Regional and District Mapping

GEOLOGY OF THE PRE-TERTIARY ROCKS IN THE ROCK CREEK–GREENWOOD AREA (82E/2)

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INTRODUCTION

The area covered in this study is the west half of NTS sheet 82E/2 south of latitude 49°10′ north in the Boundary District of south-central British Columbia. This area contains "windows" of Paleozoic and Mesozoic volcanic and sedimentary rocks between large down-faulted blocks of Tertiary cover. By contrast, the east half of 82E/2, and beyond to the Grand Forks gneiss complex, contains mainly the same Paleozoic and Mesozoic rocks with isolated small blocks of Tertiary cover. The purpose of the study has been to extend geological knowledge gained from recent work in the older, well-mineralized rocks in the east half of the map sheet to the same rocks in the west half. Specifically the objectives of the research are:

- To determine the stratigraphy and structure of the late Paleozoic Knob Hill Group of cherts and greenstones.
- To assess the significance of the serpentinites and associated diorite in relation to the stratigraphy of the Knob Hill Group.
- To search for equivalents of the late Paleozoic Mount Attwood sedimentary rocks.
- To trace the middle Triassic Brooklyn Formation and overlying volcanic rocks westward from the established sections near Greenwood.
- To determine the nature of the pre-Tertiary surface at as many localities as possible.
- To provide a geological framework for the interpretation of the metallic mineral deposits of the area.

The focus of the research was to review by ground traverses, Geological Survey of Canada Maps 1500A (Little, 1983) and 10-1967 (Monger, 1968). In general these maps were found to be detailed, complete and accurate and new interpretations presented here result from the application of new concepts, the experience of the writer in the east half of the Greenwood sheet and from the opportunity to study specific problems. Figure 1-1-1 shows the geology of the pre-Tertiary rocks in the area. The outlines of the Tertiary rocks are modified from Map 1500A. Table 1-1-1 summarizes lithologies and the stratigraphic relationships and gives an explanation of the map numbers used on Figure 1-1-1.

KNOB HILL GROUP

Most of the pre-Tertiary rocks in the map area belong to the Knob Hill Group, a thick assemblage of mainly greenstone and chert. The rocks are described in two parts, a relatively undeformed segment north of the Kettle River and a much smaller, highly deformed sequence to the south.

The relatively undeformed Knob Hill rocks are found in most of the map area. They are on strike from the type locality a few kilometres east of Greenwood, but separated from it by patches of Tertiary cover. Correlations are based on this proximity and on general lithological similarities. The age is taken to be late Paleozoic from a single fossil locality in the lower part of the succession 8.5 kilometres east of Greenwood (Little, 1983).

Greenstones in the Knob Hill Group are mainly pillow lavas and breccias, and agglomerates derived from them. Good pillow structures are rare but crusts of pillows outlined by curving dark bands or epidote layers, interpillow lenses of chert, epidote or limestone, and vaguely mottled or banded dark and light green masses within the greenstone are taken to be broken remnants of pillow structures. The rocks are aphanitic, commonly calcareous and grade into massive fine-grained diorite crossed by fine, irregular, white-weathering feldspathic veinlets and lenses. Some of the fine-grained diorites are dykes whereas others cover large areas and apparently grade into greenstone as well as into medium and coarse-grained diorite. Coarse-grained diorite, referred to by Little (1983) as amphibolite and by Church (1986) as the old diorite, are striking, dark green rocks with many criss-crossing light-coloured veins of felsic rock. The veins bound blocks which differ slightly in composition and texture. Rarely the blocks have a light and dark layering. Dykes of the old diorite intrude greenstone and chert of the Knob Hill Group but the gradation from coarse to fine-grained diorite to massive greenstone and pillow lava has been observed or inferred in a number of places, particularly along the north and east sides of the Kettle River north of Rock Creek. A potassium-argon whole-rock date of 258 ± 10 Ma from drill core of old diorite from the Winnipeg mine, 7.5 kilometres east of Greenwood, is reported by Church (1986). Thus the pillow lavas, greenstones, fine-grained diorite and the old diorite are all considered to be parts of the Knob Hill Group.

