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NOTES ON THE GREENWOOD GEOLOGICAL MAP 1986

Greenwood, B.C.

by James T. Fyles

December 4, 1986

KETTLE RIVER
RESOURCES LTD.

January 20, 1987

K.L. Daughtry, Director
Kettle River Resources Ltd.
Box 795,
Vernon, B.C.

Dear Ken;

In 1981 I agreed to join Kettle River Resources to provide a geological framework for company exploration in the Greenwood area. Although this has taken longer than either of us expected, I have kept at it because new geological features turned up with each new area of exploration interest. During 1986 the work had reached a stage at which the main structural elements could be shown on a 1:50000 scale map which is presented herewith. The notes and diagrams explain the map. They have been written using standard nomenclature and symbols in the expectation that the Geological Survey of Canada or B.C. Ministry people may be encouraged to provide further scientific assistance.

The implications for exploration which we discussed on January 16, 1987 are listed as a series of questions. No doubt you and our colleagues will have other questions and ideas which I hope will lead to other foci for exploration.

Thank you for getting me involved in this interesting project.

Sincerely,

James T. Fyles

cc: G.O.M. Stewart
Noranda Exploration Company Limited

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NOTES ON THE GREENWOOD GEOLOGICAL MAP 1986

INTRODUCTION

This map clarifies the distribution of the rock units defined by previous workers, particularly H.W. Little (1983) and B.N. Church (1985). The general geology is clearly described by Little (p. 4-6) and the current work has produced only a few significant changes. The map symbols describing the units follow those used by Little with a few modifications. His description of the general geology is as follows:

"Metamorphic, sedimentary, and intrusive and extrusive igneous rock units, ranging in age from possible late Proterozoic to Middle Eocene are summarized in the Table of Formations. They can be grouped into seven assemblages, separated by intervals of deformation and/or regional metamorphism. The oldest (?) of these is the granitoid gneiss unit Pml of which part may represent the widespread late Proterozoic-early Paleozoic succession of southeastern British Columbia, but some of these gneissic rocks may be as late as Permian, metamorphosed by granitic intrusions of Jura-Cretaceous age.

The relationship of the granitoid gneisses to the amphibolite unit Pa and the schist unit Pm is not known. These units differ lithologically and are in general more highly metamorphosed than the Attwood Formation and Knob Hill Group. The metamorphism and deformation of map units Pa and Pm is believed to predate the Attwood and Knob Hill; it is, however, possible that units Pa and Pm, though more highly metamorphosed, are different facies of the Knob Hill Group.

The second assemblage comprises the Attwood Formation and the Knob Hill Group, both of which have yielded fossils of Carboniferous or Permian age. It may contain a disrupted ophiolite suite with which some or all of the ultramafic rocks may be associated. This assemblage was deformed and apparently eroded before deposition of Early Mesozoic rocks.

The third assemblage, the Brooklyn Formation, rests unconformably upon the Knob Hill Group. The lower part consists of the sharpstone and Rawhide members, of Middle and possibly Lower, Triassic age. The underlying unconformity is widespread in the Western Cordillera.

The fourth assemblage, map unit uTsv, is limited in extent and includes limestone, shale, and some pyroclastic rocks of Upper Triassic age. It is believed to overlie unconformably the Brooklyn Formation.

The fifth assemblage, the volcanic map unit Jv, is correlated lithologically with the Jurassic Rossland Group to the east. It rests upon other units ranging from pre-Permo-Carboniferous (?) to Upper Triassic.

All these assemblages were affected by the widespread Jura-Cretaceous orogeny during which ultramafic, and Nelson and Valhalla intrusions were emplaced. It is possible that the ultramafic bodies were empleced by a process of cold intrusion.

The sixth assemblage clearly rests unconformably upon Mesozoic and older formations. It consists of the basal Kettle River and the Marron formations of Middle Eocene age. Contemporaneous intrusions include numerous small bodies of syenitic to dioritic composition and plutonic bodies of the Coryell.

The youngest assemblage is of limited extent within the map area. It is an epiclastic breccia (recently defined in the literature as an "olistostrome") resulting from a landslide, it rests upon the Marron Formation and is also of Middle Eocene age."

New data and observations respecting this general geology are the following:

1) Structural studies of the schist unit, Pm, within the present map area confirm Little's observations that these rocks are more highly deformed than the Knob Hill and Attwood assemblages. Rocks of the schist unit have more than one cleavage and an insipient pervasive lineation, structures which are not found in the other assemblages. The Knob Hill Group and Attwood Formations are everywhere in fault contact with the schist unit except on the West Kootenay powerline 3 Km south east of Greenwood, in an area of poor outcrops where the contact is either a fault or an unconformity. Pm is intruded by serpentinite and more significantly by the old diorite which has recently been dated, and probably is Permian.

2) Little's map unit Pa is described by Church (1985 a, 1985 b) as old diorite or the old diorite complex and this terminology is used in these notes and on the map. These rocks, which form bold bluffs and open outcrops, are spectacular, coarse grained diorites crisscrossed by white discontinuous veinlets of feldspar, calcite and epidote. They grade into medium and finegrained varieties of the same rock and into crackled calcareous greenstone. They form an easterly trending belt, associated with serpentinite, extending from west of Boundary Creek near the Skomac Mine to Hardy Mountain.

Old diorite, with or without serpentinite is found at only a few places away from this belt. A cobble of old diorite is reported by Church (1985) in middle Triassic conglomerate of the Brooklyn Formation. A recent (August 1986) potassium argon date on a sample of drill core of old diorite from the Winnepeg Mine gave dates ranging from 214±1 to 258±10 Ma.

The main belt of serpentinite and old diorite dips to the north above the Lind Creek fault and beneath rocks of the Knob Hill Group with which the relationships are conflicting - old diorite intrudes and apparently also grades into greenstone of the Knob Hill. Old diorite forms very irregular masses within and adjacent to the lower part of the Knob Hill group which is a mixed group of volcanic and sedimentary rocks.

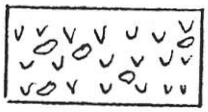
3) The Knob Hill group which occurs only north of the Lind Creek fault consists of a complicated group of grey, buff, and white chert, calcareous greenstone (some of which shows pillow structures), cherty siltstone, grey to black argillite, chert breccia, conglomerate, greenstone conglomerate, and minor limestone. This mixed succession passes upward into a less varied succession of greenstone and chert with minor pyroclastics and limestone extending as far north as Jewel Lake. This whole group dips at low to moderate angles to the north and northeast. Probably it contains several disconformities and has a total estimated thickness of more than 5 km. The only fossils reported from the Knob Hill are from the lowest

part within 200 meters of a tongue of old diorite and greenstone (Little P.12 F7 locality). They are described as carboniferous or Permian. It is suggested here that the old diorite and serpentinite are the subcrust forming the base of the Knob Hill succession. Old diorite intrudes only the lower parts of the Knob Hill group and the older (?) schist unit whereas serpentinite intruded these two units extensively forming sill-like sheets in the schist units. These older serpentinite intrusions were periodically remobilized during deformation as late as the Tertiary in the form of "cold intrusions" as referred to by Little or merely as ductile zones followed by or spread out along faults.

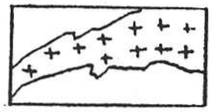
4) The stratigraphic and tectonic relationships between the Knob Hill group and the Attwood formation are still not known. The Attwood formation of grey siltstone, cherty siltstone, greywacke, chert pebble conglomerate with lenses of limestone and minor andesitic volcanics has provided several fossil collections which give a Permian and/or Mississipian age. The Attwood formation overlies probably unconformably the schist unit (Pm) at the head of McCarren Creek and eastward to the head of May Creek in an area of poor outcrops. In the same area and on the west and southwest slopes of Hardy Mountain it is unconformably overlain by the Brooklyn formation. The Knob Hill group and the Attwood formation occur in different fault slices and so far no place has been found at which the normal stratigraphic relationship can be seen. The internal stratigraphy of the Attwood formation has not been worked out.

5) The Brooklyn formation unconformably overlies all the older assemblages. The formation has three main lithological components; chert breccia - the sharpstone conglomerate of Seraphim (1956), limestone, and intrusive and extrusive microdiorite and greenstone. All the components are highly lenticular and change rapidly through lateral and vertical transition zones containing sandstone, siltstone, calcareous sandstone siltstone and conglomerate and various volcaniclastic rocks. The main components are referred to as members, some of which have been named in the past (Brooklyn, Stemwinder, Bluebell, and BC limestones. Rawhide shale, Providence Lake microdiorite, Eholt formation, etc.) The main lithologies are repeated at several levels throughout the Brooklyn succession. Diagrammatic stratigraphic columns based on mapping at scales of 1:12,000 and greater, and representing the rock types and their relationships within a small area are given in the following tables.

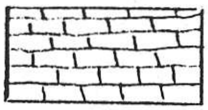
BROOKLYN FORMATION - LEGEND



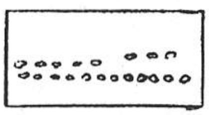
Greenstone and fragmental greenstone - blocky green aphanitic rocks with vague scattered subrounded felspathic or epidote-rich fragments 2 to 10 cm across thought to be submarine pyroclastics and flow breccias grading into volcanic conglomerates and sandstones with calcareous matrix-volcanic equivalent of microdiorite.



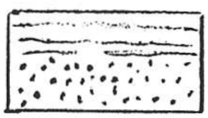
Microdiorite - dark green aphanitic to finegrained intrusive, commonly fractured and pyritic or with a vague brecciated structure on weathered surfaces. Disseminated epidote is common.



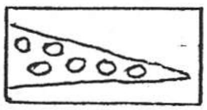
Mainly massive, buff, grey and white crystalline limestone with scattered silicate lenses or white and dark grey color bands. Some dark grey flaggy limestone with beds 5 to 20 cm thick, limestone breccia of various sized blocks is common. Limestone conglomerate with cobbles of limestone in calcareous matrix found locally. Lenses of garnet, pyrocene and epidote skarn are common.



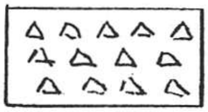
Chert pebble conglomerate-rounded white, buff to grey chert pebbles up to 3 cm across in a limestone matrix - aeolian sandstone of Seraphim (1956).



Transition clastic sediments - including green or brown sandstone, thinbedded or massive grey green brown or maroon siltstone, commonly hornfelsic with disseminated pyrite and pyrohotite, calcareous sandstone and siltstone with beds of limestone or skarn. Rare dark grey siltstone.



Limestone boulder conglomerate and interbedded coarse and fine volcanic clastic sediments. Found at 2 localities on Highway 3 near the head of July Creek, northern locality maroon colored matrix of sandstone and chert chip conglomerate. Southerly one near Athelstan road has green sandstone matrix.



