Province of British Columbia
Ministry of Energy, Mines and Petroleum Resources

PRELIMINARY MAP 48

GEOLOGIC MAP OF TERTIARY ROCKS OF THE AFTON–TRANQUILLE AREA WEST OF KAMLOOPS, BRITISH COLUMBIA

(N.T.S. 92I/9,10)

RELEASED JANUARY, 1982

GEOLOGY AND NOTES BY TOM EWING

Miles 1 0 1 2 3 4 5 Kilometres

SCALE 1:50 000

Contour Interval 500 ft.

LEGEND

QUARTERNARY (Q)

- Qal — ALLUVIUM
- Qaf — ALLUVIAL FAN DEPOSITS
- Qls — LANDSLIDE DEBRIS
- Qdf — DELTA FAN
- Qlb — PROGLACIAL LAKE BEDS
- Qd — DRIFT
- Qtg — TERRACE GRAVELS
- Qg — GRAVELS OF THE MIDLAND SURFACE

UNCONFORMITY

TERTIARY

KAMLOOPS GROUP (EOCENE)

DEWDROP FLATS FORMATION (Td)

- Tdo — OPAX BRECCIA (ANDESITE APHANITE FLOW BRESSIA)
- Tdr — RED PLATEAU MEMBER (BASALTIC ANDESITE FLOWS, SOME SEDIMENTARY ROCKS)
- Tdrm — ROSSEAU MOUNTAIN BRECCIA (GLASSY BASALT FLOW BRECCIA)
- Tdrm¹ — HYALOCLASTITE FACIES
- Tdd — DOHERTY CREEK MEMBER (BASALTIC ANDESITE FLOWS, INTERMEDIATE TO FELSIC TUFFS
- Tdc — CASTLE BUTTE BRECCIA (PLAGIOCLASE PORPHYRY ANDESITE PHREATIC AND TRANSITIONAL BRECCIA)
- Tdc¹ — HYALOCLASTITES AND AQUAGENE TUFF
- Tdw — WHEELER MOUNTAIN BRECCIA
- Tdw⁴ — PHREATIC BASALT BRECCIA
- Tdw³ — COARSE ANDESITE FLOW BRECCIA
- Tdw² — ANDESITIC PHREATIC BRECCIA AND FLOW BRECCIA
- Tdw¹ — ANDESITE FLOW BRECCIA, MUD FLOWS
- Tdm — MARA HILL MEMBER (BASALTIC ANDESITE FLOWS)
- Tdk — KISSICK BRECCIA (BASALTIC ANDESITE BRECCIA AND PHREATIC DEPOSITS)
- Tdn — NIPPLE BRECCIA (PORPHYRITIC BASALT PHREATIC BRECCIA)

TRANQUILLE FORMATION (Tt)

- Ttu — UPPER MEMBER (HYALOCLASTITE AND AQUAGENE TUFF)
- Ttmu — MIDDLE–UPPER MEMBER (TUFFS, LACUSTRINE SEDIMENTS)
- Ttm — MIDDLE MEMBERS (PILLOWED ANDESITE, BRECCIA; DEFORMED SEDIMENTARY ROCKS IN THE RED POINT AREA)
- Ttl — LOWER MEMBERS (LACUSTRINE SEDIMENTARY ROCKS AND TUFFS)
- Ttl³ — SILTSTONE, MUDSTONE, TUFF
- Ttl² — COARSE–GRAINED ANDESITE; SUBAERIAL BASALT FLOW AT RED POINT
- Ttl¹ — LACUSTRINE MUDSTONES, TUFFACEOUS SILTSTONES, TUFF
- Ttb — BORDER FACIES (LITHIC AND ARKOSIC WACKE, DARK SHALE, LOCAL COAL)

UNCONFORMITY

JURASSIC OR CRETACEOUS

- Mac — LITHIFIED POLYMICTIC CONGLOMERATE, RED–BROWN MATRIX

UNCONFORMITY

LATE TRIASSIC

- Tn — NICOLA GROUP VOLCANIC ROCKS (META–ANDESITE, TUFF)
- Ta — ARGILLITES, PROBABLY OF TRIASSIC AGE

INTRUSIVE ROCKS

TERTIARY

- Ti — INTRUSIVE ROCKS: DYKES AND SUBVOLCANIC MASSES, ANDESITE TO DACITE
- Ti² — HYPABYSSAL ANDESITE
- Ti¹ — ANDESITE DOME–PLUGS AND RELATED SILLS
- Tib — BATTLE BLUFF INTRUSIVE COMPLEX (DIABASE)
- Tib³ — UPPER SILLS
- Tib² — MIDDLE SILLS
- Tib¹ — BASAL SILLS; COARSE GRAINED SOUTH OF KAMLOOPS LAKE

LATE TRIASSIC TO EARLY JURASSIC

- Tkc — CHERRY BLUFF PLUTON (DIORITE, SYENITE)
- Tki — IRON MASK BATHOLITH (DIORITE, SYENITE)

SYMBOLS

- CONTACT: LONG DASHES WHERE UNMAPPED
- GRADATIONAL CONTACT
- TREND LINE WITHIN A UNIT
- LANDSLIDE SCARP
- OPEN–PIT MINE
- FAULT: DASHED WHERE INFERRED; DOTTED WHERE CONCEALED; DIP WHERE KNOWN
- DYKE: DIP WHERE KNOWN
- ATTITUDE OF BEDDING, JOINTING
- TREND OF ELONGATE VESICLES
- ATTITUDE OF AXIAL PLANES OF MINOR FOLDS, WITH PLUNGE
- DRILL–HOLE LOCATION
- INFERRED SHAFT LOCATION
- RADIOMETRIC AGE LOCATION; PALEOMAGNETIC SITE; VITRINITE SAMPLE SITE (R P V)
- CHEMICAL ANALYSIS LOCALITY
- THIN–SECTION LOCALITY
- ESKER

PRELIMINARY MAP 48
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NOTES TO ACCOMPANY PRELIMINARY MAP NO. 48

GEOLOGY OF THE KAMLOOPS GROUP NEAR KAMLOOPS

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INTRODUCTION

The area of this study lies immediately west of Kamloops on either side of the valley of the Thompson River and Kamloops Lake. The Trans-Canada Highway and the Afton open-pit copper mine form its southern boundary. Mapping at 1:20 000 during the 1978 and 1979 field seasons extended north to the junction of Tranquille River with Watching Creek and westward to the mouth of Rosseau Creek. This report summarizes the Cenozoic geology of the area, concentrating on the environments of deposition and style of deformation of the Eocene strata.

PREVIOUS WORK

Dawson (1895) first studied the Kamloops Lake area, distinguishing a tuffaceous sedimentary facies as the 'Tranquille beds,' and a basal nonvolcanic succession as the Coldwater Group, which is absent in the Kamloops-Tranquille area. Drysdale (1914) and Rose (1914) proposed the name 'Kamloops Volcanic Group' for Tertiary volcanic and sedimentary rocks overlying the Coldwater Group. Cockfield (1948) included the Coldwater beds in the redefined Kamloops Group during the remapping of the Nicola map-area. The designation Kamloops Group has since been extended over a broad area of south-central British Columbia to refer to the Early Tertiary volcanic and sedimentary sequence.

Mathews (1964) presented K/Ar dates distinguishing two volcanic episodes in the area: the Kamloops Group proper of Eocene age (45-52 Ma) and the Plateau lavas of Miocene age (10-13 Ma). Hills and Baadsgaard (1967) supplied additional confirmation of the Early to Middle Eocene age of the Kamloops Group. The Kamloops Group volcanic rocks are time-equivalents to the Princeton Group at Princeton (Rice, 1947), the Kettle River and Marron Formations at Midway and Penticton (Monger, 1967; Church, 1973), and the Sanpoil volcanic rocks of northern Washington (Pearson and Obradovich, 1977).

Notwithstanding the wide distribution and substantial thickness of the Kamloops Group, its type area and internal stratigraphy have never been studied in detail. This study describes this internal stratigraphy, defining two formations and 11 member-level units in the type area. An examination of the regional stratigraphy of the Kamloops Group will be presented elsewhere (Ewing, in prep.).

