CAMBRO-ORDOVICIAN VOLCANIC ROCKS IN EASTERN DAWSON MAP-AREA OGILVIE MOUNTAINS, YUKON

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ABSTRACT

Basalt and minor rhyolite flows and breccias in the northwestern extension of Selwyn Basin are stratigraphically above maroon argillite (Lower Cambrian Hyland Group) and beneath black chert (Middle Ordovician Road River Group). All are intensely folded and repeated by shallow thrust faults.

The lower part of the volcanic succession is dominated by subaqueous flows, and the upper part includes shallow and subaerial breccias and limestone pods. The volcanic unit is interpreted as many small overlapping seamounts fed by gabbroic dykes.

The basaltic rocks are alkalic and contain high concentrations of TiO_2 (1.7 - 3.6%), P_2O_5 (0.5 - 1.2%) and Zr (140 ppm). They resemble the volcanic Marmot Formation in the northeastern part of Selwyn Basin, and are consistent with extension and thinning of continental crust.

The volcanic rocks lack significant sulphide mineralization, except where hornfelsed near Cretaceous intrusions. Local high barium concentrations suggest that volcanism may have contributed to stratabound barite in overlying Devonian shales.

RÉSUMÉ

Dans le prolongement nord-ouest du bassin de Selwyn, des coulées et brèches basaltiques et quelques coulées et brèches rhyolitiques se situent stratigraphiquement au-dessus d'argilites marron (groupe de Hyland, du Cambrien inférieur) et au-dessous d'un chert noir (formation de Road River, de l'Ordovicien moyen). Toutes ces coulées et brèches sont intensément plissées et redoublées par des failles chevauchantes peu profondes.

La partie inférieure de la succession volcanique est dominée par des coulées subaquatiques, et la partie supérieure comprend des brèches peu profondes et subaériennes et des lentilles calcaires. On a interprété l'unité volcanique comme étant composée de nombreux petits guyots empiétant les uns sur les autres, et alimentés par des dykes de gabbro.

Les roches basaltiques sont alcalines, et contiennent des concentrations élevées de TiO_2 (1,7 - 3,6 %), de P_2O_5 (0,5 - 1,2 %) et de Zr (140 ppm). Elles ressemblent à la formation volcanique de Marmot dans la partie nord-est du bassin de Selwyn, et leur formation s'expliquerait bien par une expansion et un amincissement de la croûte continentale.

Les roches volcaniques ne contiennent pas de minéralisation sulfurée notable, excepté là où elles ont été transformées en cornéennes près des intrusions crétacées. Des concentrations localement élevées en baryum suggèrent que le volcanisme a peut-être contribué au dépôt stratiforme de barytine dans les argiles litées dévoniennes sus-jacentes.

INTRODUCTION

Among the generally subdued and thickly vegetated ranges south of the high Ogilvie Mountains are strips of volcanic rock that form castellated spines and grey towers. The enclosing dark shale, grit, and chert comprise Selwyn Basin, in which large, stratabound zinc-lead deposits of the Anvil and Howards Pass type are hosted by Lower and Middle Paleozoic phyllite. Dawson map-area contains similar strata and abundant volcanic rocks. Reconnaissance stream sediment geochemical surveys have located anomalous Cu, Zn, Ba, Mo and Ni concentrations draining from the volcanics and black shale (i.e. STYX claims; INAC 1981, p. 285).

Volcanism might have been accompanied by metalliferous fluids or circulating hydrothermal systems and thus caused massive sulphide deposition.

The volcanic rocks also have tectonic implications for for the region. In the Ogilvie Mountains, clastic and igneous rocks record three distinct extension events at about 1200, 750 and 530-450 Ma (Thompson et al, in press). The ca. 750 Mount Harper Complex, in a carbonate shelf environment, contains similar mafic rock types to those of the early Paleozoic Selwyn Basin volcanic unit described here.

This report addresses the economic potential of the volcanics, their stratigraphic position and presents first analyses of their composition. Field work in 1986 consisted of 1:50 000 scale mapping in specific areas as part of the regional program of stratigraphic correlation and structural assessment by the G.S.C. (see Thompson and Roots, 1981). The structural model expressed here was derived from field study since 1980 by Thompson and co-workers, and is based on the excellent reconnaissance map of Green (1972). Previous work has outlined the distribution of the volcanics, but not their stratigraphic position or internal structure. Figure 1 indicates localities described here; further map detail is available in G.S.C. Open File reports.

REGIONAL SETTING AND STRUCTURE

Sedimentary rocks north of the Tintina Fault are part of the Cordilleran fold and thrust belt, and in Dawson map-area comprise two major successions of shelf and basin affinity (Thompson and Roots, 1981). Both were displaced northward during the late Jurassic, and the basin succession has been considerably shortened by thrusts and folds. Stratigraphic packages of different ages comprise three structural sheets (see Anderson, 1987). Volcanic rocks are confined to numerous linear outcrops in the northernmost sheet (Fig. 1), which also includes two other principal rock units; the Hyland Group and the Road River Formation.

