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DIATREME BRECCIAS IN BRITISH COLUMBIA*
(82G, J, N; 83C; 94B)

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INTRODUCTION

Over the last decade considerable interest has been expressed in diatreme breccias of possible kimberlitic affinity in British Columbia (Fipke, 1983; Fipke and Capell, 1983; Grieve, 1981 and 1982; Roberts, *et al.*, 1980; Woodcock, 1978; etc.). This interest has been heightened by the reported recent discovery of diamonds in pipes north of Golden (Dummet, *et al.*, 1985; Northcote, 1983a and 1983b).

There are three main areas in which diatreme breccias are known to occur: the Cranbrook-Invermere area, the Columbia Icefield area north of Golden, and the Williston Lake area north of Mackenzie (Fig. 38-1). In all but one case (the Cross diatreme) these breccia pipes occur in a zone within the Western and Main Ranges of the Rocky Mountains which is between 20 and 50 kilometres east of the Rocky Mountain Trench. The diatremes in British Columbia intruded the miogeoclinal sequence of platformal carbonate and clastic rocks prior to deformation. With one notable exception (the Cross diatreme) all are hosted in Cambrian to Devonian sedimentary rocks which are unconformably capped by Middle to Upper Devonian strata (Grieve, 1981; Leech, 1979; Roberts, *et al.*, 1980). The Cross diatreme is located approximately 60 kilometres east of the Rocky Mountain Trench and is hosted by Pennsylvanian sedimentary rocks.

CRANBROOK-INVERMERE AREA (82G and 82J)

Forty or more breccia pipes and related dyke rocks are known to occur within the Bull, White and Palliser River drainages, east of Cranbrook and Invermere (Pighin, Fipke, personal communication). A number were visited for this study; four were mapped in detail and will be described here.

THE SUMMER 1 DIATREME (82G/11)

The Summer 1 diatreme is one of two small intrusive bodies found at the intersection of Galbraith and Summer Creeks, approximately 40 kilometres northeast of Cranbrook. It has previously been reported on by Grieve (1981). The Summer diatreme forms a rusty weathering, 50-metre-high resistant knoll hosted in rocks mapped by Leech (1960) as Late Cambrian McKay Group. In the vicinity of the diatreme the McKay Group consists of thin-bedded grey micritic limestone, argillaceous limestone, and intraformational limestone conglomerate. In only one place is the contact between the limestones and the diatreme exposed (Fig. 38-2) and there the contact is subparallel to bedding in the limestones. This is *most likely a locally developed phenomenon, as the overall outcrop* pattern (Fig. 38-2) indicates that the body must be discordant. The limestones within 0.5 metre of the exposed contact are highly brecciated and material similar to the diatreme matrix forms veinlets in the limestone breccia. No thermal metamorphic effects are evident.

The diatreme itself is a breccia throughout. It consists of angular to subrounded clasts in a medium green to grey matrix which is locally calcareous. The matrix is foliated, with the foliation striking southerly to southwesterly and/or west to northwesterly. The matrix is predominantly chlorite and serpentine (Grieve, 1981) with or without carbonate. Rare chrome diopside xenocrysts were noted. The clast:matrix ratio is in the order of 50:50, with clasts ranging from granule to cobble size. The largest and most numerous are angular limestone, limestone conglomerate, and shale fragments up to 70 centimetres in size; these comprise 90 per cent of all the clasts. The remaining 10 per cent are buff dolostones, crinoidal limestones, red-weathering thinly laminated dolostones, granites, granitic gneisses, phlogopite-chrome diopside-marbles, fine-grained intermediate to felsic volcanic rocks, and autobreccia fragments. Resistant (silicified ?) reaction rims were noted around many clasts.

Adjacent to the main diatreme (Fig. 38-2) are possibly related dykes (and sills ?). These dykes have a very fine-grained light to medium green matrix with dark green serpentine-filled ocelli. Subrounded quartzitic and granitic clasts, up to 2 centimetres in size, are locally present.

The majority of the clasts present in the main diatreme are limestones similar to, and likely derived from, the host McKay Group. Crinoidal limestone clasts are also present. Crinoidal limestones are not characteristic of the Cambrian McKay limestones and are most likely derived from younger formations. The Summer diatreme is itself deformed (foliated) and is therefore likely to have intruded the original miogeoclinal succession prior to deformation.

If this is the case, the Summer diatreme must have intruded crinoidal limestone-bearing formations which overlay the McKay Group, and blocks of these younger rocks collapsed into the breccia pipe. This suggests that the diatreme is considerably younger than its host rocks.