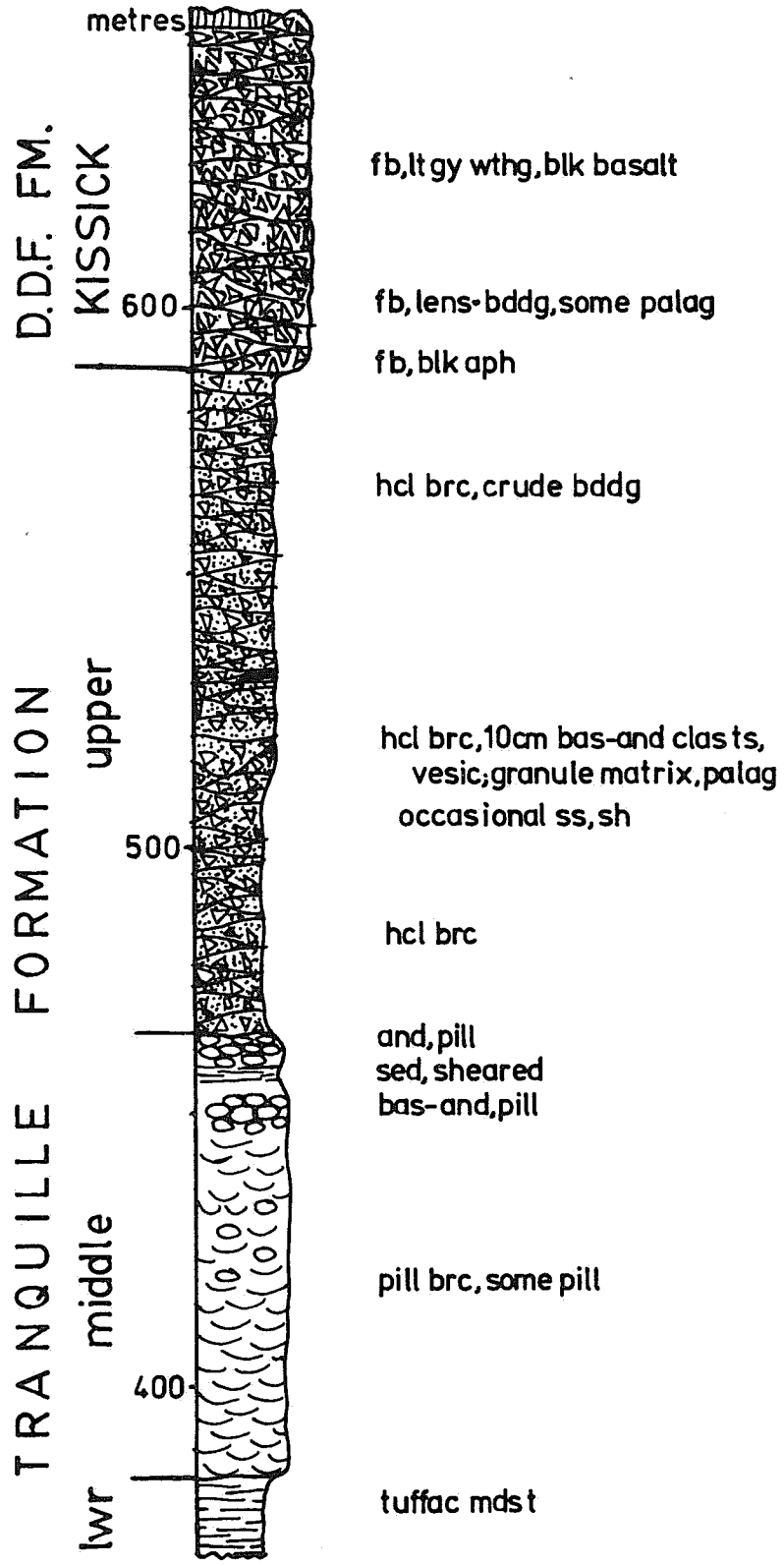

Figure 1. Stratigraphic column of the upper Tranquille and lower Dewdrop Flats Formations on the south face of Mara Hill; elevations in metres.

STRATIGRAPHY

TRIASSIC NICOLA GROUP

NICOLA VOLCANIC ROCKS (Trn)

Outcrops of metavolcanic rocks referable to the Nicola Group occur extensively in the region. Within the mapped area, these consists of plagioclase-porphyry andesites, with occasional interbedded tuffs west of Batchelor Hill. Nicola volcanic rocks have not been mapped in detail. In general, they are easily distinguished from Tertiary rocks by albitization of feldspars and patchy epidote and/or hematite alteration. In a few areas this separation is less certain, notably south of Tranquille and in the Dufferin Hill area. There, the Nicola Group is distinguished by the appearance in thin sections of stubby albitized and saussuritized andesine laths and altered hornblende set in a recrystallized, often epidote-bearing, groundmass.

ARGILLITE (a)

Northwest of Kamloops, low hills of grey-black sheared argillites have been mapped, but not studied in detail. They may be correlative with the argillites northeast of Kamloops, which yield an Upper Triassic fauna (Smith, 1979).

IRON MASK BATHOLITH (Trii)

Intrusive diorite and monzonite occur south of the study area east of and including the Afton mine. Northcote (1977) has interpreted the batholith as the subvolcanic equivalent of the Upper Nicola volcanic rocks. K/Ar dates range from 190 to 205 Ma (Preto, *et al.*, 1979).

CHERRY BLUFF PLUTON (Tric)

This pluton underlies the large bluffs of Roper Hill, Cherry Bluff, and Battle Bluff on either side of Kamloops Lake. It is petrologically similar to the Cherry Creek phase of the Iron Mask Batholith. Betmanis (1972) reported on the geology of the Roper Hill area.

JURASSIC OR CRETACEOUS

SEDIMENTARY ROCKS (Mzc)

Red-brown conglomerate and sandstone of Jurassic or later age have been reported along the Cherry Creek fault zone west of Afton (Carr and Reed, 1976). Drill hole Q-245 (shown on map) penetrates these rocks under Hughes Lake valley (Reed, 1977). Similar sedimentary rocks bearing native copper are found within the Afton deposit (A. J. Reed, pers. comm.). Conglomerates of similar appearance are seen in a road cut on the Trans-Canada Highway along Cherry Creek, where they are overthrust by Nicola Group volcanic rocks. Other small patches of these conglomerates along Cherry Creek are mapped with the Nicola Group.

North of Brocklehurst, well-indurated red-brown angular conglomerates form several low hills. The clasts are composed of argillite, greenstone, chert, and granitic material. Although Cockfield (1948) mapped this material as Coldwater beds (?), it is dissimilar to the type Coldwater beds at Merritt and lithologically similar to the mineralized sedimentary rocks in the Afton deposit.

EOCENE KAMLOOPS GROUP

The relationship of the various members of the Kamloops Group is shown on Figure 1. In the map-area, the Kamloops Group is subdivided into two formations, the Tranquille Formation and the Dewdrop Flats Formation. Hypabyssal intrusions assigned to the Kamloops Group are also abundant.

TRANQUILLE FORMATION (Tt)

The base of the Eocene succession is about 450 metres thick, consisting of sedimentary volcanic rocks largely of lacustrine origin. They make up the area north of the east end of Kamloops Lake from

Battle Bluff east past Mara Hill, which was designated the type area of the 'Tranquille beds' by Dawson (1895). This succession, mappable at scales to 1:250 000, is designated here the Tranquille Formation. The type area, as described in this report, includes reference sections northwest of Afton mine, northeast of Afton mine, and at Kissick siding south of Mara Hill.

BORDER FACIES: Tranquille sedimentary rocks not correlatable with the typical sections are found in the Afton mine and the Guerin Creek areas. The Guerin Creek sedimentary rocks consist of orange mudstone, arkosic wacke, and organic-rich shale, with a much-weathered coaly zone exposed. Similar coal-bearing sedimentary rocks form fault slices within the Afton deposit. A. J. Reed interprets these sedimentary rocks as remnants of a nonmarine near-shore facies lying to the south of the main Tranquille depositional basin (pers. comm.).

The north wall of the Afton open pit exposes four Tertiary rock types: a coarse lithic-arkosic wacke, with clasts of plutonic quartz, 'chert,' sanidine, microcline, plagioclase, biotite, phyllite, shale, meta-andesite, and metaplutonic rocks in patchy calcite cement; interbedded deformed dark shale, with flaser bedding, coal fragments and small growth faults; medium-bedded siltstone and tuff; and andesite-dacite breccia with occasional tuff clasts and two stages of brecciation and carbonate cementation. Graham and Long (1979) report similar rocks, including tuffaceous prodelta deposits and small soft-sediment slumps, in drill holes GG-1 and GG-6 near the mine (Fig. 6). Wackes and shales similar to those in the open pit are also exposed on the lower slopes of the hill northeast of the mine site, associated with an olistostrome of Nicola Group volcanic rocks.

