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CROSS RIVER SILLS, ROCKY MOUNTAINS, SOUTHEASTERN BRITISH COLUMBIA

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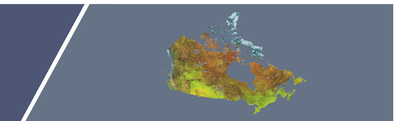


ABSTRACT

Dioritic sills up to 40 m thick were discovered by G.M. Dawson along the Cross River in the 1880's (Dawson, 1886). The Cross River Sills intrude Middle Cambrian limestone, argillaceous limestone, calcareous argillite and argillite of the Mount Docking Formation (middle Chancellor Group). The sills have metmorphosed the adjacent strata and are themselves regionally metamorphosed, folded, and crosscut by numerous nearly perpendicular quartz veins that locally contain minor chalcopyrite. Recent mapping in the Kananaskis area (McMechan, 2011; McMechan and Leech, 2011) discovered similar sills in the Mount Docking Formation along the Albert River and at Fenwick Creek. These locally contain abundant pyrrhotite and are cut by numerous barren quartz veins. They are considered to be part of the Cross River suite on the basis of geological setting, general lithology and geochemistry.

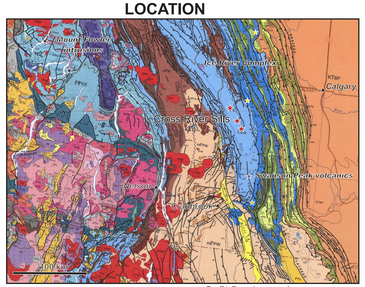
At Cross River a small zone of medium crystalline plagioclase-hornblende diorite was sampled for age dating. It contained no zircon. The hornblende had very low K content, excess Ar and produced highly disturbed spectra with non-interpretable results. Apatite fission track analysis indicates cooling in the early Tertiary and structural relationships require their intrusion by the Early Cretaceous.

High quality multi-element chemical analyses are used to characterize the compositions of the Cross, Fenwick, and Albert sills, and dykes in the McKay Group from the Kananaskis area, the Fowler sill, Milford Group and Clachnacudain pluton from the Omineca Belt and ash beds in the Exshaw and Banff formations exposed in the Front Ranges. These are compared with published results for intrusions associated with diatreme breccias in the Kananaskis area. Standard geochemical variation diagrams portray homogeneous and variable major and minor, trace and rare earth element (REE) compositions and help indicate geochemical similarities and differences amongst these suites.

Major element analyses indicate that many of the units are altered as indicated by their high loss on ignition values. Intrusive suites are mostly mafic with the exception of the dacite and rhyolite intrusive rocks in the Fowler suite and the trachyandesite and trachydacite of the Exshaw ash beds. The Albert sills are closest in major and minor element composition to the Cross and McKay intrusions. High field strength elements (HFSE) are less affected by alteration but similarly help group various suites and confirm the major element classifications. The Fowler and Cross suites have similar trace element compositions and compare closely with subalkaine, calc-alkaline, arc-type igneous rocks. The Fenwick, McKay, and Albert intrusions and alternatively Fowler and Cross sills overlap in compositional space on many of these plots but the Exshaw ash beds samples are distinct. All suites samples have continental affinities in K_2O-TiO$_2$-P_2O_5 space.

Multi-element plots and normalized to primitive mantle compositions help confirm some similarities amongst suites and show effects of alteration processes. The Cross, McKay, and Albert suites have the closest similarities in overall multi-element patterns and the Fenwick and Laussedat dyke are also closely similar.

LOCATION



★ Mount Fowler intrusion geochem sample
★ Sill localities discussed in text

Foreland Basin- U. Jurassic- Paleocene
JlK | K | uKT

Miogeocline- Platform- latest Neoproterozoic - M. Jurassic
lB | CT | DT

★ Banff tuff geochem sample
★ Exshaw tuff geochem sample

Windermere- Neoproterozoic

Belt-Purcell- Mesoproterozoic

The Cross River sills and related dykes occur in the western part of the Rocky Mountains 60 to 90 km southeast of the Devonian Ice River Complex. The Cross River sills intruded Middle and Upper Cambrian basinal strata of the White River Trough near its structurally controlled eastern boundary. Base map from Wheeler and McFeely (1991).

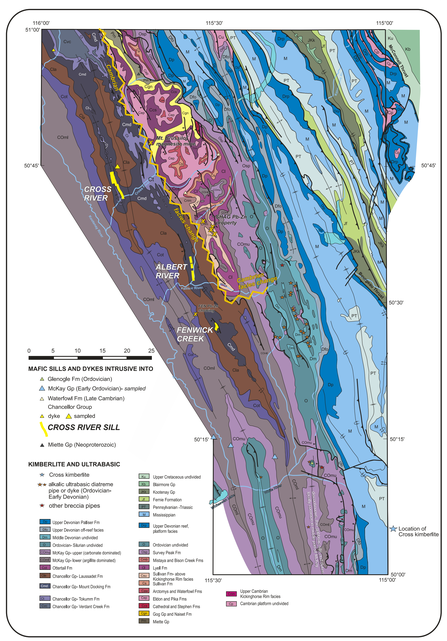
SILL CHARACTERISTICS

CROSS RIVER

Two dioritic sills with a combined exposed length of 7 km intrude the Mount Docking Formation at Cross River. The sills have maximum thicknesses of ~30 m and ~40 m, have metamorphosed the adjacent country rock for several metres, and are cut by steeply dipping quartz veins. The sills are folded and were intruded prior to Late Jurassic to Early Cretaceous compressive deformation. The fine- to medium-grained, equigranular, green-grey diorite is extensively chloritized; with minor epidote.