THE BLACKFOOT DIATREME (82G/14)

The Blackfoot diatreme crops out at 2 650 metres elevation on ridges east of the headwaters of Blackfoot Creek, approximately 65 kilometres northeast of Cranbrook. It is a recessive, green-weathering body discordant with rocks mapped by Leech (1960) as Ordovician to Silurian Beaverfoot-Brisco Formation. Folds are evident in the host rocks in the vicinity of the diatreme, where there is a deviation from the regional steep westerly dips (Fig. 38-3). The Beaverfoot-Brisco Formation in the hangingwall is characterized by thick-bedded, massive, medium grey limestones containing rugosan corals and light grey limestones in which chain corals (favosites and halosites type) are present. Thin-bedded to laminated, non-fossiliferous, purplish weathering limestones and shaly *limestones are present in the footwall. The contacts between the* diatreme and the limestones are well exposed (Fig. 38-3). As with the Summer diatreme, no thermal metamorphic effects are evident.

The Blackfoot diatreme is a composite or branching pipe-like body consisting of pale green breccia with generally small (up to 10 centimetres) subrounded to subangular clasts. The largest xenoliths present are purple-grey to buff-weathering limestones likely derived from the Beaverfoot-Brisco Formation. The clasts generally comprise up to 50 per cent of the diatreme and are predominantly

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** Presently at the University of Windsor, Ontario.

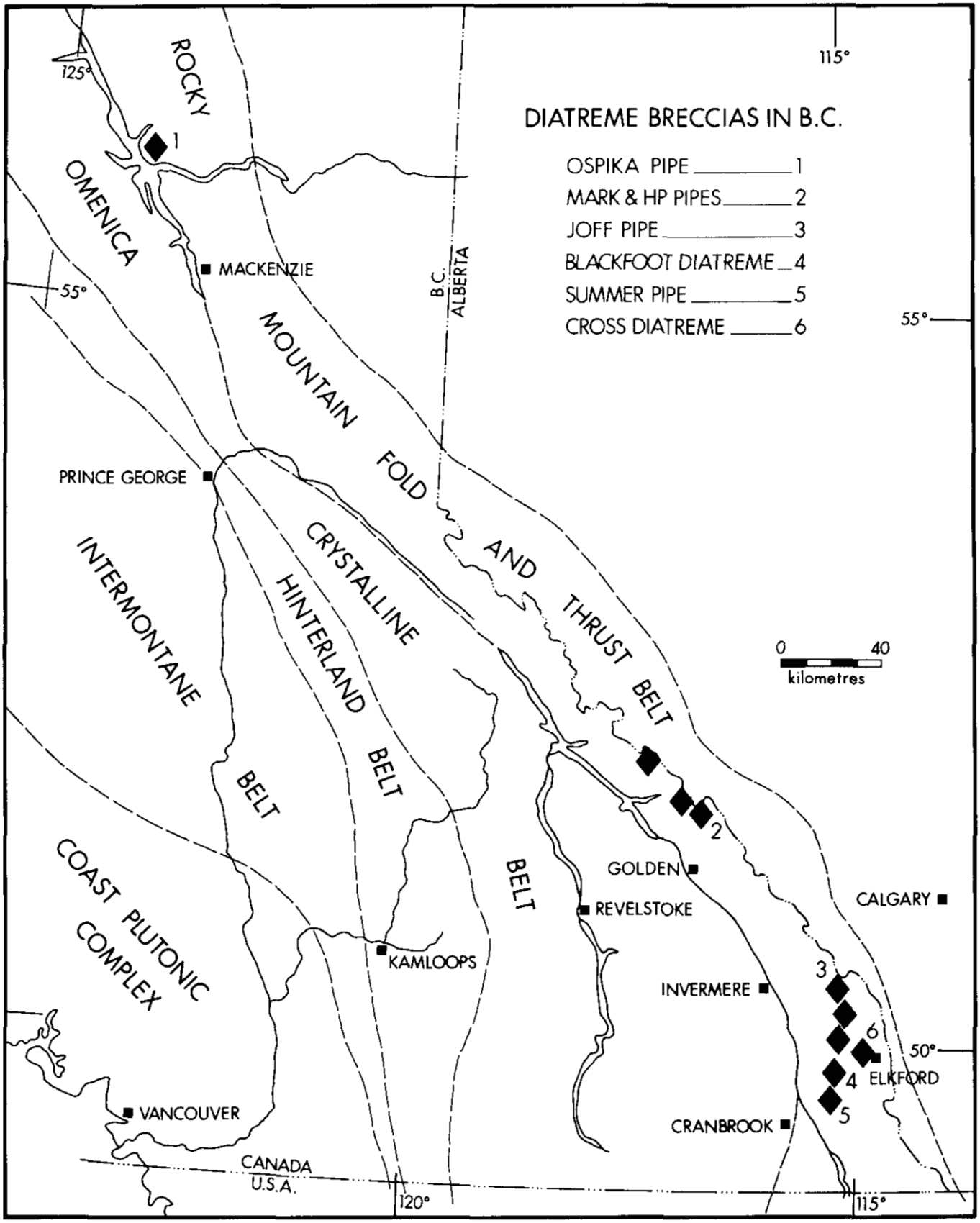


Figure 38-1. Distribution of Diatreme Breccias in British Columbia.

