The Aley Carbonatite Complex:

Structural evolution, petrogenesis, and tectonic implications of a Cordilleran niobium deposit

D.F. McLeish[1], R. Kressall[2], S.T. Johnston[1], A. Chakhmouradian[2], J. Crozier[3], and J.K. Mortensen[4]

[1]School of Earth and Ocean Sciences, University of Victoria; [2]Department of Geological Sciences, University of Manitoba; [3]Taseko Mines Ltd.; [4]Department of Earth and Ocean Sciences, University of British Columbia

I. Background – Carbonatites in the Foreland

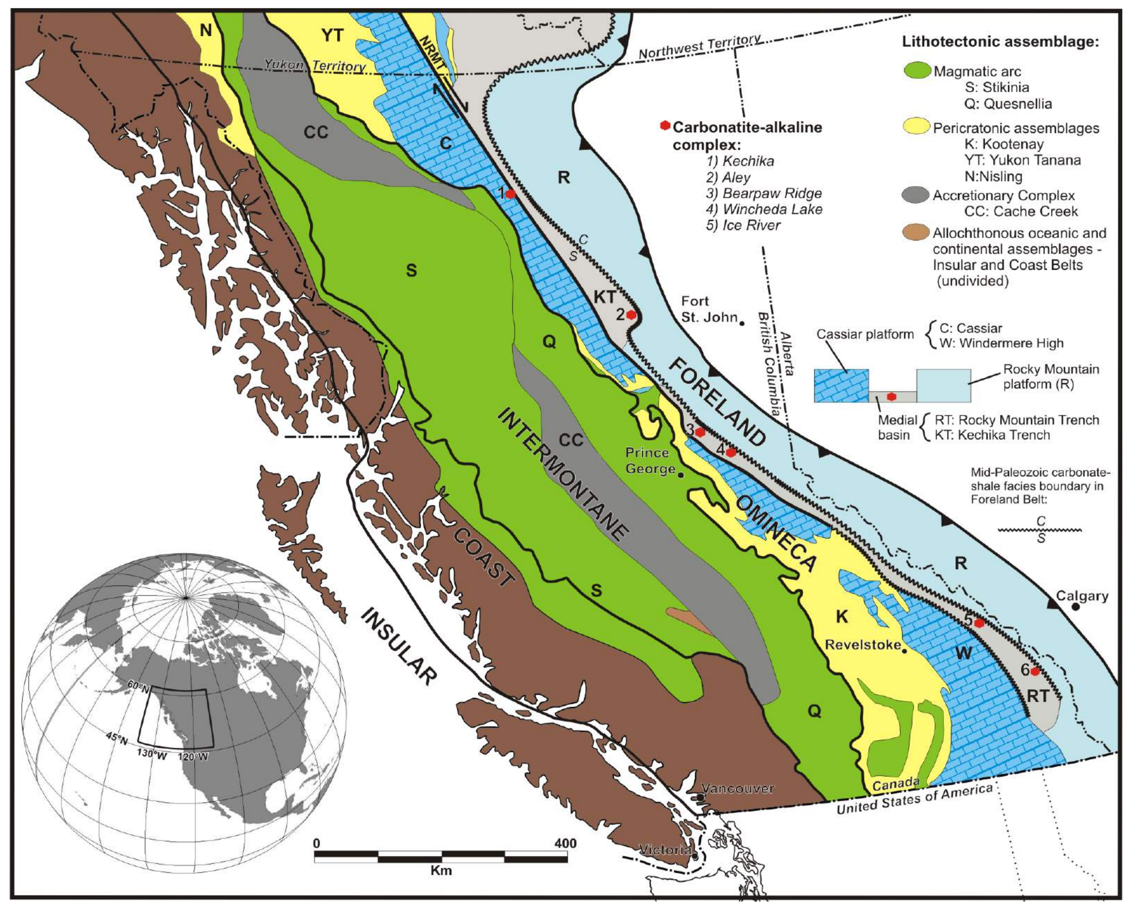


Figure 1: Tectonic assemblage map of the Canadian Cordillera highlighting Foreland Belt carbonttite-alkaline occurrences. The jagged line indicates a mapped facies boundary separating shallow water platformal sequences from basinal strata.

