

RIFT, A ZINC-LEAD MASSIVE SULPHIDE DEPOSIT
IN SOUTHEASTERN BRITISH COLUMBIA
(82M/15)

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INTRODUCTION

Rift is a stratiform zinc-lead-(copper-silver) massive sulphide showing located approximately 100 kilometres north of Revelstoke. It is easily accessible, exposed in a creek gully at an elevation of 750 metres, approximately 0.5 kilometre east, up the slope from Highway 23.

The Rift showing was discovered in 1980 as a result of a joint exploration program by J. M. Leask and E & B Exploration, Inc. Property mapping at 1:25 000 and 1:10 000 scales was initiated in 1981 by one of the authors (G. Gibson), and continued in 1982 (Gibson, 1981, 1982). Geophysical and geochemical surveys have been done in the immediate vicinity of the showing, but the continuation of the sulphide layer has not been tested by drilling. Detailed property mapping and a mineralogical study formed the basis of a B.Sc. thesis (Hicks, 1982).

REGIONAL TECTONIC SETTING

The Rift zinc-lead-(copper-silver) occurrence is in isoclinally deformed metasedimentary and metavolcanic rocks of the Selkirk allochthon in the immediate hangingwall of the east-dipping Columbia River fault zone (Fig. 1). The Selkirk allochthon is a composite terrane that was tectonically emplaced from west to east over core gneiss and mantling gneiss of the metamorphic infrastructure (Monashee Complex) along the Monashee décollement and Columbia River fault zone during Middle Mesozoic to Eocene time (Read and Brown, 1981).

Five kilometres north of the Rift occurrence the Columbia River fault terminates, and northwest-trending Hadrynian strata of the Horsethief Creek Group can be traced across Columbia Valley into the Shuswap Metamorphic Complex (Simony, et al., 1980; Raeside and Simony, 1983). Major displacement along the fault in this area may be passed to at least three major southwest-dipping bedding faults or slides that splay eastward off the fault zone into the Selkirk allochthon. These three faults have been used to subdivide the northern Selkirk allochthon into tectonic slices (Read and Brown, 1981).

The French Creek, Goldstream, and Clachnacudainn slices (Fig. 1) contain overturned stratigraphy resulting from a period of early nappe formation (Phase 1) possibly initiated during the Devonian-Mississippian Caribooan or Antler orogeny (Brown, 1978; Read and Brown, 1979). Subsequent

polyphase folding, high-grade regional metamorphism, and granitic plutonism occurred during the Middle Jurassic Columbian orogeny.

Isoclinal Phase 2 folds are dominant along the southwestern flank of the Selkirk allochthon where they are strongly overturned toward the southwest (Lane, 1977; Hoy, 1979). Phase 3 folds dominate on the northeastern flank where strata are overturned toward the northeast. An intervening zone of structural interference termed the Selkirk fan (Wheeler, 1965; Brown and Tippett, 1978) trends northwest, crossing from Illecillewaet slice into French Creek slice in the vicinity of Argonaut Mountain (Fig. 1).

STRUCTURE, METAMORPHISM, AND PLUTONIC ACTIVITY - BIGMOUTH CREEK AREA

South of Bigmouth Creek, structures are dominated by large recumbent isoclinal second phase folds with shallow northeast-plunging axes (Fig. 2). These folds comprise a structural stack at least 2 kilometres thick in the hangingwall of the Columbia River fault zone. A major structure of this generation is well exposed in the north canyon wall of Nicholls Creek where marble units are greatly thickened in the hinge of an east-closing synform. Marble units can be traced northward from Nicholls Creek along Route 23 to north of Bigmouth Creek where they gradually deflect eastward to resume the regional northwest structural grain. As they deflect, the attitudes of second phase isoclines change

from northeastward with nearly flat-lying axial surfaces to northwestward with southwest-dipping axial surfaces and shallow southeast plunges.

Third phase folds are broad upright arches plunging northwest south of Bigmouth Creek but become compressed and isoclinal northward, where second and third phase structures are approximately coaxial.

Superposition of coaxial second and third phase folds near the head of Beryl Creek produced megascopic Type 3 (Ramsay, 1967) interference patterns (Fig. 3).

