Industrial Mineral Studies

STRATIGRAPHIC AND STRUCTURAL SETTING OF INTRUSIVE BRECCIA DIATREMES IN THE WHITE RIVER–BULL RIVER AREA, SOUTHEASTERN BRITISH COLUMBIA

By H. H. Helmstaedt, J. A. Mott, D. C. Hall, D. J. Schulze and J. M. Dixon
Department of Geological Sciences, Queen's University

KEYWORDS: Breccia diatremes, kimberlite, Paleozoic stratigraphy, White River, Bull River, Rocky Mountains.

INTRODUCTION

Intrusive breccia diatremes in the White River–Bull River area (Figure 3-1-1), occurring in Paleozoic rocks of the boundary region between the Front Ranges and Main Ranges of southeastern British Columbia, were discovered during reconnaissance mapping (1:126 720 scale) in the late 1950s and early 1960s (Leech, 1958, 1964, 1979, personal communication, 1986), but did not receive closer attention until becoming targets for diamond exploration during the mid-1970s (Grieve, 1981). A small exploration rush started after a diatreme in the Crossing Creek area, originally mapped by Hovdebo (1957), was rediscovered by Cominco geologists and identified as a kimberlite. Although numerous other diatremes were found as a result of this activity, as yet diamond discoveries have not been reported in the literature. The focus of exploration has since moved to a diatreme cluster in the area north of Golden, British Columbia, where microdiamonds are reported to have been discovered from two pipes (Dummett *et al.*, 1985; *see also* Pell, 1986, 1987a, b).

In spite of the apparently low diamond potential, the approximately 40 diatremes of the White River–Bull River area pose a number of interesting petrologic, stratigraphic, structural and geotectonic problems. The Crossing Creek diatreme, also known as the Cross kimberlite (Roberts *et al.*, 1980; Grieve, 1981, 1982; Hall *et al.*, 1986, in press; Pell, 1986, 1987b; Ijewliw, 1987) thus far remains the only kimberlite recognized in the region (Pell, 1987b). It is also unique in that it occurs more than 10 kilometres east of the northerly trending zone of the other diatremes (Figure 3-1-1) in nearly horizontal strata of the Permian Ishbel Group (Grieve, 1982). As a result of the relatively open structural style in the Front Ranges, the remnants of the diatreme are little deformed and the multiphase nature of the intrusion can be recognized clearly (Grieve, 1981; Hall *et al.*, in press). Phlogopite separates from the kimberlite have yielded rubidium-strontium dates of approximately 245 Ma (Grieve, 1982; Smith, 1983; Smith *et al.*, 1987) that closely correspond to the Late Permian age of the country rock. It is thus clear that the diatreme predates the northeastward transport of the Bourgeau thrust sheet in which it is located.

The other diatremes in the area are aligned in a northerly trending zone and have intruded pre-Middle Devonian rocks affected by more complex, Main Range-style structures

