PROCEEDINGS OF THE TWENTY-EIGHTH ANNUAL KECK RESEARCH SYMPOSIUM IN GEOLOGY

April 2015
Union College, Schenectady, NY

Dr. Robert J. Varga, Editor
Director, Keck Geology Consortium
Pomona College

Dr. Holli Frey
Symposium Convener
Union College

Carol Morgan
Keck Geology Consortium Administrative Assistant

Christina Kelly
Symposium Proceedings Layout & Design
Office of Communication & Marketing
Scripps College

Keck Geology Consortium
Geology Department, Pomona College
185 E. 6th St., Claremont, CA 91711
(909) 607-0651, keckgeology@pomona.edu, keckgeology.org

ISSN# 1528-7491

The Consortium Colleges The National Science Foundation ExxonMobil Corporation

KECK GEOLOGY CONSORTIUM
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Robert J. Varga
Editor and Keck Director
Pomona College

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Pomona College
185 E 6th St., Claremont, CA 91711

Christina Kelly
Proceedings Layout & Design
Scripps College

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Funding Provided by:
Keck Geology Consortium Member Institutions
The National Science Foundation Grant NSF-REU 1358987
ExxonMobil Corporation

Learning Science Through Research
Published by Keck Geology Consortium

Short Contributions
28th Annual Symposium Volume
25th April, 2015
ISBN: 1528-7491

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INTRODUCTION

The Sanak-Baranof plutonic belt (SBPB) is a diachronous series of near-trench plutons that intrude the Chugach-Prince William terrane (CPW), and range in age from 61 Ma in the west to 48 Ma in the east (Sisson et al., 2003; Bradley et al., 2003; Haeussler et al., 2003; Cowan, 2003; Ayuso et al., 2009, Wacket, 2014). In the central part of the belt, SBPB plutons intrude Campanian to Paleocene flysch of the Valdez and Orca groups. SBPB granitoids are inferred to be the product of slab window magmatism, related to subduction of either the Kula-Farallon or the Kula-Resurrection ridge beneath the North American continent at a trench-ridge-trench (T-R-T) triple junction (Hudson et al., 1979; Hill et al., 1981; Sisson et al., 2003; Bradley et al., 2003; Haeussler et al., 2003; Cowan, 2003; Ayuso et al., 2009). The slab window juxtaposed hot upwelling asthenosphere with the bottom of the accretionary wedge (Thorkelson, 1996). This led to partial melting of the greywackes and argillites contained within the wedge, which later cooled to form the SBPB plutons (Hill et al., 1981; Barker et al., 1992; Harris et al., 1996; Faris and Paterson, 2009). The Sheep Bay and McKinley Peak plutons, both located near Cordova, Alaska are considered to be part of the SBPB. A whole rock geochemisty and Nd-Sr isotopic study of the Sheep Bay and McKinley Peak plutons by Barker and others (1992) support the conclusions of Hudson and others (1979) that these plutons are derived from partial melting of the Orca Group sediments. However, due to differences in initial Nd and Sr isopotic ratios, they suggest that the McKinley Peak pluton is derived from an isotopically distinct suite of rocks from the Orca Group. This study presents evidence that in addition to the crustal components, the Sheep Bay and McKinley Peak plutons also contain a mantle-derived component and were formed via magma mixing. The larger-scale goal is to understand magma generation in the context of existing models that require a slab window and partial melting of flysch in the accretionary complex.