II. Regional Geology

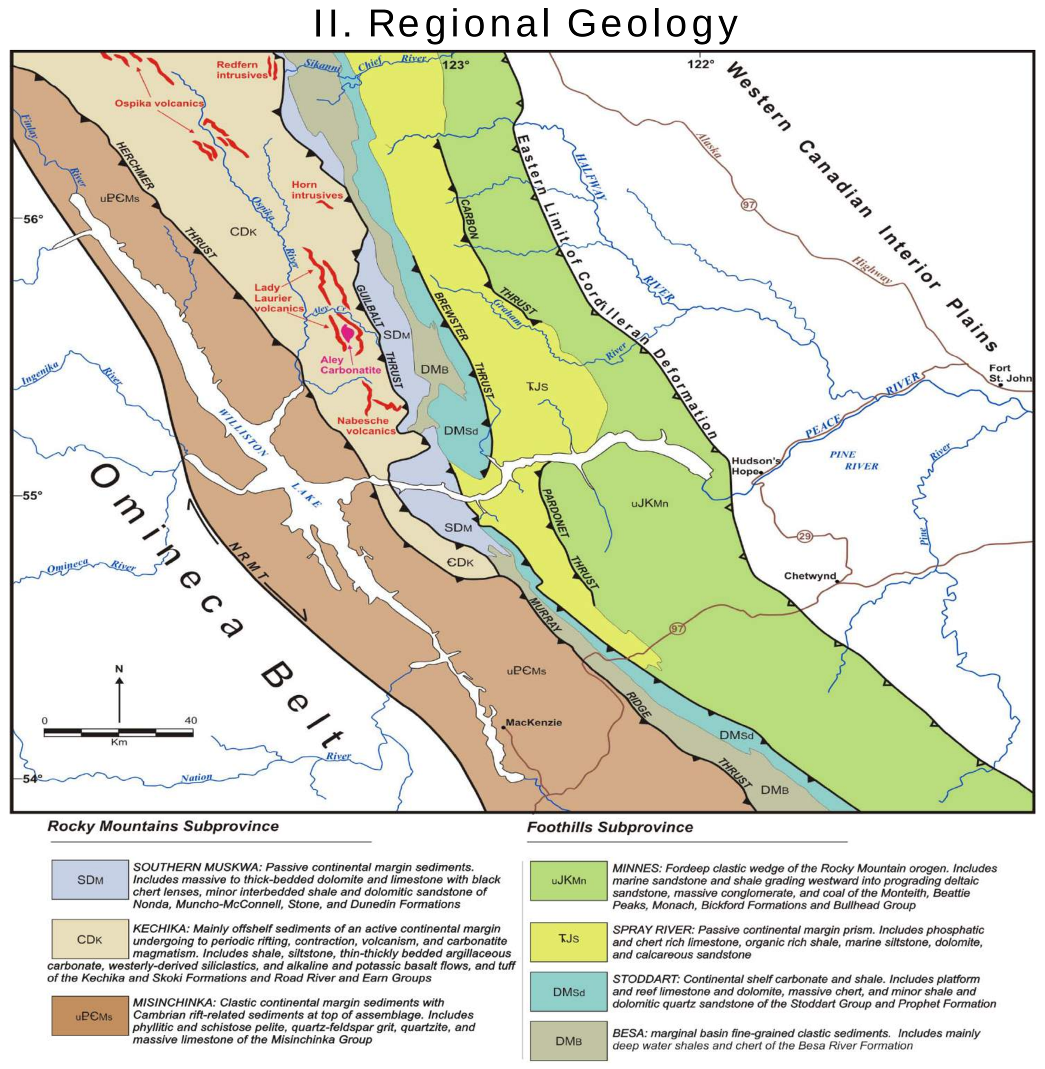


Figure 2: Simplified geological map of the Williston Lake area showing key tectono-stratigraphic divisions (after Wheeler and McFeely, 1991). Several alkaline volcanic occurrences and the Aley carbonatite complex define a strike-parallel belt of Paleozoic igneous activity unseen by Paleozoic continental shelf and margin strata to the east.

III. Deformation Record

Figure 3: D1 structures in fenitized country rock (Kechika Formation). (A) F1 Isoclinal folds and S1 axial-planar, bedding-parallel cleavage; calcite carbonatite dyke (blue arrow) folded concordantly with D1 fabric. (B) Dolomite carbonatite dyke (yellow arrow) intruding along the plane of a low-angle shear.