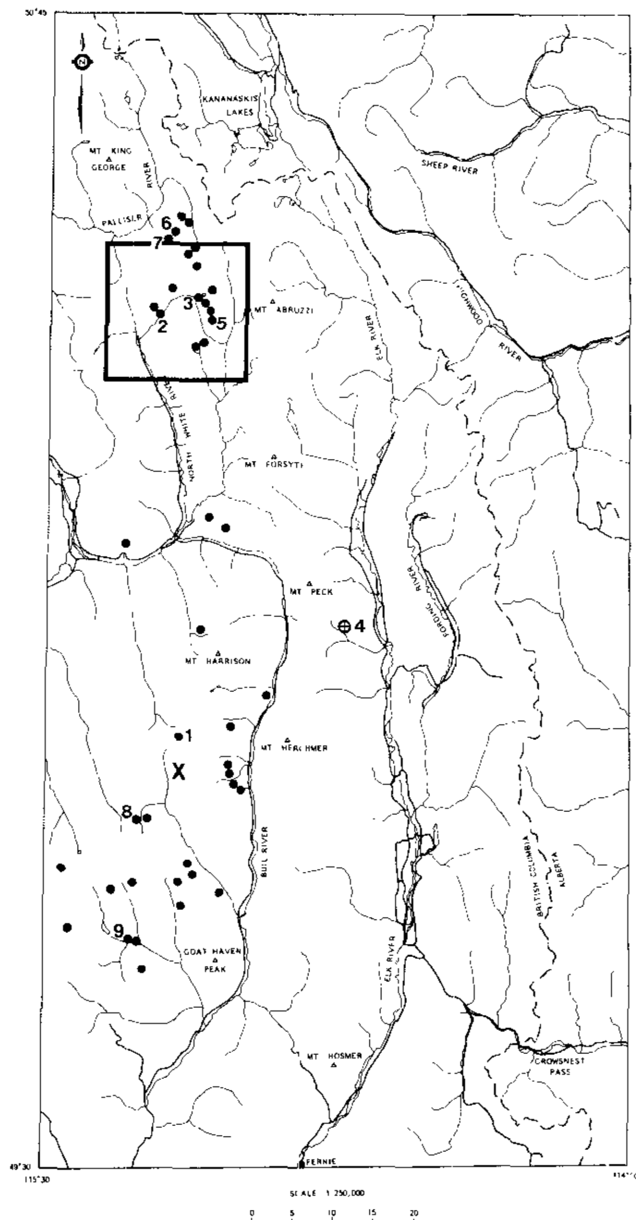

Figure 3-1-1. Location of diatremes in the White River–Bull River area. From Leech, 1979, personal communications, 1986; Pell, 1987b; J.A. Mott, unpublished field data. 1–Blackfoot; 2–White River 2; 3–Rus West; 4–Cross Kimberlite; 5–Rus 1; 6–Joff; 7–Joff West; 8–Quinn 1; 9–Summer 1 and 2; cross south of Blackfoot (1) is location of Swan claims (*see* Pell, 1987b). Black square west of Mount Abruzzi represents area of Figure 3-1-3.

