STRUCTURAL RELATIONS BETWEEN THE SHUSWAP TERRANE AND THE CACHE CREEK GROUP IN SOUTHERN BRITISH COLUMBIA

by

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ABSTRACT

The rocks of the Shuswap terrane have been the subject of controversy for more than 65 years. Jones (1959) recently presented evidence that in the Vernon map-area the original rocks and the superimposed metamorphism are all pre-Permian in age and probably pre-Cambrian. Jones also described (1959, pp. 47-49 and pp. 28-29) five different localities where unconformities separate Shuswap rocks of the Monashee and Chapperon groups from rocks of the Cache Creek group of Permian age.

The present writer mapped in detail three of these localities, near Lavington, at B.X. Creek and at Salmon River.

Near Lavington the contact described by Jones as an unconformity is considered to be a fault. However, the relations between metamorphic and non-metamorphic rocks are compatible with the existence of an unconformity which, if it exists, is not exposed.

At B.X. Creek, the arcuate path described by Jones as marking an unconformity was found to follow a nearly-straight line in a northerly direction and to coincide with two parallel, steeply-dipping and north-trending faults which truncate the non-metamorphic rocks.

At Salmon River the evidence for an unconformity is strong. The rocks below the unconformity are chloritic

and argillaceous schists of the Chapperon group and strike northeast with steep dips to the southeast and northwest. The rocks above the unconformity are calcarenites, feldspathic volcanic wackes and tuffs grading upward into argillites, and have been described by Jones as part of the Cache Creek group; they strike north or slightly east of north and dip gently to the west or west-northwest.

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Fig. 1 Salmon River Unconformity between rocks
of the Chapperon and Cache Creek groups.

CHAPTER I - INTRODUCTION

I Location

Jones (1959, pp. 28-29 and pp. 47-49) describes unconformities between Shuswap and younger rocks at five different localities. The present writer has mapped three of these localities on a large scale.

The Keefer Gulch area is located approximately two miles west of Lavington, on the north side of Coldstream Valley, which runs east from Vernon to Lumby. More precisely, the area comprises both sides of a small valley, which descends into Coldstream Valley from the north and is locally known as "Keefer Gulch". The area covers about three square miles.

The B.X. Creek area lies three miles northeast of Vernon, on the northwest side of B.X. Creek, and covers about 2.3 square miles, on and around a low hill, henceforth referred to as B.X. Hill. The locality can be reached from Vernon by the Silver Star Mountain road.

The Salmon River area, 12.2 miles west of Westwold and approximately 30 miles northwest of Vernon, covers about one square mile. It lies on both sides of the Salmon River Valley, where the motor road that joins Westwold to Douglas Lake crosses the Salmon River on two bridges that are about a quarter of a mile apart.

II Climate and Vegetation

The Keefer Gulch and B.X. Creek areas are located in the immediate vicinity of Okanagan Lake and are included in the "dry belt" of Central British Columbia. Yearly precipitation is meager here, summers are hot and dry, and winters are cold. The lower portions of the valleys, where not irrigated and cultivated, are either devoid of timber or sparsely dotted with ponderosa pine (western yellow pine). The low vegetation is characterized by patches of low bushes, sagebrush, thorns and small cactus. The upper portions of the valleys and the upper plateaus are covered by dense timber, including Douglas fir, lodgpole pine and aspen.

The Salmon River area is located immediately to the west of the "dry belt", in a moister region. Vegetation is characterized by dense conifer forest with patches of aspen and willow.

III Previous Geological Work

The three areas mapped are within the Vernon map sheet (see G.S.C. map 1059A).

Earliest accounts of geological mapping in this general region are by G.M. Dawson (1878, 1879) and by R.A. Daly (1911, 1915).

More recent work was begun in 1945 by H.M.A. Rice, and completed in 1951 by A.G. Jones who in 1959 summarized

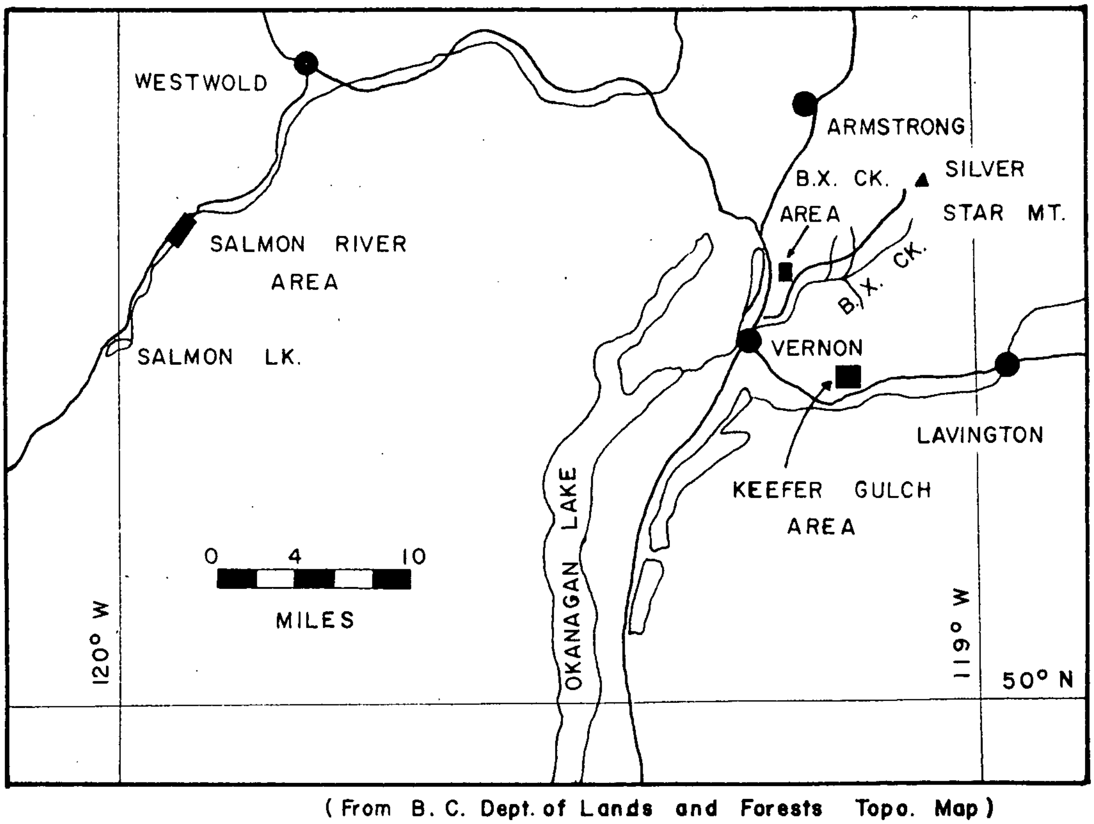

Fig. 2 Index showing location of the areas mapped.

his studies in G.S.C. Memoir 296, the most recent report available on this area.

IV General Geology

About two-third of the Vernon map sheet is underlain by a series of generally high-grade metamorphic rocks which were first named "Shuswap Series" by Dawson in 1877-78. This term was later extended by Daly (1911, p. 167) to include all "Pre-Beltian rocks in the area". Daly also stated that metamorphism in these rocks had been produced by "deep burial under Pre-Cambrian sediments or volcanics".

In his recent account, Jones (1959, p. 9) used "the term 'Shuswap' as a stratigraphic unit....much as Dawson intended it". Jones assigned to the Shuswap rocks a pre-Cambrian and possibly pre-Windermere age, and divided them into three major groups whose stratigraphic relation to one another is uncertain. At the bottom of his stratigraphic column, Jones put the Monashee group, composed largely of high-grade gneiss and schist and a small amount of marble, dolomite, slate and phyllite. The group underlies practically all the eastern half of the Vernon map-sheet, and was estimated to be at least 50,000 feet thick.

The Mount Ida group, approximately 60,000 feet thick and subdivided into six formations, was thought to overlie the Monashee group. Mount Ida rocks underlie most of the northwestern quarter of the Vernon sheet and include sedimentary and volcanic rocks which had generally "undergone low-grade metamorphism, resulting in the development of chlorite and sericite schists from volcanic and certain sedimentary rocks" (Jones, 1959, p. 18).

The Chapperon group, which in the southwestern corner of the map-area forms a northward trending belt of rocks approximately 30 miles long and one to six miles wide, was provisionally assigned by Jones to the top of the Shuswap Terrane. This group, at least 5,000 feet thick, consists of argillite, low-grade schist, quartzite and limestone. Jones remarks (op. cit., p. 30) that the rocks of the Chapperon group have "lithology and metamorphism similar to those of the Eagle Bay formation", the uppermost formation of the Mount Ida group, and that (op. cit., p. 28) "the top of the group is marked in two places by an unconformity at which Permian rocks of the Cache Creek group overlie Chapperon group rock".

The unconformity mentioned above is stated by Jones to mark the top of the Shuswap Terrane and, in the western half of the Vernon map-area, to separate Shuswap rocks of Archaean age from Cache Creek group rocks of Permian age.

V The Shuswap problem

G.M. Dawson (1879, pp. 96B-101B), described the rocks of the Shuswap terrane as part of an Archaean metamorphic complex, the relations of which to the overlying strata were not clear. He mentioned a remarkable parallelism in trend between these rocks and the overlying strata, but he suspected that this apparent conformity might have been produced by intense folding.

In 1904 R.G. McConnell and R.W. Brock published an account of the geology of the West Kootenay Map Sheet and suggested that in this area the rocks they mapped as Shuswap series were "highly metamorphosed members of the Paleozoic formations occurring in this district". This conception was chiefly due to the fact that the authors noted a gradation from high-grade metamorphic rocks into lower-grade rocks and finally into practically unmetamorphosed strata, thought to be of Paleozoic age. It was here, then, that the suggestion was first made that the metamorphism of "Shuswap Rocks" might have been induced by intrusions of any age and that such rocks are not necessarily Archaean.

In 1911-1912, R.A. Daly visited the area and examined rocks along the Canadian Pacific Railway near Shuswap Lakes. He described a locality at Albert Canyon where "...the oldest formation of the Beltian system is a quartzitic sandstone, resting unconformably on the

Shuswap Terrane..." (1915, p. 62). A few lines further, however, he also stated that "...the basal sandstone is feldspathic and has been changed into a schistose, micaceous rock which resembles the underlying orthogneiss rather closely...the sand becomes more and more quartzose further up from the gneiss...". From a suite of specimens taken by that writer at various points in the section, it appears that the transition from orthogneiss to quartzite (80 percent quartz, 13 percent feldspar, 5 percent biotite) occurs over a stratigraphic distance of 300 to 350 feet. In one of his reports, Daly also describes the metamorphism of the Shuswap rocks as "static" or "load metamorphism", produced by deep burial under pre-Cambrian sediments (1911, p. 168).

In 1913 S.J. Schofield (p. 136) described Beltian strata at Crawford Bay, on Kootenay Lake, and stated that at Crawford Creek they "...appear to pass conformably underneath the Shuswap series. If this be true, this area of so called Shuswap rocks does not belong to the pre-Beltian, but is a metamorphosed division of Beltian rocks..." He locally described the metamorphism to be connected to intrusions of the West Kootenay (Nelson) Batholith of probable Jurassic age.

In 1928 H.C. Gunning visited Daly's locality of the Albert Canyon unconformity and reported:

> "...Fresh granite dykes that cut the gneisses, also cut the overlying sediments. No unconformity

> was noted. The gneisses are exactly similar to those encountered elsewhere in the granite - gneiss-sediment complex. The intimate manner in which the gneisses are interbedded with the sediments indicates that they have been formed by replacement and injection of the sediments by a granitic magma..." (op. cit., p. 150A).

In 1929, 1930 and 1931 C.E. Cairnes (1932, pp. 66-109) worked in the northern Okanagan region, where he found Cache Creek and underlying Nisconlith beds (the latter had previously been tentatively classed as Cambrian by Dawson and as pre-Beltian or Archaean by Daly) to be equally deformed and to be affected by metamorphic processes in the vicinity of contacts with Shuswap-type rocks. Contacts of the above strata with the gneisses appeared to the author to be mostly gradational, except in places where the Shuswap consisted of massive granitic rocks, which appeared to be intrusive.

In 1934 B.B. Brock (pp. 673-699) examined a relatively small area immediately south of Kelowna, on the east shore of Okanagan Lake. There he found evidence of doming of Shuswap gneisses by an intrusive granitic body. From his investigation he concluded that the metamorphism of Shuswap rocks has been caused by upward thrusting of granitic magma en-masse, which produced doming of the strata, alinement of minerals parallel to the direction of stretching, and injection of innumerable sills of ortho-gneiss in the invaded rocks. He considered the metemorphism to be a dynamic process, and related it to igneous intrusions of possible post-Triassic age. The suggestion of dynamic metamorphism was supported by Gilluly (1934), whose contribution is based on a petro-fabric study carried out on two specimens, one of schist and one of gneiss, from Daly's unconformity locality at Albert Canyon.

In 1939, C.E. Cairnes, in summarizing his investigations on the problem, concluded that the metamorphism of the Shuswap rocks is "a relatively recent event in the geological history of this terrane". He stated (1939, p. 269) that the metamorphic changes are connected to the intrusion of Mesozoic plutons. These intrusions were characterized by "a process of gradual soaking of the superincumbent rocks", so as to produce, in most places, relatively mild deformation. By such a process he explained the generally elliptical shape of bodies of Shuswap gneisses and their gradational contacts with overlying rocks. Regarding the age of the gneisses he stated (op. cit., p. 270) that near Shuswap Lakes the formations affected by the metamorphism are probably of pre-Cambrian (Beltian) age, but that in other areas the metamorphism extended, even if in a milder form, into Late Paleozoic and probably Triassic formations.

In 1959 A.G. Jones presented evidence that in the Vernon map-area the Shuswap rocks, the superimposed metamorphism, and the accompanying minor granitic intrusions are all of pre-Permian and possibly of pre-Cambrian age. He subdivided the Shuswap Terrane into three groups the Monashee, the Mount Ida and the Chapperon group, which he considered to be separated by an unconformity from the overlying Cache Creek strata of Permian age.

VI <u>Purpose of the present investigation</u>

It is the purpose of this investigation to describe in detail three areas where the unconformity between Shuswap and Cache Creek rocks was described by Jones.

VII <u>Methods Used</u>

The three areas mapped were chosen from Jones' descriptions of the localities at which the unconformity had been found.

Field mapping was carried out by this writer between May 6 and May 30, 1963, using aerial photographs at a scale of approximately four inches equal one mile and two inches equal one mile. Base maps of the areas at a scale of one inch equal 1,000 feet and one inch equal 500 feet and with 100-foot contour intervals were also used, and the elevations of most points were checked with an altimeter kindly loaned by the University of British Columbia, Department of Geography.

VIII Difficulties encountered

The main difficulty encountered while mapping was the scarcity and spottiness of exposures. This problem was most acute at B.X. Creek. Here the low hill, around which the mapping was done, is largely covered by glacial drift and the few exposures are very small, low, and scattered. The geological information that could be gathered was therefore inadequate and too spotty to permit a convincing synthesis of the structural picture.

Exposures were also scarce in places at Keefer Gulch, but the problem here was not as acute as at B.X. Creek.

At the Salmon River location rock exposures were found to be common along the river, in roadcuts, and on steep bluffs, but a short distance away from the valley bottom, to the northwest and southeast, they are masked by a thick cover of unconsolidated glacial and fluvio-glacial material.

CHAPTER II - KEEFER GULCH AREA

I General Description

The area is located two miles west of Lavington, and comprises both sides of a small valley which descends into Coldstream Valley from the north, and which is locally known as "Keefer Gulch". A network of logging roads, which covers the northern portion of the area, is connected with highway No. 6 to the south by a jeep road which runs along the bottom of the gulch.

The southern part of the area consists of barren open slopes, sparsely dotted with pine and aspen, but the bottom of the gulch and the northern part of the area are heavily timbered with pine, fir and cedar, and covered by dense underbrush.

Glacial and fluviatile drift cover is extensive. Rock exposures are common on steep slopes, especially in the southern portion of the area, but are small and widely scattered on the gentle upper slopes and in the heavily timbered northern portion of the area.

The western and southern part of the area (see plate I) are underlain by low-grade schists, the foliation of which strikes easterly and dips moderately to the south. Several dykes cut these metamorphic rocks. The north-eastern portion of the area is underlain by unmetamorphosed volcanic wackes and breccias with interbeds of limestone, of probable Upper Palaeozoic age.

Jones (1959) suggested that an unconformity separates metamorphic and non-metamorphic rocks. The present writer mapped the area in detail and found that the two groups of rocks are separated by a series of steeply dipping faults which strike northeasterly and easterly. Five fault blocks have been distinguished and will be considered separately.

