (1966): Structure and Petrology within Shuswap Metamorphic Complex, Revelstoke, British Columbia, Ph.D. thesis, *University of Wisconsin.*

Fyles, James T. (1967): *B.C. Dept. of Mines and Pet. Res.,* Bull. No. 53.

——— (1964): *B.C. Dept. of Mines and Pet. Res.,* Bull. No. 49, pp. 71–76.

Fyles, James T., and Eastwood, G. E. P. (1962): *B.C. Dept. of Mines and Pet. Res.,* Bull. No. 45.

McMillan, W. J. (1970): *Geol. Assn., Canada,* Spec. Paper No. 6, pp. 99–106.

——— (1967): *Geol. Surv., Canada,* Paper 67-1, p. 75.

Muraro, T. W. (1966): Metamorphism of Zinc-lead Deposits in Southeastern British Columbia, *C.I.M.M.,* Spec. Vol. No. 8, pp. 239–247.

Reesor, J. E. (1970): *Geol. Assn., Canada,* Spec. Paper No. 6, pp. 73–86.

——— (1965): *Geol. Surv., Canada,* Bull. 129.

Riley, C. (1961): *C.I.M.M.,* Trans., Vol. LXIV, pp. 268–272.

Ross, John V. (1968): *Can. Jour. Earth Sci.,* Vol. 5, pp. 831–849.

Sinclair, A. J. (1966): Anomalous Leads from the Kootenay Arc, British Columbia, *C.I.M.M.,* Spec. Vol. No. 8, pp. 249–253.

Vokes, F. M. (1963): *Geol. Surv., Canada,* Econ. Geol., Report No. 20.

Wheeler, J. O. (1965): *Geol. Surv., Canada,* Paper 64-32.

CHAPTER II

General Geology

INTRODUCTION

The Shuswap Metamorphic Complex contains rocks that have been raised to a state of high grade regional metamorphism. The age of the rocks and their correlation with formations beyond the complex is speculative, but the most recent work suggests that the metamorphic rocks include Proterozoic, Palæozoic, and possibly also Mesozoic formations. Structural studies mainly by Reesor (*see* Reesor, 1965, 1970) have shown that the complex is composed of a series of gneiss domes with cores of veined augen gneiss and granitic gneiss enveloped by metasedimentary gneiss and schist. The outermost layers of gneiss and schist are riddled with layers and lenses of pegmatite and leucogranite. Three gneiss domes are found between Slocan Lake and the Monashee Mountains west of the Big Bend of the Columbia River. The Jordan River area is on the southeastern flank and 20 to 25 miles south of the centre of the Frenchman Cap dome, which is the most northerly of the three. The area includes the outermost core gneiss and is mainly within the overlying metasedimentary gneiss and schist (*see* Fig. 1).

The metasedimentary rocks include quartzite, mica schist, quartz feldspar, and calc-silicate gneiss and minor amounts of marble. They fall within the amphibolite facies of regional metamorphism and are complexly folded. Lithologic sequences, as they are exposed, are in general not stratigraphic but comprise a series of discontinuous layers. A sequence of lithologics has been pieced together in the Jordan River area by carefully mapping marker beds and by integrating the structures. This sequence is quite well known and two parts separated by a strike fault, called the Bews Creek fault, are recognized. Beneath the Bews Creek fault the formations are right-side-up, but above the fault, which includes most of the area, the stratigraphic top is not known. In the following table the formations are numbered as closely as possible in an ascending structural sequence outward and upward from the core gneisses. No reference is made to thickness in the table, and no estimate of original thickness is possible. All the formations range widely in present thickness.

UNIT 1.—MIXED GNEISS

Rocks referred to as mixed gneiss (Wheeler, 1965, p. 2) occur along the northern edge of the Jordan River area and extend northward and westward beyond the limit of mapping. These rocks include a wide variety of granitic gneisses of

Table I.—Table of Formations

Map Unit	Rock Type	Description
	Lamprophyre	Dykes
B	Porphyritic granite gneiss	Pink to greyish white, medium-grained granitic gneiss with coarse augen of potash feldspar.
	Granitic pegmatite, fine-grained granite, felsite	Sills and lenses.
A	Nepheline syenite gneiss	Grey feldspar-biotite gneiss, local lenses of syenite pegmatite; hornblende-biotite monzonite and calc-silicate gneiss.
	Amphibolite	Lenticular sills.
10	Brown mica schist, grey gneiss	Interlayered biotite schist and fine-grained grey biotite-feldspar gneiss. 10a. Zone of abundant felsite, fine-grained granite gneiss, and pegmatite.
9	White quartzite	Blocky to platy white, brownish, and greyish quartzite.
8	Calc-silicate gneiss and marble	Thinly banded, green and brown biotite-diopside gneiss, biotite schist, calcareous schists and gneisses, calcareous and dolomitic marbles, minor quartzitic lenses.
7	White quartzite	Blocky to platy white, brownish and greyish quartzite with muscovite partings.
6	Greyish and greenish-grey gneiss	Biotite-hornblende-feldspar gneiss with layers of white quartzite (6a) and calc-silicate gneiss (6b).
5	Lead-zinc sequence	Grey marble and calc-silicate schists and gneisses. 5a. Grey and white calcite marble. 5b. Fine-grained biotite schist and lime-silicate gneiss. 5c. Interlayered mica schist and quartzite.
4	Biotite sillimanite schist	Rusty weathering medium-grained coarsely crenulated biotite-sillimanite schist, minor calcareous layers.
	Bews Creek fault zone, stratigraphic relationships unknown.	
3	Mica schist and quartzite	Brown-weathering medium-grained biotite schist with interlayers of white and micaceous quartzite, minor calcareous lenses.
2	Quartzite and conglomerate	Platy to blocky white to brownish white quartzite grading downward into quartz pebble conglomerate.
1	Mixed gneiss	Medium-grained grey biotite-feldspar gneiss.

which the commonest type is medium-grained, medium- to dark-grey biotite-feldspar gneiss. Locally it contains lenticular masses of dark greenish-grey biotite-hornblende gneiss and blocky layers of fine- to medium-grained, light-grey granitic gneiss. The rocks are well foliated and near the overlying quartzite are strongly folded. Many outcrops contain two pronounced lineations. One, consisting of wrinkles and crenulations, is parallel to the axes of prominent minor folds. The other, made up of trains and elongate clusters of minerals, is folded by the minor folds and is an early lineation (*see* p. 25). Specimens studied in thin-section are medium-grained andesine-potash feldspar-quartz-biotite gneiss or garnetiferous andesine-quartz-biotite-hornblende gneiss.

The origin of the mixed gneiss is uncertain. Contact relationships of the finer grained more massive granite gneiss and coarser units within the mixed gneiss suggest that the finer parts are granitic intrusions. The uppermost contact between the mixed gneiss and the overlying conglomerate is concordant and not obviously intrusive, but metamorphism and deformation have obscured the original characteristics (*see* p. 38).

UNIT 2.—WHITE QUARTZITE AND CONGLOMERATE

The mixed gneiss is overlain by, and folded with, a prominent white quartzite containing a quartz-pebble conglomerate at the base. The upper contact of the mixed gneiss and the overlying quartzite is well exposed on the hills north of Copeland Creek, in cliffs on the west side of the Jordan River, and on the ridge east of the Jordan.

Throughout the area, deformed conglomerate lies directly on the mixed gneiss and grades upward into white quartzite. The conglomerate, which is generally less than 10 feet thick, is composed of rounded, greyish-white quartz pebbles in a matrix of finer quartz grains and varying proportions of muscovite and biotite. The pebbles are elongate, with the long axis parallel to the oldest lineation and the short axis perpendicular to the foliation planes. Some pebbles are as much as 10 inches long, 1½ inches wide, and three-quarters of an inch thick, but generally they are more equidimensional and less than 2 inches in diameter. The conglomerate grades upward into rocks composed entirely of greyish-white quartz grains as much as a quarter of an inch across, which in turn grade upward into white quartzites with smaller obscure sedimentary grains. Cross-bedding is present locally in this transition zone, indicating that the sequence, as shown in the table, is right-side-up. The cross-bedding and the discrete rounded pebbles in the conglomerate are convincing evidence that the conglomerate is sedimentary and not of tectonic origin (*see* Wheeler, 1965, p. 5).

The white quartzite above the conglomerate is platy and is locally brownish white with scattered muscovite flakes and a few crystals of black tourmaline on some foliation planes (*see* Plate VI).

The white quartzite and conglomerate, which have been mapped together, at most places are between 50 and 200 feet thick, but near the Jordan River and the head of Bews Creek in hinge zones of folds they are more than 1,000 feet thick.

UNIT 3.—MICA SCHIST AND QUARTZITE

The white quartzite of unit 2 is overlain by, and infolded with, a group of rusty-weathering biotite schists containing interbeds of quartzite and less commonly of calcareous schist. These rocks are exposed best in a belt north of the head of Copeland Creek and form thin lenticular masses to the east. The lower contact of the mica schist and white quartzite is relatively sharp and apparently stratigraphic; the upper contact is the Bews Creek fault, which is transgressive but almost parallel to the foliation.

East of the Jordan River the rocks of unit 3 are fine- to medium-grained biotite-muscovite schist, with a few layers of grey micaceous quartzite. On the ridge west of the Jordan the mica schist contains several layers of white quartzite 5 to 10 feet thick and a few lenses of calcareous mica schist and calc-silicate gneiss. On the ridge and alpine slopes north of the head of Copeland Creek, the unit is composed of biotite-muscovite schist, mica schist with feldspar porphyroblasts, grey micaceous quartzite, and white quartzite in layers up to 20 feet thick. In the white quartzite, partings coated with muscovite are common, and potash feldspar, identified in thin-sections, amounts to as much as 10 per cent.

UNIT 4.—SILLIMANITE SCHIST

The rocks of unit 4 are medium-grained brown-weathering biotite-sillimanite schist. Seen from a distance they form rusty cliffs and in outcrop have a brown and white mottled appearance caused by clusters of sillimanite and feldspar in the biotite schist. These rocks are found on the King Fissure property north of Mount Copeland, on the slopes north of lower Copeland Creek, and on the western slope of Frisby Ridge, where they are particularly well exposed on a ridge northeast of the mouth of Copeland Creek. The mica-sillimanite schists rarely contain thin layers of cream-coloured marble. On Mount Copeland are three or four marble layers a few inches to 1 foot thick. Similar layers were found on Frisby Ridge.

Foliation planes in the schist are poorly defined, but lenses of feldspar and sillimanite outline folds, and flakes of biotite produce a schistosity and a moderately well-developed lineation.

The schists are in contact on one side with quartzites of unit 5, but the other boundary, because of the structure, is not exposed within the area. Unit 4 is similar to parts of unit 3, but the two cannot be correlated on the basis of present mapping.

Specimens studied in thin-section include quartz-biotite-sillimanite schist, quartz-andesine-biotite-muscovite-sillimanite schist, and quartz-potash feldspar-sillimanite schist; apatite and tourmaline are common accessories.

UNIT 5.—LEAD-ZINC SEQUENCE

Unit 5 consists of two parts, a quartzitic part in contact with unit 4, and a calcareous part in contact with unit 6. The calcareous part contains the sulphide layer of the King Fissure property and the detailed lithology of both parts is described on page 41. In addition to exposures on the King Fissure property, unit 5 outcrops between the mouth of Copeland Creek and the crest of Frisby Ridge and is thought to occur also on the ridge north of the lower part of Copeland Creek and to extend northeast across the Jordan.

The quartzitic part of the unit consists of white, greyish, and greenish quartzite interlayered with greyish and brownish micaceous quartzite and mica schist. This is a few hundred feet thick and the layers are as much as 50 feet thick. The layer in the quartzitic part that is adjacent to unit 4 is a platy-grey quartzite, locally containing thin bands of marble. The layer adjacent to the calcareous part of unit 5 is a distinctive, somewhat calcareous, buff, grey to white quartzite a few feet thick.

The calcareous part of unit 5 contains porphyroblastic and calcareous mica schist, thin layers of calc-silicate gneiss, and at least three distinct marble layers, each a few feet thick. The one in contact with unit 6 is a prominent, grey-weathering, white, fetid calcite marble up to 50 feet thick. The other two are thinner, buff to creamy white marbles containing small schist partings or scattered medium-grained flakes of biotite. The sulphide layer is a few tens of feet from the quartzitic part of the sequence and consists of calcareous schist, lime-silicate gneiss, and local lenses of marble mineralized with fine-grained pyrrhotite, sphalerite, and galena. This sulphide layer is described in detail on page 41.

Specimens from unit 5 studied under the microscope are mainly calc-silicate gneiss, biotite-sillimanite schist, and phlogopite marble. All the rocks contain quartz and most contain plagioclase (An_{56}–An_{70}). In addition, the calc-silicate gneisses contain biotite, clinopyroxene, actinolite, and, less commonly, potash feldspar, epidote, or garnet. The sillimanite schists contain, in addition to quartz sillimanite and plagioclase, biotite, muscovite, potash feldspar, and rarely cordierite. Apatite, sphene, and locally zircon and tourmaline are accessory minerals, and chlorite, sericite, and carbonates appear in minor amounts as alterations mainly of biotite and feldspar.

UNIT 6.—GREY-GREEN GNEISS

Rocks of unit 6 are well exposed along the valleys of Copeland Creek and the Jordan River and extend southeastward across the southern part of Frisby Ridge. The rocks are mainly quartz-biotite-hornblende gneiss with lesser amounts of calc-silicate gneiss, fine-grained mica schist, and a few thin, well-defined layers of white quartzite. Although the white quartzites have been mapped at several places and provide useful markers for determining structure, neither the internal structure of unit 6 nor the detailed lithological succession within it is known. The unit is bounded on one side by the clean calcite marble of unit 5 and on the other by white quartzite of unit 7.

Most of unit 6 is fine- to medium-grained, greyish-green gneiss with a moderately well-defined foliation and a delicate lineation produced by hornblende and biotite grains. Lenses of white quartz a few inches to a foot across commonly outline tight folds and are strongly lineated.

The calc-silicate gneisses are light green and brown, fine- to medium-grained rocks with very minor thin lenses of silicate marble. Mottled, fine-grained biotite-pyroxene gneiss is the most common rock type. The calc-silicate gneisses are interlayered with mica schist and biotite-quartz-feldspar gneiss and at many places are adjacent to white quartzite.

The white quartzite layers are generally less than 100 feet thick. The rocks are platy to massive, brownish to white quartzite, indistinguishable from other white quartzites in the area. Some white quartzites mapped as unit 6a may be folded repetitions of unit 7 and adjacent calc-silicate gneiss mapped as unit 6b may, in fact, be part of unit 8.

Specimens of unit 6 contain quartz, biotite, muscovite, plagioclase, and potash feldspar, with or without sillimanite. Some contain quartz, biotite, plagioclase, and hornblende. The plagioclase ranges from An_{30} to An_{60} and the potash feldspar is orthoclase-microperthite. Common calc-silicate gneisses contain quartz, labradorite, potash feldspar, and clinopyroxene with scapolite or epidote, or with biotite and actinolite. Sphene amounts to 15 per cent of some of the calc-silicate gneiss, and tourmaline, apatite, and locally zircon are common accessories.

UNITS 7 AND 9.—WHITE QUARTZITE

White to brownish or greyish-white quartzite has been mapped in two distinct units (7 and 9) which lithologically are indistinguishable from each other. In most of the area they occur in a well-defined succession; the quartzite of unit 7 is separated from the quartzite of unit 9 by a distinctive calc-silicate gneiss (unit 8). South of Hiren Creek along the Jordan Valley the calc-silicate gneiss is very thin and the two quartzites are mapped together (*see* Fig. 2).

The quartzite is mainly vitreous, white to watery-grey quartz in which outlines of sedimentary grains are rarely seen and cannot be distinguished with certainty. Fine-grained muscovite occurs along the foliation planes and scattered grains of potash feldspar are found in thin-sections. The white-quartzite formations are relatively free of other rock types. Interlayers of mica schist or calc-silicate gneiss are found rarely and some of these, when mapped, prove to be very tight infolds of the adjacent parts of unit 8. Lenses of fine-grained gneiss, with minor amounts of potash feldspar, biotite, muscovite, and sillimanite, are found within unit 9 at the western edge of the map-area.

In a few places the quartzite has a blotchy appearance with rounded white knots an inch or so in diameter in a greyish-white matrix. These beds, referred to as pseudoconglomerate, are most common near the margins of the quartzite formations. The knots or augen are poorly defined in contrast with the pebbles of the conglomerate of unit 2. They consist of coarser-grained quartz than the surrounding rock and have a narrow dark-coloured selvage rich in silicates. Biotite, potash feldspar, sillimanite, and muscovite are common within the selvage and are scattered through the augen and the surrounding quartzite.

White quartzite forms spectacular large outcrops and cliffs, the most prominent of which are on the ridge between Hiren Creek and the Jordan River (unit 7) and on the south side of Hiren Creek (unit 9) where the quartzite is more than 1,000 feet thick. The quartzite layers outline large folds, some of which are visible from a distance, and the thickened hinge zones of folds form prominent exposures in contrast with inconspicuous thin layers on the limbs.

UNIT 8.—CALC-SILICATE GNEISS

Unit 8 is the most conspicuous calcareous unit in the area. It contains a variety of calc-silicate gneisses, marbles, and mica schists, and is closely associated with white quartzite and nepheline-syenite gneiss. The calc-silicate gneiss is fine to medium grained, commonly containing more or less calcite or dolomite and a variety of lime silicates including diopside, tremolite, actinolite, and epidote visible in hand specimens and scapolite, idocrase, and labradorite indentifiable in thin-sections. Mottled, fine-grained green (pyroxene) and brown (biotite) gneisses and schists with or without carbonate lenses are common. Layers and lenses of buff to light-grey marble and some of dolomite up to a few tens of feet thick are also common. Dolomite marble forms two conspicuous layers along the slopes north of the upper part of Copeland Creek and near the nepheline-syenite gneiss on King Resources Company property south of Copeland Creek. Thinner and less continuous layers of calcite-marble are found on both sides of Copeland Ridge near the King Fissure property. Although they are mainly fine to medium grained, some calc-silicate gneisses are coarse grained, particularly within a few tens of feet of the nepheline-syenite gneiss.

Fine- to medium-grained biotite schist occurs both at the top and at the base of unit 8, adjacent to the white quartzite of units 7 and 9. The biotite schist, because of the structure, is lenticular and is thick and conspicuous in the hinge zone of large folds such as the antiform (fold F) south of the upper part of Copeland Creek and on the ridge between Copeland and Hiren Creeks near the Jordan River, where it is infolded with unit 7 (*see* Fig. 2, Area 3).

Unit 8, normally a few hundred feet thick, pinches out south of Hiren Creek just west of the Jordan River. Near the Jordan, south of Hiren Creek, white quartzites of units 7 and 9 are mapped together and unit 8 consists of a few feet to a few tens of feet of calc-silicate gneiss within white quartzite.

UNIT 10.—SCHIST AND GNEISS

Unit 10 is mainly brown-weathering biotite schist and grey gneiss. The formation is a heterogeneous assemblage including fine- to medium-grained biotite schist with or without sillimanite, red garnets, or hornblende, together with inter-layers of fine-grained gneissic quartzite and medium-grained biotite-feldspar gneiss. These rocks occur along the southern edge of the map-area and as two infolded lenses north of Hiren Creek.