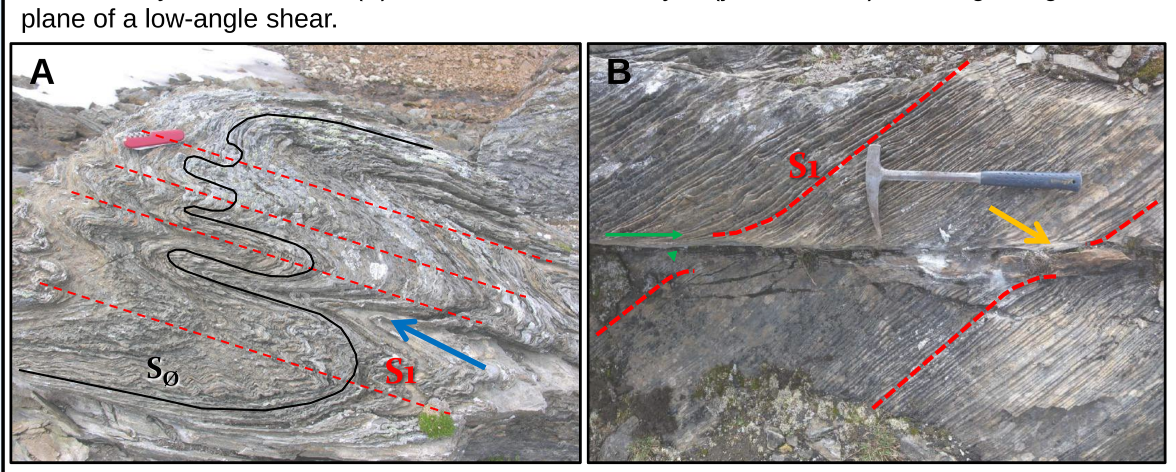
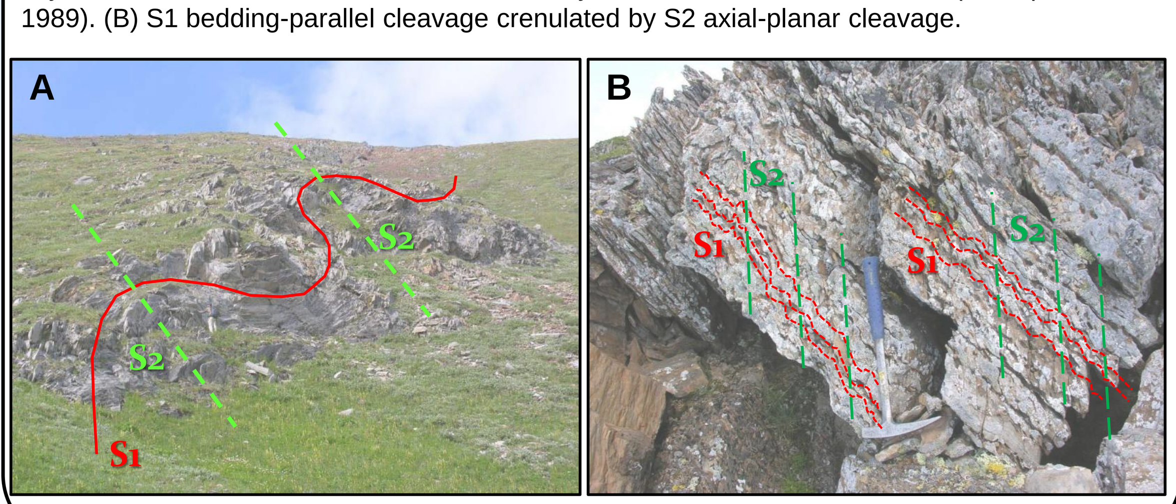


Figure 4: D2 structures in fenitized country rock (Road River Group). (A) F2 east-verging, open, asymmetric folds attributed to Cretaceous Rocky Mountain-related deformation (Thompson, 1989). (B) S1 bedding-parallel cleavage crenulated by S2 axial-planar cleavage.



Abstract

This poster presents the results from an integrated structural, petrological, and geochronological study of the Aley carbonatite complex, a property belonging to Taseko Mines Ltd. in the northeast BC Rocky Mountains. Located approximately 135 km north-northeast of Mackenzie, Aley is the largest of six known alkaline-carbonatite occurrences in the Foreland Belt of the Canadian Cordillera. Despite enrichment in rare earth elements (REEs), niobium, tantalum, and zirconium, Foreland Belt carbonatites have been subject to limited study beyond reconnaissance-scale mapping and early-stage mineral exploration. Many aspects of carbonatite petrogenesis in the Cordillera remain poorly understood and knowledge gaps – spanning structure, petrology, and tectonics – have challenged efforts to successfully evaluate and model their resource potential. Detailed geological field mapping, structural analysis, and petrological investigation of the past two summers has revealed new information regarding the structural and petrological evolution of the Aley carbonatite and has assisted in the determination of optimal drill hole locations for Taseko's recently completed 2010 exploration program.

Two major deformation phases are identified in the Aley area: a D1 phase manifest by south-verging, recumbent F1 isoclinal folds and well-developed axial-planar S1 cleavage, and a D2 phase characterized by prominent east-verging, open, asymmetric F2 folds and related S2 axial-planar cleavage. Several key structural relationships suggest that the D1 event was synchronous with ca. 365 Ma emplacement of the Aley carbonatite complex: (1) the emplacement of calcite carbonatite concordant with the D1 fabric in contrast to discordant emplacement of dolomite carbonatite; (2) the presence of D1 fabrics in xenoliths of country rock sampled by dolomite carbonatite and the spatially related Ospika pipe diatreme; and (3) dolomite carbonatite dykes and veins intruding along axial planes of F1 folds and D1 thrusts in the country rock. Examination of stratigraphic way-up indicators show the country rock to be completely overturned within the map area. This observation, combined with the isoclinal form of F1 folds and the bedding-parallel orientation of S1 cleavage, suggests that the map area lies on the lower overturned limb of a regionally developed recumbent isoclinal fold or thrust nappe structure related to Devonian carbonatite emplacement. Strong parallelism shown between mineral laminations in the carbonatite and bedding indicates that the carbonatite complex has an overall sill-like geometry.

Three Nb-bearing units are documented in the complex: (1) dolomite carbonatite, (2) calcite carbonatite, and (3) a magnetite-apatite carbonatitic cumulate unit. Pyrochlore, columbite, and fersmite comprise the dominate niobate mineral phases. Nb mineralization appears to have been concentrated initially in the heavy mineral cumulate layers. During the deformation of the carbonatite, the cumulate layers likely acted as coherent units resisting plastic flow due to the low carbonate and high apatite content of the unit. D1 deformation of the carbonatite resulted in the disaggregation of the cumulate unit and the dispersal of apatite and niobates into the carbonatite as mineralized lamellae which are concordant with the D1 fabric. D2 deformation has locally transposed the lamellae along the axial planes of Rocky Mountain folds (S2).

