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Geology of the Akolkolex River Area

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SUMMARY

The Akolkolex River area encompasses approximately 200 square miles on the western margin of the Selkirk Mountains of British Columbia. It forms the northwestern limit of the Kootenay Arc, a narrow arcuate belt of severely deformed sedimentary and volcanic rocks, and is part of the structural – metamorphic transition between the Shuswap Metamorphic Complex to the west and the Selkirk Mountain Fold and Thrust Belt to the east.

Two structural levels are evident in the Akolkolex River area. They are separated by the Standfast Creek fault, a low-angle fault which cuts obliquely upward through the stratigraphic succession from southwest to northeast. The upper structural level contains quartzite, calcareous phyllite, limestone, and carbonaceous phyllite and argillite of Early Paleozoic age which can be regionally correlated with the Hamill Group, Mohican Formation, Badshot Formation, and Index Formation of the Lardeau Group respectively. This succession has been deformed into a pair of large recumbent folds: the Akolkolex anticline and the Drimmie Creek syncline. These nappe-like structures have an amplitude approaching 4 miles, have a relatively constant interlimb thickness of 2,500 feet or less, and occupy approximately 40 per cent of the area mapped. They are nearly cylindrical in form and plunge gently in a southeasterly direction. The lower structural level contains quartzite and pelitic schist which appear to be part of the Hamill Group and possibly part of the Horsethief Creek Group of Hadrynian age. Individual structures are difficult to define due to the lack of distinctive stratigraphic markers; however, a large recumbent fold, like that in the upper structural level, is inferred from structural and stratigraphic data. Granodioritic gneiss, which forms a nearly conformable subhorizontal limit to the stratigraphic succession established in the map-area, contains local tightly appressed infolds of the overlying metasedimentary rocks.

Folds are cylindrical throughout the map-area, and a statistical analysis of the orientation of fold axes shows a pervasive southwesterly trend and low plunge which changes

progressively to a west-northwesterly trend in the northwestern part of the area. Although the map-area is on the southern flank of the Clachnacudainn salient, a domal culmination of high regional metamorphic grade, fold orientation, and style appear little influenced by it.

Metamorphic grade increases from chlorite-bearing phyllites in the upper structural level, to staurolite and kyanite-bearing schists close to the gneiss. A large temperature interval at pressures above the alumino-silicate triple point is indicated. Synkinematic metamorphic textures are present throughout much of the lower structural level.

Lead-zinc mineralization in the area is restricted to the thickened hinge zone of the Drimmie Creek syncline. Most mineral showings are on the Wigwam property, located on the north slope of the Akolkolex River. Pyrrhotite, pyrite, galena, and dark brown sphalerite occur as lenses in close association with fine-grained silicified zones within the limestone. Severe folding and local attenuation obscure definition of the lateral extent of the sulphide mineralization.

The main structures of the Akolkolex River area appear to be the result of vertical shortening and horizontal extension, like those in the Shuswap Complex, and are in contrast with the upright folding and high-angle faulting of the Selkirk Mountains and Kootenay Arc; however, the grade of regional metamorphism is typical of that in the Selkirk Mountains. Deformation at a deeper structural level may account for the contrast in structural style with adjacent areas to the east and south.

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INTRODUCTION

LOCATION AND ACCESS

The Akolkolex River area is located on the western margin of the Selkirk Mountains, and is bounded on the north by the Illecillewaet River, on the west by the Columbia River, and on the south by the Akolkolex River (Fig. 3).

Revelstoke, at the junction of the Illecillewaet and Columbia Rivers, is the only community within the map-area. It serves as a switching station for the Canadian Pacific Railway and a supply depot for lumbering and mineral exploration in the surrounding region.

Access to the area by road is limited to the Trans-Canada Highway along the Illecillewaet River valley, and to a secondary road which extends along the Columbia River and up the Akolkolex River. The interior of the area is remote and the only practical means of access is by helicopter.

PURPOSE

This investigation is part of the Southern Canadian Cordilleran Structure Project sponsored by the National Advisory Committee on Research in the Geological Sciences (NACRGS), the aim of which is: 'to study the geological structure of a strip of country across the Southern Cordillera to obtain an integrated picture of the form of the structures and the relationships in space and time between structural belts, thus leading to an understanding of the structural development of the Southern Cordillera' (NACRGS, 13th Annual Report, 1962-63, p. 22). The field mapping and laboratory work performed also constituted a thesis study for the Department of Geology, Queen's University.

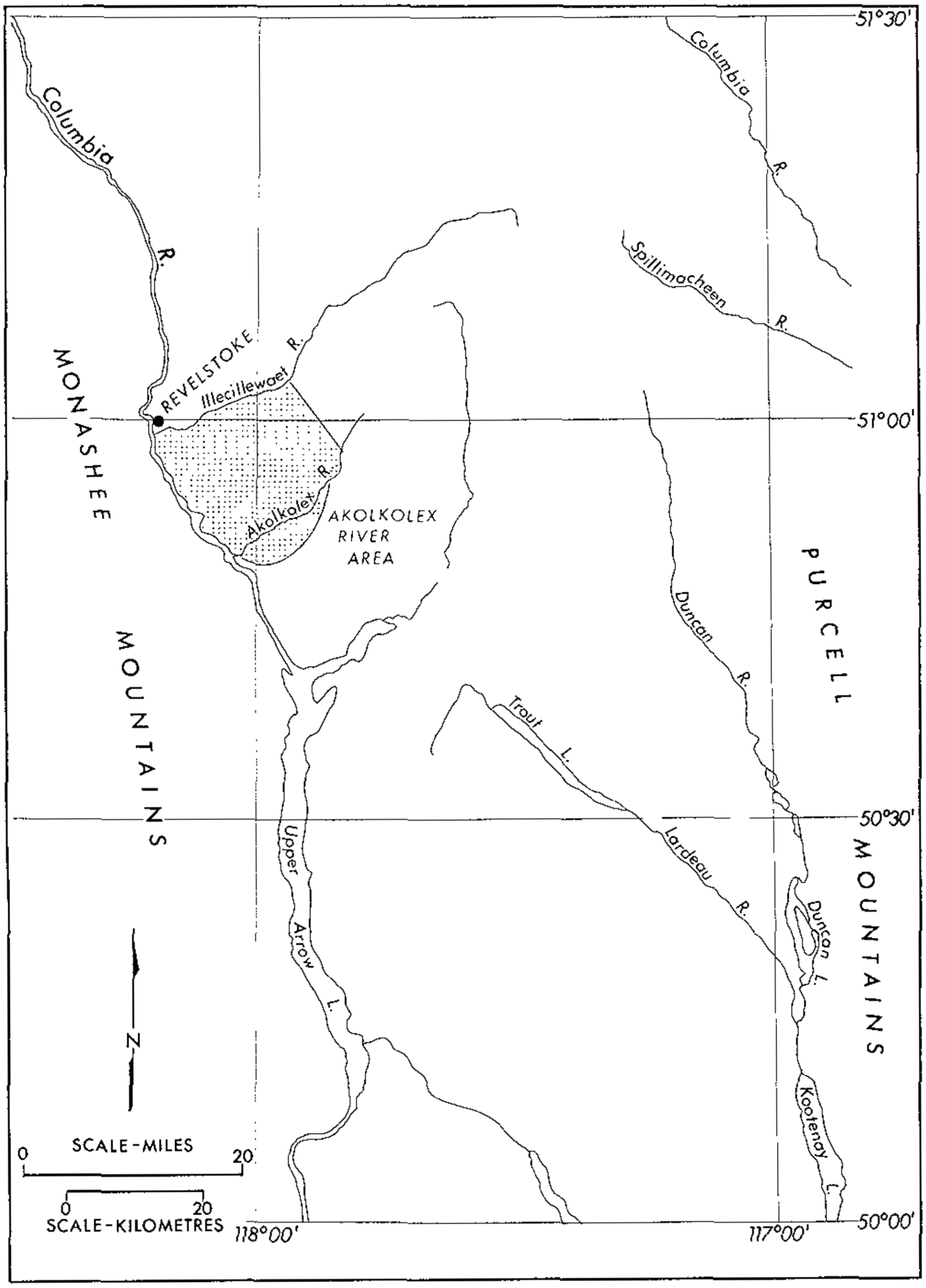

Figure 3. Index and physiographic map.

Support from the British Columbia Ministry of Mines and Petroleum Resources resulted because of interest in the bedded lead-zinc deposits of the region.

The study area encompasses approximately 200 square miles and embraces an important transition zone between two structural levels: an infrastructure represented by the Shuswap Metamorphic Complex in the west (and locally to the north), and a suprastructure represented by the Kootenay Arc and the Selkirk Mountains on the south and east.

The principal objectives of this study are to establish the nature and geologic structure of the bedrock formations, to elucidate the structural and metamorphic evolution of the area and its regional tectonic implications, and to establish the structural and tectonic setting of lead-zinc deposits which occur in the Badshot Formation.

FIELD WORK

Field work was supported by the Ministry of Mines and Petroleum Resources of British Columbia. Geologic investigations were begun in the summer of 1969, and completed after six months of field work in the summer of 1970.

Observations were plotted directly on vertical air photographs and on enlarged topographic maps (scale, 1 inch equals 200 feet) supplied by the Ministry of Mines and Petroleum Resources.

Traversing in the alpine regions of the area was uncomplicated; however, dense vegetation was a considerable hindrance below tree-line.

REGIONAL STRATIGRAPHIC AND TECTONIC SETTING

The Akolkolex River area is in the south-central part of the Omineca Crystalline Belt (Roddick, *et al.*, 1967), the core zone of the alpine-type orogen (the Eastern Cordilleran Fold Belt) which is flanked to the east by a foreland zone of decollement thrust faulting and folding called the 'Rocky Mountain Thrust Belt.' These two zones differ with respect to the nature of the rocks within them, the style of deformation, the degree of metamorphism, and the amount of plutonism and volcanism.

The southern part of the Omineca Crystalline Belt consists of three main structural elements (Wheeler, 1966a; Fig. 4). The *Shuswap Metamorphic Complex,* an elongate metamorphic culmination occurs on the west; the *Purcell anticlinorium,* a little-deformed belt of Proterozoic sedimentary rocks is on the southeast; and the *Kootenay Arc* and *Selkirk Mountains,* a belt of complex folding and faulting and low to moderate regional metamorphic grade, intervenes.

Sedimentary rocks of the Eastern Cordilleran Fold Belt – hereafter referred to as the Eastern Belt – comprise part of the miogeocline-platform assemblage which accumulated over a period of 1,100 million years apparently as a continental terrace wedge prograded into an ocean basin (Price and Simony, 1971). The wedge is made up of a series of overlapping unconformity-bounded sedimentary lenses of different ages.

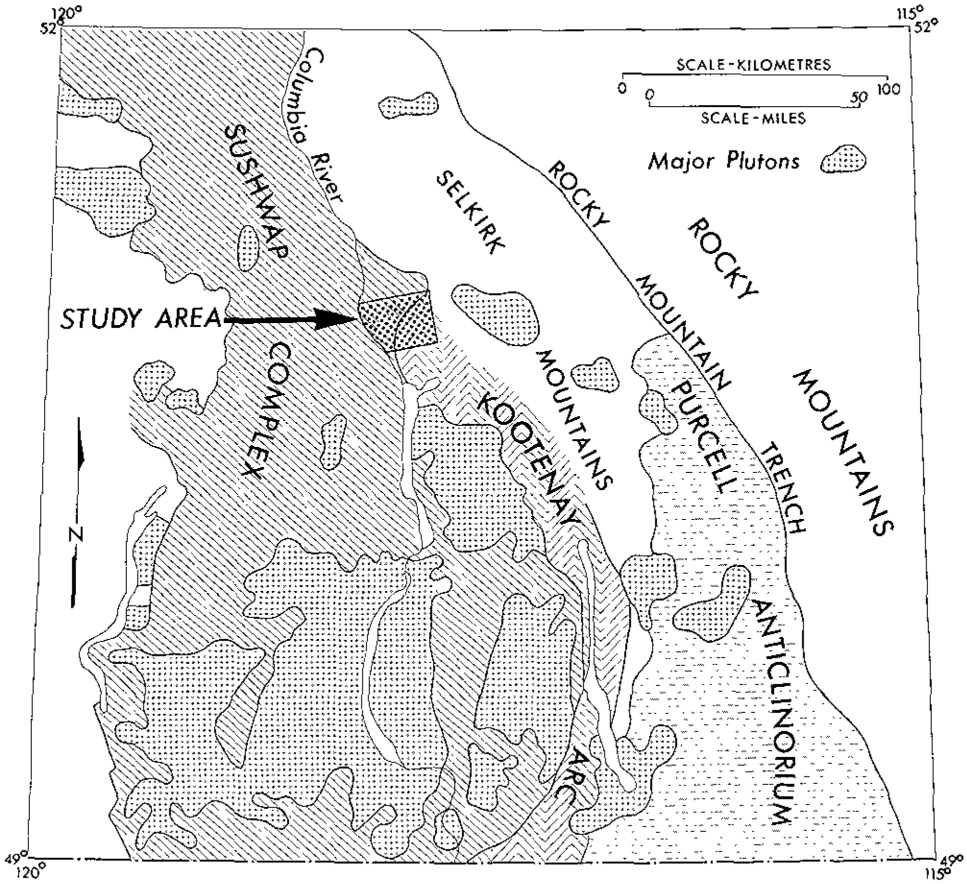

Figure 4. Map showing the main structural elements of the southern part of the Omineca Crystalline Belt.

The oldest known component of the miogeocline-platform sequence is the Purcell Supergroup, a sequence of mature fine-grained sandstones, mudstones, and carbonates of Helikian age. It accumulated along the margin of the continent under conditions apparently similar to those of the present day 'Gulf Coast geosyncline' and attained thicknesses in the range of 40,000 feet (Price, 1971).

This sedimentation was brought to a close by a period of uplift, gentle folding and faulting, granitic intrusion, and regional metamorphism in southeastern British Columbia known as the East Kootenay Orogeny (White, 1959; Leech, 1962). Onlap relationships and the thickness variations in younger strata indicate that the Purcell anticlinorium, which was uplifted at the time, has remained a positive feature since the Helikian.

Growth of the miogeoclinal wedge continued during Late Proterozoic, Paleozoic, and Early Mesozoic times as sedimentary rocks accumulated along the margin of the craton. Throughout much of this time, the Lardeau Trough on the western flank of the Purcell anticlinorium occupied most of what is now the Kootenay Arc, the eastern margin of the Shuswap Complex, and the western half of the Selkirk Mountains north of the Arc. In contrast with the thick sequence of carbonate rocks to the east, it contains much dark pelitic sediment and it represents the distal deep-water western margin of the miogeoclinal wedge.

In latest Proterozoic (Hadrynian) time, a thick sequence of immature argillites and arenites called the Windermere System unconformably overlapped part of the Purcell anticlinorium and extended as a continuous belt into the eastern part of the Lardeau Trough and the northern part of the Rocky Mountain Thrust Belt. In Lardeau Trough these rocks are called the Horsethief Creek Group and consist of approximately 6,000 feet of quartzose and feldspathic grit, sandstone, varicoloured slate, conglomerate, and limestone (Reesor, 1957).

The Winderemere System is succeeded by a mature orthoquartzite sequence of Eocambrian to Lower Cambrian age which covered most of the miogeocline. In the Lardeau Trough, it comprises the Hamill Group which is up to 9,000 feet thick and contains intercalated basic flow and pyroclastic rocks (Fyles, 1962, 1964).

Southwesterly thickening of the wedge through the remainder of the Paleozoic was accompanied by an increase in the proportion of argillaceous sediment. In Lardeau Trough, the Lower and Middle Paleozoic is dominated by the Lardeau Group, a thick sequence of black argillite, thin quartzite, pillow lavas, and immature quartz feldspar grits (Fyles, 1962, 1964). The thickness of the group is not known, but exceeds 1,500 feet.

A major facies change in the Middle and Upper Cambrian and Lower Ordovician strata occurs between the northern part of the Lardeau Trough and the Rocky Mountain Trench to the east. The lower part of the Lardeau, a thick succession of black phyllite called the Index Formation, passes into a sequence of varicoloured slates with intercalated bioclastic limestone (Simony and Wind, 1969). Further east, this slate-carbonate succession undergoes a sharp lateral change into a carbonate-bank margin within the Rocky Mountains (Cook, 1969; Aitken, 1971). Throughout much of the Lower Paleozoic this carbonate bank, termed the Kickinghorse Rim (Aitken, 1971), was the barrier between a shallow water depositional regime to the east and a deeper water basin of clastic sedimentation to the west.

The lack of fossils within the Lardeau Group makes the middle and upper part difficult to correlate with rocks to the east. A thin quartzite unit called the Ajax Formation may represent the western equivalent of Middle Ordovician quartzite (Mount Wilson Formation) which occurs east of the Rocky Mountain Trench. On this basis, the overlying part of the Lardeau Group may be as young as Devonian (Wheeler, 1970b, p. 391).

The Lardeau Group is separated from the underlying Hamill quartzites by a thin, shallow-water limestone, the Badshot Formation, in which Lower Cambrian archaeocyathids have been found.

The Lardeau Group was deformed and uplifted during the Caribooan Orogeny in Late Devonian or Early Mississippian time (Wheeler, 1970b, p. 415). Conglomerate at the base of the Late Mississippian Milford Group overlies the Lardeau Group unconformably. The conglomerate contains well-foliated clasts of Upper Lardeau rocks, which are randomly oriented with respect to the pervasive foliation of the Milford Group (Wheeler, 1966b).

Regional mapping (Wheeler, 1970b) shows that the Broadview Formation (the uppermost part of the Lardeau Group) cuts stratigraphically down through most of the Lardeau succession in the northern part of the Arc. Because of the close lithologic resemblance of the Broadview Formation to the Horsethief Creek Group, and the complete absence of possibly correlative mid-Paleozoic rock types elsewhere in the region, the Broadview has been interpreted as a slice of Late Proterozoic Horsethief Creek rocks thrust over Lardeau Group rocks during the Caribooan Orogeny (Wheeler, 1970b, p. 406).

The Cariboоan Orogeny is well documented in the northern part of the Omineca Belt (Gabrielse, 1963), and is of similar age and occupies a similar structural position to the Late Devonian — Early Mississippian Antler Orogeny in central Nevada (Roberts, et al., 1958).

Miogeoclinal deposition in the Lardeau Trough terminated with the Cariboоan Orogeny, but eugeosynclinal deposition of Mississippian to Early Mesozoic age accumulated west of the Purcell anticlinorium in the Rossland Trough. These deposits, which extend from the Salmo area on the east side of the Shuswap Complex near the International Boundary to the west side of the Shuswap Complex north of the Trans-Canada Highway, comprise the Milford Group, a series of dark slates and argillites, cherts, and limestone of Late Mississippian age; the Kaslo Group, a succession of Triassic (?) volcanic rocks that contains local ultramafic bodies and may be unconformable on the Milford; and the Slocan Group, a thick succession of argillite, with limestone and quartzite and local volcanic tuff and conglomerate, which is unconformable on the Kaslo. In the Rocky Mountain Thrust Belt, rocks of equivalent age (Late Paleozoic to Early Mesozoic) in the miogeoclinal wedge consist mainly of shallow-water carbonates and shales, siltstones, and quartz sandstones.

The entire Omineca Belt was uplifted and deformed during the Middle to Late Mesozoic Columbian Orogeny, and has remained a positive tectonic feature since that time. Northeasterly foreshortening of the miogeoclinal wedge occurred in the Rocky Mountain Thrust Belt from the Jurassic to the Eocene.

The Kootenay Arc developed in the rocks which accumulated in the former Lardeau Trough. It is a distinctive belt of complex folding which extends along the western flank of the Purcell anticlinorium from the International Boundary to near Revelstoke in a great curve that is convex eastward. Large upright folds with north and northwesterly trends are dominant, but refolded recumbent isoclinal folds occur locally. The Western Selkirk Mountains in the north and northeast have a dominant fold pattern like that in the Arc; but steep, easterly directed reverse faults are also common there.

The Shuswap Complex, west of the Kootenay Arc and northwestern Selkirks, is an elongate belt of schists, para and ortho-gneisses, migmatites, and plutonic rocks which are in the amphibolite facies of regional metamorphism. The metamorphic grade is highest adjacent to a series of domal culminations which occur at intervals along the length of the complex. The structure is dominated by isoclinal recumbent folds that trend mainly east-west, but also includes upright northwest-trending folds of varying styles and orientations. The western part of the Purcell anticlinorium is little deformed except by gentle folding and block faulting. It appears to have acted as a buttress against which rocks of the Kootenay Arc were deformed (Fyles, 1964).

STRUCTURAL FRAMEWORK OF THE AKOLKOLEX RIVER AREA

There are two distinct structural levels in the Akolkolex River area. The upper level contains rocks of Eocambrian and Lower Cambrian age which have been folded into large recumbent isoclines. The most conspicuous of these are the Akolkolex anticline and the Drimmie Creek syncline. A low-angle fault beneath these folds separates them from the lower structural level where other large recumbent folds probably occur. Grey granitoid

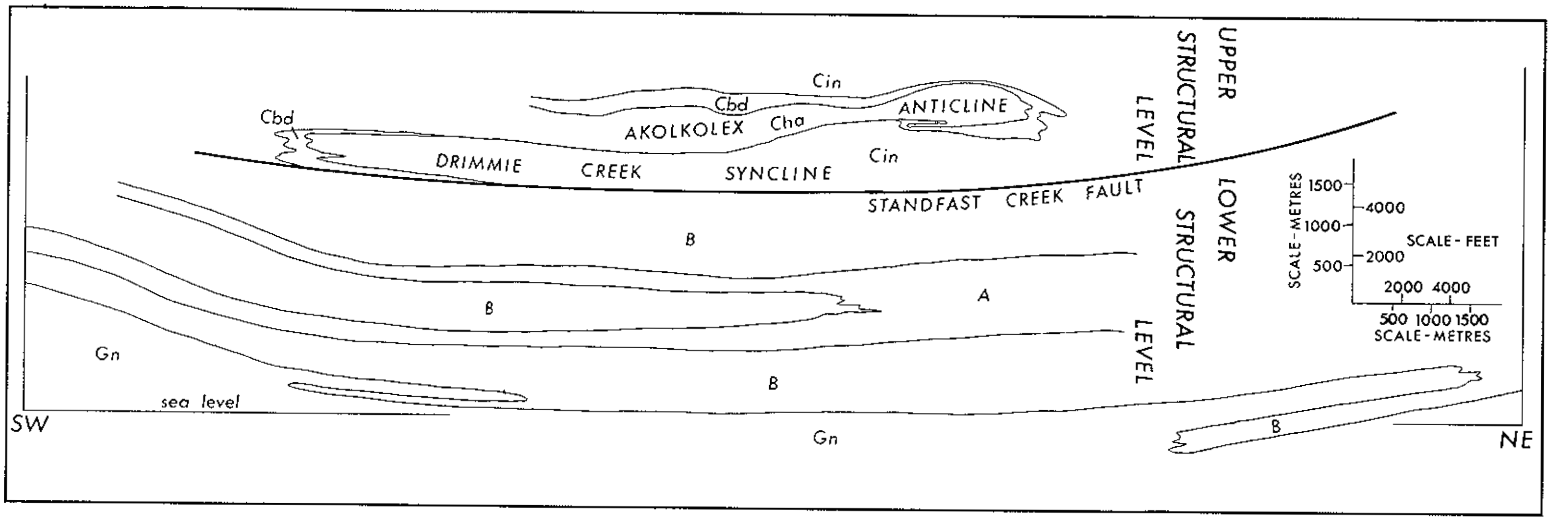

Figure 5. Generalized structure profile illustrating the main structural features of the study area.

gneiss along the northern and western margins of the area forms the lowest structural level exposed in the area.

The salient structural features are illustrated in a schematic structure section, Figure 5.

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The author wishes to acknowledge the helpful supervision of Professor R. A. Price of Queen's University who made many useful suggestions throughout the duration of this project. J. O. Wheeler of the Geological Survey of Canada was kind enough to provide unpublished data on the map-area. Able assistance in the field was provided by D. Jack (1969) and D. Noakes (1970). Mr. and Mrs. D. MacKinnon of the Revelstoke Motel were most hospitable during our brief stays in Revelstoke.

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TABLE 1. ROCK UNITS IN THE AKOLKOLEX RIVER AREA

System	Map Unit	Map Symbol	Upper Structural Level
?	Broadview Formation	bv	Black phyllite; brown feldspathic grit.
Ordovician – – – ? – – –	Index Formation	Єin	Grey and black phyllite and slate; Єin$_a$ – grey and whitish grey quartzite; Єin$_b$ – greenstone.
Cambrian	Badshot Formation	Єbd	White and grey coarsely crystalline limestone; siliceous limestone; minor dolomite; contains sulphide layers: pyrite, pyrrhotite, galena, sphalerite.
	Mohican Formation	Єmo	Siliceous green, brown, and grey phyllite; calcareous phyllite; brown micaceous quartzite; grey and buff limestone.
Cambrian and Eocambrian (?)	Hamill Group	Єha	Massive to platy, white and tan quartzite; grey and brown micaceous quartzite; grey and brown quartzose phyllite.
			— — — — tectonic contact — — — —
			Lower Structural Level
		D*	Brown and grey biotite (garnet) schist; tan and grey micaceous quartzite; black and grey slate; buff and grey micaceous limestone.
		C*	White and grey coarsely crystalline limestone; siliceous limestone.
? Cambrian Eocambrian ?		B1,2,3,4*†	Grey, black, and brown biotite-garnet schist; minor amphibolite; calcareous schist; grey and brown micaceous and feldspathic quartzite; B4$_a$ – dark grey and black phyllite and schist; coarsely crystalline grey limestone; reddish brown biotite; B4$_b$ – tan and white quartzite and micaceous quartzite; buff marble; B4$_c$ – amphibolite.
		A1,2,3*†	White, tan, and grey quartzite and micaceous quartzite; minor varicoloured schist.
		Gn*	Grey, homogeneous (quartz-biotite-hornblende-plagioclase-K-feldspar) gneiss.

*Numerals refer to individual map units of B and A.
†May not be in order of superposition.

2

STRATIGRAPHY

STRATIGRAPHIC FRAMEWORK

Each of the two distinct structural levels in the Akolkolex River area features major differences in the character and succession of the rock units, as well as in the degree of metamorphism and the structural fabric. The boundary between them is marked by a southwest-dipping fault which truncates the layering in each level at a low angle.

Quartzites, limestones, and pellite units occur in the upper level. They can be correlated with the established stratigraphic units of the Kootenay Arc and the Western Selkirk Mountains. Schists, quartzites, and granitic gneisses occur in the lower level. Correlations involving them are uncertain both locally and on a regional scale. Accordingly, the stratigraphic position and internal structure of the rocks in the lower level is uncertain. This forms the major distinction between it and the upper level. The various rock units represented in the area are described in Table 1.

UPPER STRUCTURAL LEVEL: The *Hamill Group* and *Mohican Formation* in the core of the Akolkolex anticline are composed of grey and brown quartzite and micaceous quartzite, grey, brown, and green siliceous and calcareous phyllite, and local thin buff and grey limestones. Their total thickness across the axial zone of the anticline does not exceed 2,500 feet. The Mohican Formation, which is not everywhere distinct from the Hamill Group, has been separated on the basis of its carbonate content and light brownish-green colour.