The mica schist in general is made up of micaceous layers alternating with quartzitic layers up to a few inches thick. These well-laminated rocks contain, at intervals, blocky layers of grey gneiss a few feet thick. Because of the pronounced layering, minor folds are evident in virtually all outcrops of the formation.

Sill-like bodies of granitic rock occur in the upper part of unit 10, forming a swarm of irregular intrusive sheets. These rocks are not confined to unit 10 but they become very abundant several hundred feet above the white quartzite of unit 9. Rocks of unit 10 containing abundant granitic rock are shown on Figure 2 as unit 10a.

GRANITIC INTRUSIONS

Granitic intrusions in the area include

(*a*) a variety of sill-like masses within unit 10, shown as unit 10a on Figure 2;

(*b*) porphyritic granite gneiss, map unit B; and

(*c*) lenticular pegmatite dykes.

Granitic rocks within the metasedimentary schists and gneisses of unit 10 consist of fine-grained gneisses composed of leucogranite, biotite granite, and biotite-hornblende granite or granodiorite. Rarely they are porphyroblastic, with megacrysts of potash feldspar up to one-half inch across. In the lower part of unit 10a the granitic gneisses are sills only a few feet thick. Higher in the unit they form conspicuous, roughly concordant bodies up to a few hundred feet thick. The thinner intrusions and the enclosing rocks are highly contorted. Minor folds normally several feet across involve the intrusions and metasediments and are disharmonic. Larger folds mapped locally do not have consistent fold patterns. In spite of these complexities, the folds have a uniform plunge and the metasedimentary rocks have an abnormally well-developed lineation plunging to the southwest.

Porphyritic granite gneiss of unit B is exposed along the southern and western edges of the area. These rocks stand out as rounded white outcrops along the head of the south fork of Bews Creek and extend south of the south fork of Hiren Creek. They are blocky, massive, greyish-white, medium- to coarse-grained granitic rocks with scattered porphyroblasts of potash feldspar and a poor foliation which becomes more pronounced near the margins of the bodies. The foliation lies parallel to the contacts, which transgress the adjacent formations. The granitic rocks are in contact with white quartzite of unit 9, mica schists and gneisses of units 10 and 10a. Foliation within these wallrocks is turned up abruptly along the margins of the granite gneiss into parallelism with the contact. The contacts are sharp, the grain size of the augen gneiss decreases, and the gneiss becomes more mafic toward the margins. Pegmatites and fine-grained granitic sills of unit 10a have not been found within the porphyritic granite gneiss, although none of these sills is known to be truncated by the granite gneiss. It is concluded, however, that the porphyritic granite gneiss was emplaced after the granitic sills of unit 10a and was subsequently deformed (*see* p. 25).

Lenses of granitic pegmatite, though not abundant, are scattered widely throughout the area. They do not appear to be deformed as are the pegmatites of unit 10a and are regarded as a separate later group. They are a few feet thick and a few tens of feet long and consist of medium- to coarse-grained quartz and potash feldspar, commonly in large intergrown crystals. Biotite, muscovite, and rarely black tourmaline and brown garnet are present in crystals up to 1½ inches across.

UNIT A.—NEPHELINE-SYENITE GNEISS

A thick layer of nepheline-syenite gneiss occurs within the calc-silicate gneiss of unit 8. It forms the summit of Mount Copeland and most of the ridge to the west and occurs in the valley of Hiren Creek and on the slopes between the heads of Copeland and Bews Creeks. Small concordant lenses of nepheline-syenite gneiss are found within unit 6 on the southeast slope of the ridge between Copeland Creek and the Jordan River, as well as on the south side of Copeland Creek and on Frisby Ridge, where they have not been mapped.

In the field the syenite is a grey, medium-grained, locally calcareous, feldspar-biotite gneiss with more or less well-defined foliation planes. It is not readily distinguished from biotite-quartz-feldspar gneiss, which occurs widely in the area. Locally pitted, weathered surfaces, lack of quartz, and effervescence of some specimens with acid are diagnostic features. The foliation on a regional scale has a uniform attitude, but many outcrops show vague swirling structures a few feet across as well as uniform folds (*see* Plate VII). The mafic minerals produce a poor lineation. The marginal parts of the nepheline-syenite gneiss are concordant and at some places simple, whereas at others they consist of groups of digitations. Minor structures within the syenite and larger folds (*see* p. 32) involving the syenite bodies themselves indicate that the syenite has been involved in the earliest deformation, which has produced isoclinal folds. Hence, some of the digitations are folds and others are marginal sills. The grain size of the syenite varies widely, but in general smaller bodies are finer grained than larger ones, and marginal zones are finer than the central parts of the larger masses.

Specimens studied under the microscope are fine to medium grained and are composed of potash feldspar with or without nepheline, biotite, muscovite, pyroxene, or hornblende. The potash feldspar is microcline-microperthite in which the intergrown plagioclase is oligoclase. Nepheline, inconspicuous in hand specimens, amounts to as much as 20 per cent as seen in some thin-sections. Preliminary petrographic studies suggest that the marginal zones of the main sheet of nepheline-syenite and the smaller masses contain little or no nepheline. The pyroxene is aegirine or aegirine-augite. Interstitial calcite and accessory apatite, sphene, zircon, fluorite, and magnetite are common.

Lenses of syenite-pegmatite lying parallel to the foliation and consisting mainly of medium- to coarse-grained potash feldspar are fairly common. These pegmatites have both sharp and gradational contacts with the surrounding syenite, and are most commonly concordant with the foliation, although some are transgressive. They are a few feet thick and a several tens of feet long. Clusters of coarse magnetite and calcite are common within the pegmatite. Massive and disseminated molybdenite, together with disseminated pyrite and pyrrhotite, are found locally.

Syenite-pegmatite and the adjacent calc-silicate gneiss on the north slope of Copeland Ridge are currently being developed for mining of molybdenite (*see* p. 58). Bodies of nepheline-syenite gneiss show as anomalous high areas on aeromagnetic maps (*see* Aeromagnetic Series Map 4404G, published by *B.C. Dept. of Mines and Pet. Res.* and *Geol. Surv., Canada,* 1965).

AMPHIBOLITE

Thin layers of dark green biotite-amphibolite are found at a number of places throughout the area. Commonly they occur in white quartzite in the form of layers parallel to the foliation a few feet thick and several hundred feet long. They are fine- to medium-grained biotite-hornblende-feldspar gneiss in which the mafic minerals make up more than 60 per cent of the rock. Commonly biotite predominates over hornblende, but some are mainly hornblende. Sphene and magnetite are common accessory minerals and the plagioclase feldspar ranges widely in composition. These amphibolites in the white quartzite appear to be early intrusive sills, but rocks of similar composition found in the calc-silicate gneiss may be of sedimentary origin.

Specimens of amphibolite within quartzite studied in thin-section contain hornblende, biotite, plagioclase (An_{20}–An_{50}), and locally quartz. Within the calc-silicate gneiss a common amphibolite contains biotite, epidote, hornblende, oligoclase, and calcite.

LAMPROPHYRE DYKES

Dark grey to brown dykes grouped as lamprophyres are found throughout the area. Commonly they occupy northerly trending fractures and faults (*see* p. 36) and locally they are along the foliation or cut obliquely across it. They range from a few inches to more than 10 feet thick and most are 1 to 5 feet thick. The dykes are blocky, with aphanitic margins, and local trachytic texture. In places layering, parallel to the walls of the dykes, is produced by trains of inclusions or phenocrysts. Some dykes are composite with an early aphanitic dyke and a later fine-grained or porphyritic dyke in the same fracture. Many are porphyritic with phenocrysts of biotite, pyroxene, feldspar, and, less commonly, olivine and hornblende.

Thin-sections show that most of the dykes contain euhedral and subhedral phenocrysts of biotite and clinopyroxene, surrounded by subhedral potash feldspar grains. Euhedral magnetite and apatite are common accessories. A few dykes contain biotite, hornblende, and labradorite, and others have phenocrysts of clinopyroxene and olivine in a matrix of biotite and potash feldspar. The dykes are not highly altered, but in most thin-sections small amounts of carbonate, chlorite, sericite, and serpentine in the olivine-bearing rocks can be identified.

The dykes are not deformed except by faulting which has produced local schistosity. On the basis of work by Wheeler (1965, p. 16), they are regarded as Tertiary.

CHAPTER III

Structural Geology

INTRODUCTION

The Jordan River area covers part of the southeastern corner of the Frenchman Cap dome, a gneiss dome which dominates the regional structure of the Shuswap Metamorphic Complex west of the Columbia River for almost 100 miles northwest of Revelstoke (*see* Fig. 1). In the area studied, complex multiple folds are the principal structures and the broader form of the dome is barely apparent. Small folds are seen in virtually every outcrop and larger folds can be distinguished in many of the cliffs and summits above tree line. Very large folds, outlined in mapping marker formations, display characteristics of the smaller folds. In this study, structures observed at these three scales have been integrated to determine the local geometry of the folds and the broader structural pattern.

An understanding of the structure is important in exploration. Prospecting, and reconnaissance mapping by the Geological Survey of Canada, before the present project was started suggested that most of the lead-zinc mineralization is stratiform. This study of the structure was initiated to establish the geometric form of the folded sulphide layers and to determine the relationship between these layers and the stratigraphy. With this knowledge it should be possible to

(*a*) predict where sulphide layers may outcrop;
(*b*) provide a basis for predicting the shapes of sulphide layers in depth; and
(*c*) indicate where sulphide layers might be abnormally thick along fold hinges or other structurally thickened zones.

Fold structures in the area have been determined by geological mapping, by field measurements of many hundreds of lineations, foliation planes, fold axes, and axial planes, and by plotting stereographic projections and structural profiles. The structural conclusions presented in the following pages have required continual interpretation and the integration of structural and lithological data. The lithological succession contains a number of marker formations, the mapping of which is hampered to some extent by inaccessible bushy slopes and by the lenticularity of most units. In addition, sedimentary structures that might indicate stratigraphic tops have been largely obliterated by metamorphism and deformation. As indicated on page 13, below the Bews Creek fault the rocks are right-side-up, whereas above the fault the stratigraphic top is uncertain. The lithological sequence is known with considerable certainty. A complete understanding of the geometry of the folds must await further stratigraphic data and continued detailed mapping beyond the Jordan River area.

SUMMARY

Three phases of folding are recognized. The oldest or Phase 1 folds are isoclinal and recumbent with warped axial planes and axes which plunge at various angles dominantly to the southwest, west, and east. They have extremely attenuated limbs and thickened hinge zones. Faults, essentially parallel to the foliation, accompanied the Phase 1 folding both as regional structures and as local sheared-out limbs of folds. One of these, called the Bews Creek fault, is shown on Figure 2. Phase 2 folds are overturned with axial planes dipping to the southwest and south.

The folds vary in style and plunge apparently with the position of the folds on the flanks of the Frenchman Cap dome. A broad curvature in the foliation around the southeastern corner of the dome is referred to as a Phase 3 fold, the axis of which plunges to the south and the axial plane dips steeply to the east.

The structural history of the area is envisaged as a continuing process, with several changing pulses of deformation and a single intense phase of metamorphism. The lead-zinc mineralization and the emplacement of the nepheline-syenite gneiss took place before or during the early stages of the Phase 1 folding. Faults parallel to the foliation developed late in this phase and the metamorphism reached and continued at a high grade into the second phase of folding. Masses of porphyritic granite were emplaced before, or in the early stages of the Phase 2 deformation. Phase 2 folds appear to be associated with mobility in the mixed gneiss core of the Frenchman Cap dome. The rocks were more intensely deformed near the core, and as deformation continued the Phase 2 folds near the core were progressively refolded. The Phase 3 fold developed in the waning stages of metamorphism through bending of the relatively brittle formations. Subsequent fracturing on northerly and northeasterly trending directions produced block faults and openings for the emplacement of lamprophyre dykes.

MINOR STRUCTURES

Rocks of the area contain many minor structures, the interpretation of which is important in understanding the larger folds. Most outcrops have a pronounced compositional layering, which is the original bedding modified to various degrees by deformation and is referred to as the foliation. Cleavage and schistosity transecting bedding is found only locally, most commonly in micaceous layers near the hinges of Phase 2 folds.

Most rocks contain a penetrative mineral lineation, consisting of parallel elongate grains of hornblende or sillimanite, trains of biotite, and elongate clusters of garnet or feldspar porphyroblasts. Parallel to these minerals are fine lines or rods formed by many very small folds. This mineral lineation and rodding in general is parallel to the axes of Phase 1 folds. Near the head of Copeland Creek and locally north of Mount Copeland, however, rodding in quartzite is parallel to the axes of tight Phase 2 folds. On the north slope of Mount Copeland and the hills south of Hiren Creek, slickensides, which resemble the mineral lineation, are found particularly in biotite-sillimanite schists. They are subparallel to the Phase 1 mineral lineation and appear to have formed by slippage between the layers during Phase 2 or later deformation.

Small wrinkles parallel to the axes of Phase 2 folds are seen in many outcrops. The hinge zones of most Phase 2 folds are rounded and the wrinkle lineation varies in perfection and degree of alignment. Both Phase 1 and Phase 2 minor structures are present in most outcrops (*see* Plate V).

Phase 2 Folds

Phase 2 folds dominate the structure of the area, Phase 1 folds are isoclinal and obscure, and Phase 3 folds are very broad and simple. Phase 2 folds are described first because they are the most important structures controlling the distribution of the map units, and because they can be described without reference to Phase 1 folds.

Figures 2 and 4 show the axial traces of the major Phase 2 folds, the dip of the axial planes, and the plunges of the axes. The axial traces, or intersections of the axial planes of the folds with the ground surface, have been defined by drawing the line joining the hinges of the folds. Because of the dip of the axial planes, the trace curves with topography. The indicated plunges of the fold axes are averages obtained from stereographic plots of a large number of observations. The folds are designated by letter, except one important fold called the Copeland synform. The terms synform and antiform are used in place of syncline and anticline because the stratigraphic tops are not known or may be reversed by Phase 1 folds. Phase 2 folds are also shown in the diagrammatic cross-sections of Figure 3. These have been drawn in a vertical plane as nearly as possible perpendicular to the strike of the fold axes, making use of all the data derived from the study of the minor folds. The sections are therefore slightly distorted. Most of the lenticularity of the formations is caused by the Phase 1 folds. Plates IV, VI, VII, IX, and X show the form of one large and several small Phase 2 folds. The major Phase 2 folds are described in the following paragraphs and the general characteristics are summarized on page 30.

Fold A, along the southern margin of the map-area, is an antiform which straddles the head of Hiren Creek, forms the ridge between Hiren and South Hiren Creeks, and continues eastward to the western slopes of Frisby Ridge, beyond which it dies out. The fold is outlined mainly by quartzite (units 7 and 9), calc-silicate gneiss (unit 8), and mica schist (unit 10). The fold culminates 2 to

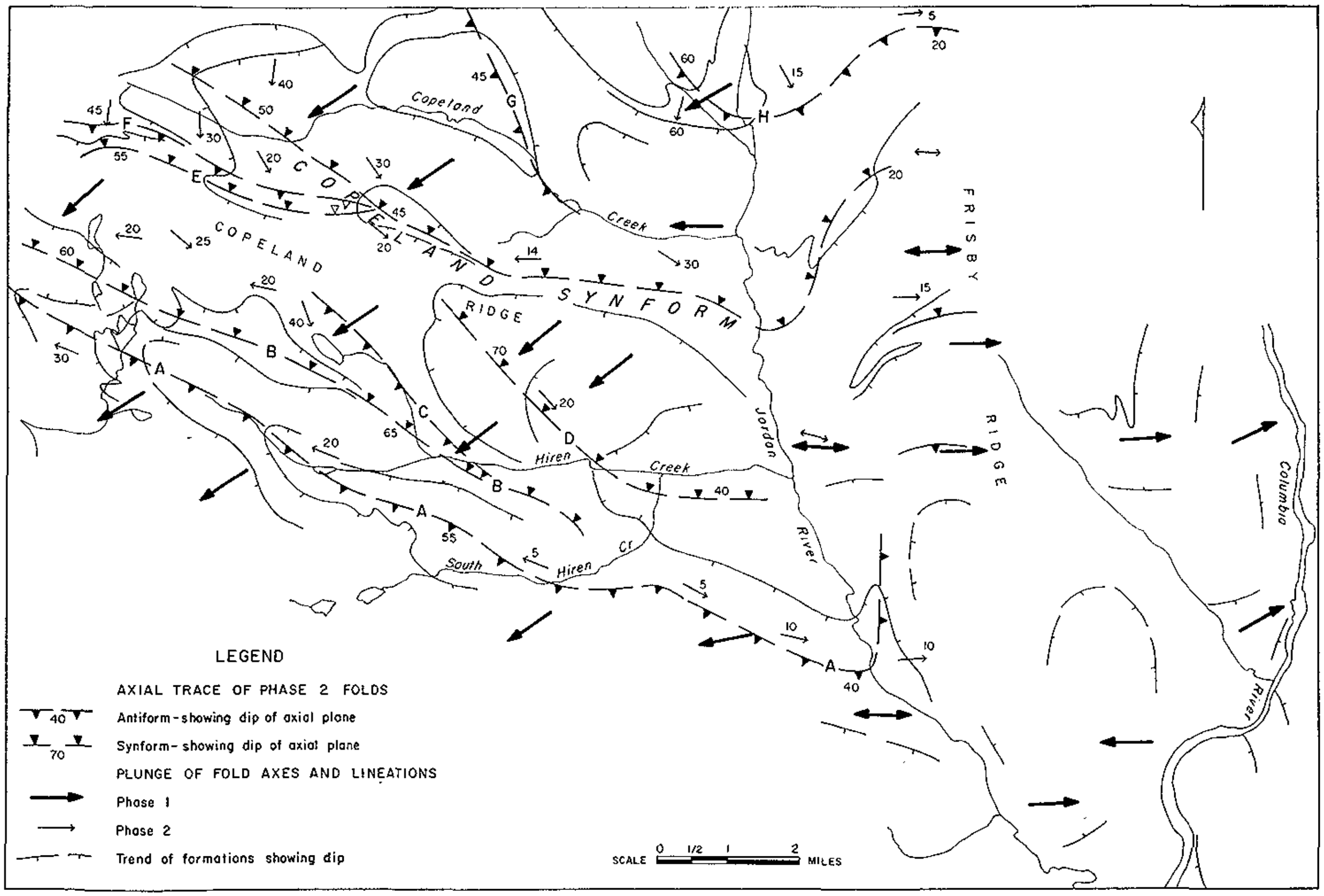

Figure 4. Generalized structural map of the Jordan River area and eastern slope of Frisby Ridge.

2½ miles west of the Jordan River, west of which the axis plunges 20 to 30 degrees to the west, and east of which the axis plunges at a low angle to the east. The axial plane dips to the south at 30 degrees near the Jordan River, curving toward the northwest in strike and steepening in dip west of the Jordan. The fold is overturned and the layers, which dip to the south, do not appear to be thickened in the hinge zone. On the lower slopes east of the Jordan River, white quartzite is slightly thickened in the hinge zone, but up the slope the fold broadens and east of the Frisby Ridge fault it has not been found.

