ALKALIC ULTRABASIC DIATREMES IN BRITISH COLUMBIA: PETROLOGY, GEOCHRONOLOGY AND TECTONIC SIGNIFICANCE* (82G, J, N; 83C; 94B)

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INTRODUCTION

Alkalic ultrabasic diatreme breccias and dykes are known to occur in the Western and Main Ranges of the Rocky Mountains in three areas of British Columbia (Figure 4-3-1). With one exception (the Cross diatreme), all are hosted by Upper Cambrian to Ordovician/Silurian miogeoclinal rocks (Figures 4-3-2 and 4-3-3). The Cross diatreme, located in a more easterly structural position, is hosted by carbonate rocks of the Pennsylvanian/Permian Rocky Mountain Group (Figure 4-3-2). All the diatremes intruded the sedimentary sequence along the western margin of the North American continent, prior to the Jura-Cretaceous Columbian Orogeny and have been deformed, weakly metamorphosed and transported eastwards during orogenesis.

These diatremes have been targets for diamond exploration since the mid-1970s (Grieve, 1981; 1982; Dummet *et al.*, 1985; Pell, 1986a) even though most are not true kimberlites. The Cross diatreme (Hall *et al.*, 1986; Ijewliw, this volume) is unique among these intrusions as it is the only true kimberlite known in British Columbia (Grieve, 1981, 1982; Pell, 1986b). The other ultrabasic diatremes in the province, which fall into two groups based on lithologic similarities, age relationships and geographic location, will be dealt with in this paper.

THE BULL RIVER-ELK RIVER AREA (82G and 82J)

Forty or more breccia pipes and related dyke rocks occur within the Bull, White and Palliser River drainages east of the towns of Cranbrook and Invermere (Grieve, 1981). The majority of these are hosted by the Ordovician/Silurian Beaverfoot Formation and underlying Mount Wilson and/or Skoki Formations, and exhibit similarities in petrography, degree of alteration and morphology. In the southern part of the area, near Summer Lake (Figure 4-3-2) two small diatremes intrude the Upper Cambrian to Ordovician McKay Group (*see also* Grieve, 1981; Pell, 1986b). These two pipes are notably different from the others in the area, as will be discussed later.

THE RUSSELL PEAK DIATREMES (82J/6)

Diatremes in southern British Columbia are typified by those in the Russell Peak vicinity (Figure 4-3-2). One pipe, south of Russell Peak (grid reference 625950E, 5587000N), is particularly well exposed on a cliff face and displays many features of pipe morphology (Figure 4-3-4) The lower portion of the exposed pipe is comparable to the diatreme facies of a model kimberlite pipe (Clement and Reid, 1986). It comprises well-foliated, tuffisitic diatreme breccia containing abundant subangular sedimentary rock fragments and subrounded cognate xenoliths (autoliths) in a matrix of vesicular altered glass lapilli, carbonate, monocrystalline quartz xenocrysts and minor oxides. Exotic material is rare, if present. Rock fragments up to 25 centimetres in size are present, but the population mode is 2 centimetres and the clast:matrix ratio is approximately 1:1. The tuffisitic breccia is medium green in colour except along the pipe walls where it is red, due to the presence of abundant hematite. At the western margin of the pipe, near the base of the exposure, a coarse contact breccia crops out (Figure 4-3-4). It contains large (up to 4 or 5 metres), chaotic, angular wallrock fragments and subordinate matrix.

Between 50 and 100 metres of well-bedded pyroclastic and/or epiclastic material is exposed overlying the tuffisitic breccia (Figure 4-3-4; Plate 4-3-1A). At the base of this zone, the material is similar in composition to the tuffisitic breccia, with increasing amounts of sedimentary material upsection (crater zone, model pipe, Clement and Reid, 1986). Thin layers of igneous material are interbedded with the Ordovician-Silurian Beaverfoot Formation carbonate rocks near the top and margins of the exposed pipe, implying an Ordovician-Silurian age (*circa* 435-440 million years) for emplacement. The succession is unconformably overlain by Middle and/or Upper Devonian strata.

A small mafic body (flow?) is located near the exposed top of the crater zone (Figure 4-3-4) and represents the only unaltered material present in the diatreme complex. It is extremely porphyritic and comprises clinopyroxene and olivine phenocrysts, clinopyroxene microphenocrysts, oxides and plagioclase microphenocrysts in a fine-grained groundmass (cpx >> 01 ≥ oxides > plagioclase ≈ groundmass). Traces of potassium feldspar are also present. Ferromagnesian components comprise approximately 70 per cent of the rock. In a nearby diatreme, similar material occurs as small dykes crosscutting diatreme zone tuffisitic breccia, suggesting that this phase was emplaced late in the intrusive sequence.

The Russell Peak diatreme is morphologically similar to a model kimberlite pipe (Clement and Reid, 1986; Dawson, 1980; Hawthorne, 1975), but petrologically dissimilar. Additional work is necessary to allow classification.

Numerous other diatreme facies pipes are located in the Bull, White and Palliser River drainages. All are petrologically similar to the Russell Peak diatreme, all hosted by Ordovician-Silurian Beaverfoot Formation strata, and some also contain epiclastic and pyroclastic crater facies deposits (for example, Joff pipe, Shatch Mountain area, 82G/11; Pell, 1986b). Vesicular glass lapilli (Plate 4-3-1B) and a carbonate-rich matrix are ubiquitous. Some additional features, not observed at Russell Peak, are evident in the other diatremes and will be briefly outlined.

Diatremes west of the headwaters of Quinn Creek (82G/14, grid reference 619050E, 5526800N) are reported to contain macrocrysts of olivine and spinel up to 5 millimetres in size (Grieve, 1981) and rare granitic and altered ultramafic xenoliths. This diatreme also contains fossil fragments "floating" in tuffisitic breccia (Plate 4-3-1C). The richest xenolith population occurs in the Blackfoot diatreme, located on the ridge east of Blackfoot Creek (82G/14, grid reference 623350E, 5537200N; Pell, 1986b). Abundant pyroxenite and some dunite nodules are present, as well as rare spinel

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* This project is a contribution to the Canada/British Columbia Mineral Development Agreement.