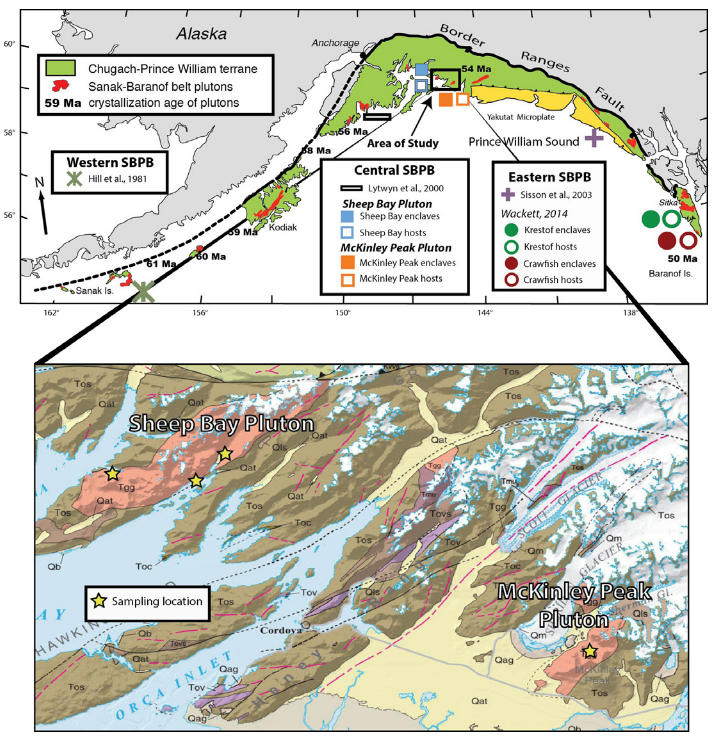

Figure 1. Simplified tectonic map (top) of southern Alaska showing location of the study area near Cordova within the CPW terrane. Symbols correspond to other geochemical studies of SBPB intrusive rocks. Inset (bottom) shows locations of sampling locations within the Sheep Bay and McKinley Peak plutons. Inset modified from Wilson and Hults, 2012.

GEOLOGIC SETTING

Both the Sheep Bay and McKinley Peak plutons intrude the Paleocene to Eocene age Orca Group in the eastern Prince William Sound (Fig. 1). The Orca group consists of interlayered greywacke sandstone, oceanic volcanic rocks, and minor pelagic mudstone. The onshore area of the Orca group is approximately 21,000 km^2 surrounding Prince William Sound (Plafker et al, 1994). The Sheep Bay pluton, located northwest of Cordova, is exposed over 120 km^2, and the McKinley Peak pluton, located east of Cordova, is exposed over 60 km^2.

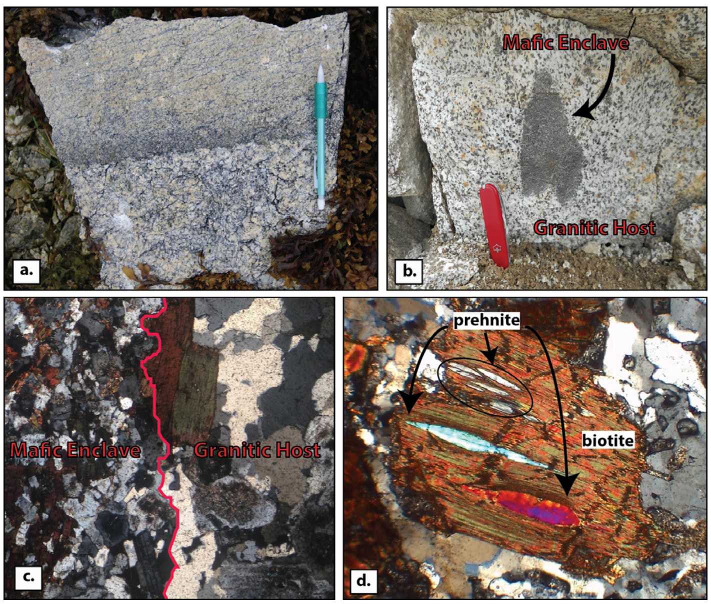

Figure 2. (a) Magmatically "graded" Sheep Bay sample. The layer bottom layer becomes progressively coarser and more felsic upsection, and ends abruptly at the contact with fine grained portion of the proceeding layer.
(b) In place mafic enclave from McKinley Peak.
(c) Thin section of sample CV14-07-D (McKinley Peak) in XPL. Boundary line between host and enclave shown.
(d) Thin section of sample CV14-07-L (McKinley Peak) in XPL. Biotite grain with prehnite inclusions shown.

FIELD OBSERVATIONS AND METHODS

The Sheep Bay and McKinley Peak plutons contain an array of mafic enclaves ~2-15 cm in diameter. The enclaves range in color index and grain size but are always darker and finer grained than the coarser grained, granitic host rock (Fig. 2, b). The darker and more aphanitic enclaves have a more pronounced boundary with the host rock. At one Sheep Bay outcrop subhorizontal magmatic layering was observed. Each layer "graded" upsection, becoming progressively coarser and more felsic, and ended abruptly at the contact with the finer grained, more mafic rock (Fig. 2, a).