Fold B, an overturned synform lying north of fold A, extends from near the mouth of South Hiren Creek northwestward across Hiren Creek to beyond the map-area. The plunge of the fold is to the west at about 20 degrees and it decreases gradually eastward. The map pattern of quartzite of unit 9 indicates that the fold becomes progressively tighter toward the east and probably decreases in amplitude so that near the mouth of South Hiren Creek it is a small parasitic fold on the northern limb of fold A (*see* Fig. 3, section G-G′).

Fold C is a broad antiform outlined by the nepheline-syenite gneiss and overlying calc-silicate gneiss, on the north side of Hiren Creek. It has a low plunge to the southeast. To the northwest it appears to broaden and die out, whereas to the southeast it becomes a small, tight fold on the south limb of synform D.

Fold D is a synform well exposed between Mount Copeland and the mouth of Hiren Creek, where it shows up prominently from the air. Toward the west it ends above the nepheline-syenite gneiss and to the east it has not been recognized with certainty, although it may continue as a broad synform east of the Frisby Ridge fault. West of the Jordan the fold plunges 25 to 30 degrees to the southeast and the axial plane dips 65 to 70 degrees southwest. Near the Jordan the axial plane strikes easterly and has a lower dip to the south. On Frisby Ridge the synform has a low plunge to the east and a gently south-dipping axial plane. This curvature of the axial plane as it crosses the Jordan is mainly caused by a broad Phase 3 fold (*see* p. 31).

The Copeland synform is well defined on the King Fissure property on the northern slopes of Mount Copeland, and the part of the fold exposed on the property is described in detail on page 46. The fold has been traced westward across Copeland Creek and is found to the east on the western slope of Frisby Ridge. On the King Fissure property and on Frisby Ridge, the fold is outlined by the rocks of units 4 and 5, particularly by the calcite-marble (*see* Plate X). To the west the form of the fold is displayed by quartzites in unit 6 and the contact between units 6 and 8 (*see* Fig. 2). The plunge of the fold axis changes progressively from 40 degrees toward 180 degrees near the head of Copeland Creek to 30 degrees toward 150* degrees on the King Fissure property. In this distance the axial plane

* In this bulletin, attitudes are designated in degrees as an azimuth from 0 to 360. The plunges of elongate elements are down in the direction indicated and the directions of dip of planes are given in words such as south, southeast, etc.

curves from a dip to the southwest of 55 degrees to a dip to the south of 45 degrees. Farther east the plunge decreases through the horizontal to a low westerly plunge east of the King Fissure property. On the property, the Copeland synform is joined on the south by fold E, a synform, and fold F, an antiform, each of which continues westward as a discrete fold. They die out to the east, and east of the point where they die out, the Copeland synform becomes very tight and plunges at a low angle to the west. To the east as far as the Jordan, the Copeland synform is poorly defined in rocks of unit 6. Beyond the Jordan it has the form of a tight, recumbent synform with a low plunge to the east (*see* Fig. 3, section H-H').

Folds E and F form a synform and antiform which arise on the southern limb of the Copeland synform north of Mount Copeland, and continue westward beyond the map-area. On the King Fissure property they are described together by Riley (1961) as the "crossfold." Fold F is a small, broad, concentric warp where exposed on the west end of the property due north of Mount Copeland. Drilling to the east indicates that it dies out eastward (*see* Fig. 7), and exposures to the west show an increase in amplitude and a change in form. At one place, about 4,000 feet northwest of Mount Copeland, near the hinge of the fold, a sharp isoclinal antiform pierces through the more broadly folded layers (*see* Fig. 3, section D-D'). A mile or so farther west, unit 7 is abnormally thick in the hinge zone of the antiform and the average plunge is 20 degrees to the southeast. Still farther west the plunge is 30 degrees to the south, and the fold, as outlined by the quartzite of unit 9, has a similar style with a highly thickened hinge zone and thinned-out limbs. The axial plane throughout the length of the fold has an average strike of 115 and a dip of 50 degrees to the south. The axial planes of the minor folds, however, change attitude from 110 dipping 45 degrees south near Mount Copeland to 135 dipping 55 degrees southwest near the western edge of the area. Minor folds are scarce near Mount Copeland but abundant farther west. Commonly more than two sets are present, both of which are regarded as Phase 2 folds. Where both sets are present, folds that plunge toward the south are folded by folds plunging toward the southeast.

The synform E, north of Mount Copeland, is a large, concentric fold lying south of the antiform F (*see* Plate X). Like the antiform, the synform changes in style and plunge toward the west. The plunge changes progressively in amount and direction from 20 degrees toward 125 degrees north of Mount Copeland to 45 degrees toward 190 degrees near the western margin of the area. The axial plane has an average attitude of 105 dipping 45 degrees south.

Fold G is a broad antiform exposed on the north side of Copeland Creek and on the ridge between Copeland Creek and Jordan River. It is defined by the top of the mixed gneiss and the overlying quartzite. The axis plunges 15 to 20 degrees toward 160 degrees and the axial plane dips 45 degrees to the southwest. The antiform has not been recognized with certainty south of lower Copeland Creek but probably it continues eastward into cliffs on the east side of Jordan River, where it becomes a tight, recumbent structure with axis plunging at low angles to the east and axial plane dipping to the south.

Fold H, like fold G, is a broad antiform defined by the top of the mixed gneiss and the overlying quartzite. It straddles the upper Jordan River, plunging south at about 60 degrees. The axial plane strikes 150 and dips 60 degrees to the southwest near the Jordan but curves rapidly toward the east to strike 85 and dip 20 degrees to the south on Frisby Ridge. This curvature of the axial plane is in part caused by Phase 3 folding.

Considered together, the Phase 2 structures comprise a group of overturned folds, with axial planes dipping at low to moderate angles to the south and southwest. The attitudes of the axial planes are fairly constant west of the Jordan, but along the Jordan they form a broad arch coincident with the southeastern corner of the Frenchman Cap dome. This arch is regarded as a Phase 3 fold. The plunge, shape, and style of the Phase 2 folds vary from place to place. Folds E and F change from concentric folds near Mount Copeland to similar folds south of the head of Copeland Creek, 3 miles to the west, and in this distance the axes change plunge from southeast to south. Most of the Phase 2 folds are of concentric style, but many small folds, particularly those near the core gneiss, have thickened hinge zones. Phase 2 folds die out along the axial plane. The synform D and antiform C, for example, broaden and end above the nepheline-syenite gneiss on Mount Copeland and on the slopes to the southwest. Also, folds D and E join the Copeland synform on the King Fissure property, and do not continue to the east. The eyed pattern of outcrop on the property is a canoe-shaped fold made up of three folds on the west and one tight fold on the east. In this area folds E and F, and some of the minor folds, are sharply conical.

Folds A, B, C, and D, which are mainly on the south side of Copeland Ridge, contrast with folds E, F, G, and the Copeland synform, which are mainly north of Copeland Ridge. The folds north of the ridge are tighter, more variable in plunge, more conical, and more variable in style than those to the south. The folds to the south appear to be somewhat later than and to be superimposed on those to the north. On Copeland Ridge, and in the long crosscut of the Mount Copeland Mine, at an elevation of 6,150 feet (*see* Fig. 2 and section D-D′ on Fig. 3), many tight, large, and small folds are exposed within nepheline-syenite gneiss and the adjacent rocks. They have low plunges both to the east and to the west, axial planes which dip to the south at moderate angles, and an asymmetry indicating that the upper layers moved northward over the lower layers. These folds continue northward and are superimposed on the south limbs of synform E and the Copeland synform on the King Fissure property.

North of Copeland Ridge, minor folds associated with antiform F and synform E change in style and attitude with the changes of the major folds. Minor folds are scarce near Mount Copeland, but abundant farther west. Commonly two sets are present in one area, both of which are regarded as Phase 2 folds. Where both sets are present, folds which plunge southward are folded by folds plunging southeastward, and folds plunging southeastward are folded by those plunging more nearly east. These exposures are interpreted to mean that Phase 2 folds northwest of Mount Copeland developed sequentially in space and time. South-plunging folds, which are dominant in the west, formed slightly before southeast-plunging folds, which are dominant farther east.

Phase 3 Folds

Only one large and several small Phase 3 folds are found in the Jordan River area. The large Phase 3 fold is an antiform which approximately straddles the valley of the Jordan River. This fold causes the axial planes of the Phase 2 folds to curve systematically from northwest with a moderate southwesterly dip west of the Jordan to east-west with a low southerly dip east of the Jordan (*see* Fig. 4). The axis of the Phase 3 antiform, as indicated by the average attitudes of these Phase 2 axial planes, plunges 20 to 35 degrees toward 160 degrees and the axial plane dips steeply to the east. The foliation, though less regular than the axial planes of the Phase 2 folds, also curves systematically across the Phase 3 antiform. The axes of Phase 1 folds on the western limb of the antiform plunge southwestward, on the eastern limb they plunge eastward.

Phase 1 Folds

Small Phase 1 folds occur in many outcrops (*see* Plate IX) and a few larger Phase 1 folds can be seen from a distance (*see* Plate XI). A few very large folds may be found by mapping, but on all scales the Phase 1 folds are relatively obscure. They are isoclinal with axial planes essentially parallel to the layering. Though the folds are obscure, the axes are outlined by a pronounced penetrative mineral lineation and rodding (*see* p. 25 and Plates V and VI).

In general, Phase 1 folds are recumbent structures with axial planes folded by the Phase 2 structures. The axial planes mainly dip southwestward west of the Jordan and south or southeast, east of the Jordan. The average attitudes of Phase 1 lineations and minor folds, obtained from stereographic plots, are shown on Figure 4. West of the Jordan, most of these structures plunge toward 235 degrees at varying angles, depending on the dip of the layers. They are oblique to the axes of the Phase 2 folds. As the Phase 1 lineations and fold axes cross the Phase 2 folds, the strike remains relatively constant and the plunge is locally to the northeast. East of the Jordan, because of the change in strike of the axes of Phase 2 folds, Phase 1 and Phase 2 folds are essentially coaxial, both trending east and having a low plunge. The axial planes of Phase 1 folds in that area dip to the south and are broadly folded on east-west axes with a low plunge.

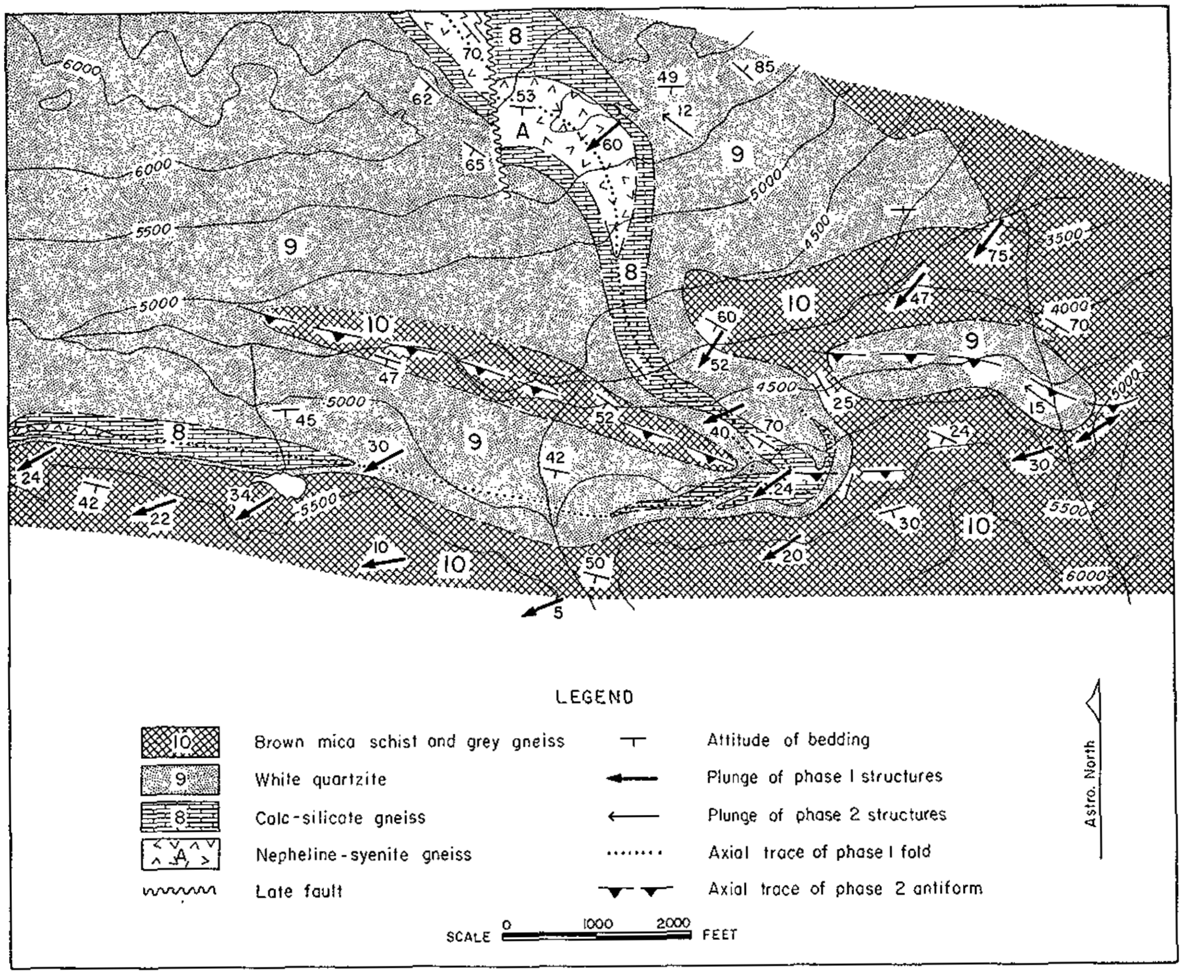

Figure 5a. Geological map showing hinge zones of Phase 1 folds in Area 1 of Figure 2.

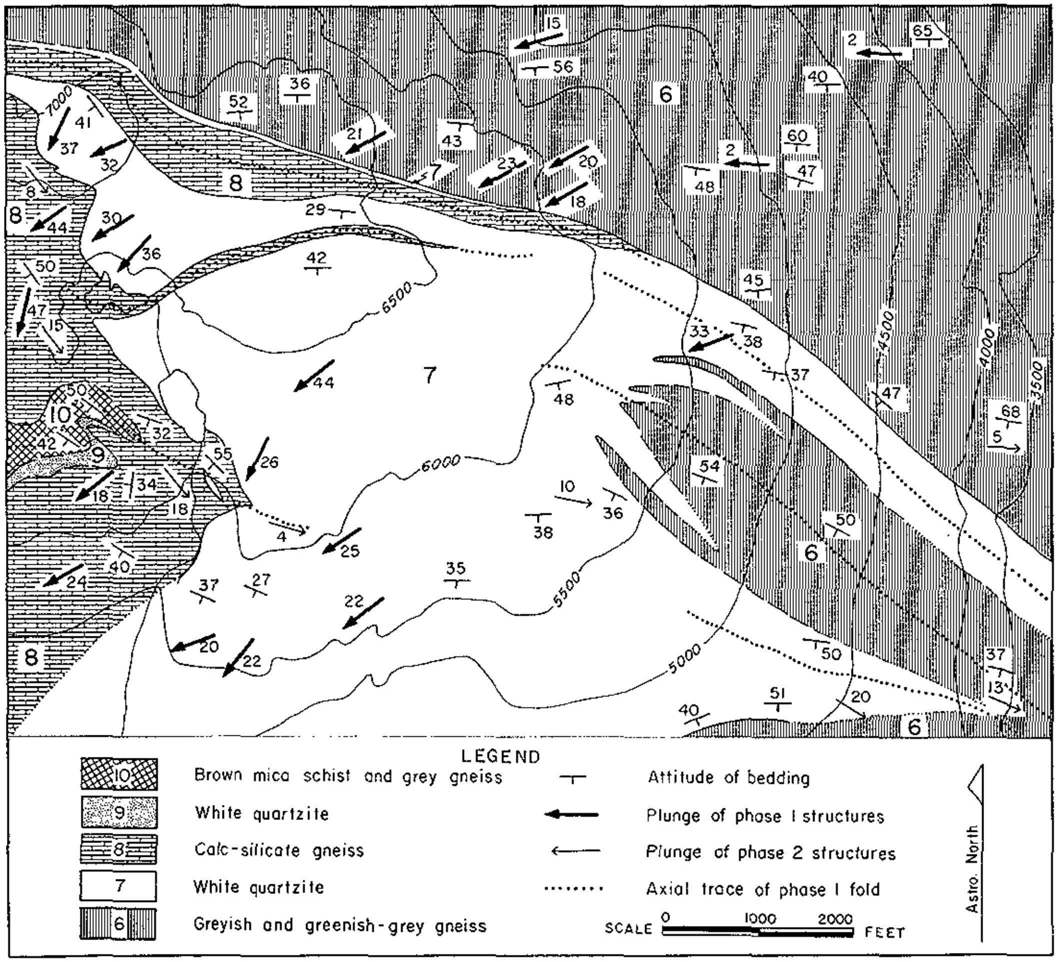

Figure 5b. Geological map showing hinge zones of Phase 1 folds in Area 3 of Figure 2.

Several Phase 1 fold hinges are outlined by the formations shown on Figures 2, 5a, and 5b. In Area 1, south of Hiren Creek, a Phase 1 fold is defined by calc-silicate gneiss, white quartzite, and nepheline-syenite gneiss. The syenite gneiss (unit A) occupies the core of the Phase 1 fold as a single layer between two layers of calc-silicate gneiss (unit 8). These rocks and the Phase 1 fold are repeated on the limbs of the Phase 2 antiform A, and are exposed between Hiren Creek and the head of South Hiren Creek. Within Area 1, the syenite and the calc-silicate gneiss terminate on the hinge of the Phase 1 fold. On the south limb of fold A, both terminate simply, south of South Hiren Creek. On the north limb of fold A, the syenite terminates north of South Hiren Creek at a point which is north 70 degrees east from the syenite termination on the south limb. Calc-silicate gneiss and white quartzite are folded together by Phase 1 structures in the hinge zone of antiform A and produce a complicated outcrop pattern, the mapping of which is not beyond question.

In Area 2, the hinge of a Phase 1 fold plunging 40 degrees toward 230 degrees is outlined by a tail of white quartzite (unit 9) in mica schist (unit 10). The quartzite terminates in schist in the form of two sharp-crested antiforms with an intervening synform. This hinge zone is on the southern limb of the Phase 2 antiform, fold A, and the hinge zone is not exposed at the same horizon on the northern limb of fold A. A thick mass of white quartzite forming a prominent hill north of the head of Hiren Creek is part of unit 9 in the thickened hinge zone of the Phase 1 fold.