The *Badshot Formation,* a resistant, grey, crystalline limestone of variable thickness, forms a distinctive marker above the Mohican Formation. Lower Cambrian archaeocyathids have been collected from it at four localities (Wheeler, personal communication, 1969). Sulphide lenses (pyrite, pyrrhotite, galena, and sphalerite) are present in some exposures in close association with bands of fine-grained quartzite.

The *Index Formation* consists of grey and black phyllite and slate with thin intercalations of green phyllite, grey and blue-grey marble, and grey quartzite. Although a number of different rock types are present, few have been mapped separately due to the complex structures in the large recumbent isoclinal folds in which it occurs throughout much of the area.

LOWER STRUCTURAL LEVEL: The lower structural level is dominated by thick intercalated units of quartzite and pelitic schist. They are in a higher metamorphic grade and are less easily differentiated than the upper level rocks. Some of the units in the succession may be repeated one or more times because of unrecognized folding or faulting. Contact relationships vary from sharp to gradational (usually over less than 100 feet) and show good lateral continuity. There is a conspicuous increase in metamorphic grade with depth.

Map units A1 to A3 and *B1 to B4* are thick alternating layers of pelitic schist and quartzite (the letters 'A' and 'B' refer to quartzite and pelite respectively, and the numerals pertain to individual map units of each). Units B1 to B4 are heterogeneous mixtures of varicoloured garnet-biotite schist and biotite schist, hornblende schist, and local amphibolite and micaceous quartzite. These rock types are undifferentiated in each unit except unit B4 which contains mappable layers of quartzite, amphibolite, and black phyllite. Units A1 to A3 are relatively homogeneous, platy quartzites with minor pelitic layers and local amphibolite layers. Units A and B constitute almost all of the succession in the lower structural level.

Map units C and *D* form a zone of alternating limestone and schist layers which occur at the top of the lower structural level in the eastern part of the map-area. Unit C, a resistant grey limestone of variable thickness (not more than 200 feet), resembles the Badshot Formation. Unit D is composed of varicoloured phyllite and biotite schist, calcareous phyllite, and micaceous quartzite. It is quite variable in character both along and across trend. There is conspicuous truncation of the upper layer of D in the eastern part of this zone.

GRANITOID GNEISS: To the north and west, the study area is underlain conformably by *map unit Gn,* a grey, homogeneous, granitoid gneiss of granodioritic composition. It consists predominantly of quartz, plagioclase ($An_{30\text{-}40}$), hornblende, biotite, and K-feldspar. The thickness of this unit is not known.

REGIONAL CORRELATION OF THE UPPER LEVEL SUCCESSION

Correlation of the Lower Paleozoic rock-stratigraphic units along the Kootenay Arc is facilitated by their great lateral continuity and remarkable uniformity. The Lower Paleozoic succession comprises three major assemblages of rocks: quartzites of the Hamill Group, calcareous schists and limestones of the Mohican and Badshot Formations, and dark graphitic phyllites and argillites of the Lardeau Group. Each assemblage is represented in the rock succession of the Western Selkirk Mountains (Wheeler, 1963, 1965).

FIGURE 2. REGIONAL CORRELATION OF THE UPPER STRUCTUAL LEVEL OF SUCCESSION

GROUP	FORMATION	DUNCAN LAKE AREA (FYLES, 1964)	FERGUSON AREA (FYLES AND EASTWOOD, 1962)	AKOLKOLEX RIVER AREA	WESTERN SELKIRK MOUNTAINS (WHEELER, 1963)
Lardeau	Broadview	Green and grey micaceous quartzite, greywacke, grit, and fine-grained mica schist.	Grey and green grit and phyllite; minor pebble conglomerate and pyroclastic rocks.		Quartz mica schist and quartz chlorite schist, micaceous and chloritic quartzite, locally gritty and feldspathic.
		TECTONIC CONTACT	TECTONIC CONTACT		
	Jowett	Fine-grained chlorite schist and feldspar chlorite schist.	Mafic lavas, pyroclastic rocks, argillite; minor limestone.		
	Sharon Creek	Dark grey to black argillite.	Dark grey to black siliceous argillite; slate, phyllite, and minor grit.	?	
	Ajax	Massive grey quartzite.	Massive grey quartzite.	Green and dark grey phyllite; local brown feldspathic grit.	
	Triune	Grey and black quartzite and argillite.	Grey to black siliceous argillite.		
				TECTONIC CONTACT	TECTONIC CONTACT
	Index	UPPER INDEX: Feldspar chlorite schist. Green mica schist and garnet mica schist; minor lenses of grey schist and limestone. LOWER INDEX: Creamy white and grey fine-grained limestone, micaceous limestone, brownish quartzite, and fine-grained grey and green schist. Grey and dark grey fine-grained mica schist, calcareous dark grey mica schist and dark grey limestone; locally grey garnet and staurolite mica schists.	Dark grey and green phyllite; dark grey argillite; minor limestone and volcanic rocks.	Grey and black phyllite and slate; thin bands of blue-grey and black limestone and silty limestone. *Green epidote - chlorite - feldspar* phyllite. Grey phyllite. Grey and whitish grey quartzite. Grey and black graphitic phyllite and slate; calcareous and siliceous phyllite and slate. Greenish grey and grey lustrous phyllite.	Dark grey to black graphitic, siliceous and limy phyllites and slates, blue-grey and dark grey limestone, limy siltstone, and intraformational conglomerate and breccia. Beds up to 10 feet thick of pale grey quartzite. Buff to grey lustrous phyllites and slates, minor limestone.
	Badshot	Grey and white crystalline limestone, dolomite, and siliceous dolomite.	Grey limestone.	Grey and white crystalline limestone; siliceous limestone and chert with associated sulphide mineralization; minor dolomite.	Dark grey, carbonaceous limestone. Grey and buff, sheared, thin-bedded limestone. Lower Cambrian archaeocyathids occur in lowest 20 feet.
	Mohican	Interlayered limestone or dolomite and green or grey mica schist; porphyroblasts of garnet, chloritoid, or biotite in higher metamorphic grades.	Dark grey and green phyllite; minor limestone.	Siliceous green and greenish brown phyllite; calcareous brown and grey phyllite; brown and grey micaceous quartzite; thin grey and buff crystalline limestone.	Greyish green and rusty green, crumpled, limy chloritic phyllite with interbeds a few inches thick of brown and buff marble. Grey and white marble underlain by buff to yellowish marble.
Hamill	Marsh Adams	Grey and brown micaceous quartzite and mica schist; white quartzite and minor brown-weathering limy schist.	Grey, brown and white quartzite; micaceous quartzite; minor phyllite.	Grey and tan quartzite; grey and brown micaceous quartzite; subordinate grey and brown siliceous phyllite.	Interbedded micaceous quartzite and quartz sericite schist. Mainly white, brown, and pale green quartzite. Crumpled rusty brown quartz mica and golden mica schist.
	Mount Gainer		White to pinkish quartzite.	Flaggy white quartzite.	Mainly white and light brown quartzite.

The Akolkolex River area, at the north end of the Kootenay Arc, is approximately midway between the central part of the arc where the stratigraphy has been studied in detail by Fyles (1962, 1964, 1967), and the Western Selkirk Mountains where Wheeler (1963, 1965) has made reconnaissance studies.

Table 2 outlines detailed lithologic correlations of rock units in the upper structural level in the Akolkolex River area, with the succession between the Duncan Lake area (Fyles, 1964) and the Ferguson area (Fyles and Eastwood, 1962) in the central Kootenay Arc, and the succession in the Western Selkirk Mountains (Wheeler, 1963, 1965).

The *Hamill Group* (Walker and Bancroft, 1929, p. 9), a thick sequence of blocky and platy quartzites, micaceous quartzite, and quartz-mica schists, is of Eocambrian and Early Cambrian age. It is overlain by the *Mohican Formation* (Fyles, 1964, p. 23) which comprises up to 1,000 feet of intercalated calcareous schists, limestone, and micaceous quartzite, and the *Badshot Formation* (Walker and Bancroft, 1929, p. 10), a dense, crystalline limestone marker several hundred feet thick. This distinctive limestone, the most important marker unit in the Kootenay Arc and Western Selkirks, has yielded Lower Cambrian archaeocyathids in three areas: the Rogers Pass area (Wheeler, 1963), the Akolkolex River area (Wheeler, personal communication, 1969), and in the Reeves Formation of the Salmo area to the south (Little, 1960). It provides a datum for time-stratigraphic correlations throughout the Kootenay Arc and Western Selkirks.

The *Lardeau Group,* which overlies the Badshot with apparent conformity, is a thick sequence of unfossiliferous graphitic phyllites and argillites, quartzites, pillow lavas and pyroclastic rocks, and grits and mica schists. It is at least 1,500 feet thick but its upper age limit and total thickness are not known. It can be traced from the north end of Kootenay Lake to the Akolkolex River area (Wheeler, 1967-68). In this interval, the base of the Broadview, the uppermost formation of the group, cuts down section northward successively truncating the Jowett, Sharon Creek, Ajax, and Triune Formations, until it lies directly upon Index phyllites, the lowest formation of the group, in the Akolkolex River area. The exact nature of this contact is still in doubt.

The distinctive succession of massive quartzites, calcareous phyllites, grey crystalline limestone, and lustrous graphitic phyllites, together with the presence of Lower Cambrian fossils in the limestone and the physical continuity of the Lardeau Group into the map-area, makes regional correlations straightforward.

The Badshot limestone in the study area is typical of that found throughout the Kootenay Arc and Western Selkirks. Its age and stratigraphic position are certain.

Index phyllites in the study area are very similar to the lower part of the Index Formation of the Lardeau Group. Furthermore, progressive truncation of the overlying Triune, Ajax, Sharon Creek, and Jowett Formations against the base of the Broadview Formation, just south of the Akolkolex River, indicates that these formations are not represented in the Akolkolex River area.

Rocks assigned to the Hamill Group in the map-area are characteristic of the grey and brown micaceous quartzites of the Marsh Adams Formation of the Hamill Group in the Duncan Lake and Ferguson areas. The lack of any conspicuous thick white quartzite markers and the appressed nature of the core of the Akolkolex fold suggest that only the uppermost Hamill quartzites are represented there.

The Mohican Formation is distinguished in the study area on the basis of its content of calcareous phyllite and crystalline limestone, however the buff-weathering white limestone marker, characteristic of the basal Mohican to the south, was not positively identified. Therefore, the correlation is not certain.

DISTRIBUTION AND CHARACTER OF ROCK UNITS IN THE UPPER STRUCTURAL LEVEL

THE HAMILL GROUP (€ha) AND MOHICAN FORMATION (€mo): The Hamill quartzite which forms the core of the Akolkolex anticline is noncalcareous, whereas the Mohican Formation, which forms an envelope around it, contains calcareous phyllite and thin crystalline limestone layers. These two units were not distinguished everywhere during the field work, but the contacts can be extrapolated by projection from structure profiles onto the geologic map (*see* discussion of structure profiles following).

Above tree-line on the north slope of the Akolkolex River, the Mohican Formation in the upper limb of the Akolkolex anticline consists of 100 to 200 feet of intercalated light grey quartzite, greenish grey phyllite, and dark grey calcareous phyllite. The upper contact with the Badshot is sharp and conformable and was traced for several miles. The lower contact with the Hamill is not as sharply defined. The Hamill Formation consists of a succession of fine-grained laminated grey and tan quartzites, grey and brown micaceous quartzites, and subordinate grey and brown quartzose phyllite. The total thickness is variable but in the order of 1,000 feet. The laminated appearance is the result of compositional banding and closely spaced partings of micaceous material which impart a platy character to the rock. Some bands are blocky to massive.

The Mohican is well exposed where it reappears in the lower limb of the anticline, in the steep cliff extending down into the Akolkolex River. It consists of intercalated quartzose green phyllite, greenish brown calcareous phyllite, grey phyllite, grey and brown quartzite and micaceous quartzite, and thin lenses and layers of grey, coarse crystalline limestone. A band of creamy white limestone a few tens of feet thick occurs near the lower contact but it has not been traced along the fold. The Mohican in this exposure is substantially thicker (600 feet) than in the upper limb, and the lower contact is far less distinct due to complex isoclinal folding.

On the east slope of Standfast Creek, intercalated greenish grey phyllite, micaceous brown and grey quartzite, and grey calcareous phyllite occur in the hinge zone of the Akolkolex anticline, but details of their distribution are not well established. A thin band of quartzite, mapped as Hamill Formation, was observed in the middle of the succession, but its lateral extent was not determined. The remainder of the rock resembles the Mohican Formation and has been included with it on the map. The upper and lower contacts are well defined by the Badshot Formation.

The same rock units occur on the south slope of the Akolkolex River. A thick section of grey and tan quartzite and micaceous quartzite in the axial zone of the anticline is bounded above and below by the green, brownish green and grey siliceous and calcareous phyllites of Mohican. However, complex folding and horizontal attenuation has obscured the stratigraphic relations in most places.

In thin section, the quartzites vary from a granoblastic polygonalized mosaic to a mortar texture. The dimensional orientation of quartz grains varies from strong to weak, and very thin plates of muscovite are sometimes present between quartz-grain boundaries. The phyllitic rocks contain abundant, short, tabular crystals of muscovite and chlorite with strong dimensional orientation, in a matrix of quartz and minor albite; thin lenses and augen of polygonalized quartz occur throughout. The limestone bands are graphitic and consist of a mosaic of twinned anhedral calcite grains cut by abundant thin laminae of coarse granoblastic calcite with a weak dimensional orientation. Small anhedral grains are common at the grain boundaries of the larger calcite crystals.

THE BADSHOT FORMATION (Єbd): *On the south slope of the lowest westerly* tributary of Standfast Creek, the Badshot outlines the upper limb of the Akolkolex anticline and consists of approximately 300 to 500 feet of finely bedded grey and dark grey, fine-grained homogeneous limestone intercalated with bands and lenses of white, coarsely crystalline marble. It thins rapidly southwestward and appears to pinch out near the base of the Akolkolex River valley, but can be traced eastward to the lower slope of Standfast Creek. Further southeast there is a small exposure of this limestone near the bottom of the Akolkolex River valley.

Archaeocyathids have been collected from near the top of the horizon (Wheeler, personal communication, 1969; *see* F_1 on Fig. 1).

On the east slope of lower Standfast Creek, a limestone band approximately 50 feet thick occupies the same stratigraphic position. It can be traced in continuous exposures into the hinge zone of the Akolkolex anticline, where it thickens abruptly. Around the hinge and along the lower limb of the anticline, it becomes more attenuated and locally is discontinuous. The lithologic similarities, stratigraphic position, and the fact that it contains archaeocyathids (*see* F_2 on Fig. 1) in an exposure on the ridge between the two westerly tributaries of Standfast Creek (Wheeler, personal communication, 1969) show that this is Badshot. Although it is attenuated and locally discontinuous, it can be traced, more or less continuously, along the lower limb as far as the Akolkolex River valley.

On the south slope of the Akolkolex River, the Badshot is not a conspicuous marker except in the upper slope. The upper part of the cliff contains two easterly diverging limestone layers. These can be traced onto the easterly slope of the adjacent creek where they pinch out. Archaeocyathids occur in the upper band (Wheeler, 1969; *see* F_4 on Fig. 1). The upper layer is part of the upper limb of the Akolkolex anticline; however the lower layer represents the lower limb of the Drimmie Creek syncline. No exposures of Badshot were found along the intermediate limb.

The Badshot forms a thick continuously exposed band of limestone and marble in the lower limb of the Drimmie Creek syncline, from the Akolkolex River northward to Ghost Peak, and from here to the head of Greely Creek. The mineralized section on the north slope of the Akolkolex River, 500 to 700 feet thick, is known as the Wigwam Lime (named after the Wigwam Mining Co., of Tacoma, Washington, original owners of claims encompassing this area).

The lowest 150 to 250 feet of the Wigwam Lime consists of light to dark-grey-banded limestone intercalated with lenticular masses of coarse white and buff marble, and thin bands of grey and greenish grey calcareous schist and phyllite. This is overlain by a conspicuous band of laminated, homogeneous, fine-grained, light grey to black calcareous quartzite approximately 100 feet thick. Lenses of pyrite, pyrrhotite, galena, and sphalerite with iron oxides occur in close association with the quartzite at the Wigwam property. Approximately 100 to 150 feet of grey and greenish grey phyllite separates this mineralized section from another 200 to 300 feet of grey and dark grey, thinly bedded limestone above, which is intercalated with thin bands of grey and greenish grey phyllite and feldspathic schist.

This sequence of units can be followed to Ghost Peak, except where the upper 200 feet of limestone and phyllite are missing because of erosion. South of Ghost Peak, a dolomite band, approximately 10 feet thick, occurs within the quartzite layer and has oxidized sulphides, pyrite, sphalerite, and galena associated with it. This was the only place where dolomite is conspicuous in the Badshot Formation.

From Ghost Peak, a rugged horn capped by approximately 400 feet of limestone, the Badshot extends east as a marker bed approximately 100 to 200 feet thick along the lower limb of the syncline to where it is lost from view at the head of Greely Creek. It reappears for a short distance on the east slope of Greely Creek.

Textures in the Badshot limestone are variable. Locally, the calcite grains form an equigranular mosaic with dimensionally oriented wisps of carbonaceous material along the grain boundaries, and minor amounts of fine-grained anhedral quartz are present locally. In others, lenticular masses of coarse anhedral calcite transect a fine-grained matrix of anhedral calcite. The calcite is invariably twinned.

THE INDEX FORMATION (€in): The only relatively simple and well-exposed section of Index Formation is on the north slope of the Akolkolex River adjacent to the upper limb of the Akolkolex anticline.

The basal part is a light grey phyllite which overlies the Badshot Formation. The contact is sharp and was traced for several miles. This layer is a few tens of feet thick and grades upward into the dark grey and black phyllites and argillites which constitute most of the remainder of the unit.

The dark phyllites vary in competence. Incompetent phyllites are lustrous, black, very graphitic, and well foliated with conspicuous thin laminae of silty reddish brown iron oxides (limonite ?) and milky quartz. Partially oxidized cubes of pyrite are often aligned in the foliation. The more competent phyllites are grey to black, contain conspicuous amounts of quartz, albite, and calcite, are generally thinly bedded, and often contain silty partings. They are intercalated with massive quartzose and calcareous layers a few tens of feet thick.

Near the top of the unit, there are dark grey and blue-black, fine-grained marble bands which vary in thickness from a few inches to a few feet and which often contain abundant micaceous and silty partings.

The phyllites consist of varying proportions of muscovite, chlorite, clay minerals, albite, iron oxides, and graphite. The muscovite usually occurs as short tabular crystals set in a fine-grained matrix of chlorite and albite. Polygonalized quartz grains occur as thin laminae and lenses. Graphite is present throughout as trains of equidimensional grains parallel to the schistosity. Two distinctive subunits occur in the middle of the Index Formation in the exposure on the upper limb of the anticline. Subunit $€in_a$ is a thin continuous quartzite marker, and subunit $€in_b$ is a thin, homogeneous greenstone marker. Each has been traced for more than a mile toward the Akolkolex River. Subunit $€in_a$, a few tens of feet thick, is a blocky homogeneous quartzite that varies from light whitish brown to dark grey. It is composed of equidimensional, polygonalized quartz grains with variable amounts of interspersed anhedral albite. The lower contact is a transition through thin layers of grey phyllite and quartzite. The upper contact, which is much sharper, is a transition to dark, siliceous slate and phyllite. Subunit $€in_b$, approximately 100 to 200 feet above subunit $€in_a$, is a dense homogeneous aggregate of albite, epidote, muscovite, and chlorite with subordinate quartz.

Numerous veins and lenses of white, coarsely crystalline quartz cut the entire succession.

The Index Formation also forms the core of the Drimmie Creek syncline, but the fold is tightly appressed and, although the rock types are similar to those described previously, the lack of recognizable marker units precludes a detailed outline of the stratigraphic succession.

The uppermost layer on the east slope of upper Drimmie Creek consists of complexly interdigitating, soft, greenish grey and grey calcareous phyllite with abundant thin, limonitic laminae. This layer grades downward into a more uniform dark grey and black phyllite and silty slate.

The rocks on the west slope of upper Drimmie Creek, in the hinge zone of the syncline, consist of intercalations of light greenish grey phyllite, light brown to dark grey quartzite with interbanded phyllite, and dark grey to black phyllite and slate. The greenish grey phyllite, which predominates, contains conspicuous randomly oriented white porphyroblasts of albite in a fine-grained muscovite-chlorite matrix, with accessory quartz and tourmaline. The dark phyllites contain abundant cubes of pyrite.

On the eastern slope of upper West Twin Creek, the basal members consist of very graphitic black phyllite and schist interlayered with abundant micaceous marble bands. The quartz content of the rocks increases upward. The mineral assemblage is the same as that described for equivalent rocks preceding, except that garnet and biotite occur with the albite, muscovite, and chlorite locally near the lower contact. The lower contact is not everywhere distinct and, as shown on Figure 1, corresponds with the lowest occurrence of dark grey and black slate and schist of this type. These rock types extend throughout the upper valley of Standfast Creek.

On the south slope of the Akolkolex River, exposures are sparse and access is difficult, however the rocks which were examined are like those described previously.

THE BROADVIEW FORMATION (bv): The Broadview Formation occurs superjacent to the Index Formation on the south slope of the Akolkolex River. It is composed of green and dark grey phyllite with abundant, white, recrystallized quartz pods; intercalated with this is light brown feldspathic grit with conspicuous quartz 'eyes.'

Only the lowest exposed part of the Broadview Formation was mapped, and the contact with the subjacent Index Formation was not observed, but is inferred within a vertical interval of 100 to 200 feet. The Broadview Formation is not present elsewhere in the study area.

DISTRIBUTION AND CHARACTER OF ROCK UNITS IN THE LOWER STRUCTURAL LEVEL

MAP UNITS A1, A2, AND A3: Units A1, A2, and A3 consist of quartzites which have been mapped separately but may be structural repetitions of the same unit. Units A1 and A3 can be traced from the south slope of the Akolkolex River, northward, along the east slope of the Columbia River to Montana Creek. Although they continue beyond this point, they dip parallel with the slope and cannot be accurately delimited. *Unit A2* can be traced west from the upper easterly slope of Mount MacKenzie to West Twin Creek, from where it extends en echelon onto the ridge between East and West Twin Creeks. Its distribution in the lower reaches of Greely Creek valley is uncertain and contacts shown on the map are based upon meager outcrop data.

Units A1, A2, and A3 are recognized on the basis of a relative abundance (more than 75 per cent) of quartzite over pelitic schist and are easily distinguished in the field. The change from rocks which are predominantly pelitic schist, to those which are predominantly quartzite, occurs over an interval of 50 to 100 feet. In the Mount MacKenzie area, the top of units A2 and A3 is marked by competent, whitish grey, blocky quartzite approximately 30 feet thick which contrasts markedly with the overlying grey and brown garnet-biotite schists of unit B4.

The description of a section of unit A3 on the south slope of Drimmie Creek, given in Table 3, is indicative of the character of units A1 and A2 as well.

TABLE 3. LITHIC SUCCESSION IN MAP UNIT A3

Approximate Thickness (Ft.)	Description
	Dark grey, fine-grained biotite schist.
300	Dark greenish grey biotitic quartzite.
50	Amphibolite.
200	Dark grey, fine-grained quartzite.
400	Cliff-forming, light grey and tan quartzite with minor micaceous laminae.
100	Siliceous dark grey phyllite; light tan quartzite (blocky); siliceous dark grey phyllite.
500	Fine-grained, platy, well-laminated light to dark grey quartzite with abundant micaceous partings.

The quartzite varies from whitish grey to grey, and light to dark brown. It is normally well foliated with abundant micaceous partings. Layers of garnet-biotite schist a few inches thick are common. Homogeneous, fine-grained, blocky bands a few tens of feet thick, which occur throughout are in contrast with the platy appearance of the intervening rocks. Thin lenses of vitreous quartz and metacrysts of pink garnet a few millimetres in diameter are often conspicuous in lighter coloured layers. Flecks of biotite and thin, intricately folded graphitic laminae are characteristic throughout.

In thin section the texture is dominated by mosaics of strained, dimensionally oriented and variably flattened anhedral quartz grains, with thin plates of muscovite and biotite interspersed along the grain boundaries. Plagioclase (approximately An_{25}), epidote, and tourmaline are sometimes present as small anhedral crystals within the more micaceous layers, and graphite occurs as thin wisps along grain boundaries.

MAP UNITS B1, B2, B3, AND B4: *Units B1 to B4* are thick heterogeneous pelitic schists and paragneisses which are intercalated with units A1 to A3.

B1 and B3 extend along the west slope of the Columbia River, B2 extends along the south slope of the Illecillewaet River, and B4 can be traced from the south slope of the Akolkolex River, north to Mount MacKenzie, and west from Ghost Peak to the ridge between East and West Twin Creeks; lateral continuity has not been demonstrated at the head of Greely Creek.

These units consist, predominantly, of well-foliated siliceous and feldspathic muscovite-biotite schists that are black, grey, greenish grey, and light brown and weather dark reddish brown. They also contain garnet, epidote, and hornblende. Staurolite, kyanite, and sillimanite adjacent to the gneiss contact occur in B2 but are normally only recognized in thin section. Layers of micaceous brown and grey quartzite, a few inches to a few feet thick, are commonly intercalated with the schist. Thin bands of amphibolite, coarsely crystalline marble, and calcareous hornblende-biotite schist occur locally. Lenses and knots of coarsely crystalline quartz and feldspar are very common in the foliation.

TABLE 4. LITHOLOGIC SUCCESSION OF MAP UNIT B4

Sub-Unit	Approximate Thickness (Ft.)	Description
	50– 150	Dark grey to black finely laminated quartzite; black phyllite with pyrite cubes in foliation.
$B4_a$	20– 50	Two discontinuous thin grey limestone bands.
	±100	Grey, brownish grey, and reddish brown phyllite with micaceous brown quartzite interlayered.
$B4_b$	50– 150	Light greenish grey phyllite interlayered with tan to grey blocky quartzite with thin calcareous bands. (A coarsely siliceous marble band approximately 10 feet thick occurs in middle of unit, which is underlain by pinkish quartzite band.)
B4	±50	Calcareous grey biotite schist and quartzite.
$B4_c$	50– 100	Amphibolite (siliceous and micaceous) with dark grey siliceous phyllite interbanded; coarse lenses of buff marble intermittent.
B4	500–1,000	Bronze-grey phyllite and greenish grey garnet-biotite schist with grey quartzite interlayered; recurrent lenses of coarsely crystalline quartz. Intercalated, greenish grey and brown biotite-garnet schist and grey micaceous quartzite; thin layers of soft black carbonaceous biotite schist.

From the Ghost Peak area south toward Drimmie Creek, unit B4 can be divided into three subunits: $B4_a$, $B4_b$, and $B4_c$. A section across them between Ghost Peak and Mount Cartier is described in Table 4.