Twenty samples from Sheep Bay (nine host, eleven enclave) and fifteen samples from McKinley Peak (three host, twelve enclave) were collected. McKinley Peak hosts and enclaves were collected from one location, CV14-07. Sheep Bay hosts were collected from four locations CV14-05, CV14-06, CV14-08, and CV14-11, while all the Sheep Bay enclaves were collected from CV14-06 (Fig. 1). Of these samples, 16 were chosen for whole rock geochemical analysis using XRF. Thin sections were made from 24 samples, which were then studied using the petrographic microscope and the scanning electron microscope (SEM). Whole rock geochemical data was also collected on the SEM. Major element analyses were constructed from EDS spectra generated from full thin-section SEM/EDS maps. Although major element analyses by SEM/EDS are less precise than those by XRF, no systematic difference was seen between SEM/EDS and XRF analyses on the same samples. Zircon grains were extracted from McKinley Peak and Sheep Bay samples for U/Pb geochronology and Hf/Lu isotope analysis.

PETROGRAPHY

Igneous rocks of the Sheep Bay and McKinley Peak plutons range from tonalite to granodiorite. Host rocks consist primarily of quartz, plagioclase, orthoclase, biotite, and hornblende. Chlorite is commonly present as a secondary alteration mineral after biotite. Many plagioclase grains are partly saussuritized or sericitized. The mafic enclaves have a similar mineralogy as their hosts but contain differing amounts of quartz and mafic minerals, with the most primitive enclaves containing little to no quartz and more hornblende. Enclaves are always finer grained than the hosts (Fig. 2, c). The finest grained of the enclaves contain the most hornblende. Prehnite is commonly found in the enclaves as a deuteric alteration after biotite (Fig. 2, d). Small amounts of thin, acicular apatite are present in some samples. The enclaves have a sharp but partly diffuse contact with host granitoids. The finer grained and more mafic enclaves have sharper contact with their hosts. CV14-

07-D, the enclave shown in Figure 2, is one of the most mafic enclaves, at only 50.4 weight % SiO_2, and has a correspondingly sharp contact boundary with its host. Collectively, these observations suggest the comingling of coeval felsic liquid/crystal mush with more mafic liquid/crystal mush.

WHOLE ROCK AND SEM GEOCHEMISTRY

Compositions of the host pluton samples range from 67.5-78.9 wt% SiO_2 and enclave samples range from 49.4-67.5 wt% SiO_2, based on whole rock XRF analysis. All McKinley host and enclave samples are peraluminous, with Aluminum Saturation Index (ASI) values ranging from 1.08 to 1.18. Four of the five enclave and host samples from location CV14-06 in Sheep Bay are metaluminous, with ASI values ranging from 0.94 to 0.97. The least evolved (most mafic) enclave from Sheep Bay, however, has the highest ASI of the suite, with a value of 1.03. The most mafic enclaves have much higher ASI values than similarly primitive enclaves from Krestoff Island and Crawfish Inlet (Fig. 3, a). Data taken from both SEM/EDS and XRF analyses demonstrates that in the least evolved McKinley Peak enclaves SiO_2 correlates inversely with Na_2O, CaO, and Al_2O_3. However SiO_2 correlates positively with these oxides in the McKinley Peak host granitoids (Fig. 3, a)

Trace-element data of host and enclaves from both plutons show similar patterns, including a general enrichment in the most incompatible elements, a Pb spike and a negative Nb anomaly, characteristics of arc-magmatism. Plutons in the western section of the SBPB, including Sheep Bay and McKinley Peak, exhibit low Sr/Y ratios. These ratios increase eastward across the SBPB. (Fig. 4)