II <u>Metamorphic Rocks   Sub-areas 1 and 2</u>

(a) <u>Lithology</u>

Metamorphic rocks underlie sub-areas 1 and 2. They consist of a conformable sequence of low-grade micaceous and phyllitic schists, all belonging to the greenschist facies, quartz-albite-epidote-almandine subfacies. The most common of these rocks are calcareous biotite-muscovite schists. These, in hand specimen, are dark gray, bluish gray or brownish gray, fine grained, and have a strong foliation produced by segregation of minerals into irregular layers and lenses. Schistosity and lineation are well developed and are marked by the alinement of platy and prismatic minerals along planes parallel to the general layering of the rock. In thin section these schists are seen to consist mainly of calcite, biotite, muscovite, quartz and a little albite. A few small scattered crystals of epidote are also present. The texture is lepidoblastic with granoblastic layers of quartz and feldspar. The mineral assemblage of these schists suggests that they formed from calcareous pelitic sediments.

Two types of hornblende-mica schist underlie the central part of the western half of the area. The more basic type, composed almost entirely of hornblende and

Fig. 3 Keefer Gulch, sub-area 1. Quartz boudin in highly-deformed argillaceous schist. Picture taken looking northwest.

biotite, is greenish in colour and medium grained, with numerous large porphyroblasts of hornblende. The schistosity in this rock is very well developed owing to the abundance of mica. In thin section the rock is seen to contain approximately 60 percent pale-green hornblende, 25 percent biotite, 10 percent quartz and smaller amounts of chlorite, calcite and sodic plagioclase. The texture is strongly lepidoblastic with large porphyroblasts of hornblende. A more siliceous type containing in places only 15 to 20 percent mafic minerals, is greenish gray in

Fig. 4 Keefer Gulch, sub-area 2. Hornblende porphyroblast in quartz-biotite-hornblende schist. Crossed nicols (X 15).

colour, has a poorer schistosity and, in places, somewhat resembles an impure quartzite. In thin section this rock is seen to contain up to 60 percent quartz, 10 percent albite, 15 percent biotite and 10 to 15 percent green hornblende and chlorite. The texture is lepido-granoblastic and the foliation is very clearly marked by irregular layers of granoblastic quartz which shows a strong optical orientation. These schists are of the same metamorphic grade as the pelitic schists described above, but derived from more basic, possibly volcanic rocks.

Fig. 5 Keefer Gulch, sub-area 2. Compositional layering paralleling schistosity in hornblende-biotite-quartz schist. P.P.L. (X 15)

A sequence of green chloritic phyllites and fine-grained schists crops out in the southeastern corner of the map area and extends out of it to the east. In hand specimen these rocks commonly, if not everywhere, have a well marked schistosity and lineation, and appear to be composed of a fine-grained, chloritic, quartzo-feldspathic groundmass with oriented plates of biotite and irregular porphyroblasts of amphibole. In thin section the rocks appear to be chiefly composed of chlorite, albite, quartz,

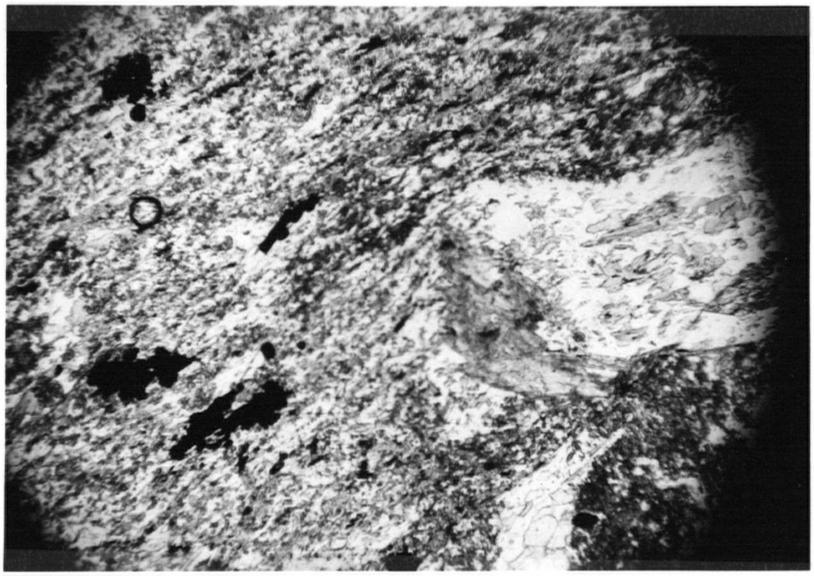

Fig. 6 Keefer Gulch, sub-area 1. Schistosity in chlorite-hornblende schist. P.P.L. (X 45)

biotite and hornblende, with scattered patches of zoisite and calcite. The texture is lepidoblastic with granoblastic layers of quartz and feldspar. The above mineral assemblage suggests that these rocks were formed by low-grade regional

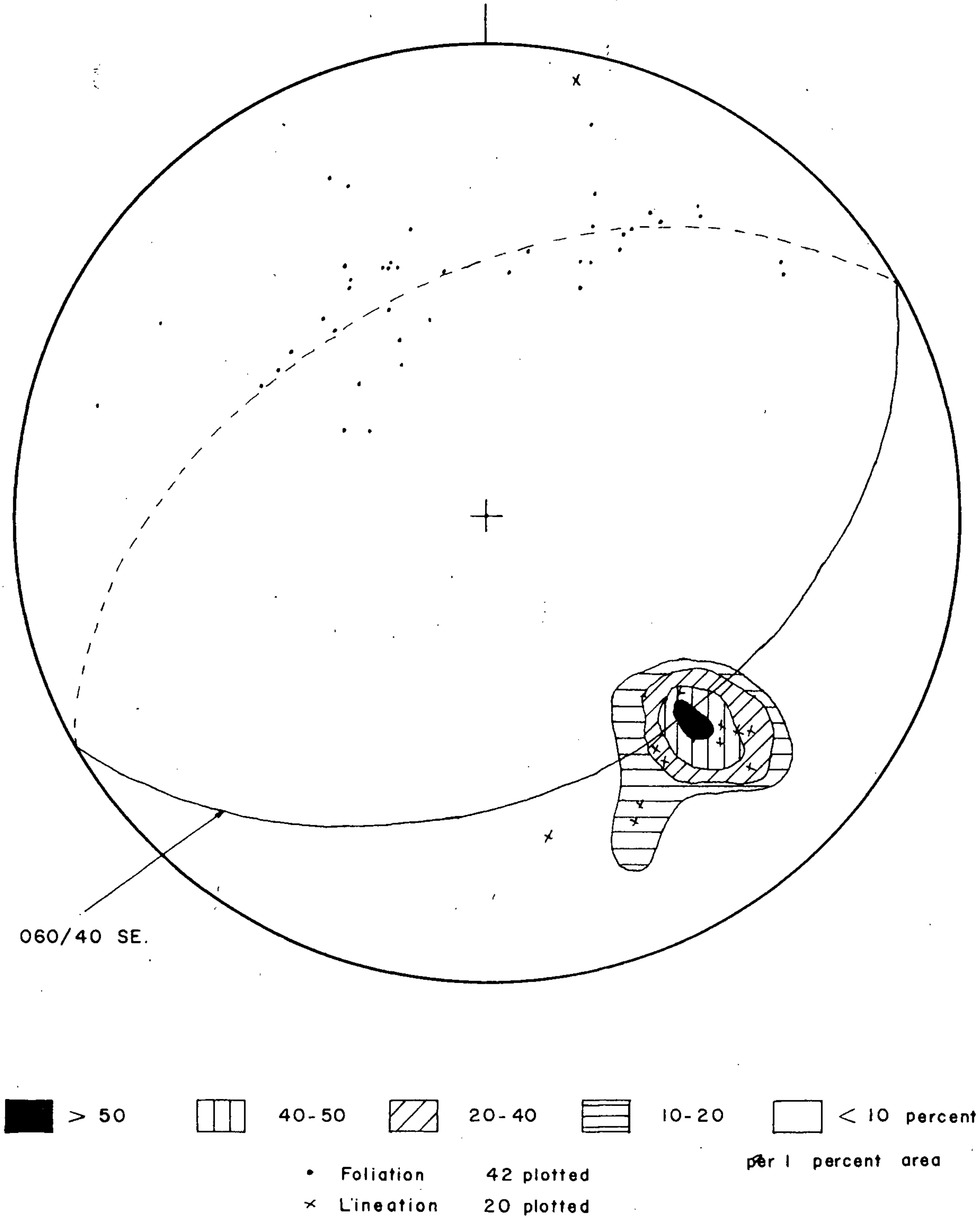

Fig. 7 Equal-area lower-hemisphere projection of poles to schistosity and lineations in sub-area 1 at Keefer Gulch. Great circle represents average attitude of schistosity.

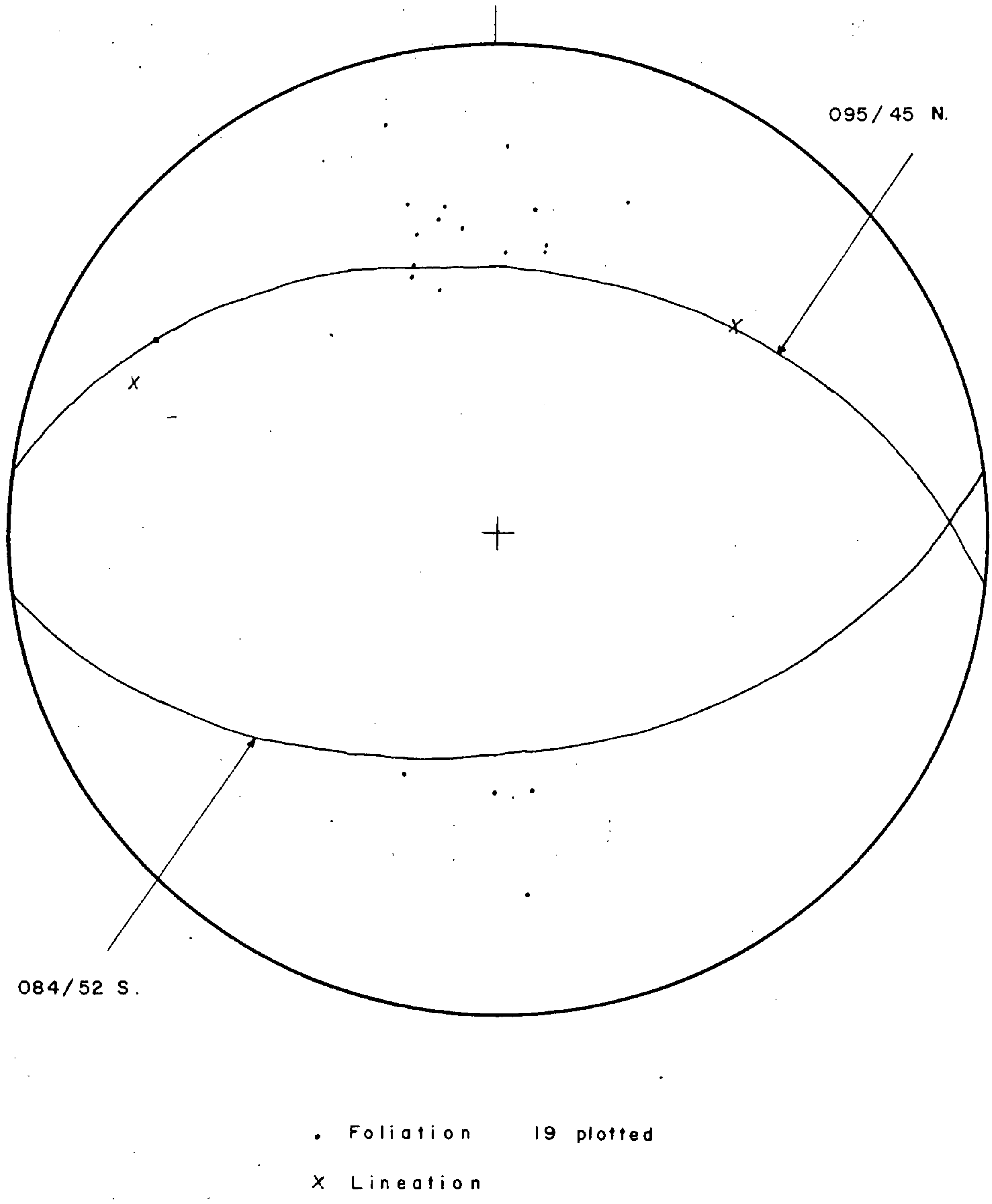

Fig. 8 Equal-area lower-hemisphere projection of poles to schistosity and of lineations in sub-area 2 at Keefer Gulch. Great circles represent average attitudes of schistosity.

metamorphism of basic volcanic rocks, probably andesitic lavas.

These phyllites and schists, which have been described by Jones (1959, p. 48) as non-metamorphosed andesitic lavas, are grouped by the present writer with the metamorphic rocks in the western half of the area. This correlation is based mainly on the conformable schistosity and equal metamorphic grade of the rocks.

(b) Internal structural relations

(1) Stratigraphy - The metamorphic rocks described above form a conformable sequence, in which strikes are approximately easterly and dips are moderate to the south and southwest. An antiform, also trending easterly, is present in the northern part of the area. The following table is a summarized description of the various types of schists in stratigraphic succession from north to south.

Approximate thickness in feet	Lithology
?	Chlorite-biotite-hornblende and chlorite-biotite phyllite; greenish; probably meta-andesite.
?	Biotite-muscovite calcareous schist; brownish-gray.

Approximate thickness in feet	Lithology
700	Muscovite-biotite argillaceous schist; limey; bluish-gray to black.
900	Hornblende-biotite-quartz schist; greenish.
700	Quartz-biotite-hornblende schist; green.
?	Argillaceous-micaceous phyllite; dark-gray.

(2) Planar structures - Both schistosity and layering are well developed in the schists of sub-areas 1 and 2. In outcrop the rocks split easily along closely-spaced planes of schistosity which are parallel to any compositional banding or layering that is present.

A plot of poles to schistosity and layering in sub-area 1 (see fig. 7) reveals a general scattering of points along a great circle which has an approximate attitude of 060/50N.W. This writer suspects that the area under consideration has undergone at least two, or possibly more, phases of folding. All that can be said about these rocks is that at the present time the general attitude of their schistosity is 060/40S.E. and that they possibly represent the faulted and re-folded southern limb of an antiform trending a few degrees north of east (see below).

A similar plot of the poles to schistosity and layering for sub-area 2 (see fig. 8), also reveals a general eastwest trend, with an appreciable scattering of points. In the extreme northern portion of the map-area the schistosity of hornblende-mica schists dips to the north and suggests an east-trending antiformal axis near the northern border of the map.

(3) Linear structures - Planes of schistosity bear one prominent lineation marked by elongated biotite flakes, hornblende crystals, and ridges of quartz or feldspar. Axes of small folds which occur on the planes of schistosity are also more or less parallel to this lineation.

Most of the lineations were found in sub-area 1, and are plotted in fig. 7. As shown on plate I, the conformity of attitudes of schistosity and lineation in metamorphic rocks on either side of Keefer Gulch should be noted. This fact does not support the existence of a north-trending fault along Keefer Gulch. Linear structures in general plunge moderately to the southeast, an average figure for such attitude being 136/38°.

(c) <u>External structural relations</u>

The metamorphic rocks at Keefer Gulch appear to be divided in two blocks by at least one branching fault which trends northeast and passes through the centre of the map-area. The two blocks are referred to as sub-areas 1 and 2. The fault is assumed on the basis of sharp lithological and structural discordance between rocks of sub-areas 2, 3 and 5, as shown on the enclosed map. The

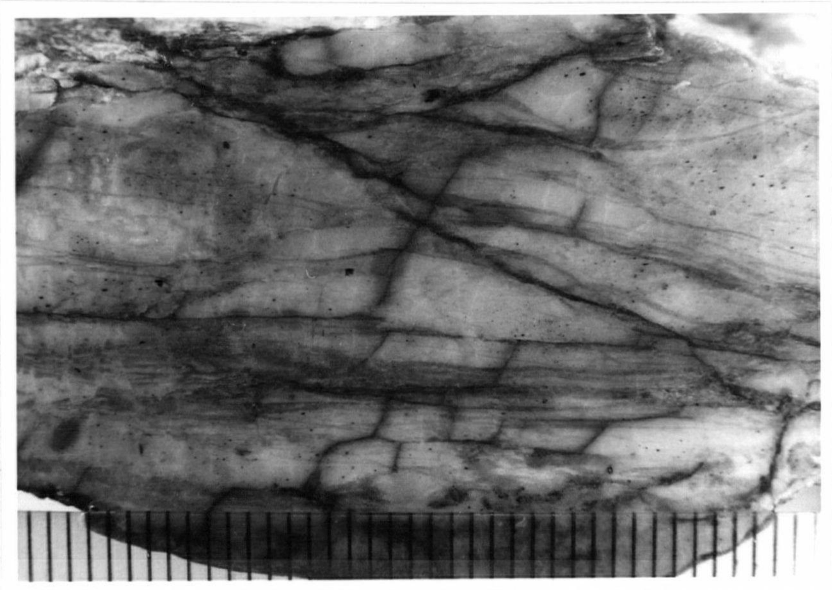

Fig. 9 Keefer Gulch. Mylonite from the fault separating sub-areas 1 and 3. 1/20 inch scale

fault is also marked by a strong lineament which is clearly visible in aerial photographs of the area.