In Area 3, a number of Phase 1 folds produce a complex pattern of the outcrops of greenish-grey gneiss (unit 6), white quartzite (units 7 and 9), calc-silicate gneiss (unit 8), and mica schist (unit 10 and parts of unit 8) (*see* Fig. 5b). An isoclinical synform on the west side of the Jordan River is defined by a uniformly dipping layer of white quartzite (unit 7), which forms the core of the fold, with rocks of unit 6 repeated on either side. To the west this synform is defined by a highly attenuated core of mica schist (unit 8) in quartzite (unit 7), which terminates near the western edge of Area 3. A complementary antiform of quartzite lies to the north and is followed by a synform with mica schist and calc-silicate gneiss in the trough terminating in the northern part of Area 3. This last synform has a very thin layer of quartzite (unit 7) on the northern limb and a tail of syenite gneiss (unit B) in calc-silicate gneiss (unit 8) forming the core which is exposed about 2 miles west of Area 3. In the southeastern corner of Area 3 a complicated hinge zone of a Phase 1 antiform is defined by rocks of unit 7 and unit 6. These folds on the average plunge 35 degrees toward 220 degrees and are on the northern limb of Phase 2 synform D. On the southern limb they plunge steeply and are poorly exposed on the slopes of Hiren Creek, and are poorly mapped.

Another Phase 1 fold, outlined by white quartzite (unit 2) and mica schist (unit 3), crosses the Jordan River near the northern edge of the map-area (*see* Fig. 2). Unit 3 in the core of the fold is crowded with small isoclines which plunge

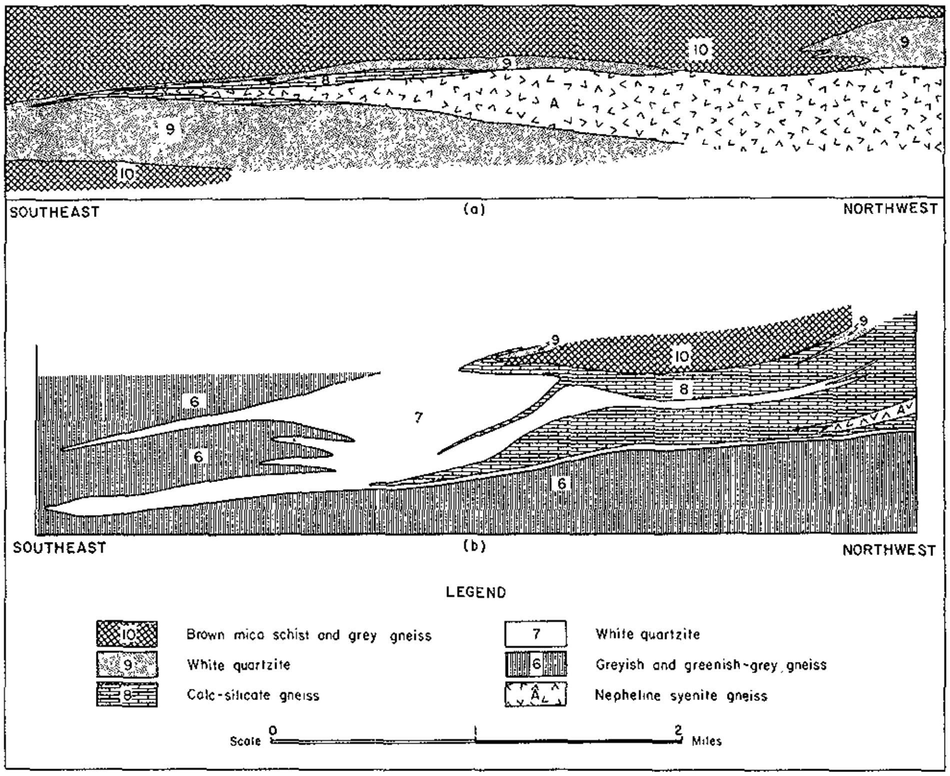

Figure 6. Diagrammatic cross-sections of Phase 1 folds.

50 degrees toward 240 degrees, and unit 3 is enveloped by unit 2 near the Jordan. The fold opens toward the east and continues beyond the area mapped. The axial plane curves across the Phase 2 antiform H, and the upper limb is truncated at an acute angle by the Bews Creek fault.

On Frisby Ridge, large Phase 1 folds are outlined by white quartzites in unit 6 and by unit 7 near the lake and the highest point on the ridge northeast of the mouth of Hiren Creek. The largest folds plunge at low angles to the east and the axial planes dip 60 degrees to the south. Hinge zones are greatly thickened and the limbs are highly attenuated. Comparable folds 1½ to 2 miles to the north have a similar low plunge to the east and have axial planes dipping about 20 degrees to the south. Phase 1 folds at these two localities lie on opposite limbs of a Phase 2 synform (*see* Fig. 3, section J-J′).

Integration of Phase 1 folds throughout the area can be accomplished only by interpreting the patterns of structure and lithology indicated on the geological map (Fig. 2). Because of the complexities of the Phase 2 folds, reconstruction of the Phase 1 folds is difficult, and attempts to integrate Phase 1 folds have not led to a consistent fold pattern. Figure 6 shows Phase 1 folds diagrammatically in cross-section at two localities where integration has been possible. The sections are approximately to scale, on a plane roughly perpendicular to Phase 1 fold axes and lineations, and are drawn with the axial trace of the folds nearly horizontal.

Section Figure 6a is along the southern limb of the Phase 2 antiform A, between South Hiren Creek and the head of Hiren Creek. Figure 6b is along the northern limb of the Phase 2 synform D on the ridge and steep northern slope of the ridge between the Jordan River and the eastern edge of the King Fissure property.

FAULTS

Two important sets of faults called early and late are recognized within the area. Strike faults of considerable extent and of unknown displacement are referred to as early faults because they are associated with the folding. Northerly trending faults with steep dip are referred to as late faults because they cut all the folds and contain undeformed lamprophyre dykes.

The largest early fault, called the Bews Creek fault, separates the gneiss-conglomerate-quartzite-schist sequence (units 1, 2, and 3) from various schists and gneisses which lie above it. The fault has been mapped from the head of Copeland Creek to the east slope of the Jordan River, and in that distance it dips at low to moderate angles to the south and is almost parallel to the layering. Regionally, the fault transgresses the formations and probably also the Phase 1 folds, both those which are structurally above it and those which are below. The fault is folded by Phase 2 structures on a large and on a small scale, but in the western part of the area it truncates Phase 2 folds.

In the northwestern corner of the map-area, on the pass between Copeland and Bews Creeks, the Bews Creek fault lies beneath, and parallel to, the layers in calc-silicate gneiss of unit 8. It truncates white quartzite and schist of units 2 and 3 and also truncates parts of a south-plunging Phase 2 fold outlined by the quartzite. Farther east the fault zone is marked by a lineament and rusty zone. It is essentially parallel to the formations, but transgresses them slightly so that the calc-silicate gneiss terminates above the fault and the mica schists (unit 3) thin beneath it. On the northern slope of the peak between Copeland Creek and Jordan River and on the upper western slope of the Jordan River the Bews Creek fault is folded by Phase 2 folds. Farther east the fault is presumed to follow the upper contact of unit 3 and to cut downward east of the Jordan into unit 2.

The Bews Creek fault appears to have had a long and complex history. Probably it originated as a thrust or slide at some time, possibly late in the Phase 1 period of folding. The fault was involved in the Phase 2 folding but at least local movement continued after Phase 2 folding. The net slip and the stratigraphic separation on the fault are unknown.

Late faults and associated fractures form a pattern of northerly trending lineaments throughout the area. They dip steeply and strike between 350 and 35 degrees. Two strikes appear to be dominant; one north and the other about 30 degrees. On many prominent lineaments no offset of the formations was detected. The offsets, where recognized, are small and vary markedly along the strike of the faults.

The most significant group of late faults is along the upper part and west side of Frisby Ridge and down the east slope of the ridge toward the Columbia River. More than half a dozen faults in this area appear to have dropped the gently dipping formations down on the east a total of more than 2,000 feet. The largest and most continuous, the Frisby Ridge fault, crosses Frisby Ridge at an acute angle and is well exposed on the steep slopes east of the Jordan and on Frisby Ridge farther north. West of the Jordan, four prominent faults in the Hiren Creek drainage area have right-hand offsets of a few hundred feet, suggesting that the formations which dip to the south are progressively dropped down on the west. A few of these faults can be followed northward, but the offsets decrease and other less prominent faults with smaller offset are recognized (*see* Fig. 2). Locally the late faults contain lamprophyre dykes either in the fault plane or in joints parallel to it. They appear to be later than the faults, although some are locally sheared. Along a fault on the south side of Hiren Creek about 3 miles west, coarse fluorite and small amounts of fine-grained sulphides in rocks adjacent to the fault have been found (*see* p. 57). Coarse galena and sphalerite occur along a late fault in the mixed gneiss north of Copeland Creek, about 1½ miles northeast of the Bews Creek Pass.

Regional Significance

The foregoing descriptions of structure and lithology describe the form and stratigraphic position of the lead-zinc sulphide layer, the exploratory and economic significance of which are discussed in chapter 4. This study also has implications regarding the regional stratigraphy and structure of this part of the Shuswap Metamorphic Complex and nearby Selkirk Mountains and Kootenay Arc. The age and the correlation of the rocks within the Complex with those in the less-metamorphosed belt to the east are problems on which considerable reconnaissance work has been done. Another related problem is whether or not there are present in the cores of the gneiss domes, or elsewhere in the fold belt, Precambrian basement rocks which were deformed prior to those in the sedimentary cover. A third is the correlation of structures within the complex with those in the fold belt to the east. This problem involves the size of the structural domains, and the controls for three phases of deformation found in many places. The present study does not provide conclusive answers to any of these problems, but the evidence from within the Jordan River area is discussed in the following paragraphs.

Stratigraphic correlations in the Kootenay Arc and Selkirk Mountains, where fossils are scarce, are based on lithology and detailed lithologic sequences. One set of marker beds near the Lower Cambrian Badshot Formation is recognized for more than 150 miles along the trend of the Arc and is present near Albert Canyon, 25 miles northeast of Revelstoke. This sequence includes the Upper Hamill Group of quartzites and micaceous rocks, the Mohican Formation of phyllites and impure calcareous rocks, the Badshot limestone, and the lower part of the Lardeau Group (*see* Fyles, 1964, p. 34). Structural studies in Revelstoke Park, which lies between Albert Canyon and the Jordan River area, suggest that rocks of the Hamill and Horsethief Creek Groups, below the Badshot, extend into the Jordan River area. Wheeler (1965) concludes from regional considerations in the Big Bend map-area that the Shuswap Complex on the Frenchman Cap dome contains rocks of the Hamill and Horsethief Creek Groups. Although facies changes are to be expected, it seems worthwhile to search the Shuswap Metamorphic Complex for the marker sequence that has been so useful for correlations within the Kootenay Arc.

In the Jordan River area, units 4, 5, and 6 form a sequence which resembles very closely the upper part of the Hamill Group, the Mohican and Badshot Formations, and part of the Lardeau Group. The marble in unit 5 could be the Badshot, because it is the only clean carbonate within the area. The schists and calcareous rocks of unit 5 are very like the Mohican. A thin grey to white calc-silicate quartzite in the quartzitic part of unit 5 (*see* p. 42) is like the uppermost quartzite of the Hamill Group, and the interlayered mica-sillimanite schist and quartzite in the remainder of units 4 and 5 are like rocks of the Upper Hamill above the Mount Gainer Formation, which is a thick white quartzite defined in the Ferguson area 75 miles to the southeast. Rocks of unit 6 above the marble, though not distinctive, could well be the metamorphic equivalents of greyish phyllites, calcareous schists, and argillites in the lower part of the Lardeau Group. The foregoing correlations would place the two white quartzites (units 7 and 9), the intervening limy calc-silicate gneiss (unit 8), and unit 10 in the Lardeau Group, no part of which they resemble in any way. These white quartzites resemble rocks in the Hamill Group below those just referred to. This problem cannot be resolved on the basis of present knowledge and it throws doubt on the whole correlation. If the correlation is correct, a strike fault between units 6 and 7 is suggested, but such a fault has not been found in the field.

The mixed gneiss (unit 1) in the Jordan River area is the uppermost unit in the granitic core of the Frenchman Cap dome (*see* Fig. 1). The upper contact of unit 1 is of significance in determining whether or not the core gneiss is Precambrian basement. This contact should provide evidence of conformity or unconformity, but within the area the evidence is inconclusive. Quartz-pebble conglomerate of unit 2 above the mixed gneiss and the quartzite of unit 2 above the conglomerate are stratigraphically right-side-up. The conglomerate, highly deformed and locally very thin, is found all along the contact, and it seems reasonable to conclude that it forms the base of the metasedimentary sequence over wide areas. The pebbles are quartz, and the matrix is micaceous. Discrete round pebbles and cross-bedding in the finer parts are convincing evidence that the conglomerate is sedimentary and not a pseudoconglomerate of tectonic origin (*see* Wheeler, 1965, p. 5). Positive evidence of unconformity, however, such as truncation of layers of mixed gneiss by the base of the conglomerate or minor structures in the gneiss that are older than Phase 1 structures, has not been found.

There is little direct evidence regarding the correlation of structures in the Jordan River area with those beyond to the east and south. On the eastern slope of Frisby Ridge, as far east as the Columbia River (*see* Fig. 4), none of the folds can be positively correlated with Phase 2 and Phase 3 folds of the Jordan River area to the west. In the adjacent Revelstoke Park area east of the Columbia, Phase 2 and Phase 3 folds described by Ross (1968) do not directly join folds on the eastern slope of Frisby Ridge and they differ in style and attitude from Phase 2 and Phase 3 folds in the Jordan River area. The Phase 2 and Phase 3 folds in the Jordan River area are of relatively limited extent, and it is concluded that they are related to the southeastern or southern part of the Frenchman Cap dome, and may have been generated by movement of the core gneiss.

Phase 1 folds extend beyond the Jordan River area. They have been mapped along the eastern slope of Frisby Ridge and can be correlated with Phase 1 folds in Revelstoke Park (*see* Ross, 1968). The axes trend westward and southwestward across the Shuswap Complex and eastward and northeastward into the Selkirks and are warped by the Phase 2 and Phase 3 folds. Hence the Phase 1 folds may be part of a regional system not related to the dome. Attempts in the Jordan River area to integrate small folds and to interpret the regional structure have not been successful (*see* p. 34). Interpretations of the size and directions of relative movement of the major folds must await determination of the stratigraphic top of the formations above the Bews Creek fault and a better integration of the small Phase 1 folds.

CHAPTER IV

Mineral Deposits

INTRODUCTION

The area contains significant deposits of lead, zinc, and molybdenum and associated minor amounts of copper and silver. These deposits are of three types:—

(*a*) Concordant lead-zinc deposits.

(*b*) Lead-zinc veins along fractures and faults.

(*c*) Molybdenite deposits associated with nepheline-syenite gneiss.

This chapter describes the mineral deposits and their geological setting with particular emphasis on the concordant lead-zinc deposits which were the object of the study. There is no recorded production from the area and no currently producing mines. In 1968, King Resources Company was carrying out an aggressive exploration of molybdenum deposits on the Knox group of claims, 2 miles west of Mount Copeland, and under agreement with Bralorne Pioneer Mines Limited were studying the King Fissure lead-zinc deposit.

Prospecting within the area has been carried on since about 1890, but very few details of this exploration have been recorded. The King Fissure lead-zinc deposit is reported to have been discovered about this time (*see* Riley, 1961), but published accounts refer only to gold along the lower Jordan River. Interest in the area was maintained by residents of Revelstoke, and in 1950 an attempt was made to develop the King Fissure property. An access road was started, but the project was abandoned after two years. In 1955, the property was staked by S. and A. Brewer, who granted an option to Consolidated Standard Mines Limited, the present owners. Sampling, mapping, and diamond-drilling of this property was done in 1956 and 1958 by the company and Bunker Exploration Ltd., and in 1963, 1965, and 1966 by Bralorne Pioneer Mines Limited. In 1963, as a result of extensive areal prospecting by Falconbridge Nickel Mines Limited, lead-zinc showings on Frisby Ridge, east of Copeland Creek, were discovered by prospector Walter Schwartz. Since 1950, prospecting was continued by local men and small companies, but their work has not been recorded.

In 1964, E. H. Ewar and associates of Peachland discovered molybdenite between Copeland and Hiren Creeks west of Mount Copeland, which has subsequently been explored by King Resources Company. In 1968, this company and associates explored all the Jordan River area and the region to the south as far as the Trans-Canada Highway by geochemical stream-sediment sampling, geological mapping, trenching, and sampling. Several new showings were discovered.

CONCORDANT LEAD-ZINC DEPOSITS

Sulphide Layer

A layer of sulphides up to 10 feet thick form part of the lithological sequence in the Jordan River area. It occurs within unit 5 (*see* p. 16) and consists of fine-grained pyrrhotite, sphalerite, galena, and pyrite with lenses of quartz and locally barite in a calc–silicate gneiss. The layer is found on the King Fissure property on Mount Copeland and near the base of cliffs above the landslide on the west side of Frisby Ridge, east of Copeland Creek (*see* Fig. 2). The sulphide layer is confined to a stratigraphic interval of less than 30 feet. In many places no significant sulphides have been found in this interval; in others, a few scattered grains of galena and sphalerite are disseminated in a narrow layer of calc-silicate gneiss; and at other places, notably on the King Fissure property, massive sulphides form a layer a few feet thick within this interval. The sulphides are associated with calc-silicates, small lenses of impure marble, knots of quartz, and locally layers of barite.

A detailed lithological succession of the lead-zinc sequence (map unit 5) exposed on the King Fissure property is summarized in Table II, and the distribution of the rock units around the eye-shaped fold at the junction of folds E, F, and the Copeland synform is shown on Figures 2 and 7. Essentially the same sequence is found on Frisby Ridge but one, and locally two, of the marble layers close to unit 6 are missing in that area.

In the lower part of Copeland Creek all of unit 5 including the marble is missing and probably has been sheared out by Phase 1 folding. The marble and mica schists, as well as lenticular masses of white quartzite, outcrop on the ridge north of Copeland Creek, but the succession is incomplete and the sulphide layer is missing. The King Fissure property, Frisby Ridge, and the ridge north of Copeland Creek are the only places in the Jordan River area where the lead-zinc sequence is exposed, and the structural interpretation suggests that beneath the surface it will not be found far from these areas. It probably occurs beyond the northeastern corner of the map-area on the wooded western slopes of the Columbia Valley.

The most common type of lead-zinc mineralization within the sulphide layer is a very fine-grained intimate mixture of sphalerite and pyrrhotite with conspicuous eye-shaped lenses of grey, watery quartz and scattered grains of pyrite and galena. The latter in general are coarser than the pyrrhotite and sphalerite and commonly the pyrite is in subhedral crystals. Quartz, calcite, diopside, calcic plagioclase, sphene, and other silicates are common gangue minerals.

In outcrop the sulphides are locally banded and, together with marble lenses, are contorted into disharmonic folds. Most of these folds lie within the sulphide layer and rarely is the sulphide layer itself folded by minor structures. The lenses of marble in places contain disseminated sulphides or lenses of massive sulphides transecting the beds.