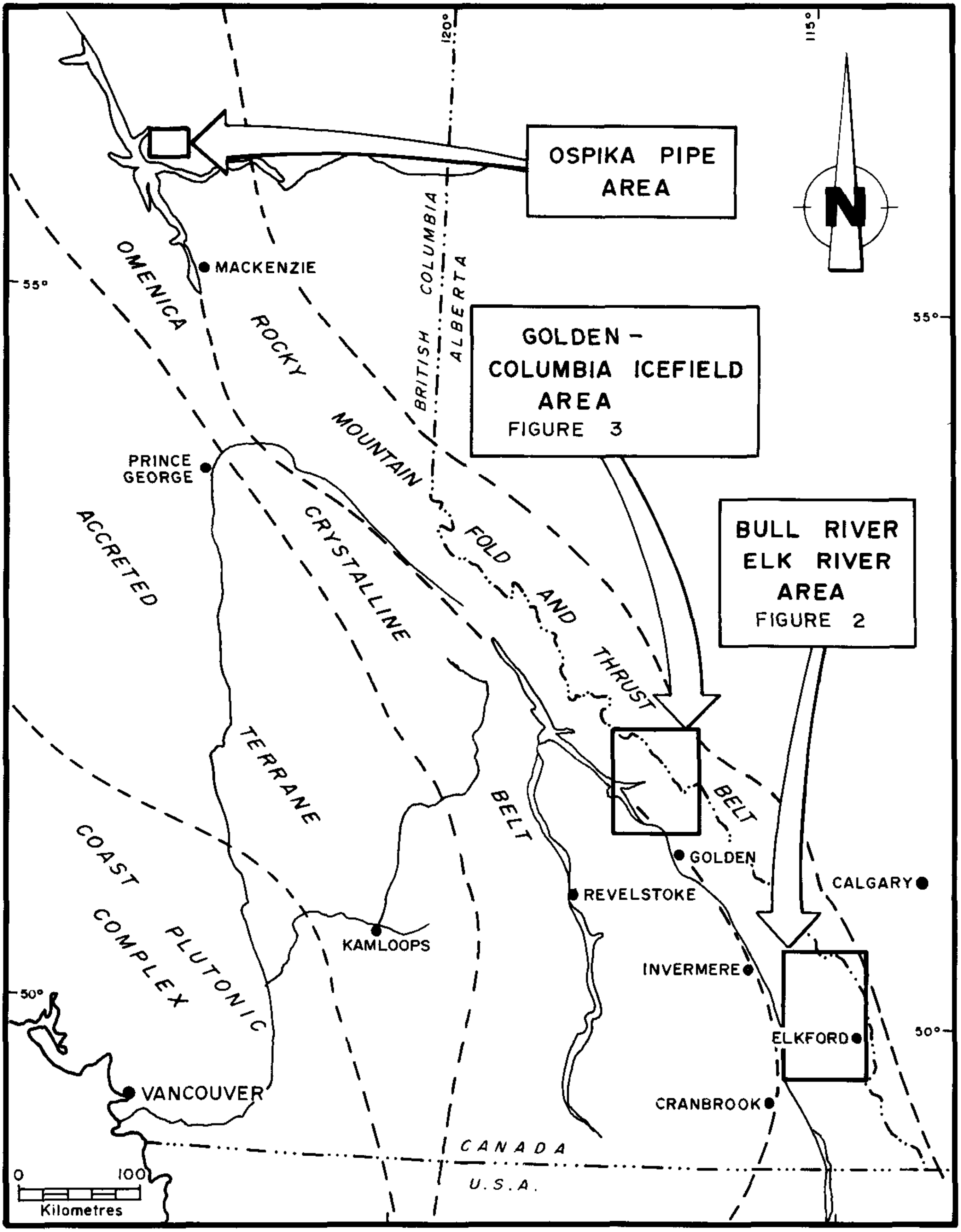

Figure 4-3-1. Index map showing general locations of alkaline ultrabasic diatreme swarms.
For detail on Ospika pipe, *see* Mäder (this volume).

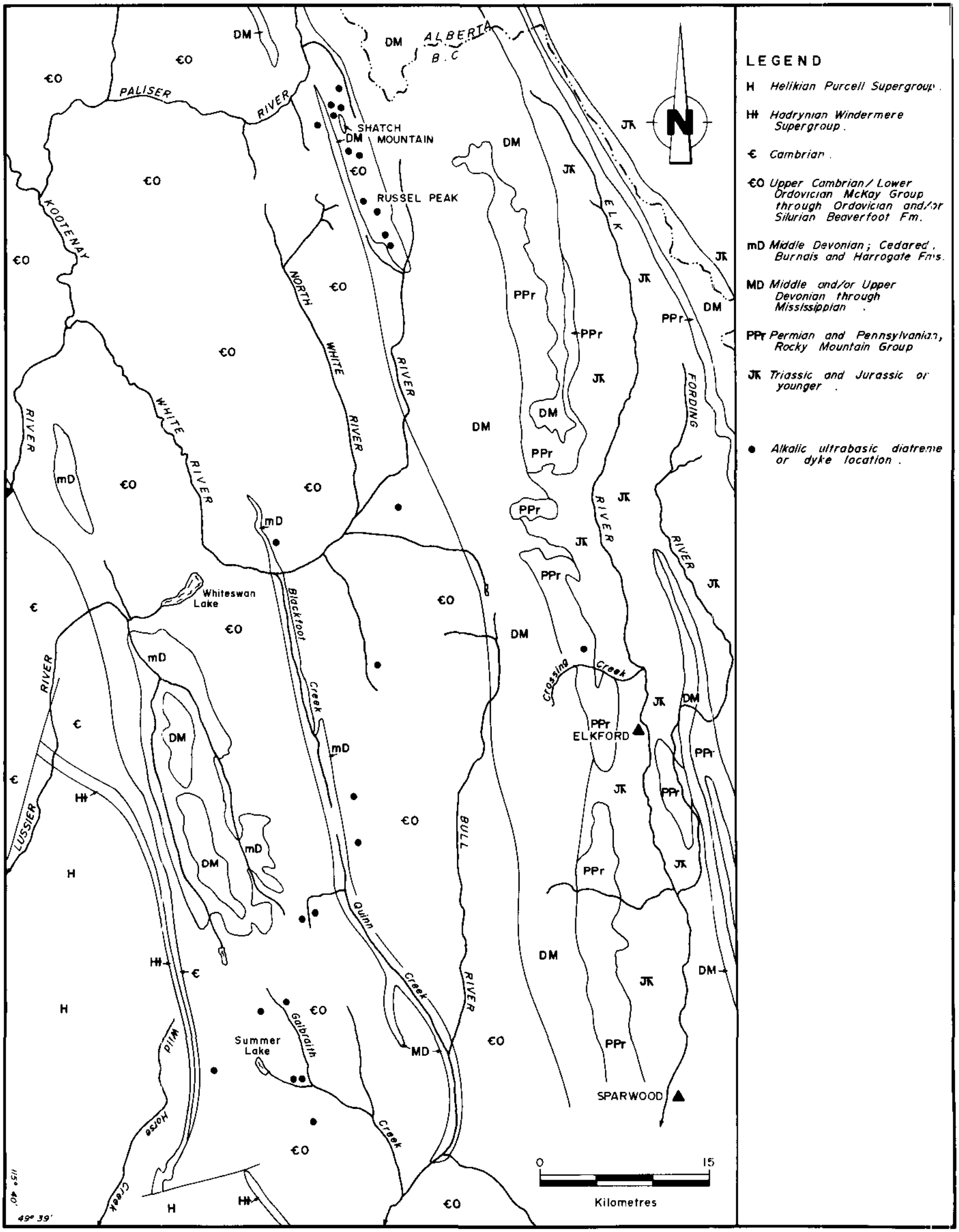

Figure 4-3-2. General geology and diatreme locations in the Bull River/White River area.
Geology modified from Leech (1960, 1979).

