

Geochemical Analysis of the Crescent Formation:  
The Kool Koast Range Basalts of Oregon and Washington

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## Introduction

The Crescent Formation is a member of the Coast Range Basalts of Oregon and Washington (Figure 1).

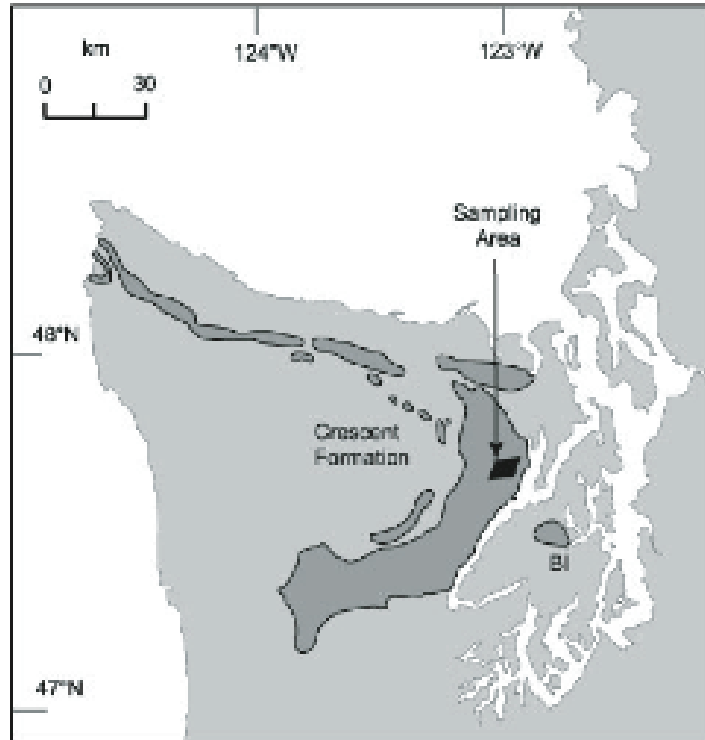


Figure 1. Map of Olympic Peninsula, Washington, showing relative location of the Crescent Formation from Harrison et al. (in preparation).

It is a subaqueous and subaerial basaltic lava flow estimated to be 16 kilometers thick. Because of its low potassium content, accurate dates for the Crescent Formation have not yet been determined, but it is thought to be similar in age to the neighboring Metchosin and Bremerton igneous provinces, dated at approximately 50 Ma (Harrison et al. [in preparation]). It has been hypothesized that this formation is also related to the Columbia

River Basalts, which are widely believed to have originated from the Yellowstone hotspot approximately 16-8 Ma (Harrison et al. [in preparation]). The Yellowstone hotspot, currently located in Wyoming, is thought to have migrated across the Western United States, erupting during its journey, to create both the Crescent Formation and the Columbia River Basalt Group (Harrison et al. [in preparation]). The Columbia River Basalt Group encompasses 175,000 cubic kilometers and shows close isotopic similarity to the Crescent Formation.

Thus far, there has been very little geochemical research done specifically on the Crescent Formation. Harrison et al (in preparation) and Babcock et al. (1992) are two of the few groups who have conducted geochemical analysis of these basalts. Using the data collected by Harrison et al. (in preparation) and Babcock et al. (1992) we conducted analyses in an attempt to continue the study of the Crescent Formation. Initially our goal was to use our results to determine the evolution and crystallization history of the basalts, but our findings only indicated the presence of one type of pyroxene, rendering the pyroxene geothermometer inapplicable. Thus we revised our goals. As the Crescent Formation is stratigraphically divided into the Upper and Lower members (Harrison et al. [in preparation]) we decided to determine whether these two units were also geochemically distinct. We hoped to find a difference between the parent magmas represented in the Upper and Lower flows. However, because of their relative similarity, we concluded that they originated from the same parent magma. We found that the phenocrysts presented more interesting and conceptually challenging data than the whole rock analyses. Finally, we were able to propose two theories for the possible origin and evolutionary history of the Crescent Formation.

In this paper we will discuss our methods of data collection and the results from the data analysis. Then we will present our interpretation of the results, followed by a thorough discussion of the potential processes that led to the genesis of the Crescent Formation basalts.

