Origin and Emplacement of Neogene and Quaternary Lavas in the Canadian Cordillera

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1. Overview and Objectives

The depth of formation of Neogene and younger (<28 Ma) alkaline volcanism in the back arc of the Canadian Cordillera can be used to constrain the depth to the lithosphere-asthenosphere boundary (LAB). This informs on the lithosphere thickness, strength, and susceptibility of deformation. Lavas form beneath the LAB and carry phenocrysts, which can be used to determine the temperature and pressure (depth) of melt formation.

Olivine and clinopyroxene major and trace element chemistry are used in this study to constrain the pressure and temperature of formation, and test for equilibrium. Growth patterns in clinopyroxene are also used to estimate lava ascent times.

2. Study Location

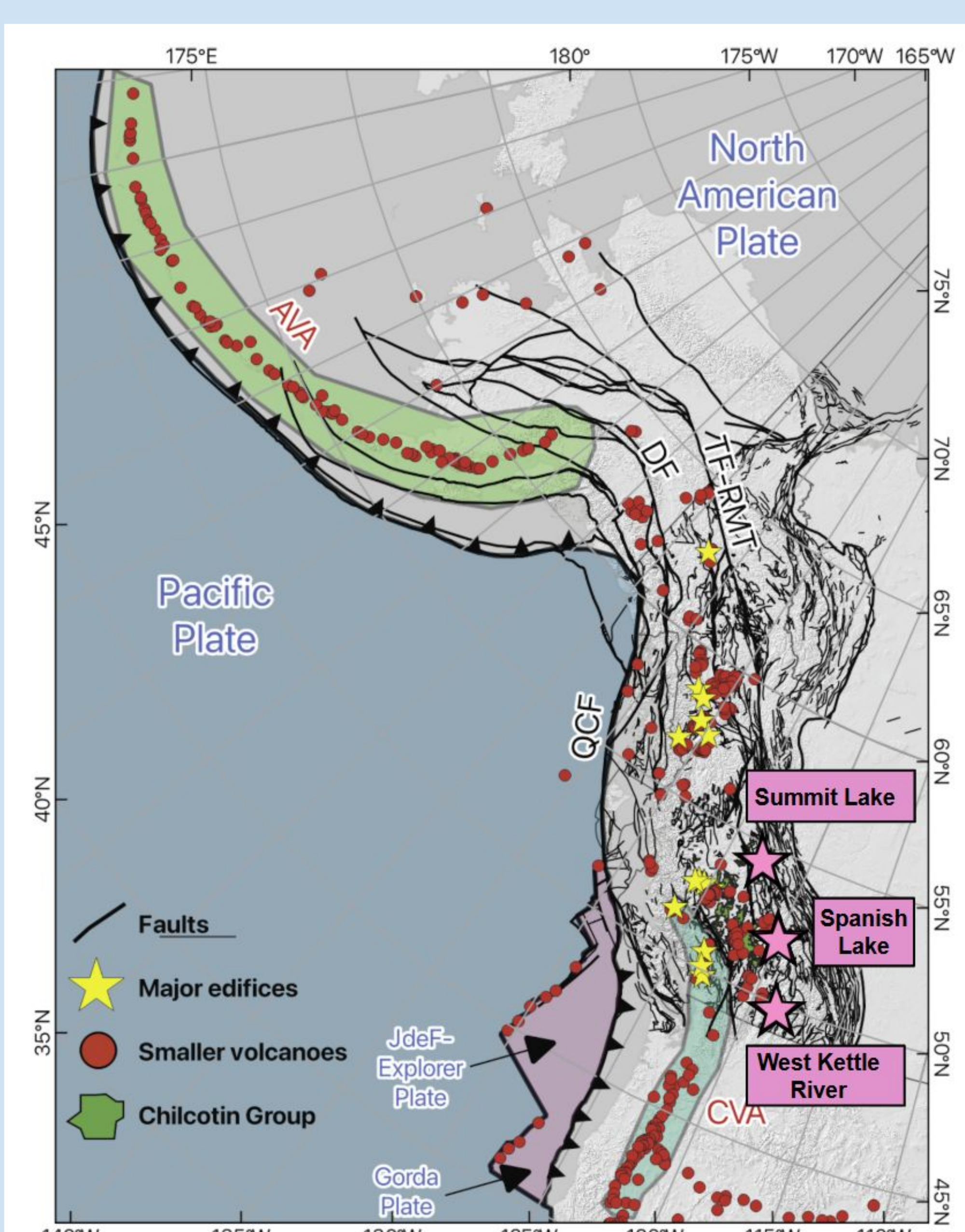

Figure 1. Map of the western margin of North America. Study areas denoted with a pink star: West Kettle River, Spanish Lake, and Summit Lake. Figure modified from Russell et al. (2023).

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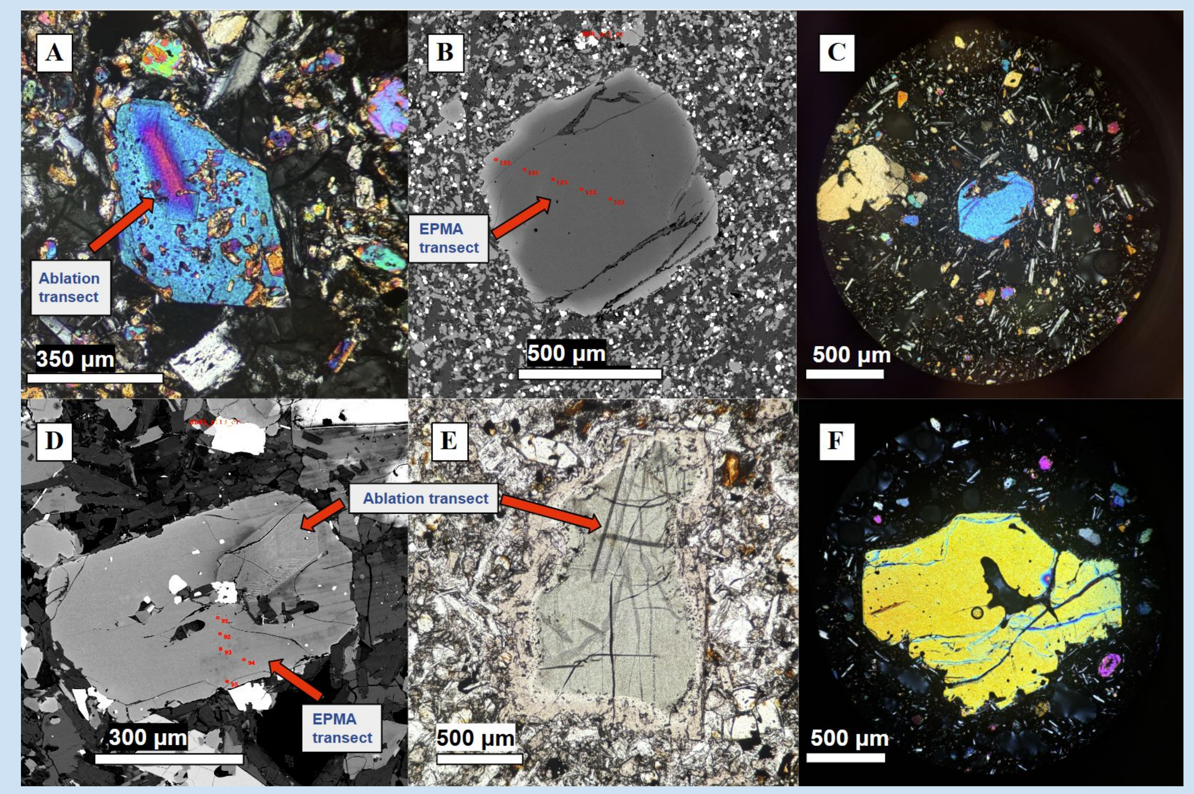
3. Petrography and Methods