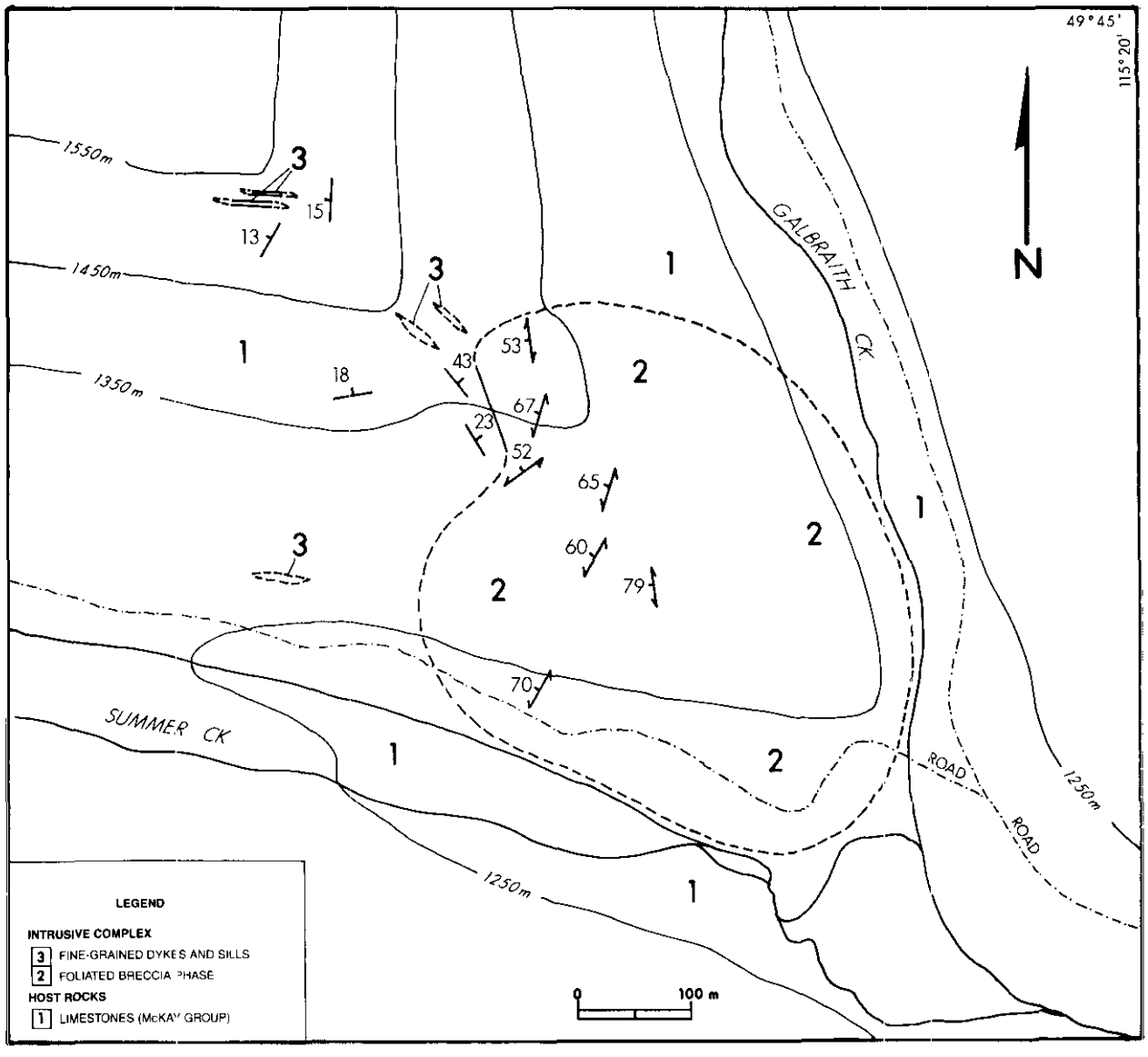


Figure 38-2. Geology of the Summer 1 pipe.