The oldest exposed basinal strata are grit, limestone and maroon

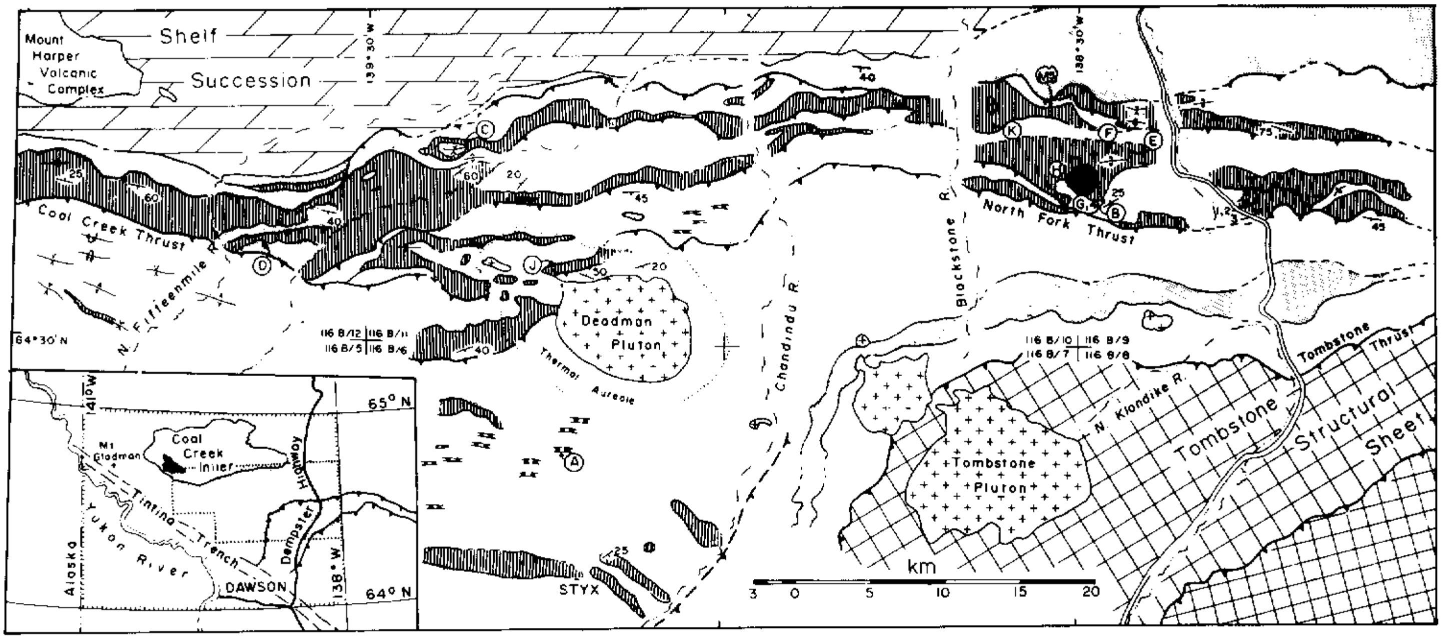

Figure 1. Generalized distribution of Cambro-Ordovician rocks (vertical stripes), Road River Formation (fine dots), and Hyland Group (no pattern) in the basin succession of the southern Ogilvie Mountains. The study area is the lowest of three structural sheets: overlapping sheets (gridded) are described in Anderson (1987). Limestone pods are short, thick lines within the volcanic belts (Dempster Highway area). Gabbro dykes (checkered) are more numerous than shown, particularly north and south of Deadman Pluton. Circled letters are localities mentioned in the text; numbers are sample locations (Table 1). Quadrants labelled with 116 B- suffix correspond to 1:50 000 map sheets available on Open File. Geology from Green (1972), Thompson and Roots (1982) and recent mapping.

argillite provisionally correlated with the latest Proterozoic and Lower Cambrian Hyland Group of Nahanni map-area (S.P. Gordey, in prep.). The Road River Group includes black argillite, siltstone and chert. In places where volcanics do not occur between them, the contact between the Hyland and Road River Groups is unclear. On both sides of the Dempster Highway, clean quartzite and wispy laminated, olive-coloured argillite and siltstone are in or overlying typical Hyland Group strata. In other places, rusty phyllitic siltstone, silvery weathering black mudstone and bioturbated green and yellow chert lie at or below the base of typical Road River Group strata. The Backbone Ranges, Kechika and Rabbitkettle formation are Cambrian units from the eastern edge of the Selwyn Basin that are missing in Dawson Map area, but which may be represented by these unassigned units (R. Thompson and G. Abbott, pers. comm., 1986).