Table II.—Lithology of the Lead-zinc Sequence

Map Unit	Thickness (Feet)	Lithology
6		Mica schist, grey gneiss, quartzite, and calc-silicate gneiss.
Calcareous Unit 5a	0– 10	Grey and micaceous marble.
	5– 15	Mica schist and calc-silicate gneiss.
	2– 15	Buff-weathering marble.
	10– 20	Mica schist and calc-silicate gneiss.
	5– 30	Grey and white calcite marble (map unit 5e).
	30–100	Fine-grained grey mica schist, minor sillimanite schist with feldspar knots, and calc-silicate schist.
	0– 20	Sulphide layer, calc-silicate gneiss, marble, and barite lenses.
	5– 30	Grey mica schist and calc-silicate gneiss.
Quartzitic Unit 5c	0– 40	Grey to white calc-silicate quartzite.
	10– 70	Mica schist, micaceous quartzite, minor calc-silicate gneiss.
	10–100	Platy-white, buff to pinkish, locally green quartzite (map unit 5d).
	20–100	Mica schist, micaceous quartzite, minor calc-silicate gneiss, and garnet mica schist.
	5– 25	Interlayered white quartzite and mica schist.
	0– 20	Grey micaceous quartzite, thin marble layers.
4		Brown-weathering biotite-sillimanite schist, with coarse, rounded feldspathic knots, few thin marble layers.

Sphalerite and pyrrhotite seen under the microscope form irregular intermixed grains, many of which are less than 0.05 millimetre across. Boundaries of the eye-shaped lenses of quartz and scattered grains of barite are sutured, having a ragged fringe of fine sulphides. In detail this fringe is made up of rounded surfaces between the minerals. These eye-shaped aggregates of quartz in the extremely fine-grained matrix of sulphides produce a cataclastic texture. The lime silicates intimately associated with the sulphides, however, appear to be undeformed and have textures like those of the adjacent metasedimentary rocks. The sulphides appear to have been deformed cataclastically, and these cataclastic textures are preserved. The subhedral crystals of pyrite developed late in the metamorphic history.

On the regional scale, the sulphide layer has been folded by Phase 2 structures and probably also by Phase 1 folds. No specific Phase 1 fold that involves the sulphide layer has been found, but repetition of the layer between the King Fissure property and the showings on Frisby Ridge indicates that it was folded by Phase 1 structures and passed through the highest grades of metamorphism. It is concluded that the sulphide layer at one time was an impure calcareous, siliceous bed, which was folded by all the apparent phases of folding and was deformed cataclastically before metamorphism.

Regional Significance

The sulphide layer in the Jordan River area is one of several concordant lead-zinc layers known in the Shuswap Metamorphic Complex, the most significant of which are on the Big Ledge property northwest of Nakusp; Wigwam, 20 miles southeast of Revelstoke; Ruddock Creek, 60 miles north of Revelstoke; and Cottonbelt, 30 miles northwest of Revelstoke (*see* Fig. 1). These deposits have many features in common and probably have had a similar tectonic history. The Big Ledge and Wigwam properties have been visited briefly by the writer on various occasions and the Ruddock Creek deposit was studied in August, 1968. It is described in detail on pages 47–57. The Cottonbelt has not been studied and is not included in this discussion.

These deposits have several similar as well as some contrasting features, which are described in the following paragraphs.

(1) The deposits are closely confined stratigraphically, but they are not in the same lithological succession and probably not in the same time-stratigraphic unit.

The Big Ledge occurs on the southern flank of the Thor-Odin gneiss dome (*see* Reesor, 1970) in a sequence of mica schists, quartz mica schists, marbles, and gneisses, which strike east and dip at moderate angles to the south. Lenses of pyrrhotite, pyrite, and sphalerite occur within a layer 75 to 200 feet thick, called the Ledge, which has been traced for several miles. The Ledge consists of fine- to medium-grained mica schist and quartz mica schist, with calcareous lenses, lying structurally beneath a sequence containing quartzites, marbles, and mica schists, and above quartzites, amphibolites, and gneisses. The sulphides are confined to the Ledge and are found at various horizons within it. The sequence lies within a few thousand feet of core gneisses within the dome, but cannot be correlated in detail with the lead-zinc sequence of the Jordan River area or with rocks containing the sulphide layer at the Ruddock Creek property, which it most closely resembles.

The Wigwam deposit occurs in siliceous layers in limestone and dolomitic limestone in the Badshot Formation (*see* p. 37 and Muraro, 1966). The Ruddock Creek sulphide layer is in a sequence of mica schists and calc-silicate gneisses and marbles. It is confined to a stratigraphic interval of a few tens of feet, and continues for several miles. In summary, the lithologic sequences containing the sulphides differ from property to property, but the sulphide layers, though lenticular, are essentially stratigraphic.

(2) At all the deposits the sulphide layers are similar in mineralogy, texture, and occurrence. Very fine-grained mixtures of pyrrhotite and sphalerite containing small augen of quartz, similar to those in the Jordan River sulphide layer, are found in the other deposits. This type of mineralization is common at the Ruddock Creek and Wigwam properties and relatively uncommon at the Big Ledge. The grades

in lead and zinc vary within the deposits and from one deposit to another, but zinc is higher than lead, and silver is less than 1.5 ounces per ton. Medium-grained massive sphalerite, with or without calcite, barite, quartz, or fluorite, is common at Ruddock Creek, less common on the King Fissure property, and found only locally at the other two deposits. Medium- to coarse-grained pyrrhotite and pyrite form the principal mineralization on the Big Ledge. Veinlets of coarse galena in marble are conspicuous at the Wigwam property and are found locally, with or without other sulphides, at some of the other deposits.

(3) All the deposits have been deformed and metamorphosed. The Ruddock Creek deposit is folded by a Phase 1 isocline, the thickest and most continuous orebody lying in the hinge zone of this fold. It has also been folded by Phase 2 and Phase 3 structures, replaced by pegmatite and deformed again cataclastically (*see* p. 57). As indicated on page 41, the sulphide layer in the Jordan River area has undergone all deformation and metamorphism recognized in the surrounding rocks. The sulphides at the Wigwam have been folded by a Phase 2 deformation, but the relationship to metamorphism and Phase 1 folding is uncertain. The Ledge is in the amphibolite facies of regional metamorphism and together with the sulphides has been tightly folded, but details of the structural history have not been determined.

Thus the concordant lead-zinc deposits of the Shuswap Complex appear to have formed along specific stratigraphic horizons at various levels in the sedimentary sequence before intense folding and metamorphism. Whether they formed by a sedimentary, diagenetic, or subsequent epigenetic process is a matter for speculation. The Wigwam most closely resembles lenticular, concordant lead-zinc deposits in the Badshot Formation along the Kootenay Arc to the southeast (Duncan Lake and Salmo), which are epigenetic and were deposited during deformation probably between the first and second phases of folding (*see* Fyles, 1967, and Sinclair, 1966). The others, which are laterally continuous beds, are probably more closely related to the original sedimentation. They were repeatedly deformed by folding and cataclasis and in some deposits, such as the Big Ledge and Ruddock Creek, recrystallized to produce medium- and coarse-grained sulphides. Migration of the sulphides from the sulphide layers was minimal, resulting in irregular sulphide lenses in the Ledge, galena veinlets in marble at the Wigwam, and sulphide veinlets near the sulphide layers on the Ruddock Creek and King Fissure properties.

The sulphide layers of the Shuswap Metamorphic Complex contain vast quantities of lead and zinc and constitute the largest known reserve in the Province. They have not yet been mined for a number of reasons. These include the thinness of layers of good grade, the low grade of some of the thickest layers, the inaccessibility of some of the deposits, and the relatively poor metal recovery obtained in testing samples. No doubt some of these deterrents will be overcome as economic and technical factors change. Further search will uncover other showings.

Other occurrences of sulphide layers may be found by geological mapping. The search for the appropriate stratigraphy and structure is a geological problem. Experience in the Jordan River area, however, has shown that because of the complexities of the geology, this type of search is time consuming and requires detailed mapping of large tracts of country, much of which is difficult to travel in. Geologically guided routine prospecting and systematic geochemical testing of stream sediments and talus fines probably will give better results in less time than will basic geological mapping.

Property Descriptions

The King Fissure property is the only significant concordant lead-zinc deposit within the Jordan River area that has been studied in detail. The property was mapped in August, 1964, on a scale of 200 feet to the inch, before the regional mapping was started. The Ruddock Creek deposit, 60 miles north of the Jordan River area, was studied in detail in August, 1968, and is included in this bulletin for comparison. These two deposits are characteristic of the concordant lead-zinc deposits in the Shuswap Metamorphic Complex, and the following descriptions emphasize characteristics of significance in exploration.

King Fissure, S. B., C. R., A. T., and Deby This property, also known as the River Jordan, consists of 16 Crown-granted claims owned by Consolidated Standard Mines Limited (company office, 320, 355 Burrard Street, Vancouver 1) on the upper north and northeast slopes of Mount Copeland. Detailed geology of the deposit, based on a planetable survey, is shown on Figure 7, together with vertical cross-sections which include diamond-drill holes made by Bralorne Pioneer Mines Limited in 1963, 1965, and 1966. A generalized lithologic succession for the property is given in Table II on page 42 and map units 4, 5, and 6 are described in Chapter II.

Details of Lithology

Some details of significance in studying the local geology and in logging drill-core follow.

The biotite-sillimanite schist (map unit 4) forms prominent red-brown outcrops along the core of the eye-shaped fold (*see* Figs. 2 and 7). It contains two or three discontinuous layers of buff to creamy white marble well within the schist, and two more layers of marble near the schist-quartzite contact. These marble layers are normally several inches thick, but in the basin east of triangulation station S, they are thickened to several feet by folding.

The quartzitic unit (5c) contains several prominent layers of white quartzite, only the thickest of which is continuous throughout the fold (map unit 5d). Some of the purest quartzite is yellow-brown, pinkish, or greenish and contains muscovite partings, which are locally bright green or small, black tourmaline crystals elongate parallel to the first lineation. The contact of the quartzitic sequence with the calcareous sequence (map unit 5b) is placed between a blocky, fine-grained quartzite containing calc-silicates and a porphyroblastic feldspar-biotite schist with calc-silicate lenses. The sulphide layer is within 40 feet of this contact.

The most prominent marble layer (map unit 5e) consists of up to 30 feet of grey and white, mottled or banded, medium-grained, fetid, calcite marble. The two other marbles in this sequence (*see* Table II) are buff- to cream-coloured and the one nearest to the grey schist and gneiss of map unit 6 contains discrete porphyroblasts of brown mica.

Map unit 6 on the property is mainly grey mica schist and greenish-grey gneiss. A lens of friable white quartzite is present just west of the small lake and calc-silicate gneisses appear on the southern limb of the fold within a few hundred feet of the calcareous map unit 5a.

Structure

The general form of the folds on the King Fissure property has been described (*see* p. 28). In cliffs on the western end of the property the marble layers, lead-zinc and quartzitic sequences form three folds (*see* Plate X), which have been named synform E on the south, the Copeland synform on the north, and antiform F between them (*see* Figs. 2 and 4). Stereoplots of fold axes and foliation planes indicate that the Copeland synform plunges at 30 degrees toward 150 degrees in this area, and these data, together with drill data, indicate that the fold tightens and the plunge decreases toward the east. The axis passes through the horizontal, and at the eastern end of the property the average plunge is 15 degrees to the west. The synform is essentially isoclinal with an axial plane, which on the average strikes 110 degrees and dips 50 degrees to the south. This doubly plunging complex Phase 2 synform results in the eye-shaped pattern of outcrops of the marble layer and the rock units which it surrounds.

Synform E in the outcrops at the western end of the property plunges 20 degrees toward 125 degrees and dies out down the plunge. This fold and antiform F are minor flexures on the southern limb of the Copeland synform where the structure was drilled on section 2 (*see* Fig. 7), although they attain regional proportions to the west (*see* Fig. 3 and p. 29).

All three folds at the western end of the property in the quartzitic and calcareous units are essentially concentric. Marker beds pass around the curving hinge zones without significant changes in thickness. Higher in the structure, in the biotite-sillimanite schist, the style is similar, and the layers are thick in the hinge zones and thin on the limbs. Toward the east, the structures and the marker beds are tightened and thinned. Near triangulation station C, essentially all the marker beds are present, but they are much thinner than to the west. The rocks have a strong, platy cleavage dipping 45 degrees to the south parallel to the foliation and a penetrative wrinkle lineation plunging at low angles to the west.

Sulphide Layer

Exposures of the sulphide layer are described in detail by Riley (1961), who refers to the East section near triangulation station C, the Cliff section near station B, the Peak section near station F, and the West section, west of the Peak. The sulphide layer on the south limb of the fold is called the No. 1 Lode and on the north limb it is called the No. 2 Lode.

In the East section on the south limb of the fold the sulphide layer ranges from 1 to 3½ feet thick and on the north limb it is somewhat thinner. In the easternmost outcrops, about 800 feet east of station C on the north limb of the fold, the sulphide layer exposed for 75 feet along the strike is about 1 foot thick. Diamond-drill hole No. 10, which intersected the sulphide layer in the east zone, encountered on the south limb a thickness comparable to that on the surface. On the north limb, three layers were encountered in the same hole, which are taken to be structural repetitions of the sulphide layer as indicated in section 3, Figure 7. The hinge zone of the Copeland synform in the East section is covered by moraine and talus between station C and cliffs of grey gneiss 2,000 feet to the east. The position and character of the sulphide layer and the question whether or not it has been thickened in the hinge zone in this area are extremely important in exploration. Judging from lineations, the axis plunges about 15 degrees to the west, but the hinge cannot be seen either in the marker beds near station C or in the grey gneiss to the east. The layers form an apparently homoclinal succession, dipping about 45 degrees to the south. Whether or not the sulphide layer is significantly thickened in the hinge of the fold can be determined only by additional drilling.

In the Cliff and Peak sections, the sulphide layer is 5 to 10 feet thick, including minor pods and lenses of calc-silicate schist and marble. On the peak it is flaggy and oxidized, but on the lower slopes recently covered by ice it is relatively fresh. Drilling indicates that the mineralization maintains its character and thickness in depth.

In the West section, the sulphide layer is split by one or more low-grade or barren layers of schist or calc-silicate gneiss. Thicknesses range from 8 to 20 feet, with a barite-rich layer in the upper part near the trough of the synform.

On the northern limb (No. 2 Lode), the sulphide layer is less than 3 feet thick and commonly less than 1 foot thick. This thinning from the No. 1 to the No. 2 Lode takes place on the northern edge of the West section where the sulphide layer passes down the steep northern limb of the antiform, F. In outcrop from there northward and eastward along the northern limb of the Copeland synform as far as the King Fissure No. 4 claim it is less than 2 feet thick. The pattern of thinning probably is irregular and related neither to the Phase 2 folds which dominate the structure nor to the Phase 1 folds which have an average plunge on the property of about 30 degrees toward 235 degrees.

Reserves in the south limb (No. 1 Lode) have been calculated as 2,873,000 tons, having a grade of 1.1 ounces of silver, 5.1 per cent lead, and 5.6 per cent zinc, with average width ranging from 3 to about 7 feet (*see* Riley, 1961). This calculation was based on the assumption that the fold plunges eastward at 12 degrees. Present knowledge of the structure and deep drilling since this calculation was made indicates that the sulphide layer continues to much greater depths and that it probably maintains the same average thickness. Consequently, a much greater potential is indicated.

It, In This property, known as the Ruddock Creek deposit, consists of 64 claims held by record by Falconbridge Nickel Mines Limited (1112 West Pender Street, Vancouver 1). The property is on the southern slopes of a ridge west of Gordon Horne Peak, a 9,500-foot summit about 60 miles north of Revelstoke. The showings are northwest of the divide between Ruddock Creek, which flows east into the Columbia River, and Oliver Creek, which flows northwest into Adams River.

The deposit is in metasedimentary rocks of the Shuswap Metamorphic Complex on the northwestern flank of the Frenchman Cap dome. The dome (*see* Fig. 1) is elongate with the long axis trending north-northwest parallel to the Columbia River. On the northern end of the dome the core gneisses lie beneath gently north dipping metasedimentary rocks, which grade upward into metasedimentary rocks containing abundant pegmatite. This pegmatite-rich zone covers wide areas between the Columbia River and Oliver Creek. On the property, pegmatite and associated medium-grained granitic rocks make up more than 50 per cent of the outcrops. These rocks are mainly, if not entirely, replacements of the metasediments, and rock units and structures can be projected and traced among the pegmatite sheets without significant displacement. Because of the abundance of pegmatite and the very few distinctive marker beds in the metasedimentary rocks, the map (Fig. 8) and sections, though drawn to scale, are interpretive and the description presented in the following paragraphs provides the basis for the interpretation.

History of Exploration

The showings were discovered in the summer of 1960 near the end of a season of systematic prospecting of this part of the Monashee Mountains by Falconbridge Nickel Mines Limited (then Ventures Limited), prospectors M. Donahue and T. Cross, under the supervision of E. Dodson.

They were drilled, sampled, and mapped in the summers of 1961, 1962, and 1963. Geological work was under the direction of H. R. Morris, who made detailed and accurate maps which formed the basis of deep drilling done in 1963. As a result of this work, several million tons of ore grading 10 per cent combined lead and zinc was discovered and the possibility of much more was indicated. No further exploratory work has been done.

The writer spent three weeks in August, 1968, on the property, making extensive use of Falconbridge maps and facilities. The work included the measurement of many minor structures, the tracing of major structural features, particularly fold hinges, and the mapping of metasedimentary units on the property and beyond it. The diagrammatic map of Figure 9 is based on maps by Morris, from which the pegmatites have been omitted. The rock units and structures have been projected through areas of pegmatite and cover (talus, moraine, snow, and ice).