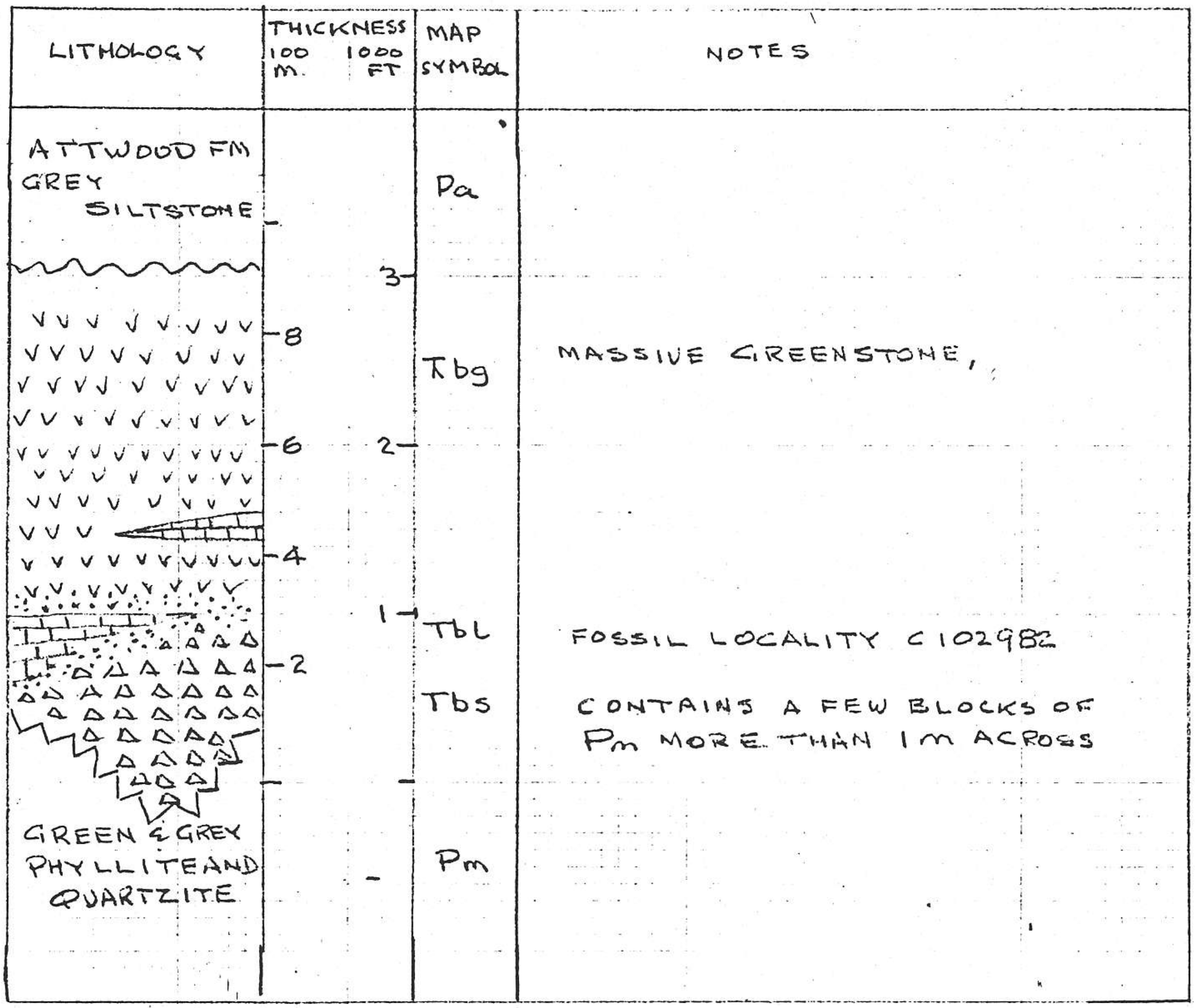
Sharpstone conglomerate-brown weathering, grey, buff, or greenish chert breccia, angular to subangular fragments mostly less than 4 cm across and rarely up to 2 m across of buff grey white and maroon chert, white and purple quartz, greenstone, limestone, chlorite schist, quartz biotite gneiss and other locally derived rock fragments.

Unconformity

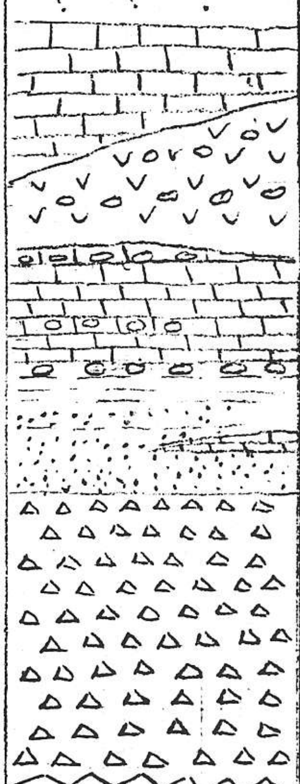
SULPHIDE ZONES

Fault

COLUMN ①
BROOKLYN FORMATION - WEST SUMMIT OF
MT ATTWOOD

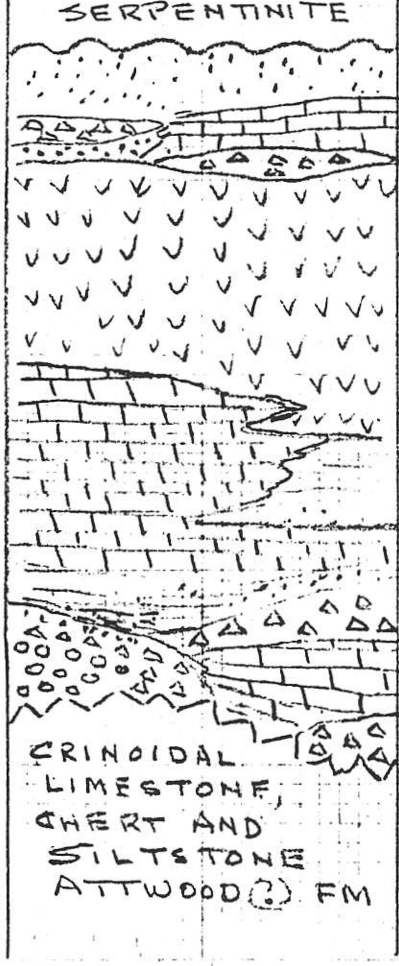


COLUMN (2)
BROOKLYN FORMATION - ABOVE & BELOW
CPR WEST OF GRANBY RIVER SOUTH OF
LOWER BROWN CREEK



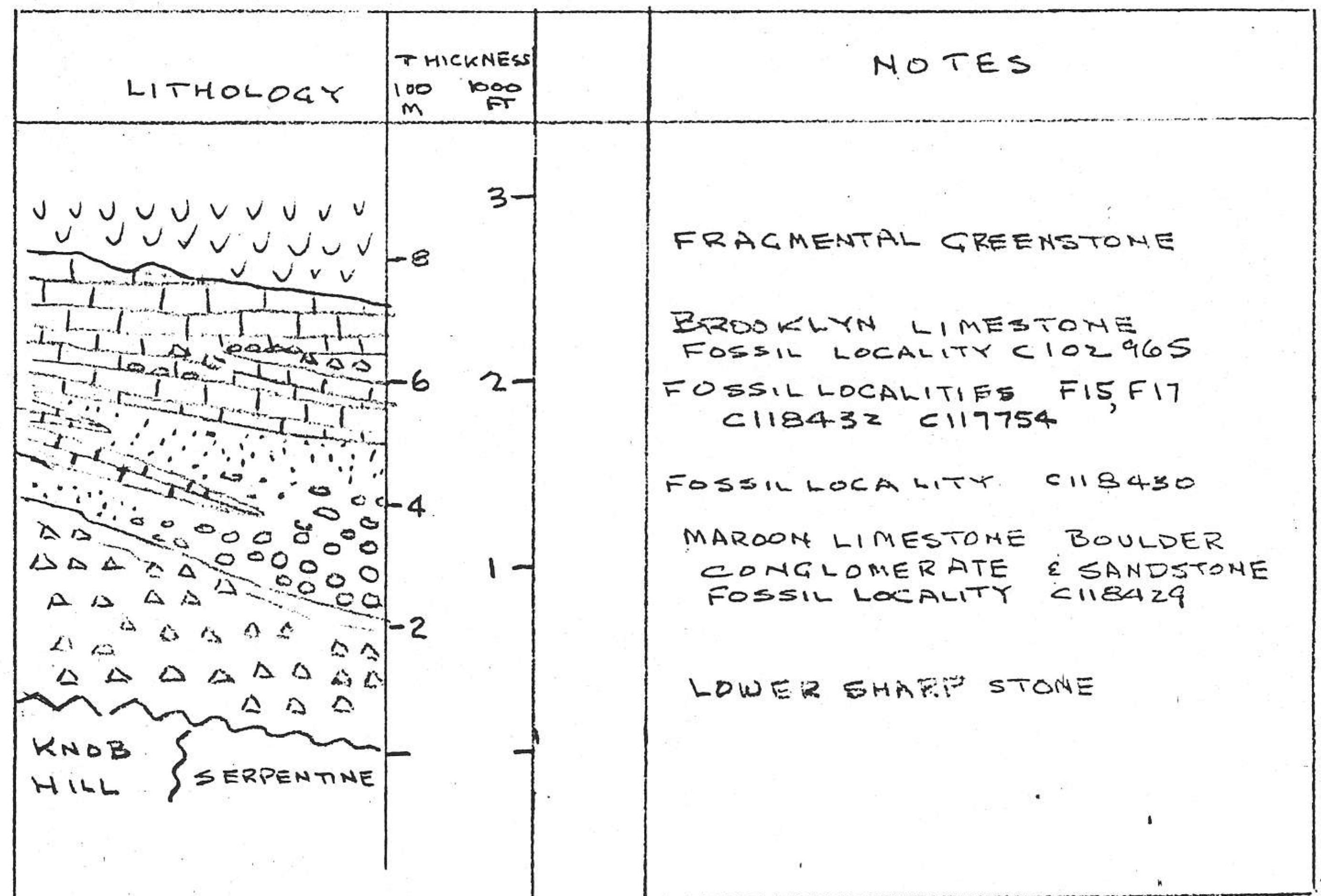
LITHOLOGY	THICKNESS 100 m	1000 FT	MAP SYMBOL	NOTES
GRANBY RIVER ? ? ?	12	4		
			Tbl	
	10			FRAGMENTAL GREENSTONE
		3	Tbg	
	8		Tbl	FLAGGY GREY LIMESTONE WITH FEW BEDS ROUNDSTONE COBBLE CONGLOMERATE
	6	2	Tbs	GREEN CALCAREOUS SANDSTONE AND GREEN HORNFELSIC SILTSTONE GRANITE & SYENITE DYKES
	4			
		1	Tbs	MASSIVE WITH FEW LIMESTONE COBBLES NEAR TOP
	2			
KNOB HILL CHERT				

COLUMN (3)
BROOKLYN FORMATION
HARDY MOUNTAIN WESTERN SLOPE TO EAST OF CROOK LAKE

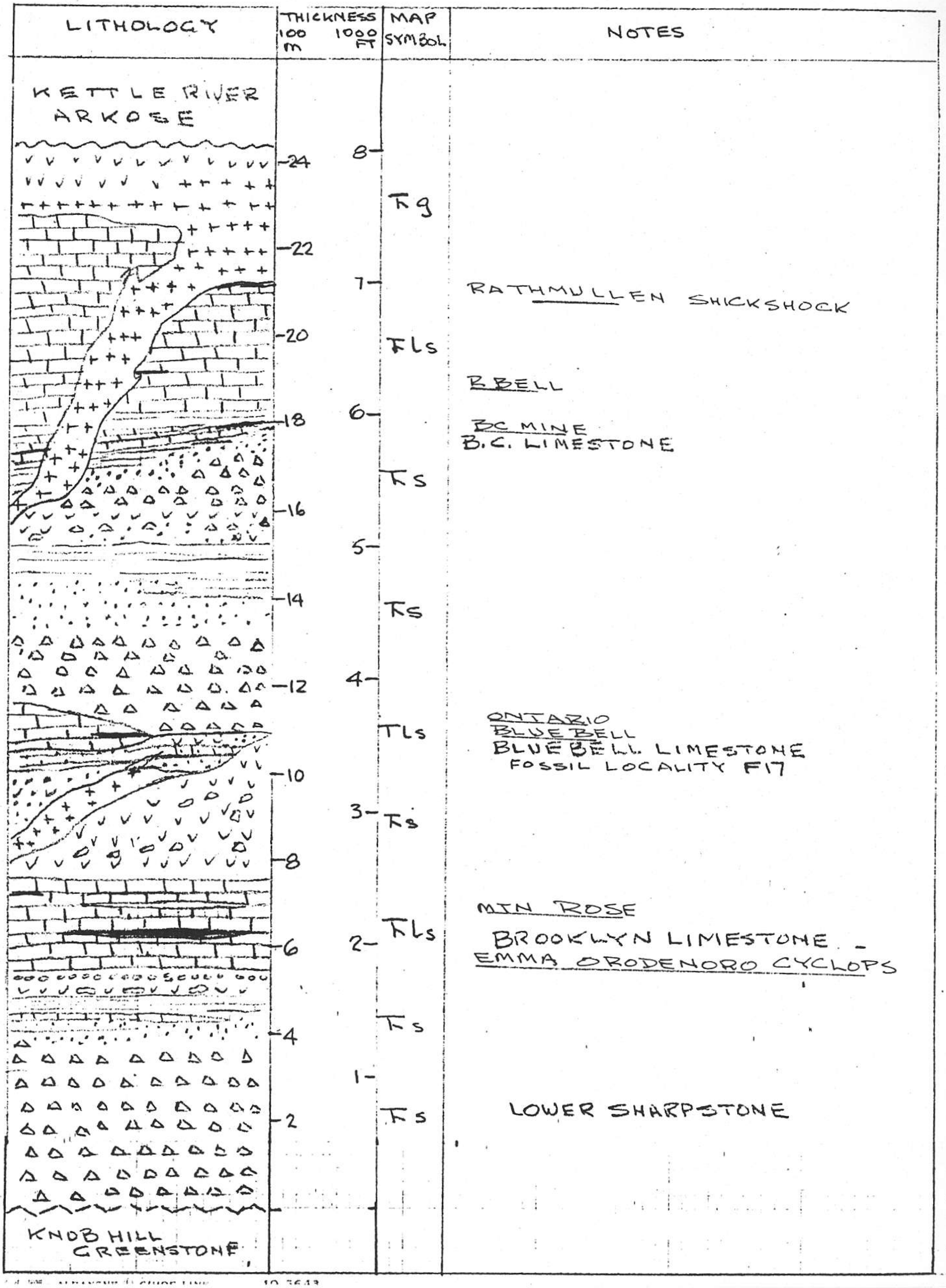


LITHOLOGY	THICKNESS 100 m	THICKNESS 1000 FT	MAP SYMBOL	NOTES
SERPENTINITE	12	4	sP	
	10		TRbs	
	8	3	TRbg	FRAGMENTAL GREENSTONE
	6	2	TRbl	SPHALERITE GALENA NE OF CROOK L. GREEN SANDSTONE, CHERTY SANDSTONE INTERFINGERS WITH LIMESTONE
	4	1		
	2		TRbs	EAGLE MTN GREEN LIMESTONE BOULDER CONGLOMERATE UNDER LOWER SHARPSTONE
CRINOIDAL LIMESTONE, CHERT AND SILTSTONE ATTWOOD(?) FM			Pa	FOSSIL LOCALITY C103914 C103915