In sub-area 1, to the east of Keefer Gulch, the contact between green chloritic schists and unmetamorphosed sedimentary rocks is also marked by a fault which was observed at two locations. In the immediate vicinity of this fault, intense fracturing occurs in both walls. The fault is marked by an irregular band of reddish-weathering, strongly slickensided and foliated quartz-sericite mylonite which varies in thickness from six inches to two feet. An attitude of this mylonite band was taken at the eastern end of the fault as marked on plate I.

Above the mylonite zone, in the hanging wall of the fault, there is a zone of intense brecciation and leaching ranging from five to 15 feet in thickness. Rock fragments in this zone range from less than one inch to one or more feet in diameter and consist only of white and gray limestone and of gray, siliceous volcanic wacke. The actual fault plane appears to undulate and branch somewhat and cuts into the white hanging wall limestone, making it discontinuous and causing a great deal of fracturing and recrystallization.

On the western side of Keefer Gulch, the contact between calcareous schists of sub-area 1 and rocks of sub-area 4 is also marked by a fault, probably the same described above, but dipping more steeply. An exposure of the fault contact was never observed, but it appears that the two sub-areas are here separated by a few feet of reddish weathering, leached, and sheared breccia. Only one small outcrop of this breccia was found, and specimens collected from it and examined in thin section appear to consist of a finely granular mass of recrystallized quartz and sericite, identical to the mylonite which was described in the preceding paragraphs as marking the fault on the eastern side of the gulch. The fault is marked by a straight and very steep gully which runs down into Keefer Gulch and which is well in line with the projection of the fault from the east.

(d) Tentative correlation

Although the experience of this writer with rocks of the Shuswap Terrane is limited to little more than four weeks of field work concentrated in the three areas described in this thesis, the following remarks can be made regarding the correlation of the metamorphic rocks at Keefer Gulch:

1. All the rocks belong to the greenschist facies.
2. Deformation was strong and probably polyphase.
3. The rocks were produced by low-grade regional metamorphism of pelites and of basic sedimentary and volcanic rocks.
4. The typical Monashee group rocks as described by Jones (1959, pp. 10-17) are of much higher metamorphic grade than the schists at Keefer Gulch. Even the low-grade metamorphic rocks of subdivision 1A-C in G.S.C. Map 1059A (1960) do not match well with the schists described above.

5. Because of their metamorphic grade and mineral assemblage, a correlation of these schists with rocks of the Eagle Bay formation (Jones, 1959, pp. 22-27) seems more appropriate than a correlation with rocks of the Monashee group.

III Intrusive Rocks

At least five different types of dyke rocks cut the low-grade metamorphic rocks which have been described above. Unfortunately no cross-cutting relations have been observed among these dykes, so that their relative ages are unknown. Absence of any of these intrusives in the unmetamorphosed Permian rocks which underlie the northeastern part of the map-area, suggests that the dykes may all be pre-Permian in age.

(a) Porphyritic biotite microdiorite

Two large dykes of porphyritic biotite microdiorite, varying in thickness from 50 to 80 feet, have been mapped in the western part of the area. One of the dykes strikes roughly northeast and dips moderately to the southeast, the other strikes slightly south of east and dips, also moderately, to the south. The course of each dyke, and especially that of the northeast trending one, is somewhat sinuous, and in places the trend is almost conformable to the schistosity of the country rocks.

A third dyke of similar composition and approximately 25 feet thick was found cutting through the basic phyllitic schists in the southeastern corner of the map area. The trend of this dyke is also northeasterly and the dip is steep to the southeast.

Fig. 10 Keefer Gulch, sub-area 1. Myrmekite surrounding a labradorite phenocryst in porphyritic biotite microdiorite. Crossed nicols (X 45)

The dyke rock is melanocratic, medium grained and porphyritic. In thin section it is seen to be composed chiefly of strongly altered phenocrysts of augite up to 3.5 mm. in diameter, of fresh phenocrysts of andesine-labradorite (An 48-54) with a thin albitic rim, and of subhedral to euhedral crystals of biotite, usually not more than 1.5 mm. in diameter. The groundmass, which forms approximately 40 percent by volume of the rock, consist of subhedral to anhedral masses of perthite, of small patches of quartz and of anhedral graphic intergrowths of quartz and orthoclase. Calcite, sericite, chlorite, magnetite and clay minerals are common alteration products. Apatite, an unusually abundant accessory mineral, occurs in subhedral to euhedral grains up to 0.7 mm. in diameter, and is associated with pyroxene. The texture is hypautomorphic inequigranular.

(b) Feldspar porphyry

One outcrop of a sheared and broken feldspar - biotite porphyry was found along the bottom of Keefer Gulch, in the northern part of the map-area. No other outcrop of this rock was found. Except for a faintly developed foliation, more or less conformable with the schistosity of the surrounding metamorphic rocks, no other information as to the contact relations of this porphyry with the country rocks is available. The rock is however believed to be of intrusive origin and probably to represent a dyke.

(c) Lamprophyre

Several biotite lamprophyre dykes were observed in the extreme southwestern corner of the map-area. The dykes range in thickness from two to 12 feet, strike northeast and dip moderately to steeply to the northwest. No thin section of the dyke rock was examined.

(d) Diabase

Two diabase dykes were found cutting through pelitic schists in the southwestern part of the map area. One dyke, approximately six feet thick, strikes slightly west of north and dips steeply to the west. The other is approximately 15 feet thick, strikes easterly, has a moderate southerly dip and is in turn cut by a steeply dipping band of quartz-feldspar pegmatite which strikes 115°. Thin sections of the diabase dykes were not made.

(e) Aplite and quartz-feldspar pegmatite

Several small bodies of aplitic quartz porphyry and of quartz-feldspar pegmatite cut through the schists in the western half of the map-area. Strikes are northwesterly and slightly south of east. As mentioned above, one body of pegmatite was found cutting through a diabase dyke. At the bottom of Keefer Gulch, a small dyke of reddish-weathering, pyritiferous quartz porphyry was found to have been emplaced along the foliation of some badly broken pelitic schists.

The aplite and pegmatite dykes are probably among the youngest intrusives in the area. At any rate, they are younger than the diabase dykes which they cut.

IV Non-Metamorphic Rocks

Non-metamorphic rocks are confined to the eastern and northeastern part of the map-area. They consist chiefly of massive green volcanic conglomerate, volcanic wackes containing lenses or large pods of gray fossiliferous limestone, green massive andesitic lava and sheared and locally strongly leached andesite breccia.[1]

These rocks are believed to be part of one fault block which was downdropped in post-Permian time so that it is now in contact with the highly deformed metamorphic rocks described previously. During faulting, this larger block, which is roughly rectangular in shape with the long side pointing to the northeast, was broken into three smaller blocks which were rotated with respect to one another. No ready correlation can be made between the pieces of this fault block; attitudes of bedding, although more or less constant within each block, are commonly very

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1 For the classification used in naming these and other volcanic sedimentary rocks in this thesis, refer to Williams, Turner and Gilbert, "Petrography", Ch. 16, 1954.

different between one block and another. For simplicity of description these three fault blocks will be referred to as sub-areas 3, 4 and 5 (see plate I).

(a) <u>Sub-Area 3</u>

(1) Lithology - Sub-area 3 is the largest of the three fault blocks mentioned above, and occupies the east-central part of the map area. To the south the block is in fault contact with the green phyllites of sub-area 1. To the north and northwest it is separated from sub-area 5 by a northeast-trending fault. To the west it is separated from sub-area 4 by Keefer Gulch.

The lowermost unit of sub-area 3 is a white, sugary limestone approximately 15 to 20 feet thick. The limestone is badly broken and largely recrystallized so that no measurements of bedding attitude could be taken. Some fragments of crinoids are present in the rock, but the age of the unit could not be determined from them.

A layer of light-gray, strongly leached pyritiferous, hard, volcanic conglomerate and breccia lies conformably above the limestone. The unit is approximately 80 to 100 feet thick and contains one lens of gray, finely crystalline, fractured limestone which is locally rich in crinoidal debris. The limestone lens is approximately 20 feet thick, at least 300 to 400 feet long and appears to be conformable with the gross layering in the breccia, which dips moderately to the northwest.

A bed of gray and medium-gray arkosic volcanic wacke, approximately 80 feet thick, overlies conformably the volcanic breccia and is in turn overlain, apparently

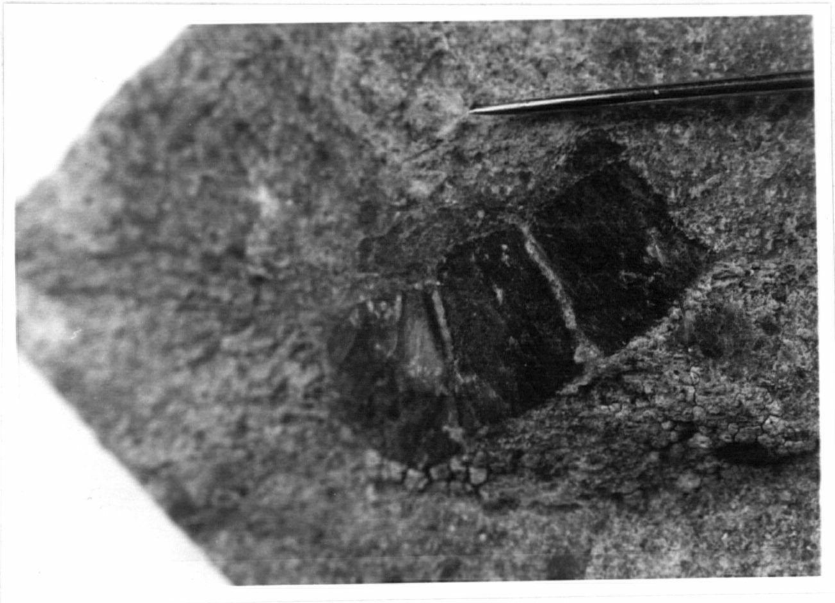

Fig. 11 Keefer Gulch, sub-area 3. Crinoid fragment in gray limestone. Needle is ½ inch long.

conformably, by two beds of sandy volcanic sediments. The lower of these is a gray to dark-gray siltstone approximately 60 feet thick with argillaceous bands and finely disseminated pyrite. The rock is in places highly fractured and contains at least one lens of gray, thinly bedded limestone, locally rich in crinoid plates. The other bed is a coarser greenish-gray lithic volcanic wacke approximately 150 feet thick, also broken in places and which contains at least two lenses of limestone, very similar to those mentioned above, but poorer in crinoidal debris.

Fig. 12 Keefer Gulch, sub-area 3. Rock fragment containing devitrified shards in lithic volcanic wacke. P.P.L. X 45.

The wacke is overlain, apparently conformably, by a green, massive, hard volcanic breccia which consists of fragments of micaceous phyllite, schist, quartzite, volcanic and granitic rocks several inches long and set in a green matrix composed of rock chips and other detritus. The rock is very poorly sorted and was formed by rapid deposition of rubble from a volcanic terrane. Fragments of metamorphic rocks were probably brought up through a diatreme with other volcanic rubble. At least one large lens of gray, thinly bedded, finely crystalline, non-fossiliferous limestone, 500 to 600 feet long and more

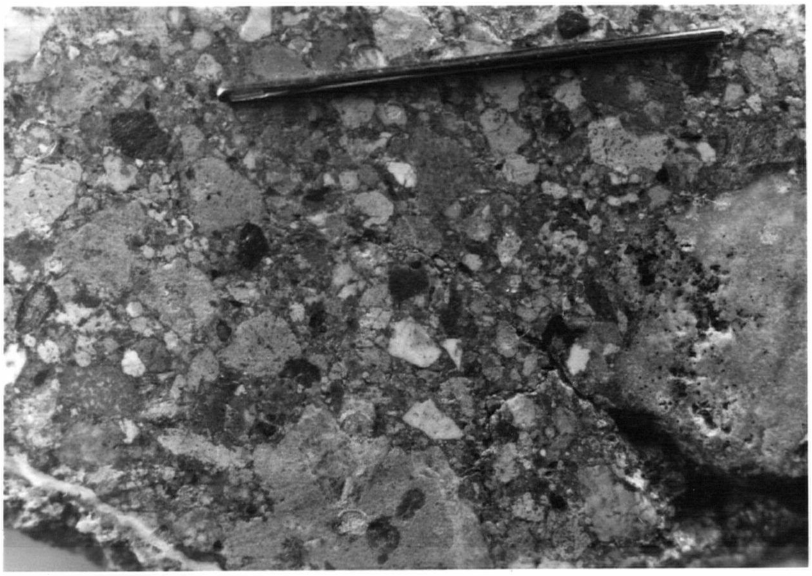

Fig. 13 Keefer Gulch, sub-area 3. Volcanic conglomerate. Needle is 1 inch long.

than 100 feet thick is interbedded with the conglomerate. The upper limit of the breccia is not known due to heavy drift cover and widely scattered exposures. Widely spaced outcrops of a greenish-gray lithic volcanic wacke, occur in the northern half of sub-area 3. Dips are not clear or very marked, but seem to be moderate to the northwest.

Scattered exposures of gray limestone, very similar to that forming some of the lenses described above were also found in this area. Elongation of these exposures parallel to the trend in the wacke, and association have led to the interpretation of the limestone as forming lenses within the wacke.

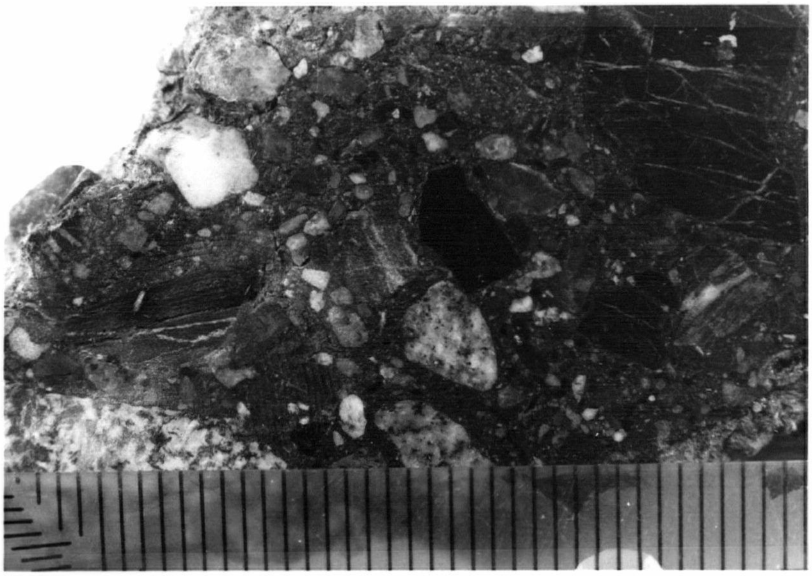

Fig. 14 Keefer Gulch, sub-area 3. Volcanic conglomerate. 1/20 inch scale.

(2) Internal structural relations - The rocks in sub-area 3 are believed to form a conformable sequence which has an approximate minimum thickness of 400 to 500 feet. The table below is a summarized description of the rock types

described above as they appear in stratigraphic succession.

Approximate thickness in feet	Lithology
?	Lithic volcanic wacke; light-greenish-gray; limestone and breccia interbeds.
?	Volcanic breccia; massive, greenish; contains fragments of schist, quartzite and volcanic rocks; large limestone lens.
150	Lithic volcanic wacke; greenish-gray, broken; lenses of fractured limestone.
60	Siltstone; gray to dark-gray; lenses of gray limestone.
80	Arkosic volcanic wacke, gray.
100	Siliceous volcanic conglomerate and breccia; light-gray, pyritiferous; reddish-weathering; lenses of gray limestone.
20	Limestone; white, sugary; broken.

Bedding dips are approximate to the north, northwest and north-northeast as shown in fig. 15. The appreciable scattering of attitudes noticeable in this diagram may have been produced by deformation which accompanied faulting. The rocks, especially in the lowermost units, are broken and fractured, with the cracks filled by late calcite.