Continuity of lithologies around the arcuate structural pattern north of Bigmouth Creek (Fig. 2) casts doubt on the existence, in the lower Bigmouth Creek area, of the 'Goldstream thrust' (Fig. 1), which is a north-dipping reverse fault separating French Creek slice from Goldstream slice (Campbell, 1972; Read and Brown, 1981). Instead, Goldstream thrust probably merges with the Columbia River fault in low ground near the mouth of Nicholls Creek, where elimination of stratigraphy has occurred along bedding faults that truncate the lower limb of Nicholls Creek synform (Fig. 2).

At the outcrop scale, Phase 2 fabrics and fabrics associated with major stratigraphic inversion in Phase 1, are difficult to separate. The prevailing minor structure is a penetrative mineral foliation, outlined by mica grains in schistose rocks, that is axial-planar to both Phase 1

- and Phase 2 (designated S_2). Throughout the area mapped, S_2 and primary layering are parallel or near parallel, indicating isoclinal deformation.
- The limbs of associated minor folds (F_2) are severely attenuated along
- the S_2 foliation with complete transposition to rootless intrafolial isoclinal folds common in many examples.

A steeply dipping crenulation cleavage (S_3) is axial planar to third phase minor folds; this cleavage is most apparent in the south where third phase axial surfaces are at a high angle to second phase foliation.

Grades of medium-pressure Barrovian metamorphism increase from south to north toward the 'Windy Range High' (Wheeler, 1965; Campbell, 1972; Leatherbarrow and Brown, 1978), a northwest-trending culmination in the sillimanite-K-feldspar metamorphic zone near Birch Creek. South of Bigmouth Creek, the widespread chlorite-biotite-muscovite-quartz assemblage in pelitic rocks defines a broad chlorite-biotite zone. This gives way northward to assemblages of the garnet zone and, in the vicinity of Rift Creek, to staurolite zone rocks. North of Beryl Creek, sillimanite-muscovite zone rocks are associated with pegmatite. Omission of kyanite zone rocks may be related to post-metamorphic faulting in Beryl Creek (Fig. 2).

Bigmouth Creek stock is a synkinematic (?) quartz monzonite pluton of probable Cretaceous age. Porphyry, with very large (to 5-centimetre) rimmed orthoclase phenocrysts embedded in a matrix of quartz, orthoclase,

plagioclase, and biotite, is cut by late stage leucocratic granite and aplite.

LITHOLOGY

Detailed mapping in 1981 and 1982 has confirmed the lateral equivalence of marble units in Nicholls canyon (Lower Cambrian Badshot Formation of Wheeler, 1965) with marbles north of Bigmouth Creek (Hadrynian Horsethief Creek Group of Wheeler, 1965; ~~and~~ Brown, ~~■w~~bet al., ~~■wa~~ 1977). This gives rise to regional stratigraphic and structural problems that cannot be resolved without further mapping between Nicholls Creek and the Goldstream copper-zinc deposit (Fig. 1). At present, formal assignment of map units to the Paleozoic Hamill Group (Marsh Adams Formation, Mohican Formation) and Lardeau Group (Badshot Formation, Index Formation, Jowett Formation, Broadview Formation) on the one hand, or the Hadrynian Horsethief Creek Group on the other, is not possible.

Three informal lithologic sequences were distinguished in the Nicholls Creek area: an eastern grit sequence (unit 1), a central 'pelite' sequence (unit 2), and a western carbonate sequence (unit 3). Top determinations from graded grit beds in unit 1 indicate that stratigraphy becomes younger toward the core of Nicholls Creek synform; this provides the basis for Figure 4a, a composite stratigraphic section. Note that scale bars on Figure 4 are approximate in view of the pronounced tectonic thickening of units in fold hinges and thinning on limbs.

UNIT 1 - 900 metres (base not exposed)

This unit consists of massive graded grit and laminated chlorite schist cycles in rhythmic units 10 to 50 metres thick. Narrow impure marble layers and talc schist lenses are a minor component of the section, as are massive, dark grey hornblende-garnet calc-silicate layers to 10 metres in thickness. The upper contact of unit 1 is locally marked by a clean calcite marble ^{layer} horizon up to 5 metres thick.

UNIT 2 - 200 metres

In unit 2, dark, recessive, locally graphitic quartz-biotite schist predominates. Banding, on a 1 to 10-centimetre scale, is caused by alignment of lensoidal quartz segregations that contain carbonaceous or micaceous layers and limy partings. Pyrrhotite comprises up to 10 per cent of the rock as fine disseminations and streaks, leading to rusty-weathering colours in most outcrops. The upper contact of unit 2 is transitional with unit 3 where interlayers of friable calcareous schist or impure marble appear in the section.