The upper part of *subunit $B4_a$*, which is subjacent to the upper structural level, is a dark grey to black graphitic phyllite and biotite schist intercalated with thin bands of grey micaceous quartzite and rare thin layers of calcareous hornblende-biotite schist. The more graphitic layers contain abundant oxidized porphyroblasts of pyrite. Two discontinuous thin bands of coarsely crystalline white and buff marble separate the upper part from a lower part consisting of lighter coloured grey and reddish brown biotite-muscovite schist.

Subunit $B4_b$, which contrasts markedly with the unit above, consists of tan to light grey blocky quartzite interlayered with subequal amounts of light greenish grey phyllite and biotite schist. Southwest of Ghost Peak, a thin cream-coloured siliceous limestone band occurs within this unit above a band of blocky tan and pinkish white quartzite, but it could not be traced laterally from there.

Subunit $B4_c$ is an amphibolite layer approximately 50 feet thick which consists of coarse-grained hornblende with local lenses of coarsely crystalline buff marble and calcareous biotite schist parallel with the foliation. It occurs near the upper part of unit B4 which consists dominantly of grey and brown biotite-garnet schist with local intercalated micaceous grey quartzite and hornblende-biotite schist like that in units B1 to B3.

This succession of rock units can be traced from the north slope of Drimmie Creek, along the lower limb of the Drimmie Creek syncline (below the Badshot Formation) into the head of Greely Creek. They can also be traced northwest on the ridge leading to Mount MacKenzie. East of Greely Creek, the units have not been differentiated.

Although exposures are scarce below the Wigwam Lime, a succession of three units can be recognized there: graphitic phyllite, tan quartzite, and amphibolite. The lower part of this same succession also occurs on the south slope of the Akolkolex River, however these units, $B4_a$ and $B4_b$ are truncated toward the upper reaches of the slope, and unit $B4_c$ occurs directly beneath the Badshot Formation.

MAP UNITS C AND D: *Map units C and D* comprise a zone of alternating schist and limestone layers which extends eastward from the east slope of upper Greely Creek to the eastern margin of the study area, subjacent to the upper structural level rocks.

The limestone layers are similar to the Badshot Formation. The intervening pelitic layers are quite variable in character and cannot be readily correlated with any of the rock units in the upper structural level. Table 5 gives a composite section across this zone, between Greely and West Twin Creeks.

Unit C consists predominantly of laminated light and dark grey crystalline limestone, intercalated with thin bands of coarse grey and buff marble, silty grey marble, and minor thin greenish grey and brown siliceous and calcareous phyllite layers. The second highest layer contains a conspicuous band of laminated white to light grey calcareous quartzite with abundant micaceous partings. The thickness of each limestone layer varies along strike from 30 to 200 feet.

TABLE 5. LITHOLOGIC SUCCESSION OF ZONE
CONTAINING MAP UNITS C AND D
BETWEEN GREELY CREEK AND WEST TWIN CREEK

Map Unit	Approximate Thickness (Ft.)	Description
D	100–300	Dark grey to black micaceous limestone interlayered with dark carbonaceous phyllite. Light grey, brown-weathering, calcareous amphibole schist; biotite-muscovite schist. Thin-bedded amphibolite with knots and lenses of coarsely crystalline quartz and calcite. Brownish grey micaceous quartzite with biotite-muscovite partings; laminated whitish grey to white fine-grained quartzite with flecks of biotite in foliation. Coarse brown biotite-muscovite schist.
C	50–150	Light to dark grey, laminated, crystalline limestone; whitish grey, finely crystalline, calcareous quartzite; lenses of buff marble.
D	200–300	Greenish grey calcareous phyllite. Finely laminated, whitish grey micaceous quartzite with abundant micaceous partings; thin bands of light grey calcareous quartzite; fine-grained greenish grey micaceous quartzite; coarse grey and brown biotite schist. Coarse, siliceous and calcareous biotite schist. Thin, whitish brown and buff, finely laminated, crystalline limestone with abundant micaceous partings.
C	25–100	Grey-weathering, coarsely crystalline limestone.
D	250–400	Reddish brown siliceous and micaceous crystalline limestone; grey and greenish grey garnet-biotite schist; grey laminated micaceous quartzite. Dark grey-black calcareous phyllite; grey biotite schist; dark grey coarsely crystalline limestone; dark grey to black siliceous phyllite; thin lenses of buff marble.
C	50–200	Grey-weathering, laminated, crystalline limestone.

TABLE 6. LITHOLOGIC SUCCESSION OF ZONE
CONTAINING MAP UNITS C AND D
BETWEEN EAST TWIN AND WEST TWIN CREEKS

Map Unit	Approximate Thickness (Ft.)	Description
D	0–500	Light grey phyllite; greenish grey muscovite-biotite schist; grey, fine-grained, laminated quartzite. Light tan to brown massive quartzite with flecks of biotite throughout. Brown and grey micaceous quartzite; greenish grey to brown siliceous phyllite and schist.
C	50	Grey, laminated, crystalline limestone.
D	50–100	Buff, coarsely crystalline, micaceous limestone. Coarse, light brown biotite-muscovite schist (local garnet). Buff, coarsely crystalline, micaceous limestone.
C	50–100	Grey, laminated, crystalline limestone.
D	100	Dark brown, fine-grained biotite schist with thin layers of light brown calcareous phyllite and coarse buff marble.
	100–150	Dark grey to black fine-grained calcareous phyllite and limestone with biotite porphyroblasts; finely laminated dark grey calcareous phyllitic quartzite; black slate.
	100–150	Dark brown, fine-grained biotite schist with thin layers of light brown calcareous schist and coarse buff marble.
C	0–100	Grey and buff, coarsely cyrstalline limestone and micaceous limestone.
D	200–300	Light grey siliceous phyllite; brown and grey biotite schist; whitish grey and tan quartzite and micaceous quartzite.
C	50–100	Grey crystalline limestone; whitish grey siliceous limestone.
D	100–150	Dark grey calcareous biotite schist; dark, fine-grained, laminated quartzite.
	50–100	Light grey garnet-biotite schist interlayered with micaceous tan quartzite and whitish grey quartzite.
C		Grey crystalline limestone.

Unit D occurs as layers composed of variously coloured biotite-muscovite schist and phyllite intercalated with lesser amounts of quartzite, marble, amphibolite, and hornblende schist. The phyllite is generally grey, greenish grey, or light to dark brown; it often contains abundant, thin, fine-grained quartzitic laminae or silty calcareous laminae. The biotite-muscovite schist is normally brown or greyish brown, and locally contains biotite porphyroblasts as books that are randomly oriented. The quartzites are generally fine grained, laminated, and vary in colour from whitish grey to tan to dark grey; they normally contain abundant micaceous partings, and thin layers of siliceous phyllite and schist commonly are intimately interlayered with them. Grey, brown, and buff calcareous phyllite and micaceous, coarsely crystalline limestone often occur close to the contact with the limestone markers. The thickness of any one rock type is usually only a few tens of feet or less.

The lower two layers of unit C extend to the bottom of the valley of upper West Twin Creek where they end abruptly. The easterly limit of the upper two layers is concealed by talus. There appears to be a left normal fault offset along West Twin Creek.

This zone of limestone and pelite units continues en echelon from the east slope of West Twin Creek toward the head of the Akolkolex River. Although the limestone unit does not change, there is some change in the intervening pelitic units. Table 6 gives a composite section of these rocks.

The most conspicuous change is an additional limestone unit which has a thick westerly tapering wedge of pelite above it. The wedge of pelite extends from the northern headwaters of Standfast Creek to the eastern edge of the map-area where it is over 1,000 feet thick. It is mainly brown and greyish brown micaceous quartzite, biotite-muscovite schist, and phyllite, however there are conspicuous lenses of whitish grey quartzite up to 500 feet thick in it which are flaggy to massive.

The pelitic layer between the upper two limestone markers consists of an internal zone of light brown biotite-hornblende schist sandwiched between thin buff-coloured micaceous marble layers. The underlying pelitic layer is also sandwiched between marble units, but it consists of black graphitic slate and phyllite with dark grey and brown calcareous schist and marble above and below it. No light-coloured rocks were encountered in this layer.

MAP UNIT Gn: Homogeneous, grey, hornblende-biotite granodiorite gneiss forms a nearly conformable lower limit to the pelitic rocks of units B1 and B2 along the western and northern margins of the area. Contact relationships are sharp in most places.

The gneiss is poorly banded, coarse grained, and moderately well foliated due to the dimensional orientation of biotite. The preferrential orientation of hornblende imparts a moderate to well-developed lineation.

Coarse white pegmatite veins of variable thickness and orientation transect the gneiss throughout and, in some areas, constitute up to 50 per cent by volume.

Plagioclase (An_{30-40}) is the dominant mineral, but potassic feldspar occurs throughout as anhedral grains and augen of variable size. Quartz occurs as lensoidal aggregates and small anhedra, and hornblende and biotite are present in approximately equal amounts. Modal and chemical analyses of the unit were not made.

In the upper portion of the unit, thin bands of pelitic schist were sometimes noted. The lateral extent of these bands was not determined, however they are considered to be structurally related to the overlying metasedimentary rocks. No attempt was made to subdivide the gneiss or to map it in detail, except for the trace of its upper limit.

3

METAMORPHISM

METAMORPHIC FRAMEWORK

Metamorphic mineral assemblages and textures in the map-area differ from the upper to the lower structural levels.

Mineral assemblages in the rocks of the upper structural level belong to the chlorite zone of the greenschist facies. There is little variation from a uniform normal assemblage comprising: quartz, albite, muscovite, and chlorite with epidote, amphibole, and opaque accessories. The textures are those of fine-grained phyllites with rare porphyroblasts.

The rocks in the lower structural level are coarser grained schists, and there are conspicuous changes in the mineral parageneses marked by the progressive downward appearance of synkinematic biotite, garnet, staurolite, kyanite, and sillimanite (Appendix). Mineral assemblages indicate that the maximum pressures in the deeper levels were above the alumino-silicate triple point pressure, and the maximum temperature of metamorphism varied several hundred degrees across the area.

MINERAL PARAGENESES OF THE LOWER STRUCTURAL LEVEL

The trace of the first appearance of biotite follows close to the boundary between the upper and lower structural levels. Biotite forms large conspicuous porphyroblasts in the pelitic rocks and fine-grained partings in the micaceous quartzites. Oligoclase (An_{15-25}) occurs as a second feldspar in the biotite zone. The other minerals include quartz, muscovite, albite, and chlorite.

Garnet (almandine ?) first appears more than 1,000 feet below the first biotite in the Twin Creeks area but closer to it southwestward at the south slope of the Akolkolex River. Thus, the biotite zone rocks occur in a westerly tapering wedge. The top of the

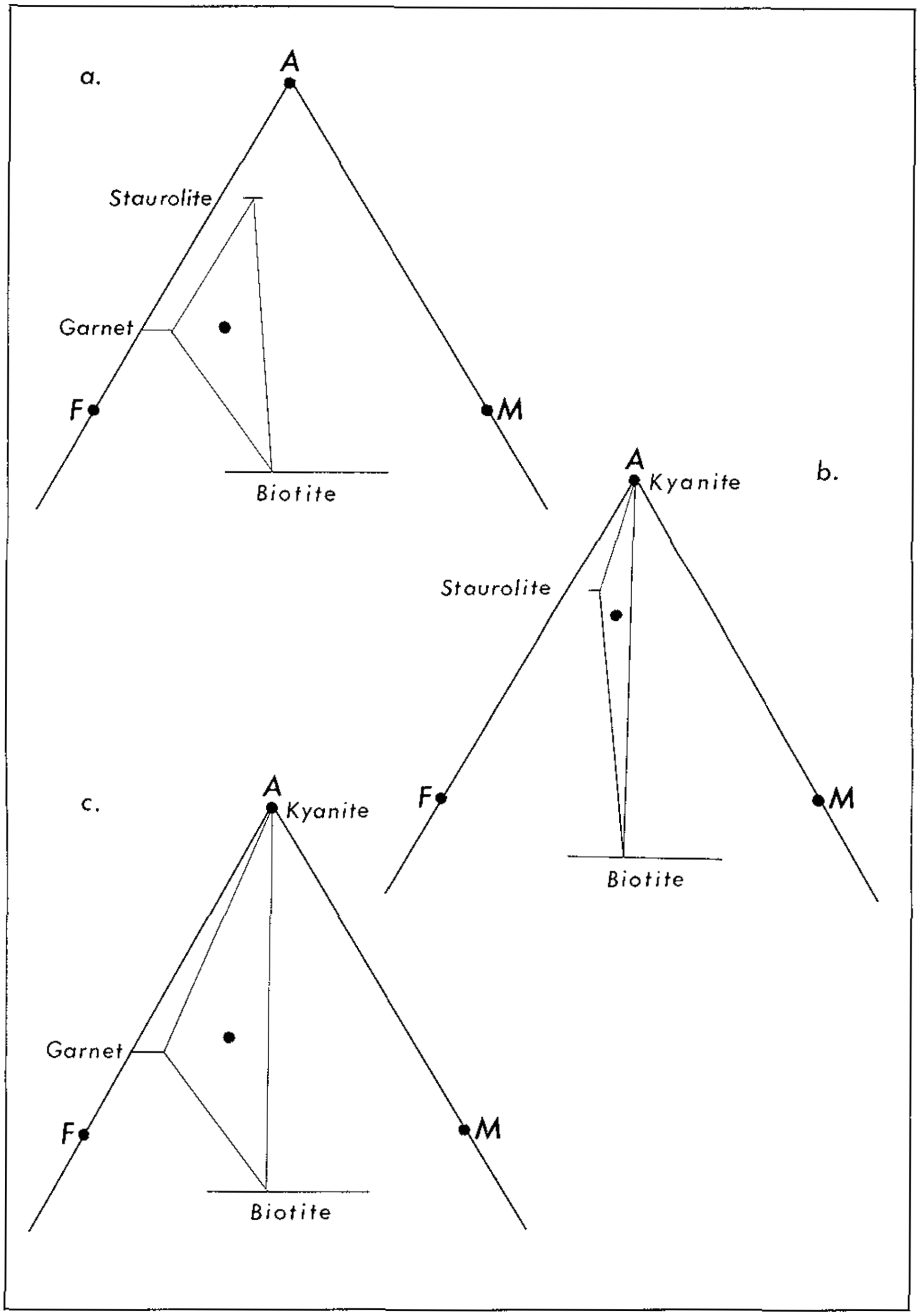


Figure 6. Observed pelitic mineral assemblages from map unit B2 superjacent to the gneiss, shown on the AFM face of the AKFM tetrahedron.

almandine zone can be outlined in the pelitic rocks of map units D and $B4_b$. Apparently bulk composition does not constitute a major control on its position.

The appearance of hornblende and almandine generally coincides with the disappearance of albite. Beyond this, plagioclase is often zoned and its composition is in the oligoclase range.

The almandine zone encompasses most of the remaining rocks in the lower structural level. The dominant mineral assemblage is: quartz, muscovite, biotite, almandine, plagioclase (An_{15-25}), and chlorite. Much of the chlorite appears to be the result of retrograde metamorphism.

Mineral assemblages containing staurolite and kyanite are confined to a narrow zone along the upper contact of the granodiorite gneiss, however isograds cannot be defined with the sparse data on critical mineral assemblages that are now available. Mineral assemblages in this zone include the following:

(1) Quartz, oligoclase, muscovite, garnet, *staurolite, biotite.*

(2) Quartz, muscovite, oligoclase, staurolite, *kyanite, biotite.*

(3) Quartz, muscovite, oligoclase, *kyanite, biotite, garnet.*

These assemblages are represented graphically in the AFM (Thompson, 1957) projections of Figure 6.

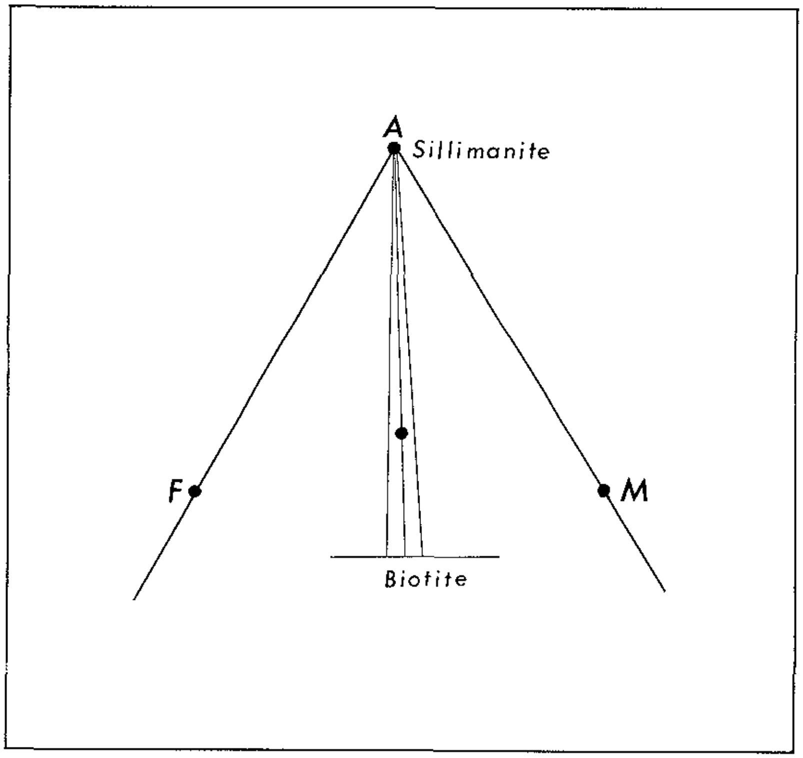


Figure 7. Observed pellitic mineral assemblage from map unit B2 contained within the gneiss, shown on the AFM face of the AKFM tetrahedron.

The occurrence of sillimanite is restricted to the pelitic rocks contained within the gneiss on the south slope of the Illecillewaet River; it occurs in the assemblage: quartz, andesine, biotite, muscovite, sillimanite (Fig. 7).

THE PRESSURE – TEMPERATURE ENVIRONMENT OF METAMORPHISM

The pattern of prograde metamorphism expressed as variations in mineral assemblages within the study area coincides with that of the type Barrovian region in the Scottish Highlands and the New Hampshire – Vermont section of the Appalachian fold region (Turner, 1968). Each spans the greenschist and amphibolite metamorphic facies of high pressure and moderate to high temperature. However, the pressure-temperature constraints of metamorphism can be more precisely defined through application of mineral assembage data in conjunction with univariant equilibrium curves for the chemical system being described. Since rocks of the study area are of a pelitic origin, they approximate the system: SiO_2, Al_2O_3, FeO, MgO, K_2O (Thompson, 1957).

The relative positions of some univariant reaction curves for ideal pelitic systems are presented on Figure 8, a segment of the petrogenetic grid which encompasses the pressure-temperature environment of the amphibolite facies. Although specific pressure-temperature values for these curves are not well documented, the relative topology of the curves and intervening divariant fields can be determined through application of the Morey-Schreinemakers rule (Zen, 1966).*

If a divariant mineral assemblage contains the products of a univariant chemical reaction, then that assemblage must have formed at or above the pressure-temperature equilibrium curve for the univariant reaction. Thus, a lower limit of pressure and temperature is defined for the mineral assemblage. This reasoning can be applied directly to the kyanite-staurolite zone of the study area. The assemblages of Figure 6 contain the products of the following univariant reactions illustrated on Figure 8.

(1) Chlorite-muscovite-garnet = *staurolite-biotite* (curve A).

(2) Chlorite-muscovite-staurolite = *kyanite-biotite* (curve B).

(3) Staurolite-muscovite = *kyanite-biotite-garnet* (curve C).

This defines a temperature interval between reaction curves 'A' and 'D' and a pressure above the kyanite-andalusite and kyanite-sillimanite reaction curves for the kyanite-staurolite zone.

Since sillimanite occurs at the lowest structural levels, a few hundred feet below the kyanite-staurolite zone, the lower limits of pressure can be further specified. Assemblages to the right of equilibrium curve 'C' are present (assemblage C, Fig. 6) but none above equilibrium curve 'D'; therefore, the pressure must be restricted to the interval between the intersection of curves 'C' and 'D' with the kyanite-sillimanite inversion curve. Since the kyanite-staurolite zone does not occupy a structural interval of more than 1,000 feet, it is safe to assume that the pressure throughout this zone is a constant. Therefore, a

*The Morey-Schreinemakers rule was deduced geometrically by Schreinemakers (1915, 1, p. 121) and analytically by Morey and Williamson (1918, p. 66). It states that a divariant assemblage always occurs in a sector which makes an angle about the invariant point no greater than 180 degrees (Zen, 1966, p. 11).

pressure-temperature trajectory for the kyanite-staurolite zone can be plotted on Figure 8 assuming pressure constant, or nearly constant, and temperature variable between the limits of equilibrium curves 'A' and 'D.'

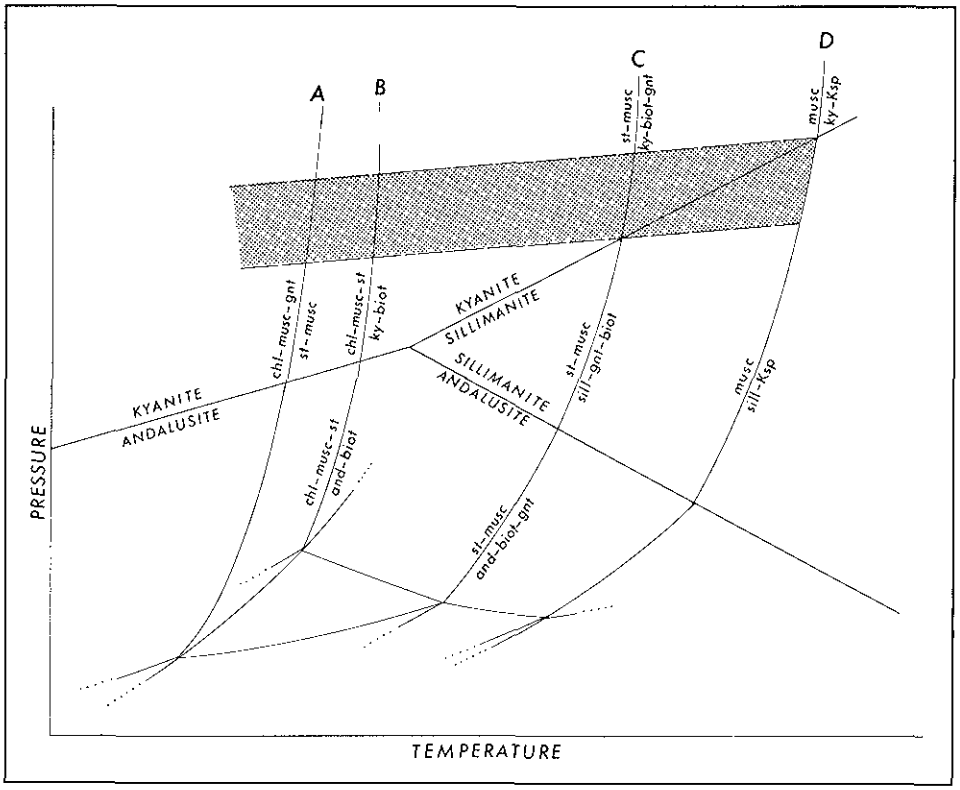


Figure 8. Petrogenetic grid showing limits of temperature and pressure near the gneiss contact.

An estimate of the total pressure differential throughout the study area can be made; by assuming a total structural interval of 10,000 feet and an average rock density of 2.5 g/cc (the average for saturated shale), it approximates 0.75 kb.

On a generalized petrogenetic grid, the pressure-temperature trajectory of metamorphism applicable to the entire study area must incorporate a temperature interval which spans the greenschist and amphibolite facies with an upper limit approaching the muscovite = kyanite + Ksp equilibrium curve and a pressure interval of approximately 0.75 kb well above the alumino-silicate triple point.

THE RELATIVE TIMING OF METAMORPHISM

The simple, downward, prograde variation of mineral assemblages and the general conformity of isograds with the lithologic layering suggest that the gneiss was an important local heat source. The timing of the metamorphism at and above the almandine grade relative to the penetrative deformation can be estimated from the shape and orientation of the foliation within garnet porphyroblasts relative to that of the surrounding matrix.

No attempt was made to evaluate quantitatively the strain recorded in these porphyroblasts; rather, the objective is to outline the time relationships between recrystallization and deformation so as to evaluate the space-time relationship of the emplacement of the gneiss with respect to the deformational history of the entire study area.

Structurally above the kyanite-staurolite zone, garnet porphyroblasts (under the microscope) are elongate in the plane of foliation and show evidence in some cases of microboudinage (Plate IA). This condition is interpreted as a combination of flattening and extension in the plane of foliation. There is little evidence of rotation involving discordance of planes of inclusions within the porphyroblasts relative to the external foliation.

Garnet porphyroblasts from within the staurolite-kyanite zone are nearly spherical. The internal inclusions are arranged either in sigmoids or in planes at an angle to the trend of the external foliation indicating that the porphyroblasts have been rotated relative to the external foliation (Plate IB). There is also evidence for the synkinematic growth of staurolite (Plate IIA) in which intergrowths of quartz show a sigmoidal distribution.

Garnet porphyroblasts from within the gneiss (Gn) complex show little evidence of strain. Inclusions within the garnets are randomly oriented and show no discordance in orientation with the surrounding matrix (Plate IIB).

These textural relationships are evidence that the gneiss acted as a local syntectonic heat source. Furthest from it, deformation outlasted recrystallization resulting in severely strained porphyroblasts, however there is a decrease in the amount of strain recorded in the porphyroblasts as the gneiss complex is approached indicating that recrystallization occurred over a longer period of time; within the gneiss, recrystallization appears to have kept pace with and possibly outlasted deformation. Thus, the metamorphic veil associated with the gneiss expanded into the overlying metasedimentary rocks and then retracted before deformation had ceased.

4

STRUCTURE

GENERAL STATEMENT

The Akolkolex River area is situated in the transition zone between two contrasting tectonic regimes: the Shuswap Complex to the west and the Selkirk Mountain Fold and Thrust Belt to the east. The Shuswap Complex is characterized by large, often rootless, recumbent isoclinal folds many of which trend east-west and are refolded about northwest-southeast axes (Jones, 1959). Structures in the fold and thrust belt of the Western Selkirks are dominated by northwest-southeast trending folds with steep east-dipping axial planes (Wheeler, 1963). They are referred to as 'back folds' because their asymmetry indicates a relative movement of east side upward in relation to the west. Upward diverging fans of steeply dipping cleavage, and steep east-dipping reverse faults are common. This dichotomy evident in major structures is also reflected in the overall pattern of strain. In the Shuswap Complex there has been lateral extension and vertical shortening; whereas in the Western Selkirks, there has been lateral shortening and vertical extension. One of the objectives of this study is to determine the nature of the changing pattern of strain across the study area and its bearing on this contrast of structural style.

The central and southern part of the Kootenay Arc occupies the zone of transition from Shuswap to Selkirk structures in the southern part of the Selkirk Mountains. The western boundary of the arc is well defined by the eastern edge of the Nelson and Kuskanax batholiths; the eastern limit is somewhat arbitrarily defined by the western limit of a thick succession of less-deformed Hamill rocks which follow the trend of the arc; this boundary coincides with a conspicuous decrease in the intensity of deformation. This part of the Kootenay Arc is narrow and distinct in both structural style and internal stratigraphy from the mildly deformed Purcell rocks of Helikian age to the east and the intrusive complexes to the west. However, in the northern part of the Kootenay Arc, the boundaries are not as distinct. Immediately south of the study area, the Columbia River valley follows the western boundary of the arc, and the eastern boundary is completely arbitrary because there is no longer an abrupt change in the intensity of deformation eastward. There, the Kootenay Arc is not the distinctive structural belt that it is further south.