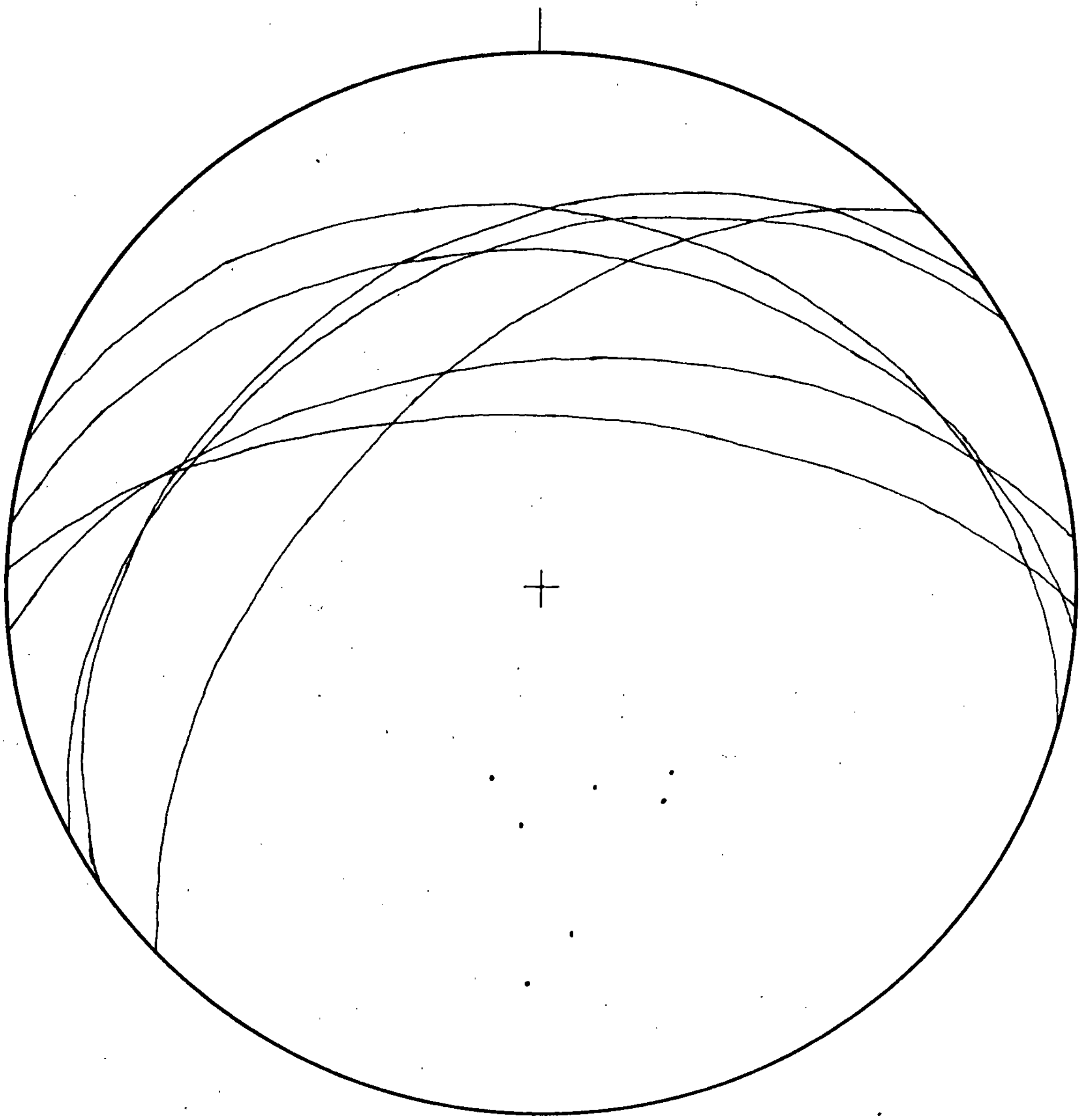

Fig. 15 Equal-area lower-hemisphere projection of bedding attitudes in sub-area 3 at Keefer Gulch.

(b) Sub-Area 4

(1) Lithology - Sub-area 4 is the smallest of the three fault blocks of non-metamorphic rocks and is exposed only along a small steep ridge which runs up the western side of Keefer Gulch. The

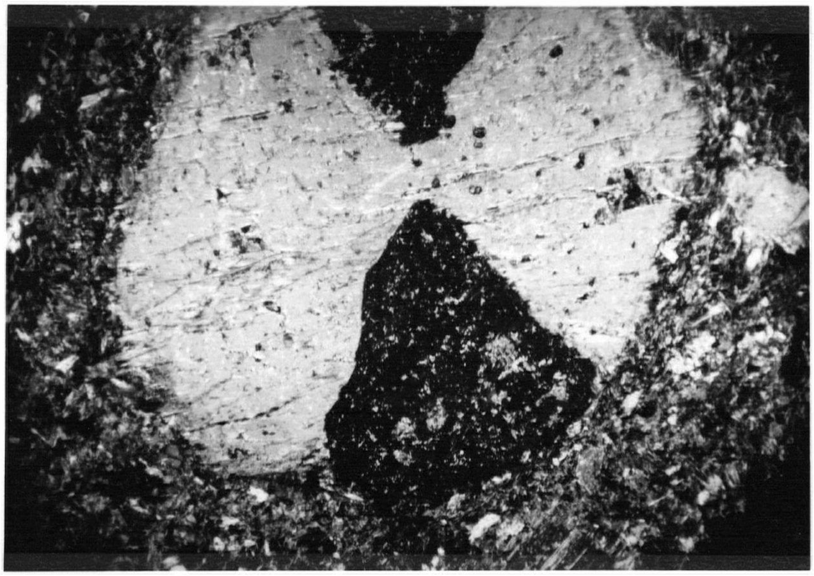

Fig. 16 Keefer Gulch, sub-area 4. Intergrowing actinolite crystals in micaceous actinolite porphyry. Crossed nicols (X 15)

rocks at the top of the ridge are stratigraphically lowest, as dips are believed to be to the east at moderate angles.

The lowermost unit in this sequence is considered to be separated from rocks of sub-area 1 to the south by a fault which is marked by a zone of reddish-weathering mylonitized breccia, very similar to the one found along the fault which separates sub-area 1 from sub-area 3. In hand specimen the rock appears to be a greenish, micaceous pyroxene porphyry. In thin section however, the rock is seen to have undergone a good deal of reconstitution, possibly deuteric alteration, and consists of large phenocrysts of pale-green actinolite, possibly pseudomorphous after pyroxene, and set in a medium-grained biotite-actinolite groundmass. (See fig. 16). Small amounts of quartz, poorly twinned albite-oligoclase (An_{10-12}), zoisite and calcite are also visible. The rock is probably an altered porphyritic andesitic lava in which the original pyroxene has changed to actinolite.

An olive-green, fine-grained arkosic wacke, not more than 10 or 12 feet thick overlies conformably the lava and is in turn overlain by a massive, sugary, white limestone, approximately 25 to 30 feet thick. In thin section the limestone is seen to be strongly recrystallized, to consist exclusively of anhedral calcite grains 2 to 3 mm. in diameter and to be completely devoid of any fossil remains. The similarity between this limestone and that found in sub-area 3 is striking and it may well be that they are the same unit. The different appearance and composition of the two layers of volcanic breccia which, as will be mentioned below, respectively overlie the two beds of white limestone on either side of Keefer Gulch, could be explained by changes along the strike.

The white limestone is succeded conformably by a sequence of green, massive volcanic breccia and conglomerate which contains irregular lenses and pods of broken and somewhat recrystallized gray limestone. The rock is massive and very poorly bedded, but attitudes of limestone layers and of irregular, more arenitic layers, suggest a moderate easterly dip, in keeping with the rough layering observed in the underlying units. Fragments of phyllite and quartzite are common in the conglomeratic portions, but are greatly outnumbered by large fragments of volcanic rocks, of amphibolite, and of coarse hornblende containing finely disseminated magnetite. These rock fragments are set in a green, amphibolitic matrix consisting of smaller rock chips and of broken crystals of hornblende usually 3 to 5 mm. in length.

In thin section the breccia is seen to contain up to 50 or 60 percent hornblende, either as broken crystals in the groundmass or as a major component of amphibolite fragments. Sphene is a common accessory mineral and occurs as large, well facetted crystals scattered in the groundmass or in fragments of amphibolite. It is possible that the amphibole present in this breccia, rather than being of metamorphic origin was produced by quenching of a hydrous basaltic magma in the manner described by Yoder and Tilley (1962). These authors obtained a mixture of amphibole, sphene, plagioclase, magnetite and glass by holding an oxidized hawaiite at temperatures ranging from 750 to 800° C for periods of 66 to 24 hours respectively, and at a water pressure of 5000 bars (op.cit., p. 444). The authors also stated that "...most runs, when quenched above the liquidus, gave charges consisting almost wholly of amphibole with minor amounts of magnetite and some glass..." (op. cit., p. 445). It is conceivable that, after quenching, the blocks of hornblende and amphibolite were brought to the surface by volcanism to be included in the breccia.

(2) Internal structural relations - Structural information in sub-area 4 is very scarce as no actual measurement of bedding can be made in the massive and non-bedded rocks. A rough attitude can however be deduced by observing the trace of contact between units, and by tracing lenses of limestone in the volcanic breccia described above; such observations suggest that dips are to the east at moderate angles. The following table is a summary of the rock types described above as they appear in stratigraphic succession.

Approximate thickness in feet	Lithology
? (more than 100)	Volcanic breccia; green, massive; contains boulders of hornblendite, quartzite, schist, volcanic rocks; some gray limestone.
30	Limestone; white, sugary.
10	Arkosic volcanic wacke; olive-green.
40	Micaceous actinolite porphyry; greenish.

(c) Sub-Area 5

(1) Lithology - The lowest exposed member of the sequence in sub-area 5 is a dark-gray to yellowish-gray andesitic breccia, locally leached and strongly sheared. The extent and nature of this breccia are unknown because of very poor exposures.

The breccia is overlain by a sequence of light-green, massive, medium-grained, porphyritic andesitic lavas, 250 to 300 feet thick. In thin section the rock has a holocrystalline porphyritic texture and consists of a groundmass of minute laths of plagioclase in which are set large phenocrysts and clusters of albitic plagioclase crystals up to 1.5 mm. in diameter, and a few subrounded and strongly chloritized rock fragments. All the feldspar is strongly saussuritized and has been reduced to albite

(An_{5-8}). Chlorite, sericite and calcite are abundant alteration products and are present everywhere as irregular anhedral masses.

A sequence of light-green, hard and fresh-looking volcanic wacke, approximately 350 feet thick, overlies the

Fig. 17 Keefer Gulch, sub-area 5. Bent feldspar crystal in volcanic wacke. Crossed nicols (X 45).

lavas. The bedding in this unit is graded and indicates that the strata face northeast. The beds range in thickness from a few inches to a few feet and grade from coarse conglomeratic bands containing fragments of volcanic rocks several inches long, to very fine-grained silty bands rich in argillaceous matter.

Towards the top of the unit, exposures become few and scattered, but the wacke appears to be overlain by a layer of greenish-gray volcanic breccia and conglomerate, very similar to that of sub-area 4 and largely composed of

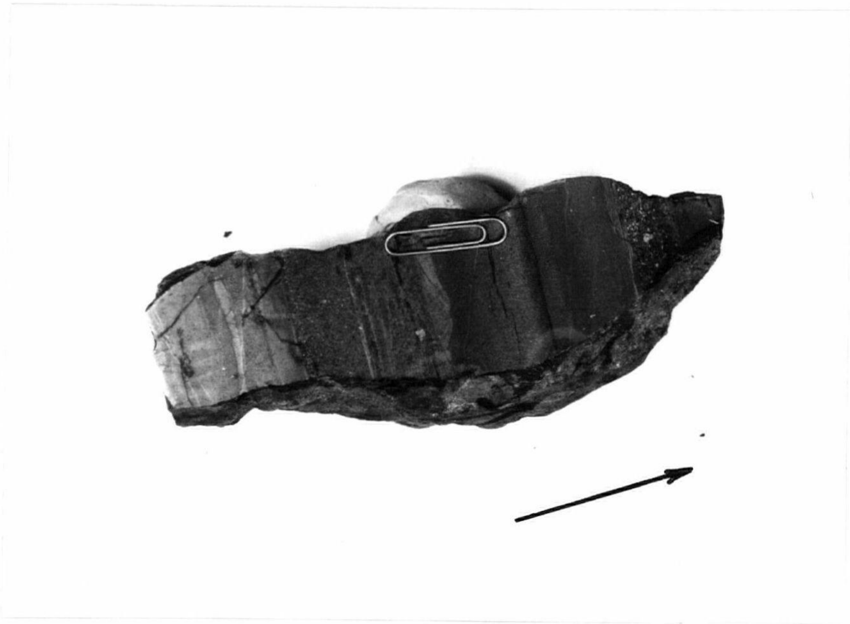

Fig. 18 Keefer Gulch, sub-area 5. Graded bedding in volcanic wacke. Paper clip is 1 inch long.

slightly rounded pebbles and cobbles of metamorphic, sedimentary and volcanic rocks. The top of this unit is ill-defined, but seems to be marked by a steeply dipping shear zone which trends southeast. Above the shear zone, exposures are totally lacking, but further to the north, and probably across a northeast-trending fault, a few scattered exposures of hornblende-mica schist were found along a logging road.

(2) Internal structural relations - Sub-area 5 is an elongated fault segment with the long side oriented northeasterly across the centre of the map-area. Strikes are south-easterly and dips are moderate to steep to the northeast. Graded bedding in the volcanic wacke indicates a normal upward sequence with beds facing northeast. This sequence is shown in the table below.

Approximate thickness in feet	Lithology
?	Volcanic breccia and conglomerate; greenish-gray, contains pebbles and cobbles of quartz, phyllite, limestone and volcanic rocks.
350	Volcanic wacke; light-green, well bedded, locally graded bedded.
300	Porphyritic andesitic lava; light-green, massive, chloritized.
?	Andesitic breccia; dark-gray to yellowish-gray.

(d) External structural relations

Sub-areas 3, 4 and 5 are underlain by unmetamorphosed, sedimentary and volcanic rocks, whereas the rest of the map area is underlain by low-grade metamorphic rocks, cut by several types of dykes. By a separate examination of sub-areas 3, 4 and 5, it has been attempted to show that these three sub-areas represent three different fault segments, all part of a fault block which was brought in contact with the highly deformed metamorphic rocks of sub-areas 1 and 2, some time after they had been intruded by the dykes. Attitudes within each fault segment are fairly constant, but are greatly different in each segment. This is believed to be the result of independent rotational movement of the three slices as faulting occurred.

The kind of deformation that was imposed on the metamorphic rocks of sub-areas 1 and 2 is also different from that shown by the unmetamorphosed strata of sub-areas 3, 4 and 5. The former rocks have been strongly deformed and probably have undergone more than one phase of folding. Metamorphic mineral assemblages, well developed foliation and lineation suggest that folding was accompanied by low-grade metamorphism and that it occurred at a depth of approximately 4 miles (Turner and Verhoogen, 1960, Ch. 18). The latter group of rocks, on the contrary, is less intensely deformed and is virtually unmetamorphosed. Most of the deformation in these rocks occurred at a much shallower depth and was of the brittle type, resulting in faulting.

The faults that bound sub-areas 3, 4 and 5 are shown on the enclosed map. The east-trending fault that separates sub-areas 3 and 4 from sub-area 1 was observed at two points to the east of Keefer Gulch and was found to dip moderately to steeply to the north. To the west of the gulch, the fault is probably very nearly vertical. Very little or no displacement of the fault occurs as it crosses Keefer Gulch, and this fact throws some doubt on the existence of a north trending fault along the gulch as described by Jones (1959, p. 48), but does not necessarily disprove it.

The northeast-trending branching fault that cuts through the centre of the map area and which bounds sub-area 5, was never observed, but its existence was invoked to explain structural and lithological discrepancies between sub-areas 2, 3 and 5. Near the centre of the map area, the branches of the fault are shown to converge and to continue as one fault to the southwest, bounding sub-area 4. The only evidence for assuming the fault exists and has such a course in this part of the map area, is the presence on aerial photographs of a strong lineament which is on the projection of the assumed branches of the fault from the northeast. Along the northern boundary of sub-area 4, rock exposures are completely absent, and the thick cover of overburden would have to be removed in order to obtain any information about this critical part of the map area.

(e) Correlation and Age

The rocks that underlie sub-areas 3, 4 and 5 were assigned by Jones a "Carboniferous (?) and Permian" age, and presently are considered to be part of the Cache Creek group.