TABLE 1

SELECTED CHEMICAL ANALYSES OF KAMLOOPS GROUP IGNEOUS ROCKS

	Ttl[2] 6-5	Ttl[2] TP 21-2	Tdn TP 43-1	Tdk TP 7-4	Tdm TP 4-1	Tdw[1] TP 13-2
SiO_2	48.28	51.51	50.26	51.52	52.79	56.03
TiO_2	1.23	1.22	0.98	1.23	1.24	1.14
Al_2O_3	16.25	15.13	14.55	17.56	16.05	16.53
Fe_2O_3	8.40	8.69	9.58	12.63	8.40	7.63
MnO	0.12	0.14	0.15	0.18	0.07	0.12
MgO	3.71	6.43	10.06	3.18	4.28	4.02
CaO	7.28	7.84	7.40	7.34	7.48	6.95
Na_2O	2.72	3.07	2.31	3.42	3.79	3.36
K_2O	2.59	2.22	2.75	2.38	2.98	2.45
P_2O_5	0.60	0.58	0.56	0.63	0.80	0.59
H_2O+	8.24	1.55	1.74	0.03	1.33	0.92
H_2O-	0.81	2.20	0.51	0.55	1.10	1.29
Total	100.23	100.58	100.85	100.65	100.32	101.03

	Tdc 4-2	Tdrm 5-6	Tdr TP 32-3	Tdo TP 39-3	Tib[3] TP 9-1	Ti[1] 31-5
SiO_2	53.44	50.85	54.44	57.46	49.40	55.19
TiO_2	1.24	1.09	0.78	0.96	1.12	0.95
Al_2O_3	19.69	16.19	18.20	15.66	17.23	16.76
Fe_2O_3	6.91	9.29	9.07	7.77	10.28	6.60
MnO	0.11	0.17	0.14	0.13	0.17	0.08
MgO	1.85	5.98	2.44	3.67	4.58	2.99
CaO	6.73	8.18	5.80	5.70	6.45	6.07
Na_2O	3.23	2.79	4.30	3.36	3.44	2.92
K_2O	2.70	2.52	3.28	3.05	2.85	3.01
P_2O_5	0.62	0.49	0.59	0.53	0.54	0.45
H_2O+	3.10	2.02	0.04	0.79	2.78	2.45
H_2O-	1.14	0.62	1.08	0.34	1.05	2.67
Total	100.76	100.26	100.16	99.42	99.90	100.14

Analyses by X-ray fluorescence, University of British Columbia.

The rocks of the border facies are interpreted to represent a delta extending northward into the Tranquille Lake about 1 kilometre, as proposed by Graham and Long (1979). The clast composition indicates a variety of source terranes similar to the pre-Tertiary rocks exposed today in the surrounding region. This delta appears to be equivalent to the middle-upper member of the Tranquille Formation in more typical sections to the north.

LOWER MEMBERS (Ttl): The lower member of the Tranquille Formation is best developed south of Kamloops Lake, where it may be subdivided into three units. The lower unit (Ttl^1) consists of 210 metres of both ridge and slope-forming yellow-brown laminated siltstone and mudstone, containing pumice clasts, mud clasts, and abundant calcic plagioclase laths. Locally its base is extensively intruded by sills of the Battle Bluff intrusive complex. The middle unit (Ttl^2) consists of 85 metres of coarse-grained porphyritic andesite (Table 1, TP 21-2), with phenocrysts of augite, pigeonite, and labradorite. The unit comprises resistant lava flows and tuffs which form ridges in the Afton area. The upper unit (Ttl^3) consists of slope-forming tuffaceous mudstone similar to the lower unit, and is greater than 30 metres thick; the top is concealed.

North of the Thompson River, thinly plane-bedded tuffaceous mudstone is exposed on the lowest slopes of Mara Hill (thickness greater than 55 metres). Over 120 metres of lacustrine mudstone and siltstone is exposed east of Battle Bluff underlying and interbedded with conspicuous sills. This section is sparingly fossiliferous (Cockfield, 1948; Hills, 1965; Rice, 1959; Wilson, 1977). Ash from this area yielded K/Ar ages on biotite and feldspars of 50 Ma (Hills and Baadsgaard, 1967). These rocks may rest on Nicola Group volcanic rocks; they correlate with the lower unit south of Kamloops Lake.

West of Red Point, lower Tranquille strata are exposed in a west-dipping homocline. The lower unit (Ttl^1) consists of over 180 metres of sparingly fossiliferous (Wilson, 1977) laminated lacustrine sediment (siltstone and mudstone), becoming more tuffaceous upwards. Minor interbeds of slide breccia with clasts of Nicola Group volcanic rocks suggest significant, probably fault-induced, relief nearby. Overlying this conformably is a thick basalt flow (Table 1, 6-5) showing colonnade and entablature joint patterns and a rubbly upper surface (Ttl^2). This indicates subaerial eruption of the flow and suggests that the lower unit essentially filled the lake basin. A further 210 metres of tuffaceous lacustrine strata, however, overlies the flow (Ttl^3).

MIDDLE MEMBERS (Ttm): The volcanic middle members of the Tranquille Formation are different facies north and south of the Thompson River. North of the river, 30 metres of pillowed andesite is exposed in the lower draws near Mara Hill (Fig. 1). Pillows range up to 1 metre in size and show dark glassy selvages with interior vesiculated zones. South of the river, andesite flow rock with zoned labradorites and clinopyroxenes forms conspicuous cuestas northwest of Afton mine and southeast of Tranquille. Some of these rocks may be intrusive, correlating with those identified by Creaney (1979) in drill holes GG-1 and GG-6. Alternatively, these latter may be localized in the Afton area.

A middle member of the Tranquille Formation forms the large cuesta west of Red Point. At its base is a columnar-jointed basaltic andesite, conformably overlying the lower Tranquille strata. Above this, a thick sedimentary and volcaniclastic section has been folded into tight recumbent folds on scales of 10 centimetres to 20 metres, verging generally northeast. This zone is interpreted to represent soft-sediment deformation associated with activity along the Cherry Creek fault zone to the southwest. The top of the middle member is formed by a 10-metre bed of graded breccia-sandstone, marking a gradation to the upper member of the formation. The present thickness of the middle member is about 230 metres.

MIDDLE-UPPER MEMBER (Ttmu): South of the Thompson River, the upper and middle portions of the Tranquille Formation form a much-sheared tuffaceous facies extending from Tranquille siding southeast to the Trans-Canada Highway. Tuff and related breccias form low ridges; interbedded siltstone and mudstone similar to the lower Tranquille are exposed only in dry gulches cutting the drift cover. Dykes are common, and one small patch of basaltic phreatic breccia was found about 1 kilometre north of Polygon Pond. Because of poor outcrop and intense shearing, detailed stratigraphy and thickness are not known, but the material correlates with the middle and upper members of the Tranquille Formation defined elsewhere.

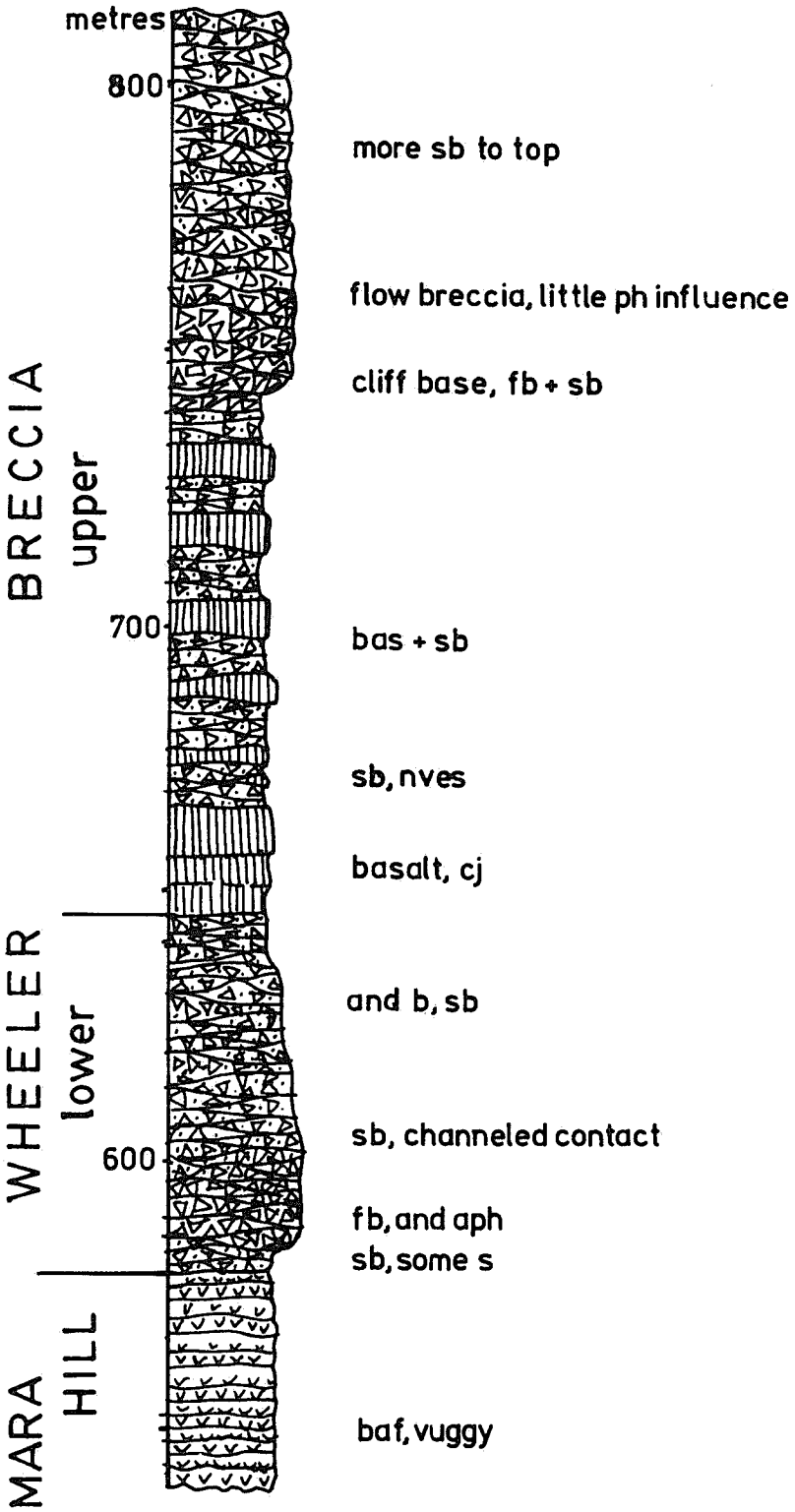

Figure 2. Stratigraphic column of the Wheeler Mountain breccia at its type locality, southwestern side of Wheeler Mountain, north-northeast of Tranquille. Top not exposed.