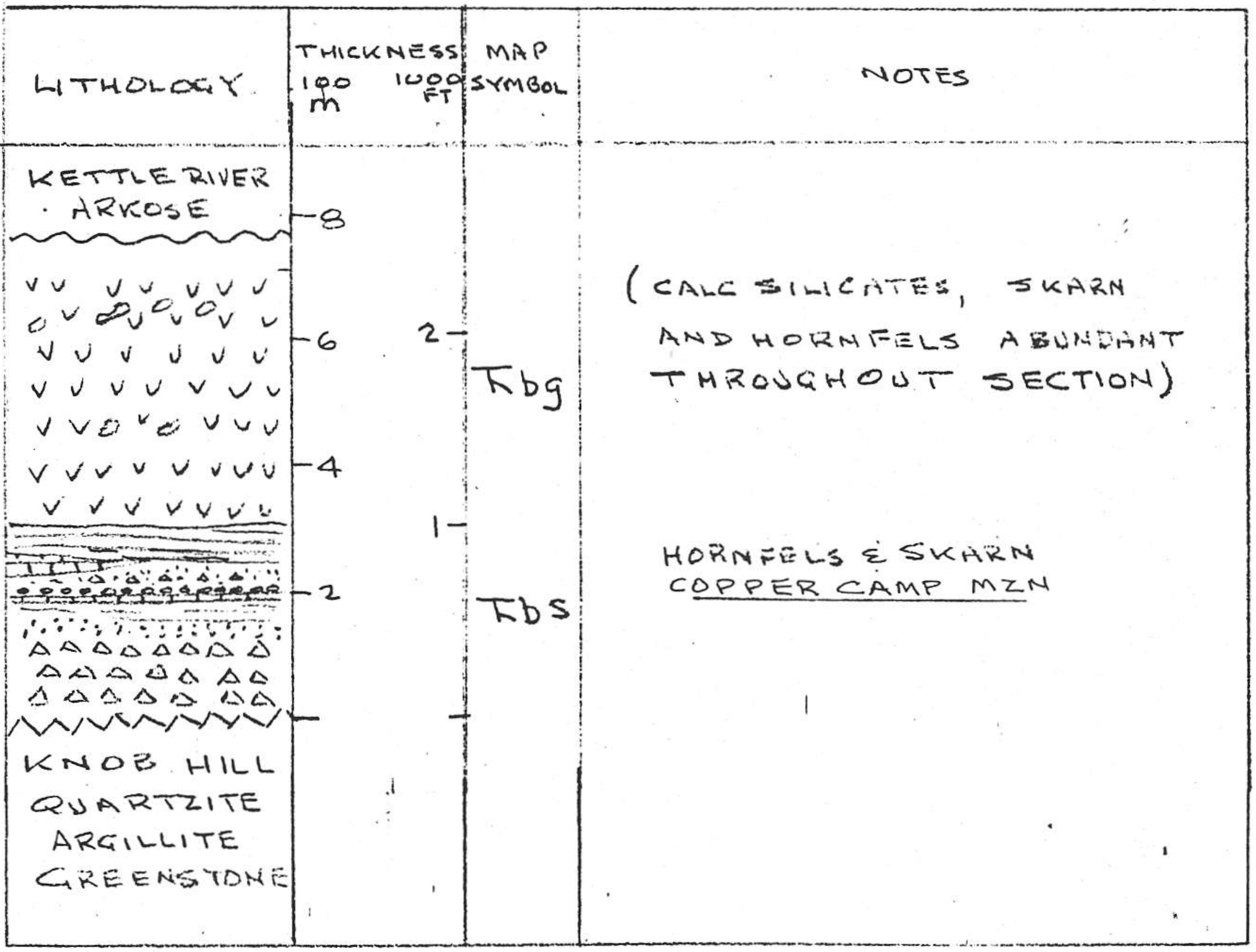
COLUMN (4)
BROOKLYN FORMATION
SECTION ACROSS HIGHWAY 3 NEAR TURNOFF TO PHOENIX



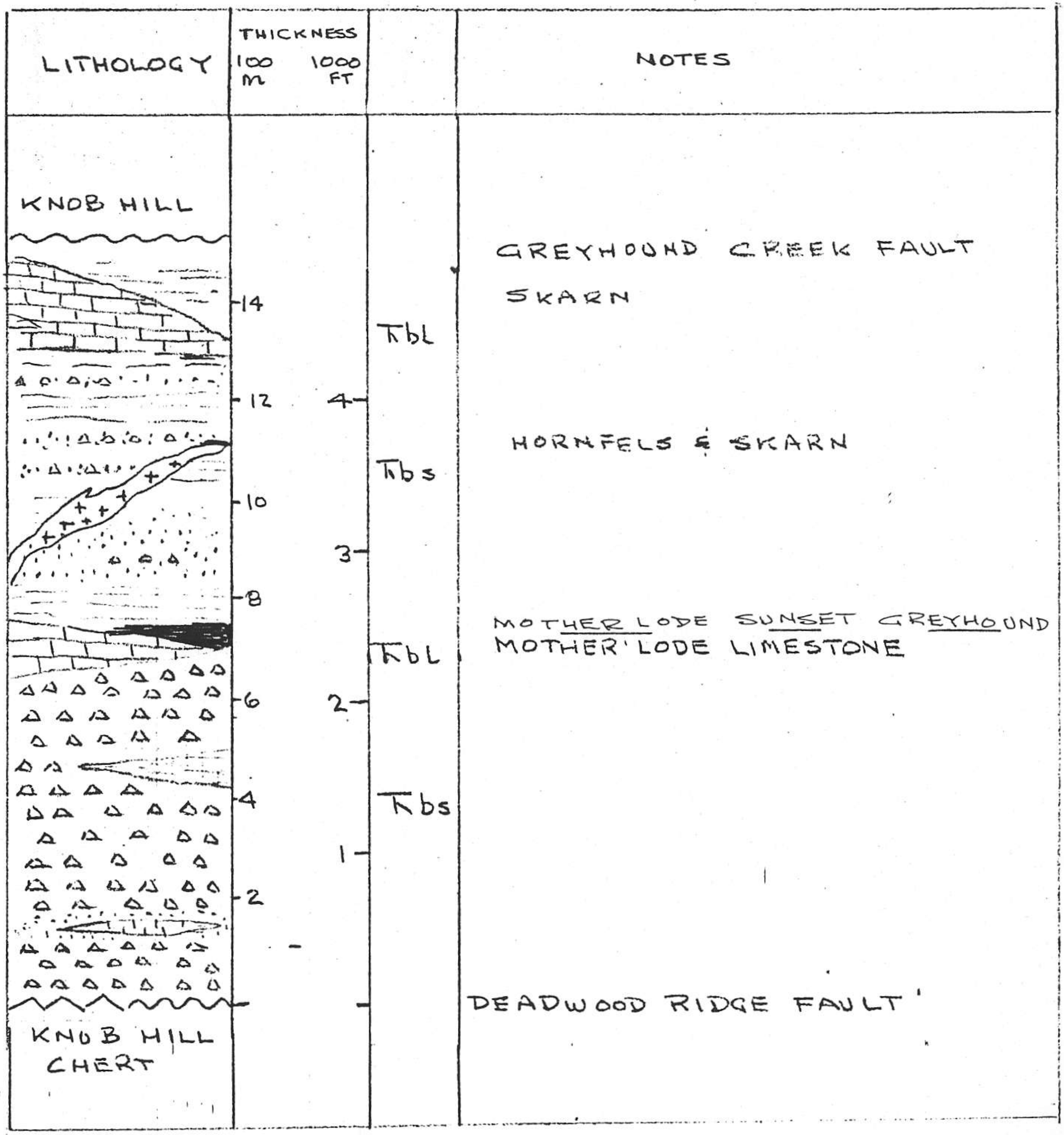
COLUMN (5)
BROOKLYN FORMATION   SUMMIT CAMP
EMMA MINE AREA - RATHMULLEN CREEK



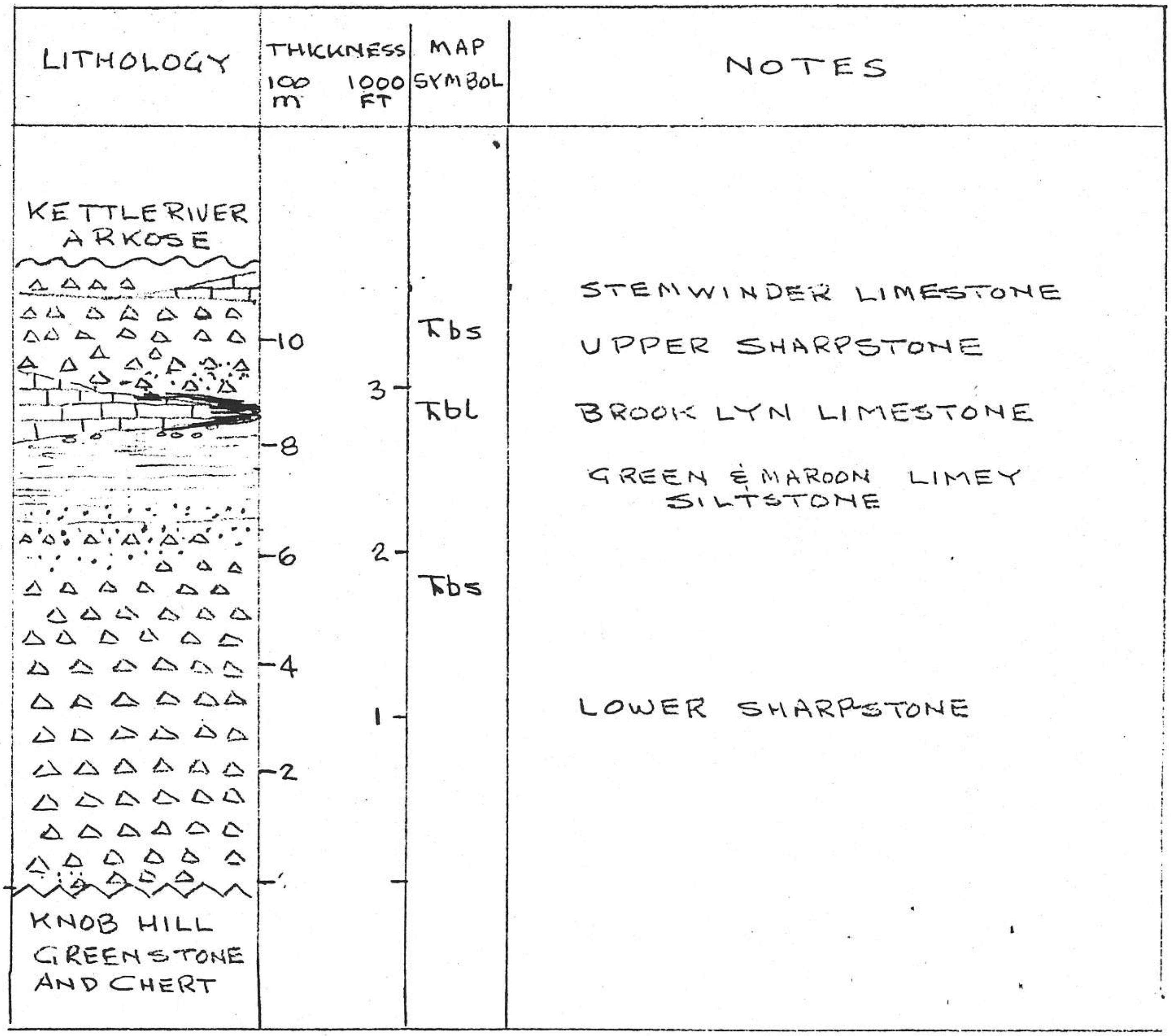
COLUMN ⑥
BROOKLYN FORMATION
BC HYDRO POWERLINE - DEADWOOD RIDGE