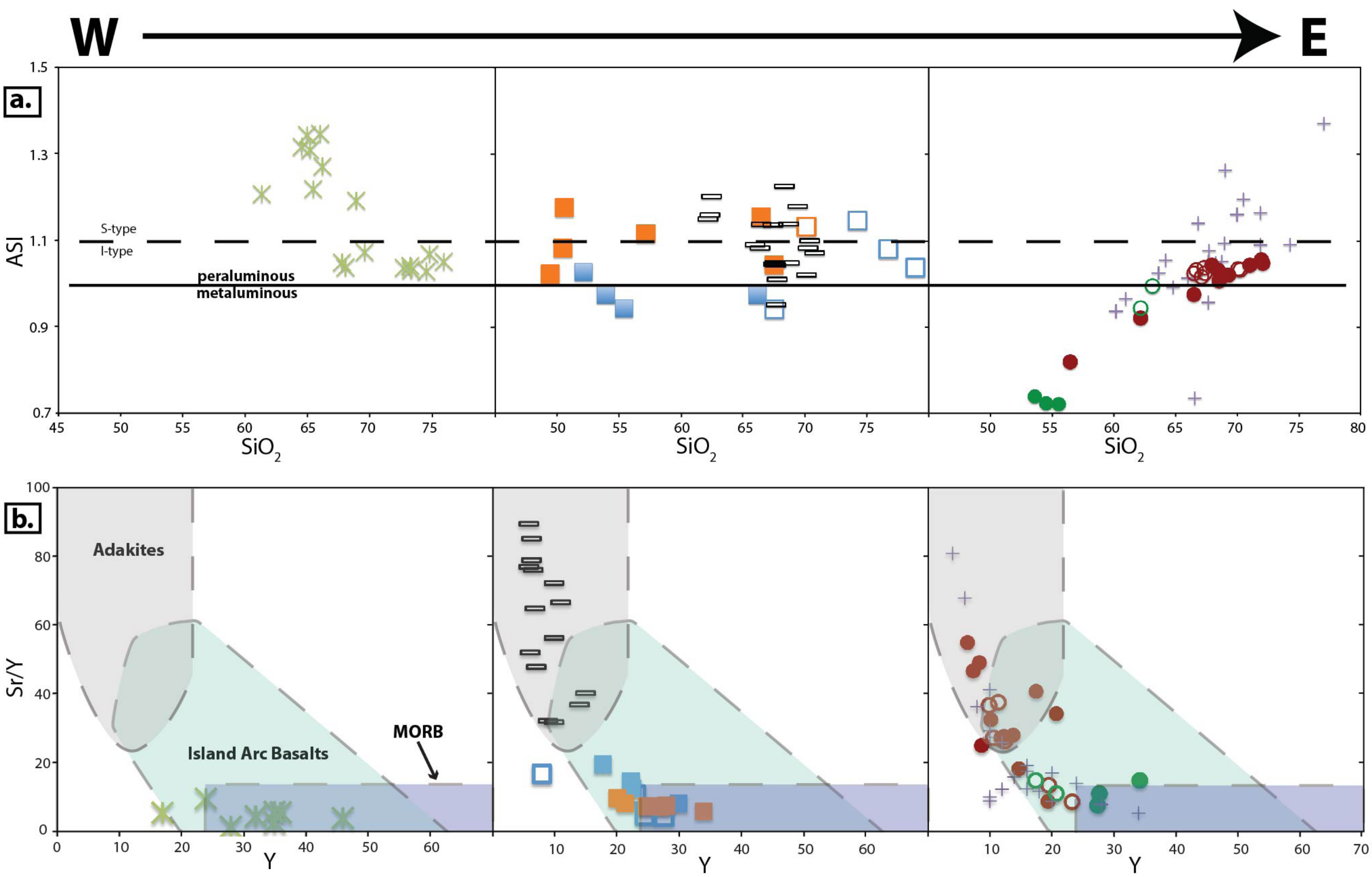

Figure 3. (a) Aluminum saturation index (ASI) for enclaves and tonalites/granodiorites from west to east. (b) Sr/Y vs Y for SBPB plutons from west to east. Fields for adakites, island arc basalts, and MORB are after Drummond and Defant (1990). Symbols same as in Figure 1.