Tectonically, the documentation of a major Late Devonian thrust nappe in the western Foreland Belt indicates that the continental margin represented by the miogeoclinal sequence host to the Aley carbonatite complex was subject to a contractional orogenic event in the mid-Paleozoic. This interpretation is consistent with stratigraphic studies that report a Devonian influx of westerly-derived coarse clastic sediment in the region (*e.g.* Gabrielse et al., 1977). In contrast, mid-Paleozoic continental margin strata in the eastern Foreland Belt record passive margin conditions and easterly-derived sedimentation. Existing tectonic models depict the Foreland Belt evolving as a single Paleozoic passive margin on the western edge of Laurentia. We propose that two separate, genetically unrelated continental margin systems exist: a west facing passive margin in the eastern Foreland Belt (Rocky Mountain platform) and an east facing orogenically active margin in the western Foreland Belt (Cassiar platform). Carbonatite magmatism has recently been shown to be globally associated with known continental suture zones (Burke et al. 2003); a line of carbonatite complexes in the central Foreland Belt, including the Aley carbonatite, is thus interpreted to approximate the cryptic suture between the two margins.

IV. Map, Cross-section, and Structural Interpretation

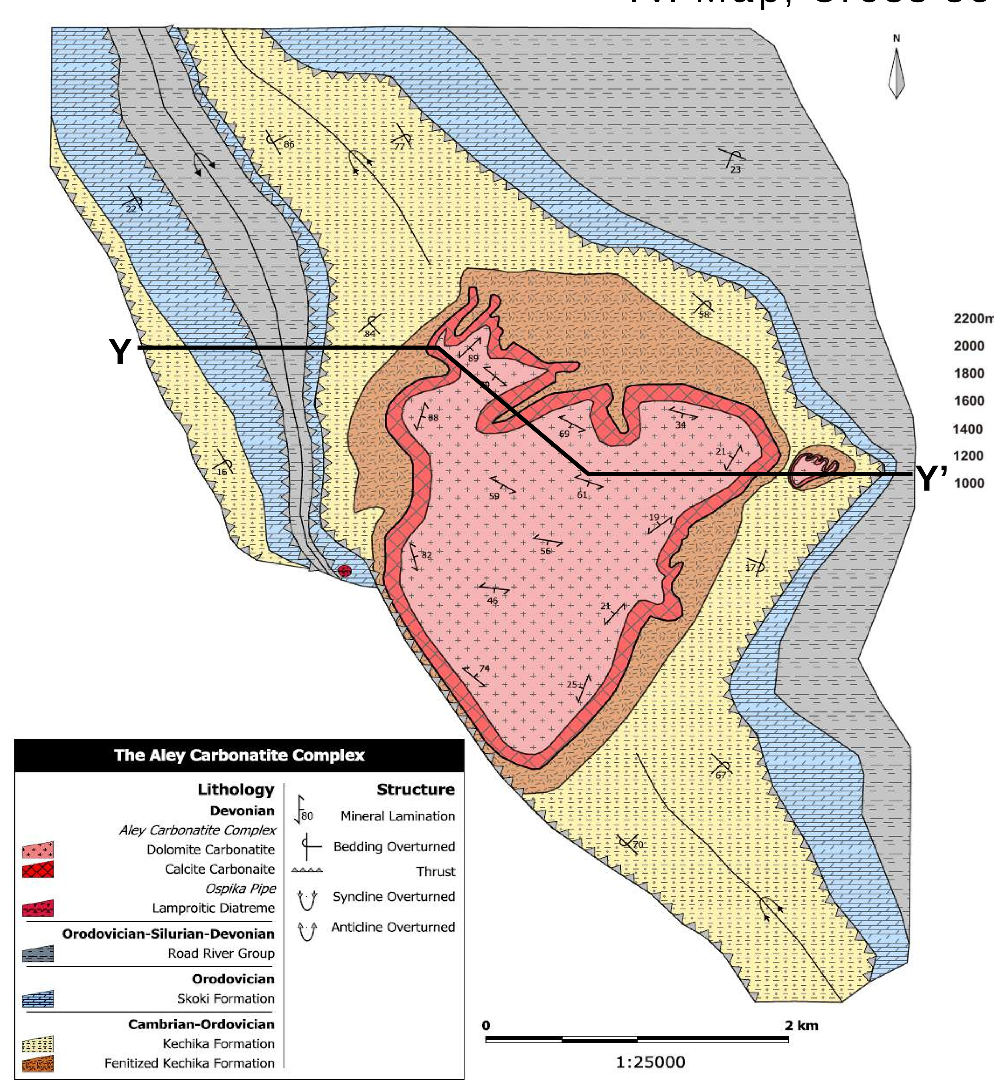


Figure 5: (A) Geological map of the Aley Creek area. (B) Cross-section (Y-Y') of the map area with structural interpretation of D1 and D2 fabrics. (C) W-E profile view of Aley carbonatie complex with key stratigraphic units labelled. (D) Idealized stratigraphic section of country rock.