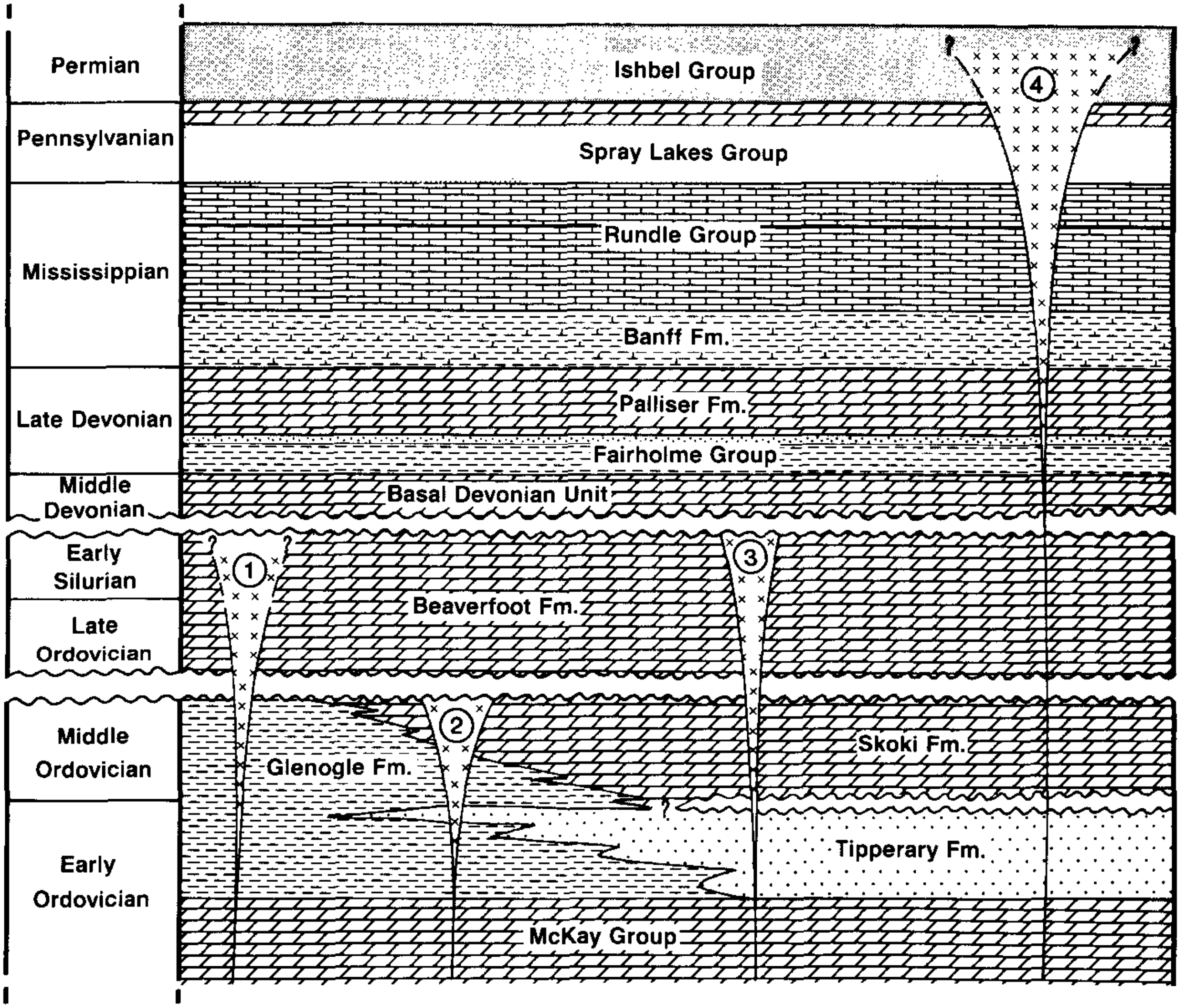

Figure 3-1-2. Diagram illustrating stratigraphic relationships in the White River–Bull River area and position of selected diatremes. Note that thicknesses of formations are not to scale, as vertical axis represents time. Diatremes illustrated area: 1–Blackfoot; 2–White River 2; 3–Rus West; 4–Cross Kimberlite.

(Figures 3-1-3, 3-1-4). Most diatremes were highly deformed during northeastward transport, and the rocks are generally too altered to be amenable to petrographic classification. An affinity to limburgites was proposed by Grieve (1981), and Pell (1987b) reported the presence of olivine melilitites in the some of the diatremes. As radiometric dates are not yet available, all age determinations must rely on relative methods – a task made difficult by the rugged terrain, the degree of deformation and apparently ambigious contact relationships, and a complex stratigraphic sequence ranging from the Late Cambrian – Early Ordovician McKay Group to a basal Devonian unit underlying the Late Devonian Fairholme Group (Figure 3-1-2). Early to Middle Ordovician rocks represent the transition between an eastern carbonate and quartzite facies (Skoki and Tipperary formations) and a western shale facies (Glenogle Formation) and are separated from the Late Ordovician – Early Silurian carbonates of the Beaverfoot Formation by a regional unconformity (Norford, 1969; Leech, 1979; Mott *et al.*, 1986). A second unconformity, also of regional extent, separates the Beaverfoot Formation from a basal Devonian unit consisting of sandy dolostone and red clastics (Leech, 1958, 1979). Pell (1987b) concluded from an interpretation of the stratigraphic position of olivine melilitite flows (Swan claims, Figure 3-1-1), and from the apparent intercalation of crater sediments of the Joff and Rus 1 pipes (Figure 3-1-1) with the carbonates of the Beaverfoot Formation, that all the diatremes were emplaced during the Late Ordovician to Early Silurian. Observations during the 1987 field season, reported in this paper, confirm that some of the magmatism indeed predated the deposition of the Beaverfoot Formation. A number of diatremes, however, postdate deposition of the Beaverfoot Formation and appear to have been emplaced during the interval represented by the post-Beaverfoot – pre-basal Devonian unconformity.