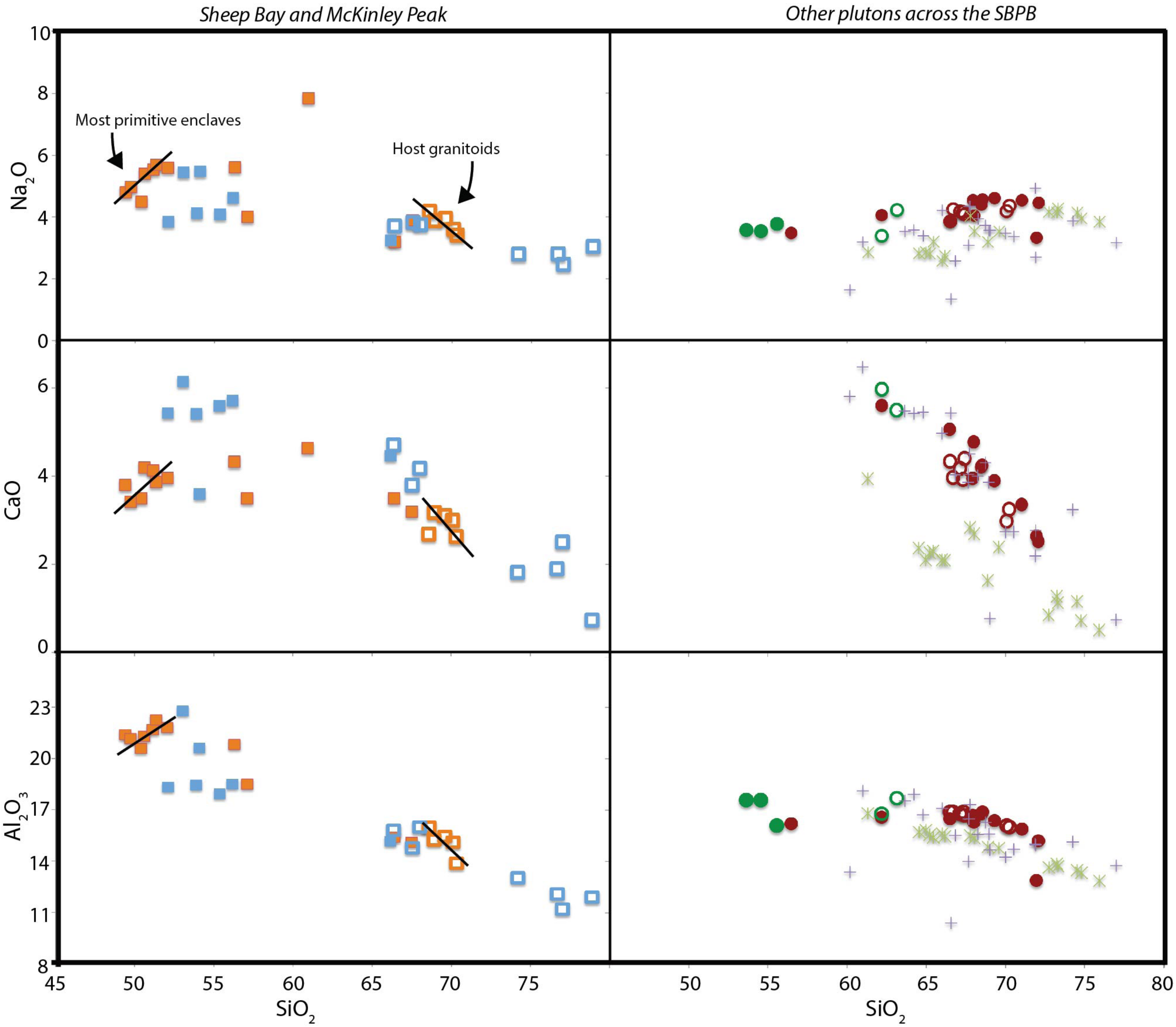

Figure 4. Harker diagrams of Na_2O, CaO, and Al_2O_3 for enclaves and tonalies/granodiorites from the Sheep Bay and McKinley Peak plutons, as well as from other plutons across the SBPB. Trendlines show for McKinley Peak hosts and least evoloved enclaves. Symbols same as in Figure 1.

ZIRCON U-PB GEOCHRONOLOGY AND HF ISOTOPE GEOCHEMISTRY

Zircon was separated from the host granite of the Sheep Bay (CV14-08) and McKinley Peak (CV14-07) plutons using standard crushing, grinding, Wifley table, heavy liquids and magnetic separation techniques. U-Th-Pb and Lu-Hf analyses were measured at the LaserChron Center of the University of Arizona by laser-ablation multi-collector ICP-MS utilizing a Photon Machines Analyte G2 Excimer laser connected to a Nu Instruments HR ICP-MS following the data reduction schemes described in Gehrels et al. (2008) and Cecil et al. (2011).