AGE OF THE VOLCANICS

Previous studies have not made clear whether the volcanics were local accumulations, possibly of various ages, or were remnants of a single extensive sheet and stratigraphic contacts are exposed in only a few places and many contacts are now recognized as thrusts, based upon older over younger stratigraphic relationships. Broad areas of volcanic rocks shown on the map (Fig. 1) result from tight folding (Fig. 2).

Observed stratigraphic relationships and evidence for age are summarized below:

At Localities A and B (Fig. 1) pillows and lapillistone tuff layers conformably overlie maroon argillite of the Hyland Group which contain **Oldhamia** and worm burrows (resemble **Rusophycus**) that indicate a Lower or Middle(?) Cambrian age (see Hoffman and Cecile, 1981; Nowlan et al, 1985).

At Locality C, volcanic debris flows and a subaqueous pyroclastic succession is directly overlain by graptolitic chert of the Road River Group of Middle Ordovician age (Green, 1972; R. Thompson, unpubl. data).

The volcanic succession includes discontinuous pods of white- or grey-weathering limestone that have yielded mollusc and brachiopod fragments (M. Orchard, pers. comm. 1982) at Locality D and **an Early Ordovician conodont** (M. Cecile, pers. comm. 1987) at Locality E (Fig. 3).

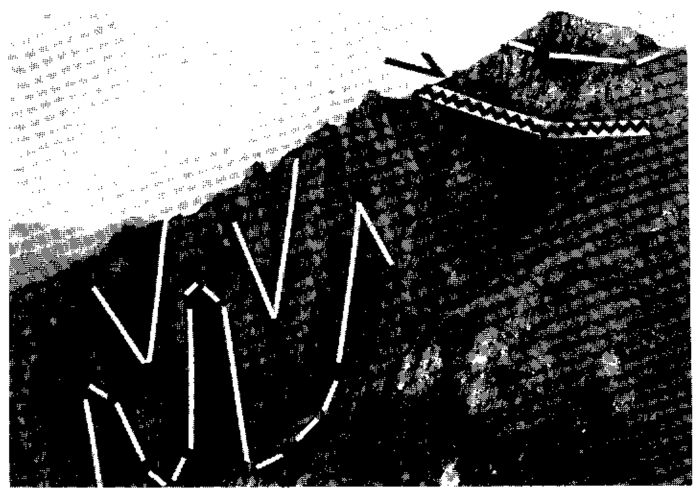

Figure 2. Tight upright folds of basaltic pillows and breccia, cut by a thrust and overlain by flat-lying flows of the same volcanic unit. The triangular scree slope below the thrust is black shale, possibly Road River Formation. Looking westward at locality K.

The upper contact of the volcanics is less clearly defined. At Locality F, hematized flows and conglomerate are interbedded with grey mudstone and calcareous siltstone. The overlying section is poorly exposed, but is lithologically similar to the unassigned units seen elsewhere between the Road River Formation and Hyland groups.

Volcanic rocks of lower to middle Paleozoic age occur along the margin of Selwyn Basin and in northeastern B.C. (occurrences reported in Cecile, 1982). Most consist of submarine flows and volcaniclastic deposits that form thin or lenticular bodies; some are in dominantly sedimentary units. The Marmot Formation of Misty Creek Embayment (**Bonnet Plume** map-area, 500 km to the east), which resembles the early Paleozoic volcanics of Dawson map-area in composition and setting, is Middle Ordovician to Lower Devonian (Cecile, 1982).

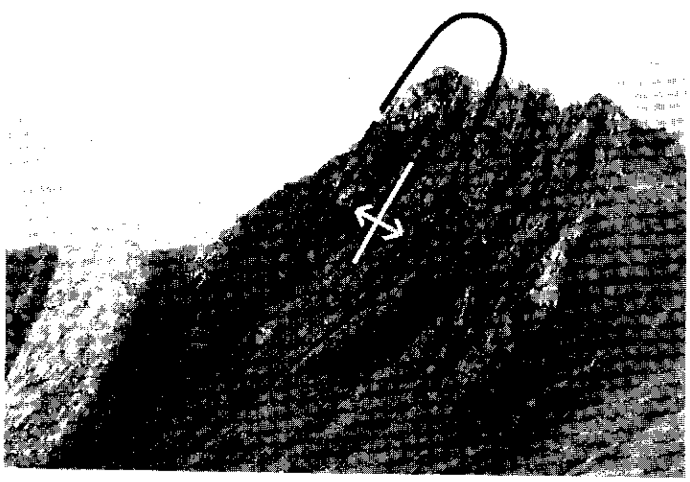

Figure 3. Isoclinal anticline of steeply dipping vesicular basalt, deduced from outward facing directions of flows and interbedded tuff. White area is a limestone pod - one in a discontinuous, 10 km long limestone layer near the top of the volcanic unit. Looking east at locality E, with East Blackstone valley and the Dempster Highway in background.