The study area occupies what is effectively the northwestern limit of Kootenay Arc. Within it the distinctive stratigraphy and structural trends of the Kootenay Arc are replaced by gneisses of the Shuswap Complex which forms a northeasterly salient from the main mass of the Shuswap Complex in the Clachnacudainn Range.

The upper and lower structural levels in the study area are separated by the 'Standfast Creek fault,' a low-angle fault which cuts obliquely upward through the stratigraphic succession on both sides of it from southwest to northeast. The stratigraphic succession has been attenuated as a result of displacement on this fault and part of it is missing completely. The fault is an extension fault because it produces extension in the direction of the compositional layering (Norris, 1958).

The upper structural level consists of the distinctive sequence of metamorphosed Lower Paleozoic rocks. They occur as a pair of large recumbent folds: the Akolkolex anticline and the Drimmie Creek syncline. The rocks in the lower level are in a higher grade of regional metamorphism and have fewer distinctive stratigraphic markers; however, they appear to have the same structural style. Granitoid gneiss forms a nearly conformable, subhorizontal lower unit in the stratigraphic succession mapped. It contains appressed infolds of the metasedimentary rocks.

The Akolkolex anticline and Drimmie Creek syncline outline a nappe several miles long that closes to the northeast. There is a penetrative subhorizontal foliation which is axial-planar to the folds. Coaxial warps and upright open folds are superimposed on these structures at all scales of observation down to the mesoscopic.

Throughout the study area, recumbent isoclines are designated type 1 folds, and upright more open folds are designated type 2 folds. This distinction is based on shape, orientation, and local age relationships. Further south in the Kootenay Arc, the isoclinal recumbent folds have been called phase 1 structures, and upright more open folds, which fold the axial planes of the isoclines, phase 2 structures (Fyles, 1964). This terminology has not been adopted here because it is uncertain whether the younger upright folds at one locality are in fact younger than the refolded isoclinal folds at some other locality. Individual fold styles may well be diachronic; some of the type 1 and type 2 folds may have formed at the same time in different places or structural levels.

Structural level appears to have exerted a fundamental control on the type of deformation. The recumbent isoclinal folds of the Shuswap Complex occur in a metamorphic infrastructure at the lowest structural level whereas the upright folding in the Selkirk Mountains is representative of a less metamorphosed suprastructural level. The Akolkolex River area occupies the transition from infrastructure to suprastructure. The main structures in it are like those in the Shuswap Complex but the metamorphic grade is like that in the Selkirks.

THE TECTONIC FABRIC

PLANAR ELEMENTS: Lithologic layering (S_0) is well developed in quartzose and calcareous rocks but is not conspicuous in the more pelitic rocks. In quartzites and

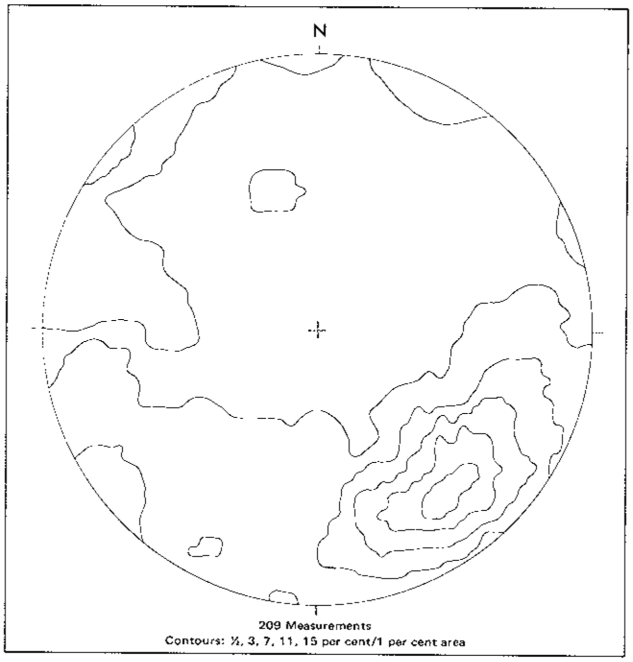


Figure 9. Orientation of type 1 fold axes.

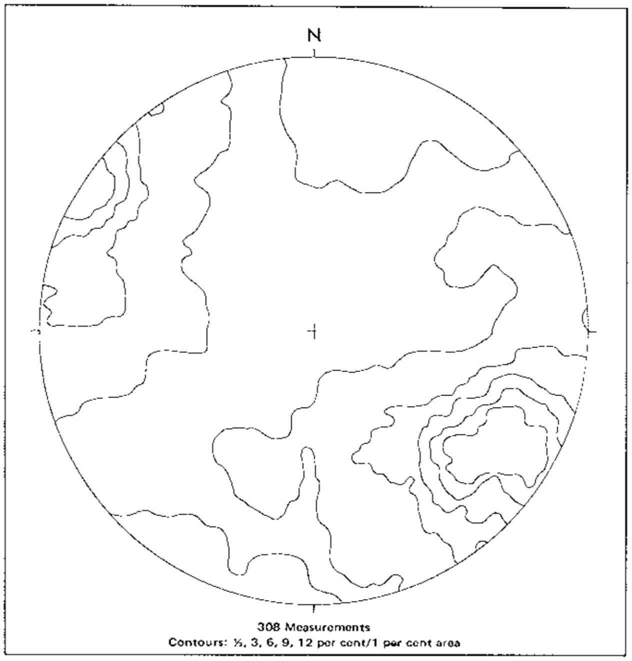


Figure 10. Orientation of type 2 fold axes.

micaceous quartzites, it is a compositional banding that varies in scale from thin laminations to beds. In limestone units, small-scale colour banding is dominant.

The most penetrative planar element is a schistosity (S_1) defined by the parallel alignment of phyllosilicate minerals. It is parallel or nearly parallel to S_0 and is axial planar to type 1 folds. A strong angular discordance between S_0 and S_1 was occasionally observed in the hinge zones of type 1 folds, however in most cases the lithologic layering has been transposed into parallelism with S_1 (Plate IIIA). For all practical purposes, S_0 and S_1 are parallel.

A fracture cleavage (S_2), which is superimposed on S_0 and S_1, is sporadically developed in the pelitic rocks of the upper structural level. It is axial planar to type 2 folds, but its limited distribution does not allow systematic measurement. S_2 orientations form part of the data of Figure 14.

Crenulation cleavage parallel to S_2 is developed in some pelitic rocks of the upper structural level. It is not a conspicuous feature as most crenulations have large wavelengths and hinge zones which are not ruptured.

Quartz-filled veins are conspicuous in the upper structural level, especially in the Index Formation. Although variably oriented and folded, most have been transported into parallelism with S_1.

LINEAR ELEMENTS: Fold axes and elongate minerals and mineral aggregates are the two categories of linear elements for which orientation data were recorded.

The orientations of axes of type 1 and type 2 folds, and type 3 folds (crenulations, which are distinguished from type 2 folds on the basis of size) were recorded separately and are summarized in the equal-area lower hemisphere plots of Figures 9, 10, and 11.

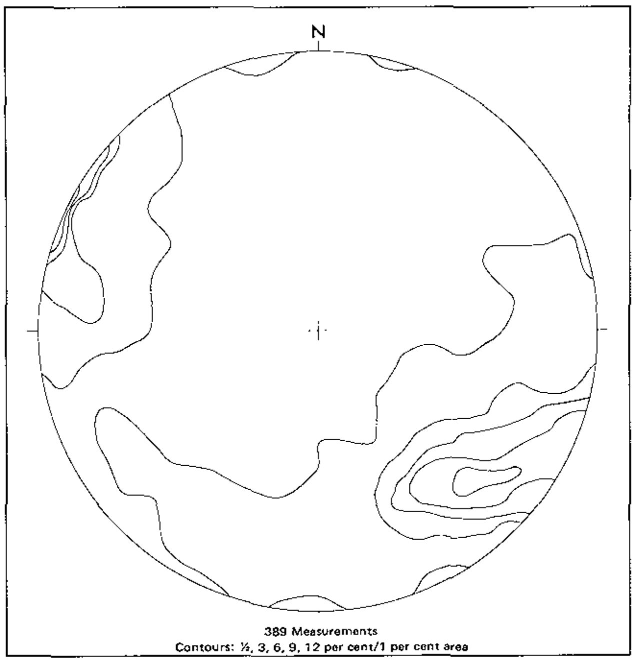


Figure 11. Orientation of type 3 fold axes.

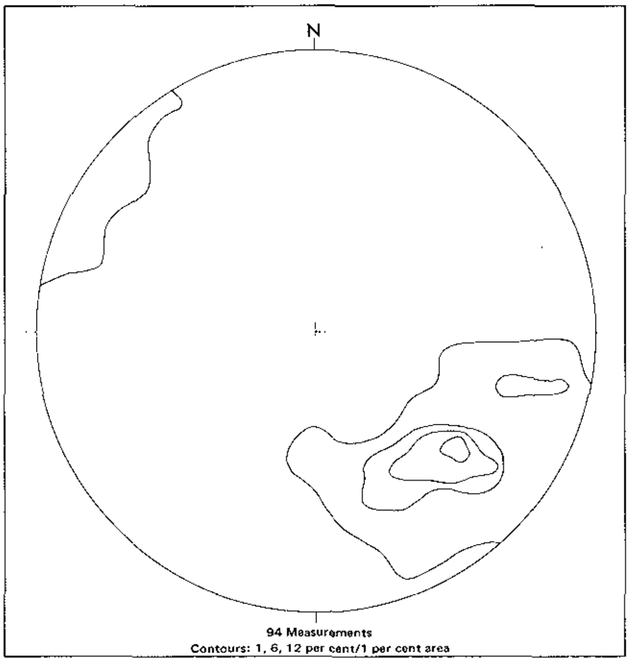


Figure 12. Orientation of mineral lineations.

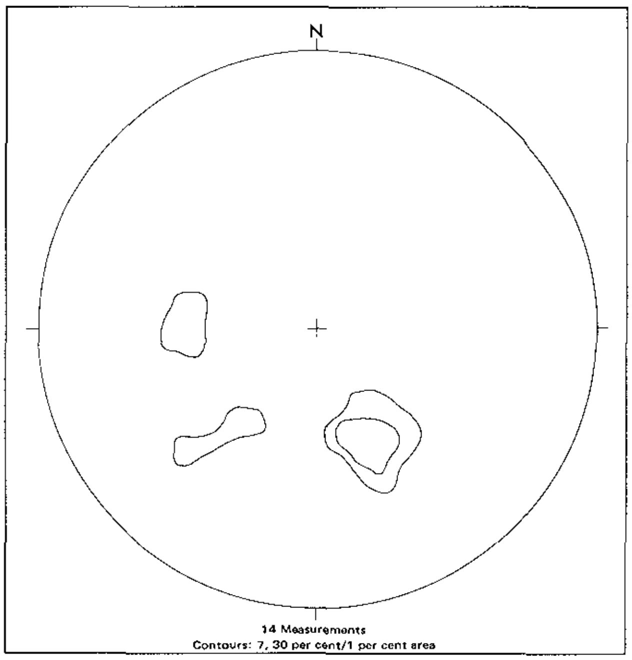


Figure 13. Orientation of mineral lineations in gneiss.

Aligned mica and hornblende grains, contained in S_1, are the dominant mineral lineation in the area. A synoptic equal-area diagram of all observations made in lower level rocks is presented on Figure 12. No attempt was made to further subdivide these data because they are few and dispersed. Lineations in the granodiorite gneiss (Gn) show greater dispersion and a steeper plunge (Fig. 13), however, the lack of data makes any close comparison with linear structures in other parts of the lower level hazardous.

FOLDS: There are three categories of folds in the area:

Type 1 folds are cylindrical, attenuated, and often rootless isoclines with thickened hinges and axial planes parallel to S_1 (Plates III A and B).

Type 2 folds are upright and more open (Plate IVA) with a poorly developed axial plane cleavage (S_2). They fold the axial planes of type 1 folds (Plate IVB).

Type 3 folds are crenulations. They show a close spatial relationship to type 2 folds but are distinguished on the basis of scale.

Type 1 folds are always isoclinal or nearly isoclinal with attenuated limbs and thickened hinges. Type 2 folds vary considerably in shape, depending upon the rock type in which they occur. In quartzose rocks, they tend to be open and nearly concentric, whereas in pelitic rocks, they are more closed and similar in style with somewhat attenuated limbs. Type 1 and type 2 folds occur at all scales of observation down to the mesoscopic. Type 3 folds are probably small-scale equivalents of type 2, but are restricted to the more pelitic schistose rocks.

The most consistent and distinctive feature of type 1 and type 2 folds is their axial plane orientations. The axial surfaces of type 2 folds are nearly vertical and strike to the southeast (Fig. 14) whereas the axial surfaces of type 1 folds are gently inclined and strike northeast (Fig. 15).

The variation in fold shape can be evaluated using a method based on the comparison of the relative curvature of adjacent surfaces in profile, using the proportional change of: the orthogonal thickness t_α and the thickness parallel to the trace of the axial surface T_α, both of which are related to the rate and direction of change of the inclination of dip isogons (lines joining points of equal slope of adjacent curves; Ramsay, 1967, pp. 359-372). The orthogonal thickness t_α – for any angle α measured from the perpendicular to the axial trace – is most conveniently expressed as a proportion of the same measurement 't_o' made at the hinge (Fig. 16); therefore the parameter t'_α is equal to:

$$t_\alpha / t_o$$

The thickness T_α can be similarly expressed such that the parameter T'_α is equal to:

$$T_\alpha / T_o$$

Since $T_o = t_o$, the parameters 'T_α and 't are dependent and

$$t'_\alpha = T'_\alpha \cos \alpha$$

Using these parameters, all simple folds can be classified into three major groups:

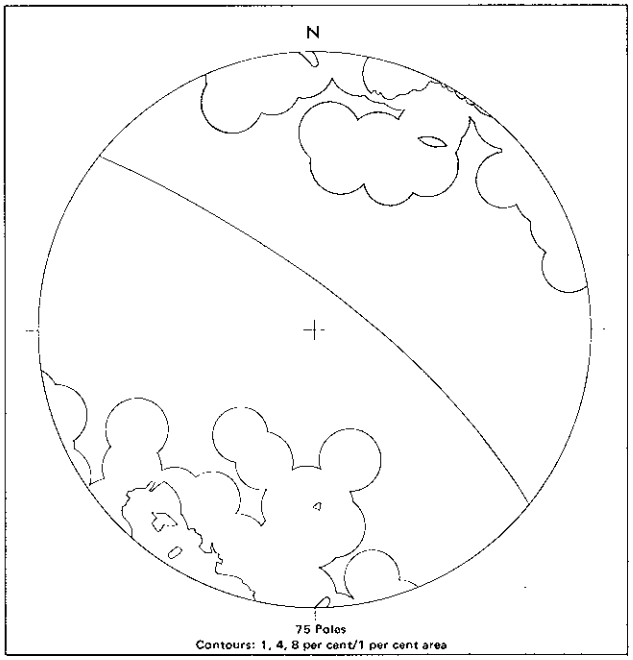


Figure 14. Orientation of poles to axial surfaces of type 2 folds.

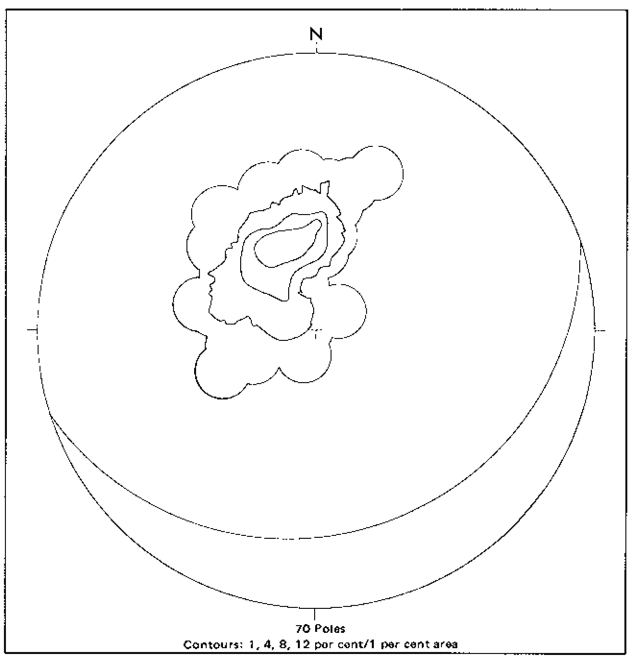


Figure 15. Orientation of poles to axial surfaces of type 1 folds.

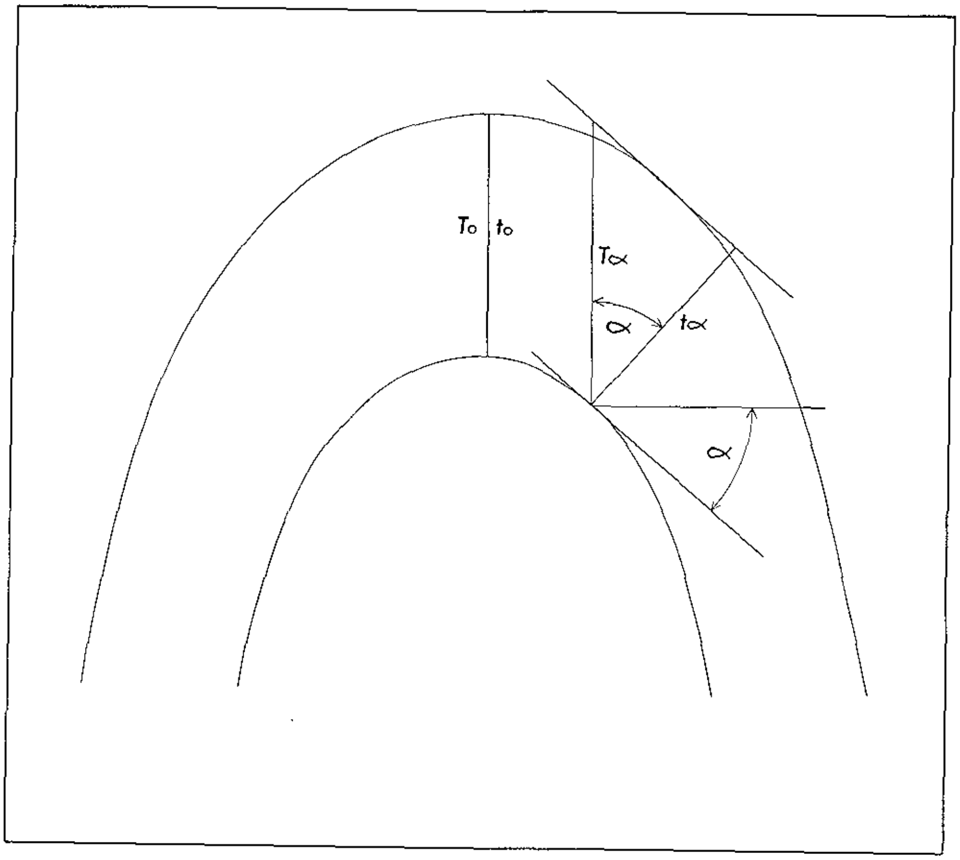


Figure 16. Diagrammatic fold profile illustrating the relationships between T_o, t_o, T_α, t_α, and α.

Class 1: The dip isogons converge inward indicating that the curvature of the inner fold surface is always greater than that of the outer; in other words, t'_α must be greater than $\cos\alpha$ (and T'_α must be greater than 1). Class 1 folds can be further subdivided: *class 1b* (parallel), t'_α is equal to 1 and the orthogonal thickness does not change; *class 1c*, $\cos\alpha < t'_\alpha < 1$ and the orthogonal thickness decreases as α increases; *class 1a*, $t'_\alpha > 1$ and the orthogonal thickness increases as α increases. It is obvious that the strength of convergence of the dip isogons increases as the value of t'_α increases.

Class 2: The dip isogons are parallel indicating that the curvature of each fold surface is equal. In other words, T'_α is equal to 1 (and t'_α is equal to $\cos\alpha$). This is the unique property of similar folds.

Class 3: The dip isogons diverge downward indicating that the curvature of the outer fold surface is always greater than that of the inner; in other words $0 < T'_\alpha < 1$ and $0 < t'_\alpha < \cos\alpha$. This implies that the orthogonal thickness of the fold limbs is severely reduced.

A graphical representation of these fold classes for various values of t'_α and α is presented on Figure 17.

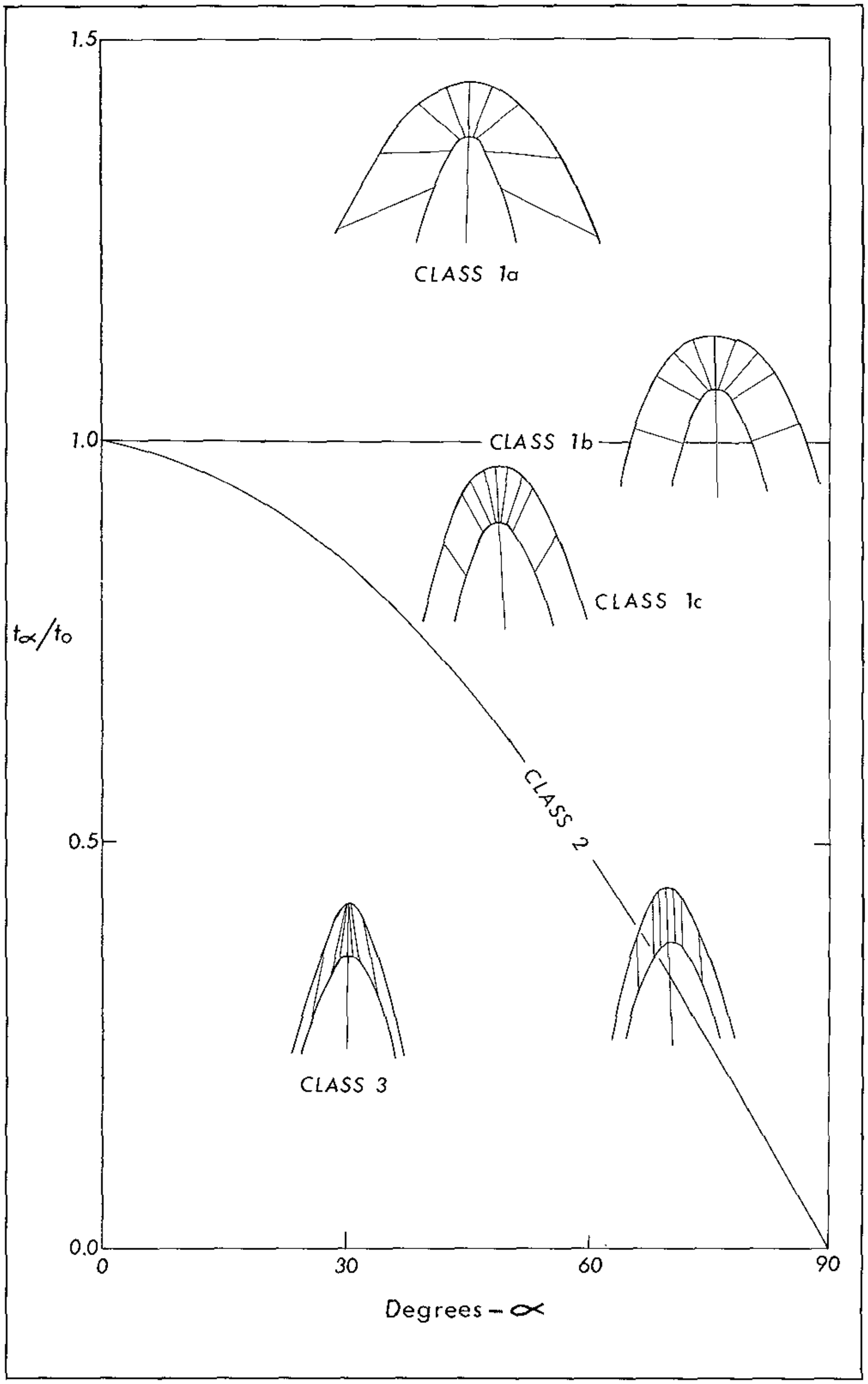


Figure 17. Classification of fold shape using the parameters, t/t_0 and α.

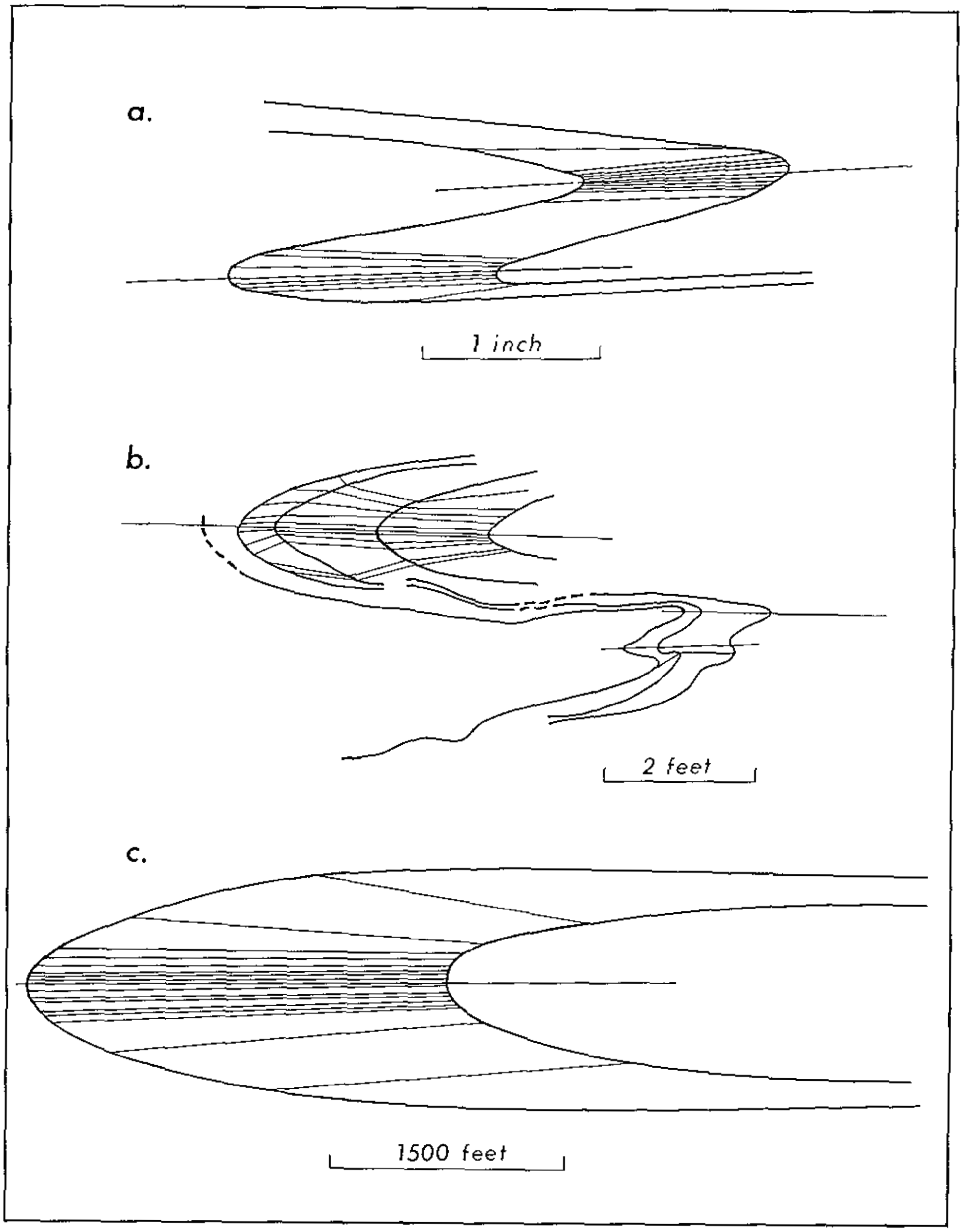


Figure 18. Down-plunge profiles of type 1 folds with dip isogons superposed.

