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DEPARTMENT OF ENERGY, MINES AND RESOURCES

BULLETIN 208

GEOLOGY AND ORIGIN OF THE FARO, VANGORDA, AND SWIM CONCORDANT ZINC–LEAD DEPOSITS, CENTRAL YUKON TERRITORY

D. J. Tempelman-Kluit

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Faro open pit and millsite during early development stages, 1968.

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PREFACE

By far the most economically valuable mineral deposits discovered in Yukon Territory to date occur in the Anvil Range. In this report the geology and origin of these massive zinc–lead deposits are discussed and data which will be of assistance to continued mineral exploration in the district are presented.

Y. O. FORTIER,
Director, Geological Survey of Canada.

OTTAWA, June 3, 1970

BULLETIN — Entstehung und geologischer Aufbau der konkordanten Zink-Blei-Lagerstätten Faro, Vangorda und Swim (Zentral-Yukonterritorium)

Von D. J. Tempelman-Kluit

Die bankigen, mit der vorherrschenden Schieferungsrichtung des Nebengesteins konkordant verlaufenden Ablagerungen liegen in kambrischen (?) Phylliten. Der Autor schliesst daraus, dass sie vor der Metamorphose und Verformung des betreffenden Gebiets entstanden sind.

БЮЛЛЕТЕНЬ -- Геология и происхождение фарских, вангордских и суимских согласных залежей цинка и свинца, центральная часть территории Юкон

Д. Й. Темпельман-Клюйт

Залежи встречаются в кембрийском (?) филлите, пластинчатые и согласные с выдающейся тонкой слоистостью вмещающих пород. Автор приходит к заключению, что эти залежи возникли до наступления регионального метаморфизма и деформации.

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GEOLOGY AND ORIGIN OF THE FARO, VANGORDA, AND SWIM CONCORDANT ZINC–LEAD DEPOSITS, CENTRAL YUKON TERRITORY

Abstract

Anvil Range is underlain by a thick sequence of Hadrynian and/or Cambrian low and intermediate grade metamorphic rocks formerly thought to be of Mississippian age. These rocks are overlain by Devono-Mississippian sedimentary strata and by Pennsylvanian and Permian volcanic and sedimentary rocks. The metamorphic, sedimentary, and volcanic strata are intruded by Cretaceous granitic rocks.

Probable Cambro-Ordovician deformation and metamorphism have imposed a strong crenulation foliation on the Cambrian (?) and older strata. Younger rocks are weakly deformed and unmetamorphosed. A number of long, steep-dipping, parallel, northwest-trending faults, some of which are intruded by peridotite, lie along Tintina Trench. Early Triassic and Late Cretaceous dip-slip movement is demonstrated on these structures, but important strike-slip displacement has probably taken place.

Three large, conformable, pyritic zinc–lead deposits aggregating more than 80 million tons of ore occur in a lithologically restricted part of the Hadrynian and/or Cambrian sequence. The deposits show evidence of having been metamorphosed and deformed together with their enclosing rocks and were apparently emplaced during Cambro-Ordovician time.

Résumé

Le chaînon Anvil recouvre une épaisse série de roches à métamorphisme faible et moyen de l'Hadrynien et du Cambrien ou du Cambrien antérieurement supposées du Mississippien. Ces roches reposent sous des strates sédimentaires du Dévono-Mississippien et sous des roches volcaniques et sédimentaires du Pennsylvanien et du Permien. Des roches granitiques du Crétacé ont fait intrusion dans les strates métamorphiques, sédimentaires et volcaniques.

La déformation et le métamorphisme, probablement du Cambro-Ordovicien, ont provoqué une forte foliation plissotée des strates du Cambrien (?) et des strates plus anciennes. Les roches plus récentes sont faiblement déformées et non métamorphisées. Le sillon Tintina est bordé par un certain nombre de failles longues, fortement inclinées, parallèles, orientées nord-ouest et dont certaines ont subi l'intrusion de la péridotite. Ces structures montrent un mouvement de rejet incliné remontant au Trias inférieur et au Crétacé supérieur, mais d'importants déplacements de la composante horizontale du rejet ont probablement eu lieu.

Trois grands gisements concordants pyriteux de zinc et de plomb, d'une réserve de plus de 80 millions de tonnes de minerais, se trouvent dans une zone lithologique restreinte appartenant aux séries de l'Hadrynien et du Cambrien ou à la série du Cambrien. Les gisements montrent qu'ils ont été métamorphisés et déformés en même temps que leurs roches encaissantes et ont apparemment été mis en place au cours du Cambro-Ordovicien.

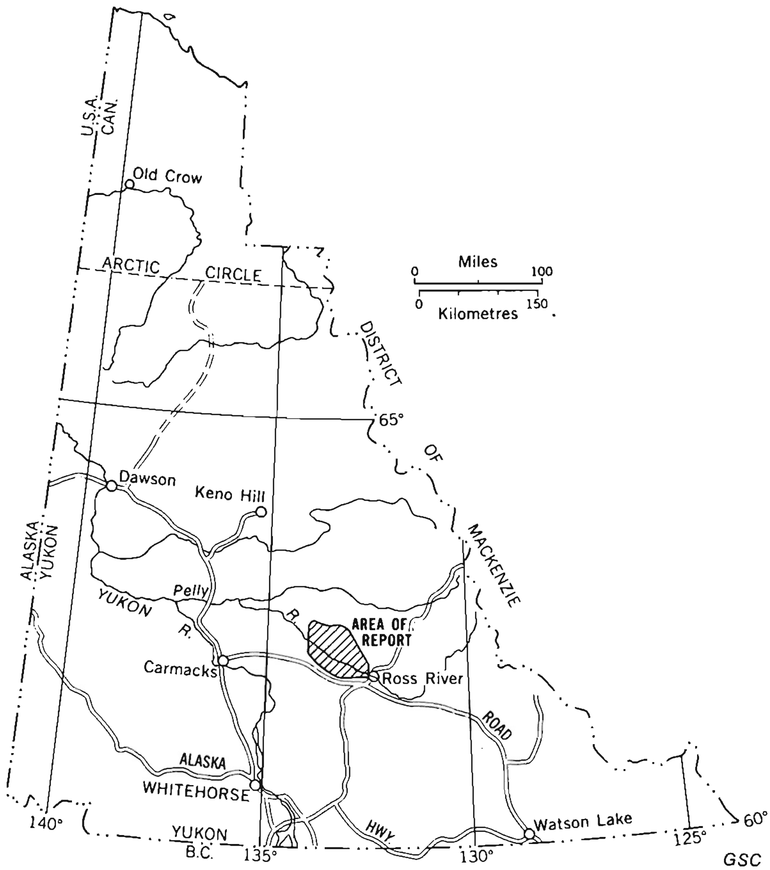

FIGURE 1. Index map.

Introduction

Anvil Range, in central Yukon Territory, contains what promise to be by far the most economically valuable mineral deposits yet discovered in the territory. The geology and origin of these massive zinc–lead deposits is discussed in this report, which also provides geological data to assist further mineral exploration in the district. The study deals with a 600-square mile region centred about 35 miles northwest of Ross River and 125 miles northeast of Whitehorse; the area is bounded roughly by Tintina Trench on the southeast, the 134th meridian on the west, Tay River valley on the north, and Ross River on the southeast (Fig. 1). The report is based on field investigations carried out by the writer during 1967 and 1968.

General Character of the Area

Anvil Range lies in the Selwyn Basin (Gabrielse, 1967a) tectonic province and the Yukon Plateau (Bostock, 1948) physiographic province, immediately north of Tintina Trench. The area is one of moderate relief characterized by smoothly rounded, dissected uplands separated by broad valleys. Outcrop is generally scarce, but good exposures are found locally along some streams and on ridge tops.

Ross River, with a population of about one hundred and fifty, is the only settlement in the district, but the town of Faro, which will house the personnel of Anvil Mining Corporation, is now (1970) under construction on the north side of Pelly River near the mouth of Vangorda Creek.

Ice covered the entire region to elevations of 6,500 feet or more during the last glacial advance. Some of the highest peaks may have escaped glaciation during this stage. The glacial history of adjacent Glenlyon map-area has been studied in detail by Campbell (1967) and many of his general conclusions apply to Anvil Range. Hughes, *et al.* (1969) have mapped glacial limits and flow patterns for a large region that includes the map-area.

Wildlife abounds in the area; of the larger mammals, moose, mountain caribou, stone sheep, grizzly and black bears, wolf, and marten are the most common. Good timber is found only along Pelly River although stunted black spruce is common on the lower slopes to elevations of about 4,000 feet. Balsam, pine and aspen are found locally. Willow, alder, and arctic black birch bushes form the undergrowth and cover the higher slopes.

Geological Work and Exploration History

The earliest recorded work by the Geological Survey in the region is that of G. M. Dawson, who in 1887 descended the Pelly River to its mouth, having portaged to the Pelly drainage from the headwaters of Frances River. Dawson's topographic map and geological

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notes describe the Anvil district briefly. In 1935, J. R. Johnston, in a reconnaissance of part of the Pelly River, produced the first geological map of the region. E. D. Kindle conducted a reconnaissance geological survey along the Canol Road in 1944 and 1945; some of his observations are applicable to the present area. Systematic mapping of Tay River and adjacent map-areas was begun in 1958 by J. A. Roddick and completed in 1960 by Roddick and L. H. Green as part of the Geological Survey's 'Operation Pelly.' R. B. Campbell investigated the geology of Glenlyon map-area west of the present area from 1949 to 1954. The district has been prospected intermittently since 1843 when Pelly River was discovered by Robert Campbell of the Hudson's Bay Company.

The Vangorda deposit was staked in 1953 by A. Kulan and associates and was optioned by Prospector's Airways, who carried out an extensive drilling and exploration program in Anvil Range between 1953 and 1956. Kerr Addison Mines Limited, the next holders of the property, staked the Swim Lakes deposit in 1963, following an airborne magnetometer survey. The mineralized zone was discovered by drilling in 1965 and 1966. Dynasty Explorations Limited began a prospecting program in the Anvil Range in 1964 and were successful in finding the Faro orebody in 1965 by a combination of geochemical and geophysical prospecting techniques. The Faro deposit was drilled in 1965 and 1966 by Anvil Mining Corporation Limited, Dynasty's successor in the ownership of the claims. Production of the Faro deposit was scheduled to begin in late 1969.

The intensive exploration of the district by companies and individuals that followed Dynasty's discovery died down by the end of 1967.

Acknowledgments

The writer thanks officers of Anvil Mining Corporation Limited, who allowed him to examine diamond-drill core and surface and underground workings on the Faro property, and who extended numerous other courtesies. Kerr Addison Mines Limited personnel were kind in permitting the writer to examine drill core obtained by them from the Swim Lakes deposit. The writer was assisted in the field by J. H. Kruzick and H. E. Dunsmore in 1967, and by G. Belik and W. F. Bawden in 1968.

General Geology of Anvil Range

The core of Anvil Range is underlain by granodiorite and porphyritic quartz monzonite that form the Anvil Batholith, intruded in Mesozoic time. A sequence of Proterozoic and Paleozoic strata, similar to that found extensively elsewhere in Selwyn Basin, flanks the Anvil Batholith. This sequence includes two regional unconformities, one beneath Devono-Mississippian strata and another below Pennsylvanian-Permian succession. The older Paleozoic rocks, dominated by thick Cambrian (?) and Devono-Mississippian sequences are mainly metamorphic and sedimentary, whereas the Pennsylvanian–Permian rocks are largely volcanic. Paleozoic beds have an aggregate thickness of about 15,000 feet. Small intrusions of Paleozoic or Mesozoic 'alpine' peridotite are associated with Permian volcanic rocks. A thick, post-Permian conglomerate lies along an important fault parallel to Tintina Trench. Acid and basic Tertiary volcanic rocks occur locally.

Unit 1

Foliated, quartz-rich metamorphic rocks, mapped as unit 1, and here included in the informally defined 'Grit Unit,' occur only along the north side of Tintina Trench where they form prominent exposures in valleys of tributaries to the Pelly River, as along the lower reaches of Vangorda Creek below the bridge. The unit consists largely of grey weathering, medium to dark grey, muscovite-bearing metaquartzite. Although the quartzite is generally massive with a pervasive foliation defined by strong preferred orientation of mica and quartz, colour banding, resulting from mineral segregation, is seen locally. The quartzite is medium to fine grained and strongly recrystallized. Locally it contains bluish grains of quartz as much as 2 mm across as well as grains of partly altered potash feldspar and these lend the rocks their gritty aspect. Muscovite, the dominant mica, occurs as ragged small flakes throughout the rocks. Chlorite is present locally in small proportions. The quartz is strongly strained, has sutured irregular boundaries and is form oriented[1]. Traces of bubble inclusions at a high angle to the foliation are common. Tourmaline and carbonate are minor constituents locally. Dark grey, graphite-rich, micaceous quartzite is commonly interfoliated with the micaceous quartz schists and is seen particularly in exposures along Vangorda Creek and Pelly River.

The stratigraphic position of unit 1 cannot be determined within the area as it is in fault or unconformable contact with younger strata wherever seen, and as older rocks are unknown. Because bedding was not recognized in these rocks no estimate of the minimum thickness of the unit can be given.

No fossils were discovered in rocks of unit 1 and their age is inferred from correlation with the lithologically similar, Proterozoic 'Grit Unit' known to occur extensively in more northerly parts of Selwyn Basin. In Sheldon, Nahanni, and Frances Lake map-areas (Roddick and Green, 1961a; Blusson, 1967b; Blusson, 1966) probable correlatives of unit 1 are estimated to be more than 10,000 feet thick. Probable correlative strata also thought to belong to the 'Grit Unit' are known southeast of the map-area immediately north of Tintina Trench in Watson Lake map-area (Gabrielse, 1967a). It has been suggested (Blusson, 1967a) that 'Grit Unit' equivalents may also underlie parts of central Finlayson Lake map-area north of Tintina Trench.

An outcrop of eclogite (?), too small to map, occurs immediately south of the Vangorda fault south of the Faro orebody[2]. The rock abuts serpentinite of unit 9 and is interfoliated with metaquartzite of unit 1. The eclogite (?) is a medium green, dense, fine-grained rock with porphyroblasts of euhedral pink garnet as much as 1 mm across. It consists largely (60 per cent) of fine-grained clinopyroxene (probably omphacite) that is colourless in thin section and has $2V \simeq 75°$. Granular aggregates of the pyroxene are composed of equant grains about 0.2 mm across. A pale green pleochroic amphibole forms prismatic grains (as much as 3 mm long) with ragged anhedral terminations. The amphibole commonly encloses grains of the pyroxene but appears to be a primary constituent rather than an alteration of the pyroxene. The garnet contains some fine grains of epidote and is commonly rimmed by minor amounts of chlorite, muscovite, saponite, and plagioclase. Opaque minerals are rare.

The association of minerals in the eclogite (?) suggests formation at extremely high pressure and temperature and the rock may represent material metamorphosed deep in the crust that has been moved to its present level along the Vangorda fault.

Unit 2

Unit 2, composed of biotite–quartz schist with associated laminated argillaceous calc-silicate rocks, borders the north and south margins of the Anvil Batholith and forms fair exposures along ridge tops. Its best exposures are along the ridge north of the Faro orebody.

[1]This term is used to describe a rock texture in which long axes of ovoid or ellipsoidal grains show preferred orientation. The rock does not necessarily exhibit preferred orientation of crystal axes.

[2]This locality has been described in some detail by Tempelman-Kluit (1970b).

Table of Formations

Era	Period or Epoch	Formation	Map-unit	Lithology	Thickness
CENOZOIC	Tertiary		15b	Conglomerate, sandstone, shale	unknown
			15a	Basalt	unknown
			14b	Rhyolitic tuff	unknown
			14a	Quartz-feldspar porphyry	
		RELATIONS NOT KNOWN			
MESOZOIC	Cretaceous or Tertiary		13	Saussuritized porphyritic hornblende diorite	
		INTRUSIVE INTO UNITS 2, 3 and 11			
	Age unknown		12	Pyroxenite, hornblende diorite	
		INTRUSIVE INTO UNITS 2 and 3			
	Cretaceous	Anvil Batholith	11	Porphyritic biotite-quartz monzonite and grano-diorite; muscovite-biotite-granodiorite; foliated equivalents	
		INTRUSIVE INTO UNITS 2, 3 and 8			
	Lower or Middle Triassic		10	Conglomerate, shale, sandstone	±2,000
		UNCONFORMABLE ON UNIT 1			
	Upper Permian or Lower Triassic		9	Serpentinite, peridotite	
		FAULT BOUNDED			
	Upper Permian	Anvil Range Group	8c	Massive resistant recrystallized limestone	±300
	Lower Permian		8b	Basalt	±1,500
	Lower Permian and Upper Pennsylvanian		8a	Chert and siliceous tuff	±2,000
		UNCONFORMABLE ON UNITS 3, 4, 5, 6, 7			
	Upper Devonian and Mississippian		7	Slate, chert, greywacke, conglomerate, limestone	±10,000

Era	Period or Epoch	Formation	Map-unit	Lithology	Thickness
PALEOZOIC		UNCONFORMABLE ON UNITS 3 and 4			
	Middle Devonian		6	Limestone and dolomite	0–100
	Silurian and Devonian		5	Medium-grained ortho-quartzite	50
		CONFORMABLE			
	Ordovician and Silurian		4	Black slate, chert	+400
		UNCONFORMABLE ?			
PROTEROZOIC	Ordovician ? Cambrian ? and/or Hadrynian ?		3	Grey lustrous muscovite phyllite, quartzose phyllite, phyllitic schist, biotite-muscovite schist	4,000?
			3a	Andesitic greenstone, chloritic tuff	
		CONFORMABLE ?			
			2	Biotite-muscovite schist, banded quartz–diopside skarn, marble, amphibolite	+2,000?
		BASE NOT SEEN			
	Hadrynian	'Grit Unit'	1	Muscovite quartzite, graphitic quartzite	?
		BASE NOT SEEN			

Rusty weathering, brown muscovite–biotite–quartz schist, phyllite, and hornfels are the dominant lithologies of unit 2, but the characteristic rock type is a whitish weathering, laminated, pale green and purplish brown, banded skarn with schistose or phyllitic partings. The muscovite–biotite–quartz schist has a well-developed foliation and is made up largely of equant, anhedral grains of quartz with scattered subhedral books of biotite and less muscovite. Euhedral crystals of staurolite, 1 to 5 mm long, and andalusite in large, subhedral prismatic grains, are common constituents. Penninite, after biotite, is rarely present. Locally the schist grades into phyllite similar to that of unit 3. The pale green and purplish brown banded rocks consist of alternating laminae of (a) fine-grained diopside–quartz skarn with calcite, amphibole, and minor brownish grossularite, and (b) biotite–quartz schist. The greenish skarn laminae are intimately intergrown mixtures of anhedral diopside and quartz in roughly equal proportions with grains about 0.2 mm across. Laminae composed essentially of intergrown green, fine-grained tremolite–actinolite with minor chlorite commonly alternate with the skarn and schist laminae. Contacts between the various types of layers are sharp; laminae are discontinuous, probably through structural terminations. Foliation, defined by thin micaceous partings parallel to the compositional layering, is present throughout. Pyrite and pyrrhotite in small anhedral grains and grain aggregates are ever-present minor constituents, and commonly thin septa of graphite lie parallel to the foliation.

White and pale grey marble, generally restricted to a 300-foot-wide zone in the upper part of the unit, is interfoliated with the biotite schist and forms discontinuous lenses from a few inches to 50 feet thick.

Amphibolite (2a), composed of green tremolite–actinolite intergrown with andesine and minor quartz, occurs in lenses of various thicknesses throughout unit 2.

Rocks of unit 2 represent an originally calcareous, silty and argillaceous, thin-bedded and fine-grained succession, dominantly of sedimentary derivation, although the amphibolite probably represents rocks that were originally volcanic.

The stratigraphic relations of unit 2 are uncertain. Unit 2 may underlie unit 3, as suggested by regional lithologic correlation, but may also overlie that unit. A strong crenulation foliation, developed in both units, has destroyed bedding, and stratigraphic relations between the two units are obscured. The stratigraphic thickness of unit 2 is estimated to be more than 2,000 feet.

The age of unit 2 is inferred from indirect stratigraphic evidence, and because no fossils were found its assigned age must be considered tentative. Unit 2 is apparently Ordovician or older because together with unit 3 it is inferred on structural grounds to underlie fossiliferous Ordovician rocks (unit 4). The metamorphism and deformation of unit 2 is more intense than that of unit 4 and this also suggests an Ordovician or older age for unit 2. Unit 2 lacks the distinctive lithologies characteristic of the Proterozoic 'Grit Unit' and is evidently of different age.

Unit 2 is lithologically similar to known Lower Cambrian strata in other parts of Selwyn Basin and is tentatively correlated with strata of that age in adjacent areas southwest of Tintina Trench; specifically with unit 1 in Quiet Lake and Wolf Lake map-areas (Wheeler, Green, and Roddick, 1960a, 1960b) and part of the Harvey Group in Glenlyon map-area (Campbell, 1967). The occurrences of unit 2 in Anvil Range are the most northwesterly known outcrops of probable Cambrian strata on the northern side of Tintina Trench in Selwyn Basin. The nearest known probable correlatives on the northern side of Tintina Trench are in Watson Lake map-area (unit 3 of Gabrielse, 1967b) 150 miles southeast of Anvil Range. Rocks of unit 2, with those of units 3 and 8a were mapped together as unit 7 and assigned a provisional Mississippian age by Roddick and Green (1961a) in Tay River map-area.

Unit 3

Phyllitic rocks assigned to unit 3 occur extensively throughout Anvil Range, both north and south of the Anvil Batholith. They weather recessively and generally form poor exposures, except along some streams and locally on ridge tops. Good exposures of unit 3 are found along Vangorda Creek and on the stream north of the Faro airstrip.

The internal stratigraphy of unit 3 is unknown because of structural complication, but an apparent sequence, applicable for most of the unit, can be given. The lower member of this succession, about 1,000 feet thick, contains phyllite and locally schist that is distinguished by its relatively high quartz content. This member is distinctive too in containing fairly abundant graphitic phyllite and in lacking large greenstone bodies (3a) although tuffaceous beds are present. The upper member of the structural sequence, about 3,000 feet thick, contains numerous large greenstone bodies and tuffaceous beds in the phyllitic rocks. The phyllitic rocks of this member are themselves less quartzose and contain a distinctly higher proportion of the mica minerals. Graphitic phyllite is absent or rare. Thinly laminated silty limestone with phyllitic partings occurs commonly in the upper 1,500 feet of this member.

Unit 3 includes well-foliated, silvery grey weathering, greenish grey chlorite–muscovite phyllite and biotite–muscovite phyllite as well as lenses of tuffaceous greenstone and amphibolite (3a). Because of the varied metamorphism of unit 3 the rocks grade in places into schist. The phyllite commonly contains 20 per cent or less quartz, but phyllite from the lower part of the unit contains more than 50 per cent quartz. Quartz and mica are segregated and form alternating folia and the difference in quartz content between phyllite of the lower and upper members is expressed in the thickness of the competent or quartz-rich folia. Folia are generally less than 2 cm thick. The proportion of chlorite or biotite to muscovite differs; in some places muscovite is the only mica, elsewhere biotite or chlorite may constitute 25 per cent of the volume of the rock. Graphitic phyllite of the lower member generally contains 25 per cent or more graphite with quartz and muscovite, but biotite and chlorite are absent. The thinly laminated, silty, phyllitic limestone of the upper member is composed of alternating laminae (one half to 2 cm) of nonquartzose phyllite and slightly silty, micritic to very fine crystalline grey limestone. In this rock the limy laminae are thicker than the intervening phyllitic ones.

The dominant layering in the phyllite is a crenulation foliation on which an older planar structure is transposed. The crenulation foliation is marked by recrystallization of micas along discretely spaced planes and the older planar structure is defined by compositional layering, at different angles to it, resulting from segregation of quartz and mica. The compositional layering in the silty limestone may represent bedding with mimetic foliation.

The tuffaceous greenstone (3a) that occurs in the upper part of unit 3 forms lenses several tens to several hundred feet thick and several hundred to several thousand feet long. It is more resistant to weathering than the enclosing phyllite and consequently forms many of the more prominent exposures of unit 3. The greenstone is fine-grained amphibolite, composed largely of intergrown, subhedral, short, prismatic crystals of actinolite with minor chlorite or biotite and local epidote. The rock contains interstitial quartz and plagioclase (commonly albite but locally andesine) in minor amounts as well as large skeletal crystals of ilmenite partly or wholly altered to leucoxene. Minor amounts of carbonate occur interstitial to amphibole throughout the rock. A rough alignment of actinolite crystals lends the greenstone a distinct linear grain.

The greenstone bodies have a well-developed foliation near their margins but internally no such foliation is generally evident. Specimens from central parts of greenstone masses, in contrast to those from the margins, are generally coarser grained and commonly contain relict, partly altered crystals of augite, oxyhornblende, and andesine as well as the metamorphic minerals actinolite and chlorite.

Locally the greenstone includes pale green laminated, tuffaceous-looking rocks composed of fine-grained actinolite with lesser epidote and chlorite. Such rocks also occur as lenses in the phyllitic rocks.

Analyses of four specimens of greenstone from unit 3a are given in Table I. The specimens are of the freshest material available and are from widely separated localities in the map-area (Fig. 2); they are thought to represent a reasonable chemical variation for these rocks and because the analyses vary little among themselves their average is considered representative of unit 3a greenstone. Comparison shows that the greenstone is chemically similar to the average of thirty-seven alkali andesite analyses given by Nockolds (1954). Relict minerals found in the greenstone also suggest that the original rock may have been andesite.

Greenstone of unit 3a is decidedly more acid than the basalt of the Anvil Range Group (*compare* analysis E of Table I with I of Table II). The greenstone contains an average of 2.5 per cent more silica, 1 per cent more alumina, and 1 per cent less magnesia than the basalt. It should generally be possible, therefore, to distinguish these rocks from one another chemically if the physical characteristics used to separate them in the field are not apparent or if the two are closely associated, as at some localities where Anvil Range Group rocks unconformably overlie unit 3a greenstone.