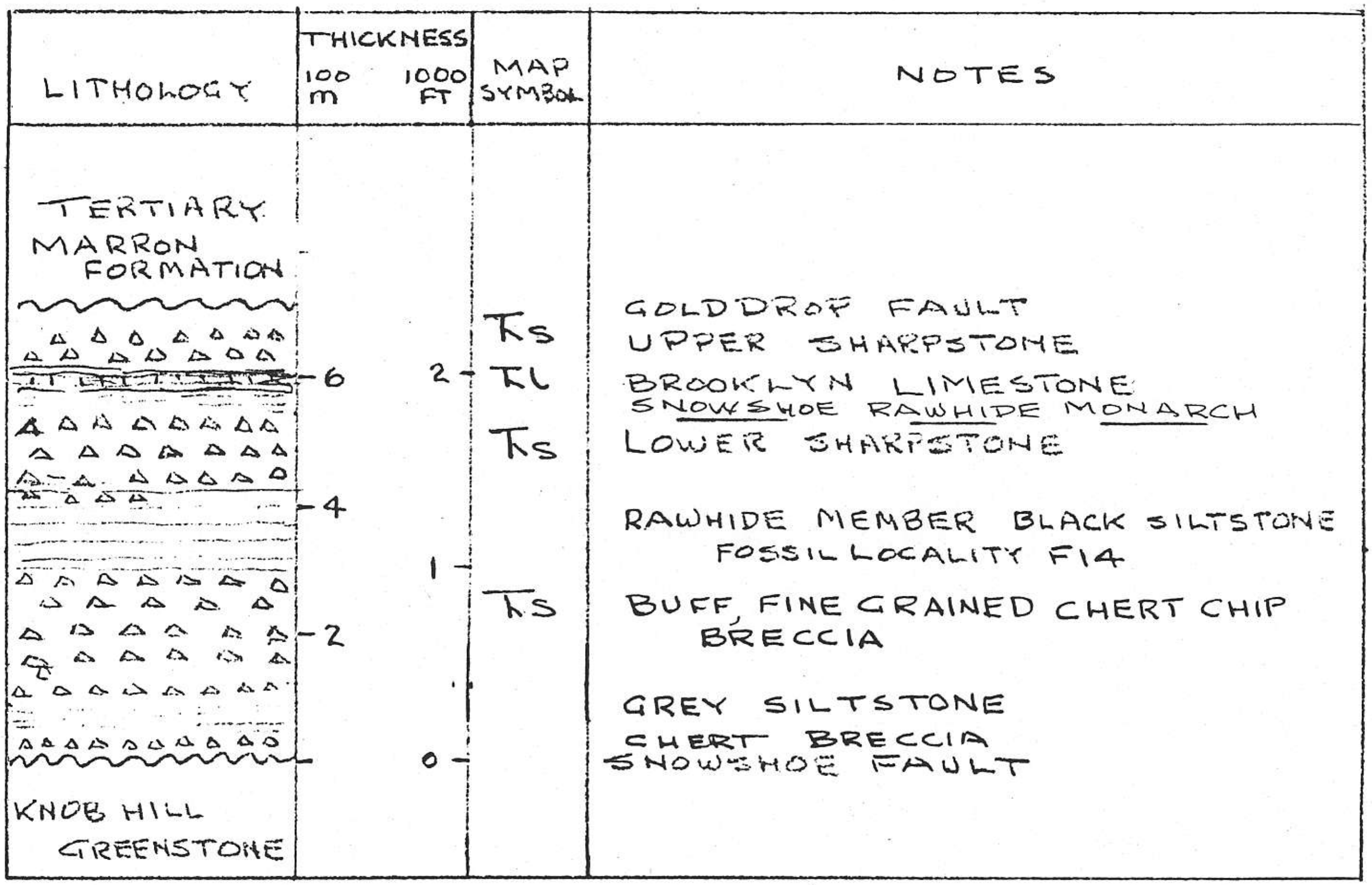
COLUMN (7)
BROOKLYN FORMATION
MOTHERLODE MINE AREA - DEADWOOD RIDGE



COLUMN (8)
BROOKLYN FORMATION
PHOENIX PIT AREA



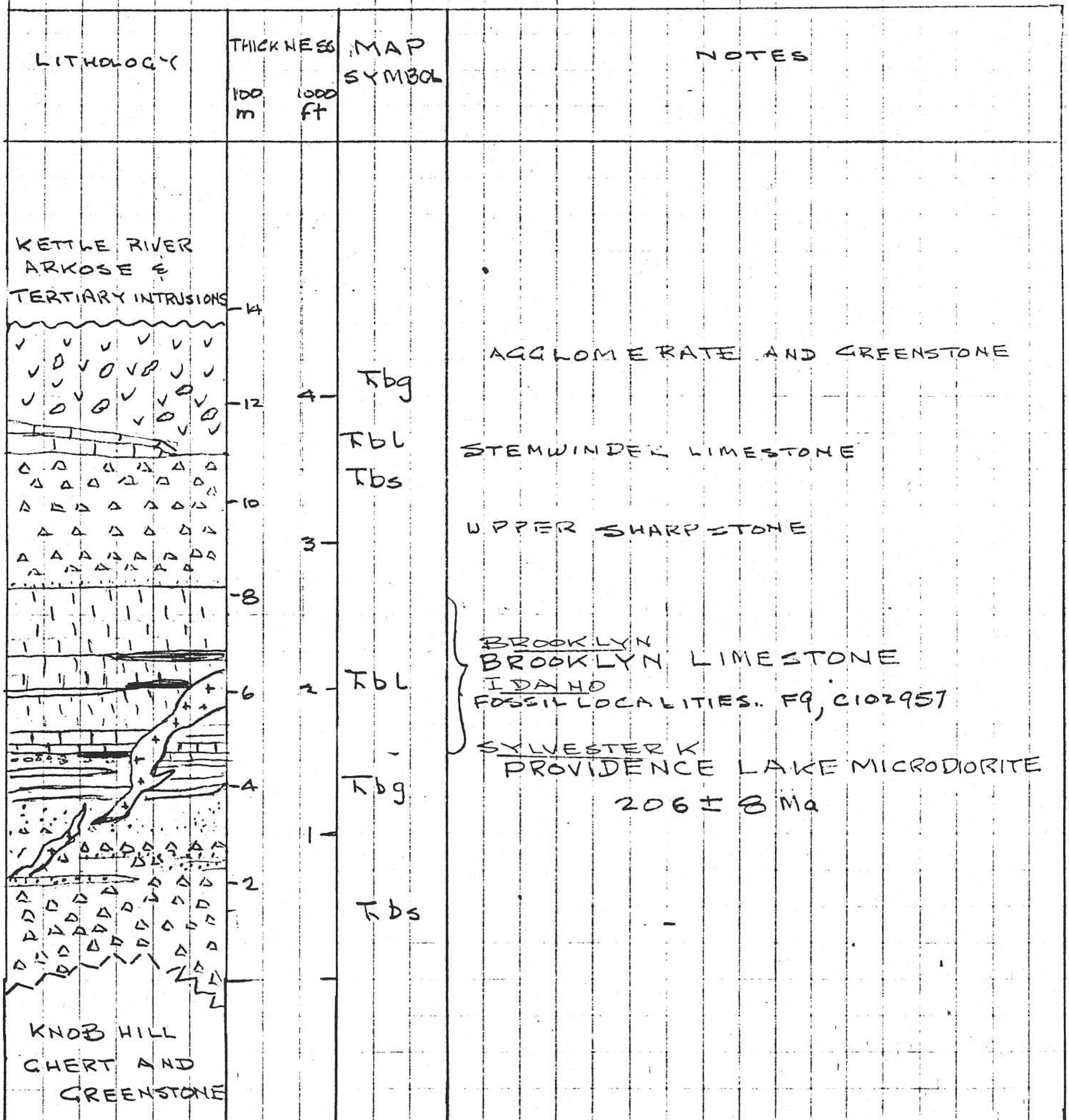
COLUMN (9)
BROOKLYN FORMATION
SNOWSHOE, RAWHIDE AND MONARCH MINE AREA



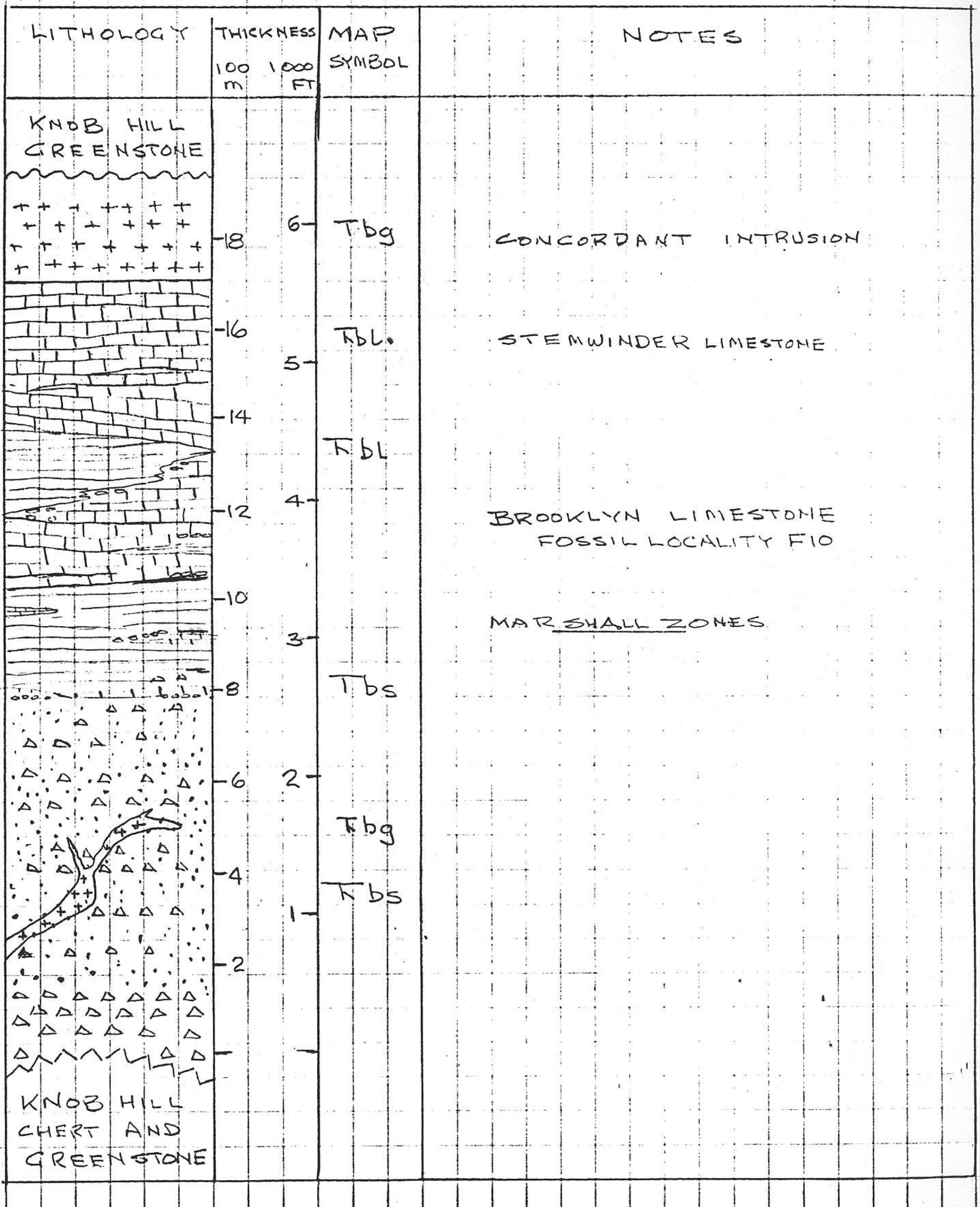
COLUMN (10)