Many small irregular masses of altered serpentinite or listwanite and schistose antigorite serpentinite occur along the valley of the Kettle River, in lower Bubar Creek and on the hills east of lower Ingram Creek. The listwanite is a yellow-brown-weathering, hard, aphanitic, grey to very light grey rock with veinlets of quartz, iron carbonate and flecks of dark

British Columbia Ministry of Energy, Mines and Petroleum Resources, Geological Fieldwork, 1988, Paper 1989-1.

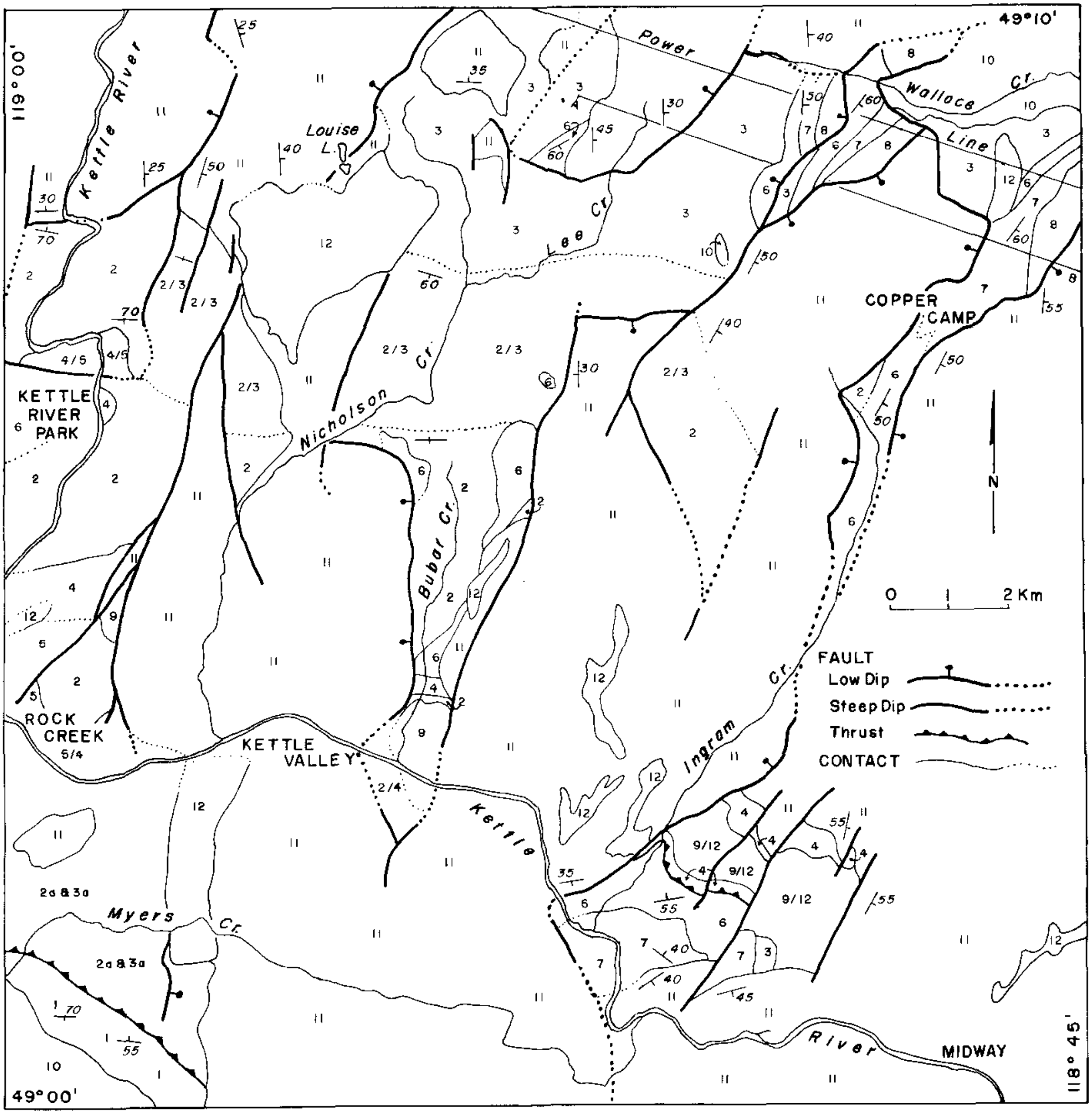

Figure 1-1-1. Geological sketch map of the southwestern part of the Greenwood map sheet. Tertiary geology modified from Little (1983).