STRATIGRAPHY

The principal volcanic rock types, described in Roots (1981) and Roots and Moore (1982), are subaqueous pyroclastic breccias (Fig. 4), debris flows and submarine lapillistone-tuff. Their areal extent implies multiple vents that probably constructed overlapping volcanoes. Continuity of pyroclastic layers and thick pillow flow units over 5 km long indicate their size. In general, pillows and massive flows dominate near the base of the volcanic units, and lapillistone tuff, heterolithic breccias and hematized volcanics dominate near the top. These features suggest a progression from a deep water to a shallow water environment.

Volcanic outcrops near the Dempster Highway (km 87-93) are capped by hematitic vesicular flows and breccia that are likely subaerial. They are interbedded with maroon conglomerate containing well-rounded basaltic pebbles and cobbles in a volcanic mudstone matrix. Pods of crudely bedded limestone with textures indicative of shallow water deposition are common stratigraphically beneath the oxidized flows and breccias. The association of subaerially erupted and shallow water deposits imply the former presence of volcanic islands.

HYPABYSSAL MAFIC AND FELSIC INTRUSIONS

Large areas south of the Deadman Pluton where maroon argillite predominates are cut by west-trending dykes spaced 50-250 m apart. The dykes are compositionally similar to the volcanics and were observed in two places to directly feed pillow flows. At locality A, texturally distinctive breccia is interfingered along the contact of the dyke, stratigraphically overlies maroon argillite and is intercalated with overlying pillows. It consists of ragged, 1-3 cm lenticles of vesicular basalt in a fine grained, indurated matrix (Fig. 5). The breccia is clearly related to the breaching intrusion, and may be useful as a guide in the recognition of vents. Northeast of the Cretaceous Deadman Pluton, medium to coarse-grained augite gabbro intrusions up to 1 km^2, in the Hyland Group may have been shallow magma chambers feeding early Paleozoic volcanism.

A light brown-weathering felsic intrusion outcrops in a subcircular area 5 km west of the Dempster Highway (Locality G). In the centre, leucocratic felsite contains up to 15% rounded, 1-2 mm quartz phenocrysts and ghost rectangular shapes (probably feldspar) with size gradations suggestive of rhythmic layering. Near the southern edge, a breccia composed of angular 1-20 cm fragments of basalt, meta-siltstone and quartzite appears to be derived from host rocks because it grades into intact volcanic flows; all rocks in the vicinity are silicified and probably constitute a hornfels around this felsic intrusion. Siliceous apophyses and felsite dykes radiate southeast.

Felsic flows are exposed in a 12 km long area east of Mount Gladman (west Dawson map-area). Greenish feldspar-phyric rhyolite flows and lithic-crystal ignimbrite are directly overlain by Road River chert.

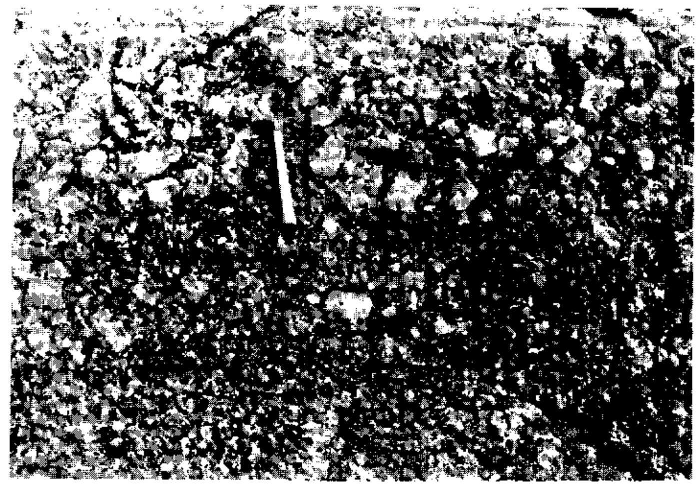

Figure 4. Inversely graded basaltic block and ash breccia interbedded with pillowed flows at locality L. The poor sorting and clast- supported texture of the angular fragments suggest proximal pyroclastic deposition. Such textural preservation is common in thicker volcanic accumulations.

COMPOSITION

The basalts contain chlorite, sericite, quartz, illite and local prehnite, indicating lower greenschist metamorphic grade. Hyalopilitic textures are well preserved and the most densely crystallized flows contain skeletal plagioclase with swallow-tail shapes and irregular interstitial opaques.