## **Methods**

Data from electron microprobe analysis of thin sections was taken from samples of both the Upper and Lower Formations. These thin sections were prepared according to standard microprobe thin section methods; polished (0.3 microns) and coated with carbon prior to analysis. Using the JEOL 8900 "Super Probe" Electron Probe Microanalyzer at the University of Minnesota we took points on pyroxene, plagioclase and ilmenite phenocrysts in all of the samples, in addition to transects across mineralogically distinct phenocryst boundaries. Microprobe conditions included a 15 kV accelerating voltage and a beam diameter of 5 microns. Phenocryst results and standards used for calibration can be found in Tables 1-4 for Upper and Lower Crescent. Whole rock geochemistry was measured at Carleton College, through XRF analysis. Whole rock data can be found in Tables 5 and 6.

In addition to microprobe findings we also used thin section analysis to identify areas in the sample that might have been weathered. Weathering can affect readings on mobile elements such as sodium and potassium, which would skew our data. Thin section analysis gave us a possible explanation for some of our outlying points.

## Results

Geochemical analysis resulted in major element weight percentages for plagioclase and pyroxene phenocrysts. In order to compile and graph our data, we checked the results against known compositions of plagioclase and pyroxenes and separated the values into Lower and Upper Crescent groups. We plotted the refined data on binary and ternary diagrams to facilitate analysis of the data.

The majority of our graphs were binary plots comparing various oxides indicative of evolution or variation in basalts. These trends would reflect development of parent magmas. We found Harker diagrams uninformative as the amount of  $\text{SiO}_2$  does not change in relation to the other common oxides in basalt. However, comparing oxides other than  $\text{SiO}_2$  seemed useful. We analyzed both phenocryst and whole rock data from the Crescent Formation samples.

Figures 2 and 3 show the difference in calcium content between the Upper and Lower Crescent for plagioclase phenocrysts.