Figure 2.
(A) Clinopyroxene phenocryst from Summit Lake (XPL)
(B) Olivine phenocryst from Summit Lake (BSE)
(C) Olivine phenocryst from West Kettle River (XPL)
(D) Olivine phenocryst from Spanish Lake (BSE)
(E) Clinopyroxene xenocryst from Summit Lake (PPL)
(F) Olivine xenocryst from Spanish Lake (XPL)



- Major elements in olivine and clinopyroxene crystals from all three study locations were analyzed using an electron probe microanalyzer (EPMA). The crystals were analyzed along transects from the core to the rim of the crystal, shown by the red dots in figure 2B and 2D.
- Trace elements in clinopyroxene crystals in the Summit Lake sample were analyzed with laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) along transects from the core to the rim of the crystals. Ablation transects can be seen in figure 2A, 2D, and 2E.

4. Growth Rate of Clinopyroxene

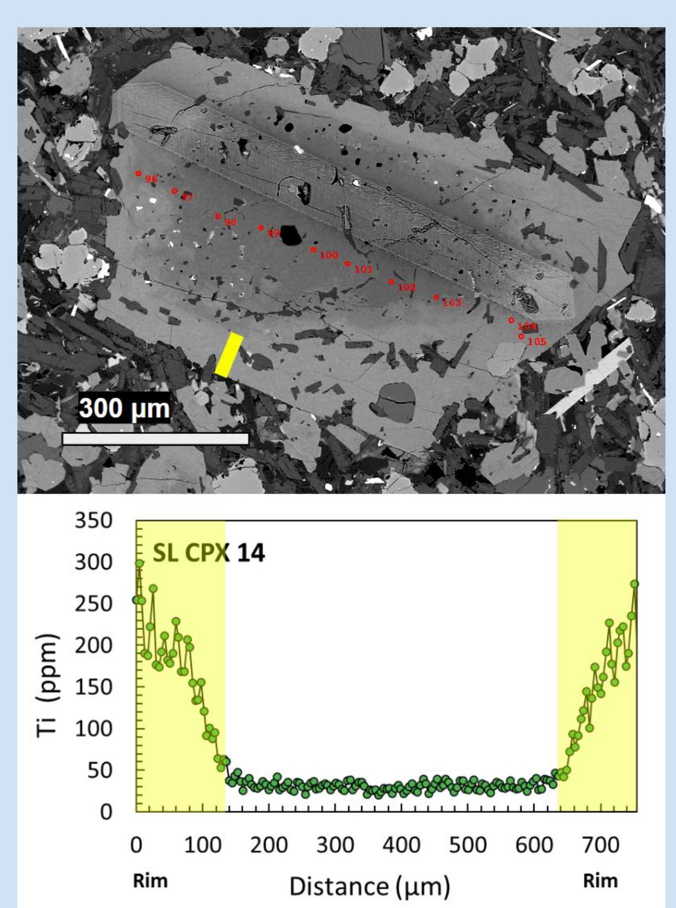
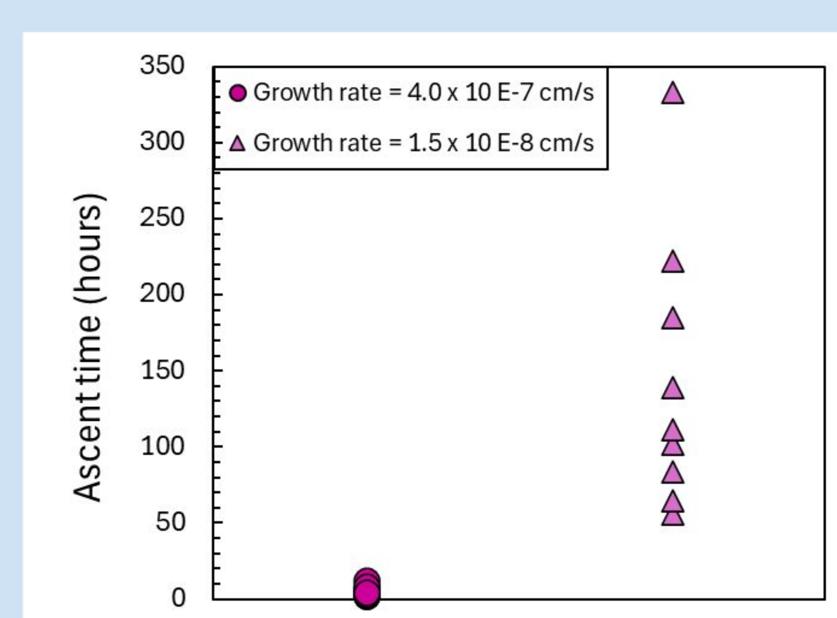