Magmatic zircon from the Sheep Bay pluton yield U-Pb crystallization age of 54.8 ± 0.7 Ma, while zircon from the McKinley Peak pluton yield U-Pb crystallization age of 54.5 ± 1.7 Ma. Zircon from the two plutons yield average εHf(t) of +7.4 and +4.8, respectively. The Sheep Bay plutons have εHf(t) values ranging from +2.8 to +9.5, although all but one of those values fall within the range of +2.8 to +6.5. The McKinley Peak εHf(t) values have a wider range, from +1.7 to +12.4 (Fig. 5).

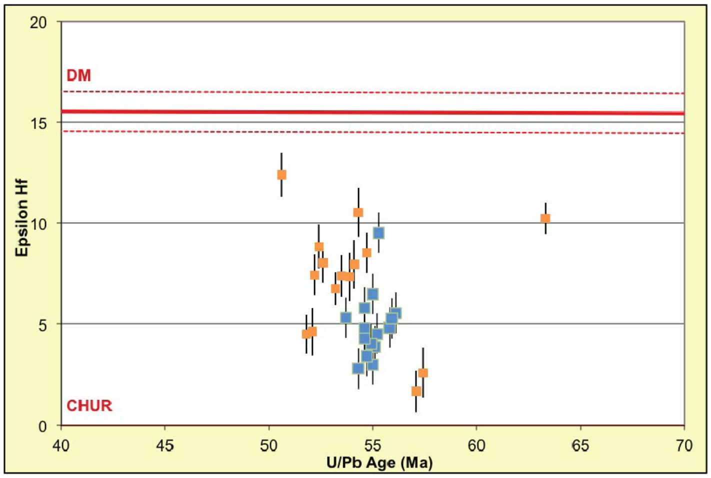

Figure 5. Epsilon HF vs U/Pb age for McKinley Peak (orange) and Sheep Bay (blue) from magmatic zircon analysis. Error bars included for each value. Depleted mantle and chondritic ranges included.

DISCUSSION

The magmatic enclaves found in the Sheep Bay and McKinley Peak plutons are relatively uncontaminated by crustal sedimentary melts, as evidenced by primitive trace element signatures and quenched mineral textures. The fairly juvenile εHf(t) values indicate that the two plutons were primarily derived from depleted mantle or juvenile crustal sources. However the range of εHf(t) values is great (particularly at McKinley Peak), and all values are lower than the depleted mantle array (Fig. 5). This suggests interaction of different magma sources and/or incorporation of more evolved crustal materials. The distinctly different and more primitive isotopic signature of the McKinley Peak pluton supports previous studies that suggest the two plutons have isotopically distinct crustal components in their source region (Barker et al., 1992, Cecil et al., 2011). The most primitive enclaves have a positive correlation between silica and Na_2O, CaO, and Al_2O_3, while the host granitoids have a negative correlation (Fig. 4). This could suggest multiple magma sources. Systematic increases in Sr/Y across the SBPB could suggest corresponding increases in crustal thickness across the CPW terrane (Chiaradia, 2015). The prehnite found in the biotite could be an important depth constraint, assuming the prehnite formed during or shortly after crystallization. Future work will focus on creating a bulk mixing model to further evaluate the petrogenetic processes that formed the Sheep Bay and McKinley Peak samples.

ACKNOWLEDGEMENTS

I would like to thank Cameron Davidson and John Garver for giving me the opportunity to be part of a fantastic project, as well as for all of their hard work and guidance along the way. I would also like to thank our great team of student-researchers, Bill Grimm, Kaitlyn Suarez, Eileen Alejos, Rudy Molinek, and Elaine Young. This research was made possible by grants from the National Science Foundation (NSF EAR 1116554 to John Garver, Union College, EAR 1116536 to Cameron Davidson, Carleton College, EAR-1062720 to Robert Varga, Pomona College) and the Keck Geology Consortium. I would like to thank Jon Johnson and the Chugach Native Corporation for allowing us to stay on Nuchek, a part of Hinchinbrook Island. I would to thank Pete Dawson and Mike Rhodes at the University of Massachusetts for their help attaining XRF whole rock geochemical data. U/Pb data was conducted at the University of Arizona at the Arizona LaserChron Center, an NSF facility run by Mark Pecha and George Gehrels. Lastly, I would like to thank my advisor Peter Crowley at Amherst College for all of his help, insight, patience, hard work and energy throughout this entire process.

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