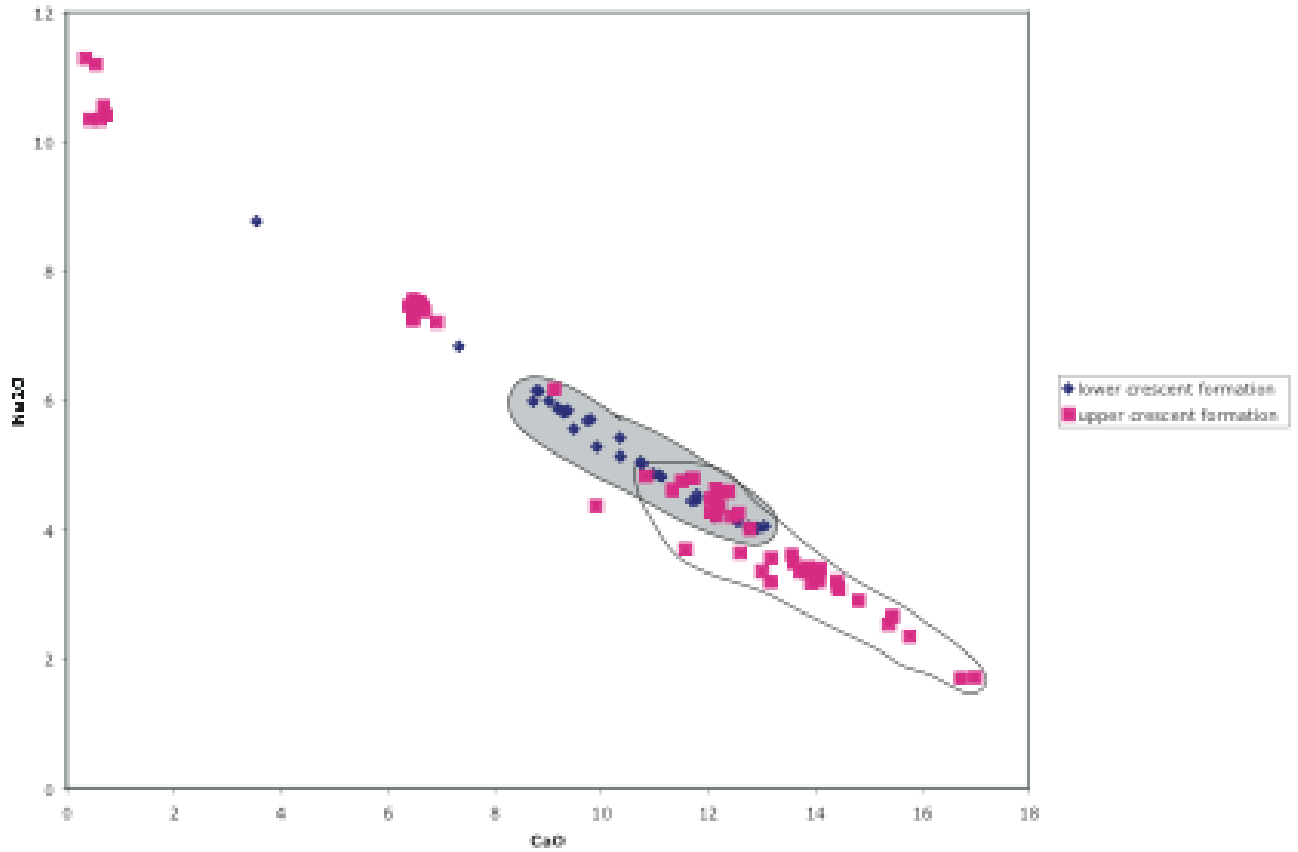


Figure 2. Chemistry of plagioclase phenocrysts of the Upper and Lower Crescent Formations, CaO vs. Na<sub>2</sub>O. Shaded field refers to Lower Crescent Formation.