Figure 3. (Above) (Top) BSE image of a clinopyroxene crystal with average growth rim size shown in yellow. (Bottom) trace element data showing rim size in transparent yellow.

Figure 4. (Right) Estimated ascent times of lavas at Summit Lake based on growth rates of clinopyroxene rims in alkaline lavas from Bonechi et al. (2019).

- Growth rims of clinopyroxene crystals can be used to determine lava ascent times from experimentally determined growth rates.
- The sizes of clinopyroxene growth rims were estimated using trace element data and backscatter electron images (BSE) of the crystals.
- Fastest and slowest growth rates for alkaline lavas were applied to clinopyroxenes from Summit Lake to determine ascent times. Calculated ascent times ranged from 2 hours to 13.9 days.



5. Olivine Geothermometry

- Major elements in olivine crystals can be used to derive crystallization temperatures.
- To obtain accurate temperatures, the olivine phenocrysts need to be in equilibrium with their host melt, which is assumed to be the composition of the whole rock that hosted the olivines.
- This can be tested using Mg - Fe exchange equilibria.
- Two different thermometers (T_{Ni} and $T_{Fe\text{-}Mg}$) were used on olivines from West Kettle River and Spanish Lake.

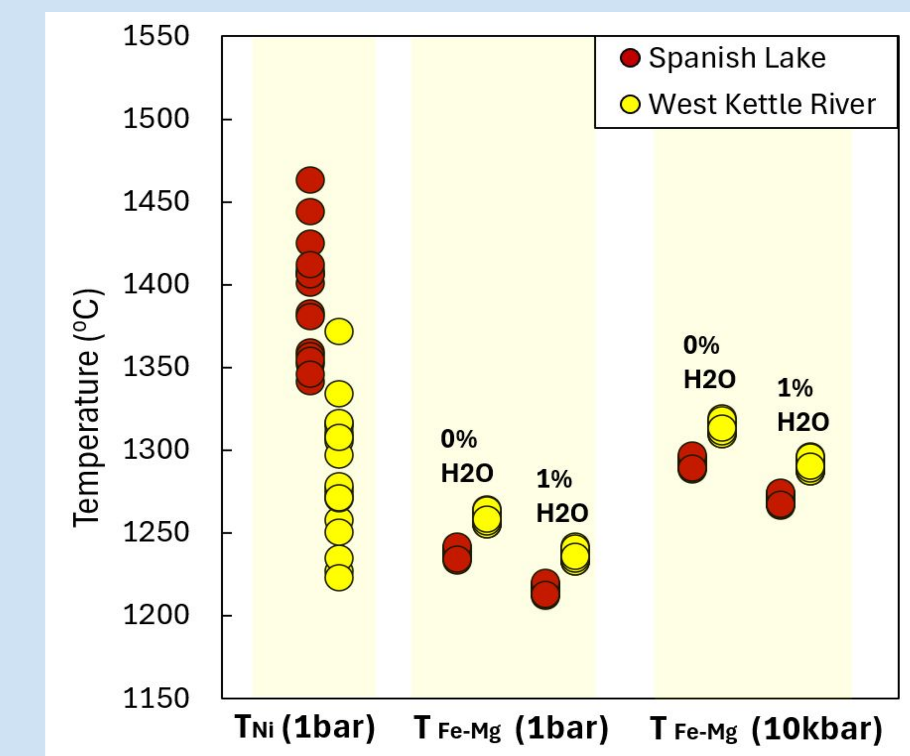