minerals and locally of bright green mica (mariposite?). Antigorite serpentinite which is a dark and light green, generally sheared soapstone, is found with the listwanite at only a few places in the map area. The smaller lenses of serpentinite and listwanite are intrusive into the greenstone. Three larger masses, one exposed on both sides of the Kettle River 1.5 to 2 kilometres north of Rock Creek, another in lower Bubar Creek and a third in the hills east of lower Ingram Creek are probably emplaced tectonically and may be parts of a north-dipping tectonic sheet of regional extent. Because of the close association of the serpentinites with the diorite, and particularly the old diorite, both in this map area and to the east, they are included with the Knob Hill Group.

The sedimentary rocks of the Knob Hill Group are mainly grey, buff or white cherts which are highly fractured and only rarely show typical ribbon structure. Grey chert grades into black chert and sooty siliceous argillite. The chert occurs as lenses in greenstone and as thick continuous masses with only minor lenses of greenstone. The small lenses which also include brick-red jasper, have irregular shapes and probably formed between pillows or lava flows. A few lenses of grey to white crystalline limestone, not shown on Figure 1-1-1, are

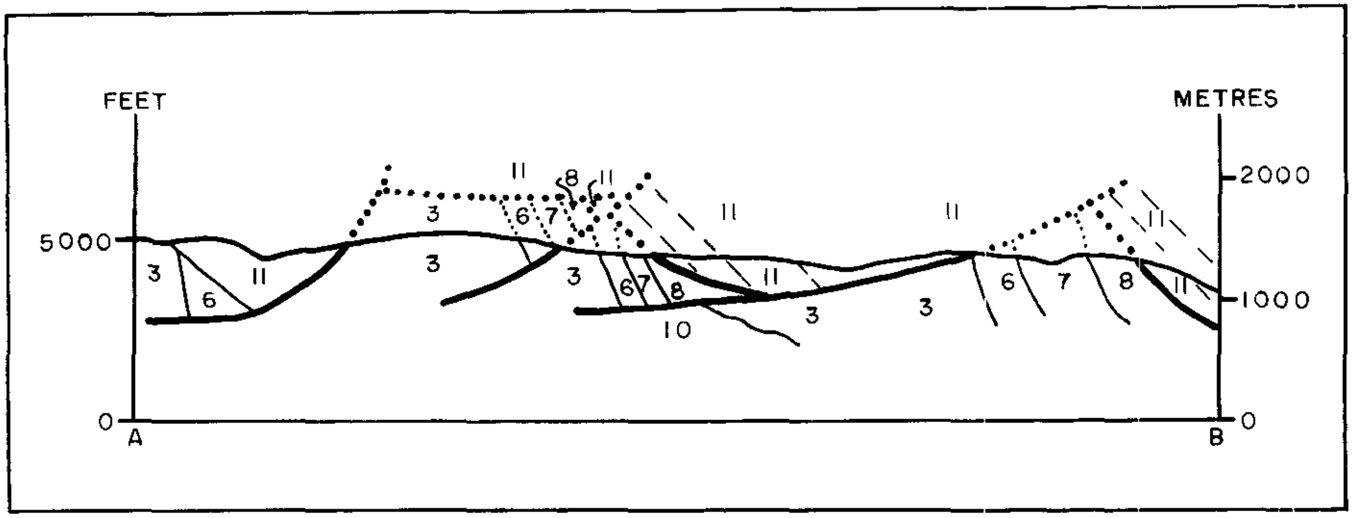

Figure 1-1-2. Diagrammatic cross-section (A-B on Figure 1-1-1) at the heads of Wallace and Lee creeks showing the apparent offset of Units 6, 7, and 8 on west-dipping listric faults.