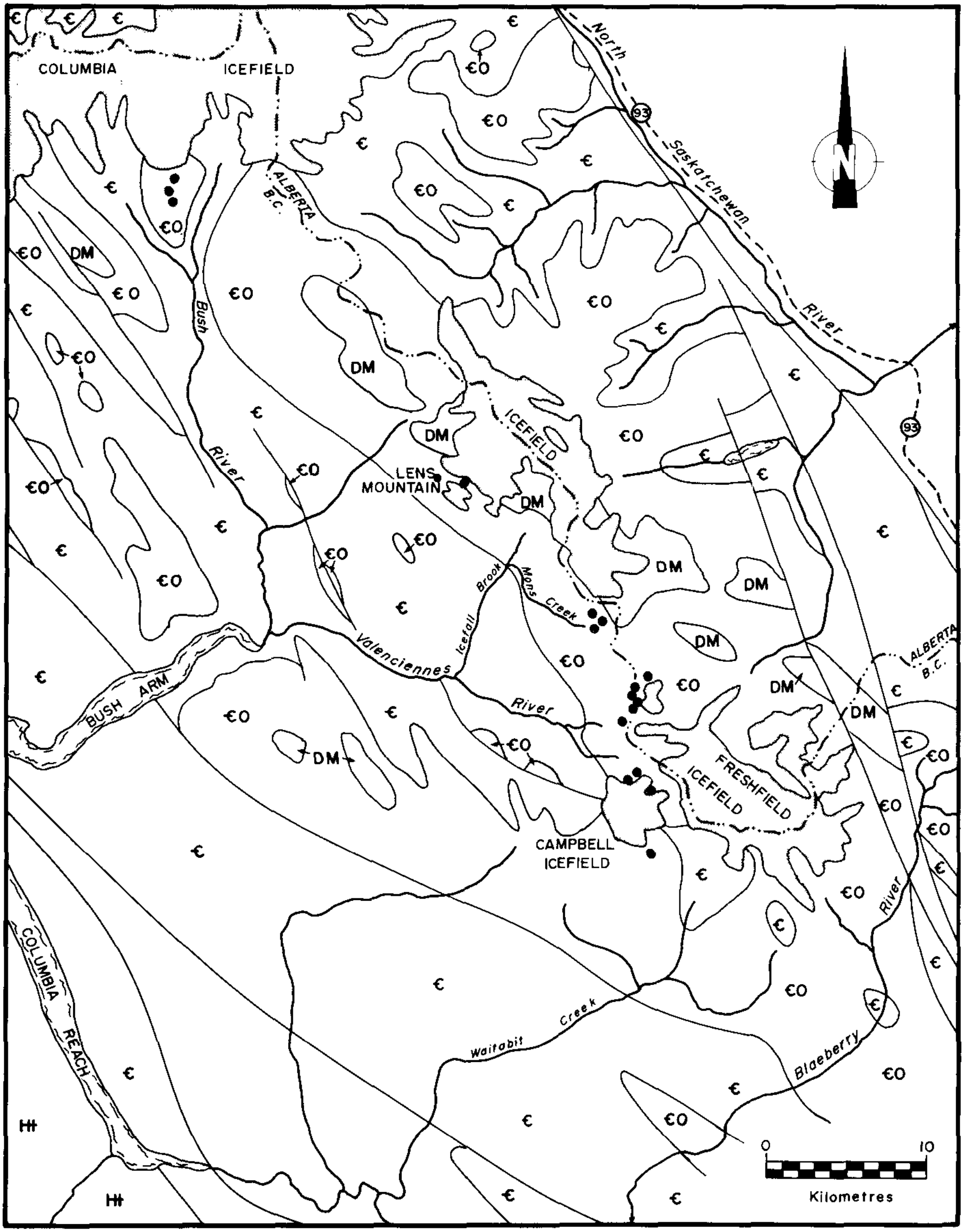

Figure 4-3-3. General geology and diatreme locations in the Golden-Columbia Icefield area.
Geology modified from Wheeler (1962) and Price (1967a, b).
● indicates diatremes or dykes. For legend, *see* Figure 4-3-2.

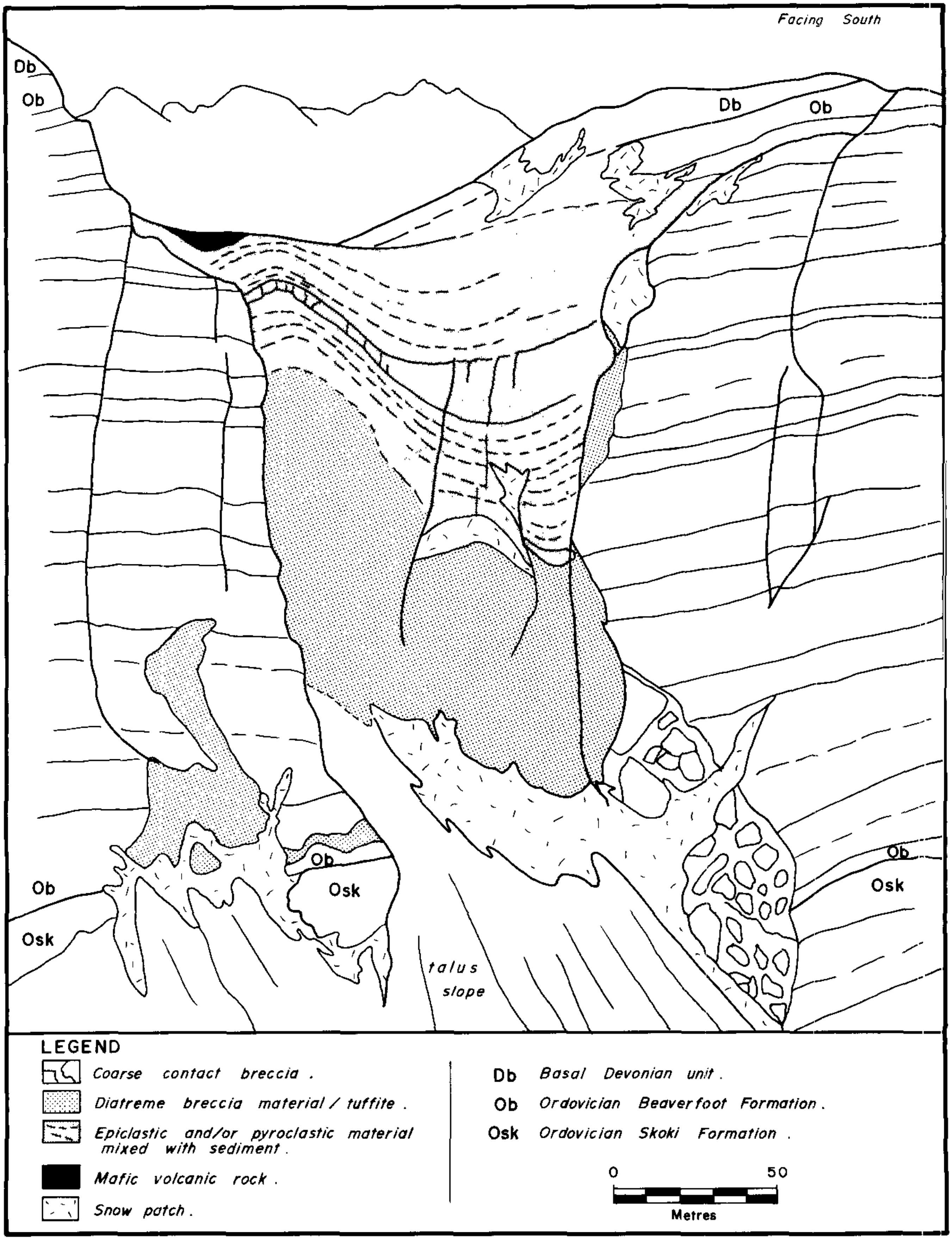

Figure 4-3-4. Geology of the Russell Peak diatreme.