BROOKLYN FORMATION

MONTEZUMA RIDGE NORTH OF PHOENIX



COLUMN (11)
BROOKLYN FORMATION NORTH OF PROVIDENCE LAKE



Geological integration between the sections shows the following:

a) The chert breccia is a locally derived fanglomerate, spread widely in some areas and more restricted in others. It is repeated at intervals throughout the section and in some places the higher fans coalesce with the basal fan. They represent pulses of high energy sedimentation which subsided to allow in filling of sandstone siltstone, tuffaceous siltstone and in distal parts of the basin the formation of limestone probably as reefs.

b) Recent conodont collections (Orchard M.J. conodont file June 1986) give a middle Triassic (Ladinian) age for limestone members at various levels in the Brooklyn succession. Many of the best collections of conodonts, as well as other fossils, have been made along and close to Highway 3 from Spencer where July Creek crosses the International Border northward to the head of Fisherman Creek near the Oro Denoro Mine. The limestones vary in iithology and include dark grey flaggy argillaceous limestone, massive grey to white limestone and heterogeneous limestone breccias and they are interbedded with different rock types at each locality. The present map shows that these localities occur in different fault slices which may have been together or at more widely separated places at the time of deposition. These variations reflect the complexity and local characteristics of the Brooklyn sedimentation. One anomaly in the fossil collections is the upper Triassic coral (Thecosmelia Suttonensis, Little's Locality 15) collected from a limestone equivalent to or stratigraphically beneath limestone which has yielded middle Triassic conodonts. Because of this anomaly Little (1983 P.18) defined a separate map unit (uTsv) but this is currently mapped as part of the Brooklyn.

A spectacular maroon conglomerate (puddingstone of Granby geologists) exposed in rock cuts on Highway 3 south of the Pheonix road junction lies disconformably above the basal sharpstone (see Column 4) and grades laterally northward and upward into maroon and green sandstone and siltstone limey sandstone and siltstone and these rocks interfinger with limestone and limestone breccia from which several of the fossil collections have been made. The maroon conglomerate is a local facies of the basal sharpstone so far found only at this locality. The cobbles are derived from a probably Permian limestone exposed on the Highway, 6 km to the south in another fault slice (cf fossil collections C118429 and C103915, C103914). In that area coarse limestone cobble conglomerate with a green matrix passes laterally into the basal sharpstone which lies directly on rocks referred to as the Attwood formation containing the probably Permian limestone (see Column 3).

The maroon conglomerates and associated rocks near the Phoenix road junction are referred to by Church (1975 P.4, 1985 P.10) as the Eholt formation of dominantly volcanic

GREENWOOD AGE TABLE

Age	Period	Series	Stage	Dated rocks
110				
118				
120				
130	CRETACEOUS			
140				
141				LION CR STOCK 143±5
150	JURASSIC			
160				
170				
176				
180				
190				
195				
200	TRIASSIC	UPPER (LATE)	RHAETIAN	
			NORIAN	PROVIDENCE L. MICRODIORITE 206±8
210			CARNIAN	
		MIDDLE	LADINIAN	OLD DIORITE 214±7 BROOKLYN LS
220			ANISIAN	
		LOWER		
230	PERMIAN	UPPER		
240				
250				
251		LOWER		OLD DIORITE 258±10
260				
270				
280				KNOBHILL, ATTWOOD
290	CARBONIFEROUS			
300				
310				
320				

origin. They contain many diagnostic sedimentary features but may well be waterlain sediments of original pyroclastic deriviation. The whole section is overlain by fragmental greenstone along a contact just east of Highway 3 which turncates the underlying conglomerate and limestone members. This contact is considered to be a disconformity (see Column 4) because no field evidence for faulting along it has been established.

c) The Providence Lake microdiorite dated by Church (1985 P.18) at 206±8 Ma (Upper Triassic) forms very irregular dykes in the Brooklyn formation of the Phoenix area. Very similar intrusions of microdiorite occur at many places in and close to the Brooklyn formation. In the B.C. Mine area southeast of Wilgress Lake they grade into or are otherwise closely associated with volcanic breccia and probably extrusive greanstone exposed extensively to the south and east. In this area the greenstones lie disconformably above calcareous members of the Brooklyn formation containing Ladinian conodonts. Similar greenstone to the south along July Creek contains conformable interbedded lenses of limestone comtaining conodonts, referred to as Triassic (Locality C118419). Thus Brooklyn vulcanism may have been initiated as early as middle or upper Triassic and continued possibly into the Jurassic. These volcanic rocks are mapped and described by Little as Jurassic (Jv) but they are shown on the present map as the volcanic member of the Brooklyn formation.

d) Subsequent folding and faulting makes it difficult to generalize about the shape and paleaogeology of the basin in which the Brooklyn formation was deposited. The simplest restoration of the major Tertiary faults suggests that in the northern part of the Greenwood area now represented by the sharpstone-sandstone-siltstone-limestone successions in the MotherLode, Phoenix, Oro Denoro and B.C. Mine areas, was dominantly sedimentary with minor pyroclastic components and subvolcanic feeders. To the east, west and probably to the north, the basin was filled mainly by volcanic rocks. The margins of the basin have not been identified but the restricted distribution of individual sedimentary members suggests complex pre Brooklyn topography possibly of toaphrogenic origin with coalescing fans deposited in relatively small basins with submarine vulcanism offshore.

6) Little's sixth and the youngest assemblages are the Tertiary rocks of the Penticton group which he describes in detail (pp 25-30) and which have been also extensively studied by Church. Only the contact relation- ships of these rocks with the older formation have been studied in this field review. All the contacts between stratiform Tertiary rocks and the older formations are faults. Dykes and sills of pulaskite and other feldspar porphyrys are common in the contact zones and tend to obscure the faulting. Details of the faulting are discussed in the following pages.

STRUCTUAL FRAMEWORK

INTRODUCTION

The regional distribution of the rock units in the Greenwood area is controlled by faults. The pre-Tertiary rocks are on the northern flank of a pre-Cambian gneiss complex exposed in northern Washington and in the Grand Forks area to the east. They are contained in a series of north dipping, discontinuous fault slices which, for discripture purposes, I have numbered upward from 3 along the International Border (anticipating that a couple more may be found south of the border) to 7 in the Greenwood-Phoenix- Eholt part of the area. The bounding faults, many of which follow or are followed by serpentinite are probably pre-Tertiary in origin but are highly modified and form an integral part of the Tertiary extensional fault regime.

Tertiary stratiform rocks in the Greenwood area are contained in fault bounded blocks which form the northern extensions of the Toroda Creek and Republic grabens identified in northern Washington. The Tertiary strata dip in general to the east. The pattern of the bounding faults, though complex in detail, consists of low east dipping faults offset by low west and north dipping faulte both of which are offset by steeply dipping faults trending 020 degrees to 035 degrees which form the graben structures mapped by previous workers. Map patterns of the Tertiary rocks are complicated by irregular intrusions only the largest of which are shown on the map.

Identification of faults and the major fault slices has been one of the main components of this field review. Some of the faults have already been named by Little and by Church. In this review faults have been identified "on the ground " by tracing contacts, identifying fault features, mapping major sheets of serpentinite and searching for pods of serpentinite along fault contacts, and by mapping geology on both sides of contacts to determine transgrassion. Faults shown on previous maps have been evaluated on the ground, and although it is difficult to prove that a feature is not a fault, many have been dropped from the present map. The faults shown are well documented but it is certain that many more exist which have not been identified.

The following descriptions are based on data collected between 1982 and 1986 and extrapotations beyond using the maps of Little and Preto (1970). To completely document the structure requires more data long the Granby River valley in the valley of May Creek and along the International border in the vicinity of Mt. McLaren and to the northwest of Greenwood.

FAULT SLICE NO. 3

Slice No. 3 contains, immediately north of the International Boundary, black phyllites, grey argillite and siltstone, sandstones and pebble conglomerates (Little P.21) lying structurally above massive greenstone and amphibolite. These rocks are intruded by an elongate stock of quartz feldspar porphyry bounded on the north by the serpentinite of the Central mining camp (No.7-City of Paris, etc.). The northern margin of the serpentinite is a fault exposed in the No. 7 Mine dipping at moderate angles to the north beneath the rocks of the schist unit, Pm. The whole zone containing the mines of the Central Camp is one of strong shearing along a layer of serpentinite into which was intruded the quartz feldspar porphyry which itself was subsequently sheared. The No. 3 slice is truncated on the west by west dipping Tertiary block faults and has not been identified beyond them because of the Tertiary cover in the vicinity of Midway.

I have studied only part of the No. 3 fault slice and draw the following conclusions.

(1) The quartz feldspar porphyry, host to some of the gold mineralization, probably intrudes the serpentine and is probably part of the Scatter Creek intrusions of Parker and Calkins (1964 P.51)(a sample submitted to Church for a zircon age determination is not yet analysed).

(2) The black phyllite, argillite etc. probably belongs to the late Paleozoic Attwood formation and judging from relationships of Attwood formation to Brooklyn greenstone in fault slice 5 to the northeast, is complexly folded and possibly faulted against the greenstone forming the central part of slice No. 3.

SLICE NO. 4

Fault slice No. 4 contains mostly metamorphic rocks (Pm) (grey and green phyllites and schists, quartzites minor marble and dioritic gneisses) and lenses of serpentinite. These rocks are highly deformed. Primary structures are obscured by pervasive schistosity, recrystallization of cherts to quartzites, gnessic banding, secondary quartz lenses, and flaser structuras in the marble crenulations. Lineations consisting of very fine crenulations and trains of mineral grains in the phyllites and schists and of rodding in the quartzites is found in essentially every outcrop. These lineations generally have a low to moderate plunge to the east or to the northwest and in a faw places where minor folds are exposed (usually in limestones) they are parallel to the fold axes. Structural studies of these features on the well exposed western ridge of Mt. Attwood failed to define map scale folds, but further studies are needed. Foliations and lineations, however, are folded on axis plunging north to north 35 degrees east around open folds with steeply dipping axial planes. These late folds ara present in other fault slices. Thay have a wide range in attitude suggesting that they have been dislocated by late (Tertiary (?)) shearing.

Fault slice No. 4 contains lenses of sharpstone and limestone which are correlated with the Brooklyn formation. These rocks outcrop near Boundary Falls, on the CPR track to the west, and near the Ruby Mine. They dip to the north and east at moderate angles and consist mainly of chert breccia, small lenses of limestone and of greenstone. Although the area is broken by intrusions of diorite, the sharpstone appears to lie unconformably on schists and gneisses (Pm?) and is truncated on the north by a northeast dipping fault striking more or less parallel to the foliation in the schist unit. This fault has not been traced beyond the area of outcrops of Brooklyn formation.

The No. 4 fault slice is truncated on the west by the Greyhound Creek and related faults on the eastern side of the Toroda Creek graben. It probably continues east to the Granby River fault including map Unit V of Preto (1970) immediately west of Grand Forks.

FAULT SLICE NO.5

The 5th fault slice forms a wedge tapering to the west between the Mt. Attwood and Mt. Wright faults which join on the western ridge of Mt. Attwood. The slice contains mainly massive fragmental greenstone of the Brooklyn formation with lenses of Brooklyn sharpstone conglomerate and limestone. Unconformably beneath the Brooklyn are lenses of quartzite and schist (Pm) on the ridge west of Mt. Attwood and of the Attwood formation in the valley of Gibbs Creek.