Figure 5. Temperatures derived from olivines using a Ni thermometer (T_{Ni}, Pu et al., 2017) and a Mg- Fe thermometer ($T_{Fe\text{-}Mg}$, Putirka et al., 2008).

6. Clinopyroxene Geothermobarometry

- Major elements in clinopyroxenes can be used to derive crystallization temperature and pressure.
- This method requires the crystals to be in equilibrium with their host melt, which is assumed to be the composition of the whole rock that hosted the clinopyroxenes.
- Assumptions about iron redox states and H_2O content of the melt are required to test equilibrium.The following assumptions were made to obtain equilibrium:
  - Fe2+/(Fe2+ + Fe3+) = 0.95
  - 2% H_2O content
- The clinopyroxenes crystallized in the melt between 36 and 40 km depth in the lithosphere, beneath the boundary between the mantle and the crust (moho). This indicates the during ascent, the melt stalled at the moho before the lava was emplaced.

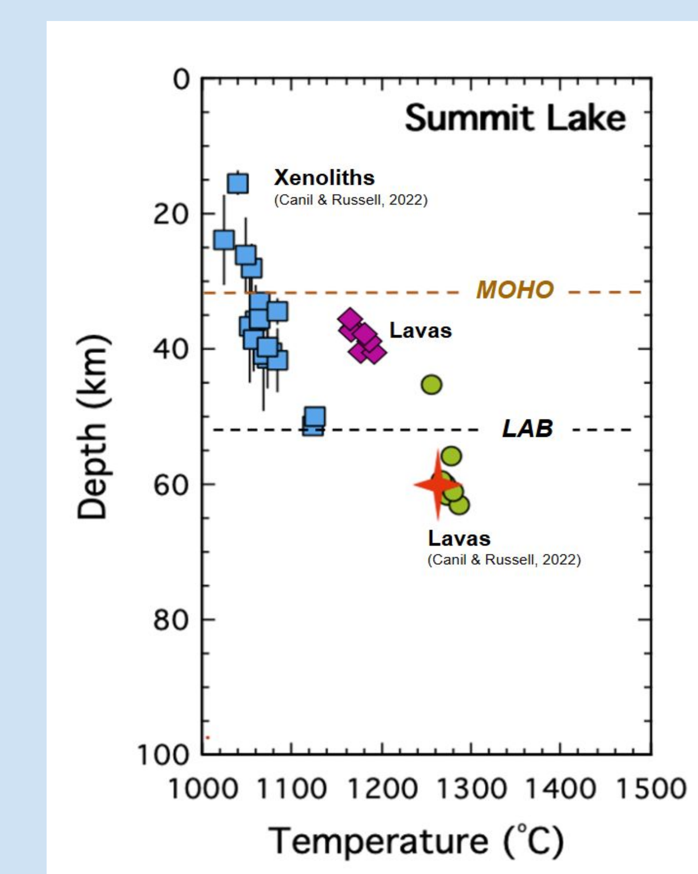


Figure 6. Depth and temperature of lavas and xenoliths from Summit Lake. Xenoliths (blue) and lavas (green) are from Canil and Russell (2022). Lavas from this study are shown in purple. Temperature and depth were calculated with a thermobarometer from Neave and Putirka (2017).

References

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