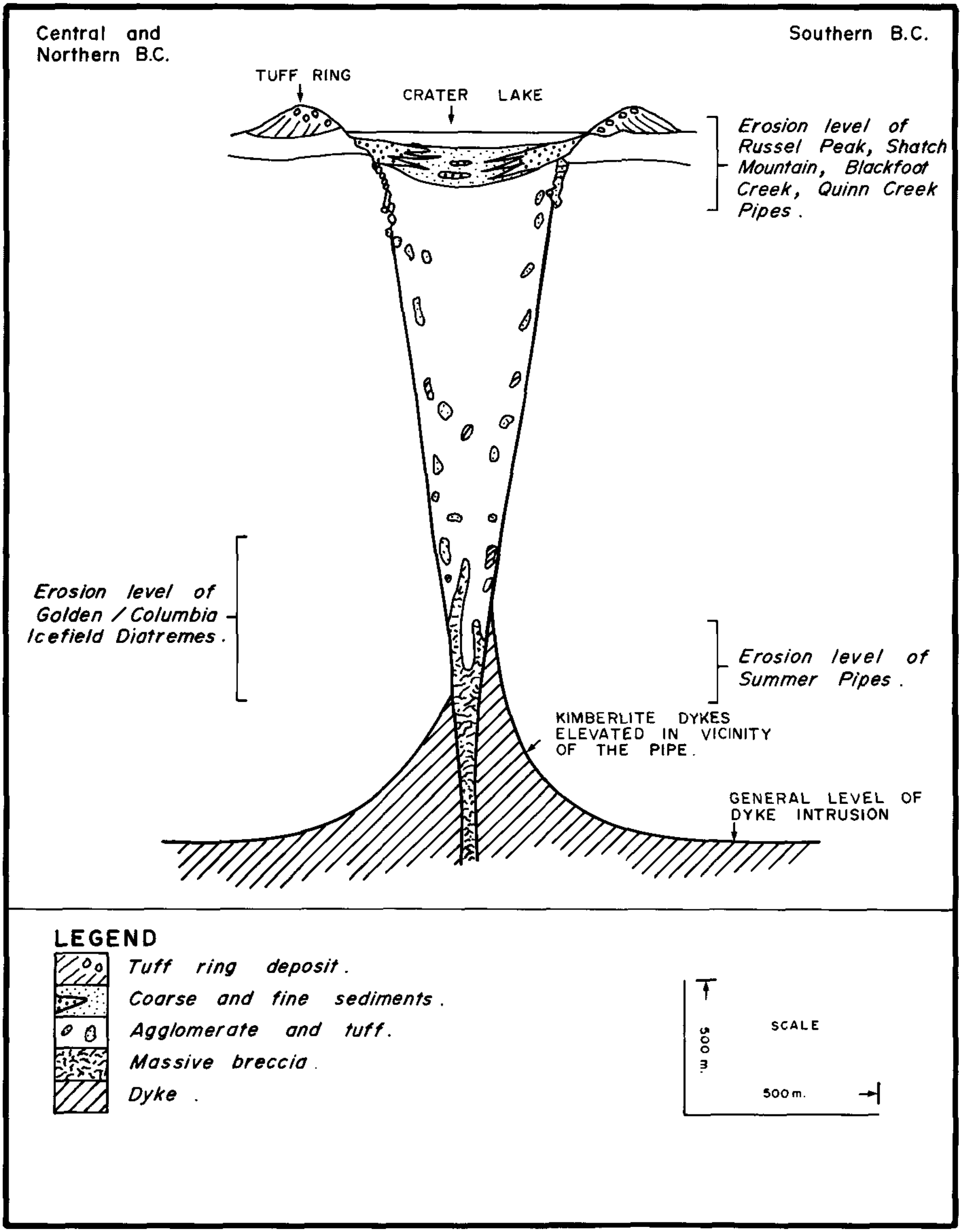

Figure 4-3-5. Generalized model of a South African kimberlite diatreme (from Dawson, 1980 and Hawthorne, 1975) with suggested erosion levels of British Columbia diatremes.

lherzolites (Ijewliw, 1986, this volume). Eclogite nodules have also been reported (Godwin, personal communication, 1985). Clinopyroxene, orthopyroxene and spinel macrocrysts are also present in the Blackfoot pipe.

SUMMER CREEK DIATREMES (82G/11)

Two small intrusive bodies are found at the intersection of Galbraith and Summer Creeks (Figure 4-3-2). They differ from those previously described in a number of ways: (1) they are hosted by Late Cambrian McKay Formation strata (Pell, 1986b), not by Ordovician-Silurian formations; (2) they are massive, brown-weathering, weakly foliated breccias as opposed to dominantly green-weathering, well-foliated tuffisitic breccias; (3) they are devoid of volcanic glass lapilli (Figure 4-3-10) and (4) fine-grained dykes, which may be associated with the diatreme, intrude surrounding sediments (Pell, 1986b) but do not cut the pipes themselves. The Summer pipes are further characterized by complex internal geology; several discrete breccia phases with variable clast composition and content and variable amounts of carbonate in the matrix are present. Contacts between breccia phases are generally gradational. The Summer Creek pipes represent a deeper erosional level than those elsewhere in the Bull, White and Palliser River areas, corresponding to the root zone (Clement and Reid, 1986; Dawson, 1980, Hawthorne, 1975) of a model kimberlite pipe (Figure 4-3-5).

GOLDEN-COLUMBIA ICEFIELDS AREA (82N/83C) AND THE OSPIKA RIVER AREA (94B)

Numerous diatremes are located along the Alberta-British Columbia border between 50 and 90 kilometres north of the town of Golden (Figure 4-3-3). Most are hosted by Upper Cambrian strata and in most cases, consanguineous dykes are also present. Characteristics of the pipes suggest that they represent deep erosional levels in a model pipe (root zone, Clement and Reid, 1986; *see* Figure 4-3-5).