UPPER MEMBERS (Ttu): The upper member of the Tranquille Formation north of the Thompson River (Fig. 1) consists of over 80 metres of palagonitic ash-rich mudflows with occasional sandstone interbeds lying conformably and gradationally on the pillowed andesites of the middle member. This material is best exposed at Kissick siding south of Mara Hill, where clasts of altered vesicular andesite compose about 15 per cent of the rock. To the west, the crudely bedded flows interfinger with the breccia of 'The Nipple,' described following. The upper surface of the member is well exposed at Kissick and is nearly flat with no evidence of erosion prior to deposition of the Dewdrop Flats Formation. The unit is interpreted as representing a hyaloclastite pile which largely filled in the Tranquille Lake immediately prior to Kissick deposition.

West of Red Point, the upper Tranquille Formation lies gradationally upon the deformed middle member. The lower unit in this area (Ttu^1) consists of 250 metres of volcanogenic mudstones and siltstones with occasional massive sandstone interbeds. The upper part of this unit is involved in minor soft-sediment deformation. The upper unit (Ttu^2) begins with a marker unit of volcanic breccia about 10 metres thick, succeeded by ashy mudflows containing large blocks of basaltic andesite. This unit may represent a hyaloclastic succession equivalent to the upper member at Tranquille.

DEWDROP FLATS FORMATION (Td)

The Dewdrop Flats Formation takes its name from Dewdrop Flats, 4 to 6 kilometres northwest of Tranquille. Imposing bluffs north of the flats provide typical sections of several members of this volcanic formation. The name replaces the informal term 'Upper Volcanics' of Dawson (1895).

BRECCIA OF 'THE NIPPLE' (Tdn): An area west of Tranquille River is underlain by phreatic breccia with clasts of porphyritic basalt (Table 1, TP 43-1). The mafic phenocrysts are polycrystalline intergrowths of augite, pigeonite, and altered olivine; labradorite forms large stellate aggregates. The breccia matrix is formed by granulated palagonitic material similar to the upper Tranquille Formation, suggesting some influence of heated groundwater in the eruption and/or transport of the breccia.

The breccia accumulation displays a moderate primary east dip, interfingering eastward with hyaloclastites of the upper Tranquille over a distance of about 500 metres. The unit ranges from zero to 100 metres thick.

KISSICK BRECCIA (Tdk): The Kissick breccia conformably overlies the upper member of the Tranquille Formation (Fig. 1) and (with a local unconformity) the breccia of 'The Nipple.' It consists of 160 to 190 metres of andesitic breccia in various facies. The dominant subaerial vent facies is typically exposed in the steep cliffs north of Kissick siding south of Mara Hill. There, crudely bedded lenticular flow breccia and subaerial mudflow units of light grey-weathering andesite (Table 1, TP 7-4) show primary dips of 30 degrees, indicating a vent area to the north. Closer to the inferred vent, palagonitic material predominates, suggesting that the Kissick unit originated as a tuff ring or maar. The breccia is traceable northward into a phreatic deposit with pronounced development of a palagonitic granule matrix (Tdk^1); some exposures show tongues of massive breccia surrounded by phreatic material. This is interpreted to be a near-shore facies of a small lake into which tongues of the breccia flowed.

A Kissick-equivalent phreatic andesite breccia (Tdk^2) forms the main ridge of Dufferin Hill south of the Thompson River. Its source may be the main Kissick vent.

MARA HILL MEMBER (Tdm): The Mara Hill member gradationally overlies the Kissick breccia in most exposures. It consists of 150 to 300 metres of red-brown-weathering basaltic andesite flows, flow-top breccias, and related mudflows (Table 1, TP 4-1), forming crude couplets of lava flow and breccia. Thin sections show phenocrysts of plagioclase, clinopyroxenes, and 'ghost' hornblende set in a plagioclase-magnetite-quartz holocrystalline groundmass. This sequence is typically developed on the western and northern slopes of Mara Hill; it intertongues with a local accumulation of dark grey breccia on the southeast side of Mara Hill.

WHEELER MOUNTAIN BRECCIA (Tdw): The Wheeler Mountain breccia conformably overlies the Mara Hill member. It exhibits a variety of facies and a range of composition, both vertically and laterally. The member is typically developed on the southwestern slopes of Wheeler Mountain north

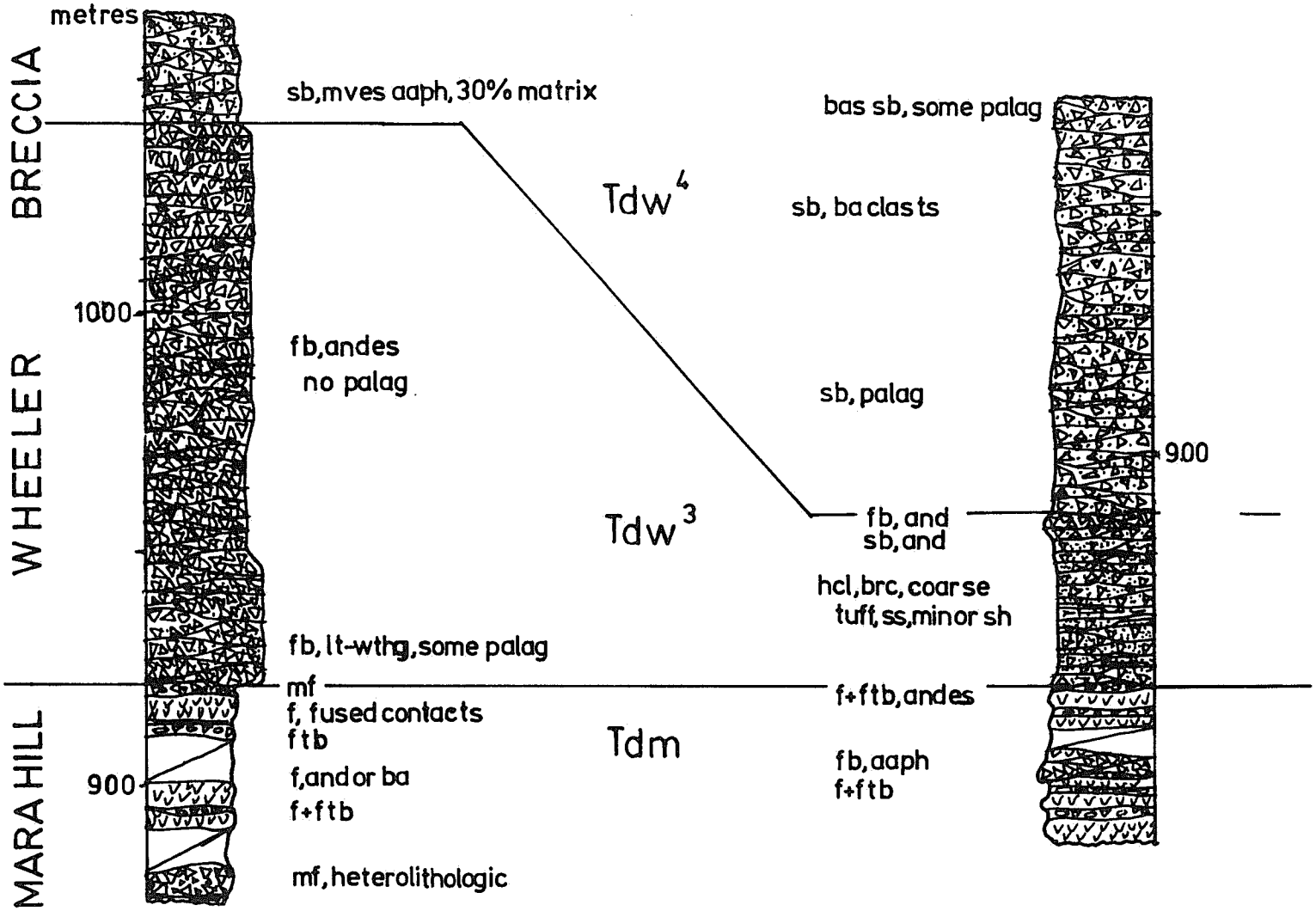

Figure 3. Stratigraphic columns of the Wheeler Mountain breccia northwest of Tranquille, showing the rapid facies change of Tdw^3 from west (left) to east (right), a distance of about 1 km.

of Mara Hill (Fig. 2), where it is 250 metres thick. The lower unit (Tdw^1) consists of andesite (Table 1, TP 13-2) flow breccia and mudflows, with some palagonitic alteration grading upward to phreatic and subaerial slope-forming breccia. The upper unit (Tdw^2) consists of mixed phreatic breccia and columnar-jointed andesite (intrusive ?), overlain by cliff-forming andesite flow breccia, which intertongues with the overlying Red Plateau member. The rocks show phenocrysts of plagioclase, augite, and pigeonite, with sparse hornblende and disequilibrium quartz in a plagioclase-magnetite matrix.