ALBERT RIVER

A cleaved, highly chloritized, fine-grained, greenish-grey dioritic sill approximately 10 m thick intrudes the Mount Docking Formation. The sill is cut by cleavage-parallel quartz veins and bordered by narrow bands of contact metamorphism. There has been extensive mixing with host carbonate in southern exposures.



Distribution of the Cross River sills and other intrusive rocks in the Rocky Mountains, Kananaskis west-half (82J W/2) map area.

FENWICK CREEK

Highly chloritized, medium-grained, grey-green dioritic sill approximately 20 m thick intrudes Mount Docking Formation. Contact metamorphism extends several metres into host strata. Sill cut by abundant steep quartz veins. Minor epidote, potassium pargasite.

MINERALIZATION

Pyrrhotite rich diorite, Fenwick Creek. | Pyritic diorite with quartz vein, Albert River. | Quartz veins, Fenwick Creek.

Sills at all localities are pyritic. The Fenwick sill contains up to 15% pyrrhotite and minor chalcopyrite (<1%). Quartz veins appear barren with minor chalcopyrite along the margins. No gold values were found with the veins at Cross River.

AGE DATING

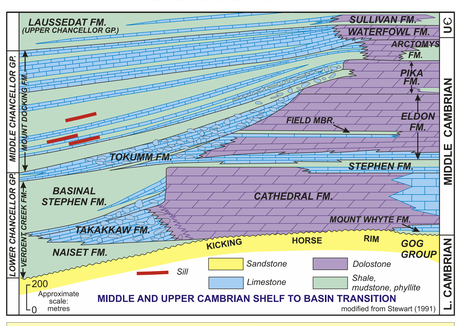
Rock sampled for U-Pb age dating, Cross River. Medium crystalline, partially chloritized plagioclase-amphibole diorite with long laths of amphibole giving a metamorphosed look. X-ray diffraction analysis indicates that the amphiboles are closer in composition to actinolite than hornblende. Remnant amphiboles at Fenwick Creek are potassium rich pargasite.

At Cross River a small zone of less altered, medium crystalline plagioclase-amphibole diorite was found and sampled for age dating. The sample contained no zircon. The amphibole had very low K content, excess Ar and produced highly disturbed spectra with non-interpretable results.

The sills post-date their Middle Cambrian hosts and were intruded prior to Early Cretaceous compressive deformation. Apatite fission track analysis indicates cooling below 100°C occurred in the Early Tertiary.

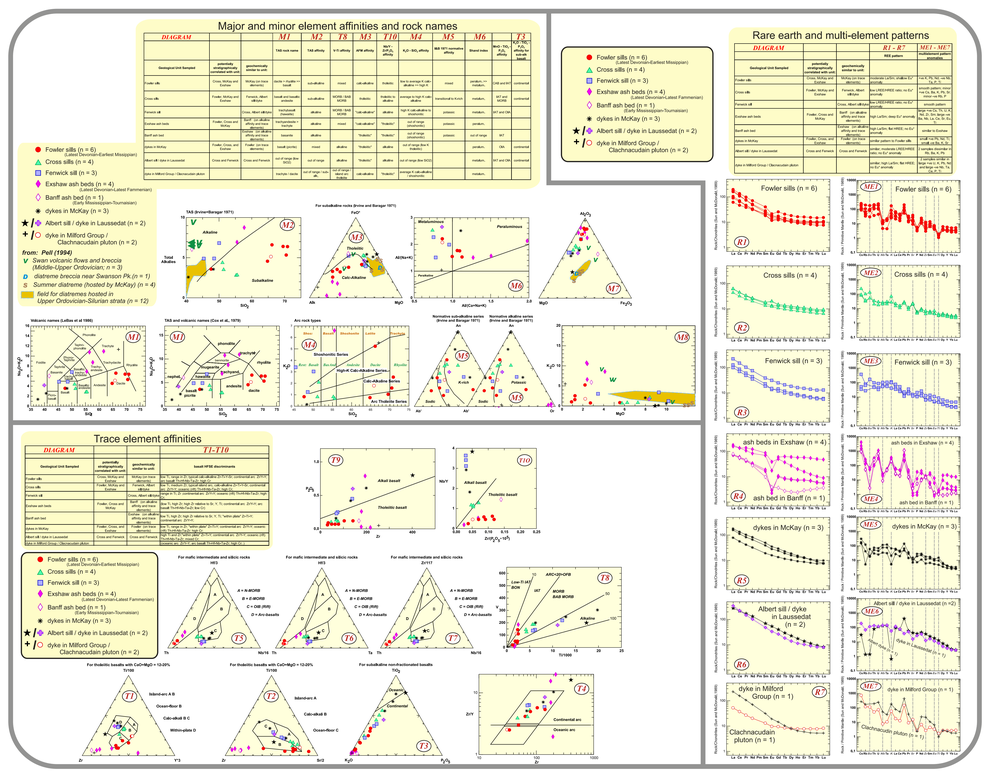
Comparison of high quality multi-element geochemistry with other Paleozoic intrusive and extrusive rocks shows they have geochemical affinities with the Latest Devonian to Earliest Mississippian Mount Fowler sills (see Geochemistry panel).