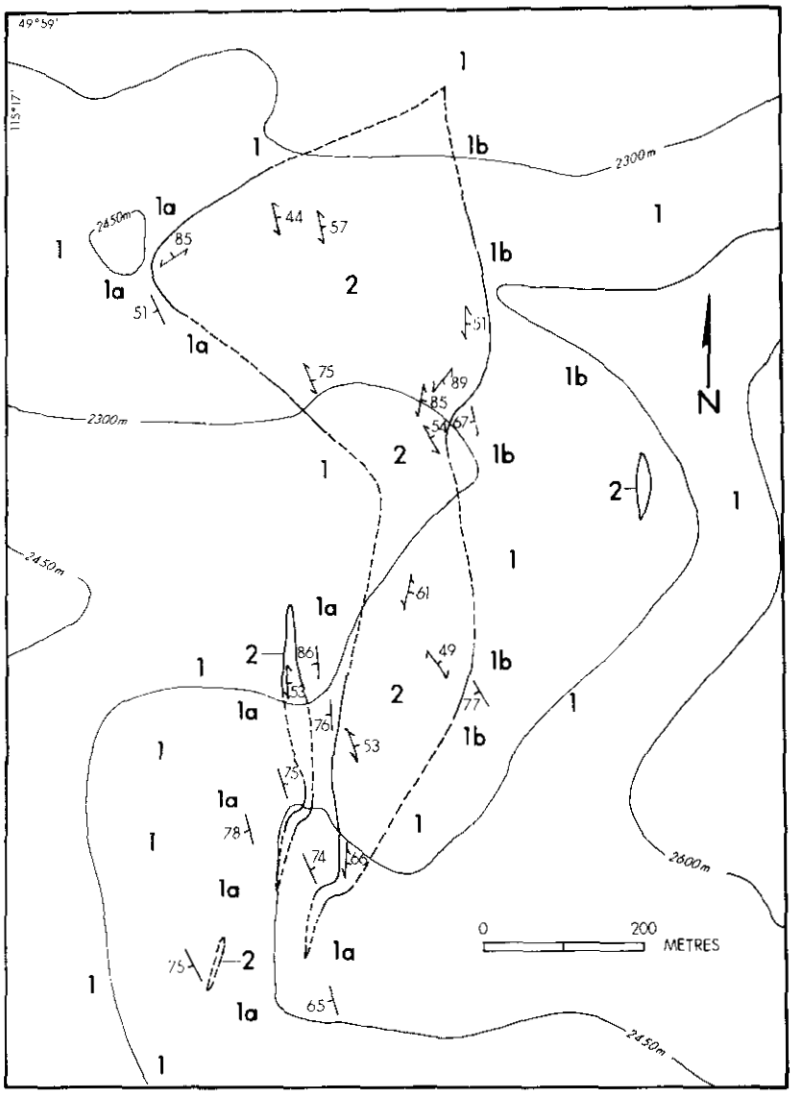
sedimentary in origin (largely limestone, some shale and dolostone fragments). Exotic material includes abundant chromite nodules, chrome diopside xenocrysts, and possible eclogite nodules. Autobreccia fragments are also common. The matrix of the diatreme is pale green consisting largely of chlorite, sericite, and carbonate. Massive, fine-grained, dark green dykes cut the main pipe.

The Blackfoot diatreme is intensely foliated near its margins and fragments have been flattened in the plane of the foliation. The centre of the diatreme is moderately to strongly foliated. Foliation is generally parallel or subparallel to the margins of the diatreme (Fig. 38-3). Locally a kinking of the dominant foliation is developed. The intense foliation suggests that the diatreme has been the site of localized shear.

THE JOFF PIPE (82J/11)

A number of small diatremes have been reported (D. Pighin, personal communication) south of the Palliser River on ridges west of Joffrey Creek, approximately 55 kilometres east of Invermere. Two bodies, exposed at 2 750 metres in elevation, were examined. Both intrude east-dipping units (Fig. 38-4) which stratigraphically underlie Middle to Upper Devonian Formations (Leech, 1979). The immediate footwall rocks in the vicinity of the main diatreme are massive, thick bedded, medium grey limestones which contain rugosan corals. These rocks may be correlative with the Ordovician-Silurian Beaverfoot Formation. Buff dolostones, sandy cross-bedded dolostones and sandstones, well-bedded siltstones, and dolomitic siltstones comprise the hangingwall strata. These lithologies are not characteristic of the Beaverfoot Formation and may be equivalent to Middle Devonian Cedared, Burnais, and Harrogate Formation strata.

The main pipe (Fig. 38-4) is very similar to the Blackfoot diatreme, consisting of small (up to 10 centimetres) subrounded to subangular fragments in a strongly foliated green matrix. Fragments are predominantly limestone, dolostone, and shale. Exotic material, such as chromite nodules, are present, but less abundant than in the Blackfoot diatreme. Within a few metres of the eastern contact of



INTRUSIVE ROCKS

2 DIATREME BRECCIA

HOST ROCKS

1 LIMESTONES, SHALY LIMESTONES (BEAVERFOOT-BRISCO FORMATION)
(a) MASSIVE GREY FOSSILIFEROUS LIMESTONES
(b) THIN-BEDDED PURPLISH LIMESTONE AND SHALY LIMESTONE

