University of Victoria | Graduate Studies

PROGRAMME

The Final Oral Examination
for the Degree of

DOCTOR OF PHILOSOPHY
(School of Earth and Ocean Science)

Casey Brant

1999 University of Waterloo BSc

"An investigation of high- and low-temperature mid-ocean ridge hydrothermal systems using trace element geochemistry and lithium isotopes"

Monday, August, 25, 2014
10:00 A.M.
Bob Wright Center, room A319.

Supervisory Committee:
Dr. L.A. Coogan, Department of Earth and Ocean Science, UVic (Co-Supervisor)
Dr. K.M. Gillis, Department of Earth and Ocean Science, UVic (Co-Supervisor)
Dr. J.T. Cullen, Department of Earth and Ocean Science, UVic (Member)
Dr. J.S. McIndoe (Department of Chemistry, UVic (Outside Member)

External Examiner:
Dr. J. Alt, Department of Earth and Environmental Sciences, University of Michigan

Chair of Oral Examination:
Dr. Sara Ellison, Department of Physics and Astronomy, UVic

Abstract

"This thesis combines mineralogical data and petrographic and field observations with geochemical analysis (major, trace and isotope) to provide new insights into the hydrology and geochemistry of mid-ocean ridge hydrothermal systems. Two study areas were chosen to study two different aspects of hydrothermal circulation: high-temperature on-axis hydrothermal systems were studied using samples from the Hess Deep Rift (Cocos Plate, Equatorial Pacific) and low-temperature off-axis hydrothermal systems were studied at the Troodos Ophiolite in Cyprus. Significant findings include the documentation of a previously unknown warm fluid which pervades the lavas leaching Li from newly formed crust. This finding corroborates a model of broad hydrothermal discharge in the sheeted dikes. In the off-axis low-temperature regime, lateral flow of warm fluid is documented for the first time in the lavas, advecting heat from the oceanic lithosphere, with minor geochemical changes to the lavas. The sedimentary cover was found to influence alteration in two ways. The longer an area remains unsedimented allowing the free ingress and egress of seawater, the deeper the enrichment of alkalis is observed. The maximum enrichment in alkalis (K, Rb, Cs) however, is similar in both locations. The sedimentary cover can also modify the seawater before it becomes impermeable to fluid flow; early metaliferrous oxide sediments react with seawater, creating a fluid with mobilizes and fractionates the REEs and Y. The fractionation results in negative Ce anomalies, positive Eu anomalies, and negative Y anomalies. Basalts altered under these conditions also lack the ubiquitous Fe-oxides and Fe-oxide/hydroxides that are commonly associated with alkali uptake. *In situ* trace element analysis of alteration minerals formed at low-temperature confirmed

that secondary phyllosilicates are strongly enriched in alkalis (K, Rb, Cs and Li), Ba is found in adularia and zeolites, Sr is hosted in carbonates, and no phases were found to be enriched in U. The concentrations of K, Rb, Cs (as well as B) are highest in celadonites, whereas Li concentrations are highest in smectites (saponite, Al-saponite, beidellite) and smectite-chlorite mixtures, and much higher than previously reported. Alkalis are also taken up into palagonite, with Li having the highest concentrations, over 1000 ppm in one analysis. Crystal chemical factors were found to be the dominant control on trace element uptake, and for the phyllosilicates no correlation was found between the temperatures, age of the crust, texture of the phyllosilicates. In phyllosilicates the K, Rb and Cs are adsorbed as exchange cations, with enrichment (Cs > Rb > K) increasing with decreasing hydration energy, whereas the uptake of Li and B does not correlate with the hydration energy. Lithium concentrations also do not correlate with the Mg content, suggesting substitution of Li for Mg is not the only mechanism of Li uptake into phyllosilicates as has been suggested.

Awards, Scholarships, Fellowships

2008 – Graduate Award, *University of Victoria*
2009 – Canadian Consortium for Ocean Drilling scholarship

Presentations

1. Brant, C. "*Lithium isotopes provide new insights into oceanic hydrothermal systems."* 18th Annual Goldschmidt Conference, Vancouver, British Columbia, Canada. July 2008. (oral)

2. Brant, C. *"Lithium isotopes as tracers of fluid-rock interactions in oceanic hydrothermal systems."* 40th Annual AGU Meeting, San Francisco, California, U.S.A. December 2007.(poster)

Publications

1. Brant, C.; Coogan, L.A.; Gillis, K.M.; Seyfried, W.E.; Pester, N.J.; and Spence. J. "Lithium and Li-isotopes in young altered upper oceanic crust from the East Pacific Rise: insights into axial hydrothermal systems." *Geochimica et Cosmochimica Acta* **2012**. 96, 272-293.