Breccias referred to the Wheeler Mountain breccia are well developed north-northwest of Tranquille (Fig. 3), conformably overlying Mara Hill rocks. Here coarse andesite breccia (Tdw^3) thins rapidly eastward and changes facies into a thin palagonitic succession; primary dips are greater than 20 degrees. Overlying this is a succession of phreatic basalt breccias (Tdw^4). The correlations of this section with units of the type Wheeler Mountain breccia are unclear.

CASTLE BUTTE BRECCIA (Tdc): The Castle Butte breccia forms imposing cliffs above Dewdrop Flats northwest of Battle Bluff and represents the lower part of the Doherty Creek stratocone (*see* Fig. 5). It consists of up to 550 metres of phreatic and transitional phreatic-subaerial breccias with clasts of coarse plagioclase-phyric andesite (Table 1, 4-2). The breccia is entirely palagonitic and fairly well bedded in the east, but coarsens and thickens westward into massive flow breccia near the inferred vent in the eastern draw of Doherty Creek. This vent is also indicated by quaquaversal dips in the breccia away from the vent. The lower part of the member in the vicinity of the vent is composed of hyaloclastite with minor sandstone, similar to the upper Tranquille Formation. The base of the Castle Butte breccia is not exposed.

DOHERTY CREEK MEMBER (Tdd): The Doherty Creek member forms the upper part of the Doherty Creek composite cone. It consists of over 600 metres of basaltic andesite and andesite flows, moderately to poorly plagioclase-porphyritic, with lesser quantities of intermediate to felsic tuffs, mudflows, and breccia. Minor intrusions also occur in this unit. The Doherty Creek member lines the top of the erosional basins developed over the eruptive centres. It dominates the western side of the composite cone, interfingering eastward with the Castle Butte breccia. It may be laterally equivalent to the Red Plateau member of similar lithology; distinction is based largely on the primary dips of the Doherty Creek member away from the Doherty Creek vents. The maximum thickness of the Doherty Creek member is about 1 500 metres; the upper and lower boundaries are gradational.

ROSSEAU MOUNTAIN BRECCIA (Tdrm): The Rosseau Mountain breccia overlies the Doherty Creek member on the ridge north-northwest of Red Point. It is composed of over 100 metres of flow breccia and mudflows with some (hydrothermal ?) palagonitic alteration. Clasts are of glossy black basalt (Table 1, 5-6) with phenocrysts of clinopyroxene, labradorite, and olivine. Crude bedding suggests a vent area to the north; the unit may represent a satellitic vent to the main composite cone. Toward Kamloops Lake the lower part of the member becomes largely hyaloclastic, forming rough badlands east of the mouth of Rosseau Creek.

RED PLATEAU MEMBER (Tdr): The Red Plateau member lies conformably upon the Castle Butte breccia in typical exposures on the southeast end of Red Plateau (Fig. 4); it interfingers with underlying Wheeler Mountain breccia on Wheeler Mountain. The member is composed of 350 to 450 metres of alternating basaltic andesite (Table 1, TP 32-3) flows and flow-top breccia with derived mudflows. Within a flow and breccia couplet, vesicularity increases upward from small (1 to 3-millimetre) vesicles to cavernous elongate vesicles up to 10 centimetres in length; these are overlain by rounded, highly vesicular andesite clasts in variably altered matrix. Tuffaceous sediments similar to those of the lower Tranquille Formation are locally developed as interflow units. In good exposures, up to 15 flow and breccia couplets can be recognized. This stratigraphy, along with substantial lateral continuity and low primary dips, suggests fissure-fed shield edifices formed by low viscosity basaltic andesite magma. Thin sections show phenocrysts of labradorite, augite, pigeonite, occasional biotite, and 'ghost' hornblende, with occasional cognate xenoliths in a plagioclase-magnetite matrix.

OPAX BRECCIA (Tdo): The Opax breccia overlies and interfingers with the Red Plateau member, as typically exposed on the west side of Opax Hill at the northern edge of the study area. It is composed of over 300 metres of cliff-forming grey andesite (Table 1, TP 39-3) flow breccia with very little matrix. Clasts are near-aphanites, with very infrequent resorbed plagioclase, amphibole, and clinopyroxene

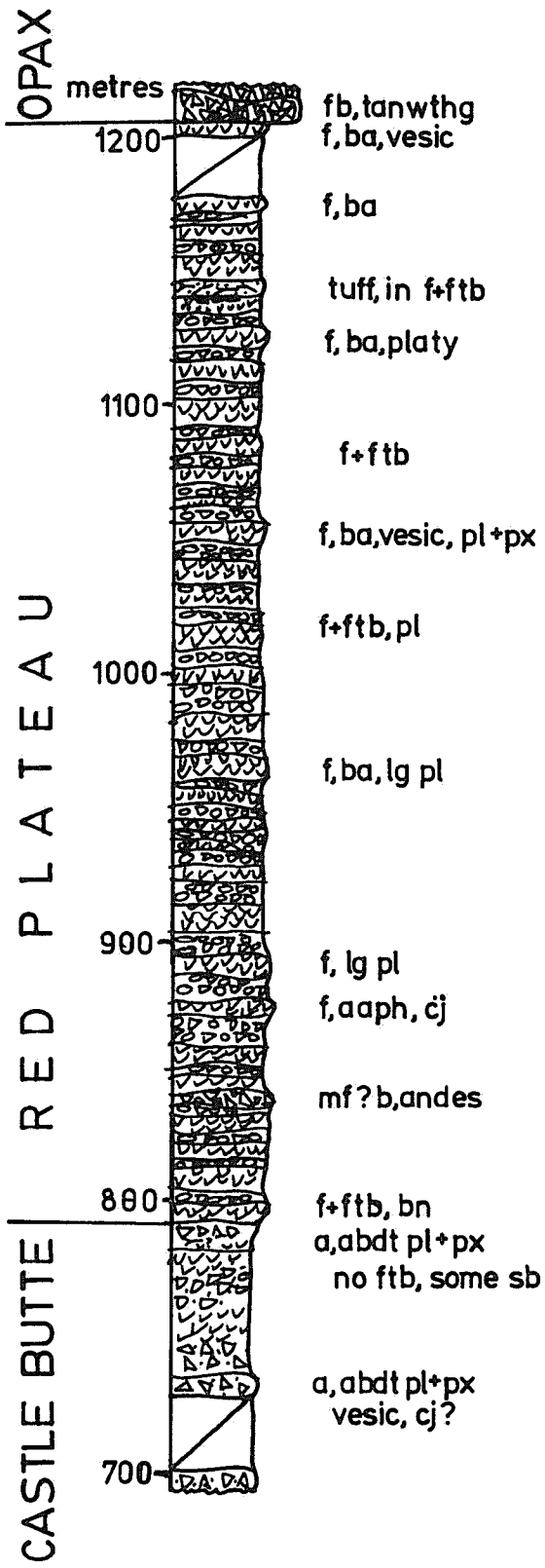

Figure 4. Stratigraphic column of the Red Plateau member in its type locality, southern side of Red Plateau, northwest of Tranquille.

in a glassy matrix showing swirled flow banding. Its uniform stratigraphy suggests that it may have been fed as a sheet from the breccia dykes which are observed in the area, rather than from central volcanoes.

INTRUSIVE ROCKS (Ti)

The Kamloops Group sedimentary and volcanic rocks are intruded by a variety of dykes, sills, and plugs. Composite dykes of columnar-jointed andesite and slabby red-brown dacite are abundant and conspicuous at Kissick siding south of Mara Hill. Dykes of andesite, dacite, and derived breccias are present in most other areas, but can rarely be mapped for any length along their strike. A small, altered intrusion is observed in the vent of the Doherty Creek stratocone.

Various masses of Tertiary igneous rock lacking diagnostic structure have been labelled intrusions on the map, mostly along the Cherry Creek fault zone. They are andesites and basaltic andesites forming fault-bounded slices which are not correlatable with the main volcanic stratigraphy. These may represent shallow intrusive and extrusive bodies which rose along an Eocene-active fault zone. Another igneous body, located near Dufferin Hill, may be just a fresh phase of the Nicola Group.

In the Kissick area, three conspicuous dome-shaped andesite (Table 1, 31-5) intrusions have been mapped, with related dykes and sills (Ti^1). These intrusions contain complex jointing and cooling patterns. The intrusion nearest the road is covered with shallow concave-out dish structures roughly 3 metres across, which form perpendicular to cooling joints. These are formed by alternating clay and carbonate alteration zones in the plug which weather differentially. Cooling evidently proceeded from a small number of foci around the intrusion, forming fanning columns and therefore dish-shaped alteration zones. Immediately west of this intrusion is a set of thin andesite sills, with a wide variety of baked contacts and complex columnar jointing. One sill appears to steepen eastward and merge with the intrusion.