The showings referred to as the E, F, G, M, T, U, V, R, and Q showings are scattered across alpine slopes which face south and west. The E showing, at an elevation of 7,600 feet, contains the outcrops of the largest orebody, which were recently washed clean by a sudden outflow of water from a small glacier lying to

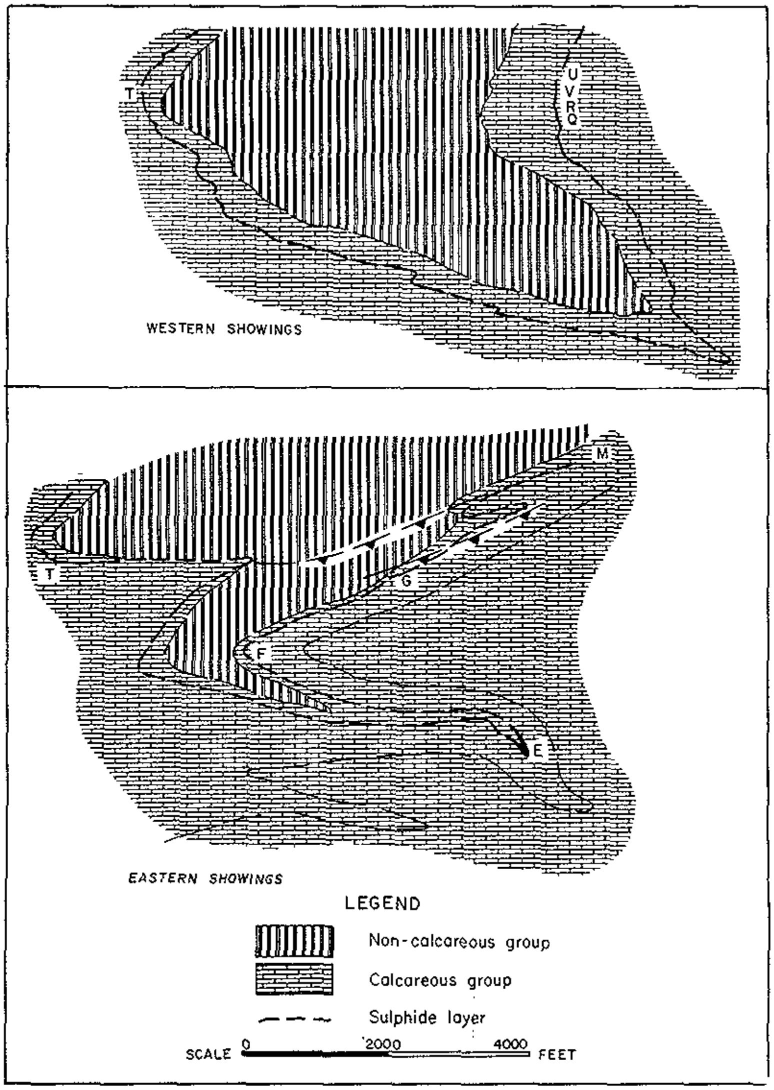

Figure 8. Diagrams showing the shapes of the folds in vertical section looking west, Ruddock Creek property (It and In claims).

the north. The V, R, and Q showings are below tree-line, extending down to elevations of 3,100 feet on the steep-gullied slopes of Oliver Creek. The other showings are above tree-line in meadows, rocky crags, or steep cliffs. All the showings appear to be confined to a stratigraphic interval of not more than a few tens of feet, and their complex pattern of outcrop is caused by multiple folding.

Summary

The rocks of the area are a varied succession of mica schist, calc-silicate schist, and gneiss, with intercalated layers of marble. These rocks form highly folded discontinuous layers and lenses engulfed by granite-pegmatite and medium-grained granitic rocks.

The dominant folds plunge 20 to 30 degrees to the west and are of two ages. The later or Phase 2 folds have rounded hinges, a modified concentric style, and vary from subisoclinal in the east to relatively open in the west. The axial planes strike north 20 to 30 degrees east and dip 20 to 30 degrees westward. One older, or Phase 1, fold has been mapped. The axis is almost parallel to the axes of the Phase 2 folds and the hinge zone near the E showing plunges 28 degrees toward 285 degrees. The fold is described as a syncline, although no evidence for the stratigraphic top of the sequence has been found. It is illustrated diagrammatically on Figure 8. The G, M, Q, R, V, U, and part of the F showings are on one limb and the T and part of the F showings are on the other limb of the syncline.

The pegmatites are irregular lenticular sheets a few inches to more than 100 feet thick, which lie subparallel to the foliation and are commonly concentrated along the hinge zones of the Phase 2 folds.

A northerly trending normal fault, which dips steeply to the west, lies west of the E showings. Zones of mylonite dipping at low to moderate angles to the west transect the sulphide layer and the pegmatite near the G and M showings, but do not show significant offset.

Lithology

Because of the extensive pegmatite and the complexities of the folding, a detailed lithologic succession has not been determined. In the area shown on Figure 9, the metasedimentary rocks have been divided into two general groups—a calcareous group and a non-calcareous group. The stratigraphic top is not known and the sequence is described with the calcareous group below the non-calcareous group, which results in the simplest structural interpretation. The calcareous group contains three or more marble layers each more than 10 feet thick, the sulphide layer, a wide variety of calc-silicate schists and gneisses, several types of biotite schist, and minor calcareous quartzite. The non-calcareous group is mainly biotite schist of various sorts and is not as widely exposed as the calcareous group. The general characteristics of the sequence are given in the following table:—

Table III.—Table of Formations, Ruddock Creek Area

Group	Thickness (Feet)	Lithology
Non-calcareous		Medium- and fine-grained biotite schist, biotite-feldspar gneiss, rare calc-silicate gneiss.
Calcareous	0–few hundred	Mica schist, calc-silicate gneiss, and marble.
	0– 50	Sulphide layer: Interlayered calcareous quartzite, marble, and mica schist with one or more layers of sulphides and quartz, local lenses of fluorite and barite.
	50–200	Biotite schist and calc-silicate gneiss.
	10– 50	Grey and white marble and calc-silicate gneiss.
	20–200	Biotite-sillimanite schist.
	10– 50	Grey and white marble and calc-silicate gneiss.
	Several hundred	Interlayered marble, calc-silicate gneiss, and mica schist, in part structural repetitions of the units above.
	Several hundred	Mica schist, platy quartzite, thin marble, in beds a few feet thick.

Rocks of the non-calcareous group are exposed best near Clear Lake* and along the ridge west of the lake. The rocks are medium- and fine-grained grey and brown biotite schist, with varying amounts of quartz and feldspar and locally garnet. No distinctive markers have been found within the group. The maximum thickness exposed in the core of the syncline is 2,500 to 3,000 feet, including pegmatite. Possibly it represents a stratigraphic thickness in the order of 1,000 feet.

The calcareous group outcrops widely, both in the area mapped and beyond it. It consists predominantly of calc-silicate gneiss and mica schist, with several interlayers of marble. The calc-silicate gneiss forms greenish-white or dark-green platy layers up to a few inches thick, interlayered with mica schist or marble. Highly siliceous creamy-white calc-silicate gneiss is described as quartzite. The silicates in general are fine-grained, but local clusters of coarse, bright-green actinolite are found. In thin-sections, actinolite, diopside, clinozoisite, and scapolite occur with varying proportions of plagioclase (An_{45}–An_{70}) and quartz. Sphene and apatite are common accessories.

The first member in the calcareous group, which separates it from the non-calcareous group, is a poorly defined discontinuous layer of marble and calc-silicate gneiss. It grades downward through a few hundred feet of mica schist and calc-silicate gneiss into a varied succession of calc-silicate gneiss, quartzite, marble, and

* Unofficial names were assigned by Falconbridge personnel to Clear Lake, Light Lake, Cirque Camp, and Main Camp (*see* Fig. 9).

sulphides known as the sulphide member. In detailed mapping near the E showing, Morris recognized two layers containing sulphides; a main layer 2 to 15 feet thick, separated by micaceous quartzite from a subsidiary layer as much as 5 feet thick, composed of calcareous quartzite containing sulphides. This subsidiary layer is below the main layer. Layers of marble and locally barite, fluorite, and micaceous and calc-silicate rocks with scattered galena occur within the syncline or above the main layer. The sulphide member, including all the sulphides and adjacent calcareous rocks, ranges from 5 to 15 feet thick without structural repetitions. Local folding has more than doubled the thickness.

The sulphide member is underlain by a few hundred feet of rusty biotite schist with minor calc-silicate lenses followed by two or more prominent layers of marble. These layers are blue-grey weathering, white, medium- to coarse-grained fetid calcite marble. Thin-bedded calc-silicate gneiss occurs in the marble, particularly along the margins, and biotite schist, which locally contains sillimanite, lies between them. Two layers, each as much as 40 feet thick, have been identified and several others have been mapped. They are found in the cirque near Cirque Camp and westward down the wooded slopes to the north of the V showing and are conspicuous on the shores of Light Lake, on the pass northeast of the lake, and on the slopes below and east of the E showing. Some of these exposures are clearly structural repetitions of the two layers closest to the sulphide member, but other marbles are exposed which are probably not repetitions.

The lower part of the succession beyond the marbles is not well known, but has been mapped in reconnaissance at the head of Ruddock Creek and on the ridges between the E showings and Gordon Horne Peak. It includes a sequence of biotite schist and calc-silicate gneiss with minor layers of marble and thin beds of platy, buff-weathering quartzite. A quartzite-mica-schist-marble sequence with repeated layers a few feet to a few tens of feet thick is well exposed in the cirque facing east at the head of Ruddock Creek.

Granitic pegmatite and associated medium-grained granitic rocks form more than half the outcrops in the area. In many places, as on the ridge north of Clear Lake, across the valley east of the lake, and on the ridge northeast of the E showings, they form thick, essentially continuous sheets, with only minor remnants of the metasediments. The principal constituents of these rocks are quartz and potash feldspar, with minor muscovite and biotite and scarce red garnet. The medium-grained granites have a vague foliation and lineation; the coarse-grained ones have quartz and feldspar intergrowths with scattered books of mica up to 2 inches across. Contacts between the granitic rocks and the metasediments are generally sharp, and between the granites and pegmatites are both sharp and gradational.

The granite and pegmatite bodies are extremely irregular. A few are tabular, crosscutting dykes, but most are lenticular, more or less concordant sheets which pass through the folded metasedimentary rocks without displacing them. Lineations and folds within remnants of metasediments within the pegmatites have the same orientation as those outside them. The pegmatites and granites appear to be dominantly, if not entirely, replacive.

Serpentinized dunite occurs in a few outcrops near the T showings south of Clear Lake and in a single outcrop a few hundred feet southwest of Main Camp. These are all rounded, brown outcrops of massive rock composed of brown olivine and greenish-white, fibrous serpentine. The outcrops near the T showings form a discontinuous northwesterly trending lenticular dyke 10 to 20 feet wide and a few hundred feet long.

Mineralization

The principal sulphides are sphalerite, pyrrhotite, galena, pyrite, and minor chalcopyrite. They occur as contorted layers and lenses associated with schist, siliceous calc-silicate gneiss, quartzite, marble, and locally barite and fluorite. Very fine-grained sphalerite and pyrrhotite with minor galena and rounded quartz eyes up to one-half an inch in diameter are common. Equally common are layers containing medium-grained dark-brown sphalerite with interstitial quartz and scattered quartz augen. Much of the M showing and parts of the G showing contain banded and minutely folded extremely fine-grained sphalerite and pyrrhotite. Galena and sphalerite occur also as scattered grains in marble, calcareous quartzite, and fluorite.

In the sulphide layer, lenses of massive sulphides up to 5 feet thick are common. They are complexly folded within themselves on axes which plunge to the west parallel to the folds in the surrounding rocks. The folds in the sulphides, which are outlined by the banding and by discontinuous layers of schist, gneiss, and quartzite, are irregular in form and usually disharmonic.

It is difficult to estimate the average grade without extensive sampling. Grades estimated to be 20 per cent combined lead and zinc over widths of 5 to as much as 20 feet are found at many places in the E showings and over widths up to 8 feet in the other showings. Lead is less abundant than zinc, and silver amounts to less than 1 ounce per ton.

Structure

The structure of the area is dominated by repetitive folding, which took place during metamorphism. It was followed by faulting. The earliest folds, called Phase 1, are isoclinal and obscure. One large, folded, isoclinal syncline with the E zone at the hinge is recognized. The later folds called Phase 2 are more open, abundant on all scales, and are well displayed. They are described first and subsequently interpreted in relation to Phase 1 folds and the later faults.

All the metasedimentary rocks have a strong lineation consisting of trains of mica flakes, aligned amphiboles, elongate quartz-feldspar lenses, and clusters of calc-silicates. This mineral lineation is parallel to rodding in quartzite and calc-silicate gneisses and to crenulations in mica schists; and both sorts of lineations are parallel to the axes of minor folds. The micaceous rocks have a strong schistosity, which is essentially parallel to the compositional layering. This layering is the bedding which has been transposed in varying degrees during folding. The schistosity and bedding have been folded together into large and small folds seen in many outcrops and outlined in mapping. These are dominantly Phase 2 folds.

The Phase 2 folds mainly have rounded hinge zones and range in form from open to isoclinal. In only the tightest folds are the beds thickened at the hinge and only locally in the micaceous rocks is there a foliation crossing the beds more or less parallel to the axial planes. The folds are of a modified concentric form. Small folds parasitic on larger folds are true dragfolds in the classic sense. On the limbs of large folds the asymmetry indicates the position of the small fold with respect to the hinge of the large fold.

Four major Phase 2 folds have been mapped (*see* Fig. 9) by following the hinge zone and by matching the attitudes of the layers and the asymmetry of the dragfolds on the limbs. These are recumbent folds with axes plunging to the west and axial planes dipping to the west at 20 to 30 degrees. Folds which close toward the south are regarded as synforms and are referred to as the F-G, T, and U-V synforms. One antiform closing to the north is called the Pass antiform and is exposed along the lower slopes north of the pass between Ruddock and Oliver Creeks. The geometry of these folds, as determined from stereoplots of measurements of the attitudes of lineations, foliations, and axial planes in the areas where the folds are best exposed, is shown in the following table:—

Fold	Axes (Azimuth and Plunge)			
	Average from Lineations and Minor Folds	Calculated from Attitudes of Layers	Attitude of Axial Plane (Strike and Dip)	Angle between Limbs (Degrees)
Pass antiform	286/25	292/26	25/28W	0–10
F-G synform	285/22	288/25	10/25W	35
T synform	282/20	294/25	20/25W	45
U-V synform	264/20	260/20	5/25W	100

The T and F-G synforms almost certainly have a complementary antiform between them, but it was not seen on the ground because of the high proportion of pegmatite and talus west of the F and G showings. It is shown diagrammatically on Figure 9, section E-F.

The folds change in form, both along the axis and along the axial plane perpendicular to the axis. They become progressively more open from east to west as indicated by the estimated angle between the limbs and illustrated on Figure 8. There are more large plications in the east than in the west. The hinge of the

U-V synform between the U and V showings is a zone of very steep dips with minor reversals, whereas the same fold to the east includes the F-G synform, the eastward projection of the T synform, and the inferred antiform between them.

A large Phase 1 fold is inferred from the distribution of the rock units and the exposures of the hinge in the area near the E showing. The general form of the fold is shown on Figure 8 and the details are sketched on Figure 9. It is referred to as a syncline because the fold opens upward, but the stratigraphic top of the beds has not been determined. The gross structure is outlined by the rock units. The non-calcareous group occupies the trough of the fold, becoming thinner toward the east and terminating in the area near the F and E showings. The calcareous group occurs on the limbs and the sulphide member, and conspicuous marbles are repeated on the limbs and thickened on the hinge.

The axis of the Phase 1 fold is essentially parallel to the axes of the Phase 2 folds. Locally in quartzitic rocks and amphibolitic gneisses rodding or mineral lineation lies at an acute angle with the axes of minor folds, but in general Phase 1 and Phase 2 lineations and fold axes are indistinguishable. No Phase 1 minor folds have been recognized with certainty. Minor folds near the E showing have the same style, asymmetry, and attitude as Phase 2 folds. The fold outlined by the sulphide member in the E showings plunges 27 degrees toward 285 degrees essentially parallel to, but somewhat steeper than, the plunge of the Phase 2 folds in that area. The axial plane, judging from the outcrop and diamond-drill intersections, strikes 70 degrees and dips 45 degrees to the northwest, essentially parallel to the layers on the lower limb of the F-G synform. The hinge zone of the Phase 1 syncline has not been recognized within the non-calcareous group, but it has been traced within the calcareous group for more than half a mile eastward from the E showings. Farther east it is covered by talus and offset by a late fault, but repetitions of the marble layers are found more than a mile east of the E showings.

Several minor folds have been found which do not fit the patterns of Phase 1 and Phase 2 folding. In general they plunge southward with axial planes which dip at moderate angles to the east. Lineations are folded by these structures, indicating that they are superimposed on the Phase 1 and Phase 2 structures.

Folds on the ridges and walls of the cirque surrounding Cirque Camp plunge 10 to 20 toward 240 to 250 degrees. Though off trend, they have the same form and asymmetry as the Phase 2 folds. They occur where the major Phase 2 fold broadens rapidly toward the west and provide direct evidence for the non-cylindrical character of the Phase 2 folds.

Faults in the area belong to two general types. Those of the first type occur along the G and M showings and in the pegmatites west of the G showing. They consist of irregular but fairly continuous branching zones of mylonite, a few feet thick, which strike north and dip 20 to 50 degrees west. These zones pass through pegmatite, some mica schist, and calc-silicate gneiss as well as the sulphide member exposed at the G and M showings. Pegmatites within the mylonite zones are reduced to banded, cherty, crushed rocks in which many of the grains are 0.02 millimetre across. Sulphides are similarly comminuted and banded and are folded into microscopic isoclines; quartzitic rocks are dense, vitreous, and cherty. Most rocks in the mylonite zones have a pronounced lineation or rodding, essentially parallel to the lineation in surrounding non-mylonitized rocks, produced by minute folds and the long axes of rolled porphyroclasts.

Faults of the second type are late block faults, the most important of which lies west of the E showings and displaces the main orebody down on the west. It is exposed in a gully 1,000 feet southwest of the Main Camp and was encountered in drill holes. On the surface it is a zone of intense fracturing and shearing and in the drill holes it consists of several feet of breccia and mylonite. On the average the fault strikes north and dips 58 degrees west. Many subsidiary fractures curve downward in the footwall of the fault for several hundred feet. If the displacement has been perpendicular to the line of intersection of the fault plane and these subsidiary fractures, the displacement, measured on the fault plane, is in the order of 700 feet down on the west in a direction of 290 degrees.

This fault is one of several which form prominent lineaments visible on air photographs. A fault trending northwest, which produces a right-hand offset of northwesterly dipping layers, lies along the face of the 9,000-foot summit half a mile northeast of the E showing and joins the main fault in the pass north of the E showing. Another fault trending north and showing a right-hand offset occurs a little more than 1 mile east of the E showing. Northerly trending linears show on air photographs along the east side of Clear Lake and on the slopes west of the T showings, but significant offsets have not been found along them.

A sequence of folding and faulting is indicated by the structures just described. Phase 1 folds, which are isoclinal with thickened hinge zones and sheared-out limbs, were folded and probably tightened by Phase 2 folding. Phase 1 and Phase 2 folding produced the same axial directions and occurred during the intense regional metamorphism. The formation of granites probably began late in the Phase 2 deformation or after it, along with the development of the pegmatites. These rocks replaced the folded metasediments controlled crudely by the layers and the axial planes of the Phase 2 folds. Subsequent movement on west-dipping shear planes produced the mylonite zones, which, judging from the orientation of linear structures within them, was a continuation of the Phase 2 movement. Minor amounts of widespread chlorite and local sericite developed in part, if not entirely, after the formation of the mylonite zones. The block faults probably were the latest significant structures.

Economic Significance

The great continuity of the sulphide member and its restriction to a narrow stratigraphic range indicates that it developed in the sedimentary sequence before deformation. The structural evidence shows that it has been involved in the whole sequence of deformation and metamorphism. These conclusions have important implications in exploration and in the economic value of the lead-zinc mineralization.

The thickness of the sulphide layer, although dependent upon the original thickness, is controlled largely by the folding. The thickest sections are in the hinge zones of Phase 1 folds and the longest dimension of these thickened zones is parallel to the fold axes. The E showings are in such a zone. The axial plane of the Phase 1 fold is curved and the diamond-drill intersections suggest that this axis probably is not quite parallel to the axes of the Phase 2 folds. Consequently, it varies in plunge with its position on the Phase 2 folds. Another fold hinge on which the sulphide member may be abnormally thick should be present on surface about midway between the E showings and Light Lake. This is an area of talus and abundant pegmatite and no sulphides have been found there. No other Phase 1 hinge zones involving the sulphide layer are known in the area, but the hinge of the E showing should continue in depth on plunge to the west. Other Phase I fold hinges may be expected beyond the area to the west.