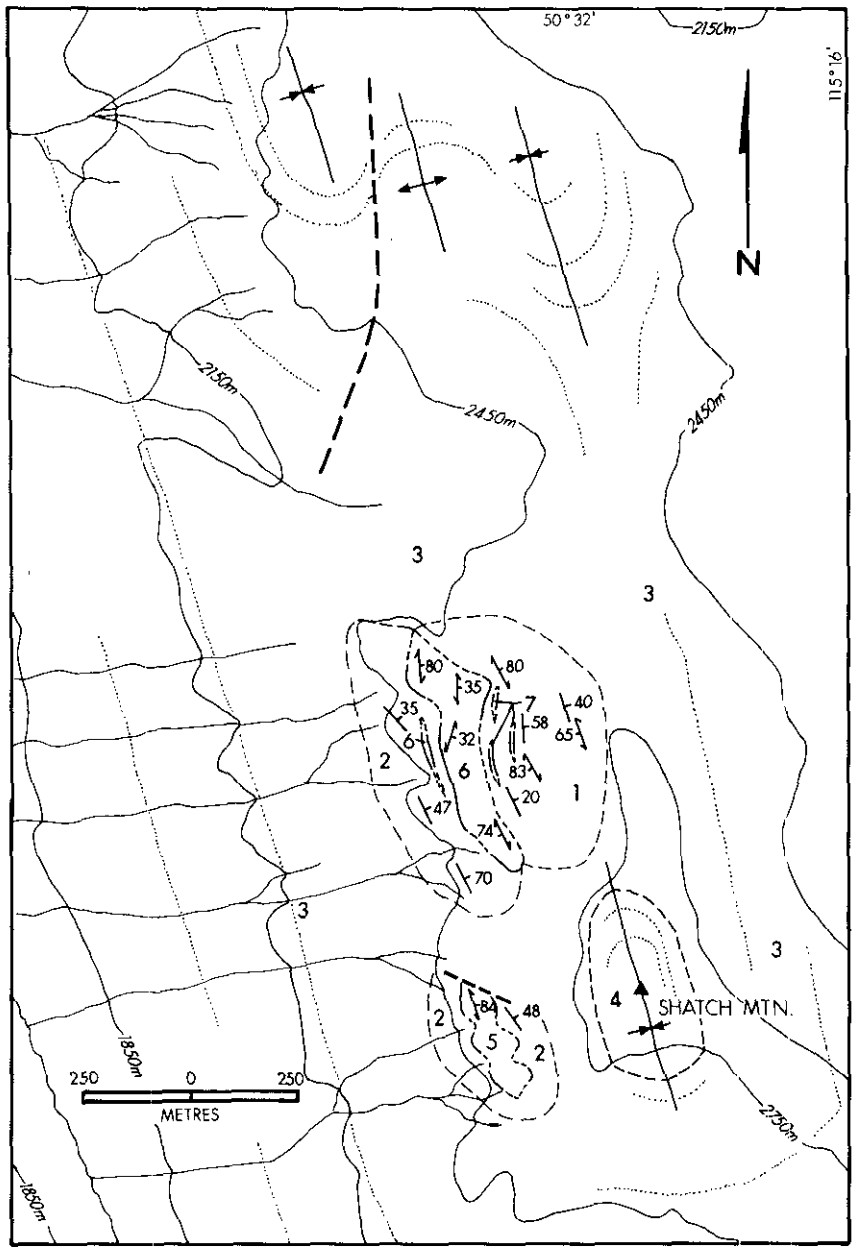
Figure 38-3. Geology of the Blackfoot diatreme.

the main diatreme the Middle Devonian (?) hangingwall sediments have been intensely hematized, appearing brick red in outcrop, in contrast to their normal buff colours. Discontinuous layers rich in subangular lithic fragments are interbedded with the altered sedimentary rocks (Plate 38-1). Moderate to well-developed graded bedding is present in the fragmental layers. The clasts in these layers are similar in composition and variety to those in the main diatreme. These graded fragmental horizons most likely represent an extrusive (tuffaceous?) phase of the main diatreme interbedded with Middle Devonian (?) sedimentary rocks.

The southern intrusive body (Fig. 38-4) is medium to dark green, fine-grained, and massive. Its margins have been highly brecciated and hematized. It contains no clasts, but small (2 to 3-millimetre) rounded serpentine nodules are locally developed. The relationship between the southern intrusive and the main diatreme is, as yet, unclear.

THE CROSS DIATREME (82J/2)

The Cross diatreme is exposed at an elevation of 2 200 metres on the north side of Crossing Creek, 8 kilometres northwest of the town of Elkford. It is 60 kilometres east of the Rocky Mountain Trench, or approximately 20 kilometres east of the centreline of the zone containing the other intrusions in the Cranbrook-Invermere area. It has previously been reported on (Grieve, 1981; 1982; and Roberts *et al.*, 1980) and therefore will only be briefly described here.



LEGEND

SEDIMENTARY SEQUENCE

MIDDLE AND/OR UPPER DEVONIAN

4 BASAL UNIT: SANDSTONE DOLOMITE, MUDSTONE, SOLUTION BRECCIA

ORDOVICIAN AND SILURIAN AND/OR MIDDLE DEVONIAN ?