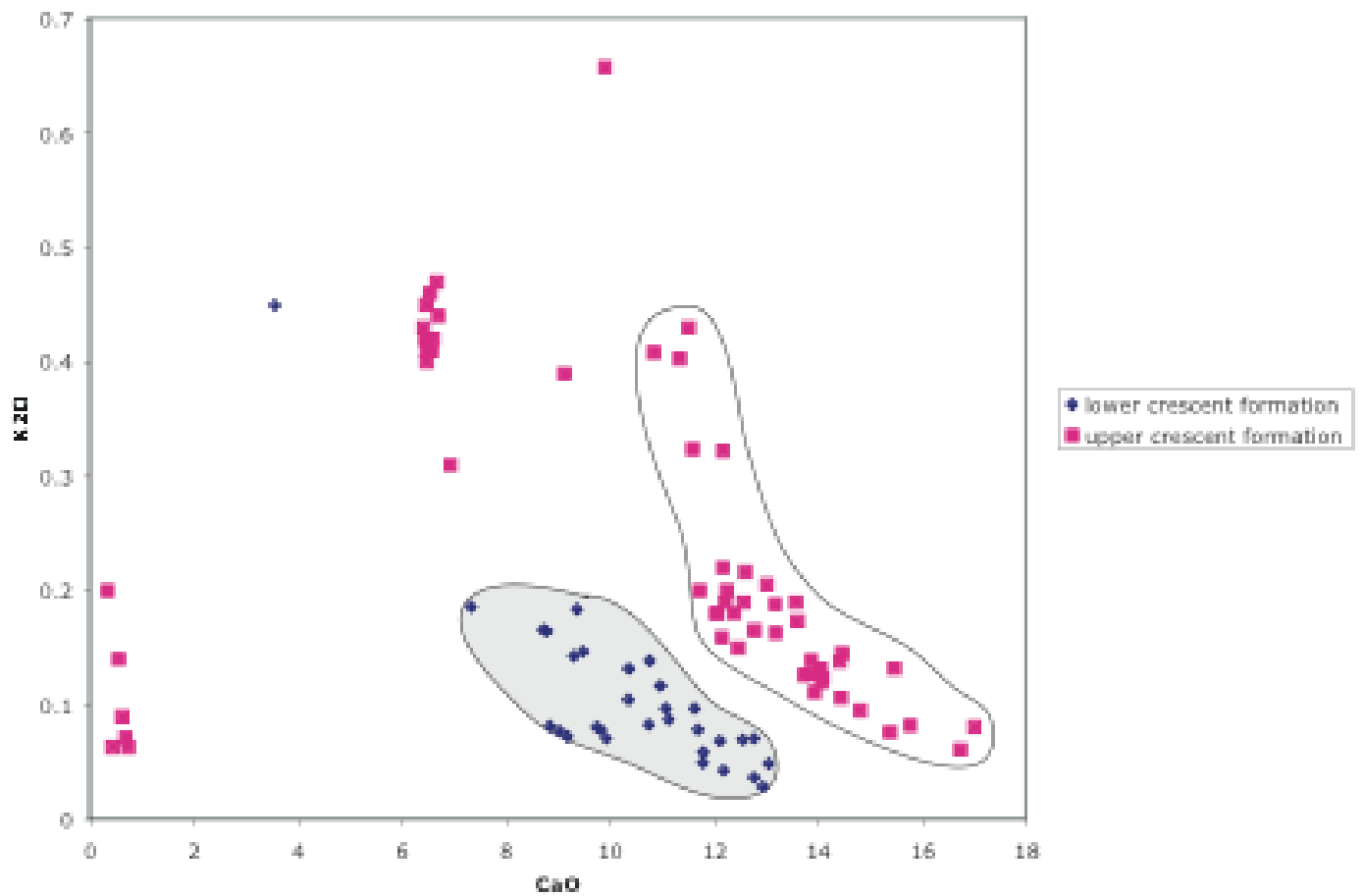


Figure 3. Chemistry of plagioclase phenocrysts of the Upper and Lower Crescent Formations, CaO vs. K<sub>2</sub>O. Shaded field refers to Lower Crescent Formation.

Figures 4 and 5 show the similarity in calcium, but a difference in magnesium and iron for the pyroxene phenocrysts.