TABLE 1-1-1
FORMATIONS AND MAP LEGEND

Age	Group/ Formation	Symbol Correlation Figure 1-1-1	Symbol Correlation GSC 1500A	Lithology
TERTIARY	PENTICTON GP	12	Emi	Dykes, sills and small plutons of alkaline syenite. Pulaskite, diorite and porphyry.
		11	Emv	Flows of andesite, trachite and phonolite, minor pyroclastics.
			Ekrs	Feldspathic and lithic tuffaceous sandstone, conglomerate and siltstone.
UNCONFORMITY				
JURASSIC AND CRETACEOUS	NELSON PLUTONIC ROCKS	10	Jkad	Granodiorite and quartz diorite.
		9	KTi	Quartz feldspar porphyry.
INTRUSIVE CONTACT				
EARLY JURASSIC		8	Jv	Fragmental greenstone.
DISCONFORMITY				
MIDDLE TRIASSIC	BROOKLYN FM	7	TR1	Limestone, siltstone, sandstone, limestone conglomerate and skarn.
		6	TRs	Chert-pebble conglomerate and chert breccia.
UNCONFORMITY				
LATE PALEOZOIC	KNOB HILL GP	5	CPkh 3	Aphanitic to coarse-grained diorite.
		4	Jum	Listwanite and serpentinite.
		3	CPkh 1	Grey to buff chert, dark grey siliceous argillite, minor greenstone and limestone.
		2	CPkh 2	Calcareous greenstone, pillow lava, breccia, minor limestone and chert.
		2a & 3a		Greenstone, chlorite schist, chert, white quartzite, micaceous quartzite and gneiss, limestone and calcareous greenstone, white dolomite.
FAULT CONTACT				
UNKNOWN	MT. ATTWOOD(?) FM	1		Dark grey siltstone and grey sandstone.

associated with either chert or greenstone. The most continuous is a bed 10 to 20 metres thick within grey chert which has been traced for almost 500 metres along strike in one of the valleys forming the head of Nicholson Creek. One lens of limestone about 3 kilometres southwest of Louise Lake is overlain by a greenstone flow in which ripped up limestone blocks clearly show the stratigraphic top to be to the north, but this is the only good top determination found in these rocks.

The thickness and the internal structure and stratigraphy of the Knob Hill Group present problems of interpretation which have not been satisfactorily resolved. Attitudes of primary structures consisting of bedding in siliceous argillites and cherts, greenstone-chert contacts, and beds of limestone, are found at relatively few places but consistently strike between 70 and 100 degrees and dip steeply north or south. Although greenstone-diorite and greenstone-chert contacts are too indefinite to be traced on the ground, infered contacts are shown on Figure 1-1-1. Chert, with little or no greenstone, outcrops in the northeast part of the map area on the hills at the head of Nicholson and Wallace creeks, whereas greenstone and diorite with only minor chert are found farther to the south and west along the valley of the Kettle River for several kilometres north of Rock Creek. Between, are mixed greenstones and cherts and these mixed rocks contain most of the limestone lenses.

No evidence has been found for tight or isoclinal folding of the Knob Hill rocks. Major repetitions of stratigraphy by faults subparallel to the formations have not been recognized although a possible east-trending fault follows the serpentinite 1 to 2 kilometres north of Rock Creek and may thicken the section. Tertiary faults cross the stratigraphy and extend it in an east-west direction and many of the fractures in the chert belong to a set of north to northeast-trending Tertiary faults. The width of the outcrop of Knob Hill rocks from the Kettle Valley to the north edge of the map area, where they are cut off by large bodies of Nelson plutonic rocks, is about 10 kilometres. These very incomplete data lead to the interpretation that the Knob Hill Group is several kilometres thick in the map area, faces north and that an intrusive feeder system of diorite and greenstone in the south and west spread greenstone flows into a sedimentary chert basin to the northeast.