V The "Keefer Gulch Unconformity"

In his report on the area, Jones (1959, pp. 47-48) describes the Cache Creek group rocks as lying unconformably on "micaceous phyllites, calcareous quartzites, mica schists and pegmatite belonging to the Shuswap Terrane". In the map accompanying his report he specifies that these metamorphic rocks belong to the Monashee group. In the same paragraph he states:

> "...The unconformity lies on the west slope of a small valley...known locally Keefer Gulch ...A consolidated breccia of the underlying phyllite marks the contact and is partly leached and altered to a white, rusty weathering, vesicular rock composed of quartz and sericite. Lying immediately above the weathered breccia is a massive, rather fresh-looking lava of green, andesitic augite porphyry comprising a more or less flat-lying flow about 10 feet thick...".

The present writer identifies the "reddish breccia" with the mylonite which separates sub-areas 1 and 4, and the "fresh-looking lava" with the micaceous actinolite porphyry of sub-area 4.

The following points are to be noted:

1. There is a sudden change in metamorphic grade and structure between rocks of sub-areas 1 and 2 and rocks of sub-areas 3, 4 and 5.
2. Numerous dykes cut the metamorphic rocks, but are absent in the non-metamorphic rocks.
3. Rocks underlying sub-area 1 and 2 are highly deformed and of low regional metamorphic grade belonging to the greenschist facies. Metamorphism probably occurred at an approximate depth of 4 miles.
4. Rocks of sub-areas 3, 4 and 5 are unmetamorphosed and less intensely deformed than the metamorphic rocks.
5. Wherever the contact between metamorphic and non-metamorphic rocks was observed, it was found to be marked by a zone of mylonite, denoting a fault. A basal breccia, marking an unconformity was nowhere observed.

Points 1, 2, 3 and 4 above, are compatible with the existence of an unconformable relation between metamorphic and non-metamorphic rocks. The contact described by Jones as an unconformity is considered by this writer to be a fault. Thus the unconformity, if it exists, is not exposed and the question must be left open.

CHAPTER III - B.X. CREEK AREA

I General Description

The area lies approximately three miles northeast of Vernon, on the north side of B.X. Creek. More precisely it covers approximately 2.3 square miles on and around B.X. Hill, a low, rounded hill, barren in its lower parts but covered by sparse conifers at its top. The area can be reached from Vernon by following the Silver Star Mountain road for approximately three miles and there turning north on a country road.

Most of the area is covered by an extensive layer of glacial and fluviatile outwash and thus rock exposures are very few and widely scattered. Metamorphic rocks of the Monashee group, consisting mainly of impure quartzite and of gneiss cut by small bodies of pegmatite crop out on either side of B.X. Hill. They strike northerly with gentle to steep easterly and westerly dips. A central strip that includes the top of the hill is underlain by sheared and broken volcanic wackes which strike easterly and dip moderately to the north and to the south. The contact between metamorphic and non-metamorphic rocks in this area has been described by Jones (1959, p. 48) as an unconformity and as following an arcuate path around the slopes of B.X. Hill. The present writer found this contact to be nearer straight than arcuate and believes it to consist of two approximately parallel, steeply dipping and north-trending faults which truncate the non-metamorphic rocks.

II Metamorphic rocks

(a) Lithology

Metamorphic rocks in the area consist mainly of biotite-quartz-feldspar gneisses, ranging in colour from brownish gray to light gray, and of medium to dark-gray impure quartzite. The gneisses are cut by many small, discontinuous, irregular bodies of light-coloured muscovite-quartz-feldspar pegmatite, which are in general parallel to the layering of the host-rock. Layering in the gneisses is well developed, with alternating dark- and light-coloured strata, ranging from a few inches to several feet in thickness and almost certainly reflecting the different composition of the original sedimentary rocks from which the gneisses derived. In thin section the rock appears as a medium-grained, granoblastic mass of quartz, feldspar and biotite. The foliation is well marked by lens-like concentrations of quartz grains, commonly strongly optically oriented, and by alined plates of biotite. K-feldspar is present in variable amounts. Plagioclase ranges in composition from An_{20} to An_{45}, but in most rocks it is oligoclase (An_{25}). Accessory minerals are zircon, apatite and magnetite.

Impure quartzite was found only in the southern part of the area, where it is interbedded with gneiss. The rock is everywhere strongly weathered and in places very argillaceous.

A massive, light-green to gray-green tremolite rock is exposed only on the eastern slopes of B.X. Hill, where it forms steep cliffs trending northerly.

Metamorphic rocks in the southern part of the map area are cut by veins of white quartz, two to five feet thick, which strike northeast and dip steeply to the northwest.

(b) Internal structural relations

Strikes of foliation in the metamorphic rocks range from northerly to northwesterly with gentle to moderate dips to the east and northeast. Some dips, however, are to the southwest, suggesting a southeast-trending fold axis. In the southern part of the area, although attitudes are scarce and exposures scattered, there is an alternation of gneiss and quartzite trending more or less northerly.

Minor fold axes plunge moderately to the southeast in the northern and southern part of the area.

(c) External structural relations

Jones (1959, p. 48) described an unconformity separating metamorphic and non-metamorphic rocks in the area. A detailed discussion of this point will be given later in this chapter, where the external structural relations of the non-metamorphic rocks are described.

(d) Correlation

Jones (1959, p. 48) describes the metamorphic rocks in the area as "mica gneiss and marble of the Monashee group, cut by pegmatite and granite of the Silver Star intrusions".

III Non-metamorphic Rocks

(a) Lithology

The most common non-metamorphic rock is a medium-gray, reddish-weathering, medium- to fine-grained, feldspathic volcanic wacke with interbeds of lithic wacke, breccia and argillite. A medium-gray, reddish-weathering, lithic volcanic wacke, usually sheared and leached, crops out on the northern and southern slopes of B.X. Hill. The rock contains small fragments of dark-gray to black phyllitic rocks and of gray, leached volcanic rocks set in a feldspathic matrix. Euhedral cubes of pyrite up to three or four mm. on the side, are scattered throughout. In outcrop the rock does not show any conspicuous compositional layering, but it has well developed, widely spaced planes of schistosity, which were apparently developed by shearing parallel to the bedding. The schistosity strikes easterly and dips to the north and to the south as shown on plate II, thus suggesting an east-trending synform. A reddish weathering, dark-gray to black, tuffaceous argil-

Fig. 19 B.X. Creek. Sheared feldspathic volcanic wacke. P.P.L. (X 15)

lite crops out within feldspathic wacke at the top of B.X. Hill. The rock is massive and forms only a few small exposures. Some light- to dark-green, massive, strongly leached volcanic pebble and boulder conglomerate, very similar to the volcanic conglomerates and breccias of

Keefer Gulch is also found on the southern slopes of B.X. Hill.

(b) <u>Internal structural relations</u>

The rocks described above strike easterly with moderate dips to the north and south, and apparently form

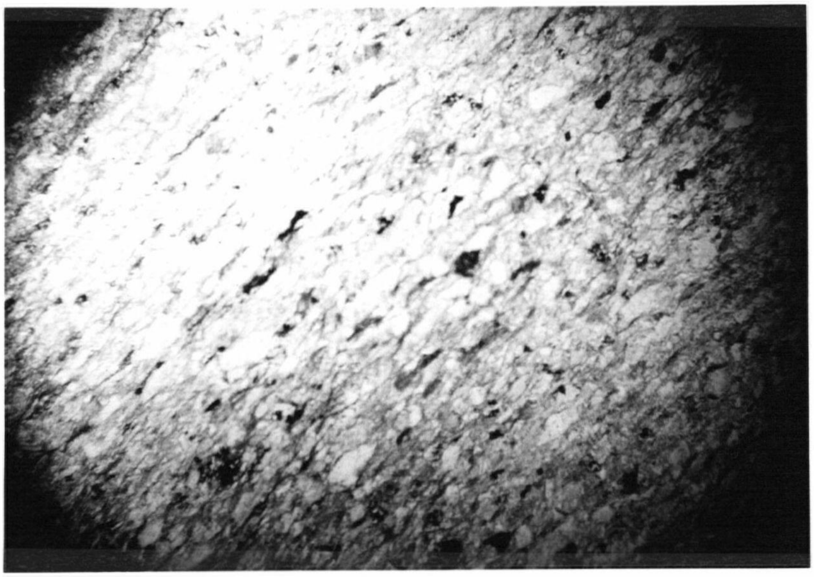

Fig. 20 B.X. Creek. Sheared feldspathic volcanic wacke. P.P.L. (X 15)

a broad east-trending synform. In the southern part of the area, attitudes are very inconsistent because of fracturing and faulting related to the north-trending fault which separates these rocks from gneiss of the Monashee group to the west.

(c) External structural relations

As shown on plate II, non-metamorphic rocks strike easterly and underlie only the central part of the area.

These rocks are truncated to the east and to the west by gneiss of the Monashee group which strike northerly and northwesterly.

The contacts between these two units follow nearly straight lines and are believed to be faults which strike northerly and dip steeply.

(d) Correlation and Age

The non-metamorphic rocks described above are very similar in lithology to the non-metamorphic rocks at Keefer Gulch which are considered to be of Cache Creek age.

IV Intrusive rocks

In the southern part of the area, non-metamorphic rocks are cut by a body of alaskite porphyry. It apparently strikes easterly and probably is a dyke. The rock is reddish weathering, light gray to almost white, fine grained, porphyritic, and sheared. A foliation, produced by shearing, strikes easterly and dips steeply to the north.

In thin section the rock has a strongly porphyritic texture. Large, euhedral crystals of strongly sericitized orthoclase and of albitized plagioclase (An_0-An_5), present in roughly equal amounts, and anhedral quartz grains with strongly resorbed borders are set in a very fine-grained groundmass of quartz and sericite.

Fig. 21. B.X. Creek. Quartz phenocryst with resorbed borders in sericitized alaskite porphyry. Crossed nicols (X 15)

V <u>The "B.X. Creek Unconformity"</u>

Jones described the area as being the site of the B.X. Creek unconformity, the outcrop of which "...trends in an arcuate path around the slopes of a conical bare hill (B.X. Hill) and lies in a position midway between the base and the crest at a more or less constant elevation..." (1959, p. 48).

A detailed examination by the present writer revealed a sharp change in lithology, structural trends, and grade of metamorphism between metamorphic and non-metamorphic rocks in the area. Exposures of the lithified regolith which, according to Jones, marks the unconformity were not found, and the contacts between metamorphic and non-metamorphic rocks are believed to be faults. This picture, similar to that produced for Keefer Gulch, is compatible with the existence of an unconformity which, if it exists, is not exposed. Thus the question must be left open.

CHAPTER IV - SALMON RIVER AREA

I General Description

The area mapped, approximately 2000 feet wide and 7000 feet long, lies along Salmon River Valley. It may be reached by following the Douglas Lake road for approximately 12.2 miles westward from Westwold.

Exposures are moderately common along the valley bottom and on the lower slopes, but at higher levels bed-rock is completely covered by a thick blanket of glacial and fluvio-glacial debris. The eastern slope of the valley is underlain mostly by highly deformed metamorphic rocks of the Chapperon group, which strike slightly east of north and dip steeply to the northwest and southeast. The western slope is chiefly underlain by fresh, undeformed sedimentary rocks belonging to either the Cache Creek or Nicola group. These strike northeasterly with gentle northwesterly dips and are believed to overlie unconformably the metamorphic rocks.

II Metamorphic Rocks

(a) Lithology

(1) Chapperon group - Rocks of the Chapperon group are highly deformed, very fine-grained, brownish-green to almost black, micaceous phyllitic schists which strike east-northeast and dip steeply. Even

in the hand specimen layering is very discontinuous, and small lenses and knots of very fine-grained quartz are much more common than continuous layers.

In thin section the rocks are seen to contain 50 to 60 percent quartz, and 30 to 40 percent biotite, commonly accompanied by smaller amounts of albite and epidote.

Fig. 22 Salmon River Unconformity. Blue pencil parallels dip direction of schistosity in Chapperon rocks; red pencil parallels dip direction of erosion surface.

Chlorite, calcite, sphene and magnetite are common accessory minerals.

The texture is usually finely lepidoblastic to granoblastic with irregular lenses of quartz. The quartz grains do not show obvious preferred optical orientation.

The schistosity is very well marked by oriented plates of mica and by the elongation of lenses of quartz, and is commonly crossed, at angles ranging from 60° to 90°, by closely spaced, post-crystalline s-surfaces of strain-slip cleavage (Williams, Turner and Gilbert, 1953, p. 213).

Fig. 23 Salmon River. Highly deformed siliceous argillaceous schist. Paper clip is 1 inch long.

Although the schists are commonly highly deformed, no clear evidence of retrograde metamorphism was found. The mineral assemblages mentioned above, and the texture suggest that these rocks are low-grade pelitic schists which probably belong to the quartz-albite-epidote-

-almandine subfacies of the greenschist facies (Turner and Verhoogen, 1960, p. 540).

Interbedded with the schists are layers of highly contorted "ribbon chert", ranging in thickness from a few feet to several hundreds of feet. Such layers are parallel to the general schistosity and are believed to represent

Fig. 24 Salmon River. Quartz lenses in siliceous schist. Crossed nicols (X 15).

original beds of chert within the shales from which the schists were formed.

A few quartz veins, 5 to 10 feet wide and trending northerly with steep easterly dips, cut the schists.

(2) Old Dave Intrusives - Several serpentinized dykes belonging to the Old Dave Intrusives (Jones, 1959, p. 34) cut the rocks of the Chapperon group. The dykes strike northwesterly and dip either very steeply or vertically. The two largest dykes are more than 300 feet thick and crop out near the

Fig. 25 Salmon River. Strain-slip cleavage in micaceous-argillaceous schist. P.P.L. (X 15).

middle of the map-area. They are paralleled to the north by three smaller bodies of serpentine. The rock ranges in colour from apple green to reddish brown and almost black, and is a strongly brecciated serpentine with irregular veinlets and pods of talcy or calcareous material.

In thin section the rock appears as a felted mass of serpentine and talc, with irregular patches of carbonate and disseminated minute euhedral to subhedral crystals of magnetite.

(b) Internal structural relations

The metamorphic rocks described above strike northeasterly and dip steeply to the northwest. Figure 25 is a lower-hemisphere equal-area projection of poles to the schistosity in these rocks.

From this diagram it is evident that:

1. The rocks form either a warped homoclinal sequence with an average attitude of 060/96°N.W., or a sequence of isoclinal folds, the axial planes of which have the above attitude.
2. The attitudes of few minor fold axes that could be obtained, produce a wide scatter of points, most of which lie near the great circle with attitude 060/96° N.W.

(c) External structural relations

The metamorphic rocks described are believed to underlie unconformably the sedimentary rocks which occupy the western half of the area. A more detailed description of the unconformity will be given later.

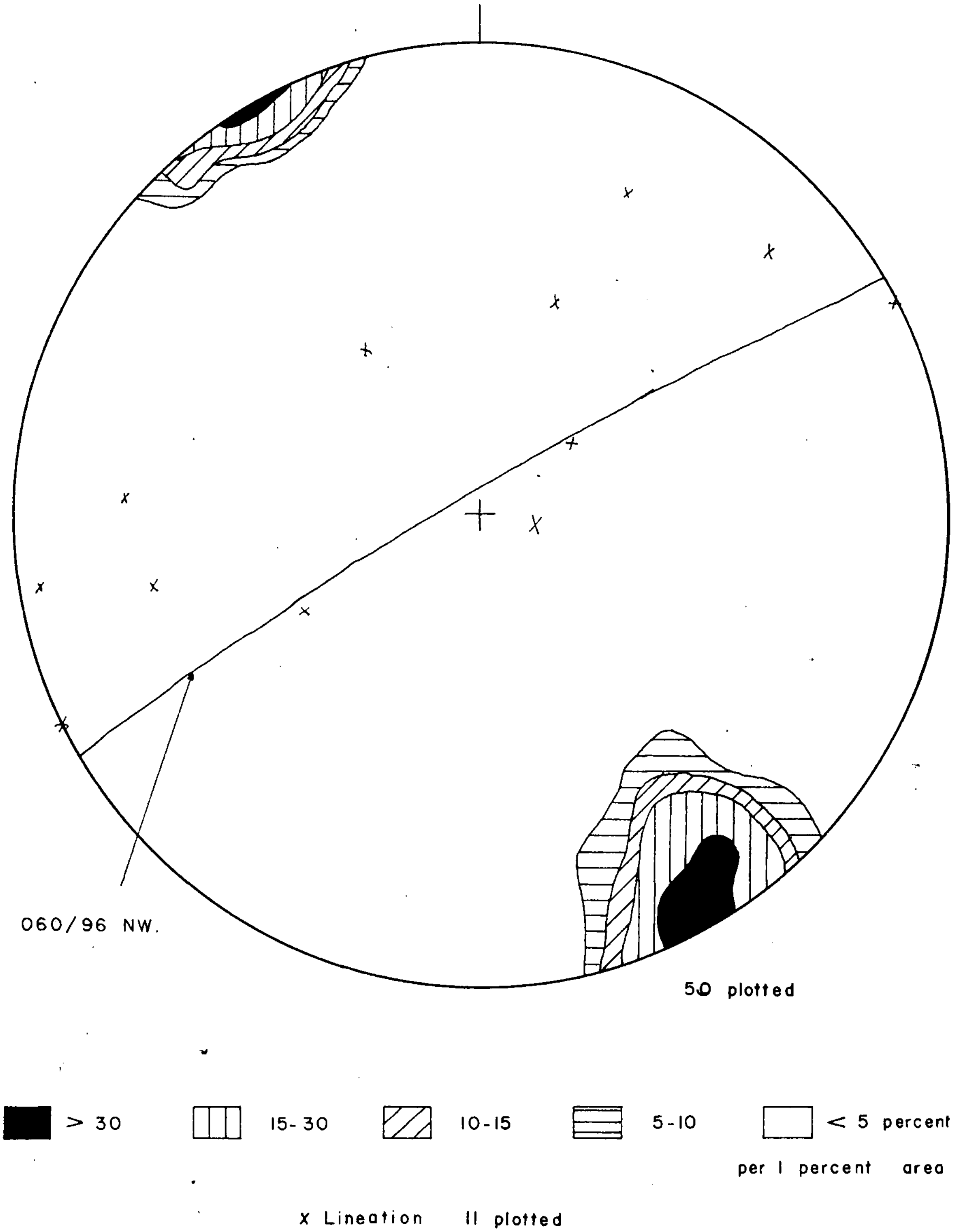

Fig. 26 Equal-area lower-hemisphere projection of poles to schistosity and of minor fold axes in Chapperon group rocks at Salmon River. Great circle represents average attitude of schistosity.