On Mt. Attwood the base and the lower members of the Brooklyn formation define an overturned syncline with axis plunging north at 35 degrees and axial plane striking east and dipping to the north. The fold is well defined by the members, by primary sedimentary features on both limbs and by a simple axial plane cleavage on the overturned limb. Minor folds in the schist unit (Pm) just below the unconformity reflect the geometry of the larger fold but on average plunge 20 degrees west of north at about 30 degrees. The fold which is truncated by the Mt. Attwood fault has not been identified in the greenstones to the east.

Another map scale fold is outlined by bedding and cleavage in the Attwood formation on the ridge north of Gibbs Creek. Dark grey to black siltstone cherty siltstone and minor limestone transected by a planar cleavage striking 130 degrees and dipping 20 degrees to the southwest define an overturned anticline with a very low plunge to the northwest. The Attwood formation at this locality is in sharp contact with Brooklyn greenstone on the northern overturned limb of the anticline. This contact which is locally well defined and dips to the south is mapped as the May Creek thrust fault by Little (1983 P.30). These relationships are shown in Figure 4.

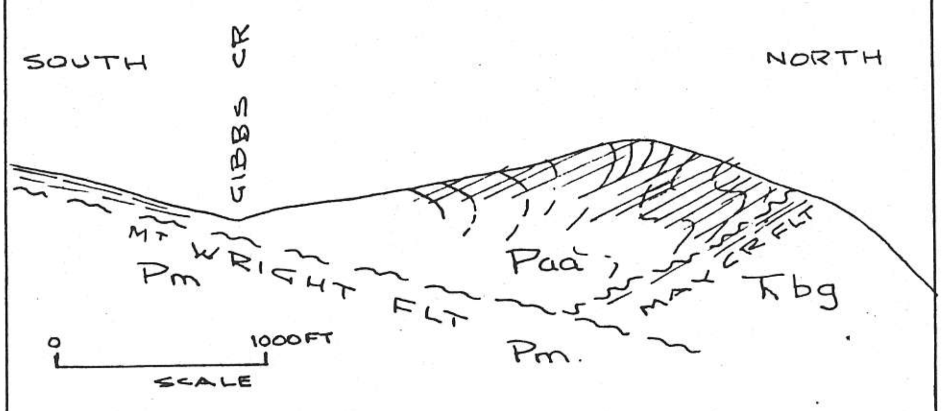


FIGURE 4. CROSS SECTION SHOWING STRUCTURE OF THE ATTWOOD FM ON THE RIDGE NORTH OF GIBBS CR. Pm-SCHIST UNIT Paa ATTWOOD ARGILITE ₜbg - BROOKLYN GREENSTONE

FAULT SLICE NO.6

This fault slice contains the Attwood formation in the area from the Skomac Mine east to July Creek, and the Brooklyn formation above Permian (?) probably Attwood formation along July Creek and on Hardy Mountain. The rocks mainly dip to the north and northeast. Cleavage is common in the grey siltstones of the Attwood formation primary structures such as graded bedding and cut and fill structures at a few places such as on the Potter Creek road southeast of Greenwood indicate the beds are overturned. Only two map scale folds have been defined in the Attwood formation. Near the Skomac Mine, Church (1982 P.64) describes a sharp-crested syncline plunging 10 degrees toward the northwest (309 degrees). The axial plane, well defined by cleavage in the siltstones, trends 105 degrees and dips 55 degrees north. The syncline is between two layers of highly sheared serpentinite followed by the Lind Creek and Mt. Attwood faults which in this area are very close together. Another fold in the Attwood formation defined by limestone and siltstone on the ridge east of Mt. Attwood near the Lone Star haul road has an average plunge of 3 degnees to the northwest (300 degrees) and a steeply north dipping axial plane (110/85 N).

The Brooklyn formation in the No.6 fault slice along July Creek and Hardy Mountain is broadly folded, on axes plunging at low to moderate angles to the north and with axial planes dipping steeply to the west. The Lind Creek fault which truncates members of the Brooklyn on the hangingwall of this slice appears to be folded along with the underlying formations.

Fault Slice No. 6 contains small irregular plutons of granodiorite exposed on the ridge east of Mt. Attwood and in the valley of Skeff Creek. Although not dated, they are assumed to be Nelson intrusions and to be an integral part of this fault slice. Further study of these plutonic rocks might shed some light on the age of the pre-Tertiary fault movements.

FAULT SLICE NO.7

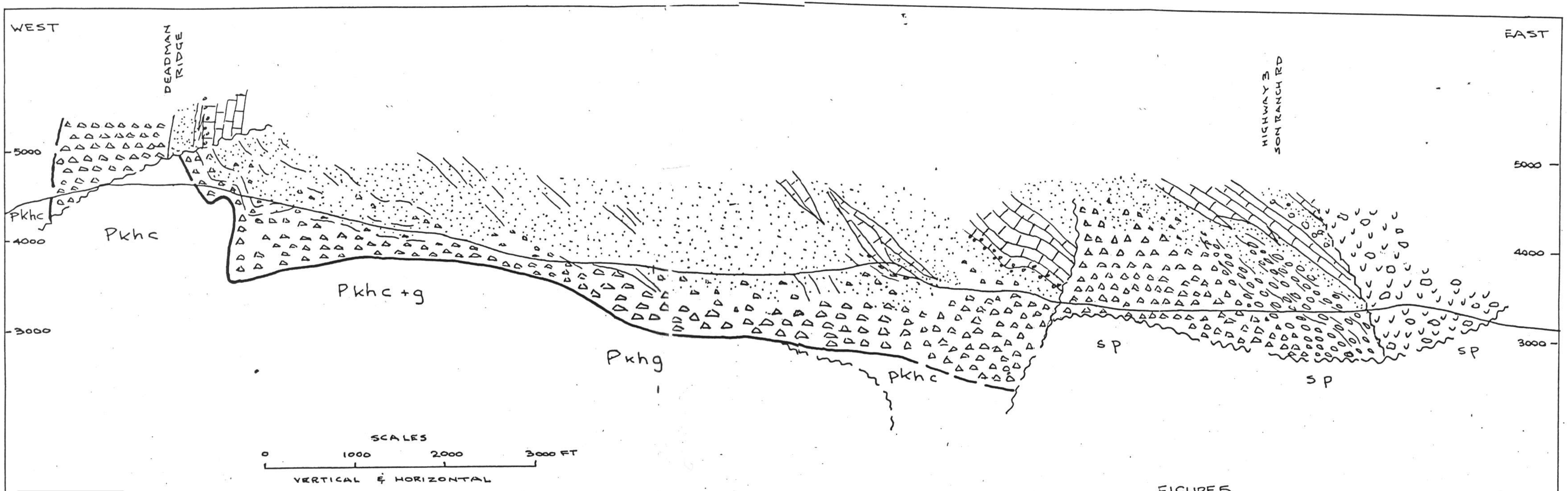
This fault slice is considered in two parts - a pre-Tertiary part which forms the local "basement" and stratiform Tertiary rocks which occupy fault blocks above the basement.

BASEMENT

The Lind Creek fault forms the footwall of the slice. It dips to the north beneath the serpentinite and the old diorite complex which pass upward and are intrusive into rocks of the Knob Hill group. This group generally dips to the northeast and north and in the lower part is complexly folded. Many minor folds in the cherts and the lenticular chert-siltstone-greenstone sequences southwest of Greenwood, on Knob Hill and west of Phoenix are local contortions with apparently random orientation. In those same areas, however, map scale folds and related minor structures plunge consistently to the north at 25-40 degrees with axial planes dipping steeply west. In areas east, northeast and north of Phoenix as far as Eholt, bedded rocks in the Knob Hill do not display minor folds. In general they dip at moderate angles to the north but in several areas the dip is to the west and northwest possibly reflecting a pattern of north plunging z-shaped overturned folds.

The Brooklyn formation in fault slice No.7 lies with marked unconformity above the Knob Hill group. The members at many places strike N 10 to 25 E and dip steeply directly across the trends of the underlying Knob Hill group. These steeply dipping panels are exposed in six faulted segments within the map area (Figure 1) from the western slopes of the Granby River, in the Summit Camp, at Phoenix, in the Mother Lode area, at the Copper Camp, and in the upper part of Wallace Creek. Only near Phoenix and eastward to Highway 3 are large folds displayed in the Brooklyn rocks. In this area vertical beds trending N20 degrees E flatten down dip to the east locally dipping at low angles to the north and northwest then flatten again to form a rolling moderate to gently east dipping monocline (Figure 5 and Seraphim 1956). The form is of an open syncline west of a small open anticline with axis plunging N20 degrees E at 10 to 20 degrees and the axial plane dipping steeply to the west.

In the other segments the members of the Brooklyn dip steeply to the east or are vertical or overturned dipping steeply to the west. The stratigraphic top as indicated by graded beds and known stratigraphy is to the east. These steeply dipping beds become more gently dipping downward and toward the east but rarely dip less than 50 degrees. In the easternmost segment the overturning is more pronounced - vertical beds flatten upward to dip west and northwest forming a series of recumbent folds northeast of the map area well displayed on Volcanic Mountain and described by Preto (1970 P.69).



FOR LEGEND SEE P5 & FIGURE 1

FIGURE 5
STRUCTURE OF THE BROOKLYN FORMATION
NORTHEAST OF PHOENIX

Plutons of granodiorite including the Greenwood and Buckhorn stocks, the southern margin of the Wallace Creek batholith and its eastern tongue referred to by Church as the Lion Creek granodiorite and the Emma porphyry are also part of the basement of fault slice No. 7. They probably form protrusions on the upper surface and southern margin of the more extensive Wallace Creek batholith which slopes irregularly to the south. The contact zones are relatively sharp to gradational with narrow zones of granitic dykes. Emplacement was apparently passive as the stratiform rocks are not folded along the contacts and the granodiortie is normally massive. Some of the contacts are Tertiary faults and small fault slivers of crushed granodiorite are found away from the main bodies north of Deadwood and in the Copper Camp. The Greenwood stock is highly shattered internally and truncated on the east by several north trending faults with a low to moderate easterly dip. Two samples of granodiorite dated by K-Ar methods are reported by Church at 128±5Ma (Dentonia Mine) and 143±5 (Lion Creek granodiorite).

Small irregular bodies of Tertiary syenite, monzonite, and feldspar porphyry as well as diorite, gabbro (Cyclops gabbro) of uncertain age also form part of the basement of slice No. 7. They become more numerous upward toward the Tertiary fault blocks.

TERTIARY BLOCKS

The largest Tertiary fault blocks containing stratiform rocks of the Penticton Group are on Thimble Mountain, at Phoenix, on Deadwood Ridge south to Midway and on Copper Mountain continuing to the south and west. The ~~Princeton~~ Penticton group almost everywhere dips at moderate angles to the east. Exceptions are along west dipping faults particularly the Deadwood Ridge fault on the Tam O'Shanter property west of Deadwood. The base of the Penticton group probably everywhere in the map area is a fault. Direct evidence for faulting is difficult to obtain because the faults dip east with the bedding, are not pronounced crushed zones, are commonly zones with many Tertiary (pulaskite) dykes and are rarely exposed. One well known exposure of the base of the Penticton Group is in the Phoenix pit on the eastern hangingwall side of the ore zone. This contact, with rocks of the Brooklyn formation, is sharp with a narrow crushed zone, contains and is crossed by many feldspar porphyry dykes, and dips to the east less steeply than the overlying Kettle River arkose and sandstone. The dykes, which are typical of the Tertiary suite, both cross and follow the contact and many are crushed, sheared, and clearly faulted. Though less well exposed, similar relationships are found at all of the east dipping basal contacts of the Penticton Group. The bedding in the Kettle River sediments and stratification in the overlying lavas always dips more steeply to the east than the dip of the contact as defined by mapping. The thickness of the Kettle River varies from nothing, where the lavas (Marron Formation) rest on the basement, to about 500 meters. The Kettle River formation is arkose, sandstone, siltstone, and conglomerate of granitic provenance and in part pyroclastic. Only rarely is a conglomerate derived from adjacent basement present within or beneath the arkose and these localities are close to west dipping faults to which the conglomerate could be related. Offset on these easterly dipping faults is not known. The only evidence is that easterly dipping fault planes on the footwall of the Phoenix ore zones have grooves and slickensides which indicate a normal dip slip in an easterly direction.