The shapes of type 1 folds of various sizes are illustrated on Figures 18a, b, and c. The variation of orthogonal bed thickness (t_{α}) with limb inclination (α) is illustrated on Figure 19. The folds in Figures 18b and c are similar folds that correspond closely to class 2 of Ramsay. The fold on Figure 18a belongs to Ramsay's class 3. Close examination of the internal arrangement of the dip isogons of Figure 18b gives detailed information with

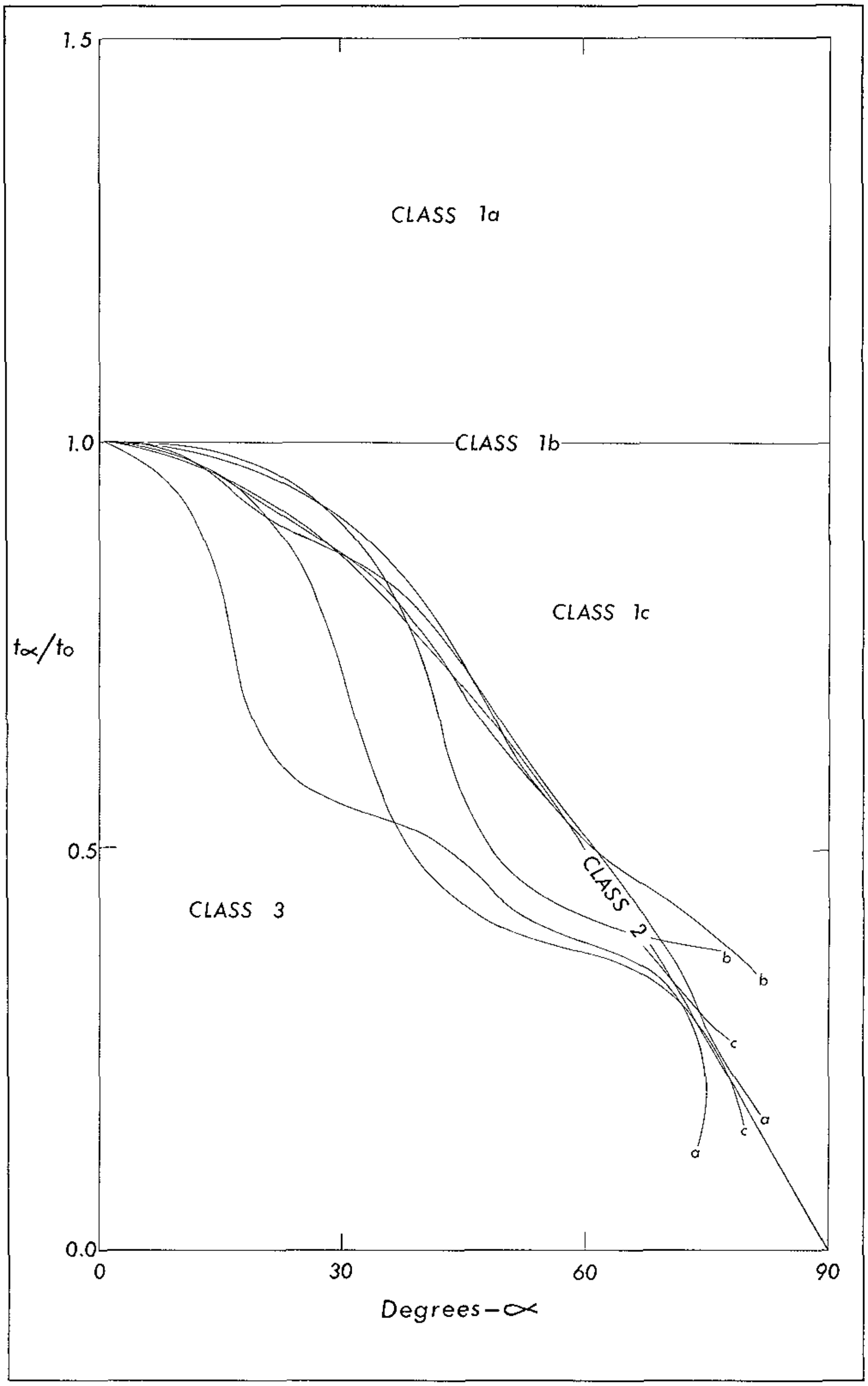


Figure 19. The variation of orthogonal bed thickness with limb inclination for the type 1 folds illustrated on Figure 18.

respect to the internal constitution of type 1 folds; the isogons alternately converge and diverge from layer to layer. Each layer is a class 1 or class 3 fold, but the overall effect is that of a class 2 fold. This pattern is probably characteristic for the type 1 folds in the area.

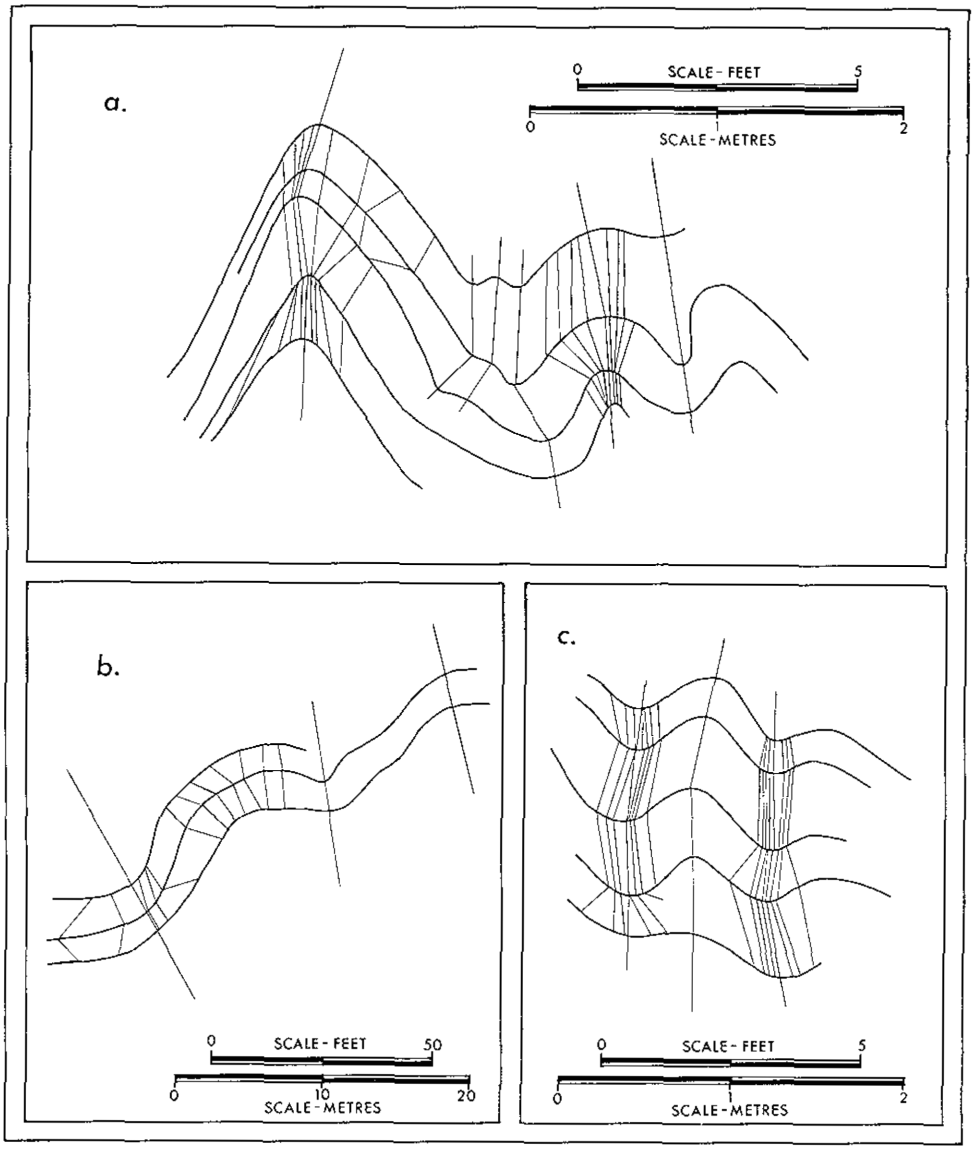


Figure 20. Down-plunge profiles of type 2 folds with dip isogons superposed.

Profiles typical of type 2 folds are illustrated on Figures 20 a, b, and c; the variation of orthogonal bed thickness with limb inclination is illustrated on Figure 21. The type 2 folds encompass a broad range, from class 1 to class 3. Their open nature is indicated by

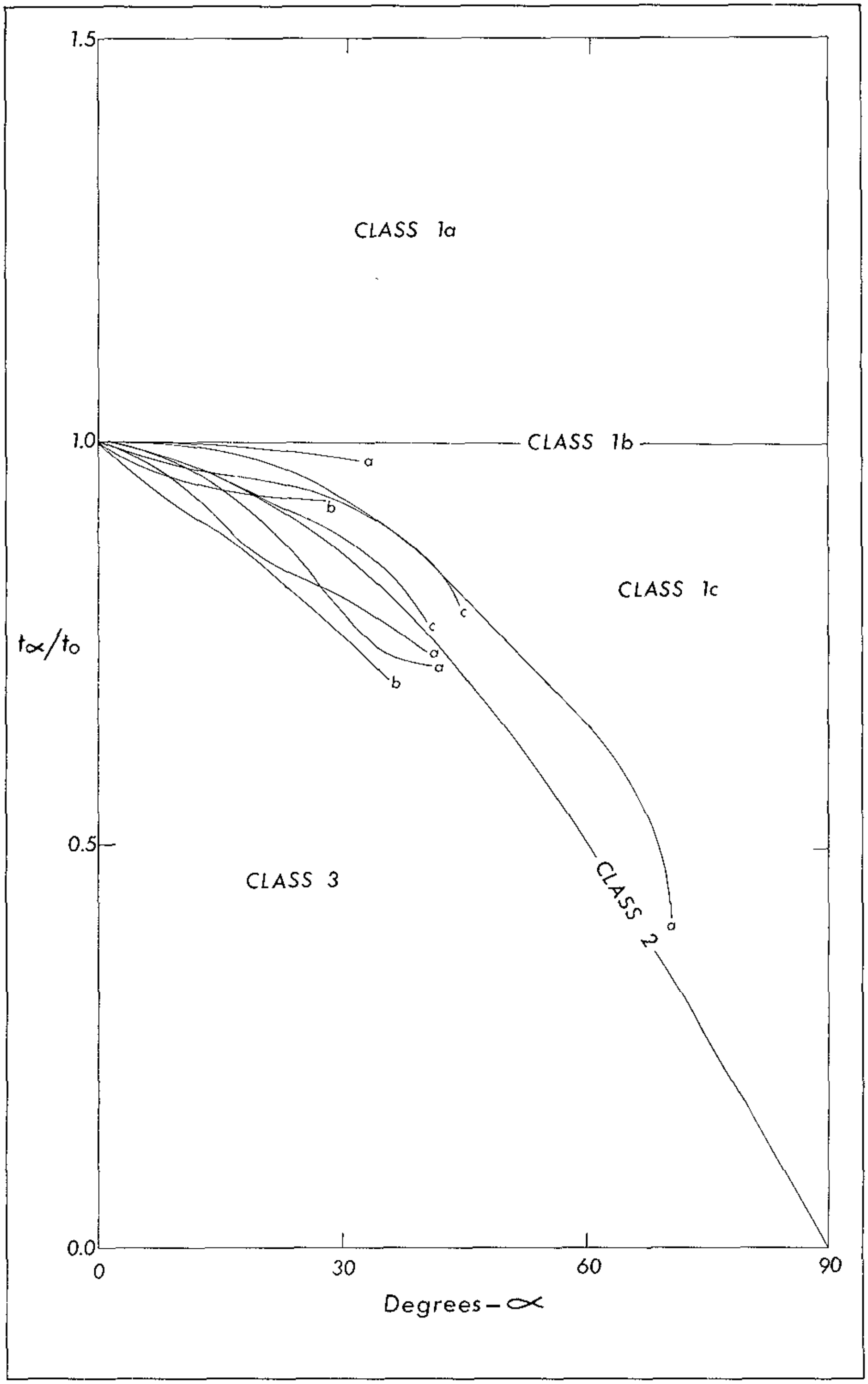


Figure 21. The variation of orthogonal bed thickness with limb inclination for the type 2 folds illustrated on Figure 20.

the smaller interval of α (usually not greater than 40 degrees) over which measurements could be made. These folds also are often composite in nature as illustrated by the alternating convergence and divergence of dip isogons on Figure 20a.

Comparison of Figures 21 and 19 illustrates the difficulty of distinguishing between type 1 and type 2 folds on the basis of fold shape alone. In circumstances where orientation of the axial surface is not clearly suggestive of one or the other, a distinction between them is subjective.

STATISTICAL ANALYSIS OF FOLD AXIS ORIENTATION: An analysis of variations in the orientation of fold axes formed an important part of this study. Statistically determined fold axes orientations provide the basis for projecting map data into structure sections in which the geologic structure of the area can be outlined.

The summary equal-area plots of axial orientations for type 1, type 2, and type 3 folds (Figures 9, 10, and 11) indicate that each category of linear fabric element shows a strong preferred orientation plunging southeast at a shallow angle, and that dispersion about each preferred orientation is the same. The azimuth and inclination of maxima for each fold type are:

142° at 21° (type 1)
122° at 18° (type 2)
129° at 20° (type 3)

with the corresponding angular separations:

type 1 – type 2 = 20°
type 2 – type 3 = 7°
type 3 – type 1 = 14°

The difference in orientation between the axes of type 1 and type 2 (and type 3) folds is the only significant variation in fold axis orientation which is consistent throughout the study area.

Geographic variations in the orientation of the fold axes have been studied using a 1-mile rectangular grid placed over the geologic map. Equal-area diagrams were generated for each category of linear element for each square mile subdomain using computer-based plotting techniques. Diagrams having similar dispersions and orientations of points were combined and the areas they represent were incorporated in larger domains that are homogeneous with respect to these linear fabric elements. The domains determined using this method are illustrated on Figures 22 and 23.

Although separate analyses were carried out for type 2 and type 3 fold hinges, it was found that the diagrams generated for each were nearly identical for any given area; therefore, these fabric elements were grouped together. By compiling the two sets of data, the domain limits of Figure 23 have been more precisely defined; however, the contribution and individuality of each has been maintained by superimposing original equal-area plots of each linear element.

The mean values for each domain of Figures 22 and 23 are summarized on Figure 24. Generally for any given area, type 1 folds have a more southerly trend than type 2 folds; however, the angular discordance between them rarely exceeds 20 degrees.

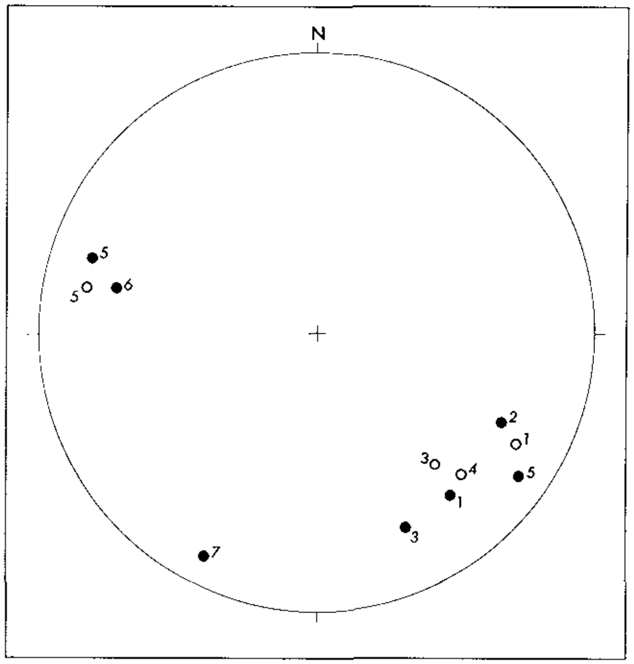


Figure 24. Mean fold axis orientation for each domain of Figures 22 (solid dots, type 1 folds) and 23 (circles, type 2 folds).

THE ORIENTATION AND CONSTRUCTION OF STRUCTURE PROFILES: The identification of large domains that are homogeneous with respect to the orientations of fold axes has facilitated the construction of accurate structural profiles (Fig. 2, in pocket) oriented perpendicular to the axis of folding (Stockwell, 1950) as determined from the fabric diagrams for the individual domains (Figs. 22 and 23). Map contacts have been projected up or down plunge into the plane of profile, and the profiles have been spaced so as to limit the maximum distance of projection to approximately 2,500 feet. All profiles are drawn as viewed from the southeast, and the sequence proceeds from higher to lower structural level.

Since isoclinal (type 1) folding is the dominant structural style of the area, the domains of Figure 22 have been used where possible for profile orientation. However, in areas where this information is not present, the domains for type 2 fold orientations have been used. The two are essentially coaxial and this interchange can be made without serious discrepancies.

STRUCTURAL GEOMETRY

THE STANDFAST CREEK FAULT: Stratigraphic relationships along the lower limb of the Drimmie Creek syncline show that the upper and lower structural levels are separated by a low-angle fault. Truncation of units is evident in both the hangingwall and footwall sequences.

In the hangingwall sequence, the fault follows the base of the Badshot Formation from the south slope of the Akolkolex River to the head of West Twin Creek; here the Badshot is truncated and the fault cuts up-section to the east into the Index Formation in the core of the Drimmie Creek syncline (*see* profile D-D″, Fig. 2).

In the footwall sequence, truncation is apparent at map scale along the south slope of the Akolkolex River (*see* profile A-A′, Fig. 2). Units $B4_a$ and $B4_b$ are progressively truncated westward until the lower limb of the syncline lies directly upon the amphibolite unit $B4_c$. Further truncation is particularly well exposed at the head of Standfast Creek. Here the highest layer of unit D progressively thickens from 0 to more than 1,500 feet eastward as the fault continues to cut up-section (*see* profile E‴-E⁗, Fig. 2). No obvious mesoscopic features suggestive of differential translation were observed along the fault trace.

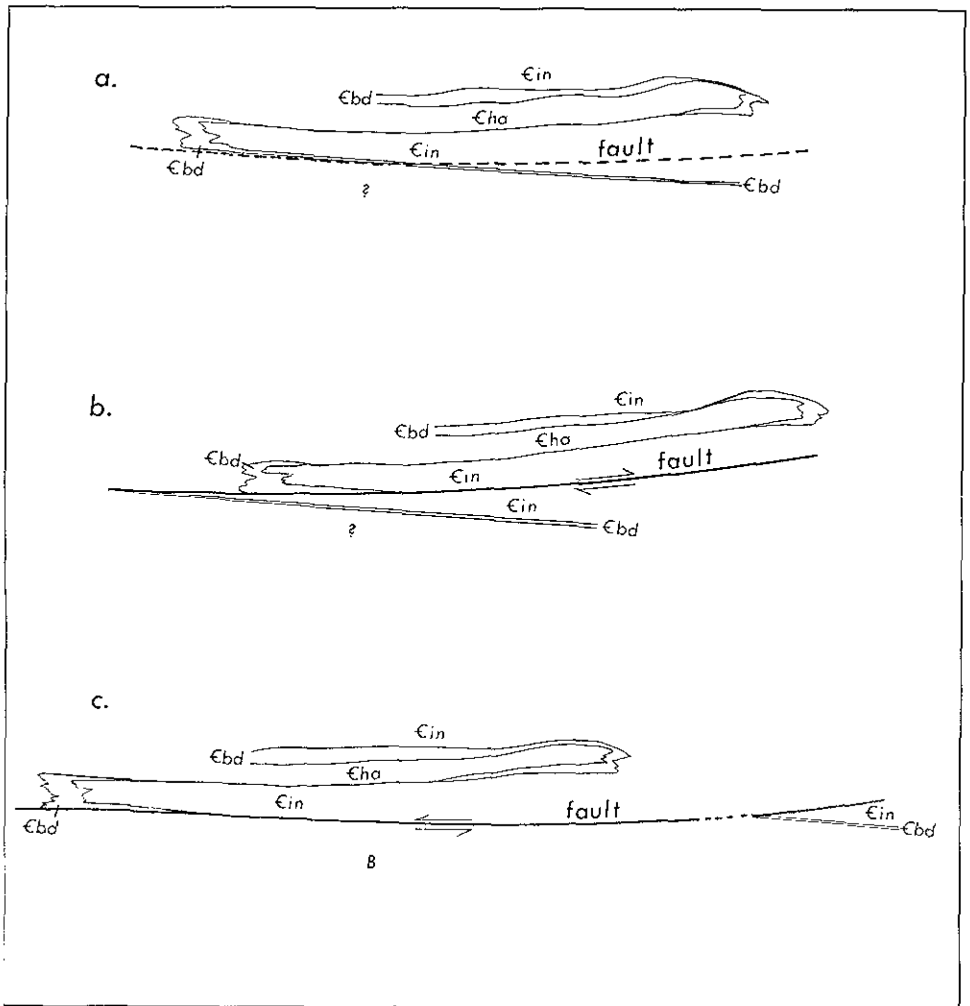


Figure 25. a – A schematic profile of the upper structural level prior to faulting; b – Partial repetition of the Badshot and Index Formations due to contraction along the fault; c – Deletion of part of the Badshot and Index Formations due to extension along the fault.

Although evidence of truncation is found only in two areas, the fault has been extrapolated along the lower limb of the Drimmie Creek syncline parallel with the layering. Since truncation of units in the footwall sequence occurs both to the west and south, the fault is interpreted to have a low southwesterly dip relative to the lithologic layering.

Extension is implied from stratigraphic relationships. A schematic diagram of the Akolkolex anticline and Drimmie Creek syncline before faulting is illustrated on Figure 25a. Contraction (reverse movement) along the fault (Fig. 25b) would cause repetition of the lower limb of the syncline and place lower level rocks over higher level rocks. Extension along the fault (Fig. 25c) causes the Index Formation to be placed directly on lower level rocks thus deleting part of the normal sequence of structures and stratigraphic units. This is consistent with field observations.

The Standfast Creek fault is important with regard to stratigraphic and structural correlations between the two levels. The upper and lower levels probably represent rocks from different areas and tectonic levels.

THE AKOLKOLEX ANTICLINE AND DRIMMIE CREEK SYNCLINE: The Akolkolex anticline and Drimmie Creek syncline are type 1 folds. They are recumbent isoclines with profiles approximating class 2 of Ramsay. They have an amplitude approaching 4 miles and a relatively constant interlimb thickness of 2,500 feet or less and occupy 40 per cent of the region mapped. These structures are well displayed in the sequence of structure profiles on Figure 2. Nearly continuous exposures of the Badshot Formation provide the main datum for accurately outlining these folds.

The hinge of the Akolkolex anticline can be observed in the cliff-face forming the eastern slope of lower Standfast Creek (Plate VA). The limbs, outlined by thin layers of limestone, converge northeastward as a thickened hinge zone of limestone in which there are complex recumbent isoclinal folds. The hinge zone is enveloped by dark grey and black phyllite and slate of the Index Formation. The lower limb is partially obscured by dense vegetation, but limestone bands within it are exposed southwest of the hinge (*see* extreme right of Plate VA).

The hinge is also well exposed further up the plunge on upper West Twin Creek (Plate VB). It is marked by appressed isoclinal folding, extreme attenuation, and abrupt lateral discontinuities in limestone bands enclosed by Mohican phyllite.

The trend of the anticline between these two exposures of the hinge zone is parallel with the trend of mesoscopic folds in this region (Figs. 22 and 23).

The upper and lower limbs of the anticline differ when traced away from the hinge zones. North of the Akolkolex River, the upper limb is marked by a thick (500 feet), continuous layer of Badshot limestone, whereas in the lower limb, the Badshot is very much attenuated and often discontinuous. In many places, the lower limb is characterized by recumbent isoclines a few tens of feet in amplitude. However, as the limestone in the upper limb is traced toward the Akolkolex River valley and onto its south slope, it too becomes attenuated and discontinuous like that in the lower limb.

A circular exposure of limestone within the core of the fold (Fig. 1) extends into the head of the lowest westerly tributary of Standfast Creek. In section, this exposure projects as a thin band enveloped by Mohican phyllite, but may in fact represent the erosional remnant of an appressed isoclinal fold on the lower limb of the anticline (profile D-D′, Fig. 2).

The hinge zone of the Drimmie Creek syncline is well exposed adjacent to Ghost Peak (Plate VI). Badshot limestone in the upper and lower limbs closes southwestward in a thickened hinge zone, of which Ghost Peak is an erosional remnant. The core of the syncline is more attenuated than that of the Akolkolex anticline.

The axial surface of the syncline is outlined directly southeast of Ghost Peak by a thin band of grey Index phyllite sandwiched between the Badshot limestone in the upper and lower limbs. A similar relationship exists within the 'Wigwam Lime' (*see* Table 1), where a thin lentil of dark phyllite and schist extends into the limestone. These dark pelitic rocks are presumably part of the core of the syncline which therefore can be traced from Ghost Peak to the southern limit of the 'Wigwam Lime.' Thus the abnormal thickness of Badshot along this zone and the fact that this is the most westerly exposure within the map-area can be accounted for by the tight synclinal structure.

The southward extension of the Akolkolex anticline and Drimmie Creek syncline onto the south slope of the Akolkolex River is complex and obscured by extensive cover of vegetation. The upper and lower limbs of the pair of folds converge westward and the intervening limb becomes severely attenuated. Internal relations at the hinge of the syncline are obscured.

STRUCTURES BELOW STANDFAST CREEK FAULT: The overall structure in the lower tectonic level is less well displayed than that in the upper because persistent marker units such as the Badshot Formation appear to be lacking. However, there are some important constraints to which interpretation of the structure must conform:

(a) The subhorizontal lateral continuity of the stratigraphy is maintained.

(b) The style of mesoscopic folding is similar to that above the fault.

(c) The upper limit of the gneiss (Gn) is conformable with the overlying metasedimentary rocks along the northern and western limits of the study area and extrapolation of this contact in structural profiles defines a relatively constant lower limit for the structures in the intervening metasedimentary rocks.