At Mission Flats, south of the Thompson River, inferred hypabyssal intrusive rocks are exposed in railroad cuts (Ti^2). These rocks, showing little structure and no brecciation, are basaltic andesite composition similar to most of the Kamloops Group volcanic rocks. They occur in the Kissick-Mara Hill section and may be feeders overlying volcanic members.

BATTLE BLUFF INTRUSIVE COMPLEX (Tib): Medium to coarse-grained diabase intrusions are found both north and south of Kamloop Lake at Tranquille. Resistant sills form cuestas north of Battle Bluff and southwest of Saltwort Pond. North of the river, three sills are distinguished, both in outcrop and in drill hole RDH-75-1 (described by Carr, 1975). The basal sill (Tib^1), 20 metres thick, follows the contact between the Tranquille Formation and basement rocks; it outcrops discontinuously behind Battle Bluff. The larger middle and upper sills (Tib^2 and Tib^3, 40 metres and over 60 metres, respectively) form concordant units with conspicuous chilled zones and hornfelsed sedimentary rocks at their lower contacts. The sills are composed of subophitic diabase (Table 1, TP 9-1) containing abundant labradorite with extensive magmatic overgrowths of oligoclase, pigeonite, augite with some overgrowths, skeletal magnetite, biotite, and rare olivine. Mathews (1964) obtained a biotite K/Ar date of 49 Ma from the sills (51 Ma using presently accepted decay constants). Small (1 to 5-centimetre-wide) microsyenite dykelets are seen in several places toward the top of the sills. In thin section they show biotite and aegerine-rimmed augite, set into an orthoclase-albite-calcite groundmass.

South of Kamloops Lake, three sills are again seen, but these are probably not directly correlative with those near Battle Bluff. The basal sill (Tib^1, about 75 metres thick) intrudes the basal contact of the Tranquille Formation, filling valleys in the pre-Eocene erosion surface. The sill is very coarse grained, but of similar mineralogy to the other sills. The middle sill (Tib^2) consists of 70 metres of fine-grained equigranular diabase, while the upper sill (Tib^3) consists of 95 metres of medium-grained diabase. The lower and upper sills form conspicuous cuestas from Saltwort Pond south to Afton and were found in drill holes N-3, N-4, and N-5 (data in Miller, 1972). A similar but higher sill was found in drill hole N-4 (Fig. 6). Sedimentary intercalations of recessive lower Tranquille lakebeds are intermittently exposed between the sills.

A thick mass of coarse-grained diabase is exposed along the Canadian Pacific tracks east of Cherry Bluff. The high cliff displays conspicuous regular banding at about 2-metre intervals, apparently a

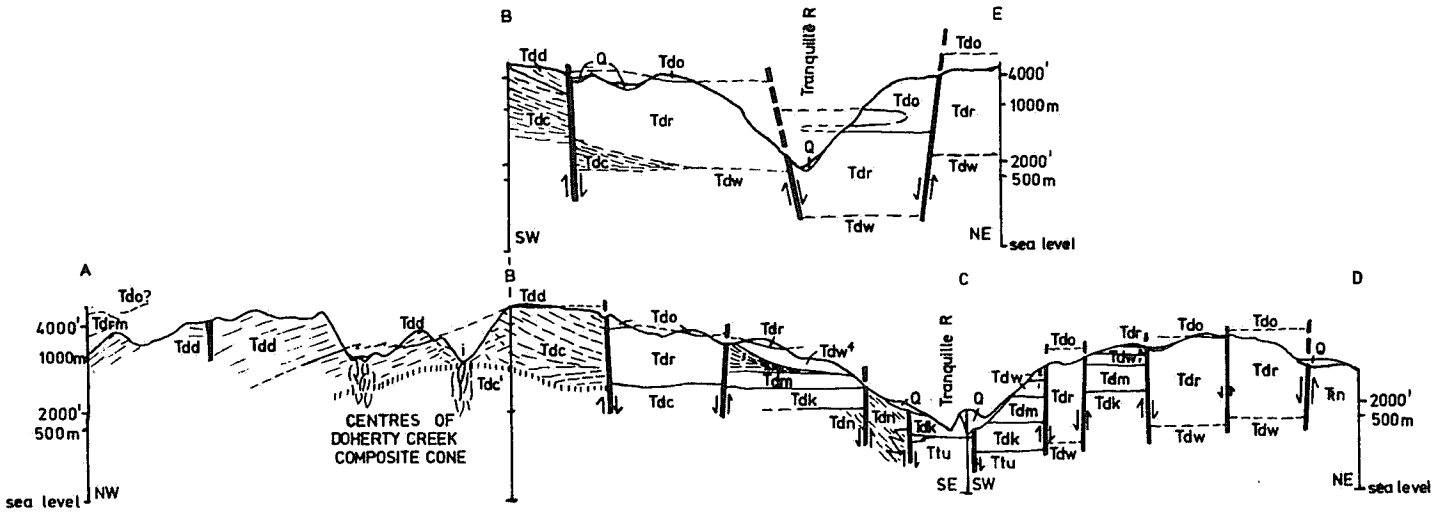

Figure 5. Cross-section of the Tranquille Canyon graben and Doherty Creek cone; section ABCD and BE.

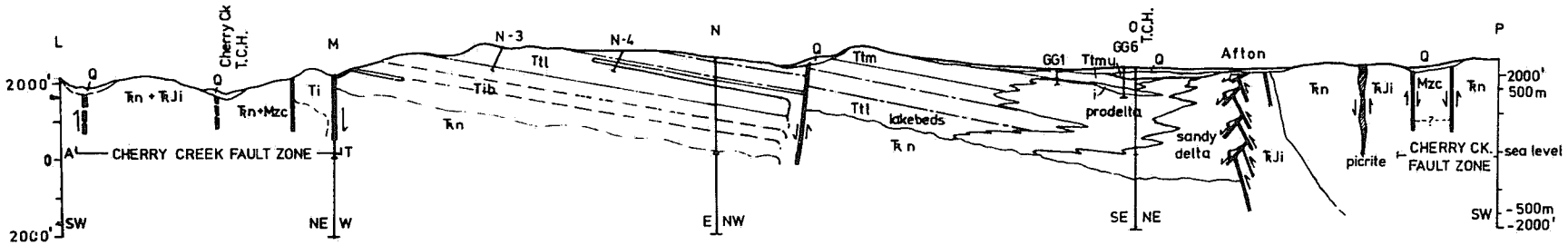

Figure 6. Cross-section of the Afton mine area; section LMNOP.

cooling phenomenon. This plutonic mass may mark the intrusive centre of the sills north and south of Kamloops Lake. Similar rocks are poorly exposed eastward on the Canadian Pacific tracks, and southward toward Afton.

The Battle Bluff intrusive complex represents the intrusion of a large volume of basaltic magma, probably at considerable depth. It may represent the subvolcanic equivalent of some of the upper members of the Dewdrop Flats Formation volcanic rocks.

QUATERNARY (Q)

GRAVELS OF THE MIDLAND SURFACE (Qg): In the valleys north of Mara Hill, the lower slopes are mantled with a substantial thickness of alluvial gravels. These may represent preglacial or interglacial alluvial fan deposits graded to the midland erosion surface of Fulton (1975); they predate the cutting of Tranquille Canyon. Later erosion has incised these materials more or less deeply. Other high alluvial patches are included in other areas.

TERRACE GRAVELS (Qtg): Along Tranquille River, flat-topped terrace surfaces about 60 metres above present river level are underlain by thick well-sorted bedded gravels. These fill a buried canyon of the Tranquille River, slightly east of the present canyon south of Wheeler Mountain.

GLACIAL DRIFT (Qd): Kamloops Lake drift (Fulton, 1975) forms a discontinuous blanket over the mapped area; it has been mapped only where it obscures outcrop. It is extensive south of the Thompson River, where it contains erratics of Eagle Hill conglomerate transported from the Copper Creek area 30 kilometres northwest. North of the river, drift forms a kettled ground north of Tranquille, low drumlins on Dewdrop Flats, and a wide variety of eskers, drumlinoids, and hummocky ground along the east boundary of the study area.

PROGLACIAL LAKEBEDS (Qlb): Pleistocene lacustrine deposits of glacial Lake Kamloops form a thin veneer on both sides of the Thompson River trough. It is discontinuous on the north side, but blankets the south side, showing well-developed strandlines in the 4 kilometres west of Mission Flats. In this area, lakebeds effectively obscure the bedrock geology.

POSTGLACIAL RAISED DELTA (Qdl): The main body of the delta of the Tranquille River is raised 3 to 6 metres above present lake level, marking a higher stand of Kamloops Lake in Early Holocene time.