Microdiamonds have reportedly been recovered from heavy mineral separates taken from two of the pipes in this swarm (Dummett *et al.*, 1985). Preliminary investigations suggest that these rocks are a suite different from those in the south, but still not true kimberlites. Further research currently in progress (M.Sc. thesis, O. Ijewliw, Queen's University) will detail the petrology and diamond potential of the Golden diatremes. One pipe has been reported from the Ospika River area. It is similar in many respects to the diatremes in the Golden area and will be briefly discussed with them.

THE HP PIPE (82N/10)

The HP pipe, located south of the Campbell Icefield (Figure 4-3-3), is the smallest, but best exposed and preserved of the diatremes in the area. Preliminary geology (Pell, 1986b) and petrology (Ijewliw, this volume) have been reported on, but a second visit, during the summer of 1986, has provided additional information. The HP pipe is a composite diatreme comprising five distinctly different breccia phases and at least that many petrologically differentiable dyke phases. The breccias differ in clast to matrix ratios, megacryst abundances (black augite, green diopside, phlogopite/biotite) and the presence or absence of additional phases such as garnets, oxides and accretionary lapilli or pellets (Plate 4-3-2A). Contacts between breccia phases may be gradational or sharp.

A rubidium-strontium age date of 348 ± 7 million years has been obtained on mica separates from this pipe, suggesting a 100-million-year difference in age from the pipes in southern British Columbia.

VALENCIENNE RIVER PIPES (MARK CLAIMS, 82N/15)

Four or more diatremes and numerous dykes are hosted by Upper Cambrian rocks near the headwaters of Valencienne River (Figure 4-3-3). Two distinctly different types are present. The first are rusty brown-weathering, weakly to well-foliated composite pipes with both massive and breccia phases. Serpentinized olivine macrocrysts (Plate 4-3-2B), coarse nonmagnetic oxides and altered peridotite xenoliths are present in some phases. Typical breccias contain 40 per cent clasts, most of which are small (1 to 5 centimetres) subangular sedimentary rock fragments (Pell, 1986b). Associated dyke rocks are fine to medium grained, extremely altered and porphyritic. The phenocryst assemblage, as can be recognized, consists of olivine, pyroxene and mica. In some phases olivine appears more abundant than pyroxene (ol>px≥mica) and in others pyroxene is far more abundant (px>ol≥mica). Oxides are a common groundmass constituent. The dykes are generally peripheral to the diatremes, but locally crosscut them.

The second type of diatreme present is brown-weathering and moderately well foliated with angular to subangular sedimentary rock fragments set in a matrix of quartz grains, chlorite and carbonate. Clasts average 1 to 5 centimetres in size with some up to 20 centimetres. The clast:matrix ratio is 2:3. Although dominantly comprised of sedimentary material, these rocks are intrusive and may be formed through fluidizing of sediment by introduction of volatiles explosively exsolved from rising and vesiculating magmas.

MONS CREEK AND LENS MOUNTAIN AREAS (82N/14, 15)

At both Mons Creek and Lens Mountain (Figure 4-3-3) the dominant intrusive lithology consists of a buff-weathering, weakly foliated breccia with a low clast to matrix ratio (approximately 1:3). Clasts are small subangular sedimentary rock fragments, predominantly carbonates, in a matrix of quartz grains, carbonate and iron oxides. This material is similar to the second type of diatreme at Valencienne River, but has a higher percentage of matrix. At Mons Creek, a small light green, strongly foliated, fine-grained intrusive breccia (apparently igneous) also crops out. It contains fragments of less than 1 centimetre size and oxides in a carbonate and hematite matrix. One small, crosscutting dyke and abundant unaltered porphyritic dyke float were observed. The dyke material comprises primary phenocrystal titaniferous augite, biotite and chrome spinel with or without olivine (cpx>>bi>spinel). Similar dyke material was not observed at Lens Mountain.

BUSH RIVER AREA (83C/3)

Near the headwaters of Bush River (Figure 4-3-3) a suite of dykes and small diatremes, somewhat similar to those at Valencienne River, intrude Upper Cambrian strata. The diatremes are clast-dominated (clast:matrix ratio is approximately 3:2) containing subangular sedimentary material and subordinate rounded granitic, gabbroic and cognate xenoliths (autoliths). Accretionary lapilli (pellets) and mica megacrysts are important phases in one pipe. Dykes are of two main types, homogeneous and zoned. The zoned dykes have coarse xenolith and/or xenocryst-rich cores (Plate 4-3-2C) and fine-grained margins. Contacts within the dyke may be gradational or distinct and often the margins exhibit a banded texture (Plate 4-3-2D). Mica is an essential component; pyroxene, olivine and chrome spinel or other opaque oxides may also be present. Most dykes are extremely altered.

OSPIKA PIPE (94B/5)

The Ospika pipe (Pell, 1986b) is a small composite diatreme containing at least five distinct breccia and massive phases. Phlogopite dominates the macrocryst assemblage, with titaniferous augite, green diopside and olivine also locally present in a fine-grained carbonate-dominated matrix. Dykes of similar material are found over 1 kilometre away from the diatreme. Rubidium/strontium age dating of mica separates has yielded an age of 334 ± 7 million years for the Ospika pipe.

DISCUSSION AND CONCLUSIONS

Three petrologically, geographically, and temporally distinct suites of ultrabasic diatremes can be recognized in British Columbia. The first is found in the Bull River area (Figures 4-3-1 and 4-3-2). Examples of both deep erosional levels (that is, root zones) and surface expression (upper diatreme and crater zones) of pipes have been recognized. The upper reaches of the diatreme zone are characterized by an abundance of vesiculated glass lapilli. The crater zone contains bedded epiclastic and/or pyroclastic rocks. Toward the periphery of the crater thin layers of igneous material are interbedded with Ordovician/Silurian Beaverfoot carbonate rocks, suggesting an age of emplacement of approximately 435 to 440 million years. The root zones of these pipes comprise macrocryst-poor breccias; chrome spinels and possibly altered olivines are sporadically distributed throughout.

The second suite, examples of which are found north of Golden and in the Ospika River areas (Figures 4-3-1 and 4-3-3), is characterized by macrocryst-rich breccias and dykes. The macrocryst population consists of titaniferous augite, phlogopite, green diopside, spinel and olivine, with either augite or phlogopite most abundant. These pipes represent the deeply eroded root zones of diatremes. Rubidium-strontium age dates of 334 ± 7 and 348 ± 7 million years have been obtained on two of the pipes.

The third petrologically distinct rock type is represented by one example, the Cross kimberlite, located at Crossing Creek, north of the town of Elkford (Figure 4-3-2). As the name implies, it is the only true kimberlite so far recognized in the province. It also is apparently a deeply eroded pipe remnant and contains olivine, phlogopite, pyroxene, garnet and spinel megacrysts as well as peridotite and garnet and spinel lherzolite nodules (Hall *et al.*, 1986). Rubidium-strontium dating of mica separates has yielded ages of 240 and 244 million years (Grieve, 1982; Hall *et al.*, 1986) for the Cross kimberlite.