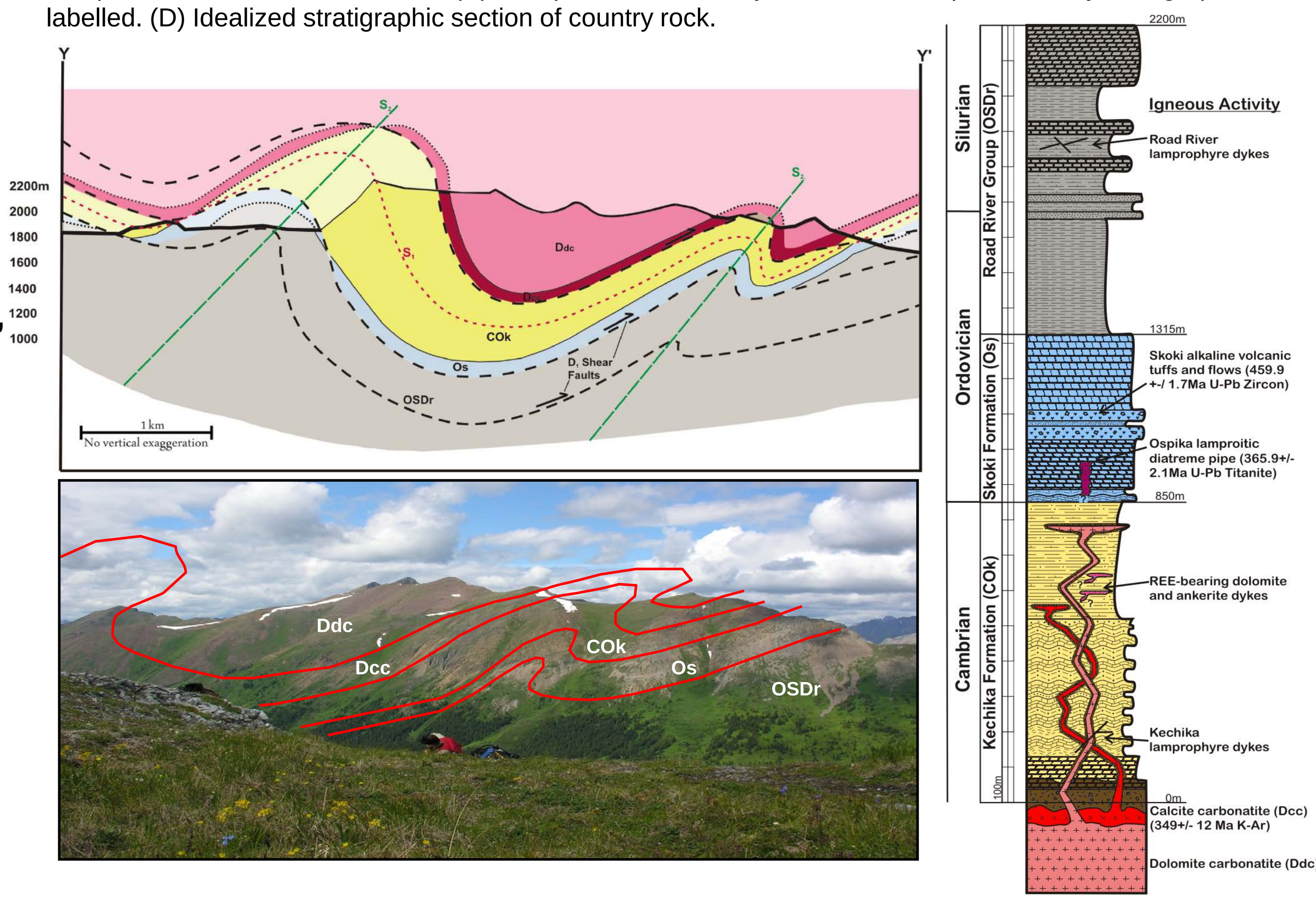
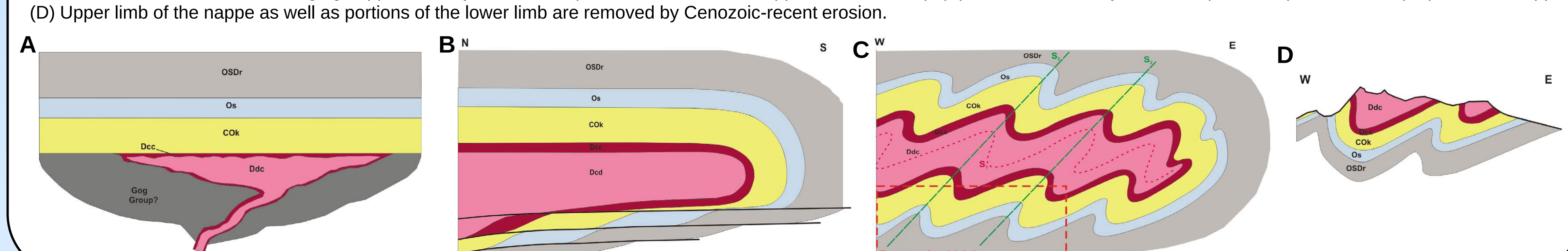
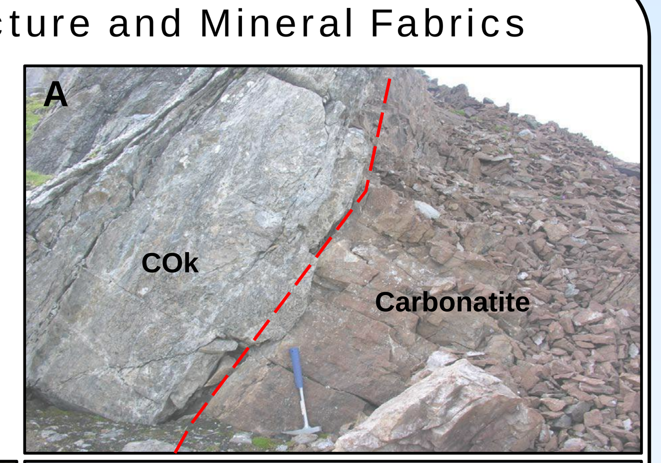