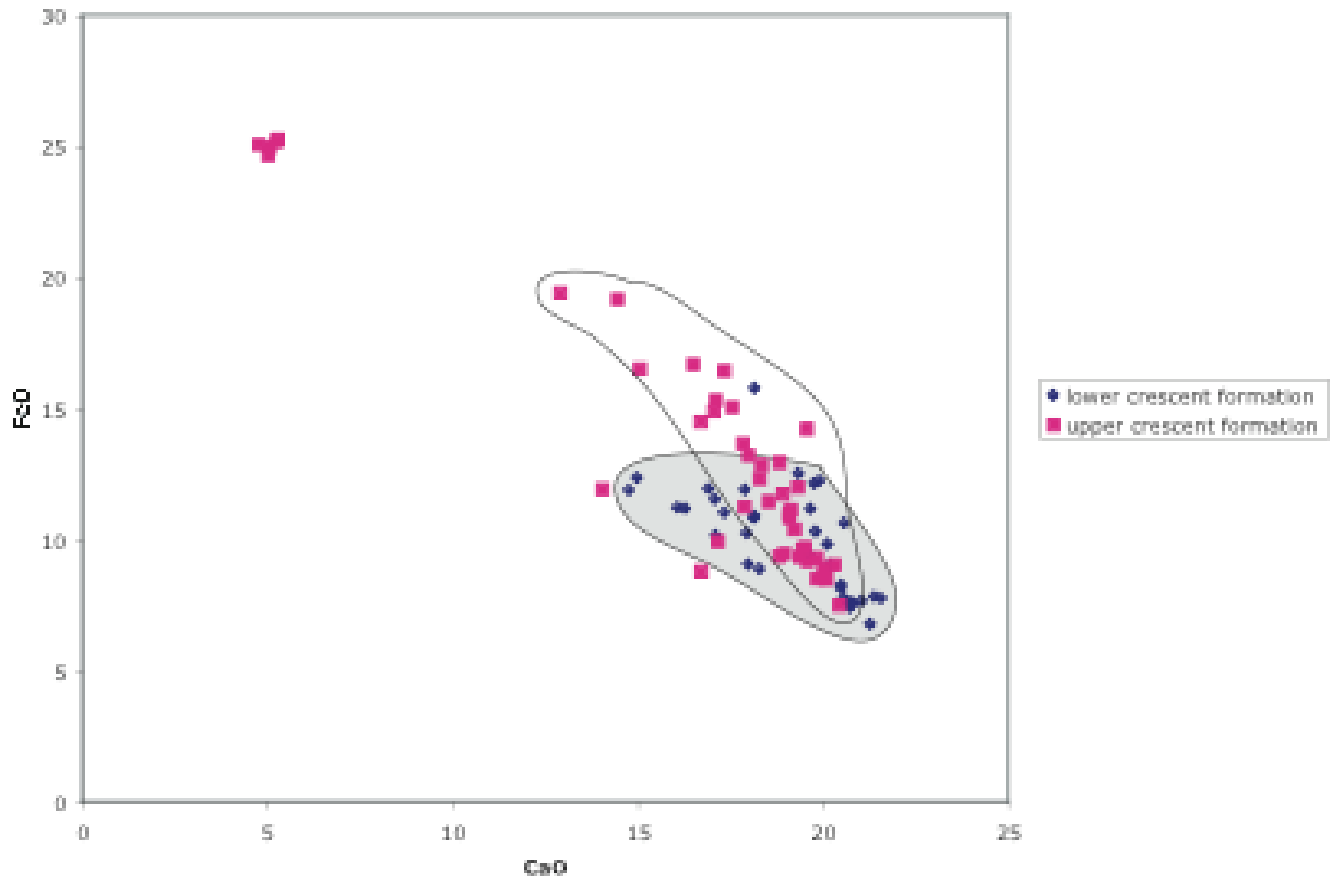


Figure 4. Chemistry of pyroxene phenocrysts of the Upper and Lower Crescent Formations, CaO vs. FeO. Shaded field refers to Lower Crescent Formation.