The age dating indicates three periods of emplacement for ultrabasic diatremes in the Canadian Cordillera. Intrusion appears to be related to extension and/or rifting along the western continental margin which both initiated, produced and deepened the basin into which the miogeoclinal succession was deposited. A major period of alkaline activity occurred *circa* 350 million years when carbonatites and alkalic syenites as well as the diatremes were emplaced (Pell, 1986c). Xenoliths in the pipes (granitics, marbles, etc.) indicate that the diatremes passed through continental crust and therefore the miogeoclinal rocks which host them rest on continental basement.

At this point it is difficult to completely assess the depth of origin and diamond potential of these rocks. When compared to current models (Haggerty, 1986) it appears that the probability of the British Columbia diatremes containing diamonds is low. From craton to margin, a sequence of kimberlite plus diamond, kimberlite without diamond (for example, Cross) and diamond-free ultrabasic diatremes (nonkimberlitic, for example, Russell Peak pipes) is commonly proposed (Haggerty, 1986). If this model is applicable to western North America, diamonds should not be found in British Columbia as most diatremes originated too far outboard of the continent. However, much more work is necessary before this hypothesis can be accepted or rejected.

ACKNOWLEDGMENTS

The Canada/British Columbia Mineral Development Agreement has provided the logistical support which made this project possible; the Natural Sciences and Engineering Research Council supplied additional financial aid. R.L. Armstrong, The University of British Columbia, provided the rubidium-strontium dating.

I would like to thank D. Schulze, D. Hall, J. Mott and J.K. Russell for helpful discussions both in and out of the field. A special thanks goes to Olga Ijewliw for a second season of capable field assistance and for agreeing to help unravel some of the story hidden in these rocks, through her Master's thesis research.