Many flows near the base of the volcanic unit contain augite megacrysts (up to 1 cm across) with clean rhombic and hexagonal shapes (Fig. 6). In many thin sections, augite is partly or totally replaced by zoisite. The groundmass of these flows is extremely fine-grained, with poorly crystallized plagioclase microlites and skeletal opaques (probably titanomagnetite). These flows were probably extruded rapidly from shallow magma chambers crystallizing augite. In contrast, medium-grained dykes contain abundant skeletal augite crystals (Fig. 7) that probably formed rapidly during intrusion. Unlike the Marmot Formation, phlogopite phenocrysts (Goodfellow et al, 1980) were not encountered in the Ogilvie Mountains volcanics.

Whole rock analyses of three mafic flows, a gabbroic dyke and a felsite sample (Table 10) show that the basalts are compositionally similar to intrusions of the Marmot Formation. Like these rocks, the felsite is high in Ba, Zr, and has an equivalent Nb/Y ratio. The mafic rocks have alkali-silica ratios near the alkalic-subalkalic boundary (Fig. 8a) and, if subalkalic, are a tholeiitic suite (Fig. 8b). Two of the samples are alkalic according to the criteria (1% K_2O, 35 ppm Rb and 300 ppm Ba) of Mahoney et al (1985). During alteration, major elements normally used to determine the alkalinity may be mobile such that the original nature of these rocks is obscured. Alternatively, immobile minor and trace element ratios may also be used to determine whether the volcanics were alkalic (Fig. 8c).

Volcanic rocks may indicate something of the character of underlying crust and the regional tectonic setting at the time of eruption. Specifically, was Cambro-Ordovician volcanism related to continental extension or to separation and production of volcanic crust? Relative to mid-oceanic ridge basalt (MORB), these samples are low in silica, have low MgO/Mgo and FeO^{tot} (.35 - .45), and have relatively high TiO_2, P_2O_5 and Zr. On discriminant diagrams that are used