TABLE I *Analyses of greenstone of unit 3a*

	A	B	C	D	E	F
SiO_2	46.8	46.2	48.5	46.7	47.1	47.63
TiO_2	1.68	1.60	1.38	3.12	1.95	2.84
Al_2O_3	14.9	15.4	15.9	16.5	15.7	14.57
Fe_2O_3	2.2	2.7	3.5	2.1	2.6	3.97
FeO	8.8	8.6	6.2	10.3	8.5	7.83
MnO	0.26	0.43	0.16	0.07	0.23	0.18
MgO	7.6	6.8	5.5	5.6	6.4	7.25
CaO	6.5	8.6	11.8	4.4	7.8	9.48
Na_2O	4.7	3.9	2.3	2.4	3.3	3.75
K_2O	0.2	0.2	0.4	1.7	0.6	1.20
H_2OT[1]	4.2	4.1	4.9	5.8	4.5	0.78
P_2O_5	0.14	0.14	0.13	0.59	0.25	0.52
CO_2	0.1	0.1	0.2	2.3	0.7	
Total	98.1	98.8	100.9	101.6	99.6	

Location of analyzed samples
A 62°20′N, 133°25 1/2′W
B 62°19 3/4′N, 133°25′W
C 62°14′N, 133°08′W
D 62°25 1/4′N, 133°09 1/2′W
Analyst: S. Courville, Geological Survey of Canada
E Average of analyses A to D inclusive
F Average alkali andesite from thirty-seven analyses (Nockolds, 1954)
[1] Total Water Content

Unit 3 is dominantly of sedimentary origin; originally the phyllite probably was silty shale. A considerable proportion of the material comprising the phyllitic rocks may be of volcanic derivation, judging from the tuffaceous-looking folia in the phyllite. The greenstone (3a) probably represents extrusive andesite, as indicated by the local occurrence of relict oxyhornblende, but an intrusive origin for some of these bodies cannot be discounted. The finely laminated amphibolite was probably volcanic tuff.

Unit 3 is overlain unconformably by Pennsylvanian and Permian volcanic rocks along its northern and southern contacts and at one locality south of the Swim deposit, by Middle Devonian strata (unit 6). Its stratigraphic relations to units 2 and 4 are not clear, but judging from the difference in intensity of deformation, unit 4 probably overlies unit 3 unconformably. The stratigraphic thickness of unit 3 is unknown, but a thickness of about 4,000 feet is estimated.

Rocks of unit 3 are of uncertain age because no fossils were discovered in them; however, they are Ordovician or older, because unit 4, which contains mid-Ordovician graptolites, apparently overlies them. Unit 3 can be correlated with rocks of known age in many parts of Yukon Territory. Parts of unit 3, particularly exposures along Vangorda Creek and certain outcrops north of Mount Mye, resemble probable Middle and Upper Cambrian strata found in the western part of Frances Lake map-area (Blusson, 1966; map-unit 10). The phyllitic rocks and greenstones of unit 3 are also similar to parts of map-unit 2 of Quiet Lake map-area (Wheeler, Green, and Roddick, 1960a) which is assigned a Middle and Upper Cambrian age; they also resemble the upper formation of the Harvey Group in Glenlyon map-area (Campbell, 1967, unit 4). Unit 3 is therefore tentatively correlated with these strata and their equivalents and assigned a Cambrian or late Proterozoic age. The nearest known equivalents of unit 3 on the north side of Tintina Trench outcrop in the northeastern corner of Finlayson Lake map-area, about 120 miles southeast of Anvil Range (Wheeler, Green, and Roddick, 1960a). Strata that are similar to, and probably correlative with, unit 3 (R.B. Campbell, pers. com., 1968) occur on the north side of the Trench in Glenlyon map-area where Campbell (1967) has included them in his Anvil Range Group.

Metamorphism of Units 2 and 3

Rocks of units 2 and 3 are metamorphosed to different degrees and range from phyllitic slate to biotite, andalusite, and staurolite schist. Metamorphic mineral assemblages found in these rocks include:

1. Quartz–muscovite
2. Quartz–chlorite–muscovite
3. Quartz–chlorite–muscovite–epidote
4. Actinolite–chlorite–quartz–albite
5. Quartz–biotite–actinolite–sphene–albite
6. Actinolite–chlorite–epidote–quartz–albite
7. Quartz–actinolite–epidote
8. Quartz–chlorite–muscovite–biotite
9. Quartz–muscovite–biotite–albite
10. Quartz–biotite–muscovite–staurolite
11. Quartz–biotite–muscovite–andalusite
12. Hornblende–biotite–quartz–plagioclase
13. Quartz–biotite–muscovite–andalusite–staurolite
14. Hornblende–epidote
15. Quartz–biotite–staurolite–cordierite
16. Quartz–diopside–calcite–chlorite
17. Quartz–diopside–plagioclase–chlorite–biotite–epidote
18. Quartz–diopside–plagioclase–sphene
19. Quartz–biotite–muscovite–staurolite–garnet
20. Quartz–biotite–muscovite–andalusite–garnet
21. Quartz–biotite–muscovite–cordierite

The assemblages are characteristic of the greenschist and almandine amphibolite facies of regional metamorphism and the order of appearance of the metamorphic minerals, i.e., biotite, garnet (locally), staurolite, andalusite, cordierite is characteristic of the Pyrenean type of metamorphism as reviewed by Hietanen (1967). This facies series is diagnostic for areas metamorphosed at relatively low load pressures.

Figure 2, a map of the isograds defined by the minerals biotite, garnet, and staurolite-andalusite, shows the approximate variation in regional metamorphic grade of rocks of units 2 and 3. Although the metamorphic zone is centred roughly on the Anvil Batholith, suggesting at a casual glance that metamorphism may be related to the intrusion, there is transgression of isograds by the granitic contact and marked variation in width of the metamorphic zone. Furthermore, the mineral assemblages are typical of regionally metamorphosed rocks.

The age of regional metamorphism of units 2 and 3 is limited to pre-Devonian by the occurrence (locality A, Fig. 2) of unmetamorphosed Devonian rocks immediately above biotite grade rocks of unit 3. Ordovician–Silurian slate (locality B, Fig. 2) shows no signs of having been affected by regional metamorphism even though chlorite–muscovite–phyllite of unit 3 is also nearby (locality C, Fig. 2). This suggests that the metamorphism may be pre-late Ordovician. It seems, therefore, that the metamorphism of units 2 and 3 is pre-Devonian and possibly pre-late Ordovician. As the rocks themselves are most likely Cambrian, a Cambro-Ordovician age for the metamorphism is suggested. This age is supported by regional evidence cited in the section dealing with ages of deformation.

Potassium–argon age determinations on coexisting biotite and muscovite in a sample of schist from unit 3 near the Faro millsite gave 93 $\pm$ 4 m.y. and 99 $\pm$ 5 m.y., respectively. These ages probably reflect a thermal metamorphic event related to emplacement of the Anvil Batholith rather than the age of regional metamorphism.

The occurrence of regional metamorphic highs around the Anvil Batholith is probably a coincidence. An apparent relationship between the degree of metamorphism and the present sequence, previously noted by Campbell (1967, p. 34) in correlative rocks of adjacent Glenlyon map-area, is evident in Anvil Range area also. Rocks of unit 2 generally contain assemblages of the almandine–amphibolite facies, whereas those of unit 3 are less metamorphosed and display assemblages of the greenschist facies. During intrusion of the Anvil Batholith, strata of units 2 and 3, already regionally metamorphosed, were raised and arched around the intrusion. This probably led to the roughly concentric arrangement of regional metamorphic isograds around the batholith.

Unit 4

Dark, recessive weathering slate of unit 4 north of Mount Mye, projects from beneath upper Paleozoic volcanic rocks of unit 8 where it underlies topographically low areas. Outcrops of unit 4 are generally poor and areas underlain by it are covered with medium to light bluish grey weathering scree.

Graptolitic black carbonaceous slate associated with dark grey to black silty shale and argillite, comprises the largest part of unit 4. Minor thin-bedded (1- to 4-inch) black, dense chert with thin carbonaceous partings was noted. On weathered surfaces the slate locally shows faint, regular colour lamination that is intersected at slight angles by a weak slaty cleavage. Small euhedral crystals of pyrite, common in the slates, locally lend the rocks a rusty weathering colour.

The dark graptolitic slate is directly, and apparently conformably, overlain by orthoquartzite of unit 5 at two localities. The slate may overlie strata of unit 3, but the basal contact is not exposed. At least 400 feet of strata, mapped as unit 4, is present in the map-area.

Two collections of graptolites from unit 4 (Appendix IA) were examined by B. S. Norford, who considers them Middle Ordovician to Early Silurian. On this evidence rocks of unit 4 are assigned to the Ordovician–Silurian and correlated with similar strata in adjacent areas mapped as unit 3 by Roddick and Green (1961a,b) and by Wheeler, Green, and Roddick (1960a,b). The fossils in unit 4 provide an upper or younger limit to the ages of units 1, 2, and 3. The marked difference in intensity and style of deformation and degree of metamorphism between unit 4 and the older rocks suggests that unit 4 overlies the older strata unconformably.

Unit 5

Small outcrops of orthoquartzite, assigned to unit 5, are found at scattered localities about 10 miles north and northeast of Mount Mye. The orthoquartzite is resistant and forms good exposures wherever it occurs. It is thick bedded and massive and lacks internal structure. The orthoquartzite is a medium to light grey rock composed wholly of well-rounded, monocrystalline quartz grains of high sphericity that range from medium- to coarse-sand sizes. The quartz grains show uniform extinction under crossed nicols. Trace amounts of tourmaline are present. Rounding of the quartz grains is more perfect in the coarse fraction than in the fines. Overgrowths of quartz in crystallographic continuity with the grains themselves, provide the only cement. Minor amounts of intergranular graphite are present throughout.

The orthoquartzite is a mature or submature sediment, possibly a second-stage sandstone; it formed under stable conditions of sedimentation, evidently in a fairly high energy environment.

Unit 5 is not more than 100 feet thick--in most places only 20 to 50 feet. It overlies unit 4 with apparent conformity and is thought to be overlain by carbonate rocks of unit 6.

Although the orthoquartzite lacks fossils, its age is bracketed by the underlying Ordovician–Silurian rocks and the apparently overlying Middle Devonian strata. Homotaxial equivalents of unit 5, that are probably Middle or Late Silurian, occur in many places southeast of the present map-area on both sides of Tintina Trench, but are considerably thicker and more extensive in these localities than in Anvil Range (Wheeler, Green, and Roddick, 1960a,b; Poole, Green, and Roddick, 1960; Blusson, 1966; Gabrielse, 1967b).

Unit 6

Small outcrops of Middle Devonian carbonate rocks (unit 6) were found at three localities; one, 3½ miles south–southwest of the Faro deposit; a second, about 2 miles south of the Swim deposit; and the other, about 8 miles northeast of Mount Mye.

At the first-mentioned locality about 25 feet of thin-bedded, platy, dark grey, fetid, carbonaceous, crinoidal, and micritic limestone occurs in an isolated outcrop apparently overlain unconformably by rocks of unit 8a and in fault contact with volcanic rocks (unit 8b ?). Diagnostic 'two-hole' crinoids from this occurrence indicate an early Middle Devonian age.

At the second locality, 'in place float' of graphitic and fetid crinoidal limestone occurs along the Swim Lakes bulldozer road[1]. In a nearby drillhole about 6 inches of the same limestone, also containing the diagnostic 'two-hole' crinoids, was intersected at a depth of 136 feet.

Massive, buff weathering light grey, bioclastic dolomite, and minor dark grey limestone, also containing Middle Devonian fossils (Appendix IB) form small isolated outcrops at the third locality north of Mount Mye. The relationship between the dolomite and limestone is not known and as bedding is not visible in these rocks the true thickness is difficult to assess; it may be as much as 50 or 100 feet. Relationships between these rocks and those of unit 5, that outcrop nearby, are obscured, but the orthoquartzite appears to underlie the carbonate rocks.

[1]The author is indebted to B. Mawer for bringing this locality to his attention.

Middle Devonian carbonate rocks (unit 4, Wheeler, Green, and Roddick, 1960a, 1960b; unit 6, Poole, Green, and Roddick, 1960; unit 12, Blusson, 1966; unit 6, Gabrielse, 1967b; unit 5 or Askin Group, Campbell, 1967) invariably closely associated with orthoquartzite like that of unit 5, are found on both sides of Tintina Trench, west, south, and southeast of Anvil Range. The outcrops of units 5 and 6 in Anvil Range are the northwesternmost known occurrences of such strata on the northern side of Tintina Trench. This and the fact that units 5 and 6 are much thinner in the map-area than their correlatives to the southeast, suggest that the assemblage changes facies or thins depositionally toward the northwest.

Unit 7

Rocks of unit 7 outcrop near the northern margin of Anvil Range and generally form good exposures along ridges. Unit 7 includes dark grey clastic rocks and associated grey to black chert. The thickness and stratigraphy of the unit has not been worked out and only a brief description of the lithologies encountered is given here. Dark grey to black, massive to thick bedded, graphitic chert, locally with poor lamination commonly associated with thin beds of dark grey, graphitic, cherty argillite and argillaceous siltstone, forms most of the outcrops of unit 7. Less commonly silty, argillaceous, medium grey limestone is found interbedded with the chert. Gritty greywacke and pebble-conglomerate, containing angular sand- and pebble-sized clasts of argillaceous chert and unstrained monocrystalline quartz as much as half an inch across locally form thick, resistant, massive, lenticular beds within the chert sequence.

Unit 7 rests unconformably on units 3, 4, 5, and 6 and is itself overlain unconformably by volcanic rocks of the Anvil Range Group; its age is therefore bracketed between Middle Devonian and Middle Pennsylvanian. During the present study Carboniferous or Permian fossils (Appendix IC) were discovered at two localities in rocks of unit 7, and Roddick and Green (1961a) also found Late Devonian and Mississippian fossils in their unit 5 which is equivalent to unit 7. Unit 7 is therefore of Late Devonian and Mississippian age. Lateral equivalents and correlatives of unit 7 occur over a large area in central Yukon northwest, southeast and south of the mapped area, and show unconformable relations to underlying strata everywhere. As mapped in the present area, unit 7 is roughly equivalent to unit 5 of Roddick and Green (1961a, 1961b), unit 5 of Wheeler, Green, and Roddick (1960a, 1960b), unit 13 of Blusson (1966), unit 7 of Gabrielse (1967b) and unit 10 of Campbell (1967). Estimates of the thickness of correlatives of unit 7 are about 10,000 feet.

Anvil Range Group

Volcanic rocks with associated chert and limestone, mapped as unit 8 and here redefined as the Anvil Range Group, occur over a large irregular area north of Anvil Batholith and form a continuous belt south of it where they underlie the first range of mountains north of Pelly River. Volcanic rocks of the group form bold resistant outcrops and underlie the more rugged peaks in the area whereas the cherty rocks are more recessive. The limestone occurs only within Tintina Trench where it forms low resistant knobs. The best exposures of unit 8 occur on Rose Mountain.

The name 'Anvil Range Group' was first used by Campbell (1967) for a sequence of grey and greenish andesitic and dioritic rocks and dark grey argillite, slate and phyllite exposed in the western part of the Anvil Range. Campbell's Anvil Range Group includes strata of probable Cambrian and of Pennsylvanian and Permian age (i.e., units 2, 3, and 8, respectively). His description does not recognize the existence of an important break between the phyllitic and volcanic rocks. The Anvil Range Group is therefore redefined here to include only those strata of volcanic affinity and of late Paleozoic age.

The Anvil Range Group is subdivided into three distinctive mappable formations: the lower, unit 8a, is a cherty and tuffaceous sequence as much as 2,000 feet thick; the middle, unit 8b, is a sequence of basalt and related volcanic rocks about 1,500 feet thick; and the upper, unit 8c, is a limestone formation with minor tuff of unknown thickness.

Unit 8a

The cherty formation is composed largely of pale green, greenish brown, light grey, and locally brick red, massive to thin bedded and laminated, more or less argillaceous and tuffaceous chert. The chert weathers an off-white and breaks into small chips; talus fragments are commonly covered with a thin film or dendritic growths of manganese oxides. Very finely divided flakes of a chlorite mineral are evenly scattered through the chert nearly everywhere and constitute a considerable proportion of its volume. Jaspery chert laminae, containing much very fine hematite, are common and locally lend the rock its distinctive, brick red colour. Thick sections of red jaspery chert occur only near the contact with volcanic rocks (unit 8b) where they commonly form a transition zone between greenish chert and massive andesite. Tiny pyrite cubes are scattered through the cherty rocks in most places. Relict 'radiolarian' spherulites, about 0.15 mm across, are common. Where evident, bedding and lamination result from alternations of more and less argillaceous chert. Innumerable tiny, irregularly oriented, quartz-filled fractures cut the chert. Massive breccia, composed of angular, but tabular, ½- to 2-inch-long chert fragments of all types set in a dark grey graphitic matrix are common throughout the sequence. They occur as lenticular beds as much as 200 feet thick, but constitute only a small proportion of the volume of the unit.

A 3-foot-thick lens of slightly sandy, brownish grey weathering, light grey, bioclastic limestone occurs in the greenish impure chert about 200 feet below the base of the volcanic member at the fossil locality on Rose Mountain. No other limestone was found within unit 8a.

Laminated green chert and siliceous tuff, lithologically like rocks of unit 8a, but differing from them in locally containing abundant potash feldspar crystal fragments, occur extensively in Tintina Trench south of Pelly River bridge where this rock has been used as rip-rap for the abutments. These rocks contain no fossils and are thought to lie in a fault-bounded block. Their stratigraphic relations are therefore unknown. The age of these cherty and tuffaceous rocks is in question, but they are tentatively correlated with unit 8a, because of their similarity to that unit.

Unit 8b

The volcanic member of the Anvil Range Group contains numerous varieties of basaltic rocks and includes tuffs, massive amygdaloidal flow rocks and pillowed basalt; massive flows and pyroclastic types are most common. The rocks are medium to dark green and massive, they lack primary layering, and rarely show foliation. Hematite, dusted through the volcanics, is especially common in exposures on the north side of Pelly River. Epidote and quartz-filled veinlets are also common in the basalt and are most prominent in the belt of rocks paralleling Tintina Trench.

Basaltic flow rocks comprise a 'mat' of tiny saussuritized plagioclase laths about 0.2 mm long that constitutes about half of their volume. Subhedral, fresh, equant to short prismatic grains of augite, about 0.5 mm across, showing occasional zoning and twinning, are scattered through the rocks and locally make up about one third of their volume. Hornblende with a pleochroic scheme in brown is present locally as subhedral short prismatic grains. Patches of penninite, with characteristic purplish and bluish birefringence, is interstitial to the primary minerals. Small euhedral grains of epidote, a normally minor constituent, are scattered through the rock, and are generally associated with chlorite. Amygdules, most of them filled with coarsely crystalline calcite, are fairly common in most outcrops but are by no means present everywhere. Other amygdule fillings include chlorite or celadonite, chalcedony, clinozoisite, and chabazite.

Amygdaloidal pillowed basalt, mineralogically identical with that described above, occurs at several localities north of the Anvil Batholith. In these rocks the pillows are about 2 feet across and normally ellipsoidal. Pillows have chilled margins; their calcite-filled amygdules are elongate and commonly arranged radially within the pillows. Where depositional tops could be determined the rocks are upright.

Fragmental or pyroclastic basalt is common north of the Anvil Batholith, but also occurs in the narrow belt of Anvil Range Group rocks just north of Pelly River. The tuffs contain angular basalt lapilli and blocks set in an altered basaltic matrix. Most fragments are like the massive flow rocks described above, but some are more scoriaceous, consisting only of a dark, nearly glassy groundmass with tiny altered plagioclase laths. Most fragments are marginally chloritized. In some of the tuffs fragments of pyroxene and plagioclase crystals constitute the smaller pyroclastic material. The groundmass of the tuffs is similar to the fragments, but is generally extremely fine grained and strongly altered to a chlorite-rich mixture. Carbonate is an important constituent in the matrix and occurs also as cavity and vein fillings.

The basalt is thermally metamorphosed near contacts with granitic rocks of unit 11. Here the rock is a dense dark green hornfels containing abundant fine, randomly oriented, prismatic crystals of actinolite intergrown with albite.

Analyses of eight specimens of Anvil Range Group basalts are given in Table II. The specimens analyzed are from widely separated localities in the map-area (Fig. 2) and probably represent the range of chemical variation in these rocks. The specimens analyzed are of the freshest material available and most are massive or pillowed basalt. Amygdaloidal and veined rocks were not analyzed. The analyses show relatively little variation among themselves and the average calculated from them (given in Table II) is probably representative of the bulk composition of the volcanic part of the Anvil Range Group. Comparison with average chemical compositions of basaltic and andesitic rocks as given by Nockolds (1954) indicates that the volcanic rocks of the Anvil Range Group are most like alkali basalt, but that they differ from this mainly in containing less magnesia and lime.

Greenish amygdaloidal basalt tentatively included in unit 8b is found at a number of scattered localities along the southern slopes of Rose Creek valley. These rocks are distinctive in containing calcite-filled, ellipsoidal amygdules, but otherwise they are similar to fine-grained tuffaceous-appearing phases of unit 8b. They are commonly sheared and have a steep-dipping cleavage. The rocks consist largely of a very fine grained mixture of chlorite and quartz. Because these rocks are apparently fault bounded, their stratigraphic relations are unknown.

The relationship between the cherty and volcanic rocks of the Anvil Range Group is clear in the vicinity of Rose Mountain, where the contact between units 8a and 8b is well exposed at several localities. There the lower member grades upward, in a 10- or 20-foot-thick interval, from tuffaceous or argillaceous chert through siliceous or cherty tuff to massive tuffaceous basalt. Similar relations are also seen laterally. The change from volcanic rocks to chert across the width of Anvil Range is a result of facies shift. The general absence of cherty rocks (unit 8a) north of the Anvil Batholith implies a change in the facies of unit 8 from dominantly volcanic north of Anvil Batholith to partly cherty in the vicinity of Pelly River.

Unit 8c

Exposures of unit 8c are of dense and massive, buff and light grey, and buff weathering limestone. Crinoid columnals are present in many places and the limestone is evidently bioclastic, but it is finely and pervasively recrystallized so that original textures are obscured and the rock is essentially a sparite. Minor quartz is present, but because grain boundaries are corroded, it is uncertain if this is diagenetic or detrital. Tuffaceous zones, marked by the presence of chlorite in the limestone, occur locally. The rock is commonly dolomitized along irregular fractures, but dolomite has not replaced the sparite itself. Bedding is distinguishable in few outcrops and for the most part the unit is so massive that no estimate of the thickness can be given. The minimum thickness of unit 8c is several hundred feet.

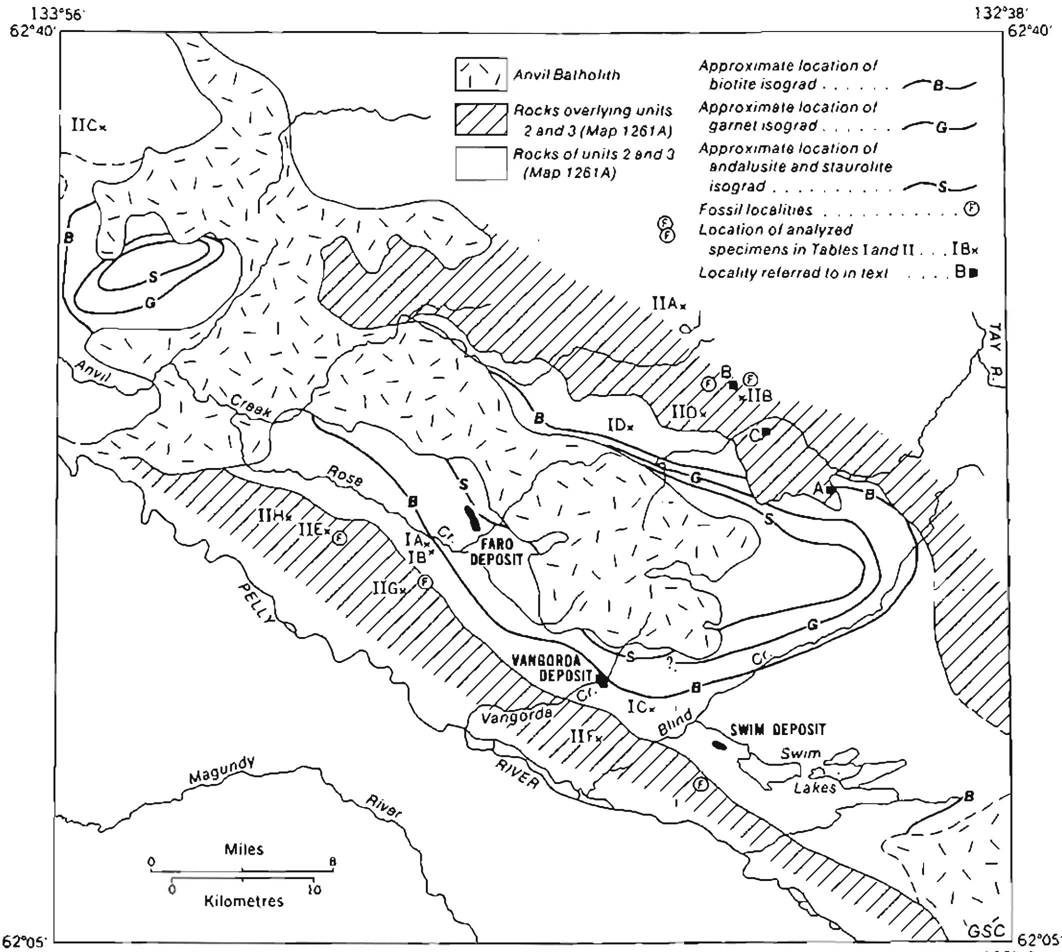

FIGURE 2. Sketch map of metamorphic mineral isograds in rocks of units 2 and 3 in Anvil area. Fossil localities and locations of analyzed greenstones are also shown and refer to tables of analyses.