The deformed part of the Knob Hill Group is exposed in a small area near the head of Myers Creek, 3 to 5 kilometres south of Rock Creek. Lithologies are very similar to those already described and they have been included with rocks mapped as Knob Hill by Little (Little, 1983). They are rusty white chert and quartzite, micaceous quartzite and banded siliceous mylonite as well as greenstone, sheared greenstone (locally with elongate pillow structures) and chlorite schist. Minor amounts of grey and white crystalline limestone grading into calcareous greenstone and limy chlorite schist are also present. A lens of white dolomite within this deformed sequence is quarried 4.5 kilometres southeast of Rock Creek by Mighty White Dolomite Ltd. In this deformed part of the Knob Hill Group lenses of relatively blocky rock, tens to hundreds of metres across, occur between zones of schist and mylonite. The schistosity and deformed zones trend 295 degrees and dip 40 to 60 degrees north but weave around the more competent blocks.

The base of this deformed zone is well defined by a sheared zone trending 305 degrees and dipping 60 degrees northeast along the contact of a belt of dark grey siltstones and sandstones which lie to the southwest. The deformed zone is more than a kilometre wide. The upper contact with relatively undeformed Knob Hill rocks is not well defined, partly because of the poor outcrops south of the Kettle River and partly because the transition appears to be gradational. More study is required to resolve these relationships and to clarify the significance of this zone of intense deformation.

ATTWOOD(?) FORMATION

Dark grey siltstones and grey sandstones in the extreme southwest corner of the map area, not distinguished from Knob Hill Group on Geological Survey of Canada map 1500A, form a distinctive unit closely resembling some parts of the late Paleozoic Attwood Formation which occurs widely in the east half of the Greenwood area. This correlation, however, is very tentative as neither the internal structure and stratigraphy nor the stratigraphic relationships with other rock units have been defined.

The siltstones have a well-developed slaty cleavage and a thin rhythmic bedding which is commonly cut by the cleavage, indicating the rocks are tightly folded. Similar features are seen in the sandstone but the cleavage is less well developed. To the south, where the rocks are intruded by a large body of quartz diorite, they are blocky hornfels and the cleavage and bedding are obscured.

BROOKLYN FORMATION AND OVERLYING VOLCANICS

These formations form a distinctive succession throughout the Greenwood area but have been identified with certainty only in the northeastern part of the study area. The Brooklyn Formation overlies the Knob Hill Group with a pronounced angular unconformity and contains Middle Triassic (Ladinian) microfossils as well as Triassic macrofossils (Little, 1983) at several localities east of the map area. The volcanic rocks which, within the map area, overlie the Brooklyn, elsewhere interfinger with it. The best section of the Brooklyn and overlying volcanics is in the northeastern corner of the map area along the B.C. Hydro powerline, where it dips steeply to the east (Table 1-1-2).

The basal conglomerate and the greenstone form good markers which are very similar to rocks found in comparable sections east of Greenwood (Seraphim, 1956). The intervening rocks change more or less systematically along strike to the south, from the relatively thin, thin-bedded succession of hornfelsic siltstone, sandstone and calcareous conglomerates along the powerline, to essentially massive skarn with lenses of white crystalline limestone to crystalline limestone with pods of skarn in the Copper Camp. Still farther to the south the only Brooklyn rocks exposed are greenish, relatively

TABLE 1-1-2
BROOKLYN FORMATION AND ADJACENT ROCKS EXPOSED ON THE POWERLINE NORTH OF THE COPPER CAMP

Thickness (metres)	Map Unit	Lithology
		Penticton Group above fault
400+	8	Greenstone, dark green aphanitic to very fine-grained blocky rock with rounded and sub-rounded fragments up to 10 cm across, rich in epidote or similar to the matrix but more feldspathic.
250	7	Mixed metasedimentary rocks including hornfelsic siltstone and sandstone, calcareous sandstone and quartz-pebble conglomerate, limestone, skarn and minor chert breccia.
125	6	Metasharpstone-conglomerate, grey to greenish grey chert breccia, angular fragments of quartz mainly less than 3 cm across.
		Unconformity
	3	Grey to brownish grey quartzite, dark grey thin-bedded hornfelsic siltstone, grey massive argillite, minor greenstone of the Knob Hill Group.

unmetamorphosed sharpstone conglomerate with a few lenses of green calcareous sandstone. In upper Ingram Creek the base of the sharpstone conglomerate, overlying dark green and purplish volcanic rock taken to be part of the Knob Hill Group, is exposed in trenches.