FIELD OBSERVATIONS

Two diatremes discovered by J.A. Mott during the 1986 field season in the upper reaches of North White River show stratigraphic relationships suggesting at least two ages of intrusion (Figure 3-1-2); one prior to deposition of the Beaverfoot Formation, and the other prior to deposition of the basal Devonian strata of the region.

WHITE RIVER 2 DIATREME

This diatreme is located on the steep northern slope of the valley of North White River, approximately 6 kilometres west of Russell Peak (Figures 3-1-1, 3-1-3). It outcrops in a nearly vertical panel of dolostones of the Skoki Formation that forms the east limb of an easterly verging syncline cored by Beaverfoot Formation (Figure 3-1-4). The Skoki Formation

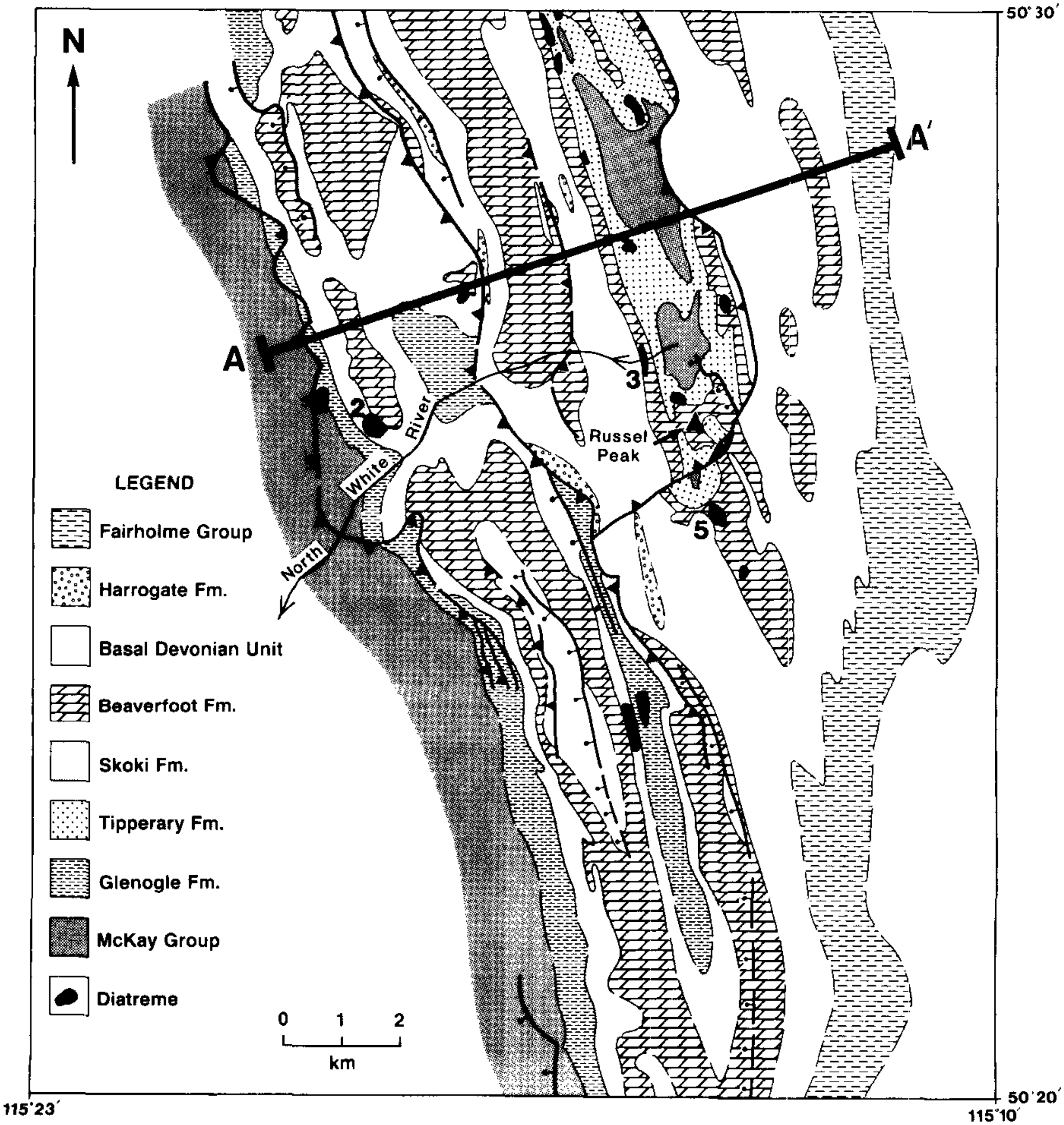

Figure 3-1-3. Location of diatremes in the Russell Peak area (*see* Figure 3-1-1). Geology after unpublished data by J.A. Mott. 2–White River 2; 3–Rus West; 5–Rus 1. Line A – A′ is line of cross-section on Figure 3-1-4.

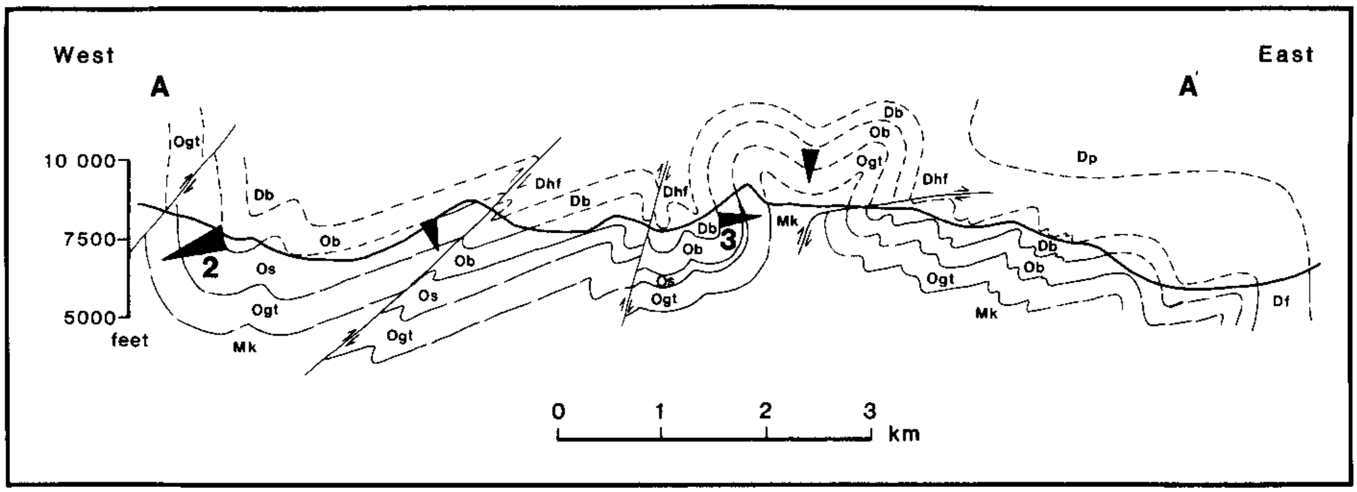

Figure 3-1-4. Cross-section A – A′ (Figure 3-1-3) illustrating stratigraphic and structural position of White River 2 (2), Rus West (3), and two other diatremes of the Russell Peak area. Mk–McKay Group; Ogt–Glenogle and Tipperary formations; Os–Skoki Formation; Ob–Beaverfoot Formation; Db–basal Devonian unit; Dhf–Harrogate and Fairholme Formations; Df–Fairholme Formation; Dp–Palliser Formation. After unpublished data by J.A. Mott.