UNIT 3 - 500 metres (top not exposed)

South of Bigmouth Creek, unit 3 includes two prominent massive, grey, thick-bedded marble units, each 150 to 200 metres thick, separated by 200 to 400 metres of schist. Marble units are mainly calcitic, but are locally dolomitized or silicified. Layering is enhanced by variations in calcite grain size and by intercalations of argillaceous or micaceous material. Upper and lower contacts of the carbonate rock units are usually poorly defined and comprise zones of pure and impure marbles alternating with schists and other clastic rocks.

Schists of unit 3 are rusty weathering, banded, and variably graphitic or calcareous. Dark greenish black 'greasy'-lustered chloritic layers mimic graphite in some exposures; with increasing chlorite content the rock grades to thick-layered quartz-chlorite schist with chert layers and lenses. Pink garnets and pyrite-pyrrhotite disseminations are common and black manganese crusts develop on fractures cutting the unit.

Several horizons of white-weathering orthoquartzite, that are 10 to 30 metres thick, are a minor but distinctive component of unit 3, south of Bigmouth Creek.

— North of Bigmouth Creek the Rift zinc-lead-(copper)^{silver} sulphide layer is contained in a 400-metre-thick, varied but largely schistose interval of unit 3 that lies between marble units (Fig. 4b). Staurolite zone rocks exposed in Rift Creek consist of layered quartz-garnet pelitic schists and layered calc-silicate rocks with subordinate psammite and marble. Intrusive masses of K-feldspar porphyritic garnet-biotite quartz

monzonite invade the metasedimentary rocks as sills, dykes, and narrow (<10-centimetre) anastomosing, layer-parallel tongues; contacts are often gradational against the country rocks. One hundred metres above the sulphide layer is a pod-like, sheared ultramafic body, 15 metres thick, containing large (to 3-centimetre) cleaved metacrysts of magnesite in a matrix of antigorite, talc, and magnetite. The ultramafic body contains — ^{SP} 2300 ppm nickel, 106 ppm cobalt, and 175 ppm copper (Hicks, 1982).

North of Beryl Creek polydeformed strata of unit 3 are in the sillimanite metamorphic zone. These include at least three coarsely recrystallized — calcite marble ^{layers} horizons, 10 to 100 metres thick, separated by quartz-mica schist, psammite, amphibolite, and calc-silicate rock (Fig. 3).

RIFT ZINC-LEAD-(COPPER-SILVER) DEPOSIT

The Rift showing consists of a number of thin layers of massive sphalerite, pyrite, pyrrhotite, and galena exposed for approximately 25 metres of strike length in a steep-sided creek gully; the thickest of the layers is about 2 metres thick. A number of thin discontinuous massive sulphide lenses, separated by schistose quartz-rich and somewhat calcareous rocks with disseminated sulphides, occur in the immediate 2 to 3 metres of footwall (Fig. 5). Hangingwall rocks are more calcareous and sulphide content is generally lower. A second massive sulphide zone, called the 'upper showing' (Hicks, 1982), is exposed approximately 90 metres stratigraphically above the main showing. Intervening rocks

include calcareous schists and thin marble bands, overlain by more pelitic schists.

— The massive sulphide layers are irregularly laminated on a <1 to 10-centimetre scale. Individual laminae consist of granular, sphalerite-rich assemblages; fine-grained, dark sphalerite; fine-grained galena that contains 1 to 2-millimetre rounded pyrite clots; or medium-grained pyrite or pyrrhotite-rich layers. Sphalerite is commonly the most abundant sulphide; pyrrhotite is abundant in the southern part of the creek gully exposure, whereas pyrite predominates in the northern part (Hicks, 1982). Galena averages from 5 to 8 per cent, and chalcopyrite and arsenopyrite occur in trace amounts. Predominant gangue minerals in the massive sulphide layers include quartz, muscovite, calcite, and minor amounts of clinozoisite. Thin calc-silicate and quartz-rich gangue layers with variable amounts of disseminated sulphides occur within the sulphide layers.