3 UNDIVIDED

2 BUFF DOLOSTONE, SANDY CROSSBEDDED DOLOSTONES, SILTSTONES, SANDSTONES

1 THICK-BEDDED GREY FOSSILIFEROUS LIMESTONE

INTRUSIVE AND RELATED SEQUENCE

7 EXTRUSIVE PHASE GRADED TUFF BRECCIA LAYERS

6 FOLIATED BRECCIA PHASE

5 MASSIVE PHASE

Figure 38-4. Geology of the Joff pipe, Shatch Mountain area.

The Cross diatreme intrudes Pennsylvanian Rocky Mountain Group strata (Hovdebo, 1957). It outcrops on a steep face and an area of approximately 55 by 15 metres is exposed. Its western contact is well exposed and clearly crosscuts shallow-dipping crinoidal dolostones and dolomitic sandstones. A small shear zone forms the eastern contact. No thermal effects on the wallrocks were observed.

The diatreme has a medium grey-green to dark green groundmass composed mainly of calcite, serpentine, mica, and talc (Grieve, 1982). Clast content varies from 20 per cent to locally as much as 40 or 50 per cent. The inclusions are angular to subrounded and from granule (millimetre) to boulder (metre) size, although most of the outcrop is characterized by fragments up to 10 centimetres in size. Limestone, dolostone, and shale clasts dominate, but rounded ultramafic (peridotite ?) nodules are also common. Xenocrysts of olivine, pyroxene (some chrome diopside), and garnet have been reported (Grieve, 1982). Strongly foliated zones are developed at the western and eastern margins of the diatreme. A hematite-rich zone is developed in the more massive central portion of the outcrop. In this zone hematite fills fractures and coats and partially replaces clasts.

GOLDEN-COLUMBIA ICEFIELDS AREA (82N, 83C)

A number of diatremes have been located in an area straddling the British Columbia/Alberta border 50 to 90 kilometres north to northwest of Golden (Fipke, 1983; Northcote, 1983a, 1983b). Microdia-