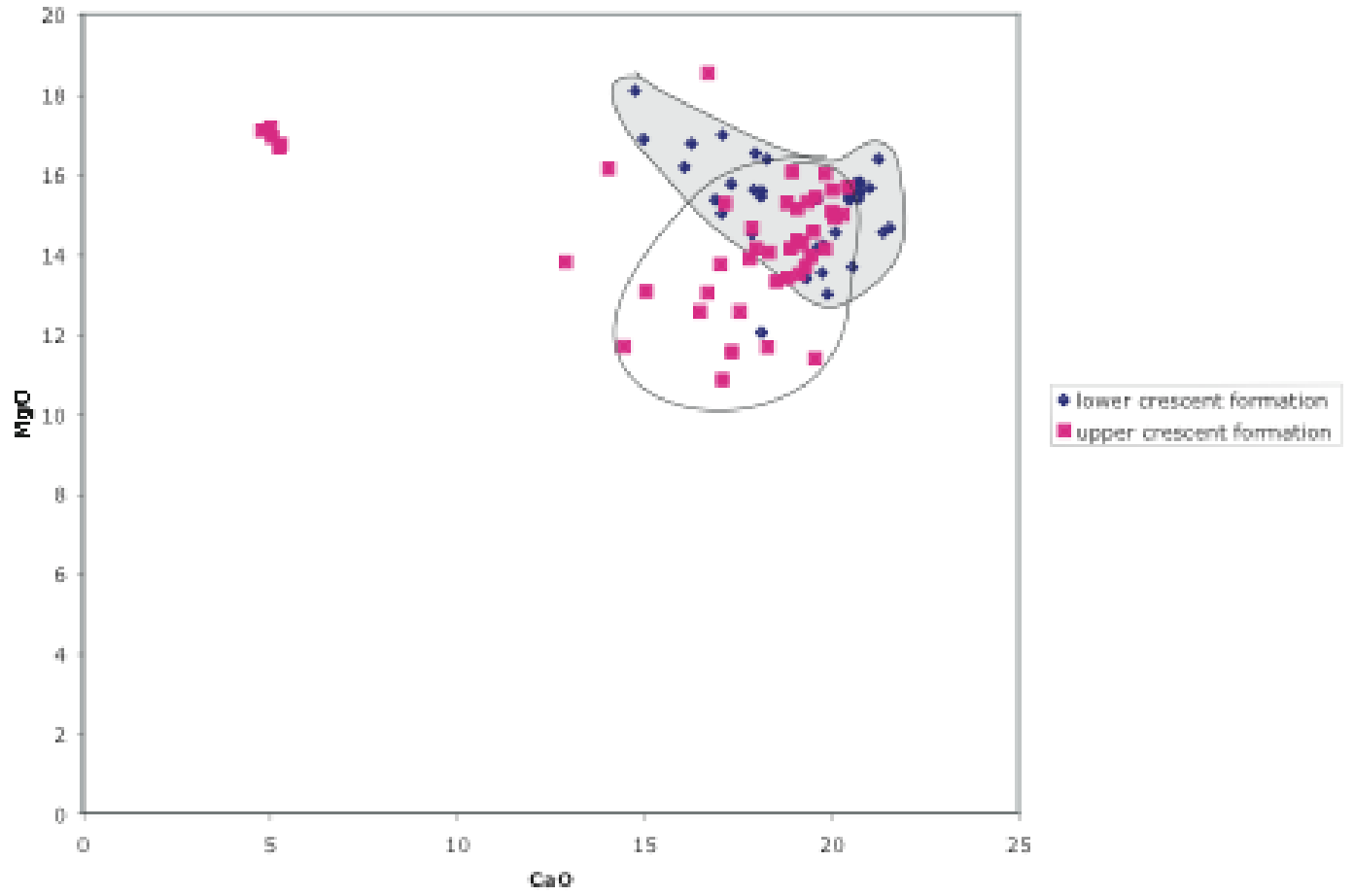


Figure 5. Chemistry of pyroxene phenocrysts of the Upper and Lower Crescent Formations, CaO vs. MgO. Shaded field refers to Lower Crescent Formation.

In Figure 6, the Upper and Lower Crescent whole rock data points cluster together, and are almost indistinguishable.