TABLE II *Analyses of Anvil Range Group volcanic rocks*

	A	B	C	D	E	F	G	H	I	J	K	L	M
SiO_2	44.3	42.4	45.3	43.3	46.6	44.5	45.9	45.0	44.7	54.20	47.63	45.78	46.77
TiO_2	1.70	1.83	1.31	2.90	2.56	3.11	2.46	2.80	2.33	1.31	2.84	2.63	3.00
Al_2O_3	14.4	13.6	12.2	15.7	15.3	15.6	14.1	16.8	14.7	17.17	14.57	14.64	14.65
Fe_2O_3	1.5	2.8	1.5	4.0	1.9	3.0	3.4	2.2	2.5	3.48	3.97	3.16	3.71
FeO	8.5	9.2	7.5	9.4	10.6	9.3	7.4	9.8	9.0	5.49	7.83	8.73	7.94
MnO	0.14	0.18	0.16	0.16	0.17	0.11	0.15	0.16	0.15	0.15	0.18	0.20	0.15
MgO	7.6	7.8	11.7	5.4	8.0	8.5	5.3	5.6	7.5	4.36	7.25	9.39	6.82
CaO	8.7	9.6	10.6	10.9	5.2	3.5	8.6	6.4	7.9	7.92	9.48	10.74	12.42
Na_2O	3.4	3.0	1.5	2.8	3.8	3.9	3.3	3.9	3.2	3.67	3.75	2.63	2.59
K_2O	0.01	0.01	0.9	0.3	0.7	1.0	0.01	0.4	0.4	1.11	1.20	0.95	1.07
H_2OT	5.1	4.0	4.0	3.5	4.7	5.4	4.3	4.8	4.5	0.86	0.78	0.76	0.51
P_2O_5	0.17	0.20	0.12	0.17	0.24	0.37	0.42	0.24	0.21	0.28	0.52	0.39	0.37
CO_2	5.2	1.2	1.4	0.5	0.3	0.1	2.8	1.2	1.6				
Total	100.7	95.8	98.2	99.0	100.1	98.4	98.1	99.3	98.69				

A B C D Anvil Range Group volcanic rocks north of Anvil Batholith
E F G H Anvil Range Group volcanic rocks south of Anvil Batholith
I Average of analyses A to H inclusive
J Average andesite, forty-nine samples; Nockolds, 1954
K Average alkali andesite, twenty-seven samples; Nockolds, 1954
L Average alkali basalt, ninety-six samples; Nockolds, 1954
M Average alkali basalt without olivine, twenty-two samples; Nockolds, 1954

A 62°29 1/2′N, 133°05′W
B 62°26′ N, 133°00 1/4′W
C 62°36′N, 133°53′W
D 62°25 1/4′N, 133°09 1/2′W
E 62°20 1/2′N, 133°34′W
F 62°13′N, 133°12′W
G 62°18 1/2′N, 133°28′W
H 62°21 1/2′N, 133°38′W

Analyst: S. Courville, Geological Survey of Canada

Unit 8c lies in direct contact with cherty and volcanic rocks near Grew Creek, but the contact dips steeply and it is not clear from the exposures which rocks are the youngest. Fossil evidence, however, indicates that unit 8c is younger than units 8a and 8b and the limestone presumably overlies the cherty and volcanic rocks at Grew Creek. The contact between unit 8c and other strata is not exposed elsewhere in Tintina Trench and it is assumed that the limestone lies in a fault-bounded block.

Because Anvil Range Group strata rest at various places in the map-area on rocks of units 3, 4, 5, 6, and 7, an important unconformity is postulated at its base. In Anvil Range unit 8 overlies progressively older strata southward, and the unconformity therefore represents an interval of erosion following at least considerable tilting, but more probably open folding of Devono-Mississippian and older rocks in Late Mississippian or Early Pennsylvanian time. The unconformity beneath Anvil Range Group strata is a regional one that has also been recognized below rocks correlative with unit 8 in adjacent parts of the Yukon (Wheeler, Green, and Roddick, 1960a, 1960b). Campbell (1967, p. 61) postulated unconformable relations between his Anvil Range Group and older strata.

Rocks of the Anvil Range Group represent an episode of widespread volcanism and related sedimentation under largely marine conditions, as attested by the fossils discovered in limestone in the unit and by the presence of local pillow structure in the volcanic rocks. To explain their impurity, the cherty rocks are thought to contain much tuffaceous material; their silica could be derived in part by solution from pyroclastic ejecta. The pebbly rocks in the chert member probably represent intraformational breccias.

Foraminifera, possibly of latest Pennsylvanian but probably of Early Permian age, were collected from a thin limestone lens within unit 8a, 200 feet below the contact with unit 8b; Late Permian foraminifera are found in unit 8c. The Anvil Range Group is evidently Permian and probably ranges down into the Pennsylvanian, judging from the 1,500 feet or more of strata beneath the lowest fossils discovered in the group.

The Anvil Range Group is correlated with similar cherty and volcanic rocks in adjacent map-areas which have previously been dated as Mississippian or younger on indirect stratigraphic evidence, and included in a general way with extensive Devono-Mississippian clastic rocks. Specifically, units in Selwyn Basin roughly correlative with the Anvil Range Group, are: map-unit 6 of Wheeler, Green, and Roddick (1960a, 1960b); map-unit 7 of Poole, Green, and Roddick (1960); map-unit 13 of Blusson (1966); map-unit 8 of Gabrielse (1967b); and map-unit 15 of Campbell (1967). Rocks of the Anvil Range Group were previously mapped by Roddick and Green (1961a) in the present area as unit 8 and tentatively assigned a Mississippian or younger age. Campbell (1967) has suggested the possible equivalence between his Anvil Range Group rocks and Permo-Triassic volcanic strata in southwestern Glenlyon map-area.

The Pennsylvanian and Permian Anvil Range Group, is the northernmost known eugeosynclinal assemblage of that age in the Canadian Cordillera.

Unit 9

Serpentinite and related peridotite occur in a narrow continuous belt along Vangorda fault north of the Pelly River and are mapped as unit 9. Though more recessive than the surrounding rocks the serpentinite outcrops fairly well because of the local rough terrain. Aeromagnetic data for Tay River area closely outline the known serpentine bodies and provide an accurate check on occurrences and extensions of small bodies covered by overburden (Fig. 3).

The dominant rock-type in unit 9 is dark green to black serpentinite. In thin section it is evident that the serpentine, mostly antigorite, is pseudomorphous after original olivine and orthopyroxene. Locally the rocks are only weakly serpentinized and here it is clear that the

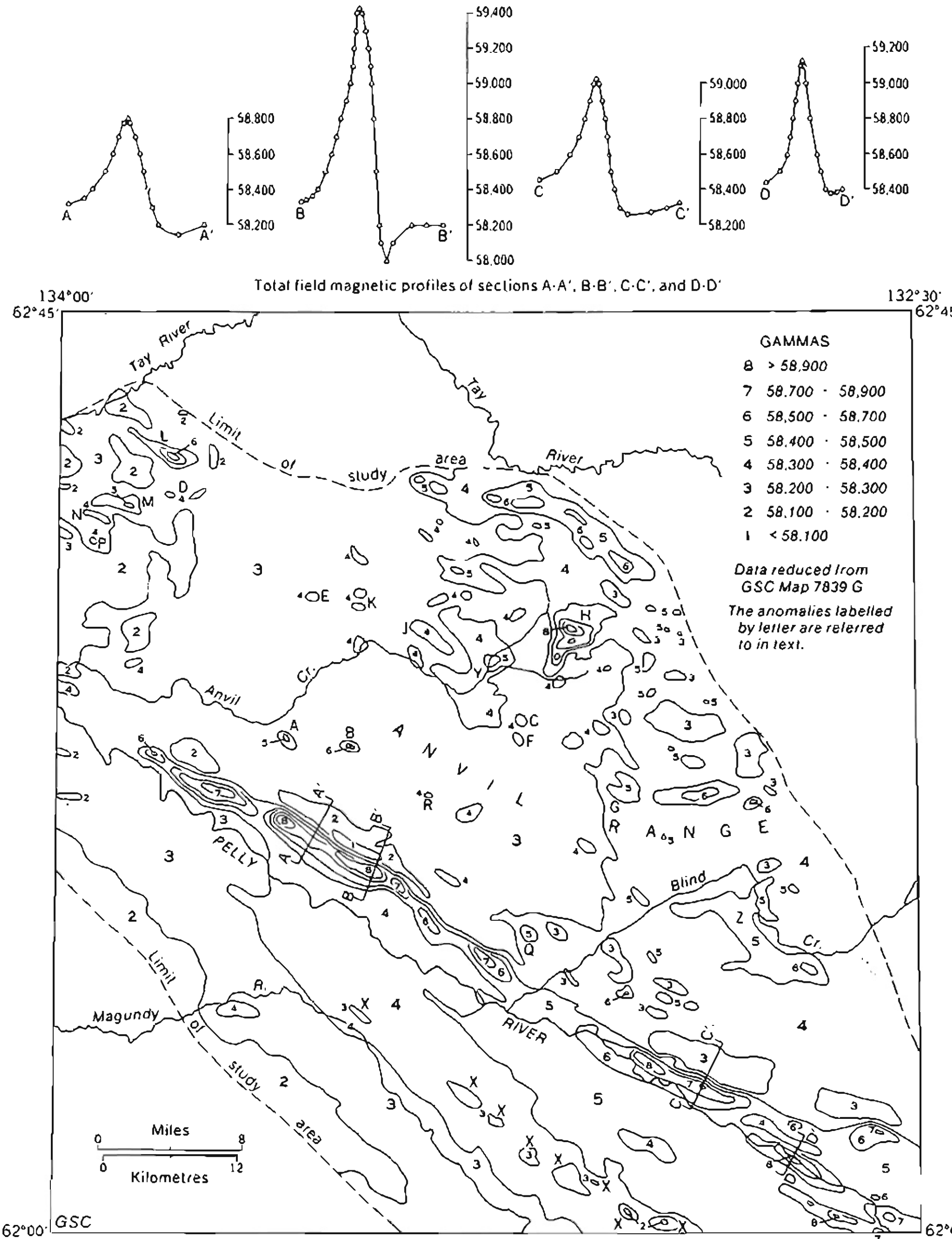

FIGURE 3. Sketch map of aeromagnetic data for Anvil area. Labelled anomalies are referred to in text.

primary rock is a harzburgite containing about 75 per cent medium- to coarse-grained, slightly serpentinized olivine and 25 per cent enstatite, more or less altered to bastite with magnetite and perovskite as accessory minerals. Along the margins of the ultrabasic band the serpentinite has been altered to a buff weathering pale greenish white talc–carbonate rock containing minor amounts of fuchsite.

The band of ultrabasic rocks, thought to be fault bounded on both sides, has Permian volcanic rocks against it on the north and Proterozoic metamorphic rocks on the south. The ultrabasic rocks were apparently emplaced in the Early or Middle Triassic prior to deposition of unit 10 (which contains pebbles of serpentine) and their transgressive relations to rocks of unit 8 indicate that unit 9 is younger than Late Permian. Ultrabasic rocks, similar to, and possibly related to those of unit 9, occur at numerous localities along and near Tintina Trench northwest and southeast of the area, and in other parts of northern British Columbia and southern Yukon. They are generally closely associated with basaltic rocks roughly correlative with unit 8, and this association prompted Aitken (1959) and Gabrielse (1967a) to consider the serpentine and basalts essentially coeval. Aitken suggested a Pennsylvanian and Permian age for the ultrabasic rocks in Atlin map-area and Gabrielse proposed a Mississippian age, based on the older dating of the volcanic rocks, for the ultrabasic rocks northeast of Atlin Horst. The serpentinite in Anvil Range is of latest Permian or earliest Triassic age. The ultrabasic bodies are typical alpine intrusives and as such were probably emplaced tectonically as crystalline masses.

Unit 10

Elongate bodies of brown weathering conglomerate that outcrop along the northern side of Tintina Trench are mapped as unit 10. The conglomerate is resistant and massive and forms good outcrops. It contains rounded fragments of low sphericity that range from coarse sand sizes to 6 inches across, but which are generally about half an inch in diameter. Maximum clast size varies from place to place; limestone invariably forms the largest fragments at any given locality. Metaquartzite (50 per cent), chert (20 per cent), basalt (20 per cent), and limestone (10 per cent) are the dominant clast types and constitute about three quarters of the volume of the rock. Other pebble types recognized include granitic gneiss and serpentinite. The fine-grained matrix of the conglomerate includes muscovite flakes and a large proportion of angular unstrained quartz grains as well as small grains of the rock material noted above, all more or less altered. The conglomerate is well indurated; calcite fills small cavities in the rock and siliceous material cements pebbles and grains so that the rock breaks as readily across the clasts as around them. The conglomerate lacks bedding and foliation and there is no obvious textural variation. Surprisingly, shaly or slaty interbeds are absent. Locally the rock is strongly fractured and steeply dipping slickensided joint surfaces are common.

Conglomerate of unit 10 rests unconformably on quartzite and schist of unit 1, a relationship that is well illustrated along Vangorda Creek. The relationship of unit 10 to strata younger than unit 1 is unknown.

All clast types within the conglomerate are demonstrably of local derivation. Metaquartzite, schist, and granite-gneiss pebbles in unit 10 are similar to, and probably derived from unit 1, whereas the chert, limestone, and volcanic rocks are obtained from the Anvil Range Group. Serpentinite was presumably derived from unit 9.

The close spatial relationship between unit 10 and the Vangorda fault and the unconformity below unit 10 strongly suggests a genetic relationship between the fault and the conglomerate. Probably unit 10 was deposited along the fault scarp formed by displacement on the Vangorda fault.

Thin-bedded and platy, medium grey, silty, and calcareous slate, locally with interbedded grey, fine-grained, argillaceous limestone, occurs at several places, and is apparently a member of the conglomerate unit. These rocks mapped as unit 10a, are best exposed in two small southwest-flowing tributaries of Pelly River immediately below the peak of Rose Mountain. The contact is not exposed, but at these two localities the slate and limestone overlie conglomerate. At least 300 feet of strata, apparently not structurally repeated, is present.

Limestone pebbles in unit 10 locally contain fossil fragments including crinoids, probable bryozoans, and other types, but fossils indigenous to the conglomerate itself were not discovered. However, the argillaceous and limy rocks of unit 10a contain a sparse conodont fauna. B. E. B. Cameron of the Geological Survey considers the conodonts a species of *Gondolella* and provisionally assigns them a Middle or Upper Triassic age (*see* Appendix I). On this evidence rocks of unit 10 are included in the Triassic. Roddick and Green (1961a) included the conglomerate with their map-unit 9 and tentatively assigned it a Mississippian or younger age, whereas Campbell (1967) assigned a possible Jura–Cretaceous age to probable correlatives of unit 10 (i.e., his unit 19b) and correlated the unit with the Tantalus Group.

Unit 11

Granitic rocks forming the Anvil Batholith (unit 11) underlie the core of the Anvil Range and form some of its higher peaks. The rocks are generally resistant and outcrop well, but the topography developed on the granitic rocks is made distinctive by its smooth upland

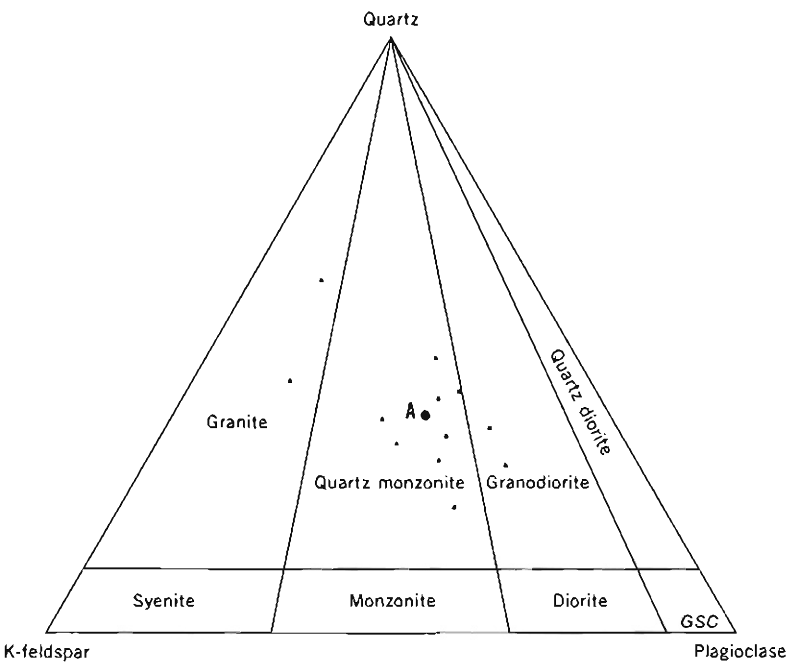

FIGURE 4. Modal compositions of granitic rocks of unit 11 in Anvil area. 'A' indicates average ratio.

slopes and cannot be considered rugged, as in many other areas where granitic rocks occur. The granitic rocks weather medium grey, but heavy lichen cover lends outcrops a dark colour.

Granitic rocks of the Anvil Batholith range from biotite–quartz monzonite to biotite–granodiorite, but most are quartz monzonite (Fig. 4) and the average modal ratio quartz: plagioclase: potash feldspar is 37:36:27. No important compositional variation is evident within the batholith, and specimens from near its margins are essentially the same as those nearer its core. The granitic rocks are generally medium grey, and medium-grained rocks with equigranular texture, but porphyritic varieties are common and foliated types are seen generally on the southern slope of Mount Mye. The porphyritic, equigranular, and foliated types are mapped separately though their mineralogical composition is essentially the same.

Except where foliated the granitic rocks are characteristically hypidiomorphic. Plagioclase forms euhedral to subhedral twinned tabular crystals as much as 5 mm long and commonly contains small inclusions of potash feldspar and muscovite. The mineral is generally weakly zoned and its composition ranges from albite to labradorite; oligoclase An_{20-30} is estimated as the average. Plagioclase is generally slightly saussuritized—in particular the cores of zoned crystals; grain boundaries with potash feldspar are commonly albitized. Orthoclase occurs as subhedral to anhedral poikilitic grains less than 4 mm long. The mineral commonly encloses small crystals of plagioclase, quartz, and biotite and is generally microporphyritic. Where the rocks are porphyritic euhedral, perthitic orthoclase, generally with Carlsbad twinning, forms phenocrysts as much as 5 cm long. Quartz occurs interstitially to the feldspar minerals and as equant anhedral grains locally enclosing biotite and muscovite. Quartz also clusters with anhedral potash feldspar and forms myrmekitic intergrowths with that mineral. Biotite, pleochroic in brown and red-brown, comprises as much as 10 per cent of the volume of the rock locally and occurs in subhedral corroded grains interstitial to the felsic minerals; it is commonly partly chloritized. Muscovite, present in small proportions in most specimens, is generally intergrown with biotite. Zircon is the most common accessory mineral; sphene and allanite are rare.

The foliated granitic rocks are mineralogically indistinguishable from those described above, but their texture differs markedly from them. The feldspars, particularly orthoclase, are commonly rounded or ovoid, which locally lends the appearance of augen texture. Plagioclase and micas are bent and quartz is form oriented and strongly strained. Segregation of minerals is weak and the rock does not exhibit well-developed compositional layering.

No stratigraphic evidence is available within or near the mapped area to limit the age of the intrusive rocks of unit 12 and the available potassium–argon age determinations on rocks of the Anvil Batholith must be considered the best approximation of their age. The following determinations have been made:

GSC 65–41; N62°27′, W133°27′30″	90 ± 5 m.y.; biotite (quartz monzonite) Roddick (1967b)
GSC 65–42; N62°17′, W133°03′	79 ± 6 m.y.; muscovite (quartz monzonite) Roddick (1967b)
GSC 65–43; N62°17′, W133°03′	87 ± 5 m.y.; biotite (quartz monzonite) Roddick (1967b)
Unpublished; N62°17½′, W133°16½′	94 ± 5 m.y.; biotite (quartz monzonite)
Unpublished; N62°17½′, W133°16½′	94 ± 5 m.y.; muscovite (quartz monzonite)

Two ages determined on coexisting biotite and muscovite in thermally(?) metamorphosed rocks near Anvil Batholith are perhaps also pertinent:

N62°22′, W133°23′	93 ± 4 m.y.; biotite (mica schist)
N62°22′, W133°23′	99 ± 5 m.y.; muscovite (mica schist)

These ages are in fairly good agreement with one another and with determinations made on similar granitic rocks elsewhere along Tintina Trench. They indicate that the granitic rocks (and metamorphosed rocks around them) began retaining argon at about 90 or 95 m.y.

Ages of the South Fork Volcanics, north of Anvil Batholith, bear on the age of the granitic rocks because these rocks are demonstrably younger than the quartz monzonite but yield older ages (100 and 117 m.y.). This anomalous situation may be explained by assuming that the South Fork Volcanics, which presumably cooled more rapidly than the quartz monzonite, began retaining argon earlier than the granitic rocks. The South Fork Volcanics therefore apparently give limiting ages for the granitic rocks and presumably Anvil Batholith was emplaced at sometime before 100 to 117 m.y.; i.e., at or before the mid-Cretaceous.

Unit 12

Small plugs of a dark greenish grey serpentinized rock occur at several localities in the area and are mapped as unit 12. The rocks weather rusty brown and are medium grained, equigranular altered pyroxenite. They contain subhedral, equant pyroxene grains as much as 5 mm across, now largely replaced by amphibole, calcite, and serpentine with trains of fine granular magnetite. No relict minerals other than pyroxene were noted. Locally these rocks grade to medium-grained hornblende diorite, comprising subhedral tablets of andesine with lesser interstitial clusters of a deep green hornblende and some quartz. This rock also contains fairly abundant apatite and magnetite and its feldspar is partly saussuritized.

The pyroxenite and diorite intrude rocks of unit 3 but their age is not limited stratigraphically; because they are lithologically unlike other rocks in the area their age and association is in question. These rocks may be related to the volcanic strata of the Anvil Range Group or they may be associated with Tertiary intrusive rocks. They are probably not part of the Anvil Batholith.

Unit 13

Dykes and plugs of saussuritized, medium grey diorite (unit 13) with altered amphibole phenocrysts are found at various localities on the south slope of Mount Mye. These rocks contain resorbed, rounded grains of quartz, about 3 mm across, in a groundmass that consists of a fine-grained mixture of sericite, chlorite, epidote, and calcite. Relict grains of hornblende, pleochroic in brown, and largely altered to epidote and chlorite, are seen rarely. Remnant plagioclase (An_{50}) grains are equally uncommon. Originally these rocks were porphyritic hornblende diorite and they are unlike other granitic rocks in the area. The diorite cuts quartz monzonite of unit 11 at several localities on Mount Mye; it may be a late phase of the Anvil Batholith or an intrusive rock younger than, and unrelated to, the quartz monzonite.

Unit 14

Several varieties of porphyritic acid igneous rocks and tuffs (unit 14) are found in the map-area. Two occurrences are known on the north flank of Mount Mye and a third lies a few miles north of these outcrops. Similar rhyolitic rocks are more widespread south of Pelly River near the western and southern margins of the map-area.

At the occurrences north of Pelly River these rocks are ignimbrites that weather a light grey and break into a rubble of angular, fist-sized fragments. The rock has an aphanitic, light greenish, greyish or reddish groundmass in which phenocrysts of clear quartz and feldspar, as much as 5 mm across, are evenly distributed. At the northern locality fragments of acid volcanic material and spherulites as much as 2 inches across, distinguished from their matrix only by slight colour differences, are evident. There a fine colour lamination is also visible in the rock. In thin section the groundmass is clearly pyroclastic, and shard-like forms, devitrified to an extremely finely divided fibrous aggregate of radially arranged feldspar and cristobalite, are discernible. Chlorite and sericite are also recognizable in the groundmass. Quartz phenocrysts are euhedral with the habit of quartz; most quartz grains are slightly resorbed marginally. The feldspar, evidently a sanidine–anorthoclase series member, occurs as euhedral or fractured grains, some of which are partly saussuritized. Trace amounts of biotite, pyrite, and schorlite were identified in thin section and minor amounts of fluorite are present interstitially.

The acid rocks south of Pelly River differ from those just described. Acid porphyries are mapped as unit 14a, whereas acid tuffaceous rocks associated with them are included in 14b. The porphyries are light grey and pinkish rocks that weather a brownish colour. They contain clear, subhedral phenocrysts of quartz and buff to white, altered looking crystals of feldspar in a fine-grained to aphanitic groundmass. Hematite and pyrite are present everywhere. Phenocrysts comprise about 10 to 20 per cent of the volume of the rock and are as much as 5 mm across. In thin section the feldspars are clouded by clay minerals, but are recognizable as orthoclase. The groundmass displays abundant myrmekitic and micrographic intergrowths of quartz in orthoclase, with feldspar the dominant component. The feldspar in the groundmass is less altered than that comprising the phenocrysts. Zircon is a trace constituent of the rock. Hematite occurs as fracture and cavity fillings and appears to have formed after pyrite. Locally the rock ranges to an equigranular, medium-grained granite composed largely of subhedral, simply twinned, orthoclase crystals with interstitial quartz and minor hornblende, strongly pleochroic in green. The rocks of unit 14a are probably best called granite porphyries.

The acid tuffs south of Pelly River (unit 14b) are finely laminated, generally light coloured, flinty rocks. In thin section they appear fairly fresh although most of the glassy material is clouded and partly devitrified. Tiny angular quartz fragments or crystallites are scattered through the rock, but undoubted pyroclastic forms were not seen. The tuffs owe their lamination to slight compositional variation between layers.

Ignimbrite (unit 14a) on Mount Mye lies on and cuts the granitic rocks of unit 11 and at the northern locality it overlies rocks of units 4 and 8. Unit 14 is lithologically similar to parts of the South Fork Volcanic unit mapped by Roddick and Green (1961a) as unit 14. On the basis of two potassium–argon age determinations of 100 and 117 m.y., the South Fork volcanics are now considered late Cretaceous and roughly contemporaneous with the granitic rocks (unit 11). Unit 14 is assigned an Upper Cretaceous age and is correlated with Roddick and Green's (1961a) unit 14.

The age of the granite porphyry and tuff south of Pelly River is unknown. Their similarity to rocks of unit 14 on Mount Mye strongly suggests that these rocks are related and units 14a and 14b are therefore tentatively assigned an Upper Cretaceous or Tertiary age. The contact between the tuff (14b) and porphyry (14a) was not seen and their relative ages are therefore also unknown.

Unit 15

An assemblage of immature, poorly indurated clastic rocks and spatially associated basalt is mapped as unit 15. Sandstone, shale, and conglomerate (unit 15a) occur at several localities in the valley of Pelly River where the coarser grained rocks outcrop well. The conglomerate and sandstone contain angular fragments of impure chert, slate, schist quartzite, and quartz and range in grain size from medium sand to boulder conglomerate with clasts as much as a foot across. The rocks are poorly sorted and their constituent fragments at any locality reflect the underlying lithology in the immediate vicinity. They are thick bedded and layering is marked largely by grain size changes. The fragments are well cemented by hematite and quartz but the rock generally breaks around the clasts. Locally these rocks grade into brownish siltstone and silty shale that contain abundant imprints of plant remains.

Basalt, mapped as unit 15b, is found near the western margin of the map-area and at an isolated occurrence near the mouth of Grew Creek. At a third locality, on a creek flowing into Rose Creek about 2 miles south of the Faro deposit (not mapped), a three-foot-thick dyke of this basalt cuts strata of unit 2. The basalt is a deep chocolate brown weathering rock that is generally strongly fractured; it is dark green on fresh surfaces. The rock is fine grained and porphyritic; its groundmass is composed of a mat of tiny plagioclase(An_{65}–An_{75}) laths with scattered epidote and brown alteration minerals. It contains sparse phenocrysts of greenish olivine as much as 5 mm across as well as a few larger grains of clear sanidine. Augite forms subhedral equant microphenocrysts throughout. Stratigraphic relations between the basalt and conglomerate are not clear, but at one place in Grew Creek a conglomerate bed containing numerous boulders of basalt in a basalt sand matrix was seen. On this basis the basalt is tentatively thought to be older than the conglomerate.