is underlain at this locality by shales and siltstones of the Glenogle Formation containing two thin ribs of quartzite previously correlated with the Tipperary Formation (Norford, 1969; Norford and Ross, 1978). The lower part of the exposed diatreme is a brown breccia consisting of rafts and fragments of black shale and dolostone within a highly altered matrix. Two fine-grained, highly altered dykes, less than 0.5 metre thick, were observed near the western contact of the diatreme. The breccia is overlain by more than 100 metres of sediments which grade from coarse, crudely layered breccia into black, finely laminated siltstones and shales. The sediments abut abruptly against adjacent Skoki Formation which appears to represent the crater wall. This feature, combined with the unique distribution of the sediments immediately and exclusively overlying the pipe, suggests that they represent a crater-fill facies. The black crater sediments are overlain, with apparent conformity, by a thin unit of quartzites which is continuous with quartzites at the base of the Beaverfoot Formation adjacent to the diatreme.

RUS WEST DIATREME

This diatreme is located slightly more than 1 kilometre northwest of Russell Peak and outcrops across North White River at its headwaters (Figure 3-1-3). The overall shape of the exposed part of the diatreme is that of an elongate body (approximately 500 by 50 metres) which, along its eastern boundary, is in contact with westward overturned dolostones of the Beaverfoot Formation (Figure 3-1-4). Outcrops north of the river consist of a reddish weathering massive breccia surrounded by a greenish grey, highly cleaved breccia which is criss-crossed by numerous fractures with red alteration rims. The massive phase contains numerous carbonate fragments, chloritic fragments and quartz grains that locally define a crude layering. The matrix of this breccia is very fine grained and highly altered. The cleaved greenish phase consists of fragments of carbonates and reddish cherts in a fine-grained, carbonaceous matrix. Bedding in a large raft of dolostone of the Beaverfoot Formation in the cleaved breccia is parallel to the steeply east-dipping Beaverfoot Formation outside the diatreme. The cleavage dips approximately 60 degrees to the east. Discontinuous outcrops along the eastern margin of the diatreme, south of the river, consist of massive and cleaved red breccia containing large fragments and disoriented rafts of dolostone. At the western margin, a thin unit of reddish sandstone and siltstone is interpreted to represent crater-fill sediments. In an outcrop along the river, these sediments are conformbly overlain by a steeply overturned unit of sandy dolostone and red shale corresponding to the basal Devonian unit of Leech (1958, 1979; Figure 3-4-1).

OBSERVATIONS AT THE RUS 1 AND JOFF WEST DIATREMES

The Rus 1 diatreme, described by Pell (1987a, b), is a funnel-shaped pipe located in the crest of an anticline of Beaverfoot Formation overlying Tipperary Formation (Figure 3-1-3). Well-layered crater-facies sediments exposed in a saddle in the crest of the anticline are juxtaposed laterally against Beaverfoot Formation which dips toward the east and west, away from the crest. Beaverfoot Formation on both limbs of the anticline is capped by Devonian strata, and the sub-Devonian unconformity projects approximately 75 metres above the upper part of the diatreme. According to Pell (1987a), thin layers of igneous material are interbedded with carbonates of the Beaverfoot Formation near the top and margins of pipe, implying an Ordovician-Silurian emplacement age. Our observations suggest that the carbonates of the Beaverfoot Formation are not interbedded with pipe material but form the margin of the original crater. Dolostone at the western crater rim, near the top of the pipe, is plastered with a red breccia consisting of small angular fragments of sedimentary and igneous (?) origin in a matrix rich in fine to medium-grained detrital quartz. Although locally parallel to the bedding of the dolostone, this material also crosscuts bedding and fills radial fractures along the pipe margin. Sedimentary breccia near the pipe margin also contains angular clasts of dolostone which appear to be fragments from the crater wall. The breccias are interpreted as slump breccia derived from the original crater rim.