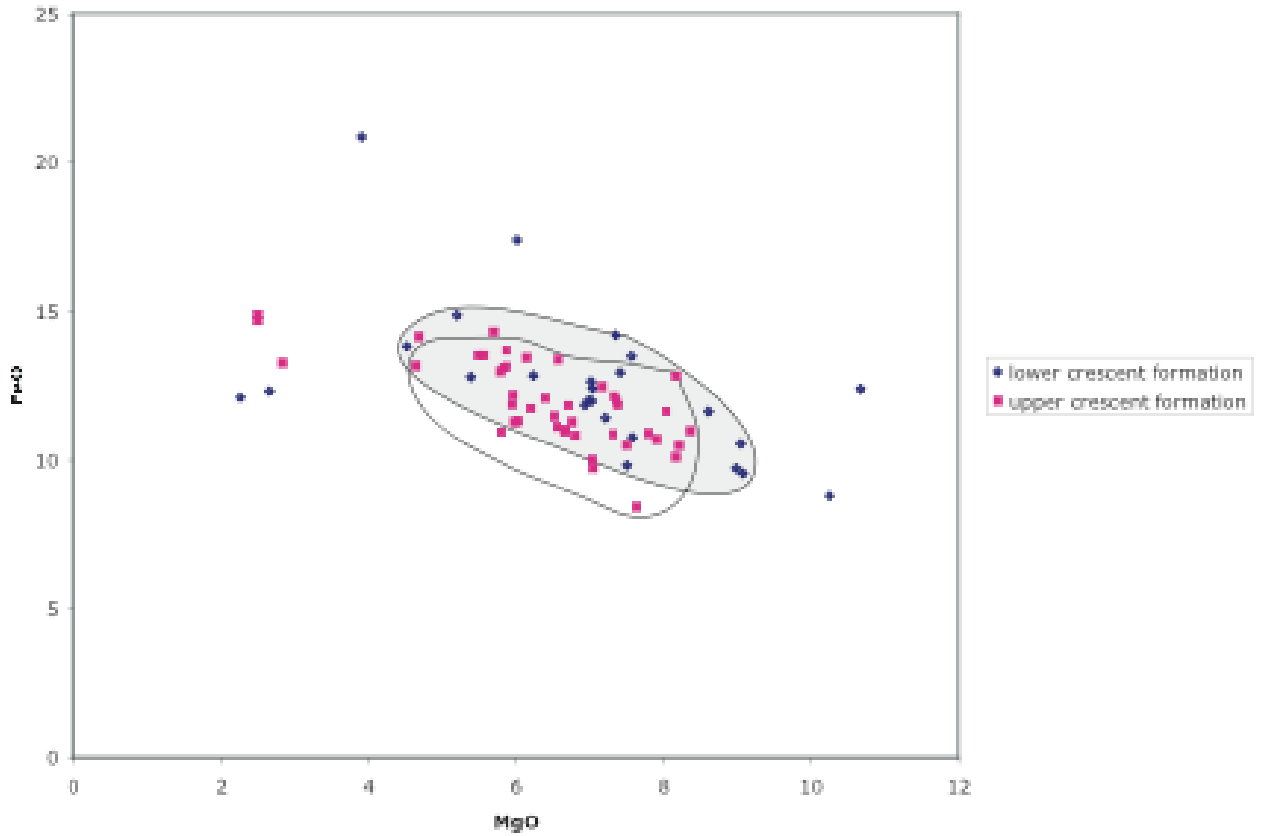


Figure 6. Whole rock Geochemistry of the Upper and Lower Crescent Formations, MgO vs. FeO. Shaded field refers to Lower Crescent Formation.

Figure 7 shows the tendency of the Upper Crescent to group, while the Lower Crescent displays a wider scattering of points.