The only evidence for dating unit 15 is the Paleocene age reported for plant remains in rocks of unit 15a by Roddick and Green (1961a).

Structural Geology

The gross structure of the Anvil Range is an irregular, relatively young, asymmetrical culmination superposed on all older structures produced by doming of the Paleozoic rocks around Anvil Batholith. This structural culmination, herein referred to as the Anvil Arch, is truncated along its southwest flank by the Vangorda fault. This fault is one of a series of long, parallel, steep-dipping, northwest-trending faults that marks the locus of the Tintina fault, a zone of regional transcurrent faulting. Blind Creek fault, which trends normal to the axis of the Anvil Arch, is a relatively unimportant fault on which minor displacement can be demonstrated.

Rock units comprising Anvil Arch are internally deformed to various degrees and in different styles, but much of this internal deformation is older than and unrelated to the formation of Anvil Arch. A strong crenulation foliation, on which an earlier foliation is transposed, characterizes the structure of the rocks of units 1, 2, and 3. Ordovician to Mississippian rocks are relatively weakly deformed with development of axial-plane foliation in the incompetent members. The Pennsylvanian and Permian sequence shows local transposition of the bedding and development of a crenulation foliation in the cherty phyllitic rocks near the base of the sequence.

The following pages contain more detailed descriptions of these structural features. Small-scale structures in the Paleozoic rocks are first reported and a description and discussion of the larger structures follows.

Small-Scale Structure in the Cambrian (?) Rocks (units 2 and 3)

Although the general structure of the Anvil Range is simple the internal structure of the various rock units that form it is fairly complex; this is especially true of the Cambrian (?) strata which are of particular importance in regard to the ore deposits of the region. For clarity the interrelationships of the various types of small-scale structures in these rocks (described in more detail below) are summarized in somewhat simplified form.

A well-developed crenulation foliation, roughly parallel to the axial plane of small-scale folds, on which one or more wrinkle lineations are evident, is present in the phyllitic and schistose members of the Cambrian (?) rocks in Anvil Range. The crenulation foliation partly or completely transposes an older planar structure outlined in different places by colour lamination, preferred orientation of micas, and lamination produced or enhanced by segregation of quartz and micas.

Linear elements defined in the phyllitic rocks include the intersection of the early and late planar structures and one or more wrinkle lineations on the crenulation foliation. The dominant wrinkle lineation is produced by kinking of the foliation and commonly obscures other linear elements.

Visible folds in the Cambrian (?) rocks are directly related to formation of the crenulation foliation and are slip folds produced by displacement on it of the early planar structure. Recrystallization of micas on discrete planes defines the crenulation foliation.

Only one strong period of deformation, resulting in the development of the crenulation foliation and folding of the early planar structure is indicated in the Cambrian (?) rocks of Anvil Range. Evidence is presented to show that this deformation probably occurred in Cambro-Ordovician time. Whether or not the folded early planar structure itself represents

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FIGURE 5

Diamond-drill core of phyllite from Vangorda deposit. Photograph illustrates the rough parallelism and planarity of the crenulation foliation F_2 (dark bands), marked by narrow, discrete zones of mica recrystallization. Note that F_2 planes bend and merge with one another and die out laterally. Also note small folds outlined by compositional layering (F_1) between F_2 planes. The photograph is taken perpendicular to the axes of the small folds. Drill-core diameter is 1.2 inches.

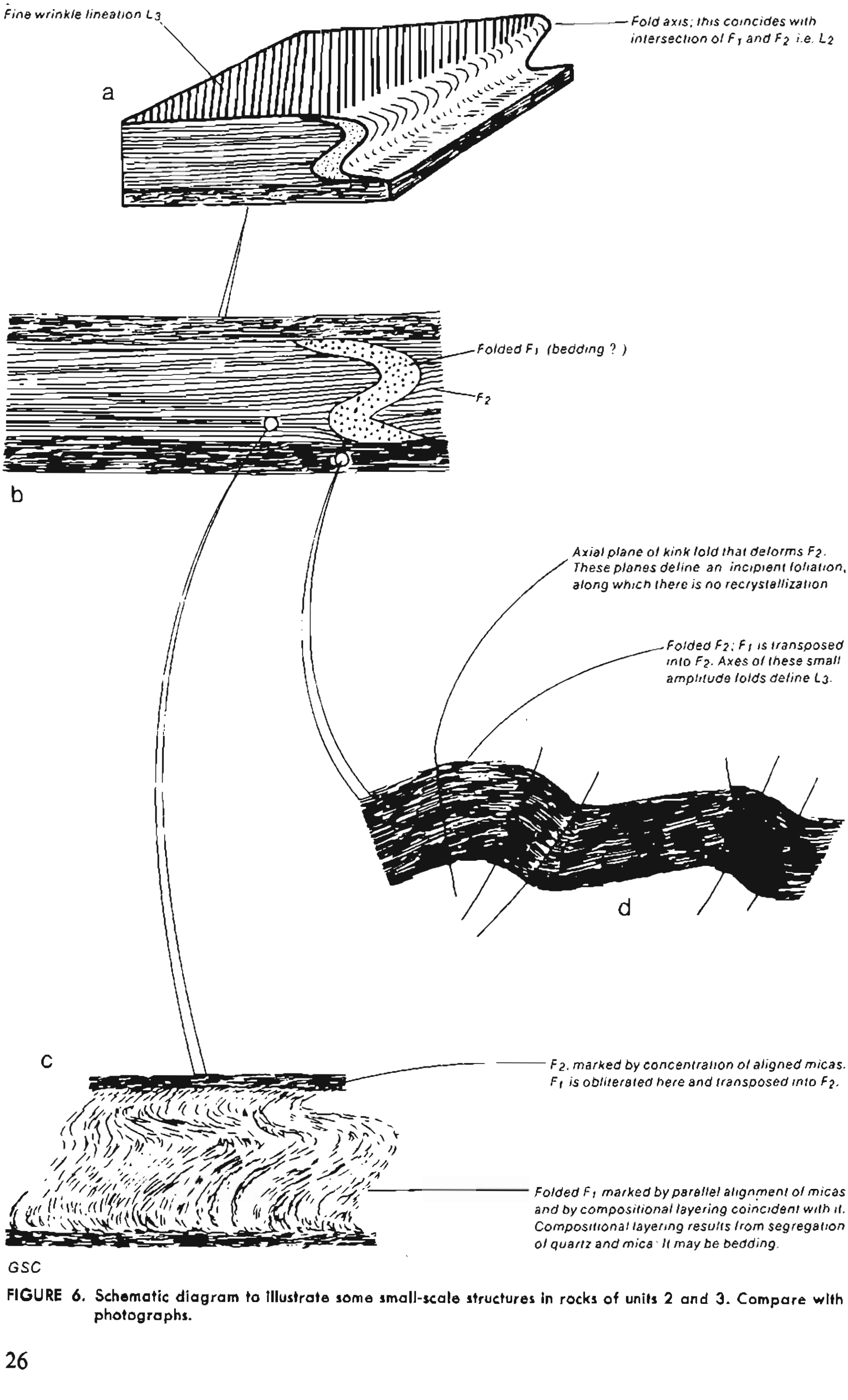

FIGURE 6. Schematic diagram to illustrate some small-scale structures in rocks of units 2 and 3. Compare with photographs.

a foliation related to an older deformation is not resolved. The wrinkle lineation imposed on the crenulation foliation may be young and evidence for an early Cretaceous age of this feature is presented.

Planar Structures

Cambrian rocks in Anvil Range show a characteristic and pervasive planar structure that for the most part masks and locally obliterates earlier structures (Fig. 5). This planar structure, herein referred to as F_2, is developed on a microscopic scale and is defined by discrete, closely spaced laminae, each 0.1 to 0.2 mm thick, of tiny, parallel-oriented muscovite flakes (Figs. 6c, 7). The laminae separate layers of quartz and muscovite, about 0.8 mm thick. Mica trains and quartz laminae in these quartz-rich bands define a planar structure oriented at various angles to F_2 which is here called F_1 (Figs. 5, 6c, 7). F_1 forms small folds or crinkles between F_2 planes; F_2 approximately defines the axial surface of the folds in F_1 (Figs. 7, 8, 9). In places F_2 is so penetrative that remnants of the earlier foliation are completely lacking and here F_1 may be considered to be completely transposed into F_2 (Figs. 6d, 10). F_2 is evidently a slip cleavage or crenulation foliation developed by recrystallization and partial transposition of F_1.

Spacing of the slip planes or thickness of the intervening rock slices ranges from 0.1 mm to 30 cm and is bimodally distributed in this range with modes averaging about 0.8 mm and 8.5 cm. F_2 slip surfaces are not strictly planar or parallel, but bend and merge with one another; they die out laterally by gradual decrease in the amount of slip (Figs. 8, 11a–e). The displacement on slip planes seems to have occurred on two scales; movement of about several centimetres can be shown on slip planes spaced some centimetres apart and marked by a zone of mica regrowth several millimetres thick; on a smaller scale displacement of about several millimetres can be demonstrated on slip planes separated a fraction of a millimetre and only marked by a thin zone of mica neocrystallization. It seems, therefore, that the spacing of slip planes and the thickness of the zone of mica recrystallization is roughly proportional to the amount of slip.

Where F_1 is present it is outlined by a faint, very fine, regular lamination, 0.1 mm thick, produced by segregation of muscovite and quartz and seen in the slices or microlithons between F_2 surfaces (Figs. 5–10). Mica is oriented parallel to the compositional layering of F_1, which is at various angles to F_2. F_1 is more penetrative than F_2 and obscures any earlier structures that may have existed. F_1 has the characteristics of an axial-plane foliation but no folds related to it were seen, and because F_1 coincides with bedding defined by compositional layering it may be a foliation developed parallel to bedding.

The degree or completeness of transposition of F_1 into F_2 differs regularly from place to place. In the vicinity of the Swim deposit S-shaped open folds commonly outline F_1 between F_2 slip planes (Figs. 11e, 12). Northwestward these small folds become less common and are gradually replaced by tighter folds (Figs. 11f, 13) and by the sheared-out limbs of folds (Fig. 14). Near the Faro deposit F_1 is generally drawn out and brought nearly into coincidence with F_2 (Fig. 11g).

At some localities where metamorphism has been weak, notably east of the Swim deposit, the planar structure in the slices between F_2 planes is not an earlier foliation, but a bedding defined by compositional layering, colour lamination and grain size variation, along which there has been no neocrystallization (Fig. 15a). At these places recrystallization on F_2 is also slight and is evident on thin, widely spaced planes. Elsewhere compositional layering, outlined by alternating thin laminae (2 mm thick) of limestone and phyllite show neocrystallization and development of good foliation only in the phyllitic parts and here F_2 displaces the compo-

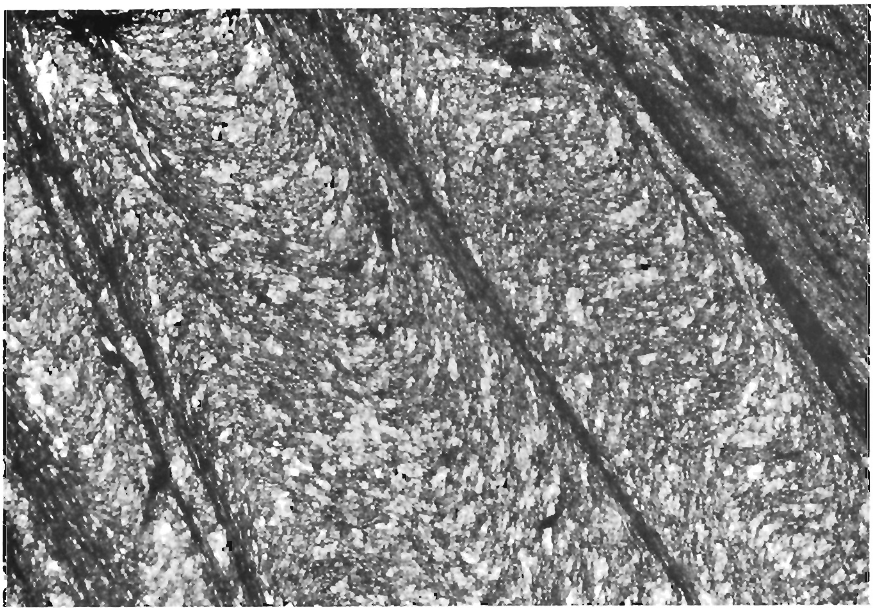

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FIGURE 7. Photograph of a thin section of phyllite showing relationships of F_1 and F_2. Note that F_1 is outlined by oriented micas and by trains of quartz grains. Plane light.

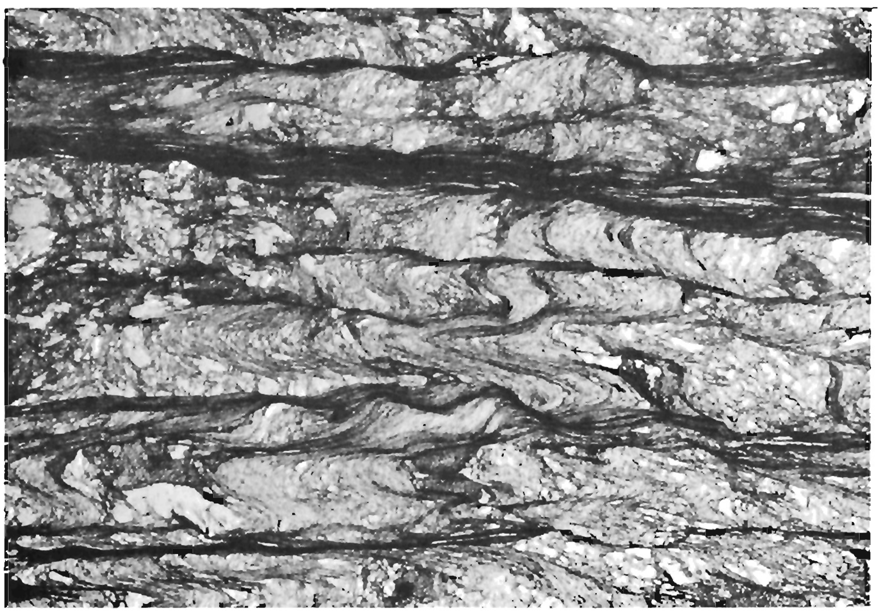

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FIGURE 8. Photograph of a thin section of phyllite in plane light showing relationships F_1 and F_2. Note that F_1 is folded and penetrative, whereas F_2 is relatively flat and on discrete planes. Also note that F_2 planes bend and merge with each other, die out laterally, and that mica regrowth zones vary in thickness along their length.

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FIGURE 9. Photograph of a thin section of phyllite showing variation in spacing of F_2 planes. Note that F_1 is folded and defined by quartz trains and oriented micas. Plane light.

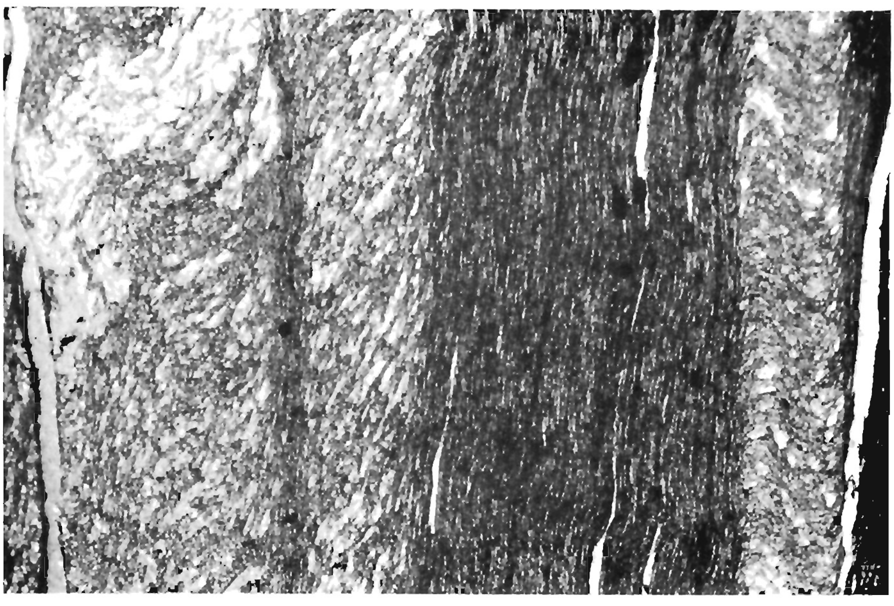

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FIGURE 10. Photograph of a thin section of phyllite in plane light. Note the difference in thickness of adjacent F_2 planes, both marked by mica regrowth. Note folded F_1. Compare with Figures 7 and 9.

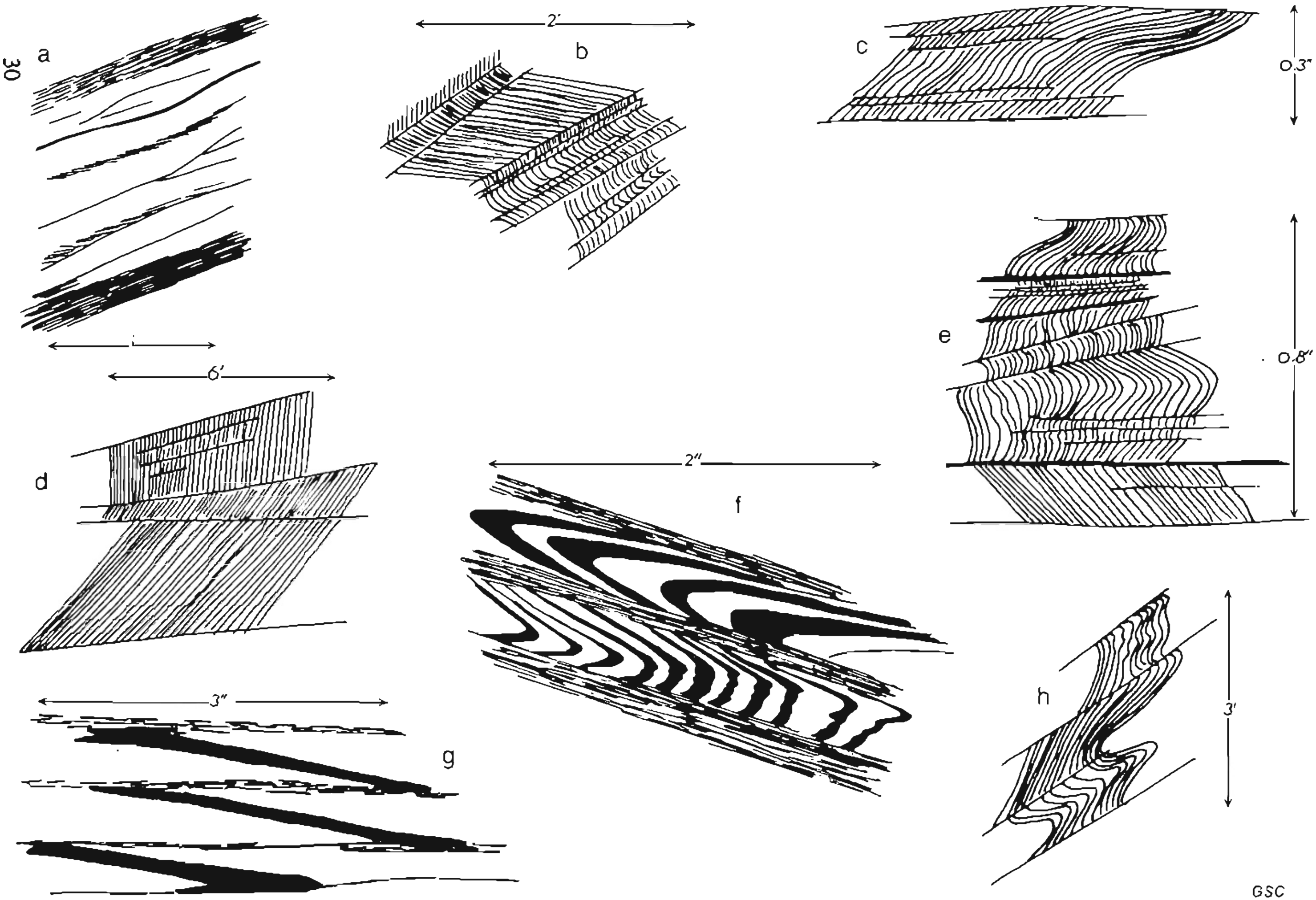

FIGURE 11. Sample profiles of some typical mesoscopic structures in Anvil area. Compare with photographs.

FIGURE 12

Photograph of drill core from vicinity of Swim deposit. Note that the folds outlined by F_1 are relatively open. Compare with Figures 13 and 14. Photograph shows the folds in true section. Drill-core diameter 1.2 inches.

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FIGURE 13

Photograph of drill core from Vangorda deposit showing fairly tight folds (bottom) and the sheared outline of a fold (top), both outlined by compositional layering (F_1). Folds are shown in true section. Drill-core diameter is 1.2 inches.

FIGURE 14

Drill core from Vangorda Creek vicinity. Note that F_1 (compositional layering) is generally subparallel to F_2, except in the centre of photograph where it outlines the hinge of a small fold. Folds shown in true section. Drill-core diameter is 1.2 inches.

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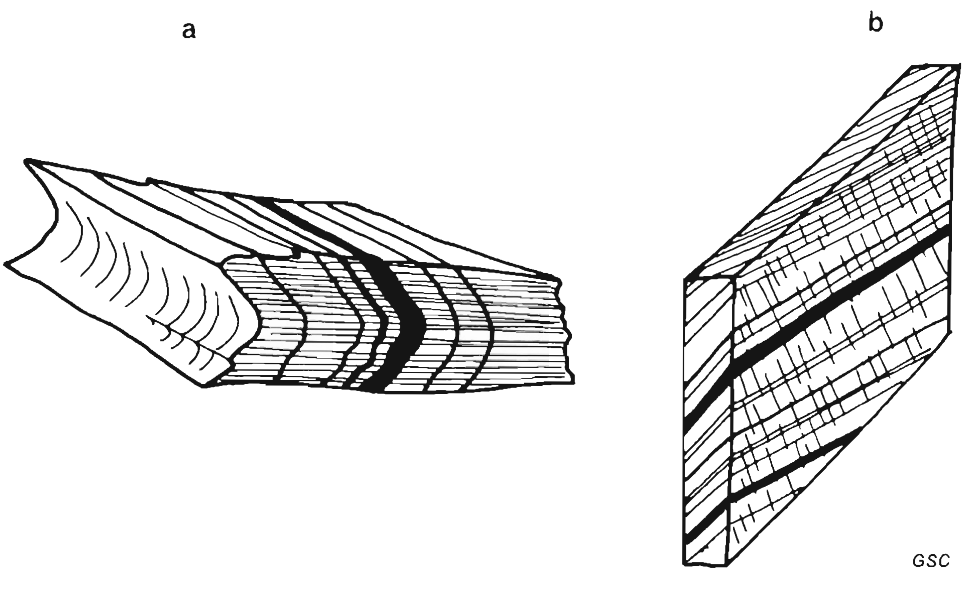

FIGURE 15. Sketch to illustrate the relationship of bedding, F_2, and the lineation produced by their intersection as seen in rocks of units 2 and 3.

FIGURE 16

Photograph of drill core from vicinity of Swim deposit showing kinked F_1 which deforms L_3. The fold is shown in true section and the core diameter is 1.2 inches.

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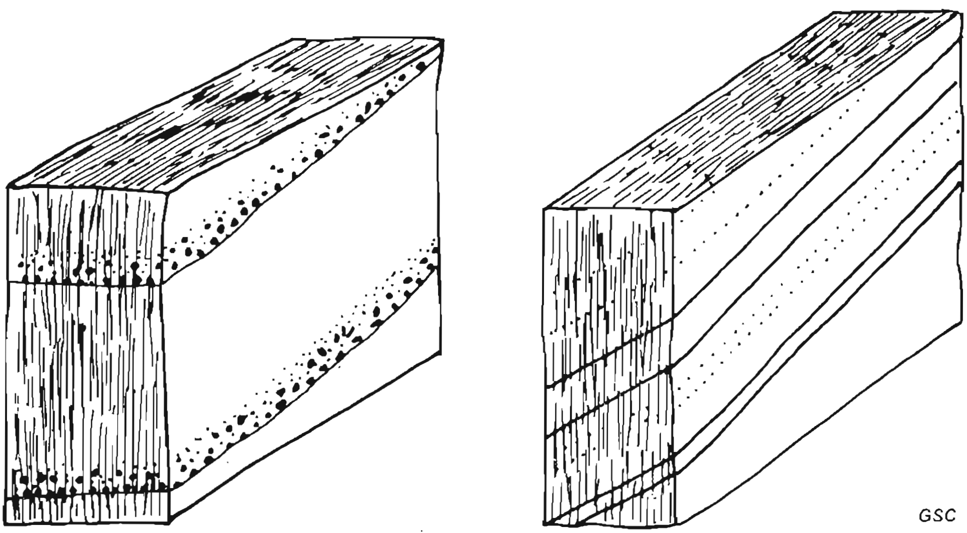

FIGURE 17. Planar structures in rocks of unit 8.

sitional layering and the foliation coincident with it. These features strongly suggest that F_1 is a foliation developed parallel to bedding and that it may have formed without the aid of deformation.

A third weak planar structure, F_3, is mainly confined to the completely transposed (on F_2) micaceous parts of the phyllitic rocks of Anvil Range (Fig. 6d). It is defined by cleavage parallel to the axial plane of tiny open wrinkles that outline a lineation, L_3, on F_2 (Fig. 6a). In contrast to the earlier planar structures no recrystallization was noted along F_3, which may therefore best be referred to as a kinked cleavage (Fig. 16) and may be likened to incipient crenulation foliation. F_3 has not affected the deformed first foliation.

Linear Structures

Two types of linear structures are evident in the Cambrian rocks of Anvil Range. The commonest of these is a relatively coarse wrinkle lineation on F_2 found at most localities and designated L_3. It forms regular open crinkles coincident with the intersection of F_3 on F_2 (Fig. 6a, d). The wrinkles have an amplitude of about a millimetre and their wave length is two or three times their amplitude; they are asymmetrical with one limb dipping somewhat more steeply than the other.

At some localities where recrystallization on F_2 has not been strong and thus the micaceous partings are thin, the intersections of F_1 on F_2 form a good linear element, L_2, outlined by faint compositional banding on F_2 (Fig. 7). In most outcrops this linear element is obliterated by the superposition of the wrinkle lineation, L_3, but where seen L_2 is parallel with the axes of minor folds transposed on F_2.

Aside from the coarser wrinkle lineation, L_3, mentioned above, one or more very fine wrinkle lineations are locally and uncommonly evident on F_2. The relationships of these wrinkles to other linear and planar elements is unknown, but it is demonstrable that some of these fine wrinkles predate L_3 and some are younger. Those that predate L_3 coincide with the intersection of F_1 and F_2, i.e., L_2.