An interesting problem is posed by an occurrence of olivine basalt above crater sediments of the Rus 1 diatreme (*see* Pell, 1987a, b). Unlike any rock type related to the diatremes, this olivine basalt contains exceptionally fresh phenocrysts of olivine, suggesting that it may be much younger than the highly altered and deformed rocks of the diatreme.

The Joff West diatreme (Figure 3-1-1) contains crater fill more than 50 metres thick comprising laminated red shale and siltstone, locally with large angular clasts and rafts of dolostone of the Beaverfoot Formation derived from the crater wall or rim. These sediments are downfaulted against the crater wall and against diatreme breccia containing fragments of dolostone, limestone, quartzite, and reddish chert similar to that occurring in the Rus West diatreme. The crater sediments of the Joff West diatreme resemble the reddish clastics of the basal Devonian strata, suggesting that the diatreme may have breached the pre-Devonian erosion surface.

DISCUSSION AND CONCLUSIONS

The fact that crater sediments of the White River 2 diatreme are overlain by basal Beaverfoot Formation indicates that the diatreme was emplaced about 455 million years ago, during the approximately 10-Ma interval represented by the sub-Beaverfoot unconformity. This corroborates the presence of Late Ordovician magmatism, though it is not known whether the White River 2 diatreme and pre-Beaverfoot Formation olivine-melilitite flows on the Swan claims (Pell, 1987b) are genetically related. It is also not yet clear whether a relationship exists between the flows at the Swan claims and the mafic White River sills in McKay Formation, north of Mount Harrison (Figure 3-1-1). On the other hand, one such sill, outcropping along Thunder Creek on the east limb of the Thunder Creek anticline (Leech, 1979), is cut by a diatreme breccia, approximately 5 kilometres northwest of Mount Harrison.

As shown by the conformable contact between crater sediments and basal Devonian strata at the Rus West pipe, diatremes were also emplaced at about 400 Ma, during the approximately 30-Ma interval represented by the pre-Devonian unconformity. It is likely that several other diatremes (for example, Rus 1, Joff, Joff West) breached the pre-Devonian erosion surface, and their craters were filled with clastics similar to those within the basal Devonian unit. As clasts of Devonian strata have not been recognized in any of the breccias, the diatremes appear to have predated the deposition of the basal Devonian unit. As crystalline xenoliths have been identified in breccias of several pipes, we conclude that the diatremes were emplaced along a north-trending normal fault system located in the pre-Paleozoic sialic basement west of the Alberta arch (Ziegler, 1969). This system was active from Late Ordovician through Mid-Devonian times and may have been reactivated in Permian times to provide a channelway for the Cross kimberlite.

ACKNOWLEDGEMENTS

We gratefully acknowledge financial support in the form of a British Columbia Geoscience Research Grant, a Department of Energy, Mines and Petroleum Resources Research Grant, and Natural Science and Engineering Council Grants to J.M. Dixon, H. Helmstaedt and D.J. Schulze. J.A. Mott's fieldwork was supported by the Geological Survey of Canada. We are thankful also to O. Ijewliw, G.B. Leech, M.E. McMechan, B.S. Norford, J. Pell, A. Polak, B. Simser, and J. Wynn for stimulating discussions and help, both in the field and in the office.

REFERENCES

Dummett, H., Fipke, C. and Blusson, S.L. (1985): Diamondiferous Diatremes in Eastern British Columbia (Abstract), *Canadian Institute of Mining and Metallurgy,* Bulletin, Volume 78, pages 56-58.

Grieve, D.A. (1981): Diatreme Breccias in the Southern Rocky Mountains, *B.C. Ministry of Energy, Mines and Petroleum Resources,* Geological Fieldwork, 1980, Paper 1981-1, pages 96-103.