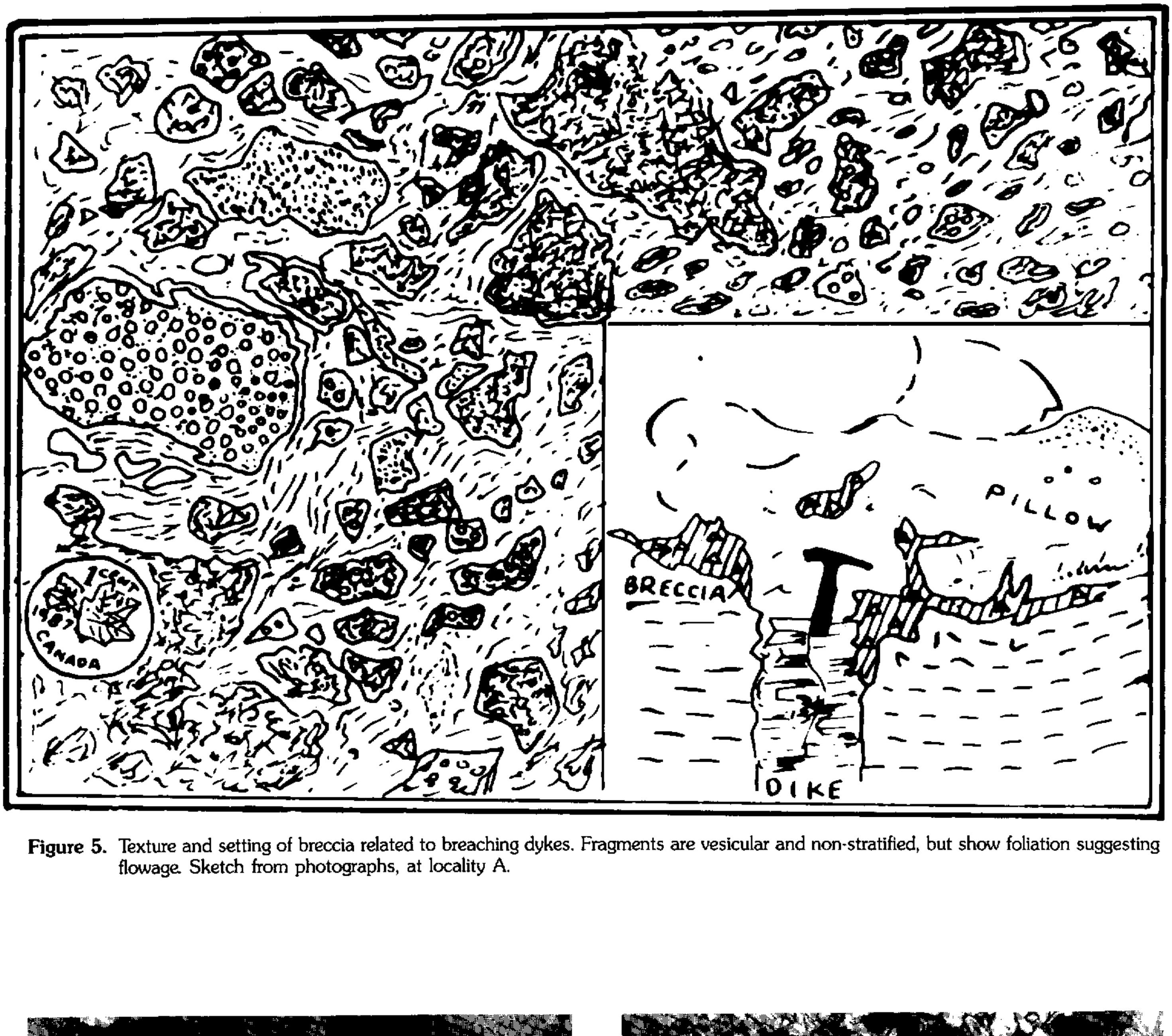

Figure 5. Texture and setting of breccia related to breaching dykes. Fragments are vesicular and non-stratified, but show foliation suggesting flowage. Sketch from photographs, at locality A.

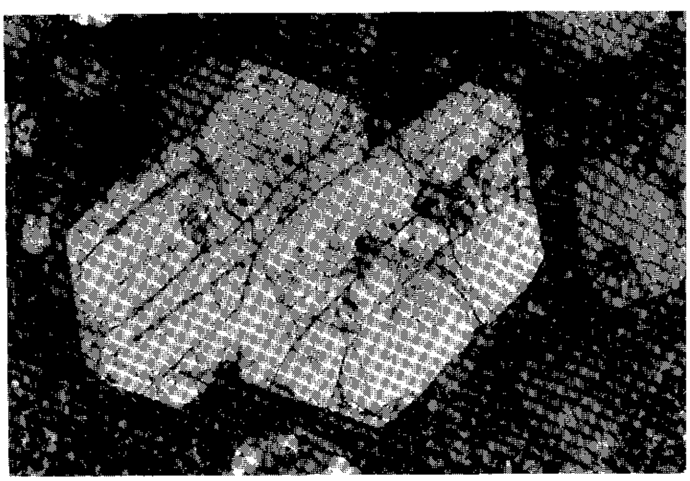

Figure 6. Basal basalt flow contains large, well formed augite phenocrysts (this one 2 mm long), smaller zoned phenocrysts (possibly orthopyroxene, replaced by calcite) in a groundmass of plagioclase microlites, interstitial opaques with sphene overgrowths. Plane- polarized light. From locality M.

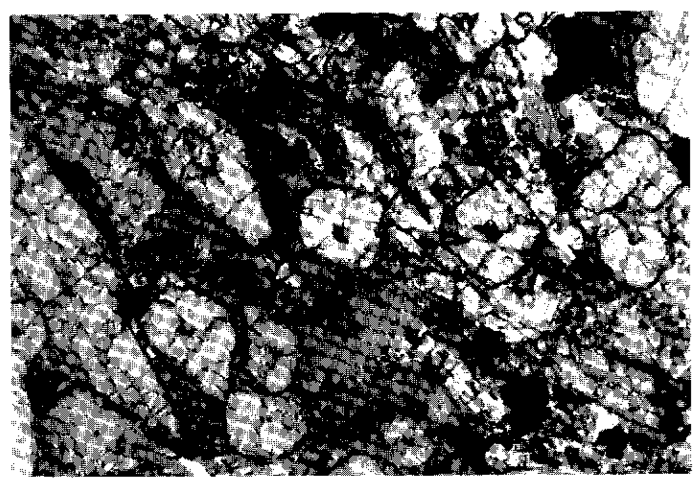

Figure 7. Gabbroic dyke containing hollow, spindle-shaped and skeletal titaniferous augite crystals, with decayed plagioclase (whitish), interstitial chlorite (grey) and opaques. Largest crystal at left edge is 1.2 mm long. Plane polarized light. From east of Dempster Highway (km 82), at location of sample #3.