The same two members of the Brooklyn Formation and the overlying volcanics occur again 2 to 4 kilometres to the west, exposed mainly on the south side of upper Wallace Creek. The section is very similar to that just described. The Brooklyn limestone is lenticular and in the westernmost outcrops consists of several metres of limestone-boulder conglomerate overlain by hornfelsic siltstones and skarn. Lenses of roundstone conglomerate occur in the uppermost part of the section in or just below the overlying volcanic rocks. All the rocks are metamorphosed and grade northward into gneissic amphibolite, fine-grained biotite schist and marble exposed in Wallace Creek.

Five kilometres to the west, on the ridge north of Lee Creek, a small lens of chert-pebble conglomerate and breccia overlain by greenstone or green sandstone dips and faces to the southeast. The upper part of the section is covered by Tertiary rocks, but this section is probably a faulted segment of the sections described in upper Wallace Creek.

Isolated patches of chert-pebble conglomerate and chert breccia also occur to the south. They are brown-weathering greenish grey rocks composed of rounded and subangular fragments of chert, minor greenstone, siltstone and limestone, mostly less than 3 centimetres across, in a matrix of similar material. At places they are poorly cemented and the fragments break out, a characteristic not found elsewhere. The patches have no bedding but, judging from their shape and the basal contacts, which at some places are well exposed, they appear to form channel fillings and erosional remnants unconformably above the Knob Hill rocks.

Sharpstone conglomerate exposed near the entrance to Kettle River Park is correlated with the Brooklyn Formation but the correlation is very uncertain. These rocks are dark grey chert breccia composed of angular and subangular chert fragments, less than a centimetre across, in a grey sandstone matrix. Lenses of conglomerate with rounded cobbles of chert, siltstone and volcanic rocks, and of dark grey slaty siltstone within the chert breccia, dip north at moderate angles. These rocks are in fault contact with diorite to the north and probably unconformably overlie Knob Hill rocks to the south, although this contact has not been traced far to the west. Similar dark grey chert breccia is found along strike east of the Kettle River, to the south near the outcrops of serpentinite about 2.5 kilometres north of Rock Creek, and in lower Bubar Creek where they are along strike from a patch of Brooklyn conglomerate. The distribution and significance of these rocks require further study.

Finally, a thick section of the Brooklyn Formation crops out between Midway and lower Ingram Creek and is well exposed along Highway 3 between 6 and 7.5 kilometres west of Midway. The rocks are thermally metamorphosed and intruded by Tertiary dykes and irregular bodies of pre-Tertiary diorite and quartz feldspar porphyry. The formation exposed has two members, a limestone with an apparent thickness of more than 750 metres, lying beneath a sharpstone conglomerate more than 550 metres thick. The base of the section is covered by the valley of the Kettle River and the top is truncated by a fault lined with serpentinite. The stratigraphic top has not been determined with certainty. The limestone is grey and white, finely crystalline with blocky beds 10 centimetres to 1 metre thick and thin partings of hornfelsic siltstone. The sharpstone is composed mainly of angular and subangular chert fragments generally less than 2 centimetres across and minor amounts of greenstone, jasper and limestone. Interbeds of hornfelsic siltstone and sandstone, and conglomerate with a calcareous matrix occur as lenses within the sharpstone.

Detailed correlations of these rocks with the type section at Phoenix are speculative. If the limestone west of Midway is the Brooklyn limestone, and if the section is right side up, the sharpstone conglomerate above the limestone is the "upper sharpstone" of the Phoenix section and the basal sharpstone conglomerate is not exposed in the valley to the south.