(d) Correlation and Age

The schists described above are low-grade metamorphic rocks of pelitic origin. In metamorphic grade and lithology they are similar to some of the metamorphic rocks at Keefer Gulch.

Jones (1959) has mapped these rocks as part of the Chapperon group, which he considered prě-Cambrian in age and very similar in lithology and metamorphic grade to the Eagle Bay formation, a portion of the Mt. Ida group.

The Old Dave Intrusives which cut the Chapperon group rocks were not found anywhere cutting the younger sedimentary rocks, and are therefore considered to be pre-unconformity in age. Their highly broken present appearance suggests that they were probably affected by some of the later phases of deformation which affected the Chapperon rocks.

III Non-metamorphic rocks

(a) Lithology

The lowest unit of the non-metamorphic rocks is a basal conglomerate which varies from 25 to 50 feet in thickness, is poorly bedded and contains sub-angular to poorly rounded pebbles, cobbles and boulders of light-gray quartzite, greenstone, chert, light-gray limestone, quartz and phyllite, set in a brownish-green, calcareous, slightly recrystallized biotitic matrix. The rock also contains irregular fine- and coarse-grained lenses and layers of calcarenite, which, together with a rough layering and alinement of the pebbles, mark a crude bedding. In outcrop the hard, siliceous fragments weather differentially from the matrix and stand out, thus producing a very rough, irregular surface. The rough layering in the rock is

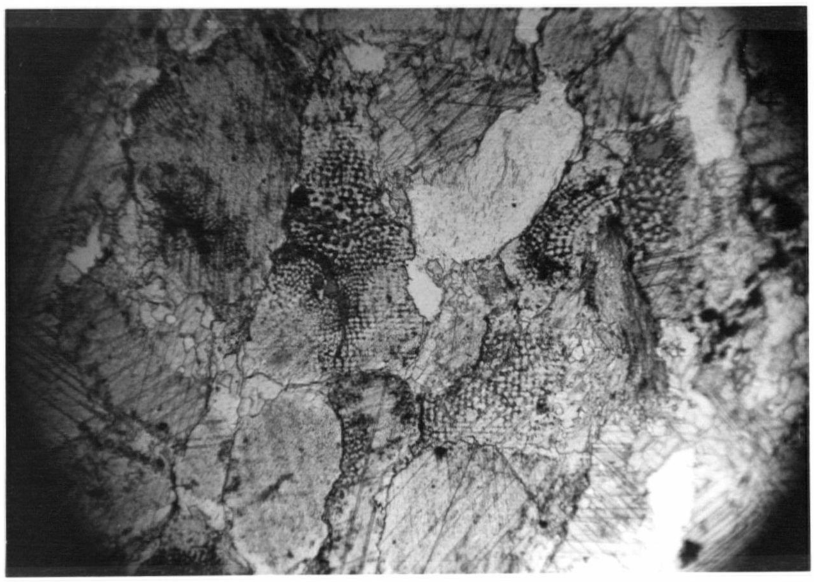

Fig. 27 Salmon River. Crinoid plates in calcarenite. P.P.L. (X 45).

conformable with that of more clearly bedded units higher in the sequence. In two places exposures were found in which both schist and overlying conglomerate are visible. The contact between the two units is sharp, unconformable and gently undulating.

Conformably overlying the conglomerate is a layer of medium- to dark-gray, coarse calcarenite, approximately 10 feet thick. In thin section the rock is seen to consist chiefly of subrounded fragments of limestone, and to contain abundant crinoidal and other organic debris (see fig. 27). Subrounded pebbles of chert and quartzite are also present in moderate amounts. The coarse calcarenite grades upwards into a finer-grained, darker-gray to almost black, tuffaceous and commonly argillaceous calcarenite, approximately 25 to 30 feet thick. The rock contains few cherty and some fossil fragments.

A 2.5 to 3-foot layer of light-green to greenish-gray, thinly bedded, silicified vitric crystal tuff overlies the calcarenite. This unit, although thin, was found to be very continuous and proved to be an excellent marker bed. In thin section (see fig. 28) the rock appears to consist mainly of a very fine-grained, siliceous matrix, rich in sericite, chlorite and carbonate, and probably representing altered glass. Small amounts of albitized feldspar, quartz, mica, chloritized hornblende and some altered fragments of chert are set in the matrix. The delicate bedding, the texture, and the extensive alteration suggest that the rock is a water-lain tuff.

Above the green tuff is a band of massive, brownish-gray to almost black feldspathic graywacke approximately 10 feet thick. In thin section the rock is seen to be very poorly sorted and to consist mainly of subangular grains of sericitized feldspar and quartz, 1.5 to 2 mm. in diameter and set in a matrix of biotite, calcite and argillaceous material. Chlorite, apatite and pyrite are common accessory minerals. Very few highly altered fragments of argillaceous rocks are also present. A bed of

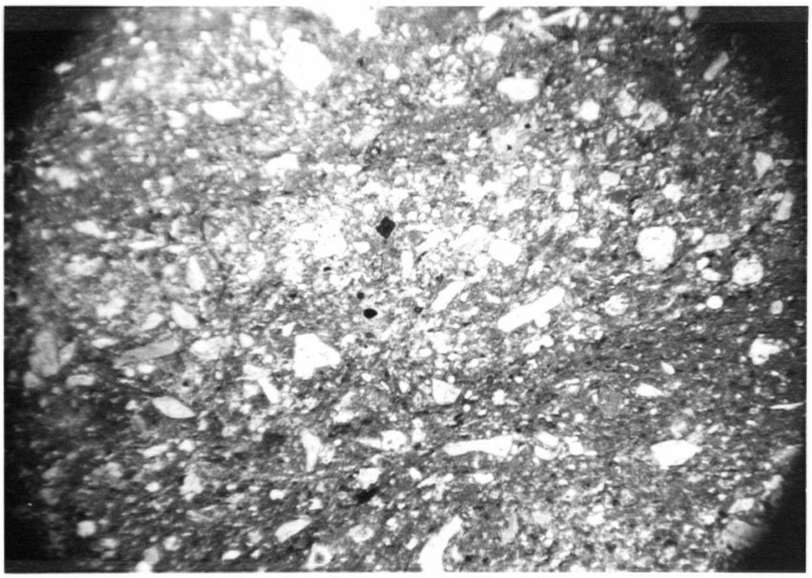

Fig. 28 Salmon River. Vitric crystal tuff. P.P.L. (X 15).

medium-grained, massive, green, andesitic rock, approximately 25 to 30 feet thick overlies the graywacke. In hand specimen the rock has the appearance of a basic intrusive rock, but in thin section it is seen to consist chiefly of subhedral, ragged crystals of actinolite set in a felted groundmass of clinozoisite, chlorite and calcite practically devoid of quartz and feldspar. The actinolite crystals commonly contain patches of calcite and clinozoisite. In three exposures, more than 2500 feet apart, this unit was found in contact with the graywacke or with overlying argillite. The contacts do not show any evidence of chilling or any other feature that might suggest the rock to be a basic sill. The constant stratigraphic position and thickness, together with mineral composition and texture suggest that the rock is an altered, andesitic crystal tuff or possibly a lava flow.

Conformably overlying this unit is a black, thinly bedded calcareous argillite with some thin, tuffaceous bands. The rock is hard and has a marked subconcoidal fracture, but where weathered it is very fissile and friable. The thickness of the unit, although it could nowhere be measured in a continuous exposure, is probably in the order of 60 to 70 feet.

A second bed of altered, andesitic crystal tuff, or andesitic lava, approximately 20 feet thick, overlies the argillite. In the hand specimen the rock is massive, fine grained porphyritic and brownish green in colour. In thin section it consist of subhedral, broken crystals of pale-green hornblende, of sericitized and broadly twinned feldspar, and of quartz showing embayed crystal faces, set in a matrix rich in biotite, hornblende, calcite, chlorite,

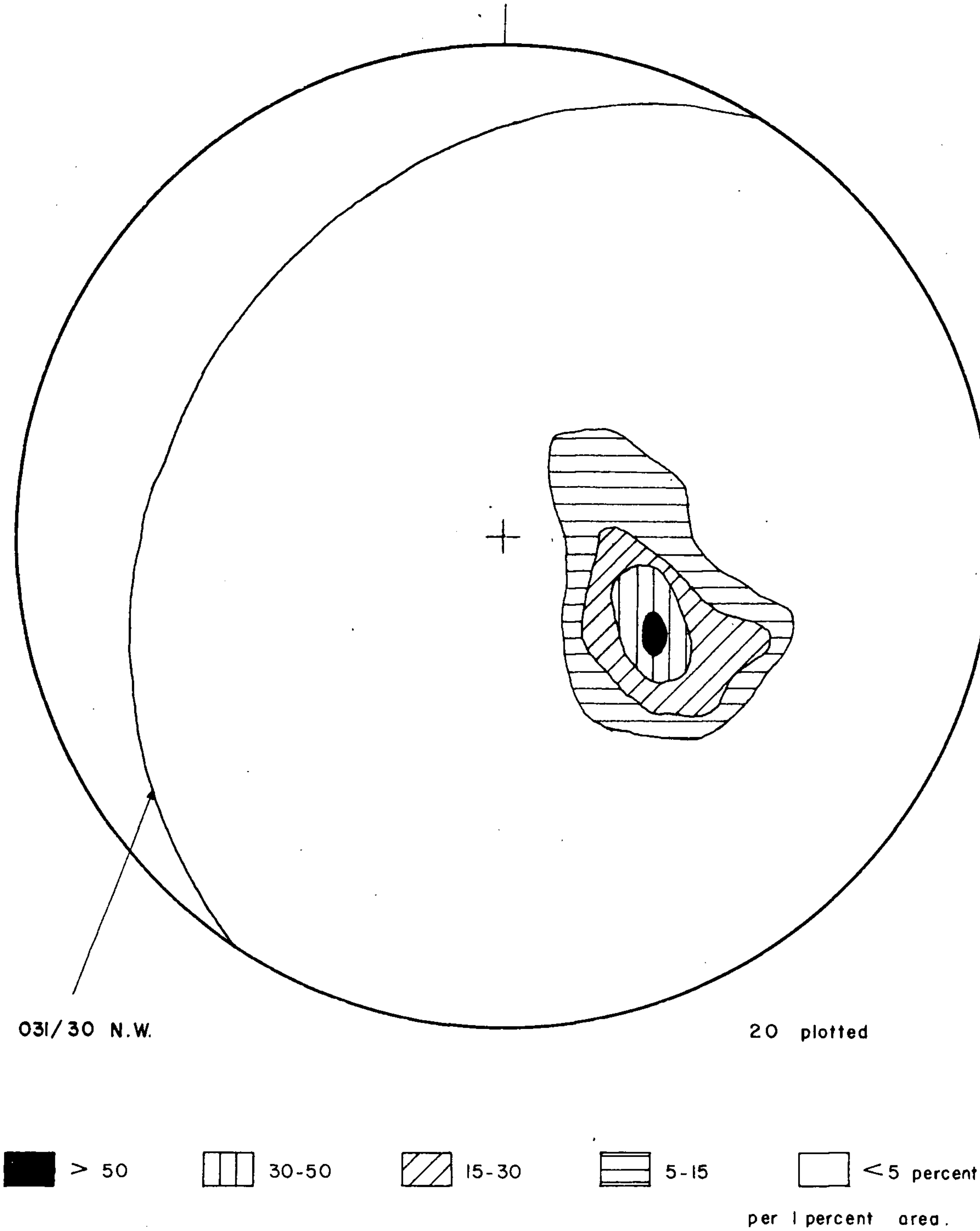

Fig. 29 Equal-area lower-hemisphere projection of poles to bedding in non-metamorphic rocks at Salmon River. Great circle represents average attitude of bedding.

fine-grained quartz and argillaceous material. A few altered fragments of basic rocks are still discernible as clusters of feldspars, epidote, calcite and biotite. Apparently conformably overlying this unit is a brownish-gray, massive, feldspathic graywacke very similar to that described above. The thickness of this unit is unknown as only small scattered exposures were found surrounded by a thick cover of drift.

(b) Internal structural relations

The rocks described in the preceding paragraphs strike northerly to northeasterly and dip moderately to gently to the west and northwest. Figure 29 is a lower-hemisphere equal-area projection of poles to bedding, and shows a fair concentration of points, the centre of which gives an average attitude of 031/30°N.W.

The following table is a summarized description of the rocks described in the preceding pages, as they occur in stratigraphic succession.

Approximate thickness in feet	Lithology
?	Feldspathic graywacke; brownish-gray; tuffaceous; massive.
20	Altered basic crystal tuff or lava; dark-brownish-green; vesicular; fine-grained; porphyritic.

Approximate thickness in feet	Lithology
70	Black argillite, calcareous; thin-bedded; tuffaceous bands.
30	Altered basic crystal tuff or lava; medium- to light-green; medium-grained, porphyritic, massive.
10	Feldspathic graywacke; brownish-gray. Massive.
3	Vitric crystal tuff; light-green; thin-bedded, silicified.
30	Calcarenite, fine grained, tuffaceous; dark-gray, locally argillaceous.
10	Calcarenite, coarse; medium- to dark-gray; contains crinoidal debris, chert and quartzite fragments.
25-50	Basal conglomerate; greenish- to brownish-gray; calcareous; contains cobbles of chert, quartzite, limestone and phyllite.

(c) External structural relations

The sedimentary and volcanic rocks described above are separated from the underlying metamorphic rocks of the Chapperon group by an unconformity which is marked by a basal conglomerate of variable thickness. The unconformable contact was observed at six different and widely separated exposures (see Frontispiece and Fig. 26). In every instance the contact was found to be sharp, undulating, and marking a discordance of attitude of as much as 90 degrees.

In two exposures the schistosity of the metamorphic rocks was found to continue into the overlying conglomerate as a set of closely spaced shear planes oriented at a large angle to the bedding. This feature is believed to have been produced by late deformation which caused further movement along the schistosity in the metamorphic rocks, and which continued upwards producing shear in the younger sediments.

Additional evidence for the unconformity is:

1. Rock fragments in the basal conglomerate are exclusively of metamorphic rocks in part similar to those underlying the eastern half of the area.
2. Dykes of the Old Dave Intrusions are apparently truncated at the contact with the non-metamorphic rocks.
3. There is a sharp difference in metamorphic grade between Chapperon group and younger rocks.

(d) Tentative Correlation and Age

Jones (1959, p. 29) correlated the rocks overlying the Salmon River unconformity with the Cache Creek group "...because of their striking similarity in lithology and because, where they extend into the adjacent Nicola map-area, they have been mapped as Cache Creek by Cockfield

(1948) for lithological and stratigraphic reasons".