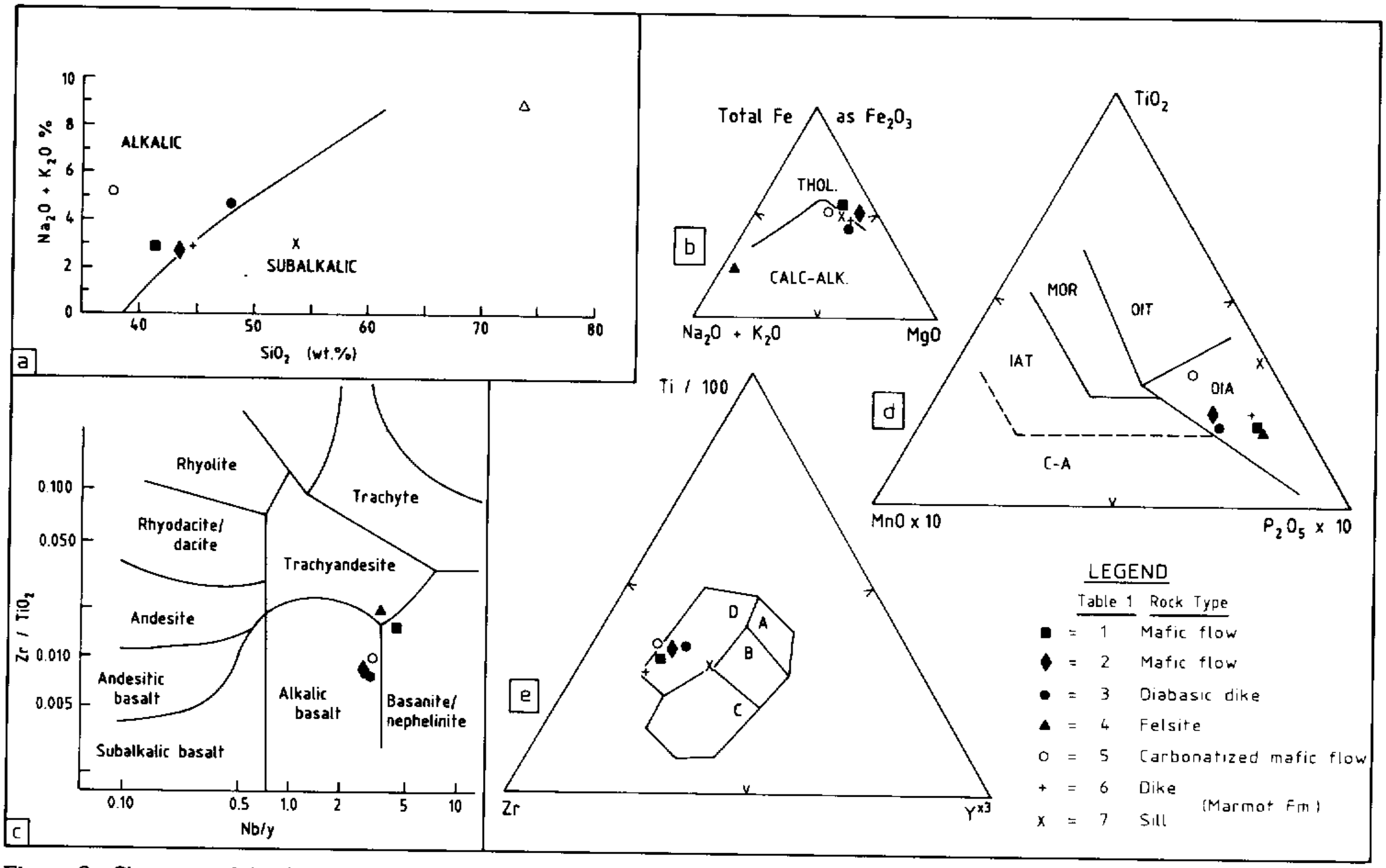

Figure 8. Chemistry of the Cambro-Ordovician volcanics: a) Total alkali- silica diagram, with dividing line from Irvine and Baragar, 1971; b) A-F-M diagram for subalkalic rocks: boundary between tholeiitic and calc-alkalic from Irvine and Baragar (1971); c) Fractionation ($Zr\text{-}TiO_2$) and differentiation (Nb/Y) ratio diagram devised by Winchester and Floyd (1977); d) Mn-Ti-P discriminant diagram (Mullen, 1983): OIA = oceanic island alkalic; OIT = Oceanic island tholeiitic; MORB = mid-oceanic ridge basalt; IAT = Island arc tholeiite; C-A = calc-alkalic basalt; e) Zr-Ti-Y diagram for basalts (Pearce and Cann, 1975); A+B = low K tholeiite; B = Ocean floor basalts; C+B = calc-alkalic basalts, and D = within plate basalts.

to indicate paleo-tectonic setting, these rocks plot in the "oceanic island alkalic" and "intraplate" fields (Figs. 8d and 8e), which reflect their high P_2O_5 and low Y concentrations, relative to other types of basaltic. Intrusions from the Marmot Formation also plot in similar fields.

It is not possible to conclude whether the crust was thinned to the point of developing oceanic characteristics, but the high Nb and P_2O_5 relative to oceanic islands, such as Hawaii (Table 1), imply a crustal contribution (see Dupuy and Dostal, 1983). They are, however, significantly different from average MORB composition, and it is unlikely that oceanic crust was produced in the Selwyn Basin.

MINERALIZATION

The volcanics show little economic mineral potential. Sulphide showings are sparse, few quartz veins were located, and there is no evidence of large hydrothermal systems (such as zoned alteration or epidote-encrusted fissures) that might indicate that sulphides precipitated on the ancient sea floor.