LANDSLIDE DEBRIS (Qls): Three large landslides have been identified on the south side of the Thompson River. They occur on a dip slope of middle and upper Tranquille Formation volcanic and sedimentary rocks which have been oversteepened by glacial excavation of the Kamloops Lake trough. The two upper landslides are composed of middle Tranquille Formation debris, which slid on underlying mudstones; the scarp of the eastern slide is localized by a small east-down fault. The lower landslide is developed in much-fractured tuff of the middle-upper member, and exhibits a fresh scarp at 530 metres elevation. At least two slides have taken place here; the younger one is very recent. Potential for more landslide activity on these slopes is high.

West of Red Point, a large mass of Rosseau Mountain breccia has slid semicoherently into the Kamloops Lake valley from the south face of Rosseau Mountain. This mass slid over the hyaloclastic southwestern facies of the member and, in part, the upper Tranquille hyaloclastites, in response to an oversteepened slope. Potential for rockfalls and small slides is still present in this area.

ALLUVIAL FANS (Qaf): Small postglacial alluvial fans have been constructed along the northern side of the Thompson River valley. Larger fans extend southward across Dewdrop Flats deriving material from the high south face of the Red Plateau.

FAN DELTAS (Qfd): Alluvial fan-deltas have been built into Kamloops Lake by Doherty Creek and other streams cutting down through the rimming bluffs.

ALLUVIUM (Qal): The largest area of alluvium in the study area is the delta of the Thompson River east of Tranquille, which has grown westward nearly to the Tranquille River raised delta. Other small areas of undifferentiated alluvium underlie small alkali lakes south of the river and the valleys of Tranquille River and Cherry Creek.

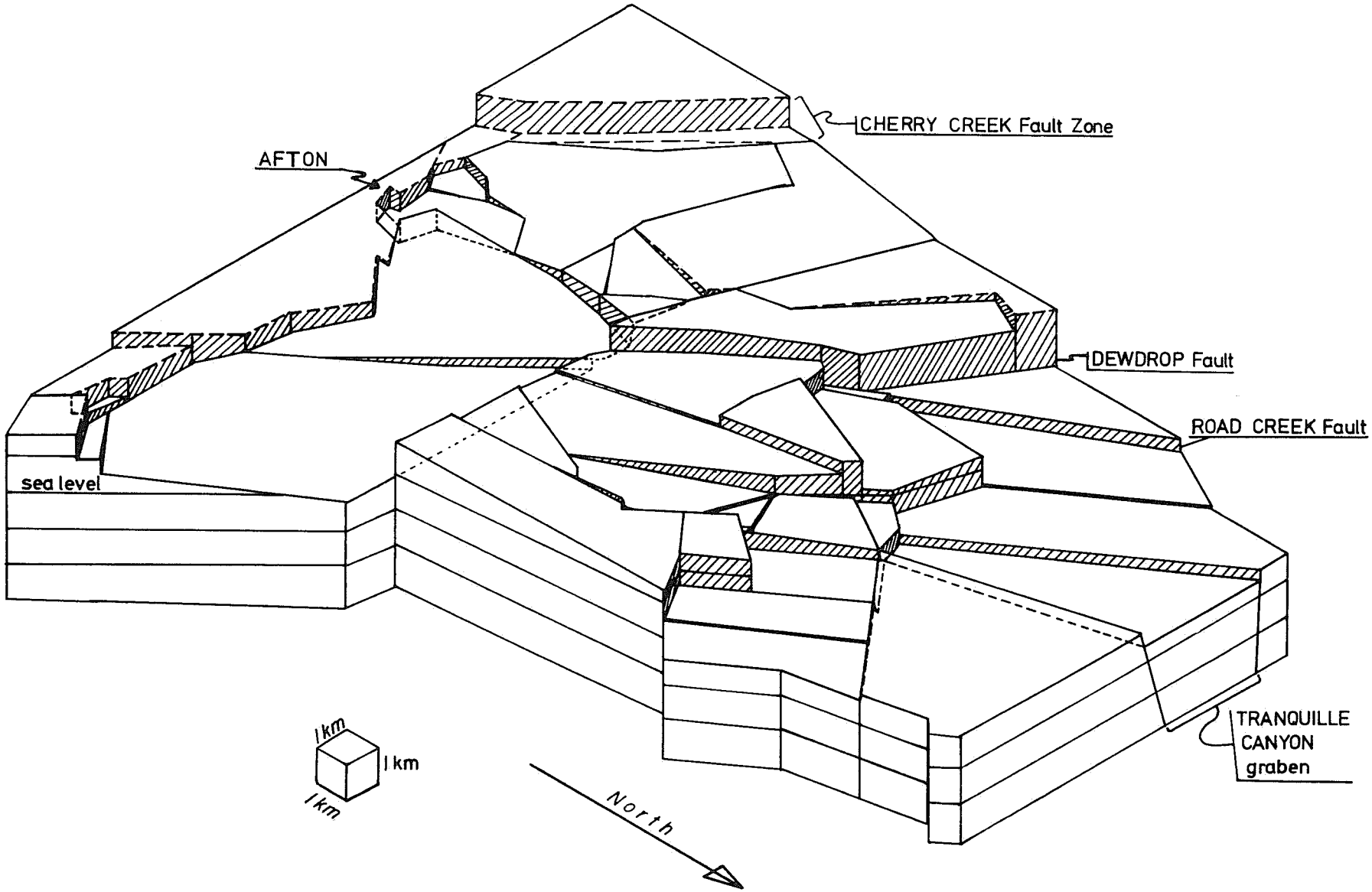

Figure 7. Isometric block diagram of the map-area. View is from the northeast; the east and north walls of the graben have been removed for clarity. Datum is the inferred base of the Tertiary; no vertical exaggeration.

STRUCTURE

BASEMENT STRUCTURE

Basement structure is complex and has not been studied for this report. The presence of northwest-southeast linear features has been noted by Carr and Read (1976); intrusion of the Iron Mask and Cherry Bluff rocks was localized by such features, as was deposition and preservation of later Mesozoic sedimentary rocks. These sedimentary rocks may, in fact, represent an earlier cycle of basin development and tectonic activity similar to that which took place in the Eocene.

SYNDEPOSITIONAL STRUCTURE

Some structures show definite activity during the deposition and eruption of Eocene rocks. The Cherry Creek fault zone localized hypabyssal bodies which may represent magmas rising upward along a leaky active fault zone. This zone continues northwest under the main body of Kamloops Lake. To its west, no Kamloops Group volcanic rocks are preserved. This fault zone formed a tectonically active southwestern boundary of the Tranquille depositional basin; this interpretation is supported by the soft-sediment deformation observed west of Red Point. Minor faults and folds in and near the fault zone suggest right-lateral strike-slip movement.

Relationships at Afton mine (summarized in Preto, 1972, and Carr and Reed, 1976) indicate subsidence of large mineralized blocks of Triassic rock into the Tranquille basin off the upthrown side of high-angle reverse faults (as shown on Fig. 6). Also, the Tranquille Formation around the mine is in a nonvolcanic deltaic facies, as described previously, indicating that the Afton structural zone was active during Tranquille time and represented the southern margin of the Tranquille depositional basin. This complex zone follows the northern boundary of the Iron Mask Batholith with a thin selvage of Nicola Group rocks from Afton east to the Dufferin area.

Immediately east of Battle Bluff, Tranquille sedimentary rocks are inferred to be faulted down about 120 metres against the east margin of the Cherry Bluff pluton. This faulting took place before the intrusion of the Battle Bluff sills, which pass uninterrupted through the fault plane.

There is no firm evidence for other faults in the area being active during deposition of the Kamloops Group. The anomalous thickness of the Kamloops Group in its type area relative to other exposures in the region, however, suggests subsidence in the Tranquille area. The northern and eastern boundaries of the Tranquille basin are not known. The present eastern edge of Tertiary outcrop does not appear to be the original boundary, as fine-grained lacustrine sedimentary rocks are exposed at the bounding fault. However, basaltic andesite flows rest directly on basement rocks at Strawberry Hill east of the North Thompson River, indicating a basin boundary at or west of the North Thompson.

SYN TO POST-DEPOSITIONAL STRUCTURE

Figures 5 and 6 are sections across the Tranquille area; Figure 7 is an isometric diagram of the inferred base of the Eocene. The area consists of a large number of flat to gently tilted and folded blocks and panels, separated by high-angle faults. The dominant structure is a complex graben (Figs. 5 and 7) with the greatest relief in the northern part of the area, along Tranquille Canyon, gradually decreasing to the south. South of the Thompson River valley, which is localized along Eocene faults, panels dip gently to moderately north. To their west, a large east-dipping panel contains an open syncline, while a smaller panel immediately north of the Afton is tilted toward the mine area (Fig. 6). These panels cascade off the rigid blocks of the Iron Mask Batholith and the Cherry Bluff pluton. These Triassic-Jurassic intrusions buttress the southern and southwestern sides of the subsidence structure.

Northwest-southeast faults, such as the Road Creek-Coal Hill faults, show varying degrees and senses of displacement. They represent the dominant fault trend of the southern part of the area, ranging in azimuth from 130 degrees in the south to 145 degrees in the north. These may in part be reactivated Mesozoic features. More northerly trends are observed in Tranquille Canyon and appear as aeromagnetic lineaments to the northwest.