Cockfield, when describing the contact relations between Cache Creek and Nicola rocks (1948, p. 8) refers to a supposed unconformity previously mapped by Daly (1915, pp. 122-123) in the vicinity of Campbell Creek, on the north shore of the South Thompson River. At this locality, the basal bed of the Nicola rocks is a conglomerate, 150 feet thick and containing rounded and angular fragments of rocks resembling those of the Cache Creek group. In his later examination of the Cache Creek-Nicola relations, Cockfield states that since "...this conglomerate...was discovered at several places in close association with rocks that are lithologically identical with other members of the Cache Creek group..." its identification as a basal conglomerate has become extremely doubtful. Regarding the Nicola-Cache Creek contact, he continues "...the contact was, therefore, drawn where the rocks became preponderantly of volcanic origin, that is, at the base of the massive Nicola greenstone...". In the same paragraph, Cockfield also states that the contact seemed to separate perfectly conformable rocks, although greater changes in lithology characterized the Cache Creek type rocks, as compared to the Nicola rocks.

D.N. Hillhouse (Address to the Vancouver Geological Discussion Club, Feb. 4, 1964) while mapping in the Douglas Lake Plateau, just west of the area that is now being described, found no evidence of unconformity between Nicola and Cache Creek rocks.

From the above summary of the literature, the following points emerge:

1. Jones correlated the non-metamorphic rocks in the area with the Cache Creek group because of similarity with other Cache Creek rocks and because they are extensions of areas underlain by rocks mapped by Cockfield as Cache Creek.
2. Cockfield arbitrarily placed the Cache Creek-Nicola boundary at the bottom of the massive Nicola greenstone, but did not admit the presence of the unconformity suggested by Daly.
3. Neither Cockfield (1948) nor Jones (1959) had any definite paleontological or structural evidence on which to base the separation of Cache Creek rocks from Nicola rocks in the Douglas Lake Plateau, or by which to correlate the rocks overlying the Salmon River unconformity with the Cache Creek group.
4. More recent investigators apparently find no definite change from Cache Creek rocks into Nicola rocks in the Douglas Lake region.

This writer did not find any fossils that could be used in dating the rocks which overlie the unconformity at Salmon River, and provisionally considers them to be "Carboniferous or later" in age, and possibly as young as Upper Triassic.

IV Young Intrusive Rocks

(a) Lithology

(1) Hornblende microdiorite - Dykes of hornblende microdiorite range in thickness from 3 to 15 feet and strike northerly and easterly with vertical or very steep dips.

Fig. 30 Salmon River. Twinned hornblende phenocryst replaced by calcite and epidote in hornblende microdiorite. Crossed nicols (X 45).

In the hand specimen the rock consists of partly chloritized subhedral to euhedral phenocrysts of hornblende as much as 2 cm. long, set in a light-green, aphanitic to finely crystalline groundmass.

In thin section the texture is holocrystalline, hypautomorphic porphyritic. The phenocrysts form 15 percent of the rock and are subhedral crystals of greenish-brown hornblende commonly twinned on the (100) plane, and extensively replaced by pistacite and penninite (see fig. 30). The groundmass is fine grained and consists mainly of poorly developed crystals of saussuritized plagioclase, some grains of quartz, sericite and calcite.

(2) Latite porphyry - Two dykes of latite porphyry ranging in thickness from 10 to 25 feet and striking northerly and northeasterly with steep westerly and southeasterly dips, were found in the area. In hand specimen the rock is brownish-gray, fine grained porphyritic with subhedral to euhedral crystals of plagioclase up to 3 mm. in diameter.

In thin section the rock is seen to contain 70 percent subhedral to euhedral phenocrysts of plagioclase, 10 percent green hornblende and less than 10 percent anhedral quartz grains set in a fine-grained matrix of anhedral feldspar and quartz. The plagioclase is strongly zoned in an oscillatory fashion, and averages An_{35}; some crystals are cloudy and extensively replaced by sericite, whereas other are clear and fresh. Combination twinning of plagioclase crystals according to the albite and carlsbad laws is striking in this rock (see Fig. 31).

Hornblende crystals are usually corroded, subhedral laths, commonly enclosed by larger plagioclase grains and replaced by calcite, sericite and chlorite. Quartz phenocrysts are scarce, invariably anhedral, and with strongly rounded borders. Common accessory minerals are calcite, chlorite, apatite and pyrite.

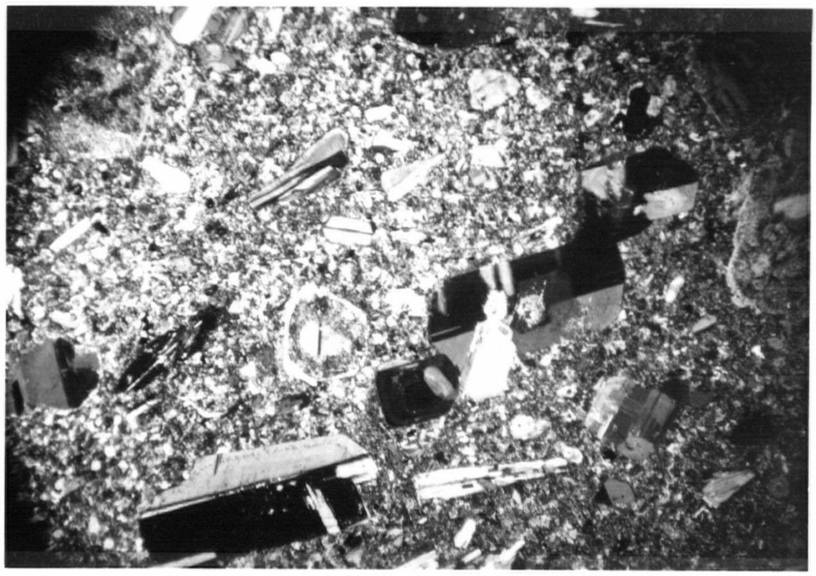

Fig. 31 Salmon River. Combination twinning of andesine phenocrysts according to the carlsbad law in latite porphyry. Crossed nicols (X 15).

(3) Alaskite - Two alaskite dykes, approximately 25 feet wide and striking easterly with steep northerly dips, were found in the area.

In hand specimen the rock is very light gray to almost white and medium to fine grained porphyritic with small subhedral phenocrysts of quartz and feldspar.

In thin section the texture is markedly porphyritic, as slightly zoned and sericitized subhedral phenocrysts of andesine (An_{35}), strongly sericitized K-feldspar and anhedral grains of quartz with rounded borders stand out

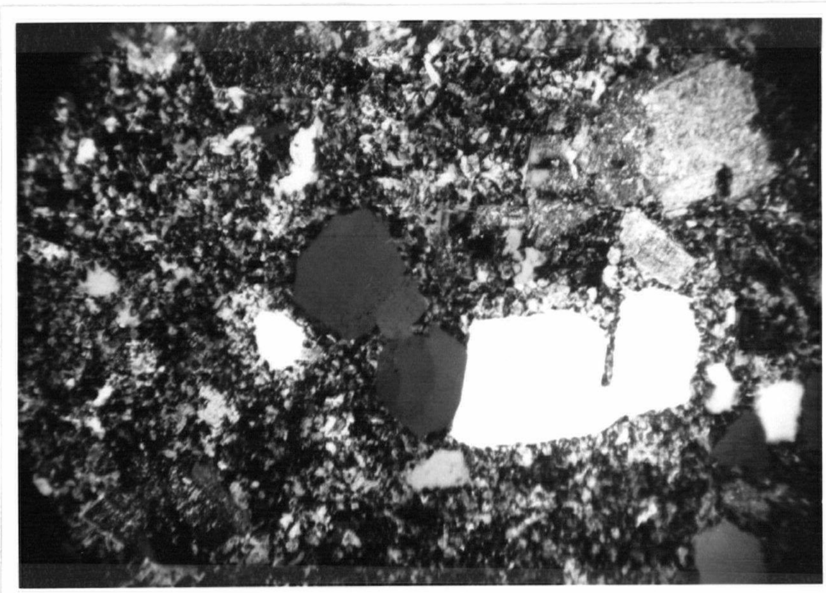

Fig. 32 Salmon River. Quartz phenocrysts with embayed borders, and myrmekitic groundmass in porphyritic alaskite. Crossed nicols. (X 45).

in a fine-grained groundmass of myrmekitic quartz and K-feldspar (see Fig. 32). Some subhedral plates of muscovite are also present. Accessory and alteration minerals are apatite, pyrite, limonite, calcite and chlorite.

(b) Age

The three types of dykes described above cut both metamorphic and non-metamorphic rocks in the map area. They are possibly related to the Coast Intrusions (Jones, 1959, p. 7) which are represented a few miles to the north of the map-area by a batholithic mass.

CHAPTER V - SUMMARY AND CONCLUSIONS

Jones (1959, pp. 47, 48 and 28) described unconformities between Shuswap and Cache Creek rocks at Keefer Gulch, near Lavington, at B.X. Creek and at Salmon River. The present writer mapped these three areas in detail.

Highly deformed regional metamorphic rocks and relatively undeformed and unmetamorphosed sedimentary rocks, chiefly volcanic wacke and breccia, with some argillite and limestone, were found in all three of these areas.

At Keefer Gulch an unconformity could not be demonstrated or refuted. The exposed contact between metamorphic and non-metamorphic rocks was found to be a steeply dipping fault, the amount of displacement along which is unknown. Evidence compatible with the existence of an unconformity is the sharp difference in grade of metamorphism, lithology, and structure that exists between metamorphic and non-metamorphic rocks, and the fact that dykes cut only the metamorphic rocks.

At B.X. Creek, as at Keefer Gulch, an unconformity could not be demonstrated or refuted. The contact between metamorphic and non-metamorphic rocks was nowhere found exposed. The non-metamorphic rocks strike easterly and occupy the central part of the area. They are truncated to the east and to the west by gneiss of the Monashee group which strike northerly and northwesterly. As shown on plate II, the contacts between these two units are believed to be two faults which strike northerly and dip steeply.

At Salmon River strong evidence of the angular unconformity postulated by Jones was found. The unconformity separates highly deformed schist of the Chapperon group from relatively undeformed and fresh sedimentary rocks which presumably belong to the Cache Creek or the Nicola group. If these rocks are part of the Cache Creek group, then the underlying Chapperon rocks are pre-Permian. In this case the metamorphism of the Chapperon group could be related to the Cariboo orogeny of post-Ordovician to pre-Mississippian time (White, 1959), or to some earlier period of deformation. If the rocks overlying the unconformity are part of the Nicola group, which is at the present time regarded as resting disconformably on the Cache Creek group (Cockfield, 1948, p. 8), it is possible that the Chapperon group is a part of the Cache Creek group. Metamorphism could then be related to the Cassiar orogeny of post-Upper Permian to pre-Upper Triassic time (White, 1959).

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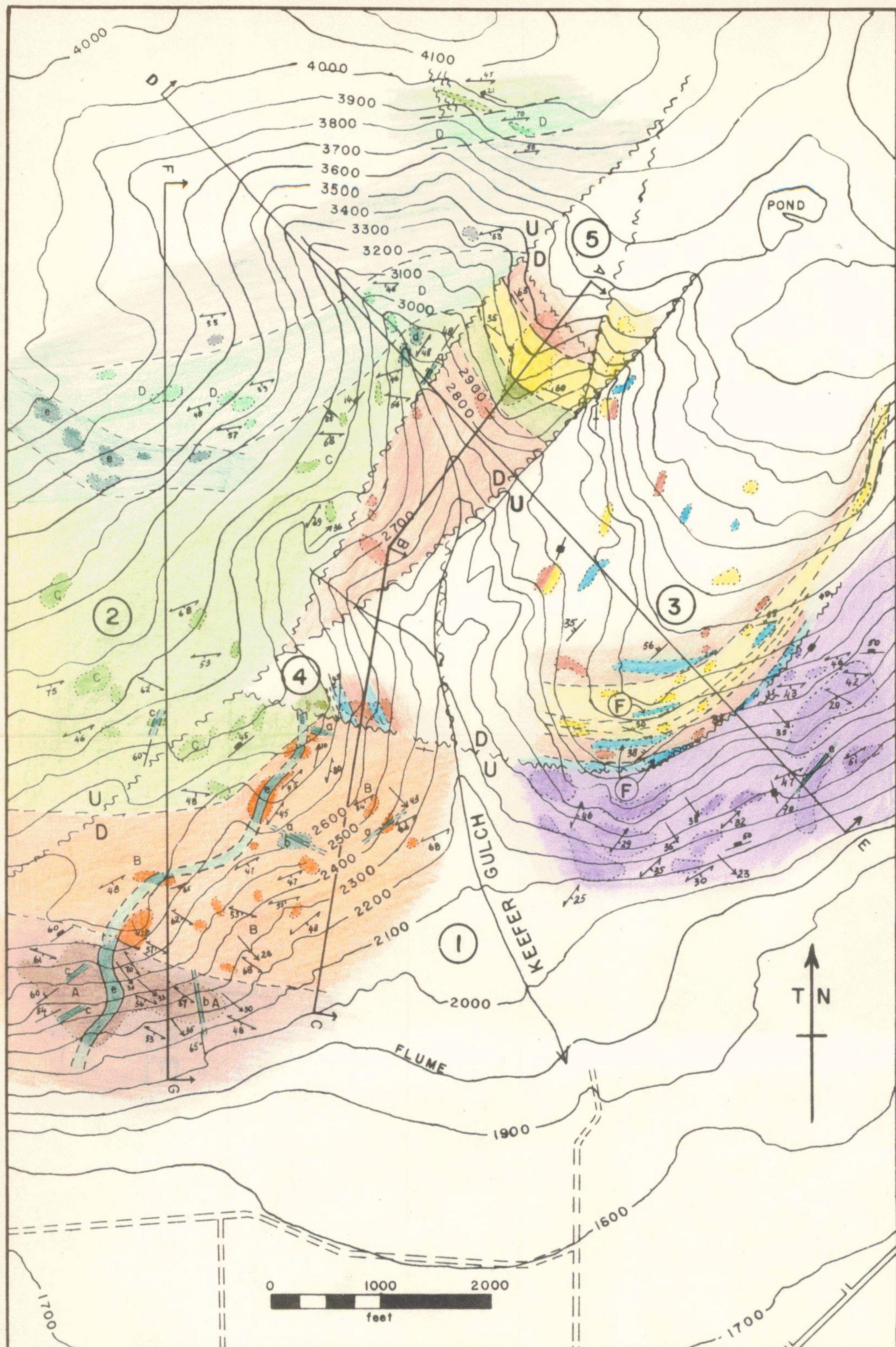

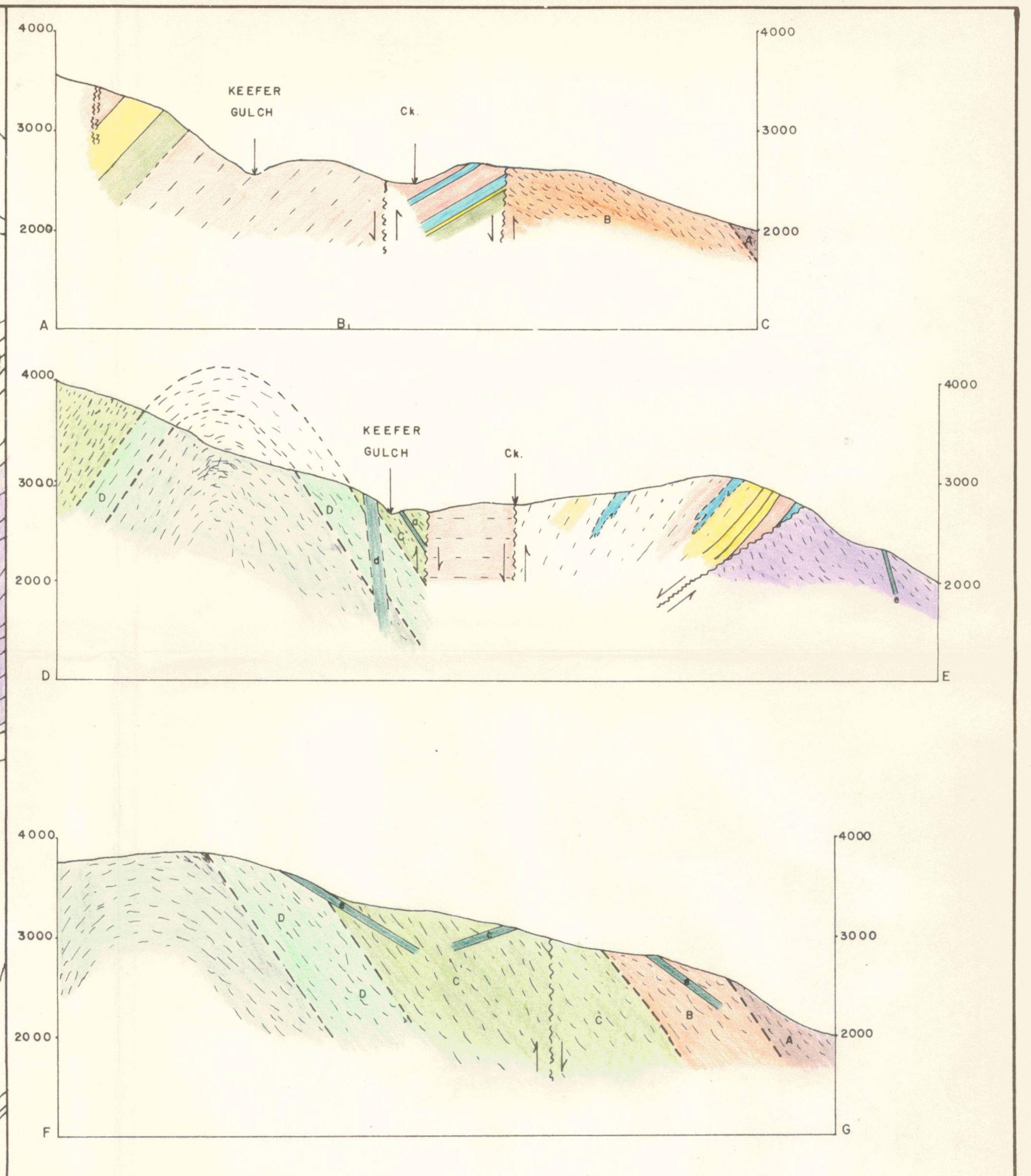

Base map compiled by the B.C. Topographic Division. Approx. mag. decl. 23° E.