Because L_2 is generally masked by L_3, sufficient data for its orientation are not available. However, fold axes of transposed F_1 trend northwest and plunge gently. The coarse wrinkle lineation, L_3, trends east–southeast and generally plunges in that direction at small angles.

Folds

Aside from the wrinkles described as the linear element L_3, folds of only one style are recognized in rocks of units 2 and 3 (Figs. 5–13). These occur on three distinct scales: the smallest are measured in millimetres and are seen in almost any thin section of the phyllitic rocks (Figs. 7–9); the intermediate are measured in centimetres and can be seen in most hand specimens and outcrops (Figs. 11–14); and the largest are a hundred or more feet across and are discernible only in a few large outcrops. The folds are identical in geometry and orientation; they are generally subisoclinal, cylindroidal slip folds with axial angles of 30 or 40 degrees and with gently plunging northwestward-trending axes. Sample profiles of some small- and intermediate-scale folds are given in Figure 11. The small-scale folds are generally seen in mica-rich phyllitic rocks, whereas those of intermediate size occur in quartz-rich phyllite. The largest folds are outlined by some of the greenstone masses (unit 3a). Small- and intermediate-scale folds are defined by F_1 and locally by bedding, and the large-scale folds are outlined by the contact between greenstone and phyllitic rocks.

The lack of obvious marker horizons in phyllitic rocks of units 2 and 3, and the strong crenulation foliation, combine to obscure any folds larger than those described; the existence of folds sufficiently large to map could not be demonstrated. However, the incompetence of the phyllitic rocks suggests that such large structures, if present, are rare, because the rocks have yielded internally on closely spaced slip planes. In other words, the small folds and related structures may not be minor features related to larger folds, but may instead be the main products of the deformation in units 2 and 3.

The greenstone (unit 3a) apparently did not yield to the deformation by internal slippage to the extent that the phyllitic rocks have because the crenulation foliation is developed only in the margins of greenstone masses. Instead it deformed in larger units and occurs now as fold hinges of much the same shape as, but larger than, the small folds in the phyllitic rocks. The upper and lower contacts of the greenstone masses are, by analogy to the smaller folds, probably structural discontinuities or slip surfaces and are therefore probably fault contacts. These faults are to the greenstone what the crenulation foliation is to the smaller folds. The faults probably dip southwestward at moderate angles and their displacement, again by analogy to the small structures, is probably in the same order of magnitude as the size of the folds themselves, i.e., several hundred feet. This is borne out by the spacing of greenstone bodies which are generally several hundred feet apart across the strike. No evidence indicating the sense of movement on the faults was found.

To summarize: there are folds of similar shape on three distinct scales; the smallest are measured in millimetres, the intermediate in centimetres, the largest in tens of feet. The three scales are apparently related to the amount of movement on associated slip planes and reflect the lithology of the folded rocks.

Small-Scale Structures in Rocks of Units 4 and 7

Rocks of unit 4 are poorly exposed and small-scale structures other than a cleavage transverse to bedding were not seen. The cleavage is weakly developed and may be the result of slight pervasive recrystallization. Unit 7 was not extensively examined but in the few exposures seen the argillaceous members show a fairly good cleavage, resulting from weak pervasive recrystallization. No folds were seen in rocks of unit 7.

Small-Scale Structures in Rocks of Anvil Range Group

The volcanic member of the Anvil Range Group is generally massive and structureless, but the cherty member (8a) commonly shows a foliation on which a lineation is locally evident. No large-scale structures are known in unit 8, although fold repetitions are probably present considering the marked variation in apparent stratigraphic thickness of the unit from place to place. In some outcrops the cherty member shows bedding outlined by compositional layering and enhanced on weathered surfaces by colour lamination. Most outcrops show a weakly developed foliation, which transects the bedding at various angles (Fig. 17). Where seen the foliation is defined by weak orientation of tiny chloritic mica flakes within the chert, not along discrete slip surfaces, but throughout the rock. The recrystallization of micas gives the chert a distinctly phyllitic character. The intersection of the foliation and bedding is not commonly seen, but where present defines a weak lineation. A very fine wrinkle lineation is locally seen on phyllitic foliation surfaces at various angles to the intersection of bedding and the foliation. Not enough of these were observed to offer suggestions about their origin. Although no minor folds were seen in the cherty member of the Anvil Range Group, it seems that the weak but pervasive foliation may be an axial plane foliation or slaty cleavage related to development of unrecognized folds in these rocks.

Ages of Deformation

With the possible exception of L_3 the minor structures found in the rocks of units 2 and 3 are not seen in the younger strata of units 4, 7, and 8. This strongly suggests that the deformation of the presumed Cambrian rocks occurred before deposition of unit 4, or in pre-mid-Ordovician time, and also implies that unit 4 overlies older rocks with marked angular unconformity. If the evidence is valid this deformation must have occurred in Anvil Range in Cambrian or Early Ordovician time. On a regional scale this strong orogenic episode may correlate with a period of important early Late Cambrian deformation in the southeastern part of Selwyn Basin (Wheeler, Gabrielse, and Blusson, 1968), and/or with marked regional unconformities beneath latest Ordovician strata found in the Mackenzie and Cassiar Mountains (Gabrielse, 1967a).

An alternative explanation of the marked difference in style of deformation between units 2 and 3 and unit 4 is that the structural style is stratigraphically controlled and that deformation was weaker in higher stratigraphic units than in lower strata. A seemingly progressive decrease in metamorphic grade from unit 2 to unit 4 may be related to such a stratigraphic change in minor structures. If this explanation is valid the deformation is pre-Middle Devonian because strata of that age overlie folded rocks of units 2 and 3 with marked angular unconformity.

Minor structural elements in rocks of unit 8a are post-Permian and may have formed during the early Cretaceous, a time of widespread deformation in much of the northern Cordillera. Formation of the minor structures may have accompanied or slightly preceded intrusion of the Anvil Batholith and formation of the Anvil Arch. The parallelism of the linear element in rocks of unit 8a, based on a few scattered observations, with L_3, the wrinkle lineation in the Cambrian (?) strata, suggests that the two may be syngenetic and implies that the older rocks, i.e., units 2 and 3, were affected by the early Cretaceous orogeny.

Evidence that the regional unconformities beneath unit 7 and the Anvil Range Group mark periods of strong deformation is lacking. More probably these unconformities represent intervals during which tilting, uplift, and perhaps open folding occurred. On this basis all rock units younger than the Cambrian are thought to have been significantly folded only during early Cretaceous time.

Anvil Arch

Anvil Arch is a domal or anticlinal culmination roughly 40 miles long and 15 miles wide with an amplitude of about 2 miles that trends northwest roughly parallel to Tintina Trench. Its core is occupied by granitic rocks and around these lie the Paleozoic strata. Rock units are repeated on the flanks of the granitic area and dip away from it. The arch has a gently dipping northeast limb and a more steeply dipping southwest limb. In the northwest Anvil Arch plunges gently beneath its cover and terminates in a structural depression containing late Paleozoic volcanic rocks in adjacent Glenlyon map-area (Campbell, 1967). On the southwest, the arch ends in the vicinity of Blind Creek, where its form becomes obscured. A structurally elevated zone does continue southeastward beyond Blind Creek and can be traced by the occurrence of metamorphic rocks along the north side of Tintina Trench through Finlayson Lake and into Watson Lake map-area (Wheeler, Green, and Roddick, 1960a; Gabrielse, 1967b).

Major flexing to produce the Anvil Arch evidently occurred in post-Permian time, for the rocks of the Anvil Range Group are affected. The spatial relationship of the Anvil Batholith to Anvil Arch strongly suggests that the flexure developed about mid-Cretaceous time during intrusion of the batholith. Minor elevation and tilting of the arch, probably in

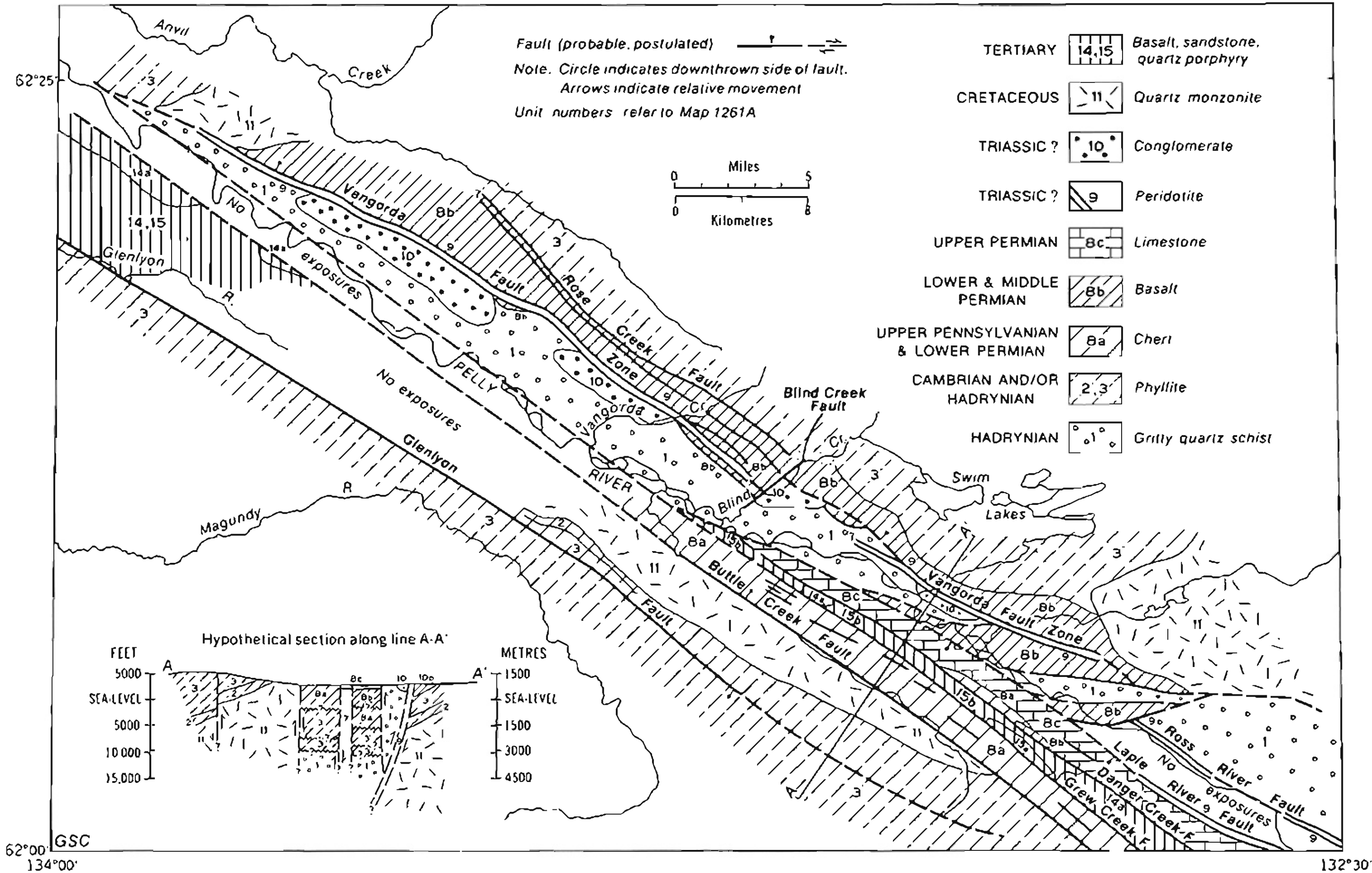

FIGURE 18. Sketch map of faults along Tintina Trench.

Late Mississippian or early Pennsylvanian time, is reflected by the fact that the unconformity below the Anvil Range Group overlies progressively older rocks southward. Some steepening of the southeast limb of the arch may have occurred during movement on the Vangorda fault.

Faults

A number of steeply dipping, subparallel, northwest-trending faults along the valley of Pelly River mark the Tintina fault zone in the map-area (Fig. 18). The faults separate rocks of widely different ages and although only dip-slip movement is apparent they are probably strike-slip faults. The various faults are described below and the evidence for their displacement and its timing is assessed. The evidence is compared with other data for faulting along Tintina Trench.

Glenlyon Fault

The southwesternmost of the faults along Tintina Trench, named the Glenlyon fault, extends from Glenlyon River to the southern boundary of the area (Fig. 18). The fault brings rocks of unit 3 against similar strata of a higher stratigraphic level and the apparent dip-slip component of movement in the central part is northeast side up relative to southwest side. The amount of apparent dip-slip movement approximates several thousand feet. Evidence of lateral displacement is lacking. The fault was not investigated in its southeast part, but its continuity is indicated by a series of aligned aeromagnetic lows that coincide with its known extension (*see* Fig. 3). Asymmetry of the aeromagnetic profiles across it suggests that the Glenlyon fault may dip northeastward. Movement on the Glenlyon fault is post-Cambrian, and cannot be limited closely on evidence at hand.

Buttle Creek Fault

This fault follows Buttle Creek for much of its known length (Fig. 18) and brings sheared cherty rocks, probably of the Anvil Range Group, against probable mid-Cretaceous, foliated quartz monzonite. The northwestward extension of the fault is obscured by overburden, but the fault may continue into Glenlyon map-area. The Buttle Creek fault dips steeply, judging from its map-pattern, and may be vertical. The apparent dip-slip component of movement is about 5,000 feet and the southwest side has moved up relative to the northeast. There is no evidence of lateral displacement on the Buttle Creek fault. Because it cuts granitic rocks presumed to be of mid-Cretaceous age, the Buttle Creek fault probably moved in Late Cretaceous and/or Tertiary time.

Rocks exposed between the Buttle Creek and Grew Creek faults are cut by a number of smaller, steeply dipping faults parallel to the larger structures. These smaller faults have the same sense of movement as the Buttle Creek and Grew Creek faults.

Grew Creek Fault

Grew Creek fault (Fig. 18) occupies a well-defined linear depression for much of its length and separates Tertiary rocks of various types from probable Permian strata. The fault presumably dips steeply and the apparent dip-slip movement, of unknown magnitude, has dropped the northeast side down relative to the southwest. Movement apparently took place after the Permian but the time of its initiation is not known. Paleocene (?) rocks on the north side of the fault are folded and locally sheared indicating that the latest displacement followed deposition of these rocks.

The Grew Creek fault most probably merges with the Danger Creek and Lapie River faults near its northwesternmost known extremity as indicated in Figure 18.

Danger Creek Fault

Danger Creek fault (Fig. 18) separates Late Permian limestone from various Tertiary rocks. Apparent slip movement of 1,000 feet or more can be demonstrated on the fault, but strike-slip displacement cannot be shown. The fault has brought the northern side up relative to the southern. Dating of the movement on the Danger Creek fault is similar to that on the Grew Creek fault and has the same limitations.

Lapie River Fault

This fault, followed in places by a steeply southwest dipping sheet of ultrabasic rocks, separates Upper Permian carbonate rocks from Proterozoic gritty quartzite and Anvil Range Group basalt. Only apparent dip-slip movement can be demonstrated on the Lapie River fault and the sense of movement is north up, south down. If the fault dips southward, as suggested by the aeromagnetic profiles across it, the displacement is normal. The Lapie River fault is Triassic or younger, but may not have moved during the Tertiary. Near Blind Creek the Lapie River fault probably merges with the Buttle and Grew Creek faults.

Four small faults that trend eastward between the Lapie and Vangorda structures probably merge with both these faults at their eastern and western extremeties, as shown in Figure 18.

Ross River Fault

An important fault, intruded by a steeply dipping, discontinuous sheet of serpentinite, is inferred between the Lapie and Vangorda faults in the southeast part of the area (Fig. 18). The apparent movement has the same sense as the Lapie fault and may have occurred at the same time. No rocks are exposed between the Lapie and Ross faults in the area mapped, but immediately to the southeast (Wheeler, Green, and Roddick, 1960a), Anvil Range Group basalt occupies this fault block.

Vangorda Fault

A fault zone, along which ultrabasic rocks of unit 9 are intruded, is inferred along the contact between the Anvil Range Group and unit 1 and can be traced for 40 miles immediately north of Pelly River (Fig. 18). The northwest end of the Vangorda fault is obscured by overburden, but the fault probably terminates near the margin of Tay River map-area; beyond this point the fault lacks magnetic expression, indicating that at least the ultrabasic rocks intruded along it are absent here. In the southeast the Vangorda fault makes a pronounced eastward bend and there subsidiary faults branch off the main structure (Fig. 18) to join the Lapie River fault.

The Vangorda fault zone apparently dips steeply southwest, judging from the asymmetry of the aeromagnetic profiles across the ultrabasic rocks intruded along it. The minimum stratigraphic omission across the Vangorda fault is 5,000 feet and the displacement is probably several times that figure. It implies reverse dip-slip movement on the Vangorda fault with relative upward movement of the southwest side. A minimum movement of 2,000 feet in the opposite sense is indicated by the conglomerate of unit 10, which incorporates rock fragments of unit 1 and the Anvil Range Group and which presumably formed beneath the Vangorda fault scarp. This apparently ambiguous situation can be explained if lateral displacement of at least several miles accompanied the vertical movement or if relaxation, expressed by normal movement, followed the original reverse dip-slip displacement on the fault.

Movement on the Vangorda fault presumably began before emplacement of the ultrabasic rocks in latest Permian or earliest Triassic time. Initiation of movement is tentatively thought to have taken place in the latest Permian or earliest Triassic. Displacement must have ceased before deposition of unit 10 in the Middle or Late Triassic. Renewed displacement must have occurred subsequent to intrusion of the granitic rocks, because the Vangorda fault apparently truncates a body of these rocks near its eastern end.

Blind Creek Fault

The Blind Creek fault is a northeast-trending structure whose existence is inferred along the lower reaches of Blind Creek from the apparent noncontinuity of rock units across that stream. It is probably a steeply dipping normal fault on which the northwest side has moved up relative to the southeast side. The Blind Creek fault apparently offsets the Vangorda fault and may be related to doming of the Anvil Arch.

Summary

The various faults in the area form an extensive, branching, northwest-trending network about 8 miles wide that crosses the map-area diagonally. The faults dip steeply; the northern ones apparently dip to the southwest, whereas others are probably vertical or northeast dipping.

Rocks of widely different ages outcrop between faults and all major units are apparently involved in the faulting. Mesozoic and Tertiary coarse clastic rocks, exposed nowhere else in the map-area, are extensive in some of the fault blocks. Stratigraphic omission of between 1,000 and 5,000 feet can be demonstrated across each of the faults and implies dip-slip movement of at least that magnitude on them. The sense of the apparent dip-slip movement differs from one fault to another and displays no regular pattern. However, in the present area the net result of this movement has been to bring rocks south of the fault zone upward by 5,000 feet or more relative to those north of it. Strike-slip movement cannot be demonstrated on any of the faults, but the length and continuity of the fault system and the ambiguous dip-slip relations on some faults like the Vangorda imply that important strike-slip displacement has probably taken place. Several pairs of faults bounding the individual long, narrow blocks had dip-slip movement that should have led to steep tilting of those blocks. That such tilting has not occurred can also be taken as evidence of major strike-slip movement on the faults. Finally, the relatively small amount of dip-slip movement across the fault system as a whole seems incompatible with a structure of its magnitude; this also suggests that strike-slip movement may have been considerable.

The depth to which the faults extend is not known, but the abundance of serpentinite and the local occurrence of eclogite along the northern faults suggest that these structures may extend well down into the crust, perhaps to the mantle. The southern faults, which do not contain serpentinite, may not be such deep structures.

Displacement on the faults occurred at various times. The northernmost structures apparently moved in Early Triassic time, before initiation of movement on the southern faults. Offset on the southern faults probably began in Late Cretaceous time, perhaps after some of the more northerly structures ceased moving. There is no evidence to indicate that any of the faults moved between Early Triassic and Late Cretaceous time.

Fault-bounded blocks behaved essentially as rigid masses and are not sheared internally. Shearing is confined to local narrow zones. Subsidiary faults parallel to the larger structures that have the same sense of movement as the bounding Grew Creek and Buttle Creek faults are common between those faults and in the block between the Danger Creek and Lapie River faults.

Tintina Fault System

The Tintina fault system, at least 600 miles long, is a zone of major transcurrent faulting on which about 250 miles of right lateral displacement has been postulated (Roddick, 1967a; Tempelman-Kluit, 1970a). Although the evidence for the amount and even the sense of movement is questionable, transcurrent displacement seems necessary to explain local marked differences of geological terranes on opposite sides of Tintina Trench. The pattern of major and minor subparallel, branching faults occupying a broad zone in the present area is compatible with the general scheme of faulting postulated along Tintina Trench. Although evidence from the map-area by itself sheds no light on the nature and amount of transcurrent faulting, it does confirm the timing of movement as being in part Late Cretaceous and Tertiary. However, there is no evidence of faulting during the early Paleozoic as Roddick (1967a) has suggested; in the present area all displacement seems to have occurred in Early Triassic and later time.

The association of ultrabasic rocks along a number of the faults in the map-area is apparently not unique for Tintina Trench, although similar occurrences of rocks are not mapped elsewhere along it. Aeromagnetic data for adjacent areas (*see* Geol. Surv. Can. aeromagnetic maps 7209G and 7006G) indicate that steeply southwestward dipping, sheet-like masses of such rocks are present at other localities along the trench.

Aeromagnetic Data

Total field aeromagnetic data at a scale of 1 mile to 1 inch and for nominal ground clearance of 1,000 feet are available for all of the area studied. This information is compiled and reduced in Figure 3. The data show a fair correlation to the geology and demonstrate a regional increase in magnetic response from west to east. They outline a continuous belt of linear highs along the northern edge of Pelly River valley flanked by broad lows. Numerous smaller anomalies are superimposed on this pattern. The magnetic data do not outline the belt of phyllitic rocks that are host to the zinc–lead mineralization in the district, nor do they consistently pinpoint the known sulphide bodies.

Areas with low magnetic expression outline the known extent of the Anvil Batholith and the phyllitic and schistose rocks of units 2 and 3. Local highs within this broad low zone, e.g., anomalies A, B, and C (Fig. 3), pinpoint occurrences of magnetite-rich pyroxenite (unit 12). Other weak highs such as D, E, F, and G may reflect the presence of important amounts of pyrrhotite in thermally metamorphosed rocks at the margins of Anvil Batholith.

The linear belt of highs along the north side of Pelly River, many of which have a magnetic relief of 1,000 gammas or more, are in direct response to the steep-dipping, sheet-like occurrences of ultrabasic rocks exposed there. Peaks of these anomalies pinpoint occurrences of rocks mapped as unit 9 and permit tracing of these rocks between areas of outcrop (*compare* Fig. 3 with geological map). Four sample magnetic profiles at different places across this belt (Fig. 3) exhibit a weak asymmetry, indicating that the ultrabasic rocks dip steeply to the southwest. Noncontinuity of magnetic highs in this belt reflects the lensoid nature of the occurrences of ultrabasic rocks along Vangorda fault.

A number of moderate anomalies are apparently caused by the andesitic volcanic rocks of the Anvil Range Group. The pair labelled H (Fig. 3) coincides with the occurrence of such rocks as do J, K, L, M, N, and P. Most of these anomalies exhibit a common northwestward elongation that may reflect a depositional trend of the volcanic rocks on the pre-Anvil Range Group unconformity.

Total field magnetic response over known occurrences of zinc–lead mineralization is generally poor. Of the three large bodies only the Vangorda has definite magnetic expression (Q). A weak anomaly (R) some distance from the Faro deposit, with a relief of 30 gammas, may be related to pyrrhotite developed at the granite contact rather than to the deposit itself. No magnetic relief is evident over the Swim zone although good ground magnetic response is reported. The lack of response over Faro and Swim may result from the deeper burial of these bodies compared with Vangorda. The shallow dip of the three bodies probably also hinders detection by total field techniques. Such bodies may be more susceptible to horizontal field detection methods.

Seven elongate, aligned magnetic lows of moderate to slight relief, south of Pelly River (labelled X on Fig. 3), are centred on a belt of phyllitic rocks thought correlative with units 2 and 3. The northwesternmost of these anomalies coincides with the Glenlyon fault and the other aligned anomalies are probably an expression of the southeastward extension of that structure. The continuation of this fault is therefore mapped along the northeastern edge of the anomalous lows and its position is shown in Figure 18. Broad highs like Y and Z may be related to local variations in the regional trend.

Mineral Deposits

Three pyritic zinc–lead deposits aggregating 80 million tons of proven ore reserves lie on the southwestern flank of Anvil Arch. The deposits, found in a restricted part of the Cambrian (?) phyllite of unit 3, are tabular and concordant with the prominent foliation (F_2) of the enclosing rocks. The deposits are chemically alike and contain about 10 per cent combined zinc and lead with an ounce or more of silver per ton, and minor copper. Of the three only the largest, the Faro orebody, is being readied for production.

The primary objective of the present work is to relate the known mineral deposits to the regional geology and to determine geological controls for recovering zinc–lead from the Anvil district; it is hoped that this will stimulate and aid continued mineral exploration not only in this area, but in Selwyn Basin in general. To this end the following pages contain descriptions of the geology of the three known deposits, a comparison of the three and a discussion of their possible origins and controls. Parts of Selwyn Basin in which geological conditions are similar to those in Anvil Range are outlined. The importance of probable Cambrian strata to the localization of ore and the presence of greenstone near zinc–lead deposits are emphasized as guides to further exploration.

Swim Lakes Massive Zinc–Lead Deposit

(Also see descriptions by Green, 1965, p. 36; Green, 1966, p. 50; Findlay, 1967, p. 40.)

The Swim deposit, about a mile west of the northwest end of the largest of the Swim Lakes (*see* Map 1261A), was staked in 1963 following an aeromagnetic survey. Ground magnetic, electromagnetic, self potential, and gravimetric surveys were conducted over the area in 1964 and the deposit was drilled with 30 steep-angle and vertical holes (cumulative footage about 15,000 feet during 1965 and 1966). Now the property is inactive and no further work is planned in the near future.

Outcrop is scarce in the vicinity of the Swim deposit and the orebody itself is not exposed. Scattered float and small outcrops are of grey phyllite and slaty phyllite of unit 3. All information regarding the deposit is derived from the writer's examination of the drill core stored on the property and from diamond-drill hole plans kindly supplied by Kerr-Addison Mines Limited.

The Swim deposit is an irregular, digitate, tabular zone of sulphide minerals in a 'quartzite' gangue surrounded by a partial mantle of creamy white phyllitic rocks that are richer in quartz than the phyllite elsewhere in the map-area (Fig. 19).