The zone in which layers of units C and D are repeated has two possible explanations. The repetitions may be due to early imbricate thrusting, or they may be the result of attenuated recumbent isoclinal folds.

Repetition due to thrusting should produce repetitions of the detailed internal stratigraphy in each slice provided there are no facies changes. However, unit D is quite variable in lithology both along and across strike (*see* Tables 5 and 6). Each layer does not necessarily reflect the detailed lithologic characteristics of the one below it.

Repetition as a result of appressed isoclinal folding should produce:

(a) A symmetric distribution of lithologies – across the axial surface – within each of the layers of unit D.

(b) The successive alternation in lithologic characteristics for each layer of unit D.

(c) Convergence and divergence of unit C into and from hinge zones.

These relationships are satisfied at the head of Standfast Creek; here a mirror symmetry in the distribution of rock types occurs in unit D between the three uppermost repetitions of unit C. Furthermore, the mineral composition and carbonaceous content of each is substantially different (*see* Table 6); the lower contains dark, argillaceous phyllite and schist which could represent Index, while the upper is typical of light-coloured calcareous Mohican schist and phyllite. The upper two limestone layers converge westward and appear to form an anticlinal hinge on the ridge between Standfast and West Twin Creeks (*see* profile E'''-E'''', Fig. 2) with Mohican beds in the core. This implies that a syncline containing Index beds and closing in the opposite direction should occur below. However, this lies beyond the limit of mapping.

Throughout the remainder of this zone, there is little stratigraphic or structural evidence for attenuated isoclinal folding. If other closures are present, they are obscured from view. Detailed field studies further east may provide other evidence.

In the remainder of the map-area, the lower structural level contains quartzite layers (units A1, A2, A3) and pelite layers (units B1, B2, B3, B4). Projection of surveyed points on these units into structural profiles leads to problems in lateral correlation. Two quartzite units on the west are aligned with only one more massive quartzite unit to the east. There may be inconsistencies in the designation of map units east of Greely Creek, or units A1 and A3 may represent the limbs of a large recumbent isoclinal fold which closes eastward around a thickened hinge zone of quartzite, part of which is represented by unit A2 (*see* profiles F-F''' and G-G", Fig. 2). On the ridge between East and West Twin Creeks, the exposed thickness of A2 is substantially less than that south of the Twin Butte area. This may indicate proximity to the eastern limit of the hinge zone.

THE GNEISS CONTACT: The contact between the gneiss and the metasedimentary rocks is conformable. Foliations on either side are parallel, and lineations also appear to be parallel. Where exposed, the contact is sharp and there is no evidence of mylonitization.

On the south slope of the Illecillewaet River, two bands of interlayered pelite and quartzite approximately 500 feet thick were mapped within the gneiss. Successive traverses across the more westerly occurrence indicates that these metasedimentary rocks are an extension of unit B2 and represent an appressed infold within the gneiss (*see* profile G-G', Fig. 2). The lateral dimensions of the metasedimentary rocks in the Twin Butte area were not determined; however, the relationships are assumed to be the same. Intercalation of gneiss and metasedimentary rocks was also observed over a small interval near the mouth of Drimmie Creek.

On the basis of these observations, it would appear that the gneiss was involved with the metasedimentary rocks in the development of isoclinal recumbent folds of the same style as those which occur above it. There was no evidence found to indicate a late forceful intrusion of the gneiss.

MACROSCOPIC UPRIGHT (TYPE 2) FOLDING: Regional variations in the orientation of the dominant foliation (S_0 and S_1) are illustrated on Figure 26. Each hatched line represents the average strike and dip direction in localized areas containing closely spaced data stations.

In general, the dominant foliation outlines a gently undulating southeasterly dipping homocline in which dips are less than 40 degrees. Along the northern border of the area it dips south to where it fans southeastward as a series of broad lobate structures. Within this area the orientation of the foliation outlines broad curvilinear antiforms and synforms that generally terminate as partial domes or basins. One conspicuous antiform extends from Mount MacKenzie, south, to Drimmie Creek. The east slope of the

Columbia is a dip-slope which eventually curves eastward, around the southern termination of the antiform, to form a dip-slope along the north slope of the Akolkolex River near its mouth.

LATE, HIGH–ANGLE FAULTS: A conspicuous high-angle right-hand fault extends along the trace of the West Twin Creek and appears to link with a similar high-angle displacement to the south in the lower limb of the Akolkolex anticline (Fig. 1). A steep easterly dip is indicated by its trace. Another fault with similar properties occurs in the northeastern limits of the study area, south of upper East Twin Creek.

Since these faults transect all other structures, they are interpreted as late features.

5

DISCUSSION

STRATIGRAPHIC CORRELATION OF THE LOWER STRUCTURAL LEVEL SUCCESSION

The rock succession of the lower structural level is difficult to correlate both internally and regionally because the distinctive Lower Paleozoic succession of Hamill quartzite, Badshot limestone, and Lardeau pelite cannot be recognized within it and because there is a gap between the upper and lower structural levels across the Standfast Creek fault; there is little constraint on the correlation of the lower level rocks. However, the scope can be narrowed considerably by combining lithologic and structural data with the following assumptions:

(1) that the standard Lower Paleozoic succession (Hamill - Badshot - Lardeau) extends beyond the study area at least locally, and

(2) that facies changes have not altered the basic lithologic characteristics of this succession.

There is justification for these assumptions because quartzite, marble, and pelite units, which resemble the Hamill, Badshot, and Lardeau, do occur west of the study area in the Jordan River area (Fyles, 1970).

CORRELATION OF UNITS A AND B: The Badshot Formation is an important and persistent regional marker unit. The complete lack of carbonate bands within units A and B suggests they belong either to the underlying Hamill and Horsethief Creek Groups or the overlying Lardeau Group. Moreover, the thick, homogeneous, and relatively pure quartzites of units A have their counterparts in the Hamill Group but not in the Lardeau Group. Accordingly, the A units probably represent the Hamill quartzites and the B units, the Hamill and Mohican or older pelitic rocks.

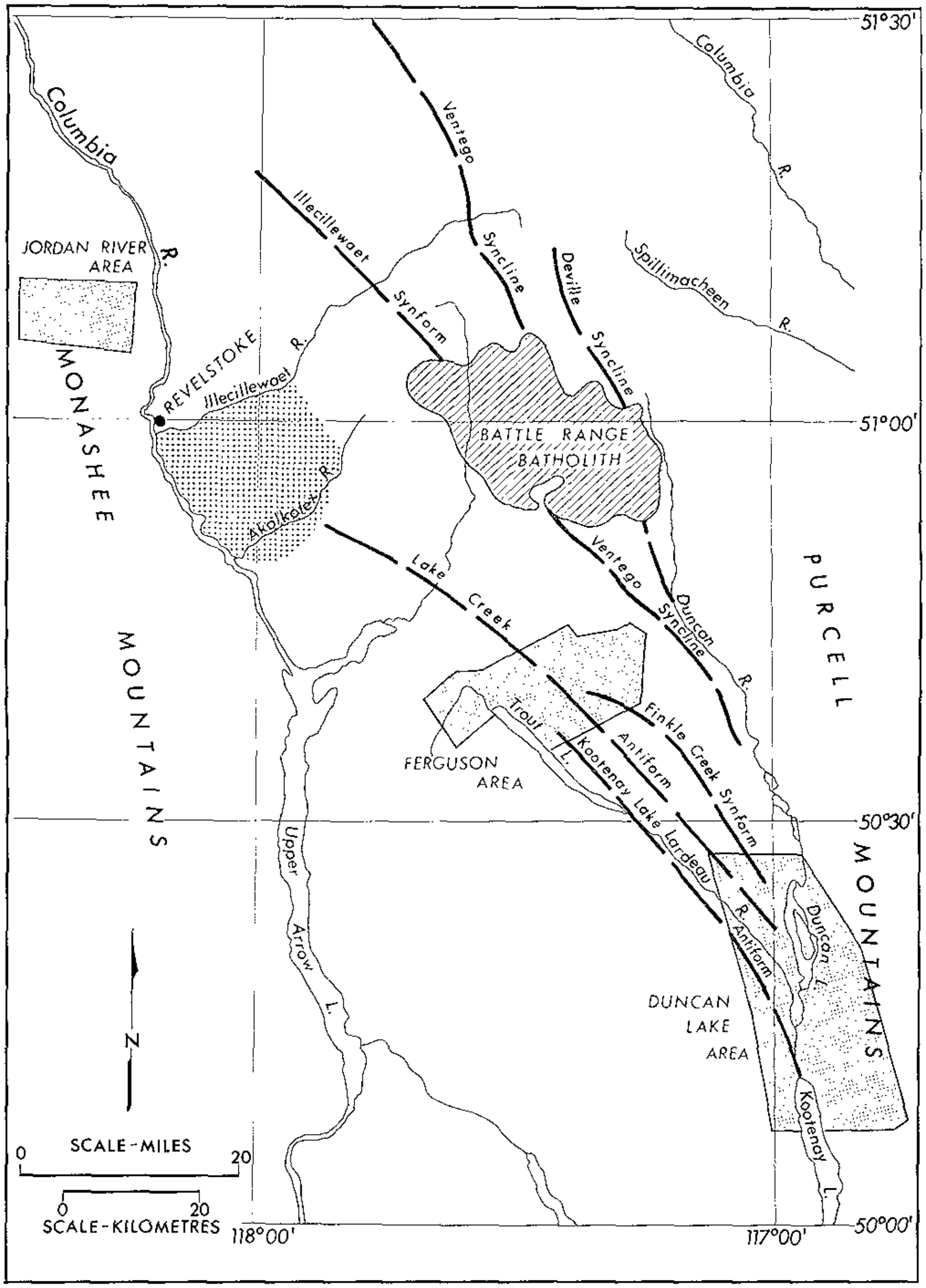


Figure 27. Index map showing the location of the Duncan Lake area, the Ferguson area, and the Jordan River area.

The B units cannot be clearly correlated with the Hamill or Horsethief Creek Groups on lithologic criteria alone. From the large recumbent fold inferred in the structural interpretation of profile G-G'' (Fig. 2), it would appear that both groups may be present, their distribution contingent upon whether the fold is an anticline or syncline. Subunit $B4_b$ contains a sequence of rock types (a buff marble band below a pinkish quartzite) that might be correlative with the Hamill-Mohican boundary. However, subunit $B4_a$, directly above, is more graphitic than Mohican rocks found within the Akolkolex anticline, and the remainder of B4 beneath $B4_b$ is more pelitic and darker coloured than typical upper Hamill. The possibility that unit B4 represents, in part, a western pelitic facies of the Hamill Group must be considered. Wheeler (1963) has suggested that such a facies change takes place to the north in the Rogers Pass map-area.

If unit B4 is Hamill and Mohican, then the inferred fold is a large anticline with units B1 and B2 forming the lower limb. Unit B3, in the core of the fold, could be either lower Hamill (a pelitic facies) or part of the upper slate unit of the Horsethief Creek Group; there is no way of making a distinction. Diagnostic evidence for the Horsethief Creek Group in the form of massive grit units, lensoidal conglomerates, and breccias was not observed.

Unfortunately, the correlation of the B units are based on the geometric constraints imposed by a fold structure which itself is largely an inference. For this reason, the correlation is largely indeterminate.

CORRELATION OF UNITS C AND D: The distinctive rock types comprising units C and D bear a strong resemblance to parts of the Index, Badshot, Mohican, and Hamill Formations. The limestone layers of unit C, in particular, are like those in the Badshot Formation. Their quartz content, colour, and texture all suggest that they are correlatives, but unfortunately there is no faunal evidence to substantiate this. The wedge of quartzite in the highest layer of unit D at the head of Standfast Creek closely resembles the Hamill Group. The enveloping siliceous schists, micaceous quartzite and schist, are more pelitic than the Hamill, and may represent the Mohican Formation or part of the Hamill not previously separated. The remaining layers of D are more difficult to correlate on lithologic criteria alone. The upper two layers of C at the head of Standfast Creek appear to form a westward closing anticline with Mohican in the core. The next lowest dark pelitic layer of D is typical of the Index, and may represent the core of an appressed syncline which closes to the east. The remaining layers of D do not exhibit such consistent alternation. Each layer contains rocks characteristic of both the Index and Hamill. At the head of West Twin Creek, each layer of unit D contains both Index and Hamill-like rocks. If the limestone layers of unit C are the limbs of appressed folds, the alternation of stratigraphy between Index and Hamill is not conspicuous.

REGIONAL STRUCTURAL CORRELATIONS

THE KOOTENAY ARC NORTH OF KOOTENAY LAKE, AND ADJACENT PARTS OF THE SELKIRK MOUNTAINS TO THE EAST: Detailed studies in the Duncan Lake and Ferguson areas (Fyles, 1964; Fyles and Eastwood, 1962) (Fig. 27) and reconnaissance mapping (Wheeler, 1963 and 1970) provide a comprehensive account of the structural fabric from the north end of Kootenay Lake to the Akolkolex River area.

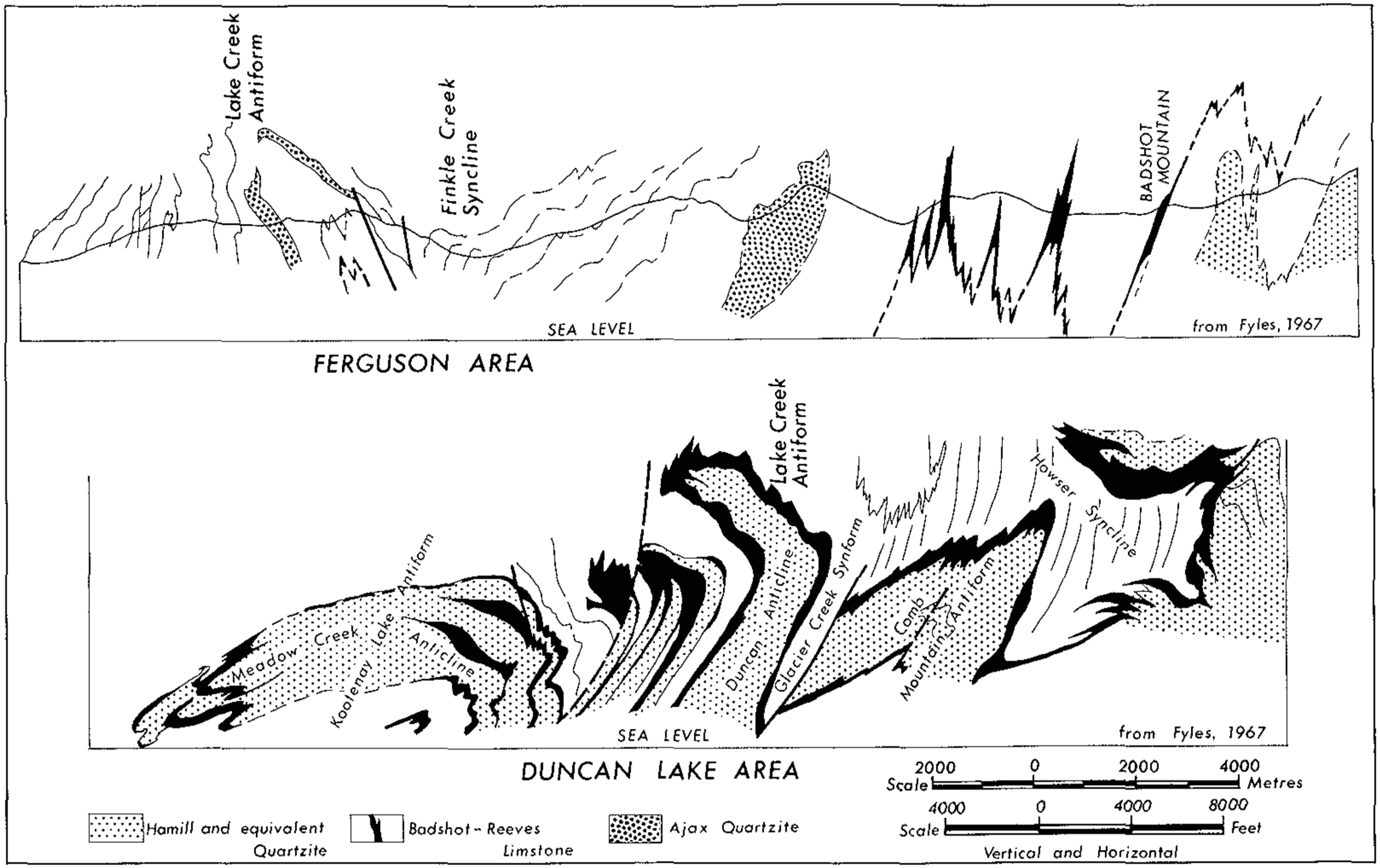


Figure 28. Generalized structure profiles of the Duncan Lake and Ferguson areas (after Fyles, 1967).

UPRIGHT FOLDS: The regional structure in this segment of the Kootenay Arc is dominated by large upright folds which are continuous along much of its length. They are called phase 2 structures (Fyles, 1964) because in the Duncan Lake area they deform the axial planes of earlier recumbent isoclines (phase 1 structures).

In the Duncan Lake area, the upright (phase 2) folds occur as a series of large, north-trending pairs with shallow plunges and steeply dipping axial planes. When viewed in profile from the south, they have the form of a reverse N (И) which is slightly overturned to the east (Fig. 28). In the southern part of the area, they trend 345 degrees, plunge 10 degrees northwest, and the axial planes dip moderately to steeply to the east and west. In the northern part of the area they trend 325 degrees, plunge 10 degrees northwest, and the axial plane dips steeply to the east and west. The fold style varies with rock type. Concentric folds are confined to the most competent rocks, whereas somewhat attenuated similar folds, and locally chevron folds, are found in the incompetent rocks. Two of the largest folds in the area, the Kootenay Lake antiform and the Lake Creek antiform, can be traced northward into the Trout Lake area.

In the Ferguson area, phase 2 folds are isoclinal or near isoclinal, northwest-trending structures with shallow plunges and steeply dipping axial planes (Fig. 28) which form an upward diverging fan in profile. The hinge zones are tightly folded, and the limbs show evidence of attenuation. In addition to the Kootenay Lake and Lake Creek antiforms, another fold, the Finkle Creek syncline, is conspicuous in the eastern part of the area.

As these folds are traced beyond the north end of Trout Lake, there is a significant reduction in amplitude until only a broad arch, representing the Lake Creek antiform, remains in the upper reaches of the south slope of the Akolkolex River, the flanking folds having died out along strike. Within the study area, the antiform is no longer distinguishable, and poorly defined type 2 warps and buckles (Fig. 26) are all that remain. These warps become less evident along the northern border of the study area where the layering dips uniformly south.

Although they terminate along strike, there is correspondence in *space* and *orientation* between the phase 2 folds of Fyles and type 2 folds in the study area. It is important to note that this type of folding becomes less dominant along the Kootenay Arc northwest from Trout Lake.

The decrease in fold amplitude along the arc is in contrast with an increase in the amplitude of upright folds in the belt of Hamill rocks east of the arc. In the Duncan Lake area, these rocks are essentially unfolded, but northward, two large folds, the Ventego syncline and the Deville syncline, emerge at about the same latitude (at the north end of Trout Lake) where the Kootenay Lake, Lake Creek, and Finkle Creek folds begin to die out. North of the Battle Range batholith (Fig. 27), another large structure, the Illecillewaet synclinorium, emerges adjacent to the west limb of the Ventego syncline. This synclinorium is actually developed in Lardeau Group rocks which are a continuation of those in the eastern margin of the Kootenay Arc to the south.

From this it is apparent that the locus of large-amplitude upright folding shifts eastward in an *en echelon* fashion, a clear indication that there is no firm distinction between upright northwesterly trending folds in the Kootenay Arc and those in adjacent parts of the Selkirk Mountains to the north. Thus, the eastern limit of the Arc is uncertain north of Trout Lake.

RECUMBENT ISOCLINAL FOLDS: The occurrence of recumbent isoclinal folds south of the study area is restricted to the Duncan Lake area. Here they are called phase 1 folds (Fyles, 1964) because they are the earliest structures observed.

These folds are extremely attenuated, with sharp thickened hinges and stretched and sheared limbs which are discontinuous in many places. Four large folds are defined from the macroscopic distribution of lithologies: Howser syncline, Duncan anticline, Meadow Creek anticline, and St. Patrick syncline. In generalized profile (Fig. 28), each roots in a westerly direction, rises moderately to steeply eastward, and is sharply overturned (back-folded) to the west by the major phase 2 structures. The Howser syncline, located at the northern end of Duncan Lake, is the most northerly phase 1 fold in this part of the arc.

To the south, along the western border of Kootenay Lake, folds equivalent in style and orientation are present; however, detailed structural relationships are not well exposed (Fyles, 1967).

Unlike the upright northwesterly trending folds of the Kootenay Arc and adjacent Selkirk Mountains, individual recumbent isoclines cannot be traced along trend for any distance. However, there is a close correspondence of style, axial orientation, and relative timing between isoclinal folds of the Akolkolex and Duncan Lake areas. The only major difference is the amount of subsequent refolding which has affected them.

This dichotomy of vergence may reflect the presence of the Purcell anticlinorium adjacent to the Duncan Lake area. It is a large, little deformed, prograded wedge of well-indurated mature clastic sedimentary rocks of Helikian age which may have acted as a buttress against which isoclinal folds in the Lower Paleozoic rocks to the west were back-folded as they rode up the west flank of the anticlinorium. To the north, the anticlinorium is a less prominent structural feature; this may partially explain the lack of back-folding in the Akolkolex River area.

JORDAN RIVER AREA OF THE SHUSWAP COMPLEX: The Jordan River area, on the southern flank of the Frenchman's Cap Gneiss Dome, northwest of the study area, is on-strike with the structural trend of the Kootenay Arc. Three main categories of folds have been described there (Fyles, 1970): (1) obscure, attenuated, recumbent isoclines which trend westerly and west-southwesterly (phase 1 folds); (2) more upright and open folds of variable style and orientation which fold the axial planes of the isoclines (phase 2 folds); and (3) broad regional warps about north-northwest axes which affect the trends of the other folds (phase 3 folds).

The structure of the area is dominated by several large phase 2 folds which are draped around the southern flank of the gneiss dome. Generally they have the profile (viewed from the east) of an 'N' overturned to the north. They vary systematically in trend from southeast to south to northeast as the area is traversed from west to east. Considerable variations in plunge, style, and shape occur along the trend of individual folds and between folds. They vary from cylindrical to conical, concentric to similar, some are doubly plunging, and closely spaced folds sometimes merge along trend. Generally, folds in the northern part of the area are tighter, more variable in plunge and style, and more conical, with low southerly dipping axial planes. Folds in the southern part of the area are more open and cylindrical with moderately to steeply dipping axial planes. A somewhat sequential development is indicated since folds to the south appear partially superimposed upon those to the north.

The isoclinal phase 1 folds are obscure and appressed with extremely attenuated limbs, and axial planes which are folded by the phase 2 structures. West of the Jordan River, they have a trend of 235 degrees and axial planes that dip gently southwestward. East of the Jordan River, they trend east-west with axial planes dipping south and southwesterly. Throughout, there is a pervasive mineral lineation which is parallel to the axes of the folds.

There is one major phase 3 fold which is a broad warp about a north-northwest axis corresponding to the trace of the Jordan River valley; its axial plane is essentially vertical. This accounts for the systematic change in trend of the phase 1 and phase 2 folds and reflects the broad curviplanar nature of the southern flank of the gneiss dome.

The gap in exposed geology and the lack of stratigraphic control between the Akolkolex and Jordan River areas makes correlation of individual structures impossible. However, the basic pattern of deformation is similar — recumbent isoclinal folds have been deformed by folds with more upright axial planes. The only conspicuous change is in fold trend, from the pervasive northwest-southeast Kootenay Arc trend to the east-west Shuswap trend. However, this appears to be a progressive change which takes place between the two areas (Fig. 29).

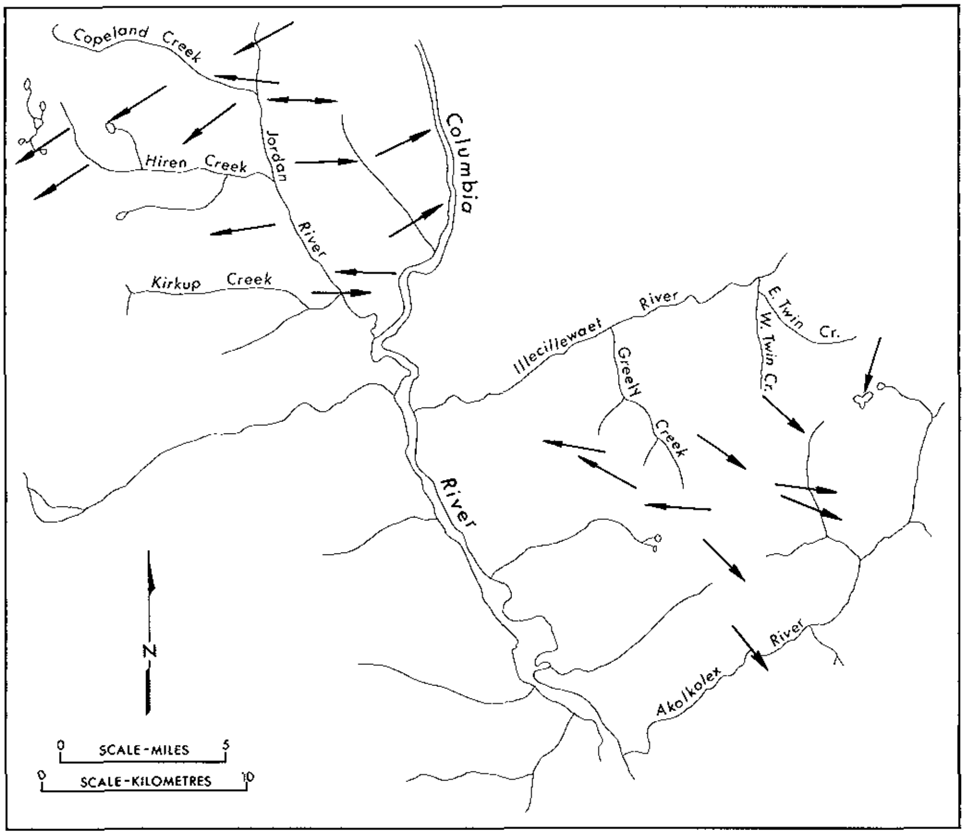


Figure 29. Regional variation in trend of recumbent isoclinal fold axes in the Jordan River (Fyles, 1970) and the Akolkolex River areas.

The subsequent more upright folding (phase 2 and 3 folds) of the Jordan River area show little direct continuity with the upright folds and warps (type 2 folds) within the study area. However, unlike the spatial continuity of upright folding along the Kootenay Arc and adjacent Selkirk Mountains, a large variation in fold style and orientation takes place in the interval between the Jordan River area and the Akolkolex River area. This discordance may be related to the Frenchman's Cap Gneiss Dome which appears to have played an important role in the development of phase 2 folds (Fyles, 1970).

THE ROLE OF TECTONIC LEVEL

The variation in structural style between the study area and adjacent areas appears related to variations in tectonic level. Wegmann (1963) has distinguished three basic tectonic levels through structural analysis: the suprastructure, a regime of brittle deformation with little or no attendant metamorphism; the intermediate level, a transition zone of steep metamorphic gradient, complex shearing, and disharmonic folding, which varies in thickness and position; and the infrastructure, a mobile regime of plastic deformation, complete metamorphic reconstitution, and migmatization. The distinction between the suprastructure and the infrastructure does not necessarily relate to that between cover and basement.