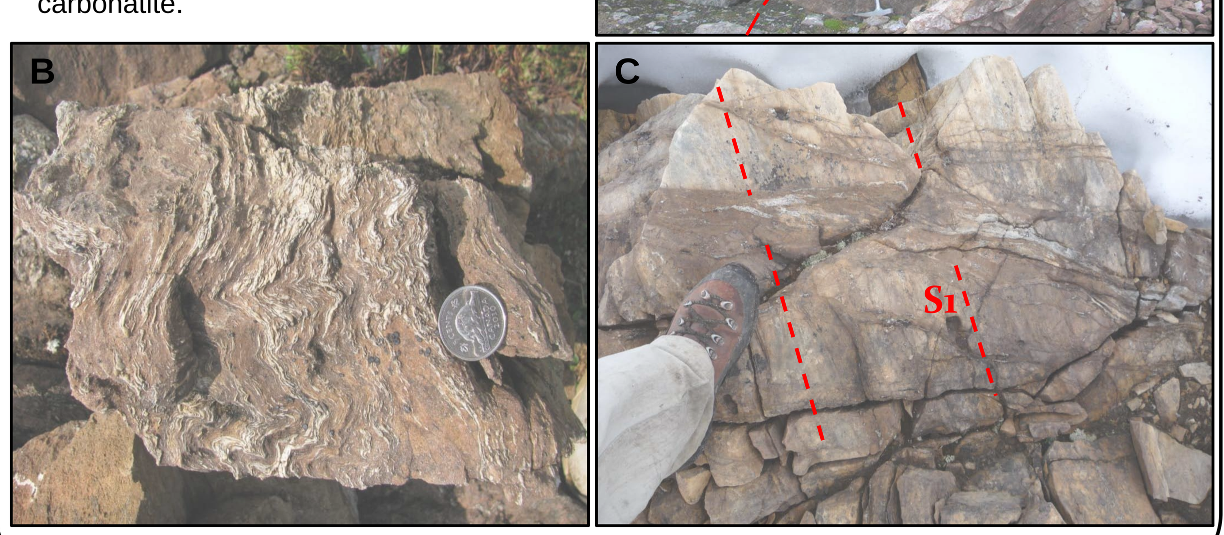
Figure 6: Schematic model depicting the structural evolution of the map area. (A) Carbonatite intrudes as a sill like body in the Late Devonian. (B) Major Late Devonain contractional deformation event forms south-verging nappe cored by carbonatite (black lines at base of nappe are D1 shears). (C) Cretaceous Rocky Mountain (Laramide) deformation (D2) folds the nappe. (D) Upper limb of the nappe as well as portions of the lower limb are removed by Cenozoic-recent erosion.



V. Carbonatite Structure and Mineral Fabrics

Figure 7: (A) Carbonatite-host rock (Kechika Formation) contact zone showing bedding-parallel nature of contact and therefore the sill-like geometry of the intrusion. (B) D1 tight to isoclinally folded fabric in carbonatite defined by well-developed apatite mineral laminations. (C) Magmatically late dolomite carbonatite cross cutting S1 fabric in calcite carbonatite.





VI. Geochronology

Figure 8: Single-grain U-Pb titanite dating on lamprophyre dykes of the Aley carbonatite complex and spatially related Ospika pipe diatreme indicate an age of *ca.* 365 Ma for magmatism and associated D1 deformation event. (B) Country rock xenolith containing S1 fabric in the Ospika pipe indicates D1 event is 365 Ma or older.