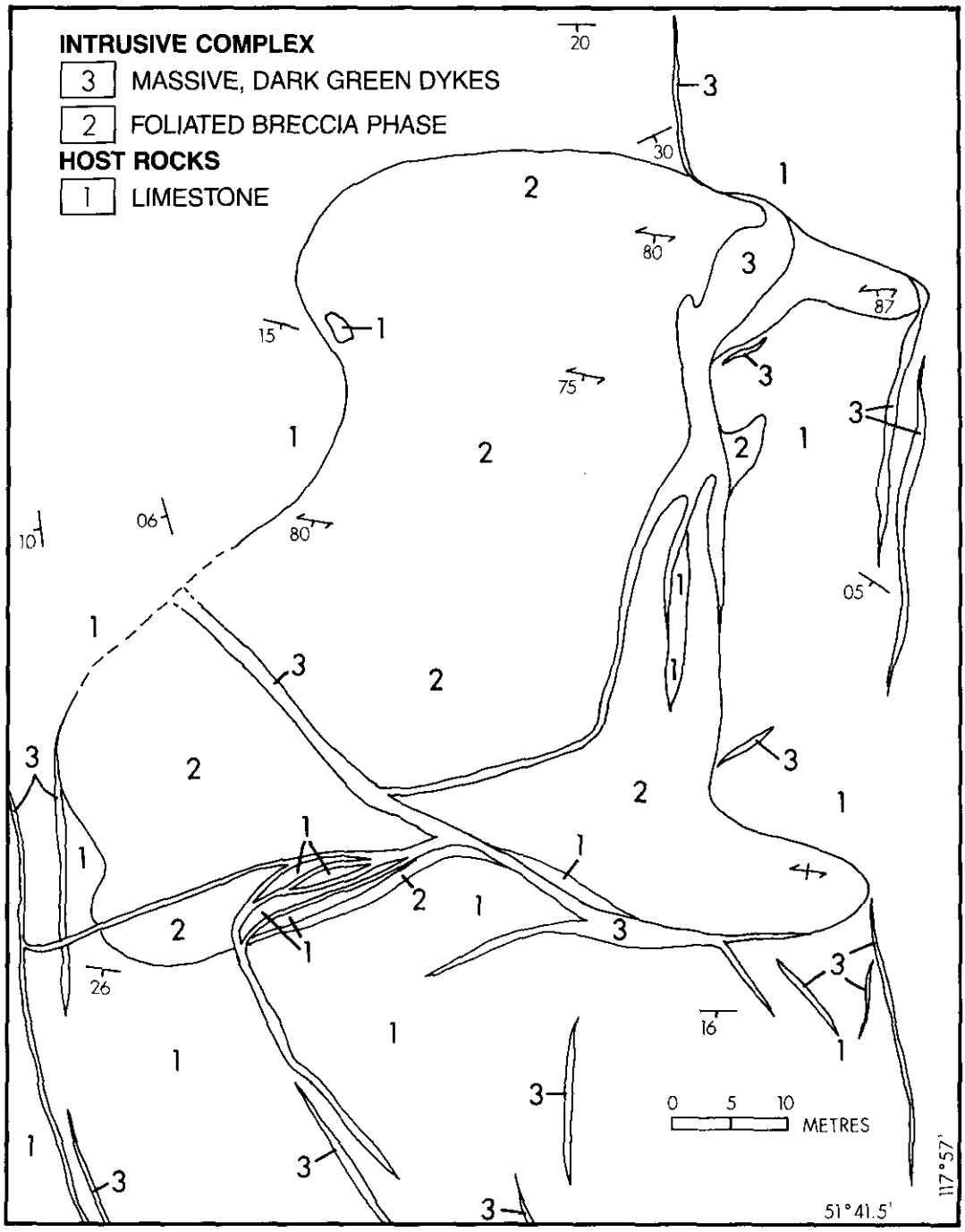


Figure 38-5. Geology of the HP pipe, south of the Campbell Icefield area.

monds have been recovered from heavy mineral separates taken from two of the pipes in this swarm (Northcote, 1983a, 1983b). The terrane north of Golden is rugged and the diatremes are exposed at elevations of 2 200 to 3 000 metres. Two of the diatremes were visited during the 1985 field season.

THE MARK DIATREME (82N/15)

The diatreme examined is the largest of seven pipes on the Mark claims (Northcote, 1983a) and one in which a microdiamond was found. It is exposed on steep cliffs between 2 700 and 3 000 metres in elevation and occupies an estimated 10-hectare area (Northcote, 1983a). The contacts are not well exposed, covered either by glaciers or talus.

The diatreme is well foliated and medium brown to rusty red weathering. It does not stand out in marked contrast with the buff-weathering fossiliferous and nodular limestones and dolostones of the Ordovician Skoki Formation (Norford, 1979) which it intrudes; therefore, it is difficult to locate from the air.

The Mark pipe is characterized by the presence of numerous (approximately 40 per cent) small subrounded clasts in a light green to grey matrix. Most of the clasts are 5 centimetres or smaller, with rare subangular xenoliths up to 15 centimetres in size. Limestones, dolostones, shales, and minor quartzites comprise the majority of the breccia fragments. Xenocrysts of augite and chrome diopside are sparsely distributed throughout. Chromite and ilmenite grains have also been identified in heavy mineral separates (Northcote, 1983a). Chrome micas (mariposite) are disseminated in the matrix of the pipe and occur as coatings on quartzite clasts. Massive, dark green, fine-grained dykes cut the diatreme and surrounding sedimentary rocks.

THE HP PIPE (82N/10)

The HP pipe is the most southerly diatreme so far recognized in the Columbia Icefield-Golden area. It is located approximately 50 kilometres due north of the town of Golden; exposed at an elevation of 2 400 metres, near the toe of the Campbell Icefield. The HP pipe is small, covering an area of only 40 by 80 metres; however, it is exposed in a flat, recently deglaciated basin which offers nearly 100 per cent exposure and is therefore ideal for study.

The HP pipe has sharp, steeply dipping contacts with the horizontal to shallow-dipping grey Cambrian limestone beds which host it (Fig. 38-5). It has a light to medium green, well-foliated carbonate-serpentine-rich matrix and contains abundant (approximately 40 per cent) breccia fragments. Angular to subrounded xenoliths of limestone and shale, 1 to 30 centimetres in size, predominate; subrounded ultramafic (pyroxenite ?) nodules (Plate 38-2) and fine-grained autobreccia fragments are also common. Xenocrysts of phlogopite, chrome diopside, and black pyroxene are abundant and can be up to 5 centimetres in size. Picroilmenite, chromite, and pyrope grains have been identified in heavy mineral separates (Fipke, personal communication).

The main breccia pipe has a well-developed foliation which is at a high angle to its eastern and western margins (Plate 38-3 and Fig. 38-5). The clast-rich, foliated phase is cut by dark green, fine-grained, massive dykes (Plate 38-4 and Fig. 38-5) which are generally free of xenoliths but may contain pyroxene and phlogopite xenocrysts. The margins to these dykes are sharp to gradational with the breccia.

WILLISTON LAKE AREA (94B)

OSPIKA PIPE (94B/5)

Only one breccia pipe has so far been recognized in British Columbia north of Prince George. It is a small diatreme (roughly 50 metres across) located on Cominco's Aley claims, approximately 140 kilometres north-northwest of Mackenzie (*see* also Pell, this volume) on the east side of Williston Lake between the Peace Reach and the Ospika River.