PLATE I

KEEFER GULCH

LEGEND

CENOZOIC

Pleistocene and Recent

- Glacial and lacustrine sediment.

UPPER PALAEOZOIC OR LATER

Carboniferous (?) and Permian

Cache Creek Group

- Green, dark-gray and buff volcanic breccia
- Green volcanic wacke. Massive to well-bedded.
- Green andesitic lava
- Gray to white limestone. Massive to thinly bedded. Locally fossiliferous.

PRE-UPPER PALAEOZOIC

Pre-Carboniferous

Mt. Ida Group (?)

- Dyke rocks: (a) Aplite and pegmatite. (b) Diabase. (c) Lamprophyre. (d) Feldspar porphyry. (e) Biotite microdiorite.
- Green chlorite-biotite-hornblende phyllite.
- A B Pelitic micaceous schist. (A) Brownish, calcareous. (B) Bluish-gray, argillaceous.
- C D Green hornblende schist. (C) Siliceous (D) Micaceous.
- Dark-gray argillaceous phyllite.

- Bedding, tops known. Inclined, vertical.
- Bedding, tops unknown. Inclined, vertical.
- Jointing, inclined, vertical.
- Schistosity, inclined, vertical.
- Lineation, plunging.
- Geological boundary, definite, indefinite.
- Fault, defined, assumed.
- Shear zone.
- (3) Structural sub-area.
- (F) Fossil locality.
- Outcrop area.
- Highway.
- Country road.

Geology by V. Preto, 1963

Drawn by V. P.

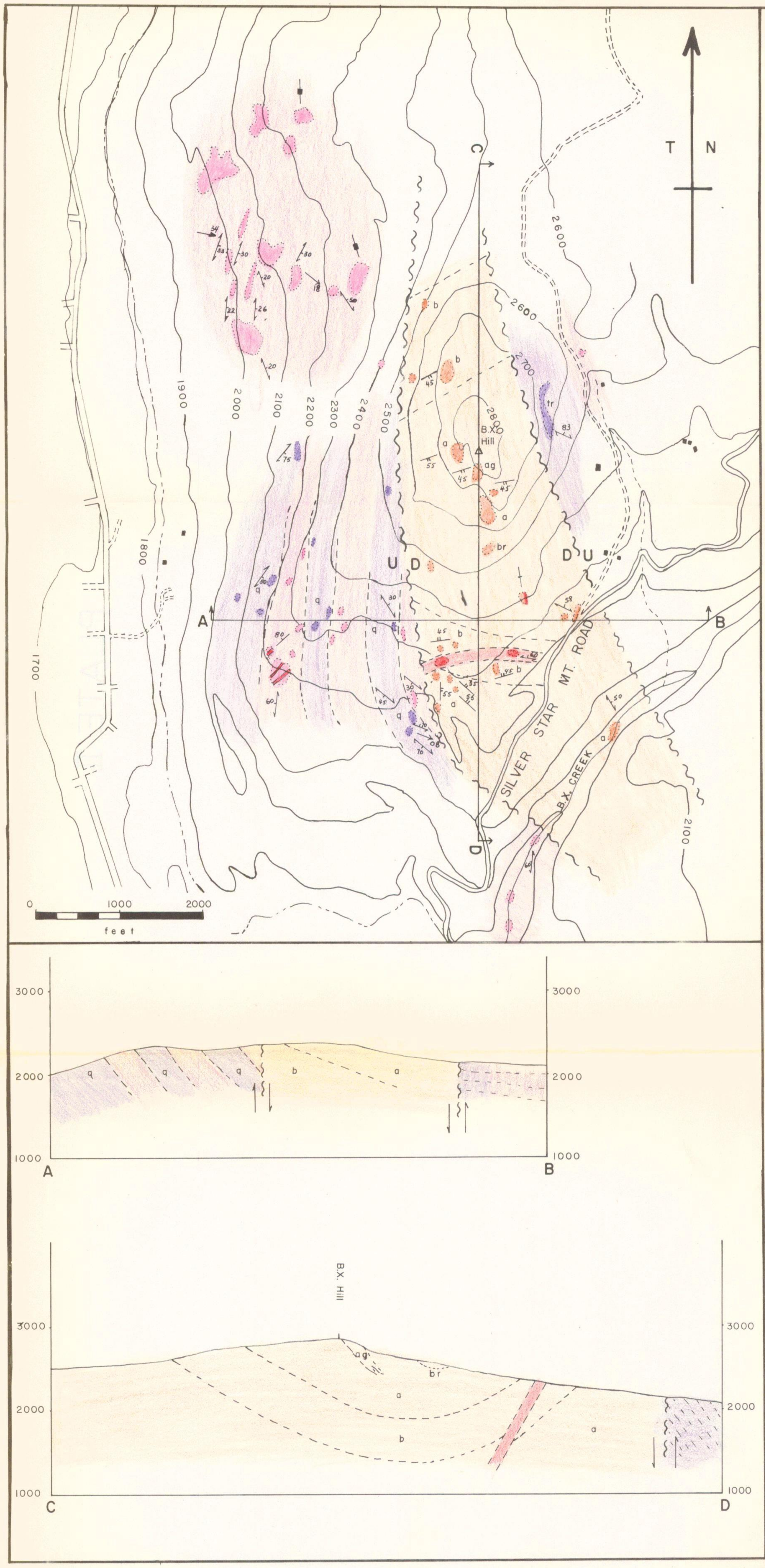

PLATE II

B.X. CREEK

LEGEND

CENOZOIC

Pleistocene and Recent

Glacial outwash

UPPER PALAEOZOIC OR LATER

Post-Permian

Alaskite porphyry, quartz veins

Carboniferous (?) and Permian

Cache Creek Group

Volcanic wacke (a) feldspathic; (b) lithic
Interbeds of breccia (br) and argillite (ag)

PRE-UPPER PALAEOZOIC

Pre-Carboniferous

Monashee Group

Biotite-quartz-feldspar gneiss, hornblende gneiss. Cut by muscovite-quartz-feldspar pegmatite and quartz veins

Impure quartzite (q); tremolite rock (tr)

Bedding, tops unknown. Inclined, vertical

Jointing; inclined, vertical

Foliation; inclined, vertical

Lineation, plunging

Geological boundary; definite, indefinite

Fault; defined, assumed

Outcrop area

Well-travelled road

Secondary road

Flume

Building

Base map by B. C. Topographic Division. Approx. mag. decl. 23° E.

Geology by V. Preto, 1963

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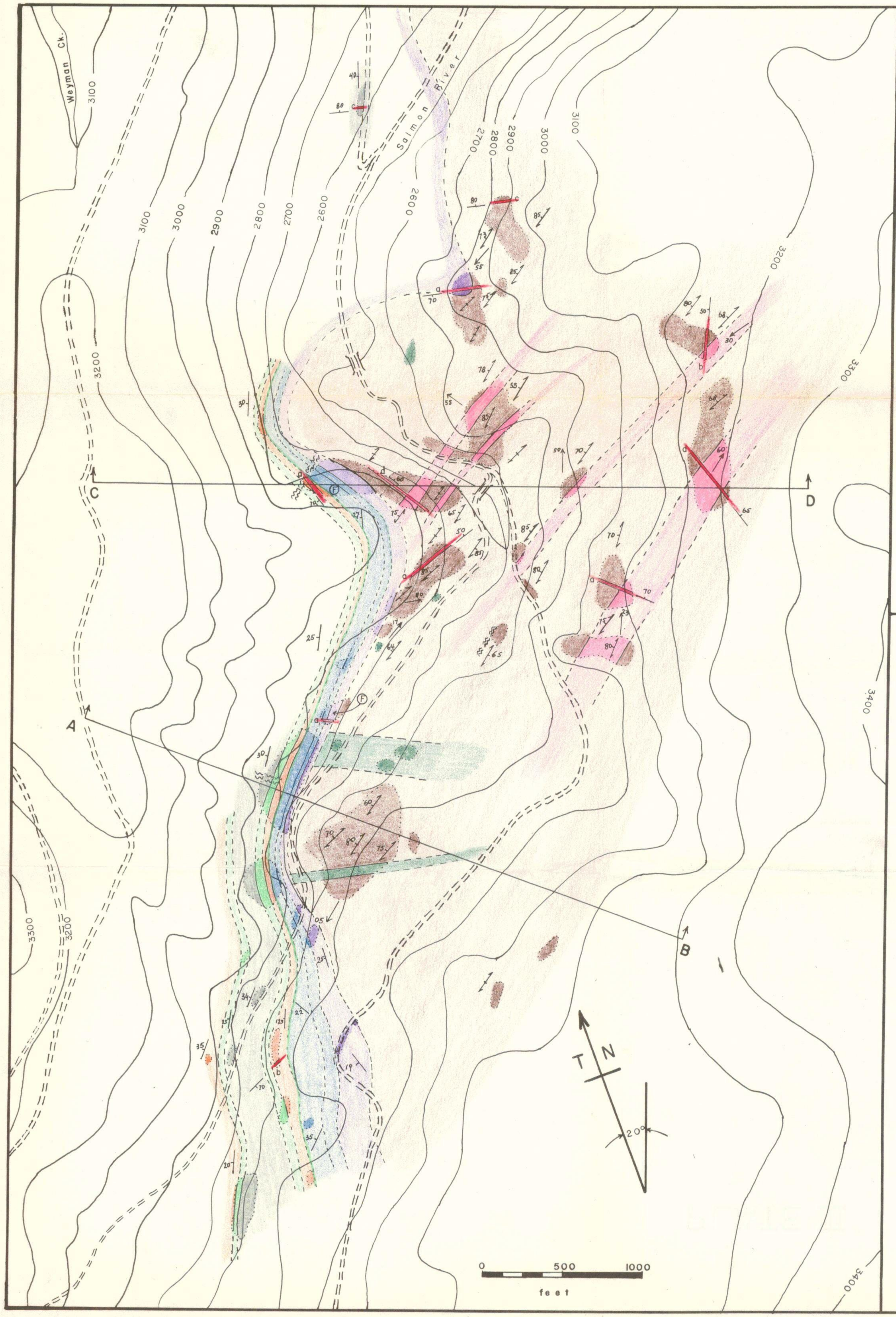

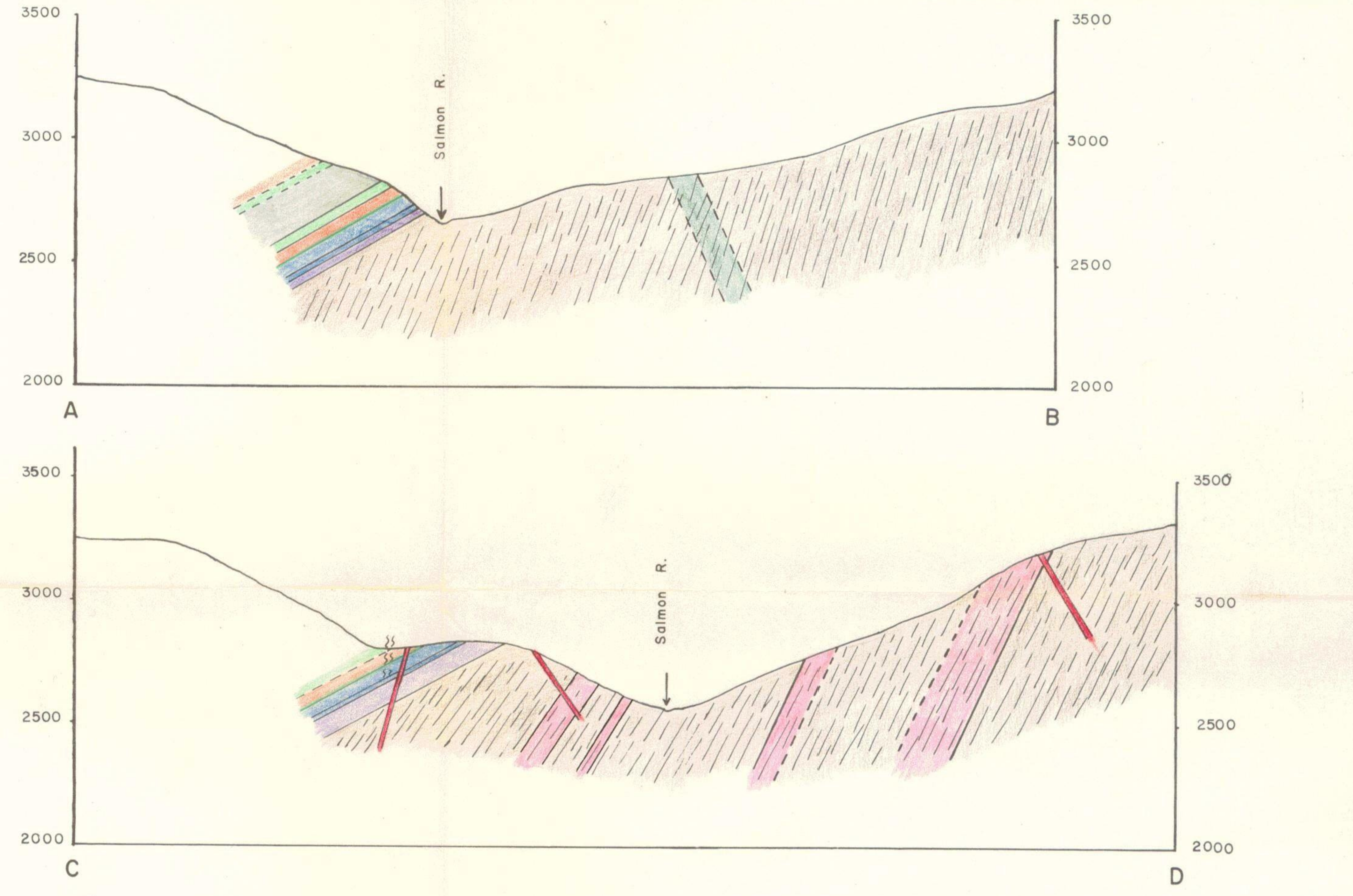

PLATE III

SALMON RIVER

LEGEND

CENOZOIC

Pleistocene and Recent

- Glacial and fluviatile outwash

MESOZOIC

Jurassic and/or Cretaceous

- Dyke rocks: (a) Hornblende microdiorite, (b) Latite, (c) Alaskite, (d) Quartz veins

UPPER PALAEOZOIC

Permian or Upper Triassic

Cache Creek or Nicola Group

- Feldspathic graywacke
- Altered crystal tuff or lava. Thin-bedded vitric-crystal tuff
- Thin-bedded, black argillite
- Fine- to coarse-grained calcarenite
- Basal conglomerate

PRE-UPPER PALAEOZOIC

Pre-Upper Triassic

Old Dave Intrusions

- Serpentinized ultramafic dykes

Chapperon Group

- Dark-gray to black micaceous schist
- Ribbon chert

- Bedding, tops known; inclined, vertical
- Schistosity; inclined, vertical
- Lineation, plunging
- Geological boundary; defined, assumed
- Zone of shearing
- Outcrop area
- Fossil locality
- Secondary road
- Bridge

Base map by Topog. Div. Canada Dept. of Mines and Tech. Surveys

Approx. mag. decl. 23° E.

Geology by V. Preto, 1963

Drawn by V. P.