These faults, with a low easterly dip, are offset by other faults with a low westerly dip which form the eastern margins of the Tertiary blocks. These are the Neff Creek (Fyles 1983), Gold Drop, Deadwood Ridge (Little 1983) and Copper Mountain (Fyles 1986) faults and an unnamed fault only a short length of which has been mapped on Wallace Creek at the northwestern corner of the map area. These principal faults have many subsidiary breaks associated with them including the complex Snowshoe and related faults at Phoenix, the MotherLode, Sunset, Greyhound and associated faults near Deadwood and the many breaks in the Copper Camp. Commonly these faults are associated with spectacular zones of brecciation and crushing. Polished and slickensided surfaces are to be seen in mine workings, road cuts and locally in natural outcrops. From these exposures, from mapping the fault trace and in a few places from drill and underground data, the dip of the faults is to the west and northwest at angles no greater than 35 degrees and for some as low as 10 degrees. Grooves and slickensides on exposed fault planes have a complex pattern, but on northerly striking faults they show a dominant dip slip down on the west. On low northwest and southwest dipping faults identified as part of this set such as the Snowshoe near Phoenix and the faults near Deadwood, there is a large component of slip in a westerly direction and the net slip is probably between west and the dip direction. The offset is confirmed locally by the displacement of rock units. Northwest of Phoenix, a distinctive porphyritic syenite is broken into two or more segments, each higher segment being slipped toward the west along the Snowshoe fault which in this area strikes east and dips at a low angle to the south. Similarly the MotherLode orebody west of Deadwood is the western upper segment of a larger mineralized zone which includes the Sunset and Greyhound orebodies to the east lying beneath two or more successively lower faults dipping at low angles to the northwest. The magnitude of the apparent offsets in these localities is in the order of 1 to 1.5 Km. On a regional scale a comparable pattern of offsets can be deduced by matching the faulted segments of the Brooklyn formation across the six major west dipping faults. Estimates of the magnitude of the net slip depend on the rotation of the Tertiary strata and on projections of the Brooklyn formation to the fault planes, both of which are difficult to define. For practical purposes the apparent offsets are as follows; Neff Creek fault 5 Km, Gold Drop-Snowshoe fault 0.5 Km, Deadwood Ridge fault 3.5 Km, Copper Mountain fault 2.5 Km. The net slip is much less. Most of the low west dipping faults continue down dip into the basement. At Phoenix, however, the Gold Drop fault, through a series of splits, appears to join a low east dipping fault to form a sort of klippe or fault bounded structural basin.

Faults trending between N5 degrees E and N30 degrees E with steep dips commonly to the west form the third element of the Tertiary fault system in slice No. 7. They are well exposed in the Phoenix pit where they are marked by gossan zonesup to 2 meters thick of fault gauge containing vuggy quartz-carbonate coated breccia fragments. In the pit they are vertical north trending faults which drop the ore down on the west by a few tens of meters. South of the pit they join another fault of the same set trending N30 degrees E dipping 70 degrees W with dip slip of 100 meters down on the west. Other faults of this set with the same sense of displacement occur in the Snowshoe and other ore zones to the east. Regionally, faults of this set have been mapped on Thimble Mountain, in the head of July and Fisherman Creeks west of Highway 3, through Deadwood (the Greyhound Creek fault of Little) and south of Greenwood. Displacements on the faults identified are down on the west and they appear to belong to the set of "trap door" structures described by Monger (1968) from the Rock Creek area to the southwest. Unlike these, however, the faults near Greenwood appear to be discontinuous either because of hinged displacements or abrupt changes in attitude where they meet other faults or other weaknesses in the rocks.

INTEGRATION OF THE STRUCTURE

The foregoing structural data are generalized in Figures 2 and 3 to which have been added the Granby River fault from Preto (1970) and faults from Little's 1983 map north of Midway. Figure 3 has been drawn by projecting cross sections onto a single vertical plane as if the geology continued unchanged between sections and the average dip of the fault slices was 25 degrees to the north. Granitic plutons are not shown and a few structures have been arbitrarily adjusted to fill spaces. Figure 3 therefore is a diagram which together with Figure 2 leads to the following conclusions.

1) The consistent pattern of displacements of the Brooklyn formation on low west dipping normal faults in Slice No. 7 leads to the conclusion that another fault of this set has offset the formation from the Phoenix area to the Deadwood area. It is obscured by the Greyhound Creek fault. Probably to the south it is represented by the sub-Tertiary fault east of Midway passing through the Sappho property (Sappho fault) and possibly to the north by the Windfall Creek fault mapped by Little (1983 P.31).

The Granby River fault is one of the same set of westerly dipping normal faults. Some of the low west dipping faults which cut the Tertiary die out down dip in the older rocks. Others appear to join the faults which bound the pre-Tertiary fault slices, many of which join or are displaced by the Granby River fault. These relationships lead to the conclusion that much of the Tertiary extension has resulted in rotation of the upper fault blocks on the low west dipping faults and strike slip on the north dipping pre-Tertiary fault zones.

2) Evidence for pre-Tertiary faulting is scattered and indirect. Early large movement on the faults bounding the slices 3 to 6 is suggested by the complicated distribution of the rock units. Recognizable units are present in each slice which cannot be matched structurally from one slice to another. Broad folds of the Lind Creek fault in the Hardy Mountain area reflect the open folds in the Brooklyn formation in the footwall of the fault, but in other places folds in the Brooklyn are clearly truncated by the faults. The best interpretation would seem to be that the major movement which took place on these faults was post Brooklyn and pre Nelson. The faults followed sheets of serpentine and serpentine worked its way along the fault zones during this and subsequent deformation.

3) Pre-Tertiary fold patterns are also based on scattered evidence. Folds in the Brooklyn formation plunge between north and N35 degrees E. Comparable folds with the same axial trends occur in the Knob Hill group in slice No.7 and in the schist unit (Pm) in slices 4 and 5. The folds in slice No.7 are more open than those in the lower slices.

Fold axes in the Attwood formation (slices 5 and 6) plunge at low angles to the northwest and parallel some of the lineations in the schist unit of slice No.4 North and northeast plunging folds have not been found in the Attwood formation. I have no good explanation of these contrasting fold patterns.

4) The contrast between the steep fault bounded grabens of northern Washington and the low dipping Tertiary faults in the Greenwood area is remarkable. It is tempting to speculate that the low dipping faults near Greenwood are the deep expression of the steeper faults exposed "up plunge" from the Toroda Creek and Republic grabens to the south. Obscure, low dipping faults may also be present, however, in Northern Washington. The Lambert Creek thrust on the northern edge of the Republic quadrangle may be one of these (see Muessig 1976).

IMPLICATIONS OF CURRENT GEOLOGICAL DATA FOR EXPLORATION

Have we thoroughly explored Brooklyn formation?

Model - syngenetic diagenitic copper-iron.
Age and origin of skarn (?).
Significance of Sylvester K gold mineralization.
Age and source of gold.
Favourable or preferred stratigraphic interval and setting.
Eye, Wilgress Lake zone, Hex on North Fork, Empire Creek in Washington.

What are our chances in serpentine related gold zones?

Model - serpentine as source
serpentine as originator of favourable structures.

Zones of Interest
a) Winnipeg - Crown - Wendy - Ophir as far as Skylark ground.
b) No. 7 - City of Paris, Azure - Lonestar.
c) Rainbow
d) Serp grid

Where are the Tertiary structures with epithermal gold zones?
a) North to northeast trending faults and fractures with open breccia.
b) Tam O'Shanter area Sappho, Seattle Mine area at Republic.
c) Rock Candy and North Fork.
d) Prospecting of known structures.

Is there any gold potential related to Nelson intrusions?

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GEOLOGICAL MAP OF GREENWOOD - 1986 DATA

1:50000

LEGEND

FIGURE 1

- **Ep** PENTICTON GROUP
  - STRATIFORM UNITS - KETTLE RIVER FM, MARRON VOLCANICS
  - INTRUSIVES - PULASKITE, SYENITE MONZONITE
- **Tb** BROOKLYN FORMATION
  - g GREENSTONE & RELATED MICRODIORITE
  - l LIMESTONE & MINOR SKARN
  - s CHERT BRECCIA, SANDSTONE & SILTSTONE
- **Pa** ATTWOOD FORMATION
  - a BLACK SILTSTONE, CHERTY SILTSTONE, MINOR GREENSTONE
  - l LIMESTONE & CHERT
  - bx CONGLOMERATE & BRECCIA
- **Pkh** KNOB HILL GROUP
  - c CHERT, GREY ARGILLITE, & SILICEOUS VOLCANICS, LIMESTONE
  - g GREENSTONE & AMPHIBOLITE
  - bx CONGLOMERATE & BRECCIA
- **Pm** SCHIST UNIT
  - GREY & GREEN PHYLLITE, QUARTZITE (META-CHERT) META DIORITE, GNEISS & SCHIST

INTRUSIVE ROCKS

- qfp QUARTZ FELDSPAR PORPHYRY (TERTIARY?)
- qd GRANODIORITE & QUARTZ DIORITE (NELSON)
- od OLD DIORITE COMPLEX (LATE PALEOZOIC)
- sp SERPENTINITE (LATE PALEOZOIC?)
- g GABBRO (AGE UNKNOWN)
- d DIORITE (AGE UNKNOWN)

GEOLOGICAL CONTACT

TERTIARY FAULT

LOW DIP (45°)