The sulphide layers are only locally thickened by the Phase 2 folds. Local contortions at the hinges of the large Phase 2 folds or along the limbs may produce small orebodies plunging to the west with the Phase 2 folds.

The sulphide member is replaced by pegmatite, the distribution of which cannot be anticipated. Although the structure and stratigraphy of the sulphide layer are fairly well known and can be projected, the difficulties of finding the layer are significantly reduced by the unpredictable character of the pegmatite.

Extremely fine-grained sulphides such as those in the area affected by the mylonite zones may require special treatment for the recovery of the lead and zinc.

LEAD-ZINC VEINS

Several northerly trending faults and fractures in the Jordan River area are mineralized. They contain widespread iron carbonate, pyrite, and, locally, galena and sphalerite. The structural pattern of the faults and fractures is outlined on page 36, and of lamprophyre dykes, which they commonly contain, are described on page 22.

During the course of mapping, two lead-zinc showings were found. The first is adjacent to a fault on the south side of Hiren Creek about 3 miles west of the Jordan River (*see* Fig. 2). The showings are on the north side near the base of a steep draw at an elevation of 3,700 feet. A fracture, which strikes north and dips 75 degrees to the west, transects grey mica schist and a layer of buff-weathering fine-grained dolomite. The dolomite west of the fracture contains fine- to medium-grained galena, sphalerite, and pyrite. The mineralization is mainly in the dolomite, which is a maximum of 6 feet thick and continues 20 feet west of the fracture. Pyrite occurs in the fracture both near the dolomite and above it to the south. The fracture is adjacent to a major northerly trending fault, which, south of the lead-zinc showing, contains masses of purple fluorite.

The second showing is at an elevation of about 7,000 feet, about a mile northeast of the pass between Copeland and Bews Creeks (*see* Fig. 2). The showing is of coarse galena, sphalerite, and dark-brown iron carbonate along a fracture which strikes 15 degrees and dips 70 degrees east. The mineralized core is up to 6 feet wide and extends along the western slope of a cliff for an estimated 150 feet. Masses of galena and sphalerite are up to 2 feet thick and lie on either side of a lamprophyre dyke. The dyke is highly altered, suggesting that the sulphide mineralization is later than the dyke.

MOLYBDENUM DEPOSITS

Molybdenite associated with nepheline-syenite and syenite gneiss occurs widely within the Jordan River area and beyond it. Significant deposits of molybdenite have been found along the northern contact zone of the large mass of nepheline-syenite on the north slope of Copeland Ridge, about 2 miles west of Mount Copeland (*see* Fig. 2). These showings were found by E. H. Ewar and associates in 1964 and have since been intensively explored by King Resources Company (*see* p. 40 and Ann. Repts., 1965, p. 205; 1966, p. 228; 1967, pp. 261–263).

The mineralization consists of flakes and clusters of molybdenite with pyrite and pyrrhotite in syenite, syenite-pegmatite, and in calc-silicate gneisses near the margins of the nepheline-syenite bodies.

Nepheline-syenite gneiss (map unit A) forms an extensive, irregular but concordant sheet, mainly within calc-silicate gneiss of map unit 8 (*see* p. 19 and Fig. 2). It outcrops over large areas in the western part of the Jordan River area and extends a short distance to the west into the upper part of Bews Creek. Molybdenite has been found associated with this sheet on the north slope of Copeland Ridge, on the south slope of this ridge a mile south of the summit of Mount Copeland, and has been reported at several other places by prospectors of King Resources Company. A thin layer of syenite gneiss occurs also in calc-silicate gneiss of unit 6 on the ridge between the Jordan River and Copeland Creek and on Frisby Ridge, but molybdenite is not known in these areas. Nepheline-syenite gneiss is reported from west of the Perry River, 10 to 15 miles west of the Jordan River area (*see* McMillan, 1970). Molybdenite was discovered associated with this gneiss by George Warren, prospector for Rip Van Mining Ltd., of Calgary, in 1968. This association of molybdenite with syenite and nepheline-syenite has not been previously reported in

British Columbia and appears to represent an association comparable to that found in the Haliburton-Bancroft area of the Grenville metamorphic belt of Ontario (*see* Vokes, 1963, p. 130).

Knox (Mount Copeland Mine) This property was originally located in 1964 as the Joan group by E. H. Ewar and associates, of Peachland. The claims were purchased by King Resources Company, who abandoned the original claims, relocating them in 1967 as the Knox group. The group includes more than a hundred claims covering Copeland Ridge, west of Mount Copeland. The main showings are between elevations of 7,000 and 7,200 feet on the north slope of Copeland Ridge, about 2 miles west of Mount Copeland. Between 1965 and 1967 the showings were mapped, sampled, and drilled from surface by short holes. The geology of an area around the showings is sketched on Figure 10, which is an enlargement of part of Figure 2. Most of the early work was done on relatively low-grade mineralization in the western part of the area. The Glacier zone to the east, drilled in 1967, was found to contain high-grade molybdenite, and an adit was driven at the 6,650-foot level to further test the zone. Early in 1968 a long crosscut was collared to reach this zone from a site at an elevation of 6,150 feet on the south side of Copeland Ridge (*see* Fig. 2). The adit and a raise system near the showings broke through early in 1969. Rocks near the showings consist mainly of calc-silicate gneiss (map unit 8), syenite, and nepheline-syenite gneiss (map unit A). Below the showings is a layer of white quartzite (unit 7) and outcrops of greenish-grey biotite and hornblende-feldspar gneiss (part of map unit 6). The calc-silicate sequence includes thin-bedded green and brown calcareous biotite-diopside gneiss, layers of buff-weathering dolomitic marble, commonly 5 to 20 feet thick, and lenses of dark greenish-brown calcareous hornblende-biotite gneiss. The syenite gneiss is a medium-grained, poorly foliated, grey to pinkish-grey biotite-feldspar rock forming a marginal facies of a large mass of nepheline-syenite.

In general the rocks strike 110 degrees and dip 30 to 50 degrees to the south, but they are complexly folded. The showings are on the southern limb of the Phase 2 synform E (*see* p. 29 and Fig. 2), the hinge of which is exposed in cliffs below the showings. Minor Phase 2 folds plunge between south and southeast at low to moderate angles and are common in all the rocks. Large Phase 2 folds appear to have curving axes which vary in attitude between south and southeast and have a low to moderate plunge. Phase 1 folds and lineations plunge at low angles to the west and are folded by the later structures. Structurally, the area is in a zone of transition between very tight Phase 2 folds plunging south and southeast and more open folds to the south of Copeland Ridge, which have a low plunge both to the west and to the east. Synform E changes from a concentric structure, east of the showings, to a highly attenuated similar fold, west of the

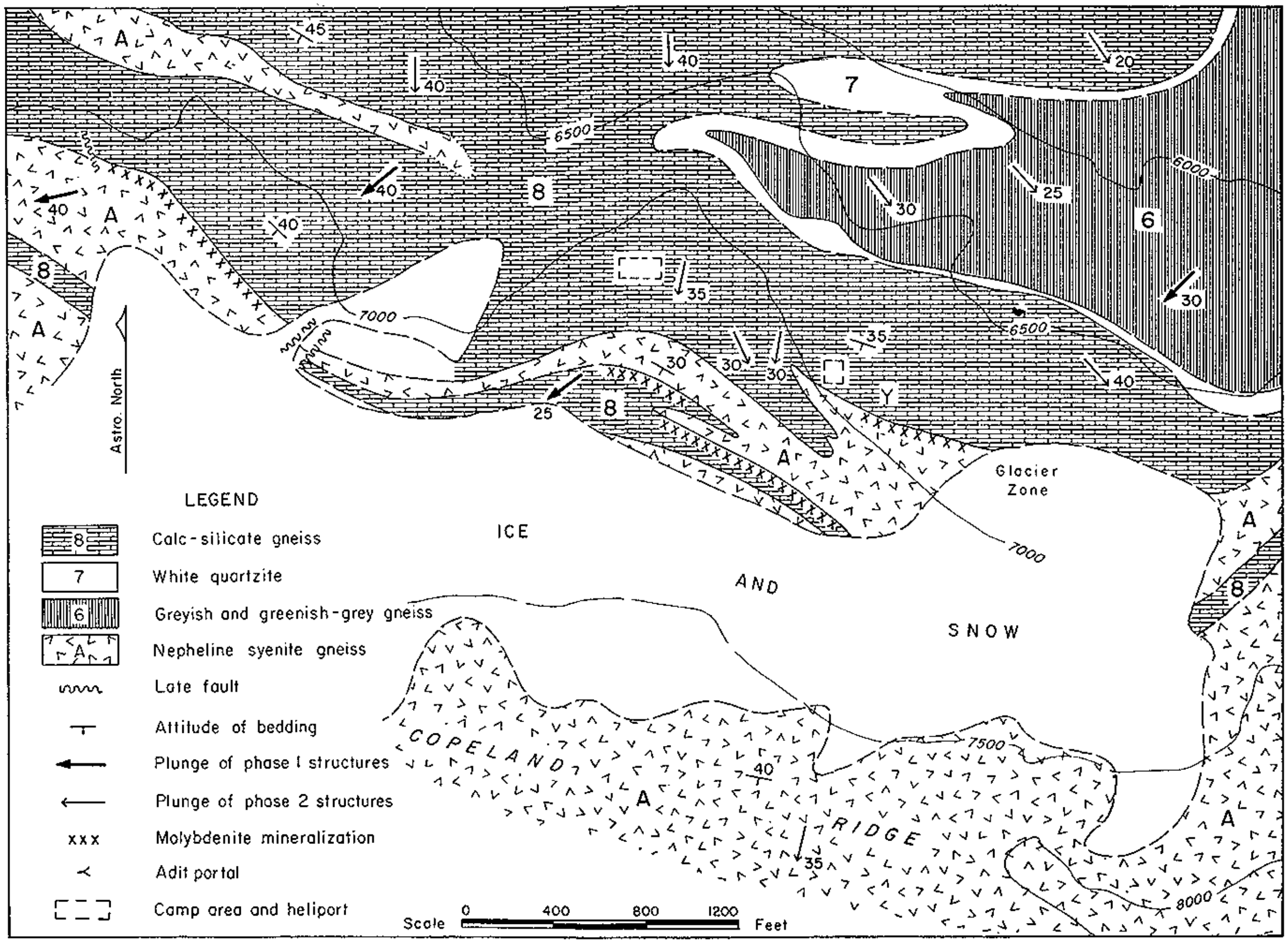

Figure 10. Geological map of the molybdenite showings of the King Resources Company, Copeland Ridge.

showings. These structural changes have taken place during metamorphism, and evidence of regional shearing is obscured by recrystallization.

Molybdenite in the Glacier zone occurs in an irregular lens of pegmatitic and aplitic syenite near the contact between syenite gneiss and calc-silicate gneiss to the north. The pegmatite is a medium- to coarse-grained, light greenish-grey to white rock composed of potash feldspar and irregular clusters of biotite. The aplitic syenite or aplite is a whitish medium-grained rock with a sugary texture intimately associated with pegmatitic syenite, or pegmatite. Textural and structural relationships in the 6650 level suggest that the aplite has formed adjacent to the pegmatite by bleaching of the syenite gneiss. Irregular masses of coarse calcite containing clusters of biotite, pyrrhotite, pyrite, and ilmenite, but no molybdenite, are also associated with the pegmatite. Molybdenite occurs in the aplite and pegmatite as disseminated flakes, clusters of grains, and massive pods. Where relationships are clearest, it lies between grains of feldspar and in fractures.

Drilling and careful mapping have shown that the pegmatite-aplite-molybdenite zone has the form of a folded lens up to 10 feet thick. The fold has a low plunge to the southeast and appears in plan to be S-shaped, consisting of a synform lying north of a small antiform, both having axial planes dipping at moderate angles to the south. In detail, the pegmatite and aplite are irregular and concentrations of molybdenite are highly variable.

On surface, the northernmost limb of the zone is 4 to 10 feet thick, and is exposed along the strike for about 400 feet before passing beneath a small glacier to the east. To the west it curves abruptly toward the southeast around the synformal hinge of a tight fold plunging southeastward. The 6650 adit encountered 20 feet of almost massive molybdenite in this hinge zone and the high-grade section has been traced down the plunge by drilling. To the south of this hinge zone lenses of pegmatite and aplite containing more or less molybdenite are exposed on surface and in the adit and are considered to be folded repetitions of the same mineralized pegmatite and aplite zone. The full extent of the entire zone down the dip to the south and down the plunge of the folds has not been determined.

To the west, for several thousand feet from the Glacier zone, molybdenite occurs in calc-silicate gneiss (*see* Fig. 10). Molybdenite, pyrite, and pyrrhotite occur as scattered and disseminated grains along the foliation of the gneiss in discontinuous lenses which form three sets of showings, each several hundred feet long and a few feet to a few tens of feet thick. These lenses tested in the early part of the exploration programme are of relatively low grade and are discontinuous.

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Plate I. View looking south toward Revelstoke down the Jordan River valley from the ridge between the Jordan River and Copeland Creek. Frisby Ridge on the left, Mount Begbie beyond the Jordan River area in the right distance.

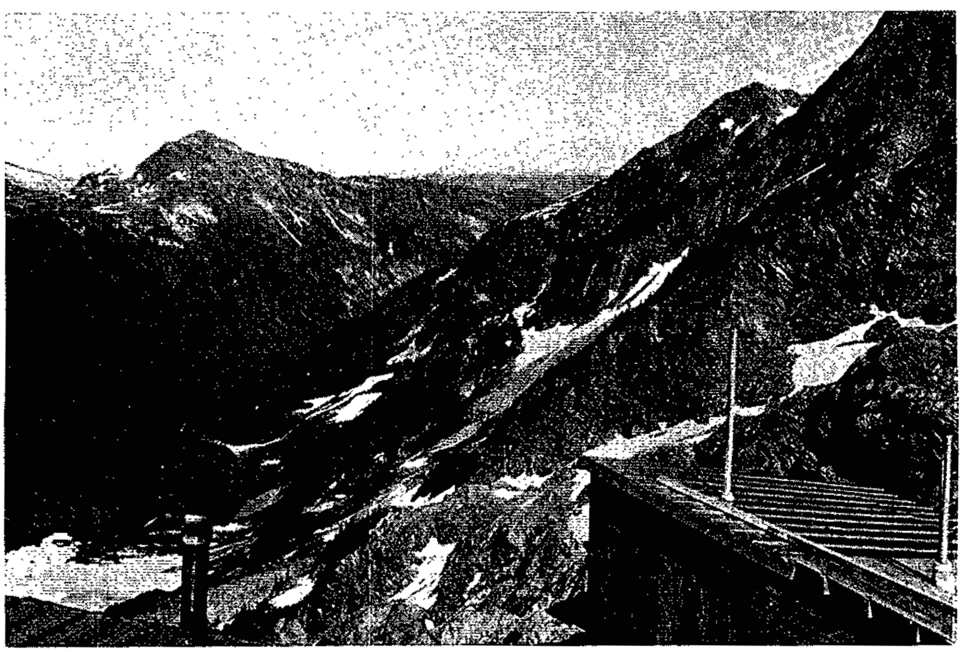

Plate II. Upper valley of Copeland Creek from the north camp of King Resources Company, looking north of east.

Plate III. Valley of Hiren Creek, looking east toward Frisby Ridge and the Selkirk Mountains in the distance. Cliffs on the right are mainly quartzite of map unit 9.

Plate IV. South Camp of King Resources Company at the portal of the Mount Copeland mine on the south slope of Copeland Ridge, looking west.

Plate V. *Phase 1 rodding in quartzite plunging steeply to the south, crossed by* Phase 2 wrinkle lineations plunging gently to the northwest, on the ridge south of Hiren Creek, 3 miles west of Jordan River. The rocks are on the steeply dipping northern limb of antiform A.

Plate VI. *Phase 2 fold in white quartzite* (map unit 2) on the ridge north of Copeland Creek, looking southeast down the plunge. A wrinkle lineation is parallel to the axis and the Phase 1 lineation is folded with the beds.

Plate VII. Phase 2 folds in nepheline-syenite gneiss (map unit A), looking northwest down the plunge of minor folds on the northern limb of antiform A, south side of Hiren Creek.

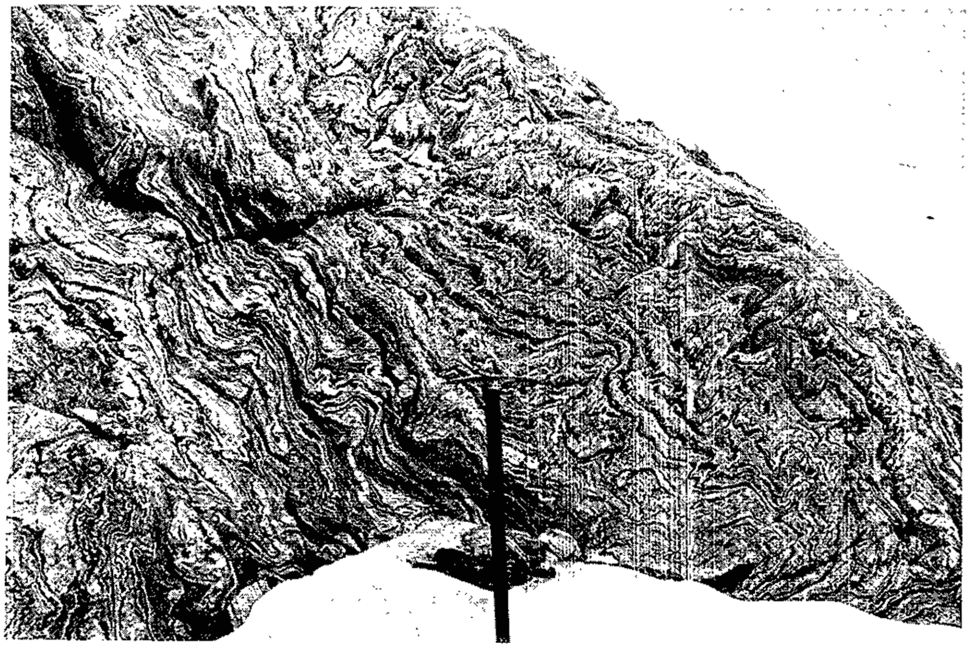

Plate VIII. Calcareous calc-silicate gneiss of map unit 8, near the western end of Copeland Ridge, showing disharmonic folds on the northern limb of synform B, view looking west down the plunge.

Plate IX. Phase 2 fold in quartzite of map unit 9 on the southwest slope of Copeland Ridge, looking east along the plunge, which is low. Mottled structures are remnants of Phase 1 folds with curved axial planes and axes oblique to the Phase 2 axes.

Plate X. Phase 2 synform (fold E) and antiform (fold F) on the King Fissure property outlined by marble, quartzite, and schist of map unit 5, looking east obliquely across the plunge.