Chemical analyses of the massive sulphide layers reflect the high sphalerite content, with zinc ranging from approximately 24 to 32 per cent (Table 1). The weighted average of 25 chip samples is 29.75 per cent zinc, 5.28 per cent lead, and 0.03 per cent copper (Hicks, 1982). Gold values ranged from 0.06 to 0.25 gram per tonne and silver, from 0.3 to 10 grams per tonne in seven grab samples collected by ^{S.} M. Leask (personal communication, 1980). Gold and silver values for the six massive sulphide samples analysed in this study (Table 1) were below the

utilized detection limits of 0.3 and 10 grams per tonne respectively.

spell out? Semi-quantitative emission spec values for barium ranged from trace amounts to 1.2 per cent in a footwall sample (84R-9B). Hicks (1982) reported a slight but distinct chemical zonation with Pb/Pb + Zn increasing vertically. This was not confirmed, however, in our limited sampling; in two sets of chip samples across the sulphide layers and immediate host rocks Pb/Pb + Zn apparently varied randomly from approximately 0.18 to 0.8 (Table 1; Fig. 5).

Disseminated sulphides, primarily pyrrhotite and sphalerite, occur throughout the immediate footwall rocks; zinc averages 3.11 per cent and lead, 0.48 per cent (Hicks, 1982). Sulphide content in hangingwall rocks is lower; zinc averages 0.8 per cent and lead, 0.2 per cent.

Immediate host rocks for the massive sulphide layer include calcareous, quartz-rich schists. They strike east-southeast, and dip variably to the south (Fig. 6). Tight to isoclinal minor folds and a distinct biotite and muscovite foliation that generally parallels layering reflect the intense regional deformation. Thin, rusty-weathering amphibolite, calc-silicate gneiss, and diopside and actinolite-bearing marble layers occur in both footwall and hangingwall rocks. Dark grey, fine-grained impure quartzite layers are common in the footwall, and an impure marble forms the immediate hangingwall. Medium to coarse-grained orthogneiss, and late stage quartz monzonite sills and dykes intrude the succession.

COMPARISON WITH OTHER LEAD-ZINC DEPOSITS, SOUTHEASTERN BRITISH COLUMBIA

The Rift deposit contrasts markedly with lead-zinc deposits in the Kootenay Arc to the south (Fyles, 1970; Hoy, 1982). Kootenay Arc deposits include deposits in the Salmo camp, and the Bluebell, Duncan, and Wigwam deposits (Fig. 1). They are hosted by a relatively pure, but locally dolomitized, silicified, and brecciated Lower Cambrian carbonate unit. Although deformation may be intense, the regional metamorphism is generally of greenschist facies grade. Rift has, however, many similarities with lead-zinc deposits that occur in the Shuswap Metamorphic Complex to the west. These deposits include Cottonbelt and Jordan River on the flanks of Frenchman Cap dome and Big Ledge on the southern flank of Thor Odin dome (Fig. 1). These deposits are large, stratabound, sulphide-rich layers within well-layered platformal successions of dominantly carbonate, schist, and quartzite (Hoy, 1982). The immediate host rocks are generally calcareous schists. Pyrrhotite and sphalerite are the dominant sulphides, with galena and pyrite as minor phases. Shuswap deposits, and the Rift deposit, are part of the enclosing stratigraphic succession and have undergone all phases of the intense regional metamorphism and deformation. They are examples of the 'exhalitive sedimentary' (or sedex) deposits of Hutchinson (1980), and formed by base metal accumulations in a shallow marine, dominantly clastic environment.

Age estimates for the Rift showing from galena lead-isotope data (C.I. Godwin, personal communication, 1984) summarized in Hicks (1982) are lower Cambrian to upper Hadrynian (≈ 0.52 Ga). Similar isotopic characteristics and age estimates are obtained for the stratiform deposits of the Anvil District, Yukon Territory and the Cottonbelt deposit (Hicks, 1982)

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TABLE 1
BASE METAL ANALYSES OF MASSIVE SULPHIDE LENSES AND HOST ROCKS, RIFT SHOWING
(See Fig. 5 for sample locations)

No.	Pb per cent	Zn per cent	Cu per cent	Pb/Pb+Zn	Lithology
84R-10	5.75	29.3	0.017	0.164	upper massive sulphide lens
84R-9C	13.9	25.1	0.009	0.356	main massive sulphide lens
84R-8F	6.83	31.7	0.067	0.177	main massive sulphide lens
84R-8E	7.01	31.3	0.067	0.182	main massive sulphide lens
84R-9B	0.048	0.012	0.018	0.800	siliceous, calcareous schist
84R-9A	9.01	23.9	0.039	0.273	lower massive sulphide lens
84R-8C	5.00	26.8	0.032	0.157	lower massive sulphide lens
84R-8B	0.015	0.074	0.021	0.202	chert, quartzite, siliceous schist

*Arrange
in order
84R-3B,
etc.*

OK as is