STEEP DIP

PRE-TERTIARY FAULT

TEETH ON HANGINGWALL

FOLD AXES

LINEATIONS

ATTITUDE OF FOLIATION

ATTITUDE OF BEDDING

GEOLOGY BY J.T. FYLES & B.N. CHURCH

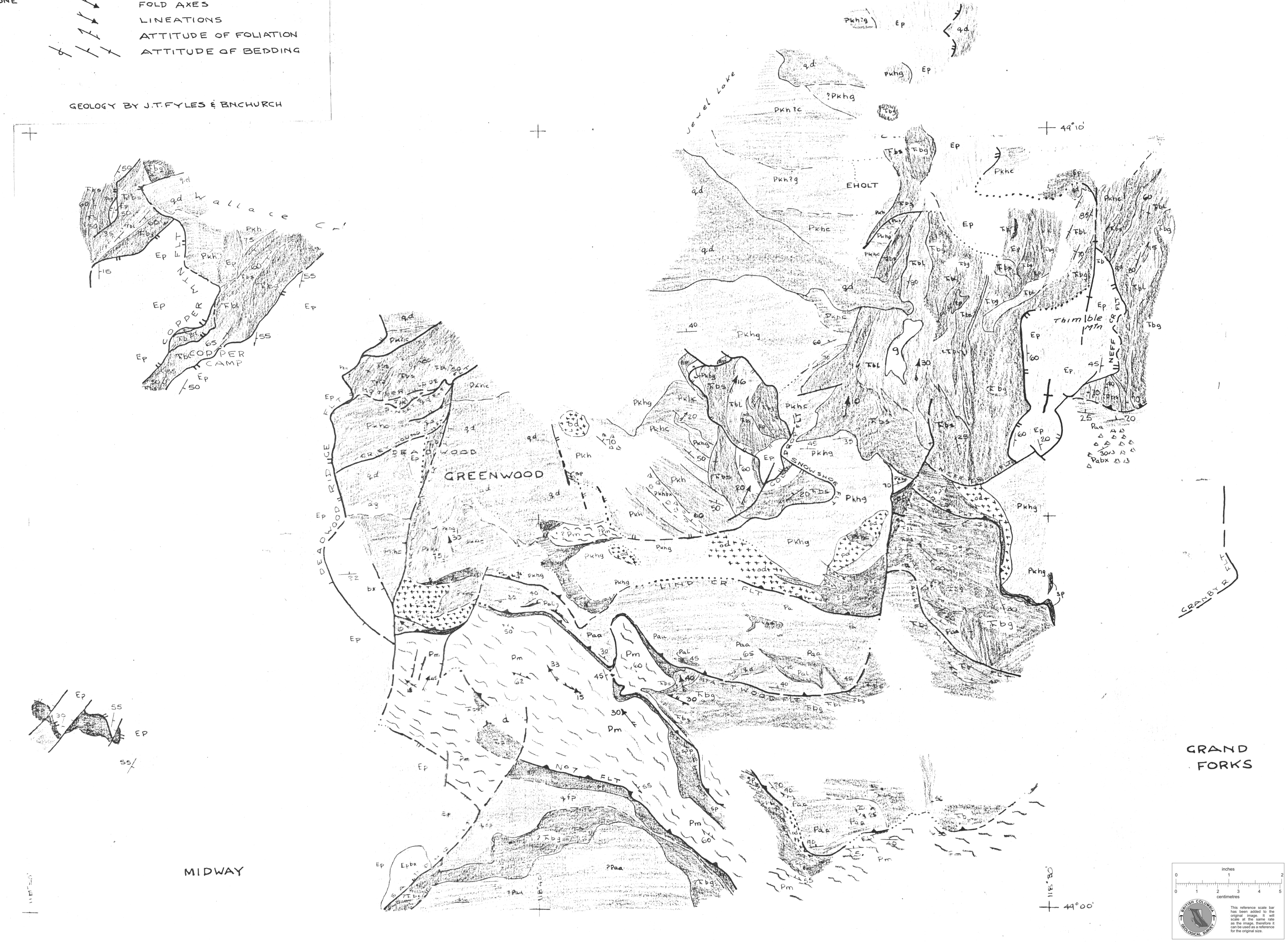


FIGURE 2

MAP SHOWING THE MAIN FAULT SLICES AND TERTIARY FAULT BLOCKS

SCALE 1:50000

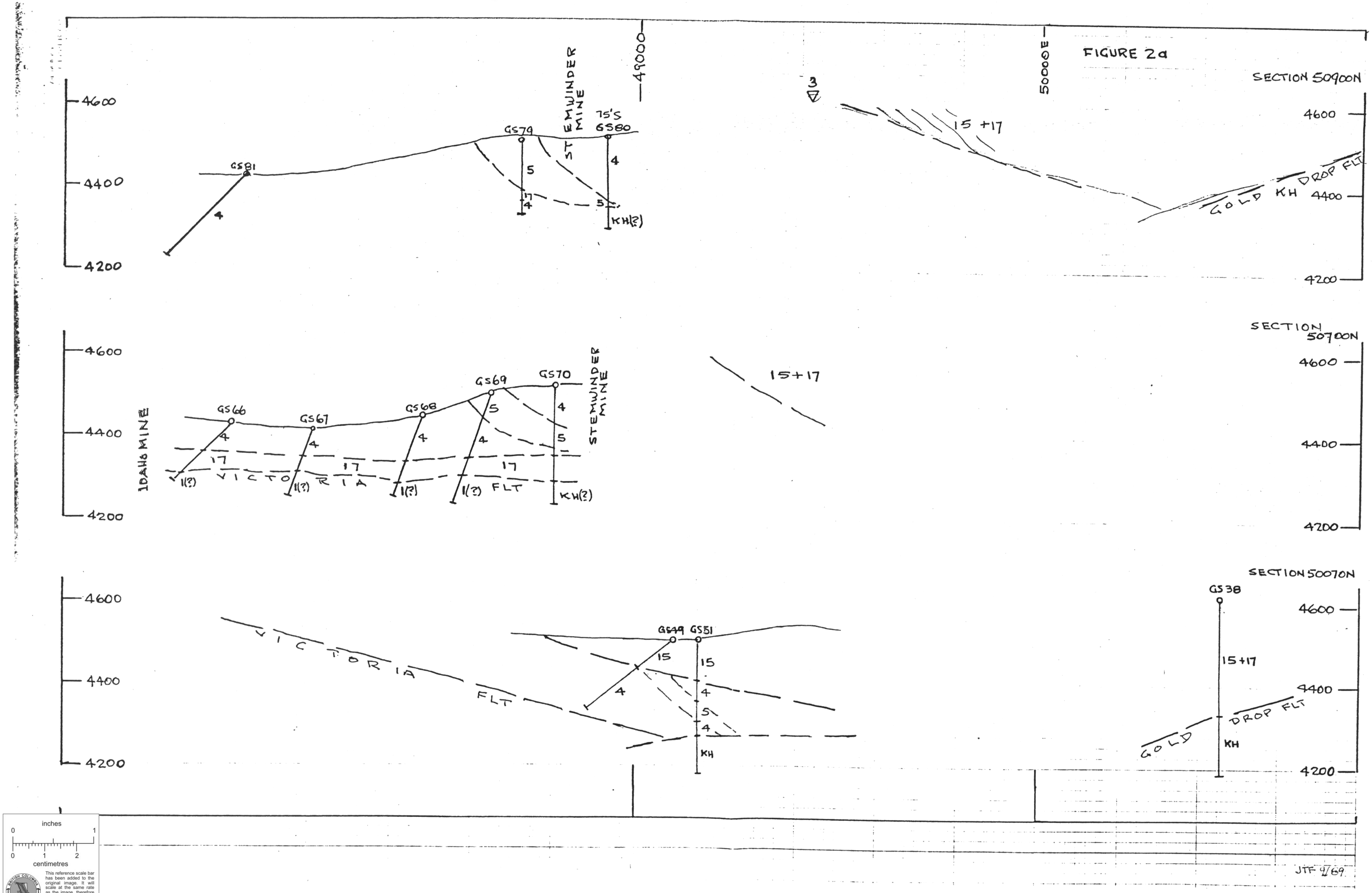
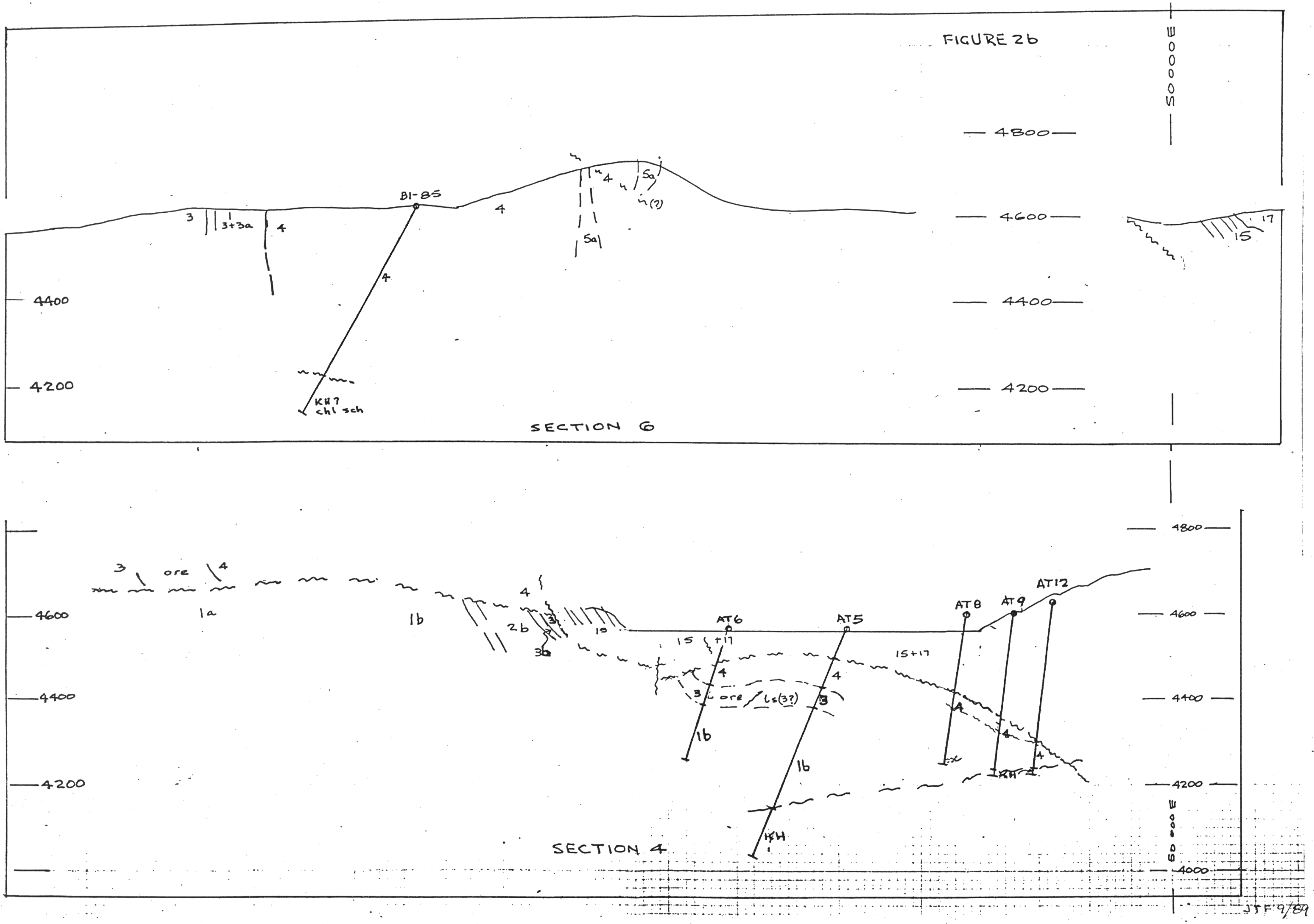


FIGURE 2a
SECTION 50900N
49000
50000E
STEMWINDER MINE
75'S
GS80
GS79
GS81
KH(?)
15 +17
GOLD DROP FLT
KH
4600
4400
4200
SECTION 50700N
IDAHO MINE
GS66
GS67
GS68
GS69
GS70
STEMWINDER MINE
VICTORIA FLT
1(?)
15+17
SECTION 50070N
GS49
GS51
GS38
VICTORIA FLT
GOLD DROP FLT
15+17
JTF 4/69

FIGURE 2b



5000 E
4800
4600
4400
4200
4000
BI-85
3
3+3a
4
5a
5a(?)
KH?
chl sch
15
17
SECTION 6
ore
1a
1b
2b
3a
15+17
AT6
AT5
AT8
AT9
AT12
ls(3?)
KH
SECTION 4
JTF 9/89

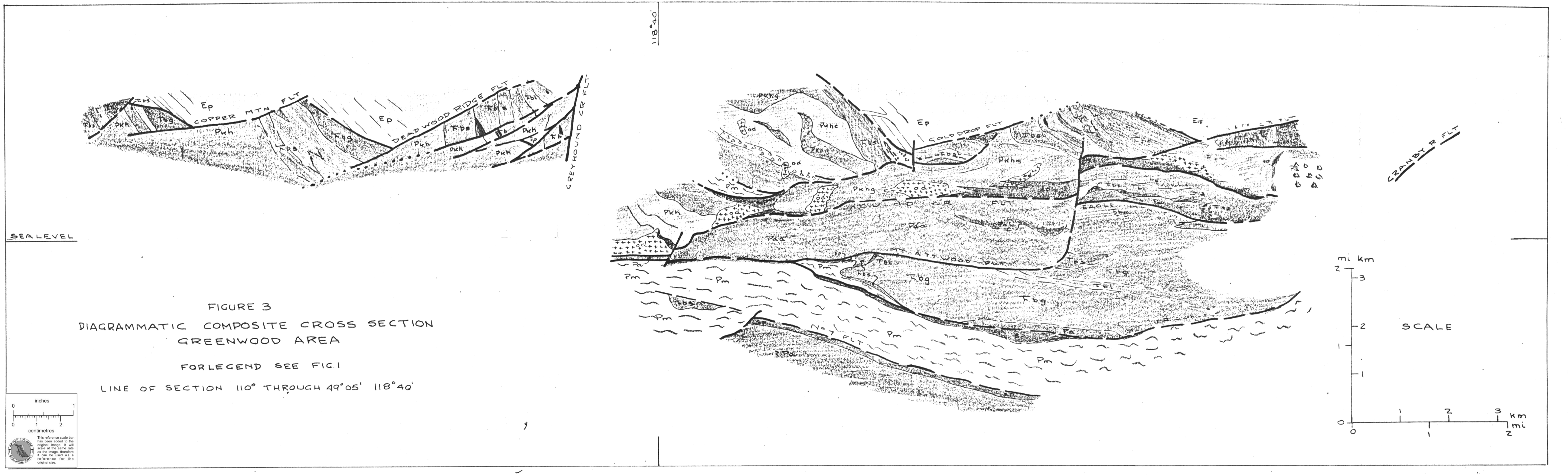


FIGURE 3
DIAGRAMMATIC COMPOSITE CROSS SECTION
GREENWOOD AREA

FOR LEGEND SEE FIG. 1

LINE OF SECTION 110° THROUGH 49°05' 118°40'