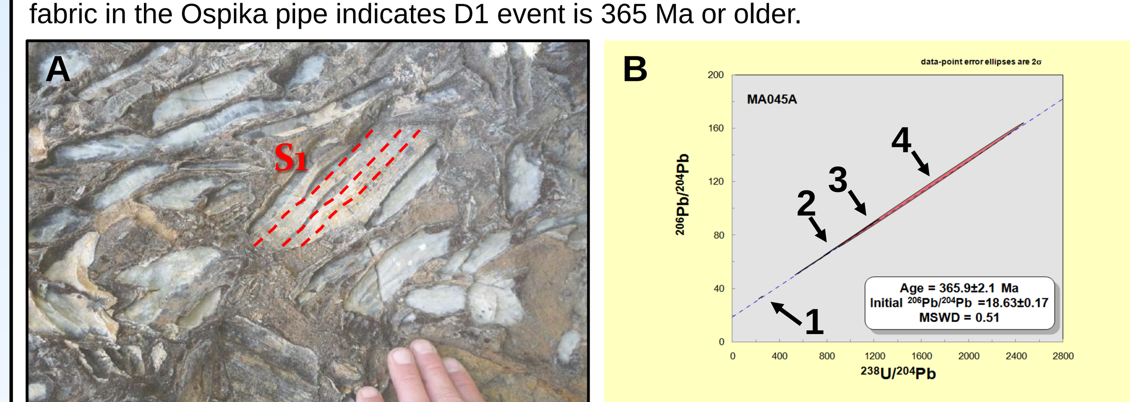
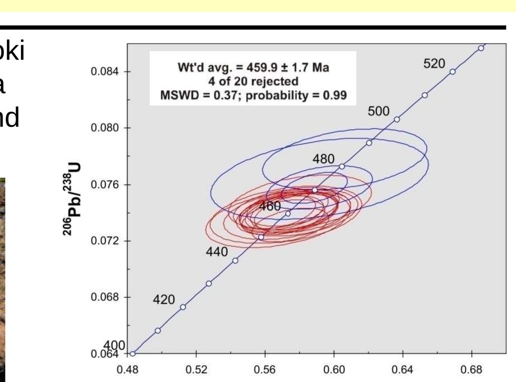


Figure 9: Single-grain U-Pb zircon dating on Skoki alkaline volcanic tuffs showing that they are not a surficial expression of carbonatite magmatism and are therefore a separate, older magmatic event

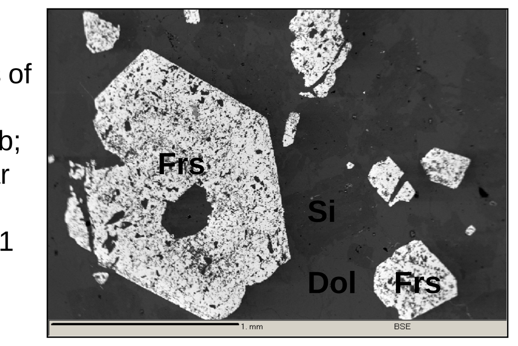


VII. Niobium Mineralization

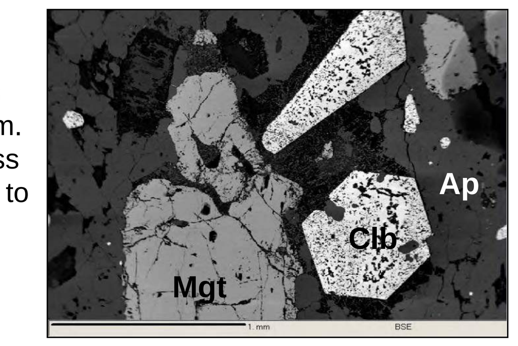
Figure 10: Nb-bearing carbonatite units:

Calcite carbonatite: Nb mineralization is characterised by fine- to medium-grained, pale yellow octahedral pyrochlore ($NaCaNb_2O_6F$; right image, grain diameter 4mm). This unit is most abundant around the peripheries of the complex where it is spatially associated with large zones of fenitization of the country rock (*i.e.* sodic metasomatism resulting in the growth of a large variety of sodic amphiboles and pyroxenes).

Dolomite carbonatite: Nb mineralization is characterised by fine-grained pseudomorphs of yelllow acicular and platy fersmite (Frs; $CaNb_2O_6$) after pyrochlore and columbite (Clb; $(Fe,Mn)Nb_2O_6$). Dolomite carbonatite is by far the most volumetrically abundant Nb unit, although it is the least mineralized (see Fig.11 below).