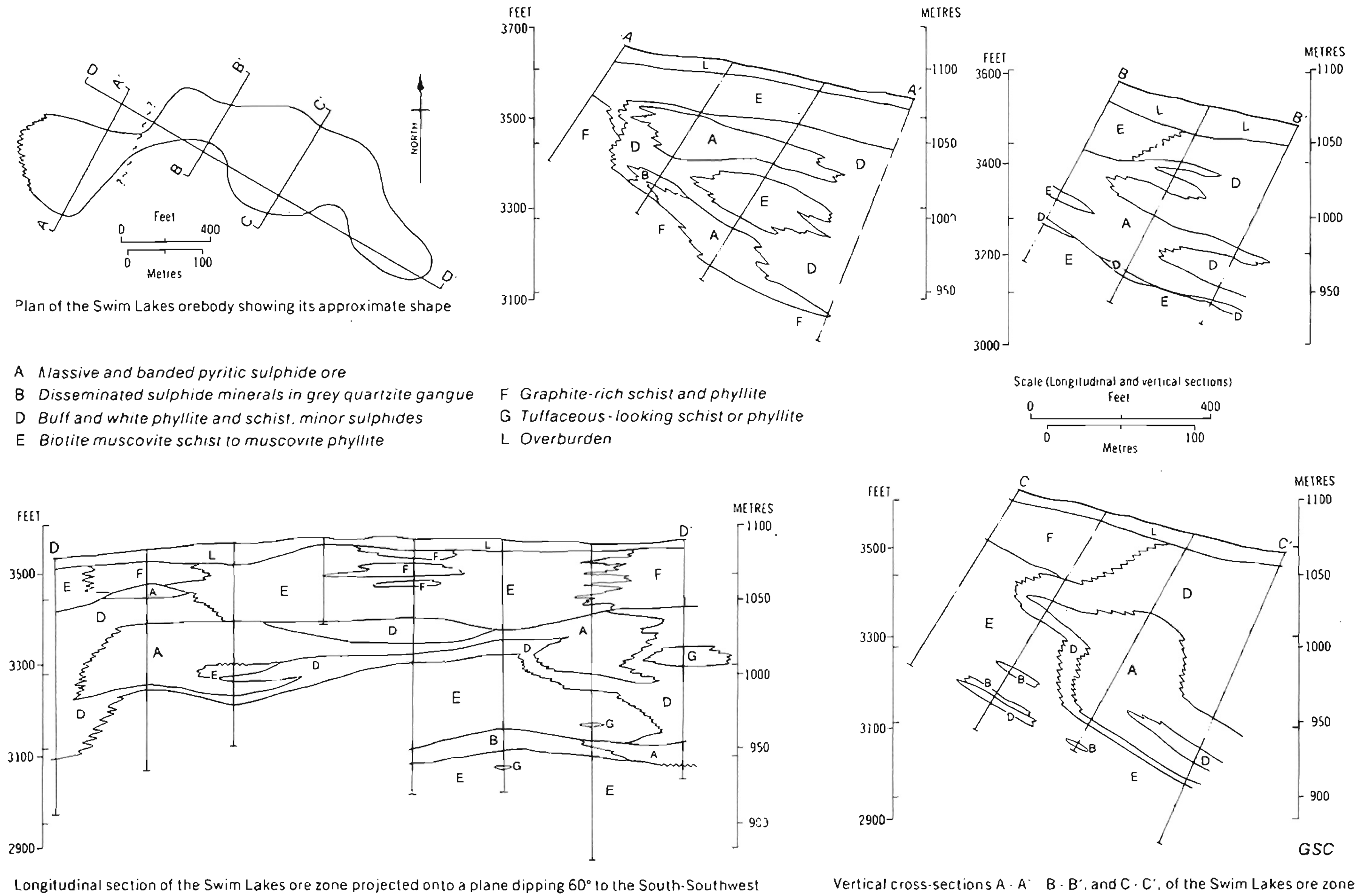

FIGURE 19. Cross-sections and map of the Swim Lakes deposit.

The phyllite surrounding the mineralized and altered zones is medium to dark grey and comprises quartz, muscovite, graphite, and chlorite. Stilpnomelane occurs locally as a minor constituent. Grain size of the minerals is fairly uniform and is generally less than 0.1 mm. Both quartz and muscovite have an average grain size of about 0.05 mm. Recrystallized quartz generally occurs as larger grains, but most of the quartz appears detrital and is not recrystallized. Muscovite aligned along F_2 is generally coarser grained than that along F_1. Tuffaceous laminae are rare and greenstone (unit 3a) was intersected in only one hole. The tuffaceous rocks are a dull green and contain fine-grained calcite and chlorite with lesser quartz, albite, and muscovite.

The pale-coloured phyllite that mantles the sulphide zone is creamy white with a faint greenish cast. It contains quartz and muscovite with minor chlorite and is generally somewhat coarser grained than the phyllite elsewhere. Average grain size is about 0.1 mm. The pale phyllite is distinguished by its light colour, which reflects a general absence of graphite or carbonaceous material. Disseminated pyrrhotite occurs commonly in quartz-rich F_1 laminae and these layers outline folds between, and are strung out along the crenulation foliation (F_2).

The sulphide zone itself characteristically contains about 50 per cent sulphide minerals in a gangue of granular grey quartz with minor muscovite. Much of the ore is compositionally layered and laminae rich in quartz and pyrite alternate with thinner layers relatively rich in sphalerite and galena. Layers have gradational boundaries and some pyrite and quartz invariably occur in the zinc–lead layers, whereas sphalerite and galena are generally present in the quartz-rich laminae. The sulphide layering is controlled by the foliation of the phyllitic host rocks. Sulphide layering corresponding to F_1 is locally visible and forms small rootless folds between the F_2 planar structures (Fig. 20). A gross layering along F_2 is present throughout (Fig. 21). It generally shows form orientation of quartz, sphalerite, and pyrrhotite and these minerals are elongated in this planar structure. Generally the layering that dips relatively steeply is F_1 and the gentler dipping foliation is F_2.

The Swim Lakes sulphide zone is a discontinuous, roughly tabular, elongate mass about 1,500 feet long and nearly 500 feet wide that trends northwest and dips northeast at 25 degrees (Fig. 19). The average thickness of the sulphide body is about 70 feet and maximum thickness (in one drill intersection) is 280 feet.

Published figures (*Northern Miner*, March 9, 1967, p. 5) indicate the presence of 5 million tons of mineralized rock containing about 9.5 per cent combined zinc and lead with 1.5 ounces of silver per ton and minor copper and gold. Zinc is the predominant base metal. The central part of the Swim deposit is richest in zinc and lead and the base-metal content falls off gradually toward the margins of the ore zone. The thickest sections contain the highest combined metal values, and variation in grade appears to be related to variation in the amount of total sulphides.

Mineralogically the Swim deposit is much like the Vangorda. Metallic minerals constitute about half the volume of the mineralized zone and include, in order of abundance, pyrite, sphalerite, galena, pyrrhotite, marcasite, and chalcopyrite. Arsenopyrite, magnetite, and tetrahedrite were also noted; the latter is a very minor constituent. Barite is fairly common in the gangue and may account for about 1 per cent of the volume of the sulphide mass. Gypsum occurs as fine prismatic crystals and is commonly found along fractures. The sulphide minerals are intergrown with quartz and barite and form a granular aggregate of roughly equant anhedral to subhedral grains in which only the proportion of minerals and their grain size changes from place to place. Pyrite forms the largest grains (as much as 0.5 mm across) and shows greatest tendency toward euhedralism. Average grain size of the sulphide minerals is about 0.1 mm. Chalcopyrite and galena locally replace pyrite. Some chalcopyrite forms exsolution blebs in sphalerite. Marcasite is secondary after pyrrhotite and

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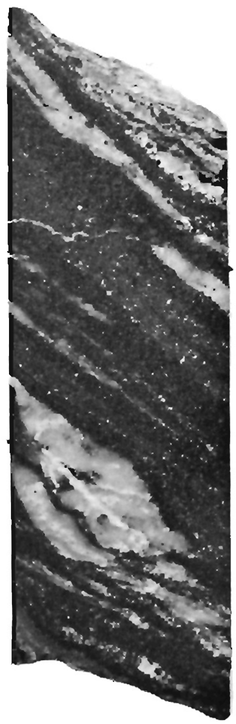
FIGURE 20

Photograph of diamond-drill core from the sulphide zone of the Swim deposit. Sulphide layers (dark) along F_1 outline small folds between the crenulation foliation (F_2) which dips gently across the core. Note that the limbs of the folds are strung out along F_2. Compare these structures in the sulphide zone to those in the host rocks shown in Figure 13.

FIGURE 21

Photograph of diamond-drill core from the sulphide zone of the Swim deposit. A gross banding of the ore is defined by alternating layers richer and poorer in sulphides and is controlled by, and analagous to, F_2 in the host rocks. Dark layers are sulphide, light layers are quartz, white is barite. Compare with Figure 5. Core diameter is 1.4 inches.



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pyrite. The minerals show little evidence of having been strained, and granulation of minerals is uncommon. Streaking and form orientation of sphalerite and pyrrhotite are common. Chalcopyrite tends to be most abundant where pyrrhotite is plentiful, whereas galena is closely associated with sphalerite. Thin, steeply dipping, regular veinlets of chalcopyrite and pyrrhotite cut the layered sulphides locally and transgress their foliation.

Results of the geophysical surveys over the Swim deposit are not available to the writer, but it is common knowledge that the magnetic response over the Swim body is good; this factor led to the original staking and later discovery of the deposit. Gravimetric results over the deposit are reported to have been conclusive and allow an accurate estimate of the tonnage of the deposit.

Vangorda Creek Massive Zinc–Lead Deposit

(Also see descriptions by Chisholm, 1957, p. 269–277; Green and Godwin, 1964, p. 31–32.)

Conventional prospecting techniques led to the discovery in 1953 of the Vangorda massive zinc–lead deposit (for location *see* geological map), partly exposed in Vangorda Creek. Drilling of more than 150 vertical holes with a cumulative footage of about 60,000 feet followed geochemical, gravimetric, and electromagnetic surveys (Chisholm, 1957). The property is presently inactive and no further work is planned.

Drill core, stored at the camp on the Vangorda property, was examined and logged in conjunction with study of a scale model also left on the ground. Although the core is still useful it has been plundered and large sections are now missing. Several representative cross-sections of the Vangorda deposit, based on the writer's examination of the core, are shown in Figure 22.

The Vangorda deposit, an irregular tabular mass of sulphide minerals with a granular quartz gangue, is partly enveloped by a narrow zone of pale-coloured phyllite in turn enclosed in phyllitic rocks of unit 3. The phyllite surrounding the deposit and altered zone is silvery grey and fine grained and contains roughly equal proportions of quartz and muscovite with lesser chlorite and fine-grained biotite. Quartz forms equant grains about 0.1 mm across and muscovite flakes are generally of similar dimensions. Muscovite grown along F_2 is coarser grained than that along F_1. Graphite is a common constituent of the phyllite; where it is abundant quartz is the only other mineral and micas are lacking. As elsewhere in the phyllitic rocks the crenulation foliation, F_2, is well developed and small folds, outlined by bent muscovite and by compositional layering (i.e., F_1), occur between these foliation surfaces. Greenstone and tuff (unit 3a) is seen locally near the Vangorda deposit and is composed of chlorite, actinolite, epidote, albite, and quartz.

The pale, white to buff rocks of the enveloping zone differ from the phyllite elsewhere in their colour. Their mineralogy is similar and they contain quartz, muscovite, and minor chlorite. They lack graphite and this may account for their light colour. Pyrrhotite and pyrite are widespread though not abundant in the pale phyllite at Vangorda.

The sulphide-rich body at Vangorda Creek generally contains about 50 per cent metallic minerals in a gangue of granular grey quartz with minor muscovite. A rude and generally poorly defined compositional layering like that in the Swim deposit is common. It is defined by laminae, 1 inch to 6 inches thick, alternately somewhat richer in quartz–pyrite and sphalerite–galena and is emphasized by streaking and form orientation of pyrrhotite, sphalerite, and quartz. As in the Swim deposit this layering is analogous to, and has the same orientation as, the foliation F_2 in the enclosing rocks. Compositional banding at angles to this gross layering and apparently corresponding to F_1 in the host rocks is seen locally (Figs. 23, 24). The average grain size of quartz in the sulphide zone is about 0.15 mm.

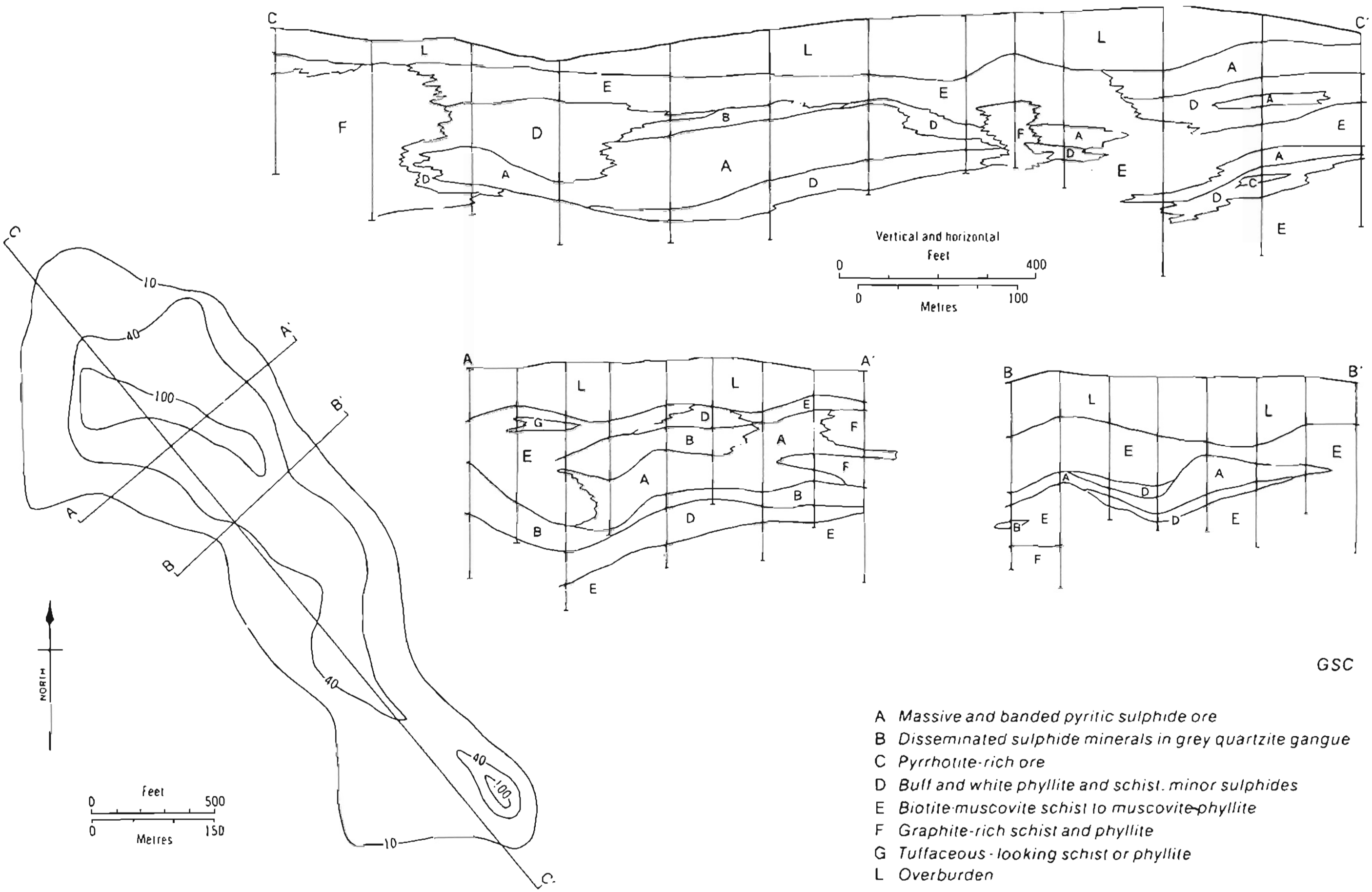

FIGURE 22. Cross-sections and isopachous map of the Vangorda deposit.

FIGURE 23

Photograph of drill core from the sulphide zone of the Vangorda deposit. Note the folded sulphide bands (black) that outline F_1. Also note that the sulphides are strung out along F_2 at the top of the core and along the limbs of the fold. F_2 is outlined in the quartzose layers (white) by segregation of micas. Compare with Figures 12, 13, 20, 21. Drill-core diameter is 1.4 inches.

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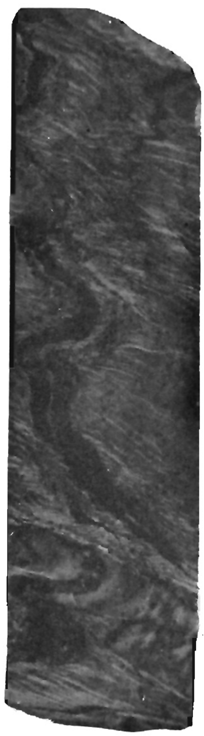

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FIGURE 24

Photograph of drill core from the pale zone around the Vangorda deposit. The dark bands are rich in sulphide minerals, mainly pyrrhotite, and outline the folded first foliation, possibly bedding. Thin micaceous partings define the irregular crenulation foliation F_2 in the pale-coloured gangue. Compare with Figure 12. Drill-core diameter is 1.2 inches.

The 'quartzite' gangue of the ore zone does not extend beyond the sulphide deposit and is mineralized where seen. Similarly the 'bleached' rocks form an irregular halo around the mineralized mass, but do not continue far from it.

The Vangorda mineralized zone is tabular and flat lying; its long axis trends northwest and is about 2,500 feet long, its width is about 500 feet and the average thickness is about 70 feet. Maximum thickness of the mineralized zone is about 200 feet. Figure 22 shows the shape of the deposit in cross-section and also variations in thickness of the sulphide zone. The sulphides form a more-or-less continuous body, but lenses of mineralization, separated from the main mass, are seen in many drill intersections; although the general shape of the sulphide zone is tabular, many irregularities occur in detail. The zone of sulphides forms the bedrock surface over much of the deposit and extends to depths of about 300 feet. Drift cover is about 50 feet thick.

Published tonnage and grade figures for the Vangorda body (Chisholm, 1957) indicate the presence of 9.4 million tons with 3.1 per cent lead, 4.96 per cent zinc, 0.27 per cent copper, and 1.76 ounces of silver per ton; 12.6 million tons of essentially barren sulphides are reported in addition to the base-metal zone. Data on variation in the base-metal content suggests that the highest concentration of zinc and lead coincides roughly with the thickest part of the body and that the concentration of these metals decreases toward the margin of the mass.

The mineralogy of the Vangorda deposit is simple; sulphides are estimated to constitute half of the mineralized zone and of these pyrite is dominant. Sphalerite, galena, pyrrhotite, and chalcopyrite are the other volumetrically important sulphide minerals in order of abundance. Magnetite and marcasite are minor constituents. Arsenopyrite and tennantite (Chisholm, 1957) have also been identified among the sulphides. Barite, though not so common in the Vangorda deposit as in the Swim, is an important minor constituent. It generally occurs as large, pale, flesh-coloured grains surrounded by the other minerals. The proportion of sulphides to gangue (quartz) ranges from roughly 10 to 90 per cent. Pyrite invariably forms the largest grains and occurs as subhedral crystals as much as 1 mm across. Average grain size of the sulphides is about 0.15 mm. The sulphide minerals are intimately intergrown with one another and with the granular quartz gangue and form an aggregate of anhedral grains. The proportion of the various minerals in the sulphide zone is fairly uniform and differences in the combined base-metal grade of the deposit appear to reflect differences in the amount of total sulphides.

Chisholm (1967) has demonstrated the lack of correlation between magnetic, aeromagnetic, and self-potential anomalies in the vicinity of the Vangorda deposit. He has also shown that these anomalies do not correspond closely to the sulphide zone. He established, however, that a general relationship does exist between geochemically anomalous soils in the area and the sulphide deposit itself, and further that there is a precise correlation of the gravimetrically anomalous zone to the massive sulphide deposit. The average specific gravity of Vangorda sulphide ore is about 4.4 which compares with 2.8 for its host rocks.

Faro Massive Zinc–Lead Deposit

(Also see descriptions by Aho, 1966, p. 127-144; Green, 1966, p. 47-50; Findlay, 1967, p. 35-39.)

The Faro orebody northwest of Mount Mye and east of Rose Mountain (*see* map) was located in 1965 by a combination of geochemical and geophysical prospecting methods (Aho, 1966, p. 147) and was subsequently explored by drilling and further geophysical work. By the end of 1967 a total of 42,878 feet distributed over 89 vertical holes had been diamond drilled to explore and outline the deposit. Late in 1966 a 2,700-foot-long crosscut was driven through the deposit at an elevation of 3,920 feet to obtain a bulk sample for milling tests. The Faro deposit is now being developed and production by open-pit mining methods began in early 1970. Development work includes the building of a 5,500-ton-per-day concentrator, completion and improvement of the access and concentrate trucking route—including building of a bridge across the Pelly River, and preparation of a townsite near the Pelly to accommodate mine and mill personnel.

Outcrop is more plentiful in the vicinity of the Faro deposit than around the Swim and Vangorda zones. Most exposures are of schistose rocks mapped as unit 3, but strata of unit 2 are found close to and north of the Faro. Rocks of unit 3 near the Faro deposit are quartz muscovite schists that invariably contain biotite and which commonly contain andalusite. Staurolite and garnet are present locally. The schist has a well-developed foliation, F_2, outlined by closely spaced zones of preferentially oriented muscovite. Between these planes muscovite is pervasively directed generally at angles to this foliation and here it outlines small rootless folds. This second preferred orientation defines F_1. Muscovite flakes are generally bent and about 0.5 mm long; the quartz intergrown with it shows granoblastic texture and its grain size is about 0.15 mm. Biotite forms undeformed books as much as 1 mm long grown across both foliations in the schist. Andalusite occurs as larger anhedral poikiloblastic grains as much as 1 cm long enclosing quartz. The mineral clearly replaces muscovite and the small-scale folds outlined by muscovite are relict textures seen in this mineral. Garnet forms large subhedral porphyroblasts as much as 2 cm across. Staurolite porphyroblasts are of similar dimensions and are subhedral and poikiloblastic. Greenstone and tuffaceous rocks near the Faro deposit have a nematoblastic texture and contain actinolite with minor quartz, biotite, and locally, chlorite. Actinolite prisms commonly outline microscopic folds analogous to those seen in the schist. Graphite schist is found locally near the Faro ore zone. It contains quartz, muscovite, and graphite. Chiastolite is generally present as euhedral, graphite-charged, short prismatic crystals as much as 5 mm long.

The crosscut and most of the drill core stored at the Faro camp were examined and the following description of the deposit and the rocks immediately around it is based on this study, and on an examination of drillhole plans and cross-sections kindly loaned to the writer by Anvil personnel. The Faro orebody is a gently dipping tabular lens of sulphide minerals in a granular quartz gangue surrounded by an irregular zone of pale-coloured schist and enclosed in quartz-mica schist of unit 3. The schist around the pale-coloured rocks is like that found in outcrops near the deposit and described above. The pale-coloured schist contains quartz and muscovite, but lacks biotite and other metamorphic silicate minerals. Its texture and structure are the same as the schist already described. At its northwest end the Faro sulphide zone abuts against white, altered, medium-grained quartz monzonite. This rock contains about 10 per cent altered euhedral biotite and 35 per cent fresh, equant, anhedral quartz. The remainder is a very fine grained mixture of clay minerals pseudomorphous after subhedral feldspar. Biotite is altered to a mixture of carbonate (probably siderite) and sericite. The granitic rocks are altered and light coloured in an irregular zone that extends as much as 300 feet away from the margin of the sulphide zone. Beyond this the alteration is not seen and the rock is a fresh biotite–quartz monzonite. A restricted zone of breccia lies above part of the Faro deposit (*see* Fig. 26). This breccia contains angular fragments of schist like that around the orebody. Fragments range from several feet to a fraction of a millimetre across. The matrix, about 5 per cent by volume, is a mixture of very fine grained chlorite. Blocks in the breccia are in all orientations. No fragments of mineralized rock were seen in the breccia and no mineralization was noted in the matrix. The breccia zone is about 800 feet deep. Its shape in plan is roughly circular. Above, below, and on its sides, the breccia passes gradationally into undisturbed schist. Several flat-lying dykes as much as 50 feet thick, of altered hornblende porphyry (unit 12) cut the breccia zone, but apparently do not extend beyond it into the surrounding rocks.

Sulphide minerals constitute roughly half the Faro ore zone and of these pyrite is the dominant member, constituting a quarter or more of the volume of the deposit. Sphalerite, galena, pyrrhotite, chalcopyrite, and marcasite constitute much of the remainder and occur in that order of abundance. Magnetite, arsenopyrite, bournonite, and tetrahedrite are present as minor or trace constituents among the more common minerals. Grain size and habit of the sulphide minerals differ. Pyrite forms the largest grains (as much as 5 mm across) and occurs as subhedral equant grains enveloped by quartz or sphalerite. It also forms masses or aggregates of smaller anhedral equant crystals. Sphalerite, galena, and chalcopyrite, in order of decreasing average grain size, occur as relatively small grains averaging between 0.2 and 0.3 mm across. Sphalerite is commonly associated with pyrite and also forms discrete layers or granular aggregates in which it is distinctly concentrated with galena, a common interstitial constituent. Minor chalcopyrite is intergrown with sphalerite and also forms exsolution blebs in that mineral. Pyrrhotite forms granular aggregates and is more abundant near the margins of the Faro deposit than in the central part of the body. It is invariably associated with chalcopyrite veinlets, but sphalerite and galena are also commonly associated. Quartz grains are equant and anhedral and average about 0.3 mm across; the mineral shows uniform extinction and has straight boundaries.

A gross, poorly defined layering, on a scale generally measured in several inches, is evident in much of the Faro ore and in the Swim and Vangorda deposits. This layering, outlined by segregation of the base metal and gangue minerals, is emphasized locally by streaking and form orientation of some of these minerals. Some layers contain quartz and pyrite with perhaps 5 or 10 per cent sphalerite and galena. Such layers alternate with others composed of 50 per cent or more sphalerite and galena, with a lower proportion of quartz and pyrite. Other layers, particularly near the edges of the sulphide mass, contain as much as 80 per cent pyrrhotite that is strongly form oriented. Boundaries between layers are gradational and the thickness of the layers changes from place to place. So far as can be determined the gross layering coincides with the transposition foliation, F_2, in the host rocks. It dips southwestward at gentle to moderate angles in much of the Faro orebody, as does F_2 in the host rocks. The layering dips steeply in the northwest part of the orebody where the sulphide mass abuts against granitic rocks. Lamination corresponding to F_1 in the enclosing rocks is rarely seen in the Faro orebody and small-scale folds like those seen in the Swim and Vangorda deposits (Figs. 20, 23, 24) are uncommon. Figure 28 shows an example of a folded sulphide layer from the Faro deposit.