The Selkirk Mountains characterize a suprastructural regime. The regional grade of metamorphism is low and the structure is dominated by thrust faults, high-angle reverse faults, and upright folds. The Shuswap Complex typifies a mobile infrastructural regime. The regional grade of metamorphism is high, granitic complexes and migmatization are common, and attenuated recumbent structures trend at right angles to the regional structural grain. The basic change in structural style between these regimes is from structures which are the result of horizontal shortening, to those which have resulted from horizontal extension. The Akolkolex River area represents part of the zone of adjustment between them. Here there is a steep metamorphic gradient, evidence of at least one major low-angle shear zone, and Shuswap style structures with normal northwest-southeast Cordilleran trends. Unfortunately, the exact nature of the change from upright folding to recumbent folding is not exposed; however, the absence of large-scale recumbent folding in adjacent areas to the south and east is indicative of a rapid transition. This change in structural style also occurs along the trend of the Kootenay Arc. In the Ferguson area, the upright folding (phase 2) is typical of that found elsewhere in the Western Selkirk Mountains, appressed recumbent folds are not present, and the exposed rocks are younger and in a low grade of regional metamorphism. However, further south in the Duncan Lake area, attenuated isoclinal (phase 1) folds reappear in the older exposed rocks, and the grade of regional metamorphism increases rapidly in a southward direction.

The dichotomy in strain relationships along the trend of the Kootenay Arc, and between the Selkirk Mountains and the Shuswap Complex in general, may represent variations in the mechanical response of rocks deformed at different tectonic levels. The Akolkolex River area is interpreted as part of the intermediate level of adjustment between the suprastructure to the east and locally south, and the infrastructural Shuswap Complex.

6

ECONOMIC GEOLOGY

Lead-zinc mineralization occurs in close association with the Badshot Formation in many parts of the Kootenay Arc. In the Akolkolex River area, a substantial occurrence occupies a zone approximately 100 feet thick and 4,000 feet long in the Wigwam Lime on the north slope of the Akolkolex River. The sulphides form lensoidal masses of fine-grained, disseminated to massive pyrrhotite, pyrite, sphalerite, and galena in order of decreasing abundance. Extensive exploratory work on the Wigwam property has been carried out over the past 50 years, including surface and underground exploration.

Limits of the mineralized zone concur closely with those of the fine-grained grey quartzite band which occurs in the middle of the Wigwam Lime succession (*see* p. 26) and forms the dominant host rock for the sulphide minerals. The sulphides occur as fine-grained, disseminated to massive attenuated lensoidal masses in the hinge zones of type 1 folds, and as coarser crystalline aggregates and streaks in local occurrences of buff-weathering marble. This zone reappears locally further north in the hinge of the Drimmie Creek syncline (*see* pp. 14, 57 and Fig. 5) and has associated with it a thin band of orange-weathering dolomitic limestone.

The character and distribution of the mineralization are intimately related to the regional structure. The Badshot Formation is severely attenuated and somewhat discontinuous away from the hinge zone of the Drimmie Creek syncline; for this reason it is unlikely that the Wigwam orebody has an extensive lateral dimension. It is also unlikely that the orebody extends beyond its present longitudinal limits; the very attenuated nature of the hinge zone south of the Akolkolex River and the sparse mineralization in the Ghost Peak area and at the head of Drimmie Creek support this contention. The source of mineralization is not known. Lead isotope studies on deposits further south in the Kootenay Arc (Reynolds and Sinclair, 1971) indicate them to be epigenetic; field evidence does not contradict or support this conclusion. Involvement of the sulphide minerals in isoclinal type 1 folding, their conformity with the lithologic layering, and attenuated nature suggest they were present during and possibly prior to deformation; however, data leading to an evaluation of the effects of deformation and elevated temperatures upon the mobilization and localization of the sulphides are not available.

WIGWAM LEAD – ZINC OCCURRENCE

The Wigwam property is situated on the north slope of the Akolkolex River, 14 miles southeast of Revelstoke. Parmac Mines Ltd. holds the following claims: BIG EDDY 1 and 2, BIG R 1 to 4, BIG M 1 to 12, BIG IKE 1 and 2, and MEL 1 and 2.

HISTORY: The Wigwam property was very active from 1924 to 1930 when the Wigwam Mining Co. of Tacoma, Washington, carried out diamond drilling (39 holes totalling 5,877 feet), extensive trenching, and development of several short exploration adits. The property has been inactive since, except for mapping, trenching, and sampling by Cominco Ltd. in 1961, and diamond drilling (eight holes totalling 4,065 feet), surface sampling, and mapping by Canex Aerial Exploration Ltd. in 1969. Estimation of ore-grade tonnages has been frustrated by complex internal structure.

GEOLOGY: The Wigwam lead-zinc deposit (Fig. 30) comprises conformable sulphide-rich lenses within fine-grained silicified limestone of the Badshot Formation. The silicified zone is a mappable unit that can be traced for about 4,000 feet northwestward obliquely across the north slope of the Akolkolex River; it is approximately 200 feet thick at its southern extremity but thins northward to less than 100 feet. In this area (Fig. 30), the Badshot Formation is approximately 500 to 700 feet thick, strikes about 135 degrees, and dips toward the northeast at approximately 20 degrees (*see* p. 26 for detailed stratigraphic description).

The Wigwam deposit is contained within the thickened hinge zone of the Drimmie Creek syncline (Fig. 2, section B-B'), a large recumbent isoclinal fold that closes toward the southwest and plunges at a low angle toward the southeast (*see* p. 00 for a detailed description). The limbs of the syncline are very attenuated (and discontinuous in places) adjacent to the hinge zone and this places severe limits on the potential for significant down-dip (into the hillside) extension of the deposit.

The silicified limestone host is light to medium grey, banded, and ranges from fine-grained to cherty quartzite, to quartzitic limestone. Within the unit are layer(s) of coarse crystalline white to creamy white limestone. The sulphides are mainly pyrrhotite with lesser pyrite, sphalerite, and galena; they occur as disseminations and in lenses up to 2 feet thick that rarely exceed 10 feet in length. The sulphides are generally fine grained except for local pockets of massive pyrrhotite. Sphalerite is more abundant than galena, which occurs in occasional isolated pods, and silver content of the sulphides is very low.

Detailed distribution of sulphide layers is complicated by tight recumbent isoclinal folds (type 1 folds in this report). Their geometry is consistent with the much larger Drimmie Creek syncline; they plunge at shallow angles to the northwest and southeast, have attenuated and discontinuous limbs, and have somewhat thickened hinge zones. Folded nature of the sulphide layers along with the dominance of pyrrhotite over pyrite indicates that the sulphides predate regional metamorphism and type 1 folding in the area (Muraro, 1967).

CLASSIFICATION: The Wigwam deposit is one of a group of concordant lead-zinc deposits that occur along the Kootenay Arc from the Metaline district of Northern Washington to north of Ruddock Creek in the Shuswap Complex. Fyles (1967) has classified the Wigwam deposit as Shuswap type; that is, it comprises conformable sulphide layers within calcareous schists and carbonates of high regional metamorphic grade. But the Wigwam deposit is unique among this class because it can be demonstrated that: (1) it occurs in the Badshot Formation of Lower Cambrian age and (2) it comprises conformable lenses within a large appressed recumbent fold. This is the only Shuswap-type deposit that can be dated stratigraphically and demonstrates that at least one Shuswap-type deposit occurs in the same time-stratigraphic interval as the concordant Salmo-type deposits further south along the arc. An important difference between them is the type of structure each is associated with; Salmo-type deposits tend to be localized along upright open (phase 2) fold structures whereas the Wigwam deposit is localized along the hinge zone of a recumbent fold structure. The significance of this difference is not understood. If the Wigwam deposit is stratigraphically representative of other Shuswap deposits, then this class is also restricted to the Lower Cambrian Badshot Formation and its more westerly and northerly equivalents.

7

CONCLUSIONS

The Akolkolex River area is dominated by large, recumbent folds which are severely appressed, and reflect a kinematic pattern of horizontal extension and vertical shortening. These structures plunge gently toward the southeast, but appear to change progressively toward a horizontal east-west orientation in the northwestern part of the area. Part of the stratigraphic succession is deleted along a low-angle southwesterly dipping fault which divides the area into two structural levels, and juxtaposes rocks of Lower Cambrian age and known stratigraphic position, with a quartzite-pelite succession most of which probably correlates with the Hamill Group. Granitoid rocks, which were involved in at least part of the structural evolution of the area, form a nearly conformable lower limit to the succession of pelitic schists and quartzites; a steep metamorphic gradient is superjacent to them. Lead-zinc mineralization is confined to the Badshot Formation in the thickened hinge zone of the Drimmie Creek syncline. Marked attenuation of the fold limbs places severe restrictions on the possible lateral extent of economically important sulphide mineralization.

The Akolkolex River area is regarded as part of the zone of adjustment between the suprastructural Selkirk Mountain fold and thrust belt, and the infrastructural Shuswap Complex.

APPENDIX

MINERAL PARAGENESES OF THE AKOLKOLEX RIVER AREA

Mineral parageneses determined from thin-section study of selected rock specimens are given in *Table 1*. Each specimen is identified with respect to the stratigraphic unit to which it belongs, and the stratigraphic units are arranged in order of increasing structural depth.

MAP UNIT	SAMPLE NUMBER	Quartz	Muscovite	Plagioclase	Chlorite	Biotite	Garnet	Staurolite	Kyanite	Sillimanite	Calcite	Epidote	Amphibole	Tourmaline	Sphene	Apatite	Opaque	Spinel
	69–43b	x	x														x	
	69–43c	x									x						x	
	69–38b	x	x	x													x	
Ꞓin	70–255	x	x															
	Pr. 1		x	x										x				
Ꞓin$_{8}$	69–74a	x	x	x	x							x						
	69–74b	x		x	x							x	x				x	
Ꞓha	70–457	x		x							x		x					
	70–93	x	x															
	69–26	x	x														x	
	69–43a	x	x														x	
	69–45	x	x		x	x											x	
Ꞓmo	69–42a	x									x		x					
	70–486			x	x						x							
	69–42b	x			x						x	x	x				x	
	69–60	x	x		x												x	
Ꞓha	69–32	x	x														x	
Ꞓbd	69–43c	x									x						x	
	69–25										x							
	70–260	x	x	x		x					x							
	70–261a	x		x								x						
	70–261b	x	x		x	x												
	70–298	x	x	x	x	x												
	70–46	x									x		x					
	70–382	x		x		x	x											
	70–450a	x		x		x												
B4	70–450b	x		x							x		x					
	70–451	x	x	x		x					x							
	70–470	x	x	x	x	x												
	70–472	x		x	x	x							x					
	70–25	x	x	x		x												
	70–40a	x		x	x	x												
	70–43	x	x	x		x					x						x	
	70–51	x	x	x		x												
	70–22	x		x		x	x											
	70–23a	x	x		x	x												
	70–23b	x		x	x	x												
	70–121a	x		x		x								x				
	70–121b	x	x	x	x	x	x						x	x				
	70–304	x		x	x	x	x					x	x		x			
	70–354	x	x	x	x	x	x				x					x		
	70–297	x	x	x	x	x											x	
A	70–203	x	x	x	x	x												
	70–205	x		x		x								x				
	70–20	x		x	x	x					x				x			
	70–75	x		x		x									x	x		
	70–76	x	x			x	x											
	70–87a	x	x		x	x	x											
	70–58	x		x														
	70–127	x		x		x										x		
	70–14	x	x	x		x					x			x				
	70–87b	x	x	x	x	x	x											
	70–89	x	x	x		x												
	70–78	x		x		x	x								x		x	
	70–16	x		x									x					
	70–29	x	x	x	x	x		x										
	70–31	x	x	x		x												
	70–123	x	x	x		x					x							
	70–120	x		x	x	x							x					
	70–135a	x	x	x		x						x		x				
	70–135b	x	x	x	x	x						x		x				
	70–159	x		x	x	x												x
	70–191	x		x	x							x	x		x	x		
	70–291	x	x		x	x	x	x	x									
	70–292	x		x	x	x	x				x	x	x		x		x	
B	70–294	x	x	x	x	x												x
	70–316a	x	x			x											x	
	70–317	x		x		x						x	x		x			
	70–316b	x	x								x							
	70–316c	x	x	x	x	x		x	x									
	70–316d	x	x	x		x		x									x	
	70–311	x	x	x	x	x	x										x	
	70–290	x	x	x	x	x	x										x	
	70–330	x		x		x						x	x		x			
	70–52a	x		x		x	x											
	70–52b	x		x		x					x		x					
	70–56	x		x		x												
	70–71	x		x									x		x			
	70–74	x		x							x	x	x		x			
	70–112	x									x							
Gn	70–150a	x	x	x	x							x	x		x			
	70–150c	x	x	x		x				x		x						
	70–151	x		x	x		x										x	
Gn	70–153	x		x									x		x			
	70–156	x	x	x	x	x				x								
	70–162	x	x	x	x	x										x		
	70–321	x	x		x	x	x		x								x	
	70–331	x	x	x														
	70–194	x	x	x		x											x	

Plate IA. Garnet porphyroblasts elongate in the plane of schistosity (x 10).

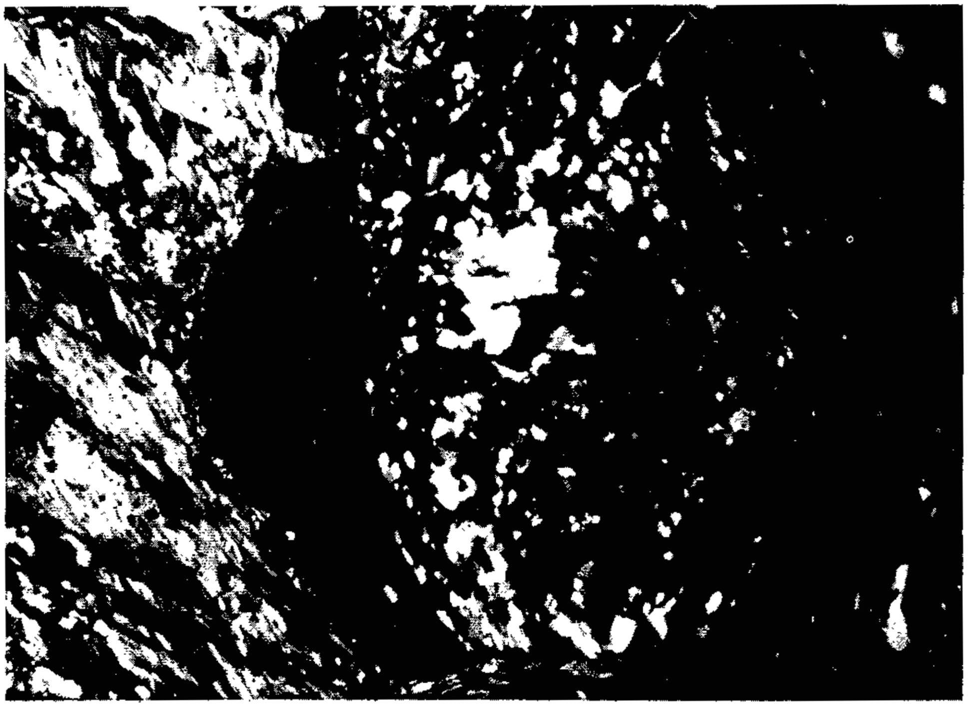


Plate IB. Sigmoidal arrangement of quartz inclusions in garnet porphyroblast (x 10).

Plate IIA. Sigmoidal arrangement of quartz laminae in staurolite porphyroblast (x 10)

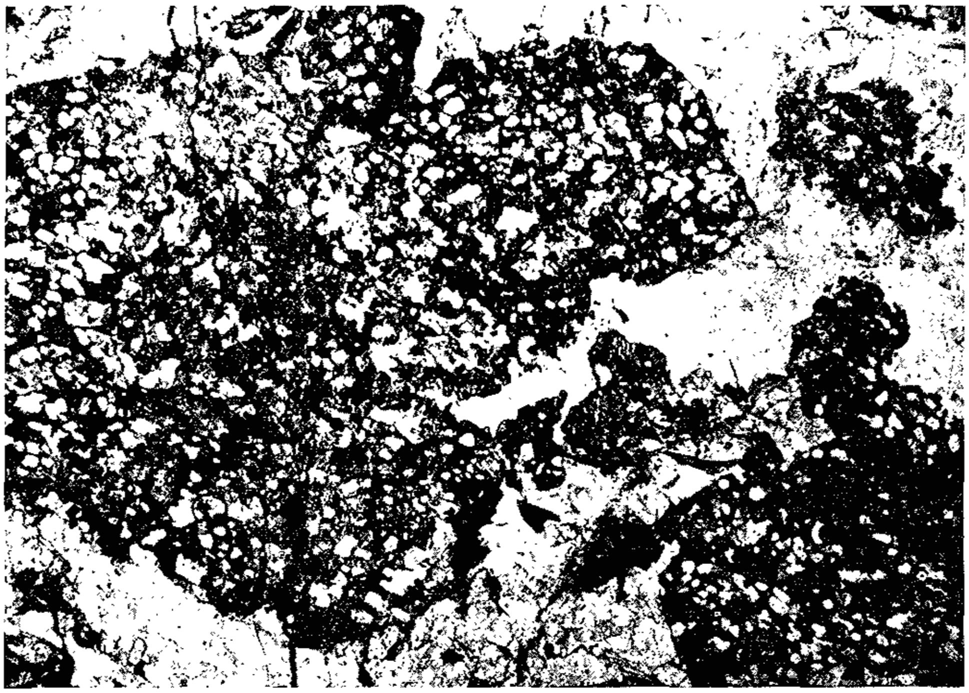


Plate IIB. Randomly oriented quartz inclusions in garnet porphyroblast from pelitic layer *contained in gneiss unit* (x 10).

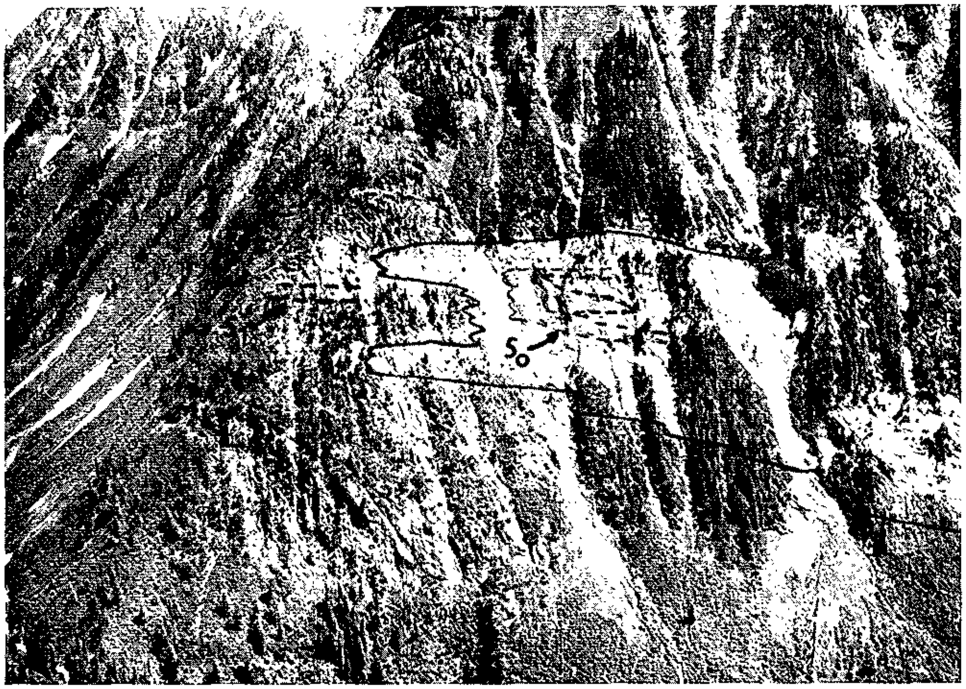


Plate IIIA. Transposition of lithologic layering (S_o) into parellelism with the schistosity (S_1) in the hinge zone of the Akolkolex anticline (view toward the southeast of Standfast Creek).

Plate IIIB. Recumbent isoclinal type 1 fold in quartzite south of Twin Butte.

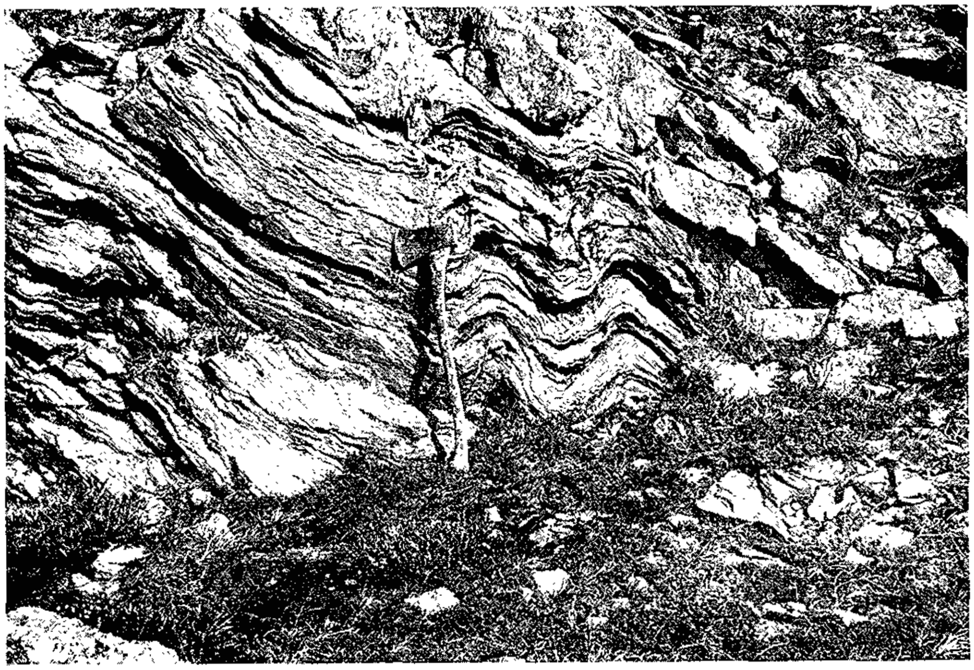


Plate IVA. Upright type 2 folds in siliceous pelite from upper Greely Creek.

Plate IVB. Axial plane of type 1 fold deformed by upright type 2 fold, southeast of Ghost Peak.

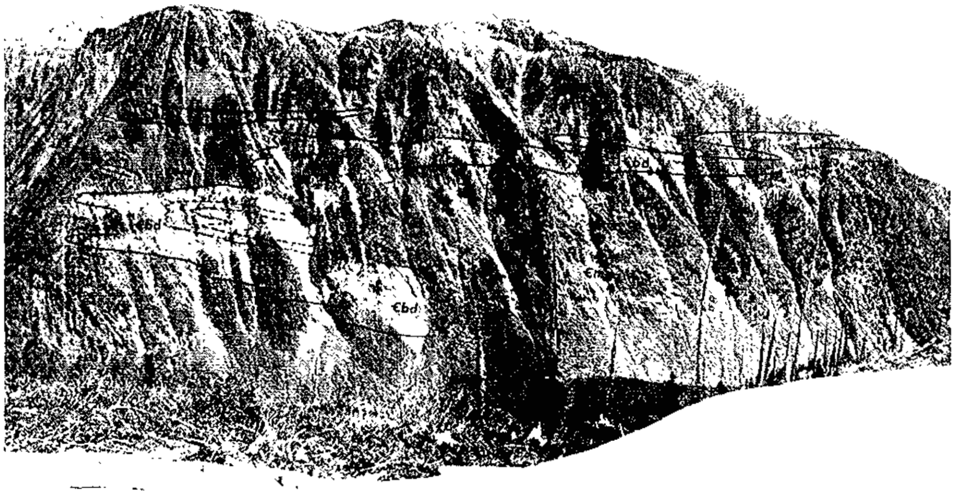


Plate VA. Hinge zone of the Akolkolex anticline (viewed toward the southeast, down-plunge) on the east slope of lower Standfast Creek; Badshot limestone (Є bd) in upper and lower limbs converges northeastward (to left); extension of limestone in lower limb visible at extreme right.

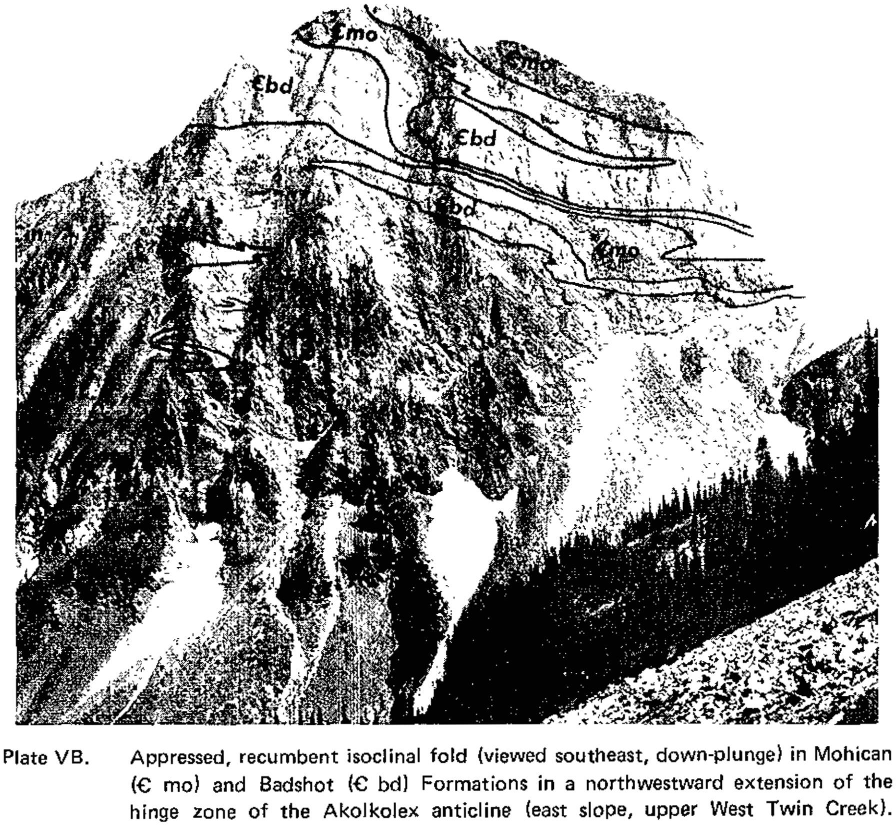


Plate VB. Appressed, recumbent isoclinal fold (viewed southeast, down-plunge) in Mohican (Є mo) and Badshot (Є bd) Formations in a northwestward extension of the hinge zone of the Akolkolex anticline (east slope, upper West Twin Creek).