The pipe intrudes Ordovician carbonates of the Skoki Formation. It is a massive to foliated red-brown-weathering breccia with approximately 30 per cent angular to subrounded fragments. Fragments are a few millimetres to 0.5 metre in size; the larger fragments are all dolomitic with prominent reaction rims or silicified margins. The fine-grained light green to grey matrix also contains xenocrysts of phlogopite, black pyroxene, and chrome diopside. Fluorite is present near the margins of the diatreme. Clast and xenocryst-rich breccia dykes, 50 centimetres wide, crop out on ridges approximately 0.5 kilometre from the main breccia pipe. These dykes do not appear, at surface, to be continuous with the diatreme, but are very similar both in matrix and clast composition. The time relationship between the lamprophyre dykes with diatreme breccia and the carbonatite complex on the Aley claims is unclear.

CONCLUSIONS

With the exception of the Cross diatreme, all the diatreme breccia pipes in British Columbia have intruded Cambrian to Middle Devonian sedimentary rocks. These pipes are all very similar, characterized by a high percentage of xenoliths, most of which are derived from nearby sedimentary rock units. Exotic material (granite, chromite, pyroxenite, eclogite) and xenocrysts of chrome diopside, black pyroxene, and phlogopite may be present. These diatremes can be subdivided into two classes based on weathering characteristics and the nature of the matrix: (1) green-weathering, strongly foliated diatremes with a light green calcareous matrix; and (2) rusty weathering, well-foliated bodies with a light green to greenish grey matrix that is, at least in part, non-calcareous. Summer, Mark, and Ospika Pipe fall into this latter class.

No absolute dates have been obtained on the diatremes; such work is currently in progress. Stratigraphic evidence suggests that the Joff pipe is Middle Devonian, the other pipes may be of similar age.

The Cross diatreme is unique among the breccia pipes in British Columbia. It crops out east of the main zone of diatremes and intrudes Pennsylvanian strata. A Lower Permian age (244 Ma) was obtained on the Cross diatreme, using Rb/Sr methods (Grieve, 1982). The matrix of the Cross diatreme is generally much darker in colour and it contains more numerous large ultramafic nodules than the other diatremes.

Some geologists (*see* Grieve, 1982) feel that the Cross diatreme is the only true kimberlite discovered to date in British Columbia. The presence of diamonds in some of the other pipes suggests that they, too, are of kimberlitic affinity although the definition of a "true kimberlite" may be too narrow to include them.

ACKNOWLEDGMENTS

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Plate 38-1A. Extrusive (tuff?) facies of the Joff pipe. Layer of diatreme 'ejecta' is interbedded with laminated dolomitic siltstones. Pencil points up.

Plate 38-1B. Close-up of extrusive facies of the Joff pipe. Graded bedding is well developed in the lithic layer. Pencil points down.

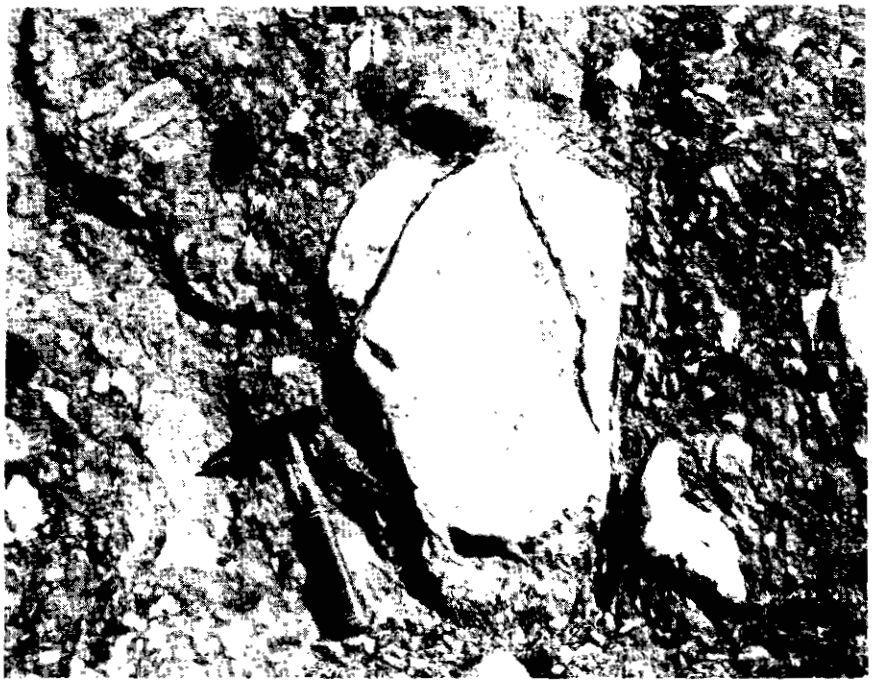

Plate 38-2A. Large limestone block in HP diatreme breccia. Dark rounded ultramafic xenoliths are also present.

Plate 38-2B. Rounded ultramafic (pyroxenite) nodule amidst angular white limestone fragments and small dark pyroxene and phlogopite xenocrysts.

Plate 38-3. Foliated diatreme in contact with limestone. The foliation is at a high angle to the contact here.

Plate 38-4. Clast-free dyke cutting main breccia pipe.