Narrow, regular, steeply dipping veinlets as much as an inch across are rare in and near the ore zone. When found, they cut across the layering described above and are generally filled with coarse-grained chalcopyrite, but also contain galena, sphalerite, and pyrrhotite.

The Faro orebody is a regular and continuous, southwest-dipping tabular lens. Its longest axis, about 4,800 feet, trends northwest. The deposit is about 1,200 feet wide and as much as 260 feet thick; the average thickness is about 120 feet. A fault, on which the southeast side has dropped 100 feet relative to the northwest, cuts the deposit near its centre (*see* Figs. 25, 26). A second fault near the southeast end of the orebody has movement of the opposite sense. The depth of the mineralized zone beneath the surface ranges between 600 feet at its centre and 200 feet near its northwest and southeast ends. The ore extends to the bedrock surface at the northwest extremity of the mineralized zone.

The main sulphide body interfingers with and terminates against granitic rocks on the northwest end. At this extremity the ore zone bows upward as shown on the cross-sections (Fig. 26). The thickness of the mineralized zone changes in a regular fashion (Fig. 25); it is

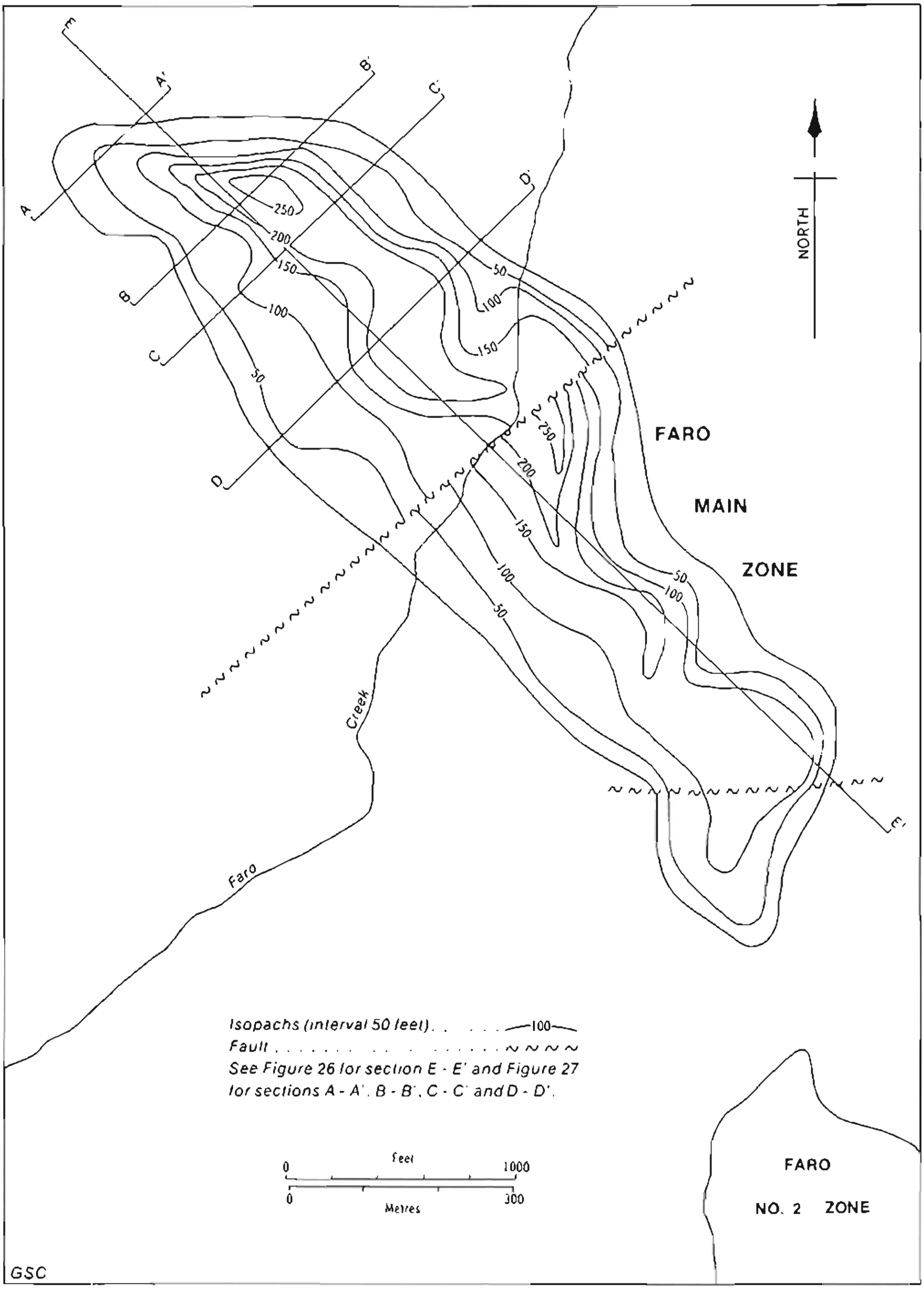
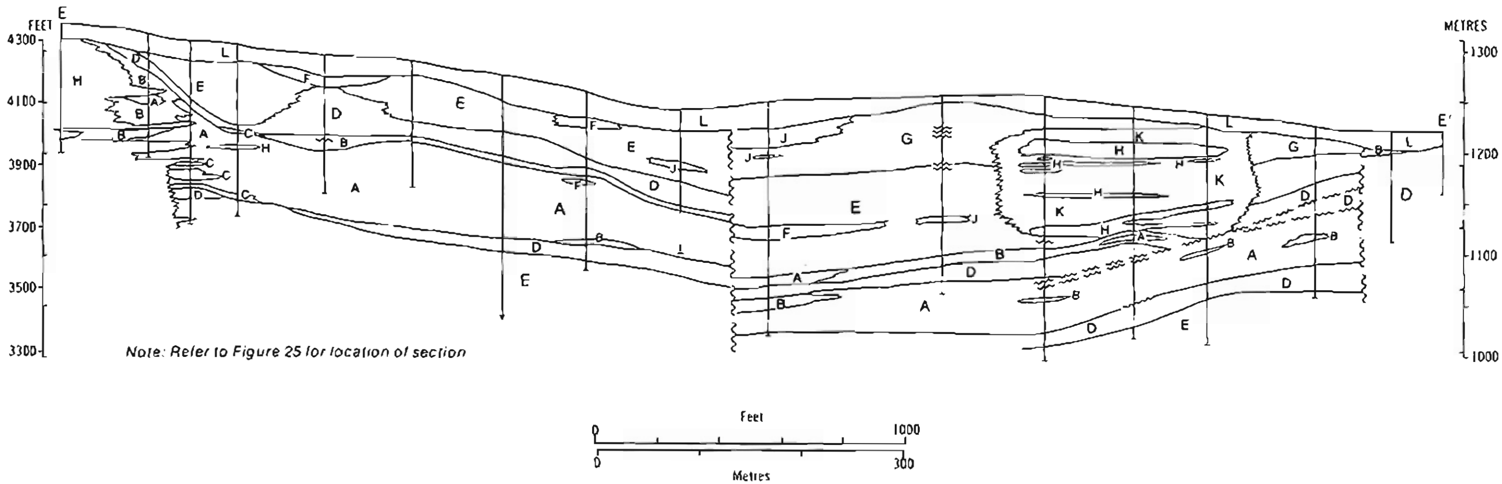


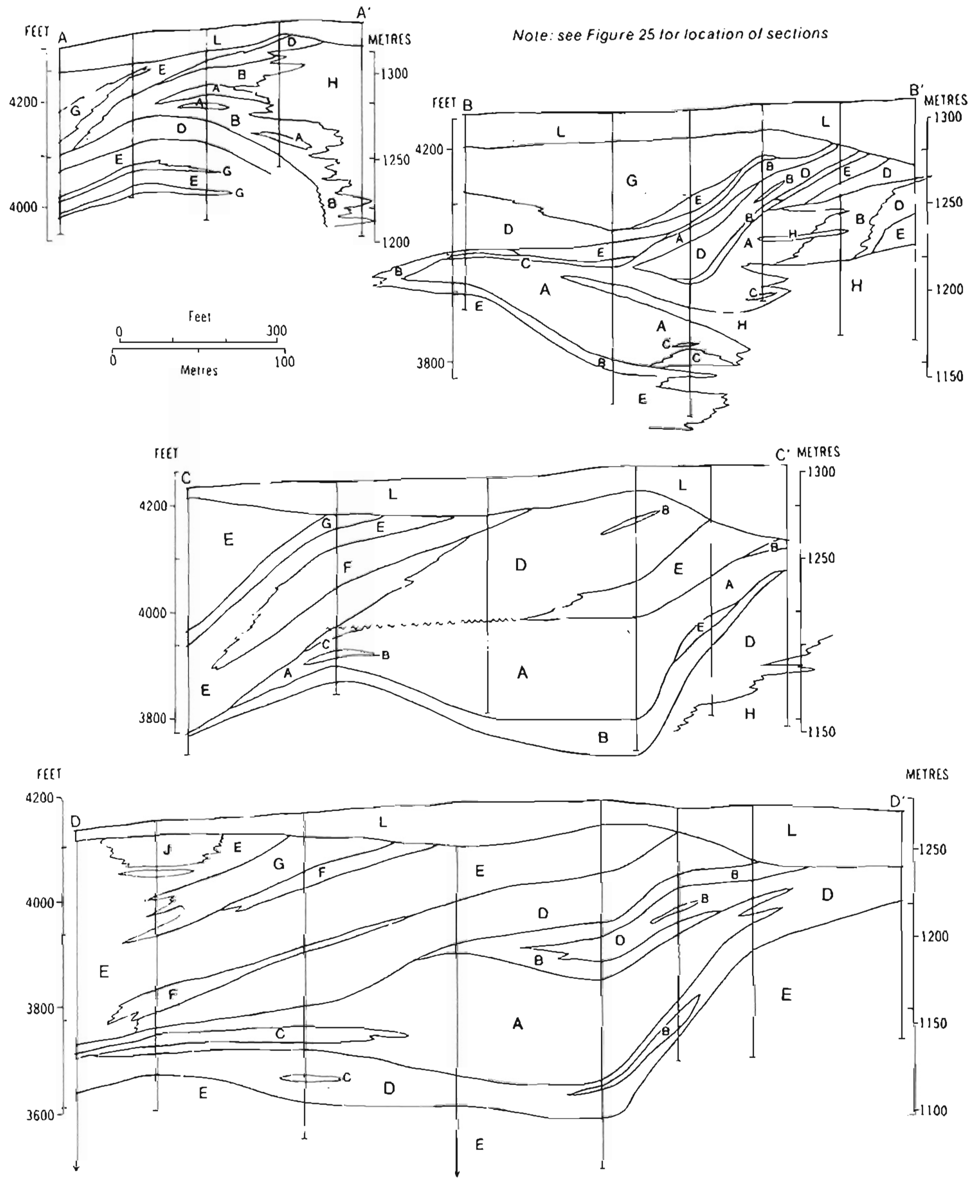
FIGURE 25. Isopach map of the Faro deposit.



A Massive and banded pyritic sulphide ore
B Disseminated sulphide minerals in grey quartzite gangue
C Pyrrhotite-rich ore
D Buff and white phyllite and schist, minor sulphides
E Biotite-muscovite schist to muscovite-phyllite
F Graphite-rich schist and phyllite
G Tuffaceous looking schist or phyllite
H Biotite-quartz monzonite and kaolinized equivalents
J Porphyritic hornblende-diorite
K Breccia
L Overburden

GSC

FIGURE 26. Longitudinal section of the Faro deposit.



A Massive and banded pyritic sulphide ore
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C Pyrrhotite-rich ore
D Buff and white phyllite and schist, minor sulphides
E Biotite-muscovite schist to muscovite-phyllite
F Graphite-rich schist and phyllite
G Tuffaceous looking schist or phyllite
H Biotite-quartz monzonite and kaolinized equivalents
J Porphyritic hornblende-diorite
L Overburden

GSC

FIGURE 27. Cross-sections of the Faro deposit.

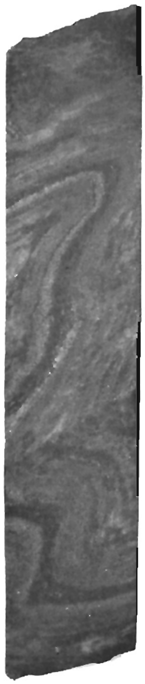

FIGURE 28

Photograph of drill core from Faro ore zone. The darkest layer is a band of sphalerite which outlines the folded F_1. The strong crenulation foliation (F_2), which for the most part controls layering in the ore and which generally obscures folds like this one in the Faro ore, is evident at both ends of the core. Drill-core diameter is 1.85 inches.

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thickest near its northwest end and from there thins out gradually. At its southeast end the Faro orebody is terminated by a gradual thinning and a decrease in the proportion of sulphide minerals. The northeastern and southwestern margins of the Faro ore zone are similarly marked by a pronounced change in the proportion of sulphides.

A second zone of sulphide mineralization, the Number 2 Zone, thinner and less extensive than the main orebody, lies 1,500 feet southeast of the southeast end of the main zone. Its mineralogy, structural and textural features are similar to those of the main orebody and this second zone is not described separately here.

Published figures indicate the presence of 63.5 million tons of ore with 3.405 per cent lead, 5.721 per cent zinc, and 1.196 ounces of silver per ton; part of the Faro deposit has an average copper content of 0.15 per cent. The ratio of lead to zinc, expressed as weight per cent, is distributed in the range 0.3 to 0.8 with the mode at 0.57; the mean weight per cent ratio lead to zinc is 0.57. Lead and zinc values are unimodally distributed in positively skewed distributions with modes at 3.2 and 5.7 per cent, respectively (Fig. 29). Silver is bimodally distributed over a range from 0.2 to 2.2 ounces per ton with modes at 0.65 and 1.60 ounces per ton (Fig. 29). Data on the distribution of base metals show that individual and combined lead and zinc values vary systematically in the deposit; the highest combined values are in the central or thickest part of the deposit and values fall off toward the margins of the ore zone. Combined lead and zinc is highest in the northwest part of the deposit.

Results of geophysical and geochemical surveys over the Faro deposit are not available to the writer but Aho (1966) has explained the lack of response of most geophysical prospecting tools over the Faro orebody. Especially worthy of emphasis by restatement is the fact

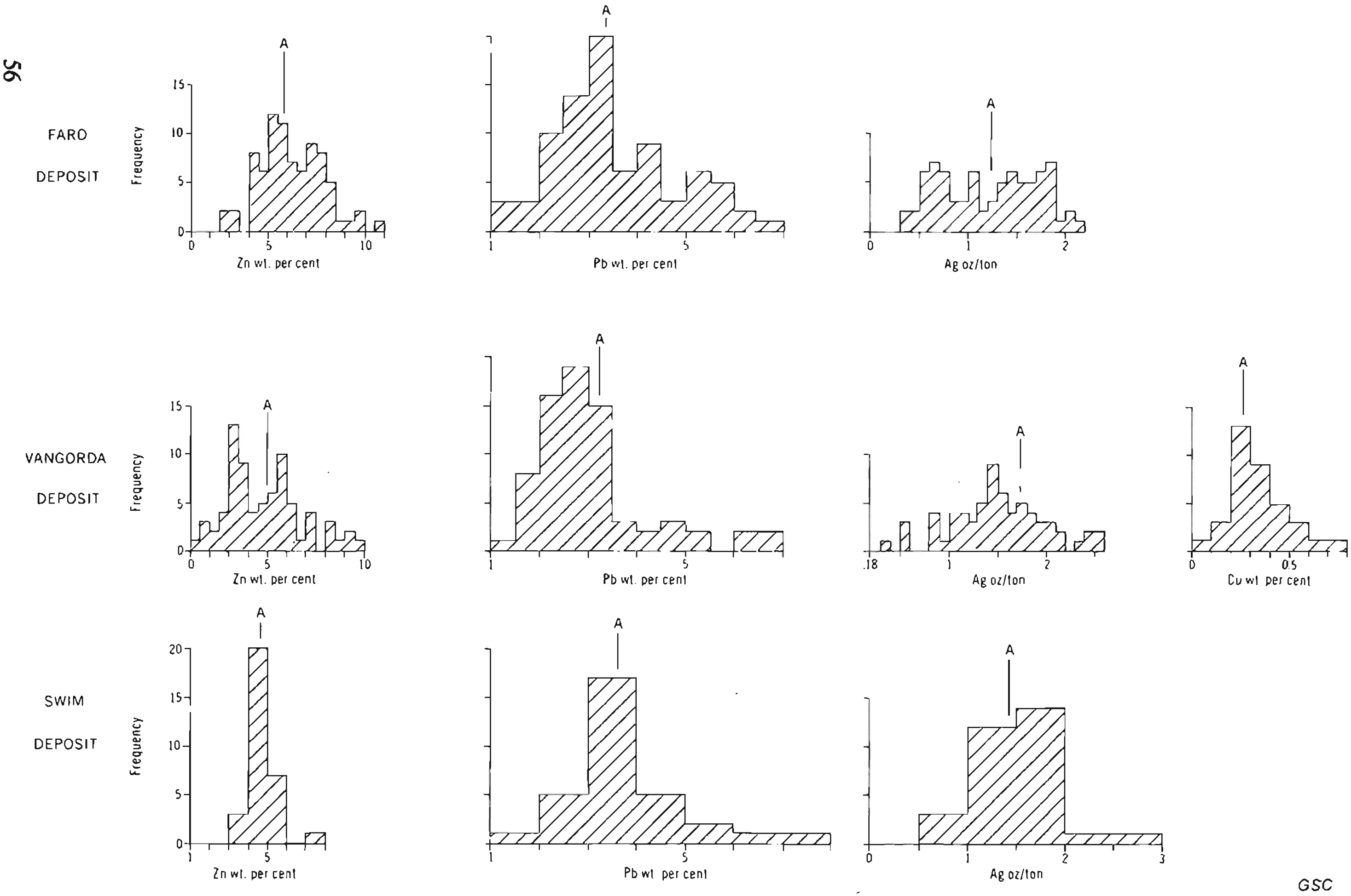
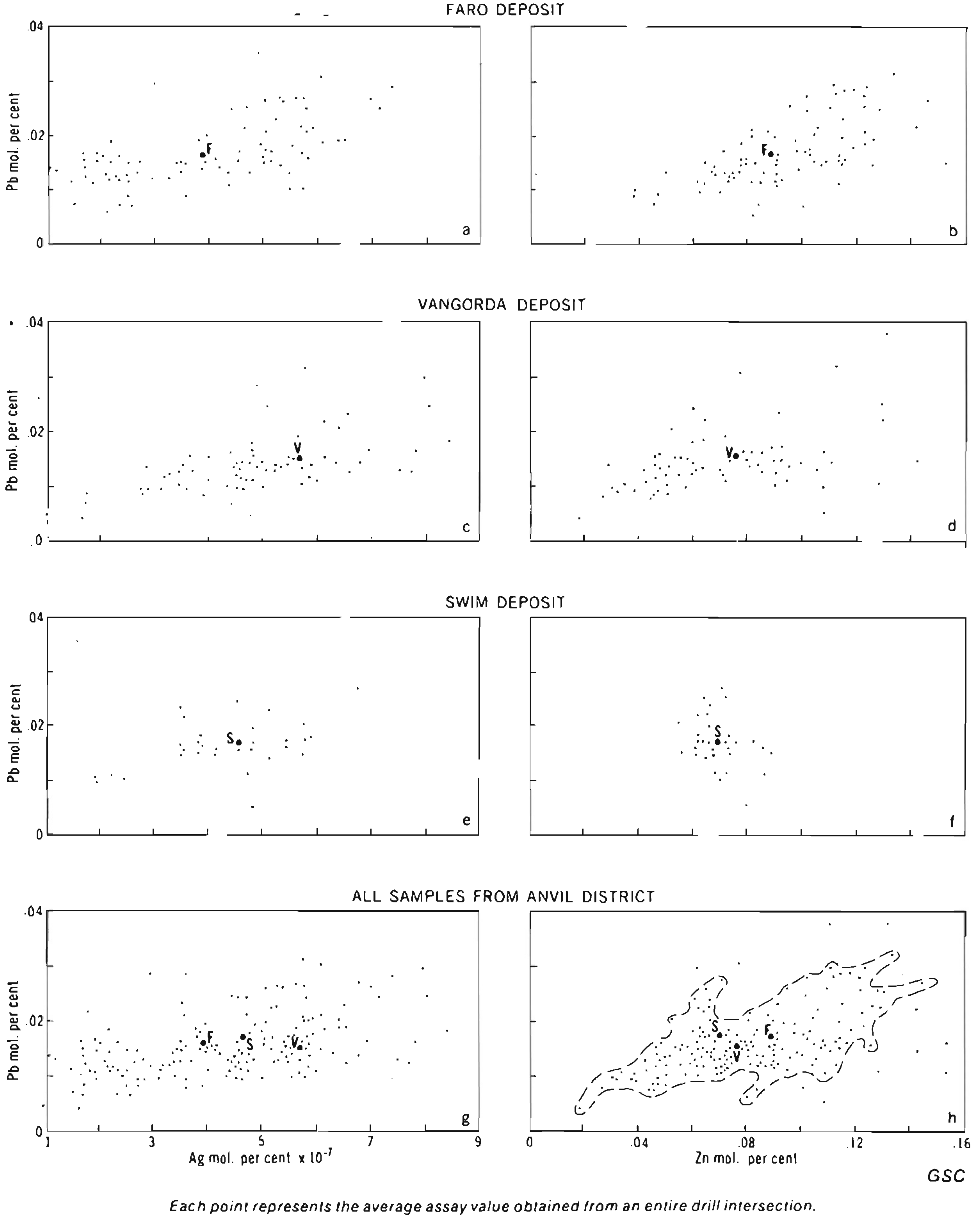


FIGURE 29. Frequency distributions of lead, zinc and silver in terms of weight per cent for the Faro, Vangorda, and Swim deposits.



Each point represents the average assay value obtained from an entire drill intersection. Plots at the bottom of the figure show all points and demonstrate the total variation of Pb:Ag and Pb:Zn in the district. The area in 'h' includes most individual ratios in the Anvil district.

FIGURE 30. Molecular ratios Pb:Ag and Pb:Zn for each of the three Anvil Range deposits with their averages (heavy point). Each point represents the average assay value obtained from an entire drill intersection. Plots at the bottom of the figure show all points and demonstrate the total variation of Pb:Ag and Pb:Zn in the district.

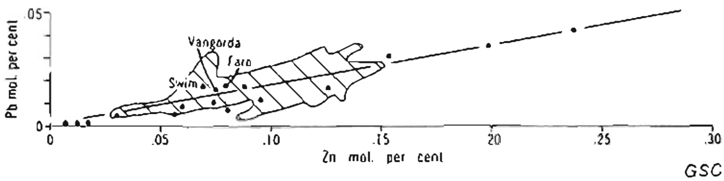


FIGURE 31. Average molecular ratios of lead–zinc in fourteen 'conformable' lead–zinc deposits in Australia, Ireland, and New Brunswick (*after* Stanton, 1958). Note that the averages for the Swim, Vangorda, and Faro deposits, also shown on the plot, conform to the trend line defined by the other deposits. The shaded area includes most individual ratios in the Anvil district.

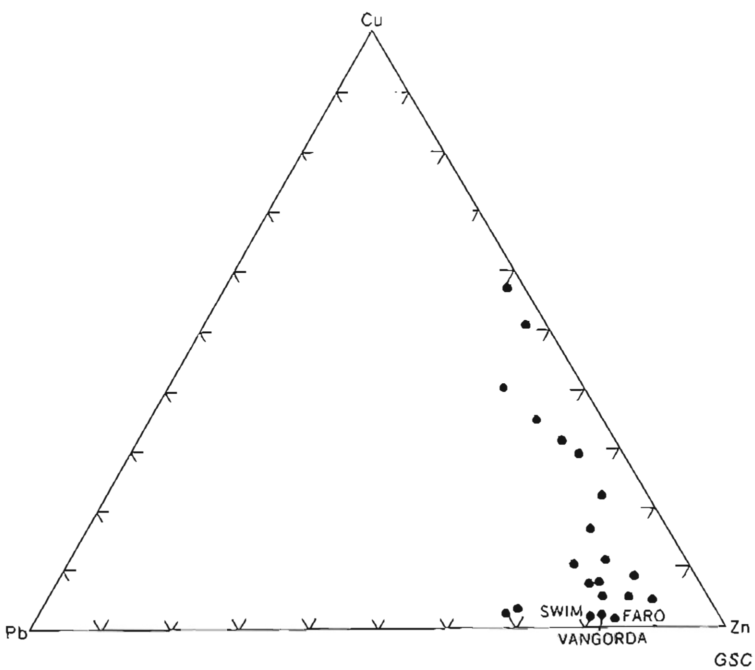


FIGURE 32. Average molecular ratios Zn:Pb:Cu for eighteen 'conformable' lead–zinc deposits in Australia, Ireland, and New Brunswick (*after* Stanton, 1958). Averages for Swim, Vangorda, and Faro, are also plotted and evidently belong to the group.

that airborne and ground electromagnetic techniques are unsuitable in the district because response from greenstone within the phyllite unit masks or obliterates effects from the Faro deposit. In this regard Aho (1966, p. 148) wrote: "Without those fortuitous magnetic anomalies, neither the airborne nor ground magnetic or electromagnetic anomalies over the Faro deposits showed any real coincidence except in a very general way, certainly not enough to have caused much interest without supporting geochemical results." Aho (1966, p. 148) also reported that a gravimetric survey over the Faro deposit gave satisfactory results providing quantitative data on tonnage when drilling information became available. He concluded: "A properly conducted gravity survey therefore appears to be the best tool for defining position of massive sulphides." The average specific gravity of sulphide ore at Faro is 4.7, nearly 70 per cent higher than that of its enclosing rocks.

Chemistry of the Ores

Available data concerning the metal content of the Anvil deposits is briefly examined in the following section and a comparison is made with similar data for base-metal deposits elsewhere. Variations in the content of zinc, lead, silver, and where determined, of copper, are examined individually and in pairs. The data used was supplied by the respective companies and represents average assays for entire drill intersections of each of the three mineral deposits.

Plots of the frequency distribution of each of the three economically important metals are given for the Anvil Range deposits in Figure 29. They show that each metal has a similar distribution in all three bodies with small differences between the deposits in the modes and range of values. The distributions for each metal is fairly characteristic in all three deposits. Plots of silver and zinc against lead, expressed in mole per cent to avoid exaggeration resulting from the different atomic weights of the elements, are given for each deposit (Fig. 30). These illustrate that the pairs, lead–zinc and lead–silver are related in much the same way in the three deposits, with differences only in the degree of correlation between the metals. For instance there is a stronger interrelation between lead and zinc in the Faro than in Vangorda, but lead and silver are more perfectly allied in Vangorda than Faro.