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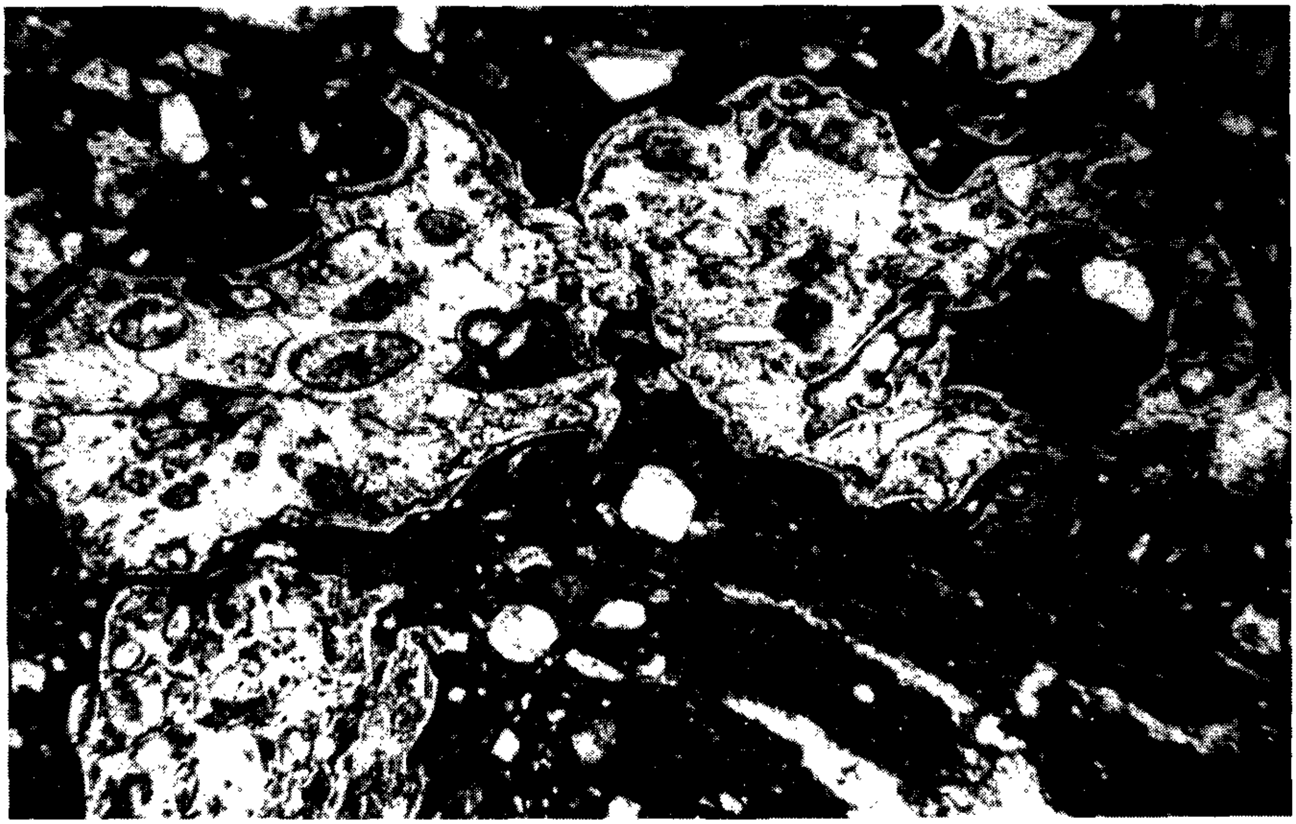
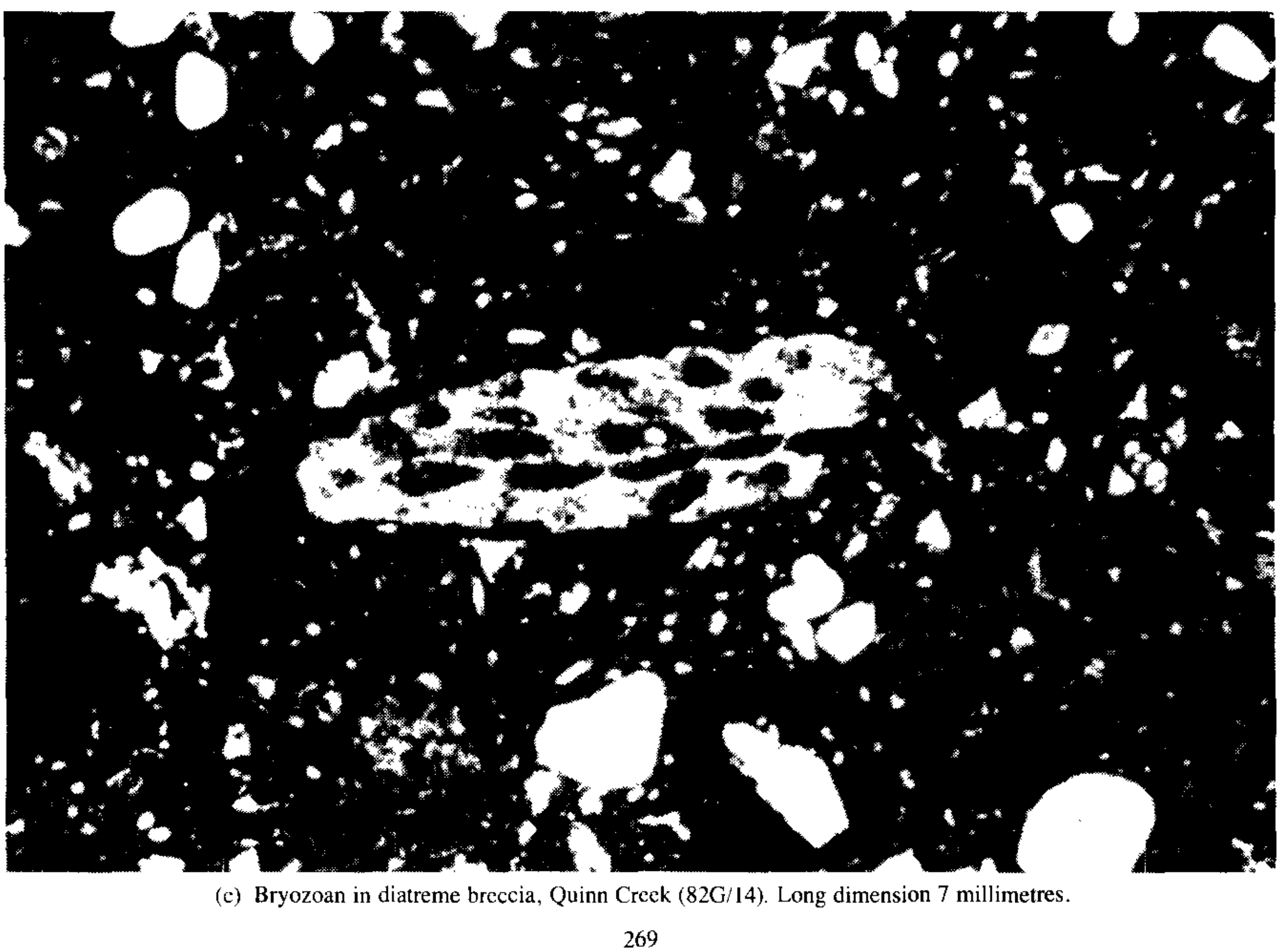
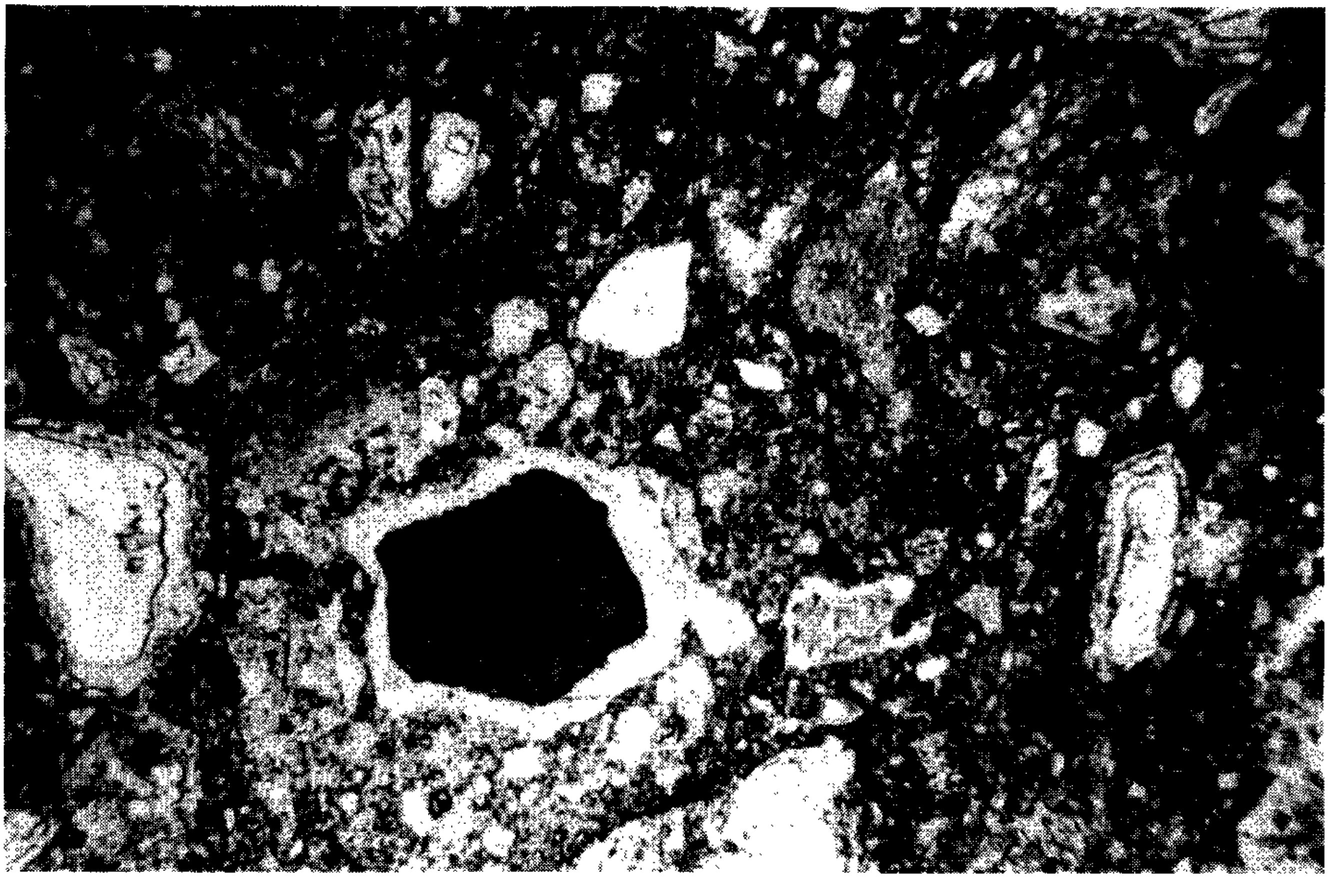
Plate 4-3-1. Characteristics of diatremes in the Bull River area.
(a) Bedded epiclastic crater infill material, Russell Peak area (82J/6). Note the resistant sedimentary layers.



(b) Photomicrograph of a vesicular glass lapilli, Quinn Creek pipe (82G/14). Long dimension 7 millimetres.



(c) Bryozoan in diatreme breccia, Quinn Creek (82G/14). Long dimension 7 millimetres.



(d) Typical material from Summer pipe (82G/11). Note chrome spinel (dark grain near centre of view) and lack of glass lapilli. Long dimension 7 millimetres.