———(1982): 1980 — Petrology and Chemistry of the Cross Kimberlite (82J/2), *B.C. Ministry of Energy, Mines and Petroleum Resources,* Geology in British Columbia, 1977-1981, pages 34-41.

Hall, D.C., Helmstaedt, H. and Schulze, D.J. (1986): The Cross Diatreme: A Kimberlite in a Young Orogenic Belt, Geological Society of Australia, *4th International Kimberlite Conference,* Abstract Series No. 16, pages 30-32.

——— (1987): The Cross Diatreme: A Kimberlite in a Young Orogenic Belt, Proceedings of 4th Interational Kimberlite Conference, *Geological Society of Australia,* In Press.

Hovdebo, M.R. (1957): Structure of the Brûlé–Crossing Creek Area, British Columbia, Unpublished M.Sc. Thesis, *University of Saskatchewan.*

Ijewliw, O.J. (1987): Comparative Mineralogy of Three Ultramafic Breccia Diatremes in Southeastern British Columbia, Cross, Blackfoot and HP (82J, 82G, 82N), *B.C. Ministry of Energy, Mines and Petroleum Resources,* Geological Fieldwork, 1986, Paper 1987-1, pages 273-282.

Leech, G.B. (1958): Fernie Map-area, West-half, British Columbia, *Geological Survey of Canada,* Paper 58-10.

——— (1964): Kananaskis, West-half (82J W1/2) Map-area, *Geological Survey of Canada,* Paper 64-1.

——— (1979): Kananaskis Lakes Map Area, *Geological Survey of Canada,* Open File No. 634.

Mott, J.A., Dixon, J.M. and Helmstaedt, H. (1986): Ordovician Stratigraphy and the Structural Style at the Main Ranges–Front Ranges Boundary near Smith Peak, British Columbia, *Geological Survey of Canada,* Paper 86-1B, pages 457-465.

Norford, B.S. (1969): Ordovician and Silurian Stratigraphy of the Southern Rocky Mountains, *Geological Survey of Canada,* Bulletin 176.

Norford, B.S. and Ross, R.J. Jr. (1978): New Species of Brachiopods and Trilobites from the Middle Ordovician (Whiterock) of Southeastern British Columbia, Contributions to Canadian Paleontology, *Geological Survey of Canada,* Bulletin 267, pages 1-5.

Pell, J. (1986): Diatreme Breccias in British Columbia, *B.C. Ministry of Energy, Mines and Petroleum Resources,* Geological Fieldwork, 1985, Paper 1986-1, pages 243-253.

——— (1987a): Alkaline Ultramafic Diatremes in British Columbia: Petrology, Geochronology and Tectonic Significance, *B.C. Ministry of Energy, Mines and Petroleum Resources,* Geological Fieldwork, 1986, Paper 1987-1, pages 259-272.

——— (1987b): Alkaline Ultrabasic Rocks in British Columbia: Carbonatites, Nepheline Syenites, Kimberlites, Ultramafic Lamprophyres and Related Rocks, *B.C. Ministry of Energy, Mines and Petroleum Resources,* Open File 1987-17.

Roberts, M.A., Skall, M. and Pighin, D.L. (1980): Diatremes in the Rocky Mountains of Southeastern B.C. (Abstract), *Canadian Institute of Mining and Metallurgy,* Bulletin, Volume 73, pages 74-75.

Smith, C.B. (1983): Rubidium-strontium, Uranium-lead and Samarium-neodynium Isotopic Studies of Kimberlites and Selected Mantle-derived Xenoliths, Unpublished Ph.D. Thesis, *University of the Witwatersrand.*

Smith, C.B., Colgan, E.A., Hawthorne, J.B. and Hutchinson, G. (1987): Emplacement Age of the Cross Kimberlite, Southeastern British Columbia, by the Rb-Sr Method, *Canadian Journal of Earth Sciences,* In Press.

Ziegler, P.A. (1969): The Development of Sedimentary Basins in Western and Arctic Canada, *Alberta Society of Petroleum Geologists,* Calgary.