NELSON PLUTONIC ROCKS

Parts of the southern edge of the Wallace Creek granodiorite batholith, and of another large pluton of similar composition to the southwest, outcrop in the map area but have not been studied. Very small fault slivers of quartz diorite occur in the Copper Camp and small granodiorite plutons are exposed near the head of Ingram Creek 5 kilometres to the west, and within the Brooklyn limestone 4.5 kilometres west of Midway. Zones of thermal metamorphism associated with these plutons extend from a few hundred metres to more than 3 kilometres from the exposed plutonic contacts.

Small intrusions, referred to as quartz feldspar porphyry, occur in a belt across the southern part of the map area, continuing to the east for 10 kilometres. These are grey, fine-grained porphyritic and equigranular rocks ranging from diorite to quartz monzonite. They are referred to by Little (1983) under the heading Map Unit KTi and are described in considerable detail. They have also been closely studied by Church (1986) who obtained a uranium-lead zircon age interpreted as an "early Jurassic zircon, probably Sinemurian, with inherited lead of early Proterozoic or Archean age" (The University of British Columbia Geochronology Laboratory report). The rocks are significant because they commonly occur with serpentinite and west of Midway they intrude it and may be the cause of the extensive alteration.

TERTIARY FAULTS

The structure of the area is dominated by Tertiary faults. They commonly form the boundaries of the Tertiary rocks and can be identified in outcrop, located as airphoto linears and inferred from offset contacts. Intense fracturing, particularly of the Knob Hill chert, breccia, fault gouge and slickensided faces are found both along faulted contacts which show on the map, and away from them. Slickensides most commonly trend east and movement indicators show normal faulting. Many faults are intruded and obscured by Tertiary dykes, but faulted dyke margins and offset Tertiary dykes, most common in the eastern part of the area, indicate that faulting continued after intrusion.

Patterns of Tertiary faulting are complex but consistent relationships across the Greenwood area indicate there are three fault sets, one with a low easterly dip, a later set with a low westerly dip and the latest which dips steeply and trends between north and northeast.

The oldest set dips east and southeast and occurs at or near the base of the Tertiary. The Tertiary formations characteristically dip east at angles commonly up to 45 degrees and locally as much as 70 degrees. The faults dip less steeply and down the dip they cut out the basal Tertiary sedimentary section. Three faults of this set with regional extent are shown on Figure 1-1-1.

The second set of faults dips at low to moderate angles to the west and produces the largest offsets. A measure of the apparent offset is given by four faulted segments of Brooklyn Formation in the northeast part of the map area as illustrated in the cross-section in Figure 1-1-2. The segments all dip steeply east, and the one exposed in the Copper Camp is offset 3 kilometres to the west by a low-angle west-dipping fault referred to as the Copper Camp fault. This second segment is also truncated by a west-dipping fault and repeated almost a kilometre farther west. If the Brooklyn section north of Lee Creek is considered to be another faulted segment, it has been offset in the order of 4 kilometres by a fault at the head of Wallace Creek referred to by Little as part of the Wallace Creek fault. The Copper Camp fault has been traced southward along the valley of Ingram Creek, crossing the Kettle River 7 kilometres west of Midway, and throughout its length it appears to have a low dip to the west. Other gently west-dipping faults occur along the west side of Bubar Creek and within Tertiary rocks east of Bubar Creek.

Three west-dipping faults occur along the northern edge of the map area and extend to the north. The one at the head of Wallace Creek is well exposed south of the creek where it dips 45 to 50 degrees west, curving westward across the head of Lee Creek where it dips north. To the west it appears to die out or to be offset by a later fault. The second, near Louise Lake, continues many kilometres to the north and is cut off by a large Tertiary syenite referred to as the Nicholson Creek intrusion (Le Cheminant, 1966) and has not been identified to the south or west. The third, though intruded by Tertiary dykes, is well defined in a canyon on the east side of the valley of the Kettle River and on Highway 33 about 9 kilometres north of Rock Creek. It dips northwest and curves northward, dipping west at low to moderate angles, and is intruded by one or more thick, grey porphyritic syenite dykes. These three faults are linked together on Map 1500A to form the Wallace Creek fault but detailed mapping along the fault trace could not substantiate the presence of a single fault.