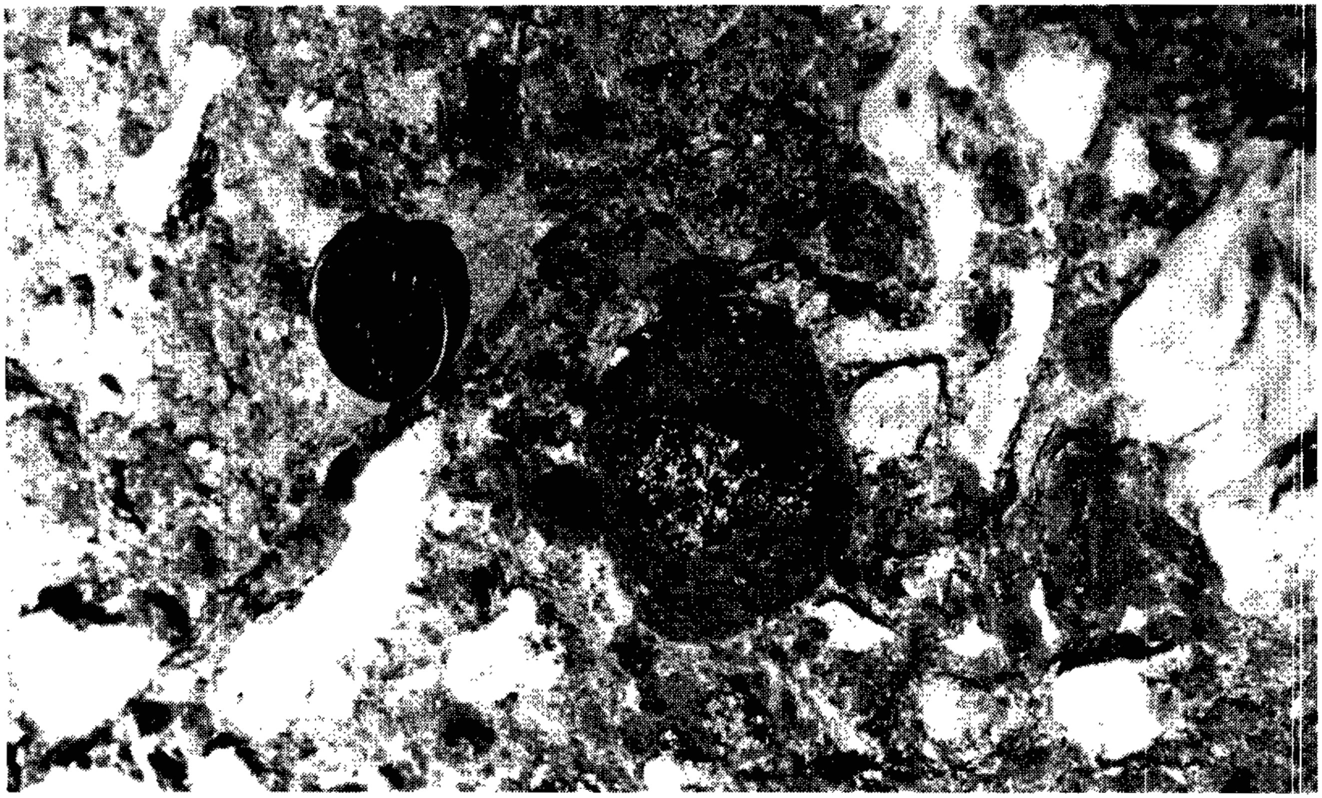
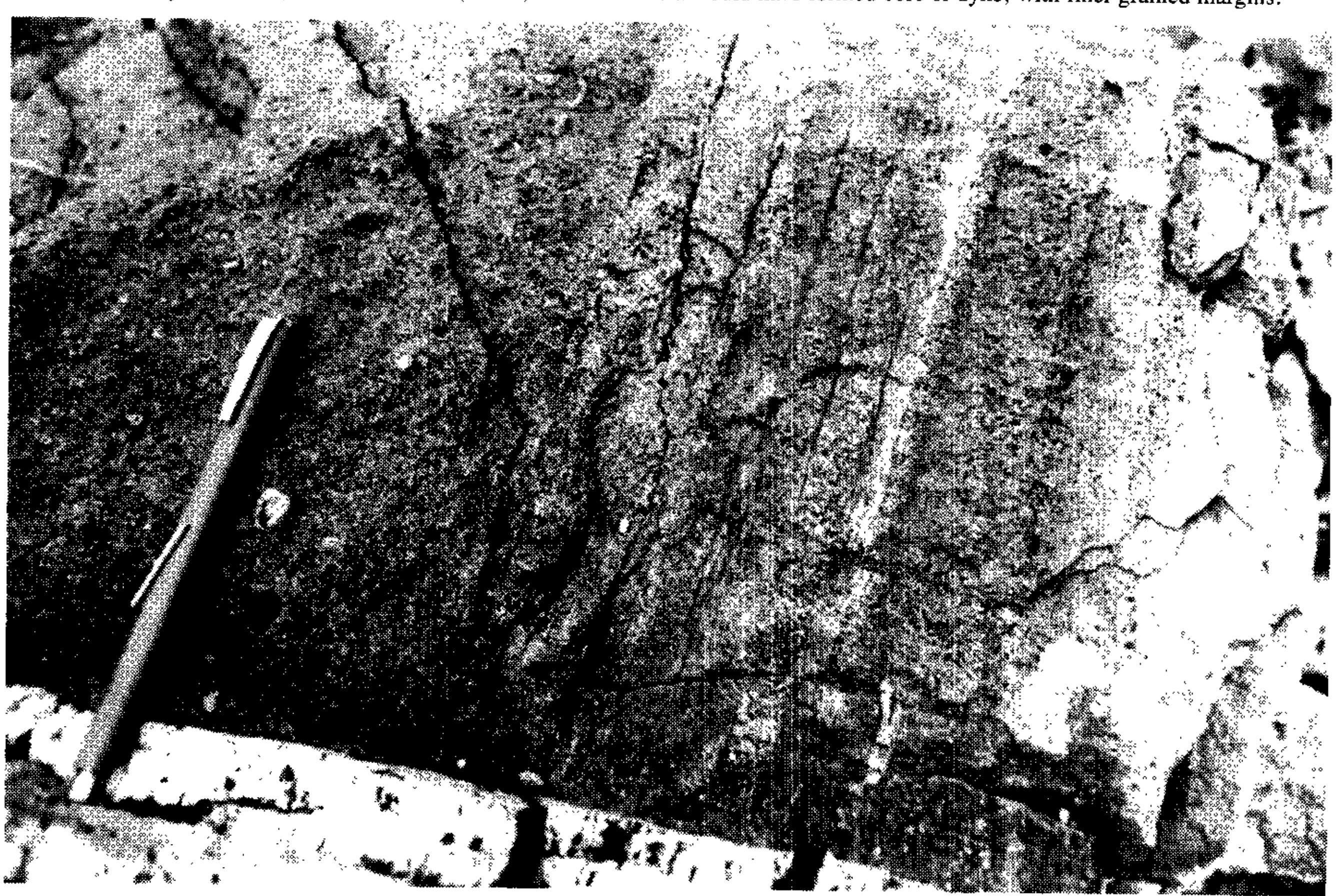


Plate 4-3-2. Characteristics of the Golden diatremes and related rocks.

(a) Accretionary lapilli, HP pipe (82N/10). Note pyroxene megacryst forming core of lapilli.

(b) Pseudomorphed olivine macrocrysts, Valencienne River area (82N/15).

(c) Zoned dyke boulder, Bush River area (83C/3). Coarse breccia would have formed core of dyke, with finer-grained margins.



(d) Finer grained dyke, Bush River area (83C/3). Note layering parallel to the margin of the dyke.