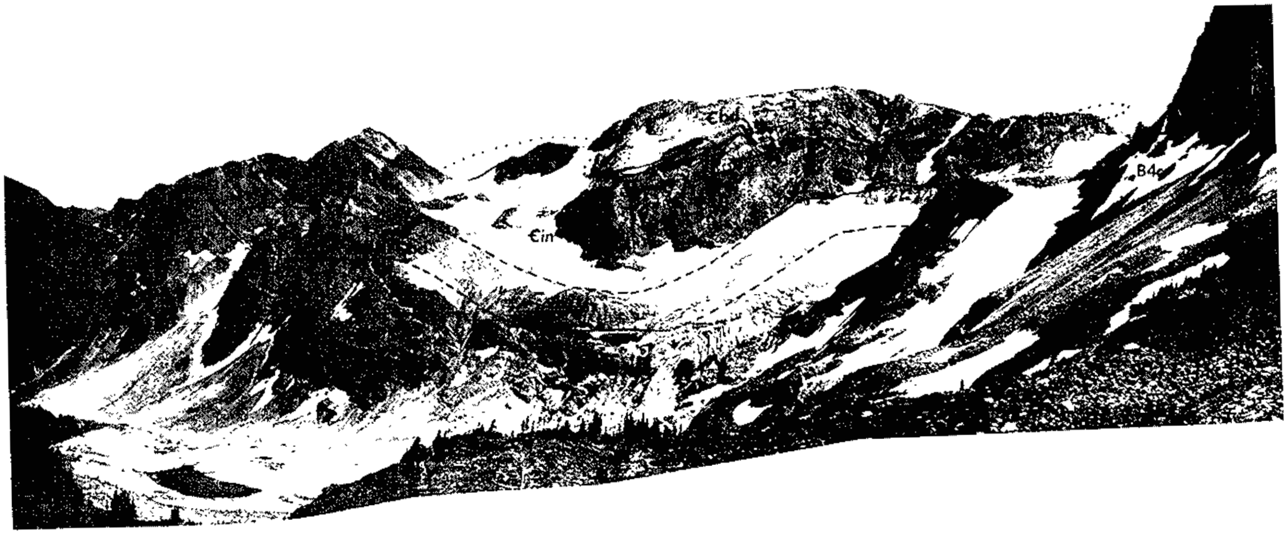
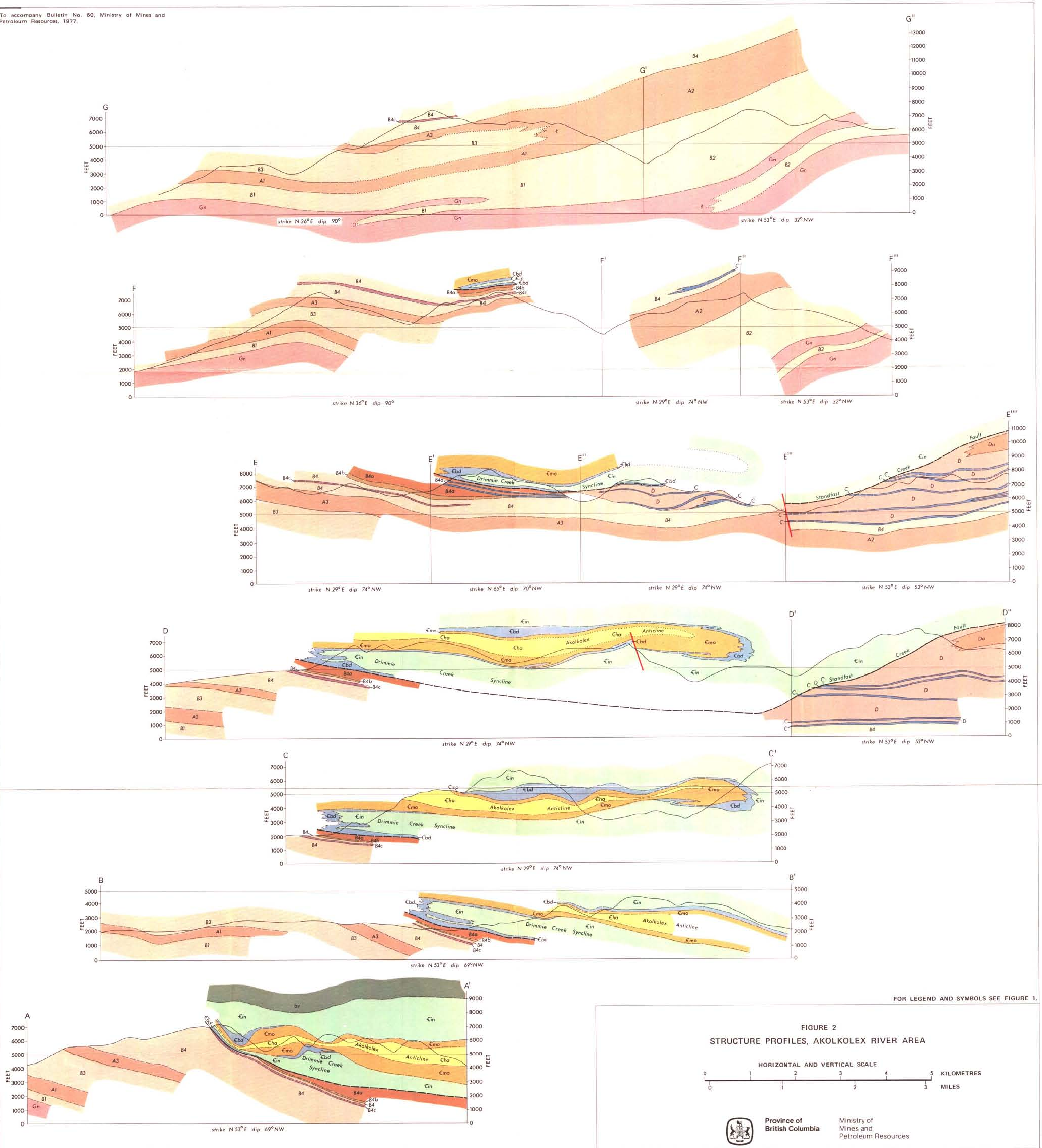


Plate VI. Hinge zone of the Drimmie Creek syncline (viewed southeast, down-plunge); Badshot limestone (€ bd) in fold limbs converges westward at Ghost Peak (extreme right).

To accompany Bulletin No. 60, Ministry of Mines and Petroleum Resources, 1977.



FOR LEGEND AND SYMBOLS SEE FIGURE 1.

FIGURE 2

STRUCTURE PROFILES, AKOLKOLEX RIVER AREA

HORIZONTAL AND VERTICAL SCALE

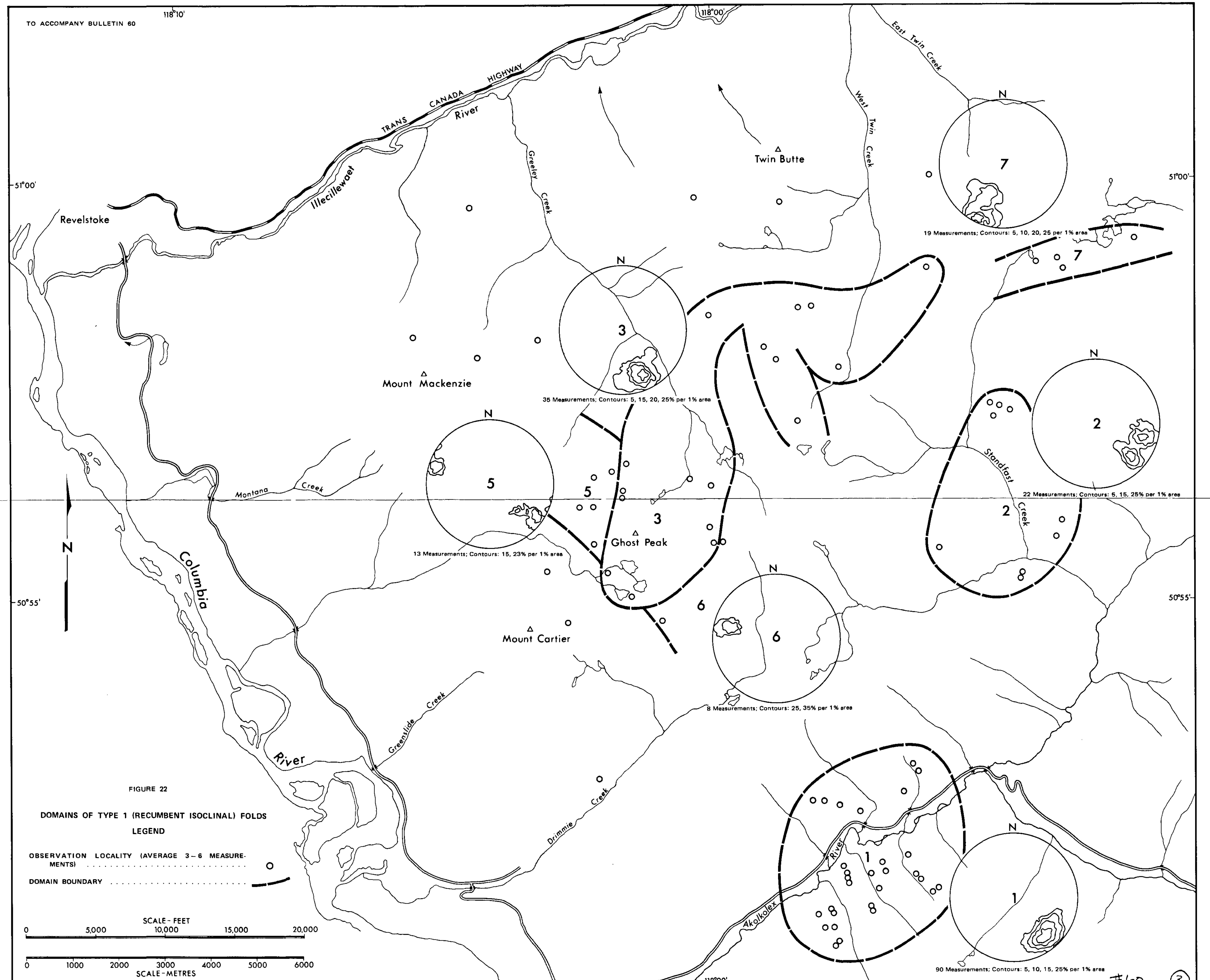
0 1 2 3 4 5 KILOMETRES

0 1 2 3 MILES

Province of British Columbia

Ministry of Mines and Petroleum Resources

#60 (2)


TO ACCOMPANY BULLETIN 60
118°10'
118°00'
51°00'
50°55'
TRANS CANADA HIGHWAY
Illecillewaet River
Revelstoke
Greeley Creek
Twin Butte
West Twin Creek
East Twin Creek
Mount Mackenzie
Montana Creek
Ghost Peak
Mount Cartier
Standfast Creek
Columbia River
Greenslide Creek
Drimmie Creek
Akolkolex River
35 Measurements; Contours: 5, 15, 20, 25% per 1% area
19 Measurements; Contours: 5, 10, 20, 25 per 1% area
22 Measurements; Contours: 5, 15, 25% per 1% area
13 Measurements; Contours: 15, 23% per 1% area
8 Measurements; Contours: 25, 35% per 1% area
90 Measurements; Contours: 5, 10, 15, 25% per 1% area
FIGURE 22
DOMAINS OF TYPE 1 (RECUMBENT ISOCLINAL) FOLDS
LEGEND
OBSERVATION LOCALITY (AVERAGE 3 – 6 MEASUREMENTS)
DOMAIN BOUNDARY
SCALE - FEET
0 5,000 10,000 15,000 20,000
0 1000 2000 3000 4000 5000 6000
SCALE - METRES
#60
3

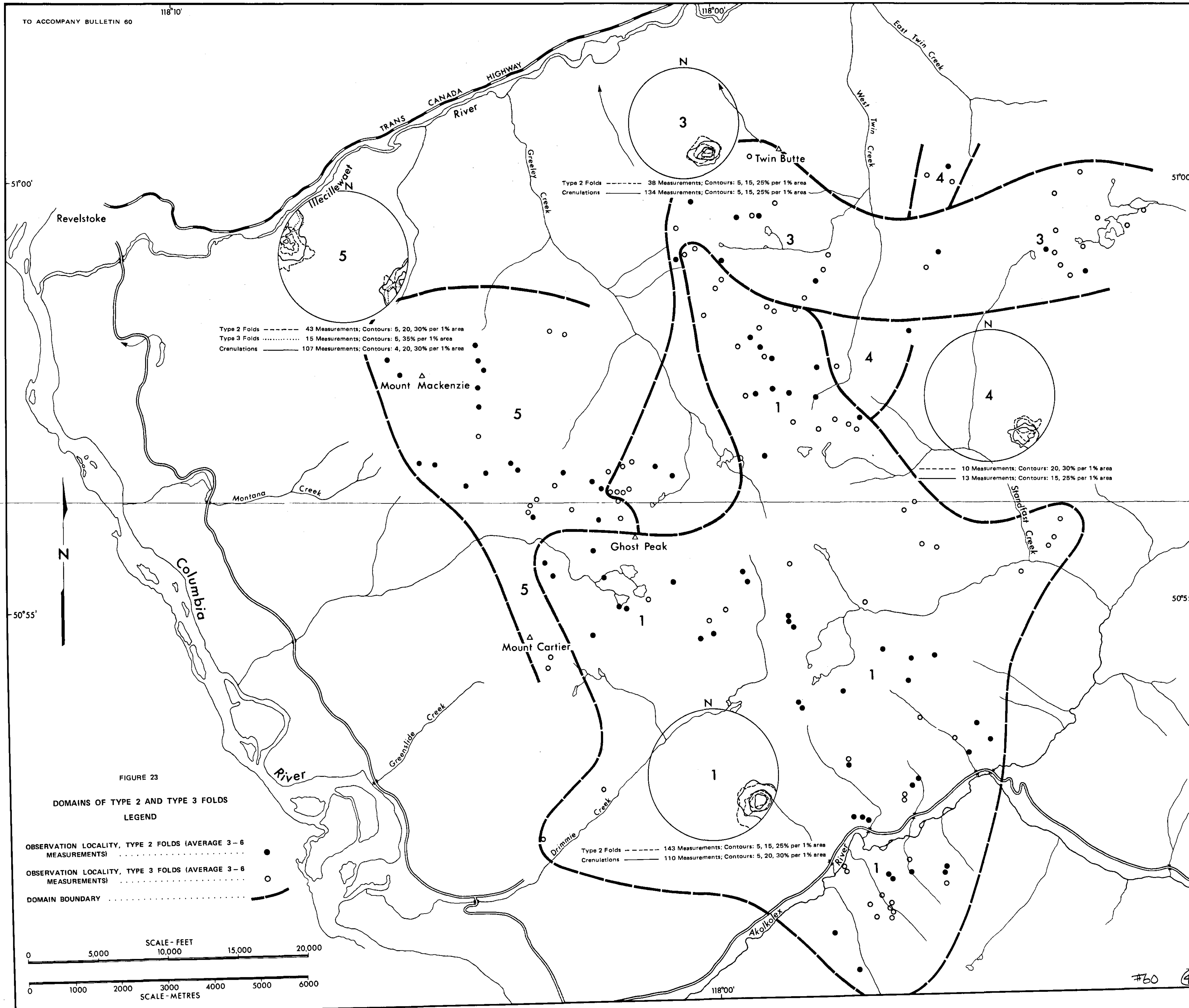
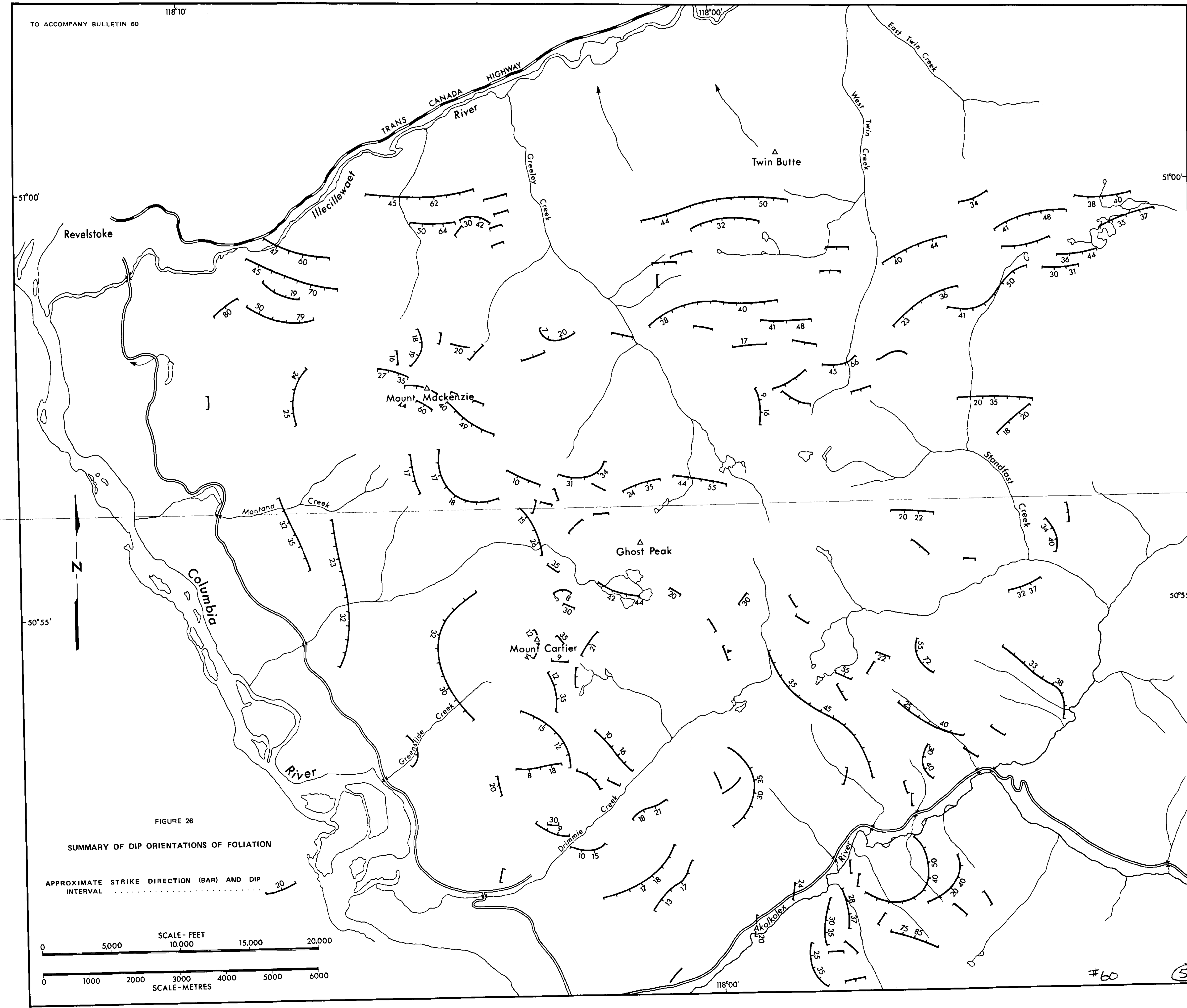


FIGURE 23

DOMAINS OF TYPE 2 AND TYPE 3 FOLDS



TO ACCOMPANY BULLETIN 60
118°10'
118°00'
51°00'
50°55'
Revelstoke
Illecillewaet
River
TRANS CANADA HIGHWAY
Greeley Creek
Twin Butte
West Twin Creek
East Twin Creek
Mount Mackenzie
Montana Creek
Ghost Peak
Mount Cartier
Standfast Creek
Columbia
River
Greenslide Creek
Drimmie Creek
Akolkolex River
N
FIGURE 26
SUMMARY OF DIP ORIENTATIONS OF FOLIATION
APPROXIMATE STRIKE DIRECTION (BAR) AND DIP INTERVAL
SCALE-FEET
0 5,000 10,000 15,000 20,000
0 1000 2000 3000 4000 5000 6000
SCALE-METRES
#60
5

FIGURE 30

GEOLOGICAL PLAN WIGWAM PROPERTY

MODIFIED AFTER COMPANY PLANS (T. MURARO, COMINCO LTD.)

FIGURE 1

GEOLOGICAL MAP OF THE AKOLKOLEX RIVER AREA

GEOLOGY BY R. I. THOMPSON
1969–1970

LEGEND

UPPER STRUCTURAL LEVEL (FORMAL ROCK UNITS)

LOWER PALEOZOIC

LARDEAU GROUP

BROADVIEW FORMATION

- bv — GREY PHYLLITE, ARKOSE, GRIT

INDEX FORMATION

- €in — GREY AND BLACK PHYLLITE AND SLATE, MINOR LIMESTONE AND QUARTZITE
  - €inb — GREY QUARTZITE
  - €ina — GREENSTONE

LOWER MIDDLE CAMBRIAN

BADSHOT FORMATION

- €bd — GREY AND WHITE CRYSTALLINE LIMESTONE

MOHICAN FORMATION

- €mo — GREY AND BROWN PHYLLITE, MICACEOUS QUARTZITE, MINOR LIMESTONE

HAMILL GROUP

- €ha — BROWN, GREY, AND WHITE QUARTZITE, MICACEOUS QUARTZITE, MINOR PHYLLITE

LOWER STRUCTURAL LEVEL (INFORMAL ROCK UNITS)

STRATIGRAPHIC SEQUENCE UNKNOWN

UNIT D

- D — GREY, BROWN, AND BLACK SCHIST, MICACEOUS QUARTZITE, MINOR LIMESTONE AND AMPHIBOLITE
  - Da — WHITE AND TAN MICACEOUS QUARTZITE

UNIT C

- C — GREY CRYSTALLINE LIMESTONE

UNITS B1, B2, B3, B4

- B1,2,3,4 — GREY AND BROWN GARNET–BIOTITE SCHIST, MICACEOUS QUARTZITE, MINOR AMPHIBOLITE

SUBUNITS

- B4a — GREY AND BROWN SCHIST, BLACK PHYLLITE, MINOR LIMESTONE
- LIMESTONE WITH $B4_4$
- B4b — WHITE AND BROWN QUARTZITE
- B4c — AMPHIBOLITE

UNITS A1, A2, A3

- A1,2,3 — GREY, WHITE, AND BROWN QUARTZITE AND MICACEOUS QUARTZITE, MINOR SCHIST AND AMPHIBOLITE

UNIT Gn

- Gn — GREY GRANITOID GNEISS (QUARTZ–FELDSPAR–HORNBLENDE GNEISS)

SYMBOLS

GEOLOGIC CONTACTS

DEFINED, APPROXIMATE, ASSUMED

FAULTS

DEFINED, APPROXIMATE (LOW ANGLE TRUNCATION OF MAP UNITS)

DEFINED, APPROXIMATE (STEEPLY DIPPING)

PLANAR ELEMENTS

SCHISTOSITY, LITHOLOGIC LAYERING — 20

AXIAL PLANE OF FOLD — 15

LINEAR ELEMENTS

AXIAL ORIENTATION OF TYPE 1 (RECUMBENT ISOCLINAL) FOLD — 20

AXIAL ORIENTATION OF TYPE 2 (UPRIGHT MORE–OPEN) FOLD — 28

AXIAL ORIENTATION OF TYPE 3 (CRENULATION) FOLD — 27

MINERAL LINEATION — 36

TRACE OF AXIAL PLANE OF MAJOR TYPE 1 FOLDS

FOSSIL LOCALITY — F2

LINE OF SECTION

PROSPECT

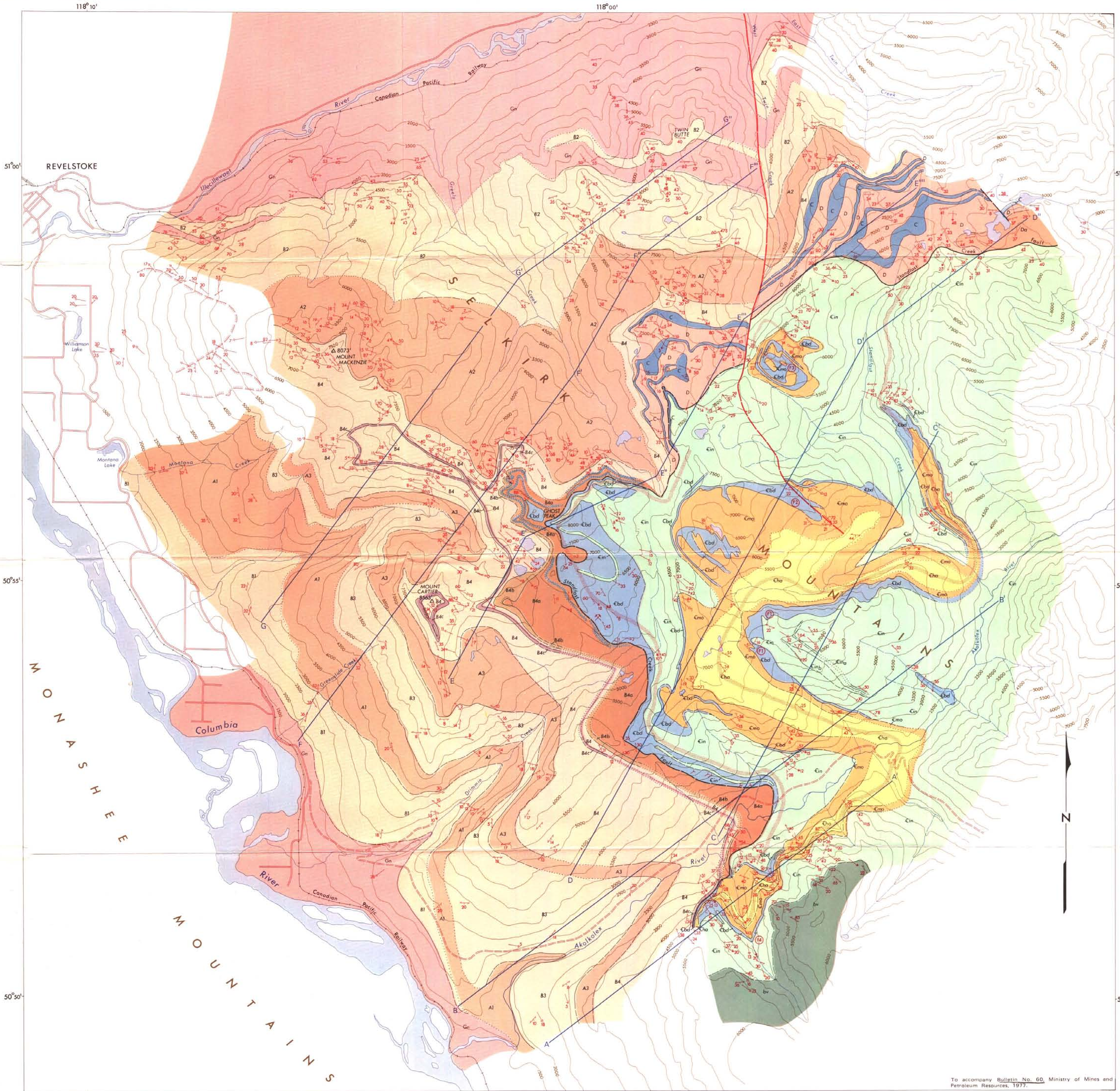
ADIT

ROAD, SIDE ROAD

LANDSLIDE

SCALE-KILOMETRES
0 1 2 3 4 5
0 1 2 3
SCALE-MILES

Province of British Columbia
Ministry of Mines and Petroleum Resources



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