These west-dipping structures are listric normal faults which tend to be curved in both plan and cross-section. They continue eastward at least as far as the Granby River fault north of Grand Forks (Preto, 1970). Probably much if not all the tilting of the Tertiary formations took place by extension and rotation on these curved fault surfaces, which in itself led to renewed movement on the bedding planes and was followed by regional block-faulting on a steeply dipping set.

The latest Tertiary faults dominate the structural grain of the map area. They dip steeply and trend between north and northeast, most commonly striking between 25 and 40 degrees. They are very abundant and only the most significant are shown on Figure 1-1-1 and the maps of Little and Monger. The faults are described and analysed in detail by Monger (1968) who included in the analysis some of the west-dipping listric faults. The late steeply dipping set in the map area have apparent offsets of no more than a few hundred metres. Most are dropped down on the west but some have west-side-up movement. Slickensides, where seen along faults, mostly have a steep plunge. The faults split and die out along strike suggesting they are hinged and that movements are transferred from one fault to another through minor adjustments on closely spaced inconspicuous fractures.

The Tertiary faulting gives a complex picture of east-west extension which seems to have developed and changed through time and to differ in style and complexity from place to place. The major elements described here are known to continue east to the Granby River fault and are probably also present in northern Washington (Parker and Calkins, 1964; Pearson, 1967).

PRE-TERTIARY STRUCTURE

Regionally, the pre-Tertiary rocks within the map area are in a zone of thrust faults in a depression accentuated by Tertiary faulting between the Kettle and Okanagan gneiss domes (Orr and Cheney, 1987). Identification of such faults was one incentive for remapping in this area. It seems probable that the zone of intense deformation in the southwest corner of the map area, which dips to the north and forms the structural base of the Knob Hill Group, is one such fault. Another fault, identified beneath the serpentinite in lower Ingram Creek and traced eastward toward Midway, truncates the Brooklyn Formation which lies beneath it. Projection of this fault to the west is speculative, but it seems possible that it follows the listwanite and serpentinite to lower Bubar Creek and appears again on the Kettle River about 2 kilometres north of Rock Creek. In this western part of the area the fault is within the Knob Hill Group. Another pre-Tertiary fault which strikes east and dips steeply, truncates Brooklyn(?) sharpstone conglomerate at the Kettle River Park but its regional significance is not known and it has not been identified to the east.

Folds have not been found in either the Knob Hill or Brooklyn rocks within the map area. The Brooklyn Formation in the northeastern part of the area strikes between 20 and 40 degrees and dips steeply east, flattening downward. These rocks cross the regional attitude of the Knob Hill Group which trends east and dips steeply. In this part of the area, before tilting on the Tertiary faults, the Brooklyn probably had low dips, was broadly folded, possibly on north-trending axes, and lay with marked unconformity above the Knob Hill Group. The Brooklyn Formation exposed west of Midway is in a lower fault slice than the Brooklyn rocks to the north and the relationships beween the two are not known.

CONCLUSION

The pre-Tertiary rocks of the map area are mainly late Paleozoic cherts, greenstones and related intrusions of diorite and ultramafic rocks of the Knob Hill Group. They form a thick suite truncated at the base by a north-dipping zone of deformation a kilometre thick, exposed in the southwestern corner of the map area. Other deformed zones, which may represent pre-Tertiary thrust faults, probably occur within the group but cannot be identified with certainty.

Rocks of the Triassic Brooklyn Formation, similar in stratigraphy to those in the Greenwood area, outcrop only in the northeastern part of the study area. Elsewhere only the basal sharpstone conglomerate is present except west of Midway where a thick but incomplete section of limestone and sharpstone conglomerate is exposed which may be part of the Brooklyn Formation at a lower structural level than the other sections.

The most significant Tertiary faults are moderate to gentle west-dipping listric normal faults, but the area is dominated by many later steeply dipping block faults trending between north and northeast.

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NOTES