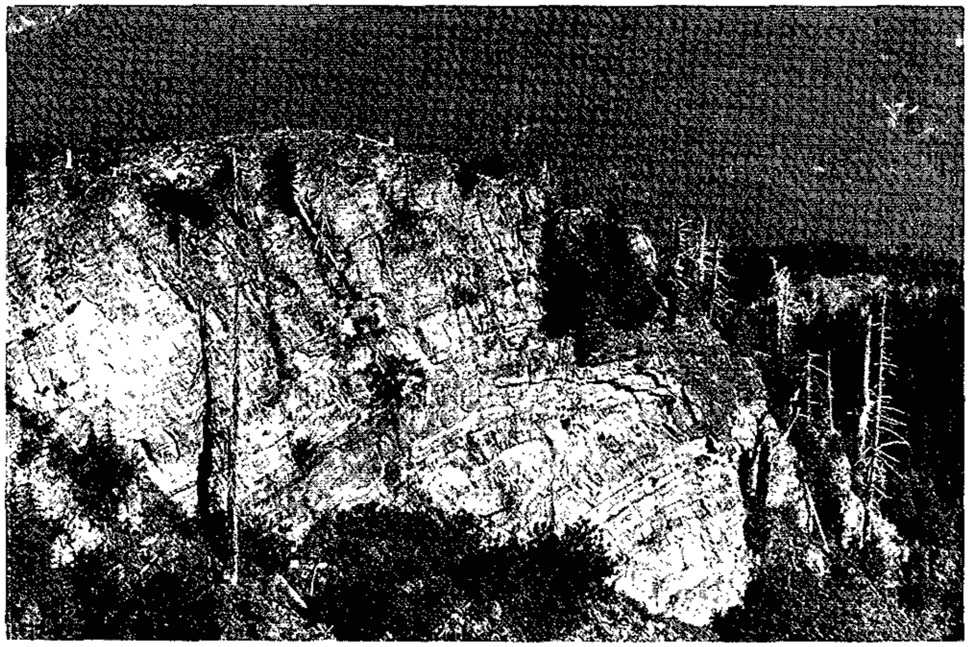

Plate XI. Large Phase 1 fold on the eastern slopes of Frisby Ridge, looking east down the plunge toward the Columbia Valley and mountains in Revelstoke Park.

Plate XII. Recumbent antiform on the northwest slope of Frisby Ridge, looking west along the gently plunging axis.

Plate XIII. Gordon Horne Peak from the west near the T showings on the Ruddock Creek property.

Plate XIV. Main Camp on the Ruddock Creek property, Light Lake, and the valley of upper Oliver Creek, 1963.

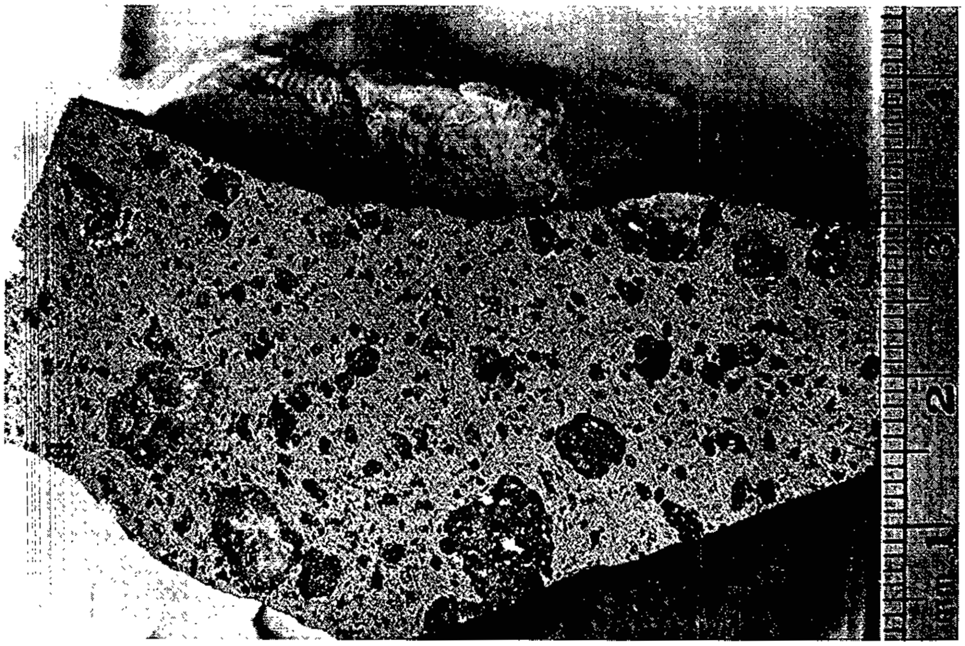

Plate XV. Pyrrhotite and sphalerite (light grey) with rounded knots of quartz (dark grey) from the sulphide layer, King Fissure property. White flecks in the quartz are pyrite and galena.

Plate XVI. Sphalerite and pyrrhotite (darkest grey) with quartz augen (white) from the sulphide layer, Ruddock Creek property.

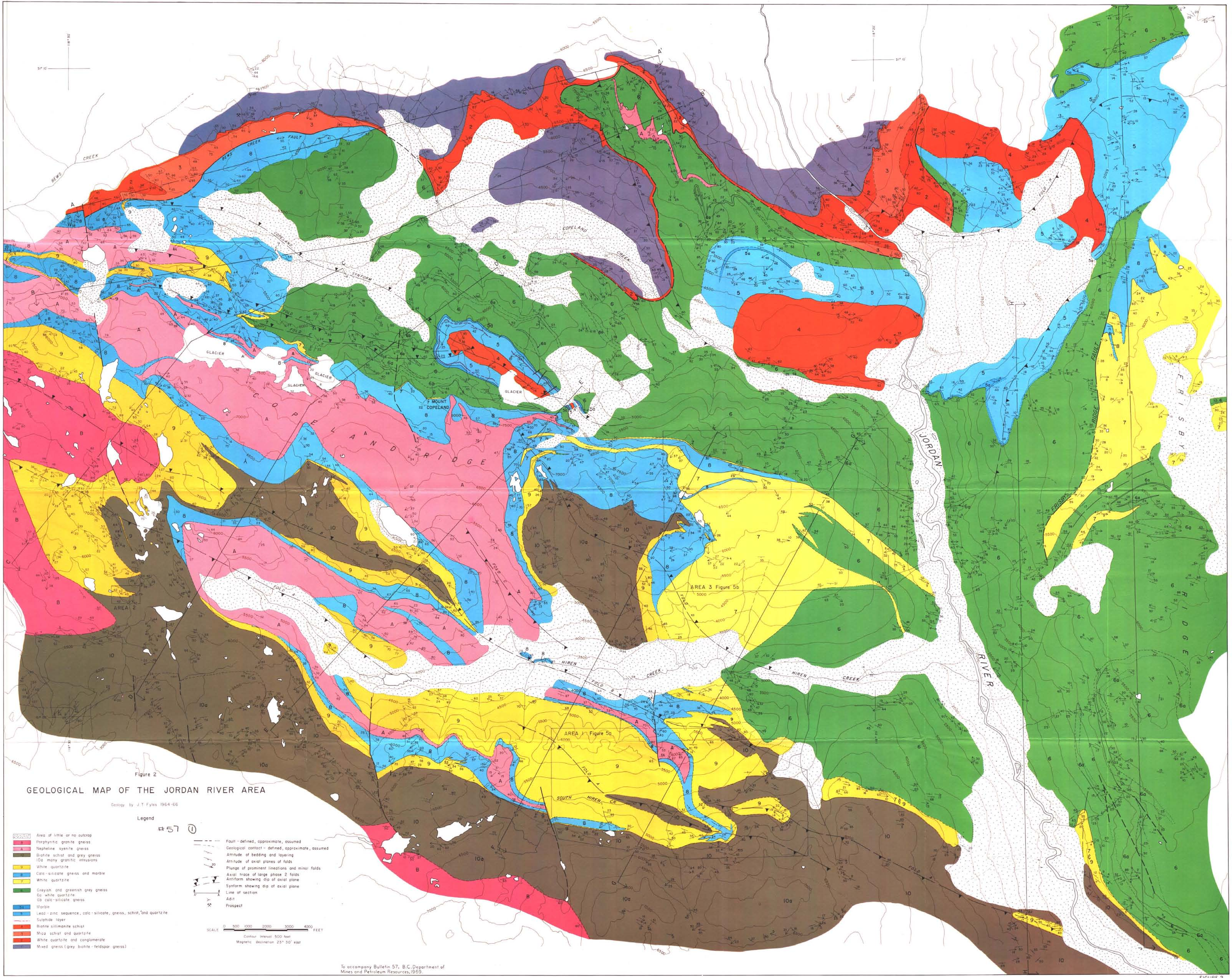

Figure 2
GEOLOGICAL MAP OF THE JORDAN RIVER AREA
Geology by J.T. Fyles 1964-66
Legend
#57 ①
Area of little or no outcrop
B Porphyritic granite gneiss
A Nepheline syenite gneiss
10 Biotite schist and grey gneiss
10a many granitic intrusions
9 White quartzite
8 Calc-silicate gneiss and marble
7 White quartzite
6 Greyish and greenish grey gneiss
6a white quartzite
6b calc-silicate gneiss
5a Marble
5 Lead-zinc sequence, calc-silicate, gneiss, schist, and quartzite
Sulphide layer
4 Biotite sillimanite schist
3 Mica schist and quartzite
2 White quartzite and conglomerate
1 Mixed gneiss (grey biotite-feldspar gneiss)
Fault - defined, approximate, assumed
Geological contact - defined, approximate, assumed
Attitude of bedding and layering
Attitude of axial planes of folds
Plunge of prominent lineations and minor folds
Axial trace of large phase 2 folds
Antiform showing dip of axial plane
Synform showing dip of axial plane
Line of section
Adit
Prospect
SCALE 0 500 1000 2000 3000 4000 FEET
Contour interval 500 feet
Magnetic declination 23° 30' east
COPELAND RIDGE
JORDAN RIVER
FRISBY RIDGE
HIREN CREEK
SOUTH HIREN CR.
COPELAND CREEK
MOUNT COPELAND
GLACIER
AREA 1 Figure 5a
AREA 2
AREA 3 Figure 5b
To accompany Bulletin 57, B.C. Department of Mines and Petroleum Resources, 1969.
FIGURE 2

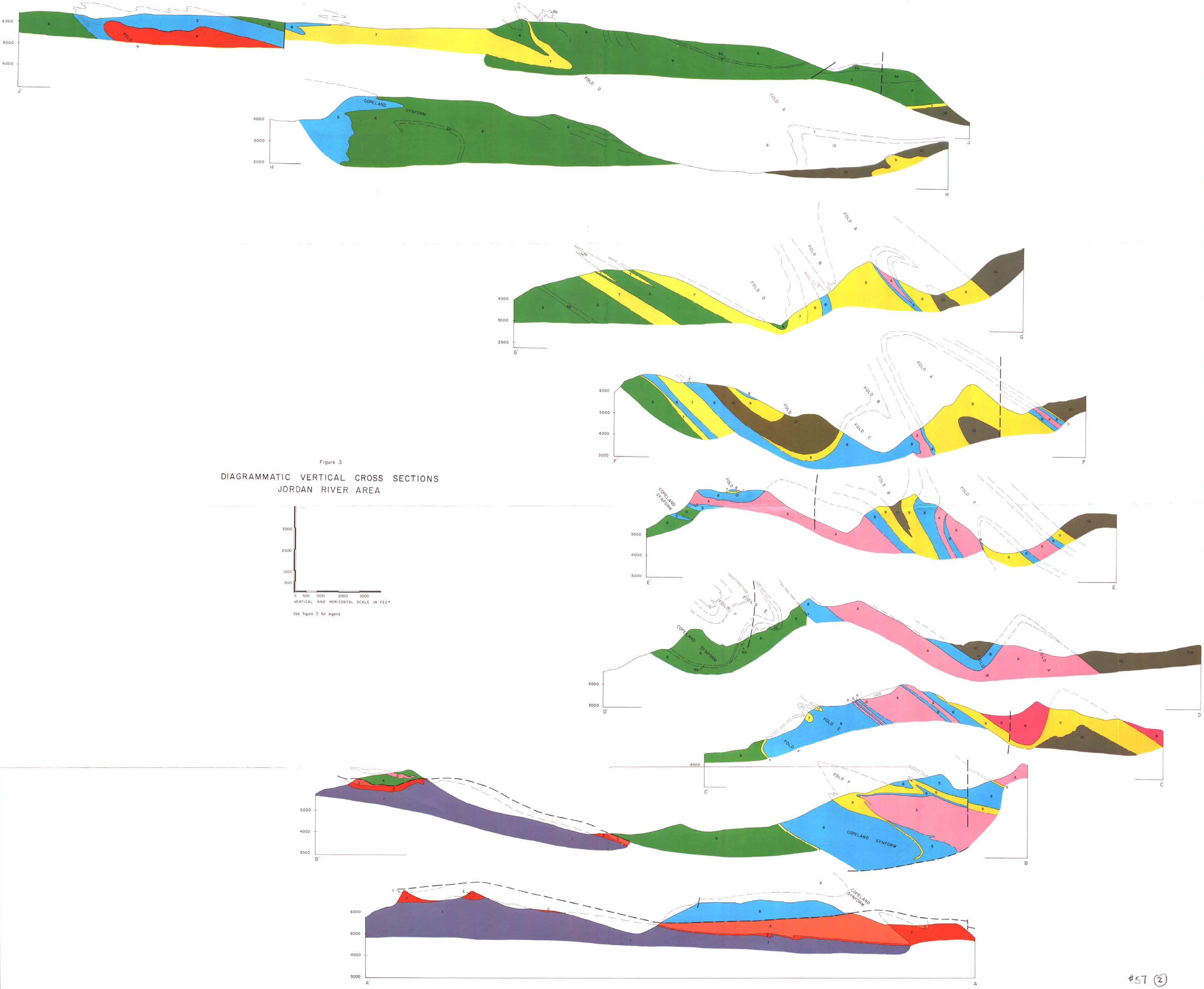

Figure 3

DIAGRAMMATIC VERTICAL CROSS SECTIONS
JORDAN RIVER AREA

#57 (2)

To accompany Bulletin 57. B.C. Department of Mines and Petroleum Resources, 1969.

FIGURE 3

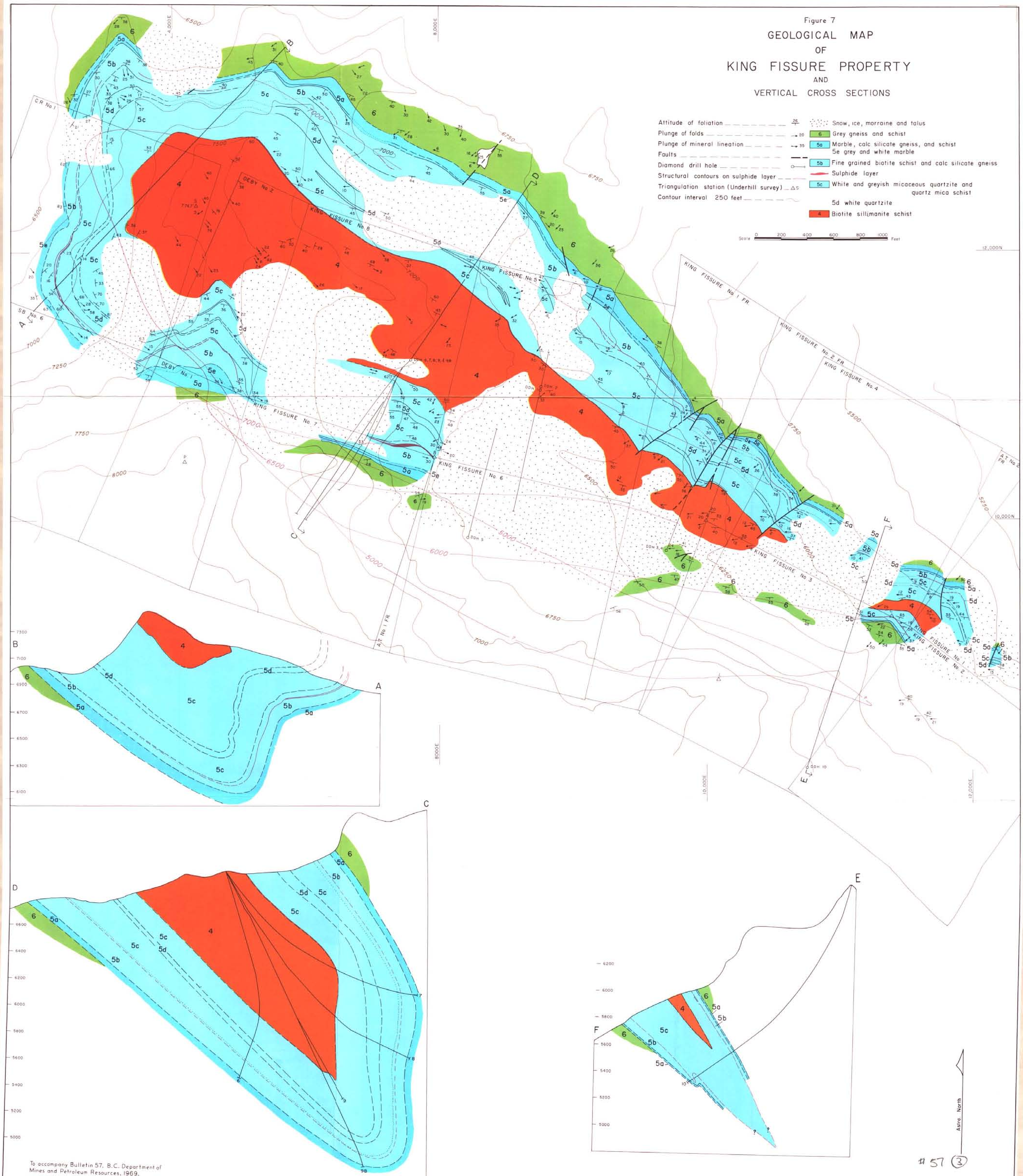
Figure 7
GEOLOGICAL MAP
OF
KING FISSURE PROPERTY
AND
VERTICAL CROSS SECTIONS
Attitude of foliation
Plunge of folds
Plunge of mineral lineation
Faults
Diamond drill hole
Structural contours on sulphide layer
Triangulation station (Underhill survey)
Contour interval 250 feet
Snow, ice, morraine and talus
6 Grey gneiss and schist
5a Marble, calc silicate gneiss, and schist
5e grey and white marble
5b Fine grained biotite schist and calc silicate gneiss
Sulphide layer
5c White and greyish micaceous quartzite and quartz mica schist
5d white quartzite
4 Biotite sillimanite schist
Scale 0 200 400 600 800 1000 Feet
KING FISSURE No. 8
KING FISSURE No. 5
KING FISSURE No. 7
KING FISSURE No. 6
KING FISSURE No. 3
KING FISSURE No. 1 FR
KING FISSURE No. 2 FR
KING FISSURE No. 4
DEBY No. 2
DEBY No. 1
Astro. North
To accompany Bulletin 57, B.C. Department of Mines and Petroleum Resources, 1969.

#57 (3)

Figure 9
DIAGRAMMATIC MAP AND CROSS-SECTIONS
RUDDOCK CREEK PROPERTY
(IT AND IN CLAIMS)

FIGURE 9