The most likely areas are limonitized and thermally metamorphosed basalt near the Cretaceous and other intrusions. Siderite rosettes, azurite and malachite in comb quartz and 1 cm pockets of chalcopyrite and galena occur about 500 m west of the felsite intrusion (locality H). Possible freibergite occurs in the vicinity (G. Carlson, pers. comm., 1979).

At locality J, about 700 m from the northwest edge of Deadman Pluton, hornfelsed volcanics contain marcasite and ferroactinolite (?) and pyrrhotite in fractures. The mineral assemblage and setting resembles mineralization at THOR Occurrence on Antimony Mountain (INAC 1981, p. 289). The thermal aureoles developed in Hyland Group grit and argillite are comparatively barren, but could contain mineralization where they intersect carbonate-rich volcanics. West of Deadman Pluton the fused volcanics are non-vesicular and contain little calcite; however, any included limestone pod may be highly mineralized.

The high barium content, particularly of the felsite (Table 1) suggests that the volcanics may have contributed to stratabound barite in the overlying Devonian black shales (e.g. REIN; INAC, 1981) several kilometres north in the East Blackstone River drainage.

DISCUSSION

The Cambro-Ordovician volcanics, fed by the spaced, subparallel gabbroic dykes, reflect minor extension. Centres of volcanic activity are numerous, small and therefore were probably short-lived. Some developed into volcanic islands, and the preservation of subaerial and submarine facies demonstrates rapid subsidence and tectonic instability. All these features suggest that Selwyn Basin volcanism was not related to a "hot spot", but was the result of magma seepage through fractures in crust under extension.

The volcanic centres may have extruded close to the northwest axis of the Selwyn Basin, a setting similar to the Marmot Formation, but were displaced toward the north side by thrust faults.

The older Mount Harper Volcanic Complex occupies a smaller extensional basin in the shelf succession (Fig. 1). It consists mostly of subalkalic pillows and breccias, with lesser subaerially erupted tholeiitic basalt and rhyolite (Roots, 1986). In outcrop, however, these rocks indicate similar depositional environments to the Cambro-Ordovician suite. Mount Harper Complex reflects a brief extension event on thick continental crust; in contrast, the alkalic Cambro-Ordovician volcanics developed on thinned crust. These two occurrences illustrate the variety of igneous response to periodic extension along the continental margin of ancient North America.

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Table 1

		Ogilvie Mtns.	basalt		Marmot.	Fm.	OIB	Felsite
	1	2	3	5	6	7	8	4
SiO_2	41.20	42.80	46.60	30.70	50.00	41.80	49.36	73.18
Al_2O_3	13.60	11.90	13.50	9.20	15.00	11.60	13.94	12.70
TiO_2	3.47	2.18	1.74	3.58	2.00	3.40	2.50	0.38
Fe_2O_3	12.00	13.00	11.70	11.40	9.30	9.30	11.40	2.40
MgO	7.49	10.70	7.37	6.34	8.00	7.30	8.49	0.41
MnO	0.19	0.18	0.18	0.20	0.10	0.03	0.16	0.02
CaO	14.60	11.40	9.24	13.20	1.00	7.50	10.30	0.25
Na_2O	1.07	1.13	4.22	4.33	0.0	0.0	2.13	0.82
K_2O	1.92	1.69	0.15	0.15	3.00	3.00	3.80	7.65
P_2O_5	1.26	0.57	0.56	0.53	0.60	0.76	0.26	0.14
Cr_2O_3	0.01	0.05	0.02	0.01	0.03	0.05	n.r.	0.01
H_2O	3.10	3.20	3.00	0.60	5.90	5.20	n.r.	0.60
CO_2	0.10	0.68	0.92	20.00	0.60	5.00	n.r.	0.0
Total	**99.40**	**99.60**	**99.20**	**98.10**	**95.80**	**96.85**	**99.03**	**99.70**
Ba	260	570	140	110	†4000	17400	135	2330
Nb	140	60	50	110	n.r.	n.r.	19	30
Rb	90	40	20	30	56	97	14	310
Sr	680	210	290	1250	398	804	375	
Y	30	20	20	20	45	70	27	80
Zr	370	190	140	340	277	351	180	320

Note: samples 1, 2, 5 are mafic flows, *3 is medium-grained dyke and *4 is felsite. Their locations are shown on Figure 1.

Samples 6 and 7 are a dyke and sill from Marmot Formation of Misty Creek Embayment (Goodfellow et al (1980).

Sample *8 represents oceanic island alkalic rocks: major elements are the average of 181 shield-forming tholeiitic flows from Hawaii (Macdonald and Katsura, 1964), minor elements from BHVO-1 standard (Abbey, 1983).

Samples from Ogilvie Mountains were analyzed by XRF; H_2O and CO_2 by wet chemical (X-Ray Assay Laboratories, Toronto). Precision quoted by laboratory is: ± 0.10% major oxides; ± 10 ppm trace elements; n.r. = not reported.

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