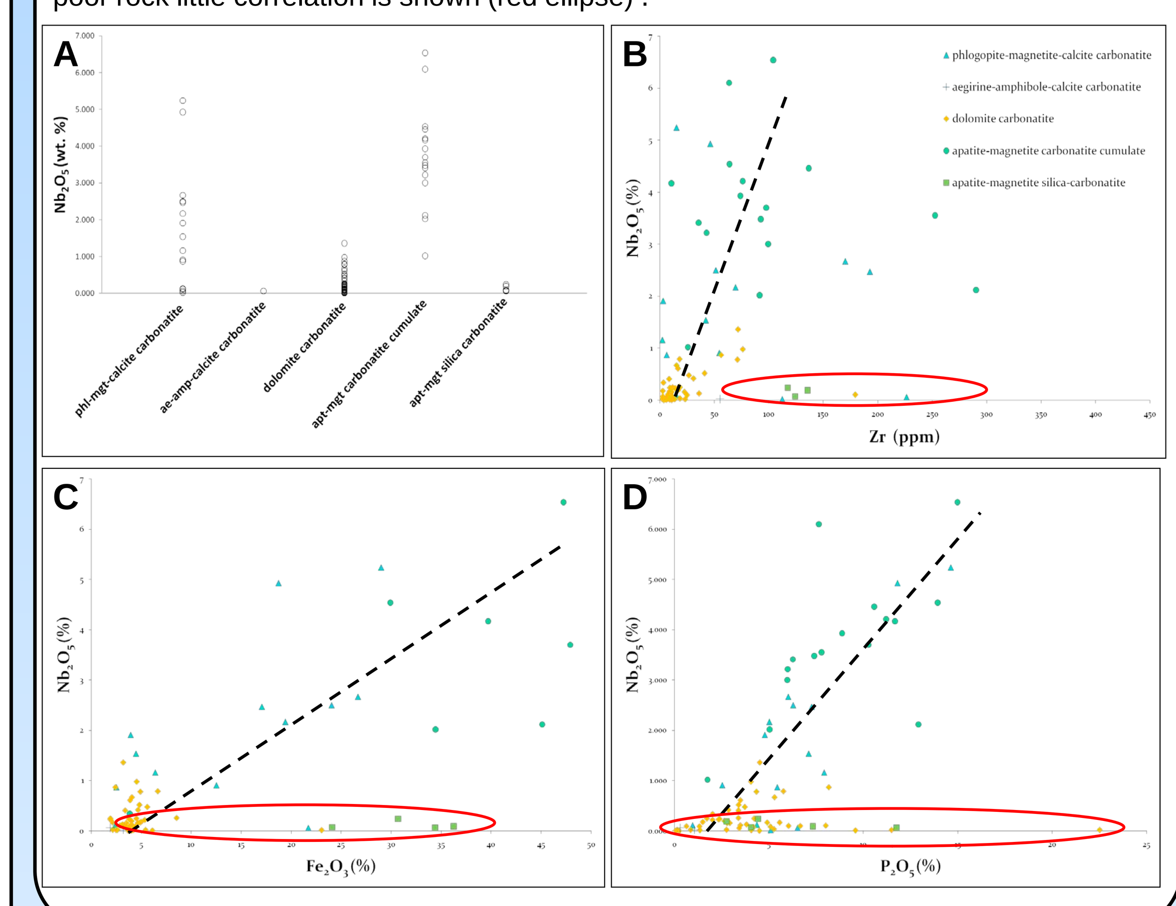


Magnetite-apatite cumulate: Nb mineralization is characterised by abundant columbite within heavy mineral cumulates as black pseudohexagonal crystals up to 1.5 mm. The unit occurs as layers of variable thickness (few centimetres to few metres) conformable to local fabric and typically displays the highest levels of mineralization within the complex (see Fig. 11 below).



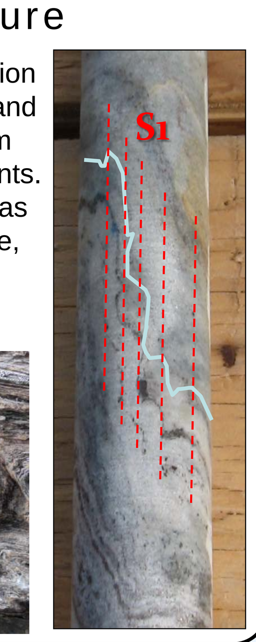
VIII. Whole Rock Geochemistry

Figure 11: (A) Distribution of Nb_2O_5 as per petrographic unit. (B-D) Correlations between $Nb_2O_5$and $Zr/Fe_2O_3/P_2O_5$ showing mineralogical association of niobates with accessory apatite, zircon and magnetite. Niobate mineralization is typically very fine to fine grained throughout the complex (see Fig. 9); these accessory minerals can be readily identified in the field with UV light (zircon and apatite) and magnetism (magnetite) tests, thereby facilitating identification of fine grained mineralized zones in the field. Note that in Nb-poor rock little correlation is shown (red ellipse) .



IX. Linking Petrology and Structure

Figure 12: D1 and D2 events have first-order control on the distribution of niobium mineralization within the complex through the reworking and deformation of mineralized fabrics. It is also likely that metamorphism and metasomatism are driven by one or both of the deformation events. Lastly, mineral lamella may themselves be a product of deformation as a result of large rheological variations between carbonate, phosphate, and oxide mineral phases during stress-induced plastic flow and kinematic differentiation associated with the D1 event



X. References

Burke, K., Ashwal, L.D., and Webb, S. 2003. New way to map old sutures using deformed alkaline rocks and carbonatites. Geology, 31: 391–394.

Gabrielse, H., Dodds, C.J., and Mansy J.L. 1977. Operation Finlay, British Columbia. In Report of activities, part A. Geological Survey of Canada, Paper 77-1A, pp. 243-246.

Thompson, R.I. 1989. Stratigraphy, tectonic evolution and structural analysis of the Halfway River map area (94B), northern Rocky Mountains, British Columbia. Geological Survey of Canada, Memoir 425, 119 p.

Wheeler, J.O., and McFeely, P. 1991. Tectonic assemblage map of the Canadian Cordillera and adjacent parts of the United States of America. Geological Survey of Canada, Map 1712A, scale 1:2,000,000.

Funding Acknowledgemetns:

NSERC CRSNG
Geoscience BC
Taseko Mines Limited