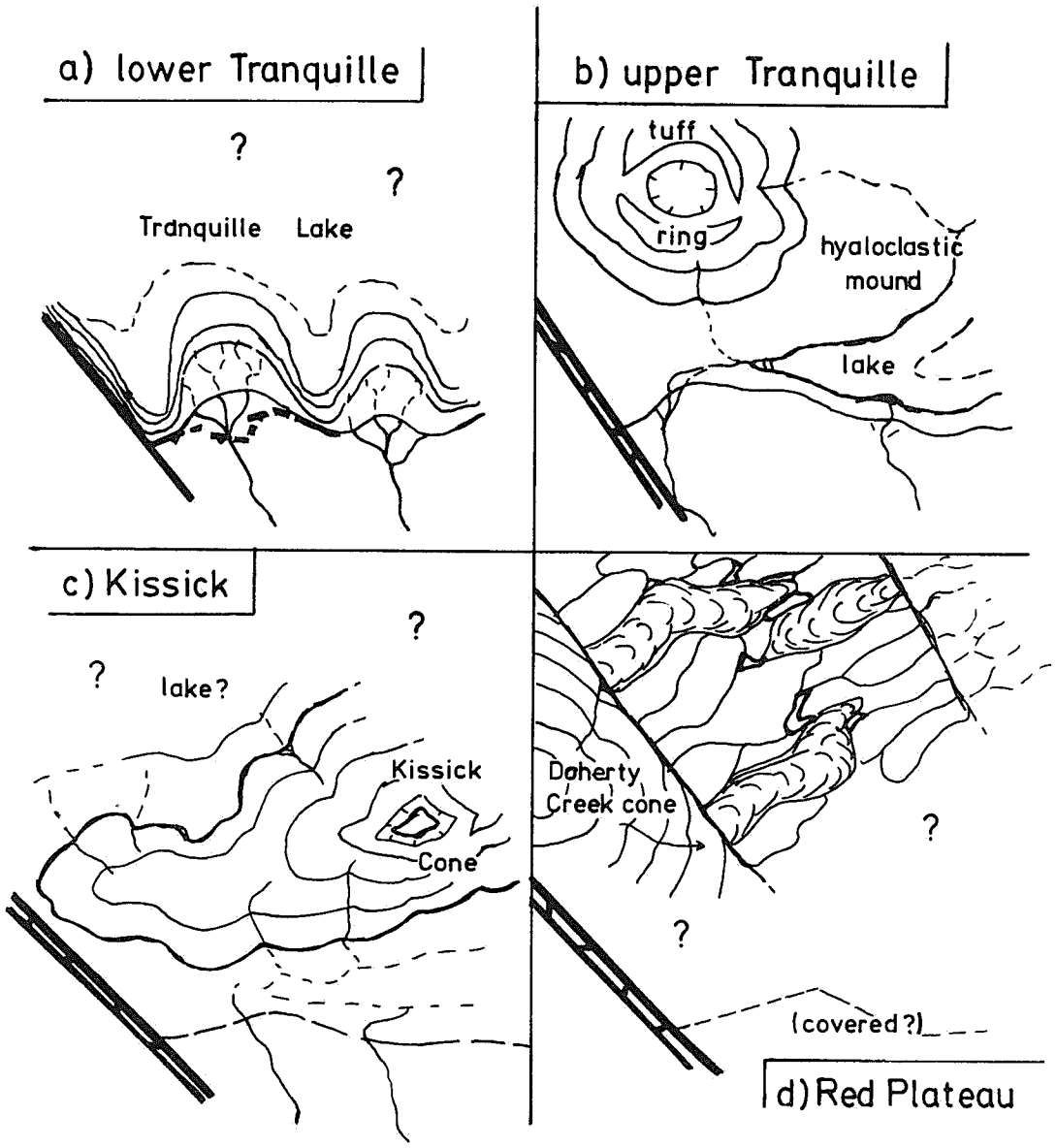

Figure 8. Paleogeography of the Tranquille area during deposition of the Kamloops Group. Cherry Creek fault zone is in lower left of all sketches. Question marks indicate the limits of exposure of rocks of that time period.

From the relationships observed in the Tranquille area, and from regional reconnaissance, it is inferred that both the Tranquille depositional basin and the Tranquille Canyon graben are extensional features formed by the pulling apart of blocks within a dominant regional strike-slip regime. Early strike-slip activity produced the Tranquille Lake basin with a compressional southern margin. Continued activity affected the later volcanism, leading to the complex graben structure observed today. This concept is developed further elsewhere (Ewing, in prep.).

SUMMARY OF GEOLOGIC HISTORY

The earliest strata exposed in the map-area record the eruption in Late Triassic time of the Nicola Group volcanic rocks and associated volcaniclastic rocks. Subvolcanic intrusions formed the Iron Mask Batholith (Northcote, 1977) and the Cherry Bluff pluton. In later Mesozoic time, the Cherry Creek fault zone was repeatedly active and localized the deposition of coarse fluvial conglomerates.

At about 52 Ma, subsidence of a block bounded on the southwest and south by the Cherry Creek fault zone and the Afton structural zone created the Tranquille basin (Fig. 8). This basin was occupied by an extensive lake, with one or more deltas built against and locally lapping over the upthrust southern margin. Rapidly increasing volcanism in the area supplied abundant plagioclase-rich ash and palagonitic debris. Local slumps of Nicola Group volcanic blocks and Tranquille sedimentary rocks into the basin attest to substantial relief and tectonic activity. Basaltic and andesitic volcanism produced pillowed andesite flows, hyaloclastites, and aquagene tuffs, leading to the filling of the lake with debris and the construction of a tuff cone of olivine basalt as seen in the upper part of the Tranquille Formation (Fig. 8b). Atop this filled lake basin, basaltic to andesitic, largely subaerial volcanic rocks of the Dewdrop Flats Formation were erupted. In the lower Dewdrop Flats, the Kissick cone was built up (Fig. 8c) just above the water table, leading to mixed subaerial-phreatic breccias. Flat-lying basaltic andesite flows and breccias built shield structures and small cones atop and around this cone. Later the Doherty Creek composite cone grew to a basal diameter of some 10 kilometres; beginning as a tuff cone, it developed to a mature subaerial basaltic andesite to andesite volcano, with at least one satellitic breccia cone and related hyaloclastites. Contemporaneous with and following the development of this cone, thick, flat-lying basaltic andesite flows were erupted in the Tranquille Canyon graben to the northeast (Fig. 8d). These were followed by eruption of a thick andesite sheet breccia. Faulting associated with the graben subsidence and regional dextral shear continued after eruption of the volcanic rocks to produce the structure shown on Figure 7.

In Late Eocene to Miocene time, a surface of low relief was developed, on which the Plateau lavas, now preserved north of the study area, were deposited at about 10 Ma. This surface was dissected to form a later (Pliocene ?) midland surface. Glacial activity during the Pleistocene excavated the large transverse Thompson River-Kamloops Lake trough, in part along pre-existing lines of weakness such as the Cherry Creek fault zone; existing stream drainage was also realigned. A proglacial lake deposited sedimentary rocks over the lower parts of the area, and postglacial deltas have been built into Kamloops Lake.

ALTERATION AND MINERAL POTENTIAL

No showings of potentially economic mineralization have been located yet within the Tertiary of the study area. Most rocks are somewhat altered by partial devitrification of glass, vesicle, and fracture filling, and alteration of some mafic phenocrysts. Clays (iron-magnesium smectites and montmorillonite), opal, and calcite are most abundant. Identifiable zeolites occur sporadically; euhedral analcite crystals were found along the Canadian Pacific right-of-way at longitude 120 degrees 30 minutes west, chabazite crystals at several locations in the Castle Butte breccia, and ferrierite (a magnesium-zeolite) at its type locality at Red Point. Microscopic zeolites were found locally in the Battle Bluff intrusions and in vein coatings in the upper Tranquille at Kissick. Bright green amygdules and occasional disseminations of celadonite (iron-magnesium mica) are conspicuous in the Red Plateau member along Tranquille Canyon. Sparse geode (quartz, calcite, and opal) occurrences were noted throughout the basaltic andesite flow sequences.

Disseminated magnetite is abundant in the Kamloops Group volcanic rocks, commonly substantially altered to hematite. Pyrite has been reported from fractures (Carr, 1975). Magnetic and induced

polarization geophysical techniques are thus difficult or impossible to apply in this area. Graham and Long (1979) have reviewed and dismissed the potential for coal resources in the Tranquille basin. Most of the Tranquille Formation is very low in organic matter, as it was deposited in an ash-choked lacustrine basin with rapid deposition. Thin deposits south of the Afton structural zone, represented by fault slices within the Afton deposit and at the Guerin Creek outlier, have been prospected in the past (Dawson, 1895) but are not economic.

Placer gold has been worked in Tranquille Canyon since the 1850's (*see* Dawson, 1895). Fairly coarse gold with accompanying platinum is still recovered in subcommercial quantities by panning in alluvium from Watching Creek and the lower Tranquille River. Terrace gravels along the lower canyon have also been hydraulically mined.

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