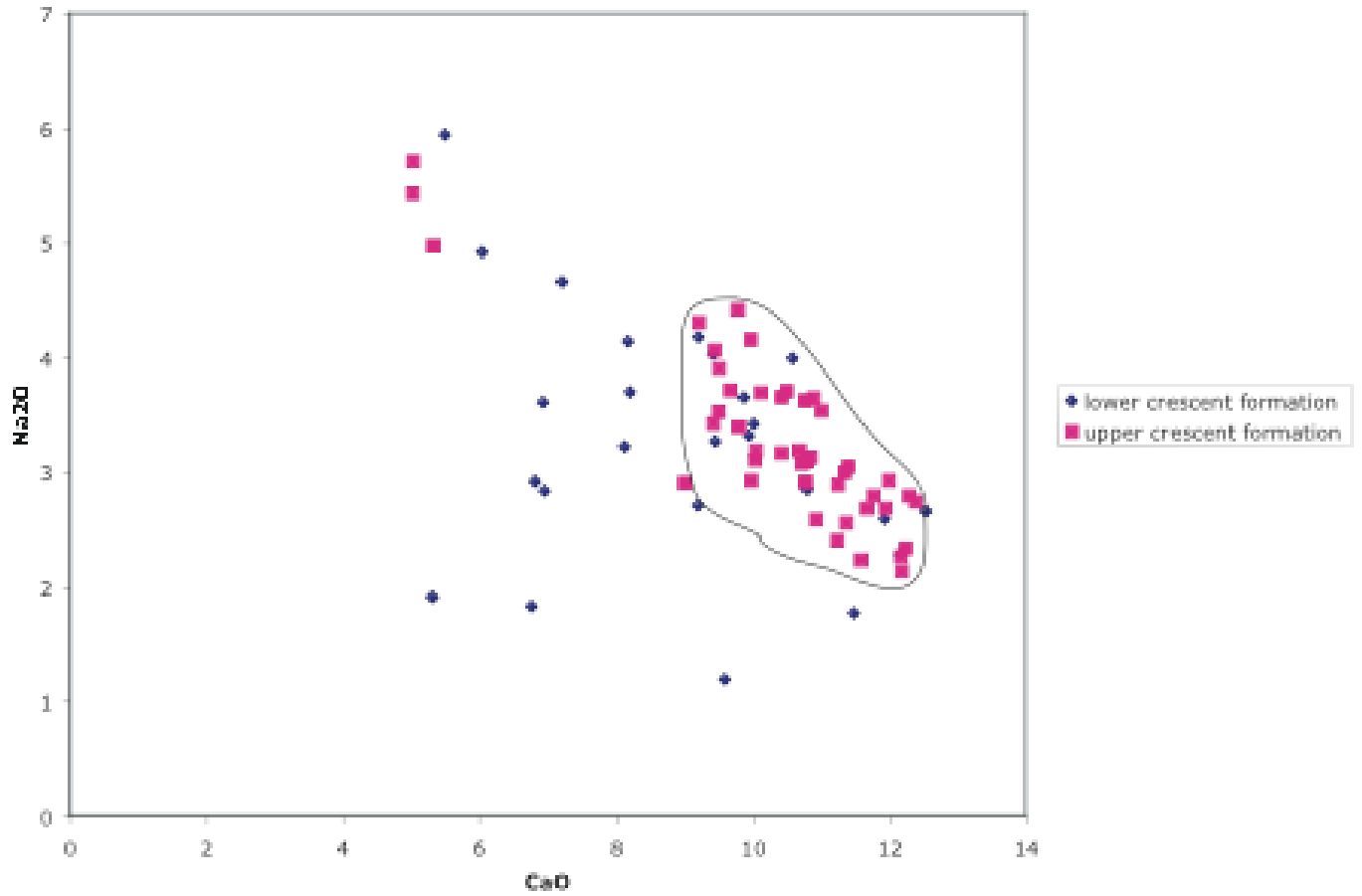


Figure 7. Whole rock Geochemistry of the Upper and Lower Crescent Formations, CaO vs. Na2O. Shaded field refers to Lower Crescent Formation.

## Discussion

Analysis of our data revealed that the magmas and phenocrysts from the Upper and Lower Crescent Formations were of similar compositions, though phenocrysts displayed greater compositional variation than the whole rock data. The data in Figure 2 and 3 revealed that the Upper Crescent plagioclase phenocrysts are more calcium-rich than the Lower Crescent phenocrysts. This difference is significant enough that, when plotted with regard to calcium, the Upper Crescent and Lower Crescent phenocrysts display two different, though parallel, trends. The relatively high calcium level in the Upper Formation suggests that it is more primitive than the Lower Formation. On the other hand, the Lower Crescent pyroxenes are more magnesium-rich than the Upper Crescent, though this difference is less pronounced (Figure 4). In Figure 5, the Upper Crescent shows higher iron content than the Lower Crescent, implying that the Lower Crescent is the more primitive of the two. Though the conclusions drawn from the plagioclase data and the pyroxene data are contradictory, we prefer to rely on the plagioclase for an accurate evolutionary history, since their solid solution state has the potential for a more comprehensive view of the crystallization process (Haileab, personal communication). Therefore, we conclude that the Upper Formation is more primitive than the Lower Formation.

In the phenocryst graphs, the Upper Formation tends to display a cluster of outlying points (Figure 5). We reexamined the samples that yielded these points in thin section and found that these phenocrysts had been weathered. And so it was that we attributed these anomalies to the weathering process.

Whole rock data produced few distinct fields, and those that they did tended to overlap considerably (Figure 6). However, in those fields we drew, the Upper Formation points clustered more closely than the points from the Lower Formation (Figure 7). We attributed this tendency of the Upper Crescent to the fact that, since it remained in the magma chamber for a relatively longer period, it had more time for its composition to stabilize with that of the foreign matter from the chamber walls and ceiling. The Lower Formation most likely shows scattered points because the magma collected contaminants from the chamber and, when it erupted, cooled with these inclusions as xenocrysts rather than equilibrating. The absence of definite fields in the whole rock data led us to conclude that the geochemical distinction between the fine-grained groundmass of the Upper and Lower Crescents is not as pronounced as previous studies suggest, although phenocrysts do indeed display some variability.

## **Conclusion**

We proposed two hypotheses regarding the formation of the Crescent based mainly on the plagioclase results. The first of these hypotheses suggests that the chamber experienced some fractionation during plagioclase crystallization which resulted in sodium-rich crystals, being less dense than calcium-rich crystals, floated relatively higher in the melt. Thus, when the chamber erupted for the first time, a large fraction of the lighter sodium-rich plagioclase was carried with it. The calcium-rich crystals were left to be spewed forth in the second and final magmatic event. Secondly we proposed that the higher calcium content of the Upper Formation resulted from a recharge of the magma chamber after the eruption of the sodium enriched Lower Formation.

## Works Cited

- Babcock, R.S., R.F. Burmester, D.C. Engebretson, A. Warnock and K.P. Clark. "A Rifted Margin Origin for the Crescent Basalts and Related Rocks in the Northern Coast Range Volcanic Province, Washington and British Columbia." *Journal of Geophysical Research*. Vol. 97, NO. B5 (1992): 6799-6821.
- Harrison, Benjamin K, Bereket Haileab and Douglas G. Pyle. "Geochemical Tracing of Basalt Province in the Early History of the Yellowstone Hot Spot." (in preparation)