GEOLOGICAL SETTING



The Cross River sills are intrusive into Middle Cambrian limestone, argillaceous limestone, calcareous argillite and argillite of the Mount Docking Formation (middle Chancellor Group), deposited immediately basinward of the structurally controlled Cambrian facies change at the Kickinghorse Rim.

GEOCHEMISTRY



SUMMARY OF GEOCHEMICAL COMPOSITIONS

High quality multi-element chemical analyses were used to characterize the compositions of the Fowler, Cross, Fenwick, and Albert sills, and dykes in the McKay Group, Milford Group and Clachnacudain pluton. As well, compositions of ash beds in the Exshaw and Banff formations and published results for intrusions associated with nearby diatremes are compared.

Standard geochemical variation diagrams portray homogeneous and variable major and minor, trace and rare earth element (REE) compositions and help indicate geochemical similarities and differences amongst these suites *(see summary tables for major, trace, REE and multi-element diagrams)*.

Major element analyses indicate that many of the units are altered as indicated by their high loss on ignition values. Intrusive suites are mostly mafic with the exception of the dacite and rhyolite intrusive rocks in the Fowler suite and the trachyandesite and trachydacite of the Exshaw ash beds (plots M1 and M4). These felsic rocks are also distinctively peraluminous compared to the metaluminous, mafic counterparts (plot M6). The Fenwick sill and Exshaw ash samples are distinctively alkaline and high K or shoshonitic affinities (plots M1, M2, M4 and M5). Amongst the subalkaline suites, the Cross sills are tholeiitic compared with calc-alkaline compositions for the Fowler suite (plot M3); both are low to average potash suites (plot M4). The sills in the McKay are characterized by the lowest silica values and alkaline (potassic) characteristics (plots M1, M2 and M4). The Albert sills are closest in major and minor element composition to the Cross and McKay intrusions.

The compositional range of nearby, and potentially genetically-related diatremes and those of the Swan volcanics and Summer diatreme, compiled by Pell (1994) is most closely similar to that for the Fenwick, McKay and Albert intrusions indicated in the major and minor element plots (e.g., plots M2, M3, M7 and M8).

High field strength elements (HFSE) are less affected by alteration but similarly help group various suites and confirm the major element classifications. The Fowler and Cross suites have similar trace element compositions and compare closely with subalkaine, calc-alkaline, arc-type igneous rocks (plots T5-T10). The Fenwick, McKay and Albert intrusions and Exshaw ash are alkaline (e.g., plots T9 and T10), and in some classifications overlap compositions found in within plate, rift environments (plots T1 and T5). The Fenwick, McKay, and Albert intrusions and alternatively Fowler and Cross sills overlap in compositional space on many of these plots but the Exshaw ash beds samples are distinct. All suites samples have continental affinities in K_2O-TiO$_2$-P_2O_5 space (plots T3 and T4).

Chondrite-normalized REE (plots R1-7) and primitive mantle-normalized multi-element plots (plots ME1-7) indicate within- and between-suite similarities and distinctions. Samples from most suites have a narrow range of REE compositions, small light REE to heavy REE ratios, and smooth REE profiles with shallow or no Eu* anomalies. Samples from the Albert, Fenwick, McKay and Milford suites have the largest La*/Lu* ratios. The ash beds in the Exshaw and Banff are important exceptions and are characterized by a broad range of REE composition and common and large Eu* anomalies. The Banff ash is distinctive from the Exshaw ash samples.

Multi-element plots (plots ME1-7), normalized to primitive mantle compositions, help confirm some similarities amongst suites and show effects of alteration processes (a range in large ion lithophile elements (Ce, Rb, Ba, K) with individual suites), feldspar differentiation (K, Sr, Eu anomalies) and influence of contamination by continental crust (positive Pb anomalies). Most suites lack the negative Nb, Zr and Ti anomalies that are the hallmark of calc-alkaline arc volcanic suites; the Fowler, Exshaw and Banff ash, Milford Group, and Clacnacudain samples are important exceptions. The Cross, McKay, Albert suites have the closest similarities in overall multi-element patterns and the Fenwick and the Laussedat dyke samples are also closely similar.

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