Comparison of the above with data given by Stanton (1958) shows that the Anvil ores are chemically similar to those in a number of 'conformable' base-metal deposits in other parts of the world. The Anvil material has the low copper content and uniform lead–zinc ratio that characterizes this group of deposits and it shows the fair correlation between lead and zinc (Fig. 30) diagnostic for all of them. It is clear from Figure 31, in which the average zinc, lead, and copper contents of these and a number of 'conformable' deposits from other parts of the world are plotted in terms of their molecular ratios, that the Anvil ores belong chemically to the strata-bound group of deposits. No data are available with which to compare the behaviour of silver–lead in the Anvil ores with that for ores from elsewhere.

Summary of the Geology of the Deposits

1. The three economically important zinc–lead deposits in Anvil Range are enclosed in phyllitic or schistose rocks of unit 3 that are considered of Cambrian or late Proterozoic age. All three deposits are in the lower member of this unit, which is distinguished from the upper

member by its higher quartz content, graphitic horizons, and lack of thick greenstone lenses. Metamorphic grade of the host rocks varies: around Swim the rocks are chlorite–muscovite–quartz phyllite; near Vangorda the rocks are schistose phyllite carrying chlorite, muscovite, and biotite; at Faro the host is quartz–biotite–muscovite schist that generally contains andalusite and local garnet and staurolite.

2. The mineralogy of the deposits is essentially identical. Quartz and pyrite are the dominant minerals and sulphides comprise roughly half the volume of the ores. Sphalerite, galena, pyrrhotite, chalcopyrite, and marcasite are the other important minerals. The proportion of pyrrhotite is notably higher in the Faro than at Vangorda and Swim. Barite is a common minor constituent of the ores at Vangorda and Swim, but was not noted at Faro. Arsenopyrite and magnetite constitute a small proportion of the ores at all three deposits.

3. Textures of the sulphide minerals are similar in all three deposits. Pyrite mainly forms subhedral equant grains enveloped by other minerals, but also occurs in masses of small grains. Sphalerite envelopes pyrite and forms granular aggregates of equant anhedral crystals. Galena is associated with sphalerite as single, small anhedral crystals interstitial to it. Pyrrhotite is found in granular aggregates of form-oriented, ellipsoidal grains. Chalcopyrite is interstitial to pyrrhotite and forms small exsolution blebs in sphalerite. Grain size of the sulphide minerals ranges considerably in each deposit, but differs more drastically between the deposits than within each. At Swim the average sulphide grain size is about 0.1 mm, at Vangorda it is 0.15 mm, and at Faro it is 0.25 mm or more. Pyrite invariably forms the largest grains in the ore zones and its maximum grain size also differs more between the three deposits than within each one. Maximum grain size of pyrite at Swim, 0.5 mm, compares with 1 mm at Vangorda, and 5 mm at Faro.

4. Structures in the ores are similar to those in the enclosing rocks. Compositional layering defined by gradational changes in the proportion of the sulphide minerals from layer to layer and emphasized by elongation of some minerals, follows the F_1 and F_2 planar structures in the host rocks. Lamination analogous to F_1 outlines folds identical to those seen in the deformed host rocks and the gross layering of the ores, analogous to F_2, coincides in orientation with F_2 in the enclosing strata.

5. Average metal content for all three deposits is: zinc 5.5 $\pm$ 0.5 per cent; lead 3.5 $\pm$ 0.5 per cent; copper 0.1 to 0.3 per cent; silver 1.25 $\pm$ 0.25 ounces per ton. The proportions of zinc and lead vary within relatively narrow limits: total base-metal content is roughly proportional to the total sulphide concentration and is generally highest along the central axis of the deposits. The ores of all three deposits show the uniform zinc–lead ratio and low copper concentration that characterizes the 'conformable' massive pyritic base-metal bodies in other parts of the world and belong chemically with this group of deposits.

6. All three mineralized zones are roughly tabular and surrounded by an irregular halo of pale-coloured rocks as much as 300 feet thick. The long axes of all three orebodies trend northwestward as do linear structures within the host rocks. The Faro and Vangorda bodies dip southwest as does the transposition foliation of their enclosing strata: the Swim orebody dips northeast with the foliation of its host. The Faro orebody is more regular in outline than either the Swim or Vangorda and the Vangorda body is somewhat more regular than Swim. Each deposit is thickest in its central zone and thins gradually toward the margins. The Faro deposit is disrupted by post-mineralization faults, but the other two deposits are not. Where the Faro orebody abuts against granitic rocks it bows upward; the other deposits show no comparable feature.

Change in Shape of an Orebody Deformed by Transposition Resulting from Slip Folding

Knowing the style of folding of the host rocks one can attempt to predict how an orebody, if present during, and affected by, the same deformation might change its shape and orientation. Phyllitic host rocks in Anvil area are deformed by slip folds and the oldest recognized layering (F_1) of these rocks is transposed to different degrees of perfection onto the superposed crenulation foliation (F_2). Bedding in the phyllitic rocks of Anvil district now transgresses the crenulation foliation in detail, but on a gross scale these two planar structures appear generally coincident. The following paragraphs trace a large hypothetical orebody through some stages of deformation by slip folding and transposition and compare the theoretically expected form with that observed in the three known sulphide deposits of Anvil district.

Slip folding of strata with alternate laminae of different competence produces, when carried to an advanced state, a tectonic layering nearly parallel with foliation and radically changes the orientation and shape of any body in the rock mass so deformed. Turner and Weiss (1965, p. 92–93) and Whitten (1966, p. 181) have outlined the process of progressive transposition of bedding by slip folding on the mesoscopic scale. Let us examine now a hypothetical orebody several orders of magnitude larger than the individual folds discussed by these authors and enclosed in a rock domain subjected to slip folding and transposition. We assume that the orebody does not differ markedly from the enclosing rocks in general competency during the deformation, and further accept that the body is compositionally layered like the unmineralized rocks around it. The hypothetical orebody therefore differs from the enclosing rocks only in mineralogy and density. We finally assume that the density difference between the mineralized and unmineralized rocks is negligible during the deformation process and that the difference in the gravitational effect on the ore and host rocks is minor compared to the force causing slip folding. The hypothetical orebody will behave like its host rocks on the small scale, and on the larger scale the entire body will reorient and change shape during folding and transposition. The initial shape and attitude of the sulphide mass and the amount or degree of transposition will determine the shape of the orebody after deformation. A tabular mass, concordant with bedding (Fig. 33) will ideally, after complete transposition, change its cross-section as shown in Figure 33a and b, and will reorient to become nearly parallel with the superposed crenulation foliation on which transposition occurred. Disconnected remnants of individual competent beds within the deformed mass will lie nearly along the foliation and are shown schematically in Figure 33b. Change in the orientation of the superposed foliation only changes the final orientation of the sulphide mass but has little effect on its final shape. Similarly, a change in the original shape and /or orientation of the orebody with respect to bedding only affects its final shape and orientation slightly.

Because the initial shape of the hypothetical orebody is probably irregular and because the amount of transposition or sliding on adjacent foliation planes is generally not uniform, the ideal shape of Figure 33b is unlikely to be found in nature. An orebody grossly concordant with bedding, but transgressive in detail (Fig. 33c) might, during progressive slip folding and transposition, show the changes in outline depicted in Figure 33d, e, f and g. Each stage tends toward a more uniform amount of transposition on successive foliation planes and the configuration of the disrupted original bedding within the ore mass shows how the complexity of large folds might decrease as the process goes to completion (e.g., the fold outlined by the disrupted beds in Fig. 33d becomes simpler in Fig. 33e and almost unrecognizable as a fold in Fig. 33f). Insets (Fig. 33h, i, j) schematically show the details of mesoscopic structures at

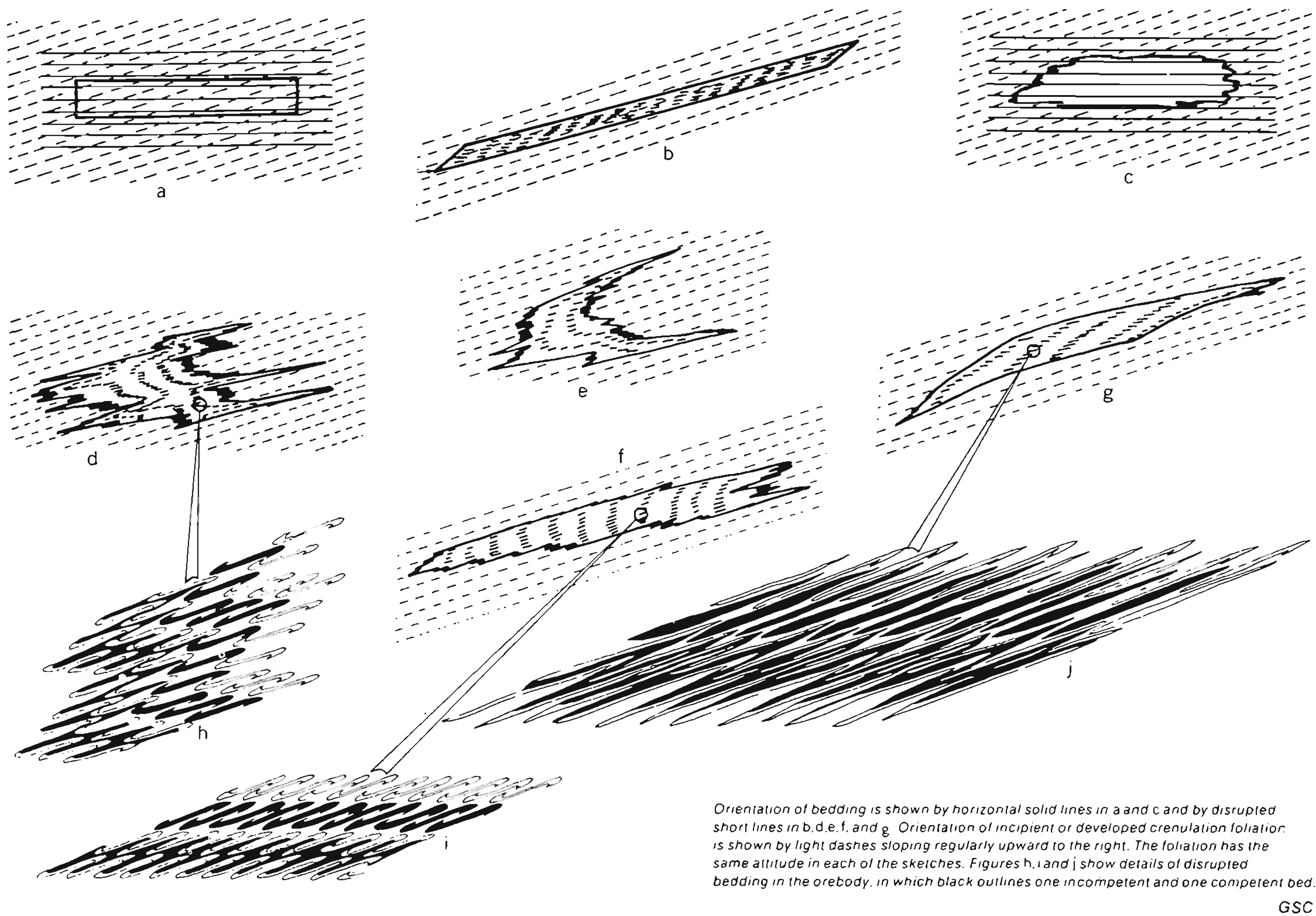


FIGURE 33. Hypothetical stages in the deformation of a bedding-controlled orebody during progressive slip folding and transposition of bedding. Orientation of bedding is shown by horizontal solid lines in a and c and by disrupted short dashes in b, d, e, f, and g. Orientation of incipient or developed foliation is shown by dashes sloping regularly upward to the right. The foliation has the same attitude in each of the sketches. Figures h, i, and j show details of disrupted bedding in the orebody in which black outlines an incompetent and competent bed.

the various progressive stages. The process may stop at or between any of the hypothetical stages so that the cross-section of any particular orebody subjected to the deformation may resemble any one of the stages and needs not approach the final form of Figure 33g.

Cross-sections of the Swim, Vangorda, and Faro deposits are similar to some of the expected stages and a section from Figure 33 can be found to correspond roughly to any of them. Comparisons are tabulated below:

Swim deposit

Cross-section AA′ of Figure 19	corresponds to hypothetical section of Figure 33d.
Cross-section CC′ of Figure 19	corresponds to hypothetical section of Figure 33e.

Vangorda deposit

Cross-section AA′ of Figure 22	corresponds to hypothetical section of Figure 33f.
Cross-section BB′ of Figure 22	corresponds to hypothetical section of Figure 33f.

Faro deposit

Cross-sections CC′ and DD′ of Figure 27 correspond to hypothetical section of Figure 33g.

The correspondence between the hypothetical cross-sections of the imaginary orebody and the cross-sections of the three Anvil deposits implies that the Anvil Range sulphide masses have in fact been subjected to slip folding and transposition and that they owe their present form and disposition largely to this deformation. The similarity of mesoscopic structures in the ores and host rocks supports this contention. The correspondence also indicates that the three Anvil deposits have reached different stages of completion in the transposition process, the Swim deposit having been least perfectly deformed whereas the Faro has most closely attained the form expected from complete transposition. As noted elsewhere, transposition in the host rocks also becomes progressively more complete northwestward of the Swim orebody. The degree of transposition of the host rocks and of the enclosed sulphides therefore apparently increases together progressively and parallel with the gradual increase in metamorphic grade of the rocks and ores; this parallel change of deformation and metamorphism may be directly related in that metamorphism may reduce the competency of rocks and ore leading to their more perfect transposition.

The similarity between the hypothetical and observed cross-sections also implies that the assumptions concerning behaviour of the hypothetical orebody during deformation are valid for Anvil district. Specifically, these assume little difference between the competency of the sulphide ores and that of the enclosing phyllite during the deformation in Anvil district and further require that the high density contrast between the ore and host rocks was not sufficient to affect the final shape of the orebodies. However, the pronounced sag in the central part of the Faro orebody may reflect the effect of gravity during or after the deformation; if so this is minor compared to the deformation by transposition.

Possible Origin of the Deposits

The massive zinc–lead bodies of Anvil Range have the mineralogy, chemistry, form, and geological relations characteristic of that group of deposits known generally as strata-bound or conformable, massive, pyritic ores. Two opposing views are currently held for the origin of such deposits. One theory explains at least some conformable orebodies as hydrothermal replacements of host rock connected with igneous activity later than and unrelated to those hosts. The other theory holds that certain of these deposits were emplaced, by one means or another (and there is considerable variation in this), essentially at the time of deposition of the host rocks and that the hydrothermal features and perhaps even the concentration of metals that they now show are, in part at least, results of subsequent metamorphism and deformation. The two theories differ largely in the timing of ore deposition relative to the age, deformation, and metamorphism of the enclosing rocks, but ascribe original mineralization to essentially the same processes. Unfortunately, many features brought forth in support of one theory can be explained as well by the opposing view, and few if any of the criteria on which arguments for one or other theory are based are conclusive. It is not intended, therefore, to review in detail the criteria of replacement features, wall-rock alteration, paragenesis, zoning, and geothermometry for the Anvil deposits. This has been done by a number of geologists for other deposits and the interested reader is referred particularly to Fisher's (1960) evaluation of these factors for the Mount Isa ores in Australia, which applies as well to the Anvil deposits. It is sufficient to say that the small-scale textural and structural features of the Anvil ores such as the granoblastic and porphyroblastic texture, the paragenetic sequence of minerals, the layering along F_2 defined by metal segregation, the form orientation of some sulphide minerals, and the small-scale folds are not by themselves or collectively proof of late hydrothermal origin. Several authors (Stanton, 1959, 1960a, 1964; Kalliokoski, 1965; McDonald, 1967; Vokes, 1968) have suggested or shown that these features are also produced in ores as a result of metamorphism of some orebodies. Variation in the pyrrhotite content of the ores is not incontrovertible proof of a metamorphic history and may simply reflect an original mineralogical difference. The pale-coloured altered rocks around the three Anvil orebodies similarly may represent a hydrothermal alteration halo, but may also have been produced as a result of metamorphism of the sulphide ores, perhaps in part through a release of sulphur from pyrite during its partial conversion to pyrrhotite. Alteration like that seen in the Anvil deposits is described from some Finnish massive sulphide bodies by Mikkola (1969) who ascribes its origin there to metamorphism of these sulphide ores.

The writer favours the view that the metals forming the ores of the three Anvil deposits were emplaced in their enclosing rocks prior to the regional metamorphism and deformation that affected the host rocks. It seems difficult otherwise to explain the parallel increase in (a) metamorphic grade of the host rocks, (b) the degree of deformation by transposition, and (c) the grain size of the sulphides. The orientation and shape of the orebodies and the differences in shape between them, also suggest that they owe their present form and disposition to the deformation that has affected the rocks of the region. Furthermore, the writer cannot reconcile the absence of district metal zoning with hydrothermal emplacement related to intrusion of the Anvil Batholith, because the deposits are widely separated and at different distances from the batholith. In short, it is difficult to envisage a scheme of hydrothermal replacement younger than the deformation and metamorphism of the host rocks that would (a) seek out and faithfully replace with sulphide part of a restricted, but not particularly distinctive, disrupted member of the host rocks, and (b) emplace at least three mineralogically and chemically similar orebodies over a distance of 15 miles or more whose (c) average sulphide grain size varies in accordance with the metamorphic grade of the host rocks[1] and whose (d) shape seems to be accountable by deformation of same type as seen in the host rocks. The author considers, therefore, that the Anvil sulphides were emplaced in their host rocks at some time before the pre-mid-Ordovician regional metamorphism and deformation and that a Cambro-Ordovician time of sulphide deposition is likely.

It is not known how the metals were originally emplaced in the Cambrian (?) host rocks, but a number of theories have been proposed to explain the deposition of sulphides in similar

[1]The grain size of the Anvil sulphides has been compared with that of other conformable deposits and an attempt made to relate sulphide grain size to metamorphic grade of host rocks in Tempelman-Kluit (1970c).

strata-bound deposits. As some of these theories may be applicable in Anvil Range a brief review of the divergent views is given here.

Because most massive, strata-bound sulphide deposits occur in, or stratigraphically close to, volcanic rocks most theories involve these rocks with the ore emplacement process. Kinkel (1966) proposed that sulphides are introduced by volcanic emanations and emplaced hydrothermally in their host rocks during or shortly after their deposition. Skripchenko (1967) suggested that submarine precipitation of sulphides at volcanic hydrothermal outlets might be an important mechanism of accumulation of some pyritic copper ores. It has also been suggested (Stanton, 1959, 1960a) that the metals of some massive sulphide deposits are supplied by volcanic exhalations or thermal springs and fixed in the host rocks biogenically while these rocks are deposited. Stanton and Rafter (1966), however, considered that the evidence from the isotopic composition of sulphur does not support biogenic fixing of a number of stratiform sulphide ores. Clark (1968) concluded that the Kuroko massive sulphide deposits of Japan are vein deposits blown from their original deposition sites by phreatic volcanic explosions. The Anvil deposits are closely related stratigraphically with volcanic rocks and graphite-bearing phyllite, which might be taken as evidence of biogenic activity, common near the sulphide masses. One or more of the theories reviewed here may explain the original emplacement of sulphides in Anvil area.

The sulphide bodies of Anvil Range may also be metamorphically localized concentrations of syngenetically sparsely deposited sulphides, following Knight's (1957) theory. It is unlikely, however, that metamorphism has played an important role in concentrating the metals, because the three Anvil deposits have the same concentration of metals, but are in rocks metamorphosed to different degrees. McDonald (1967) has reviewed evidence from a number of massive sulphide deposits which suggests that important migration of metals as a result of metamorphism is unlikely.

The sulphides that now constitute the Anvil ores were probably supplied by hydrothermal emanations (possibly related to volcanism or some other unknown source) and emplaced roughly in their present concentrations in, or as, fine-grained detrital sediments, essentially at the time these sediments were laid down during the Late Proterozoic or Cambro-Ordovician. Subsequent metamorphism and deformation probably during the Cambro-Ordovician has drastically altered the character of the ores and host rocks and has changed the shape and orientation of the orebodies. The Faro orebody was probably affected by thermal metamorphism at the time of intrusion of the Anvil Batholith, but the Vangorda and Swim bodies show no evidence of having been so affected.

Guides to Further Exploration for Zinc–Lead in Central Yukon

The following paragraphs outline some guides for continued exploration for zinc–lead in central Yukon deduced from the data for Anvil district.

Although a genetic relationship between the zinc–lead ores and the enclosing rocks cannot be proven in Anvil district, the confinement of the mineralization to a part of the phyllitic host unit implies a spatial control over the sulphide mineralization by those rocks. Future exploration might therefore be concentrated on rocks of unit 3 and strata equivalent to it as potential host rocks worthy of careful examination. Rocks lithologically similar, and probably in part equivalent to, those of unit 3, are outlined in the generalized map of Figure 34 (*in pocket*), and are all of proven or probable Late Proterozoic and Cambro-Ordovician age. Cambrian and Late Proterozoic rocks are thought favourable to zinc–lead mineralization in other parts of the Cordillera by many geologists (Gabrielse, 1969).

A second potential control for the mineralization in Anvil district, again only implied by spatial relationships in the area, is the possible connection between volcanic rocks (unit 3a) and mineralization. Such a relationship is evident in most other areas in the world where strata-bound sulphide deposits occur. Greenstone, probably equivalent to unit 3a, is widespread, though not abundant, in the Cambrian strata outlined in Figure 34, in contrast to other parts of the Cordillera where volcanic rocks are generally absent in rocks of this age. The nature of the possible relationship between the volcanic rocks and the mineralization is unknown. It is conceivable, however, that sulphide ores may occur a certain distance from, or in a specific relation to, greenstone masses of a distinctive composition or type and that such masses are not present extensively in unit 3 and its equivalents, but only in restricted areas. To define such areas is not possible with the data at hand, but study of the chemical or petrographic variation in unit 3a greenstone (major and/or trace elements) may outline facies shifts not otherwise detectable in these rocks and may distinguish volcanic rocks associated with mineralization.

Although data from Anvil district imply the unlikelihood of a direct genetic relationship between the ores and the granitic rocks of Anvil Batholith, the possibility that a relationship exists cannot be ruled out. Future prospectors may consider this eventuality.

No genetic control of the zinc–lead mineralization by the regional metamorphism can be demonstrated in the Anvil Range deposits, but the spatial relationship between the ores and metamorphosed rocks may reflect a connection. The possibility of a genetic relationship between ores and such structurally elevated zones of metamorphic rocks may be worthy of consideration in future exploration. In this regard it is useful to recall also that the coarser grained, and therefore metallurgically more desirable, ores occur in rocks of moderate or higher (biotite) grade metamorphism.

Local prospecting targets are lacking, but the zone of pale-coloured rocks around the sulphide bodies is a useful indicator of mineralization in restricted areas.

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Appendix I

GSC Loc. no.		Locality	Fauna and Age
A. Graptolites collected from unit 4 identified by B. S. Norford.			
F_1	80030	62°27.3′N, 133°02.0′W	inarticulate brachiopod ?*Caryocaris* sp. ?*Climacograptus* sp. *Glossograptus* sp. age: Ordovician, Llanvirn to Caradoc
F_2	80031	62°27.1′N, 133°04.8′W	diplograptid graptolite age: Middle Ordovician to Early Silurian, Llanvirn to Llandovery
B. Conodonts collected from unit 6 identified by T. T. Uyeno			
F_3	80033	62°22.8′N, 132°59.1′W	*Polygnathus linguiformis linguiformis* Hinde *P. varcus* Stauffer *P.* sp. (probably n. sp.) approaching *Schmidtognathus* in the size of basal cavity age: Probably late Middle Devonian (*P. varcus*-Zone, or the lower part of the *S. hermanni–P. cristatus*-Zone).
C. Brachiopods collected from unit 7 identified by E. W. Bamber			
F_4	80028	62°32.9′N, 133°08.2′W	orthotetid brachiopod ?*Michelinia* sp. ?*Ekvasophyllum* sp.—possibly *E. proteus* Sutherland age: Osagian or early Meramecian. This is a tentative age determination. The material is poorly preserved.

F_5	80029	62°32.9′N, 133°08.4′W	spiriferid, orthotetid, and chonetid brachiopods (too poorly preserved for identification) age: Carboniferous or Permian.

D. Fusulinids collected from Anvil Range Group (units 8a and 8c) identified by C. A. Ross.

F_6	80025	62°20′N, 133°33′W	*Triticites* sp. advanced form *Pseudofusulinella* sp. *Schubertella* sp. *Thompsonella* sp.

This collection contains a fusulinacean fauna very similar to that described by Skinner and Wilde, 1965, from the lower two or three zones of the McCloud Limestone, Northern California. The lowest McCloud zone generally is considered either latest Pennsylvanian or earliest Permian. Elsewhere the occurrence of *Thompsonella* in strata of fairly definite Virgilian age suggest a latest Pennsylvanian age for the lower zone and a Permian age for the higher zones. However, because *Schubertella* sp. occurs in several slides from GSC 80025 and does not occur in the lowest McCloud zone, GSC 80025 may be earliest Permian.

F_7	82435	62°02′30″N, 132°47′W	*Schwagerina* sp. (very large) age: Permian; could be Wolfcampian to Wordian

E. Conodonts collected from unit 10a identified by B. E. B. Cameron

F_8	86347	62°21′N, 133°42′W	*Gondolella* sp. A *Gondolella* sp. B *Gondolella* aff. *milleri* Muller
F_9	86348	62°21′N, 133°42′W	*Gondolella* aff. *milleri* Muller *Gondolella* sp. B *Gondolella* cf. sp. B

The specimen referred to as *Gondolella* sp. A approaches *Polygnathus tethydis* Huckriede. It is characterized by having the platform ornamented with minute shallow pits, a development which according to Lindstrom is characteristic of the Triassic. *Gondolella* sp. A is also found in Upper Triassic rocks that contain *Monotis* and which occur 25 miles north of this locality. The two collections are probably Triassic and are tentatively assigned a Middle or Upper Triassic age.

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181 Faunas of the Pleistocene Champlain Sea, *by* Frances J. E. Wagner, $3.00 (M42-181)

182 Contributions to Canadian paleontology, *by* B. S. Norford, *et al.*, $6.00 (M42-182)

183 Geology of Ordovician to Pennsylvanian rocks, M'Clintock Inlet, north coast of Ellesmere Island, Canadian Arctic Archipelago, *by* H. P. Trettin, $2.00 (M42-183)

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