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PETROGRAPHY AND GEOCHEMISTRY OF THE CRAWFISH INLET AND KRESTOF ISLAND PLUTONS, BARANOF ISLAND, ALASKA

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ABSTRACT

The Sanak-Baranof plutonic belt (SBPB) includes a series of biotite tonalite, granodiorite, and granite near-trench plutons that intrude the Campanian to Eocene flysch of the Chugach-Prince William terrane (CPW) for 2100 km along the southern Alaskan margin (Hudson et al., 1979; Hill et al., 1981; Bradley et al., 2003; Haeussler et al., 2003). SBPB intrusions have been interpreted to be the result of subduction of the Kula-Farallon or Kula-Resurrection spreading ridge at a trench-ridge-trench triple junction (Bradley et al., 2003; Haeussler et al., 2003; Cowan, 2003). The Crawfish Inlet and Krestof Island plutons, located on Baranof Island, have long been considered part of the SBPB (Hudson et al., 1979, Bradley et al., 2003 and references therein). In this study I use petrologic and geochemical data to evaluate the relationship between the Crawfish Inlet and Krestof Island plutons to other igneous rocks of the SBPB and coeval plutons of the northern Coast Plutonic Complex (located ~200 km southeast of Baranof Island). I also use the data to evaluate the petrogenesis of magmas emplaced as enclaves into these host plutons.

GEOLOGIC SETTING

The Crawfish Inlet pluton intrudes the Maastrichtian Sitka Graywacke and the correlative Baranof Schist (now known to be partly correlative to the Orca Group in Prince William Sound – Rick et al., 2014) and is exposed over 560 km^2 on southern Baranof Island in southeast Alaska (Loney et al., 1975: Fig. 1). These plutons are considered to mark the eastern boundary of the SBPB based on its anomalous forearc location and field relationships (Hudson et al., 1979; Haeussler et al., 2003; Bradley et al., 2003). Magmatic zircons from the Crawfish Inlet pluton yield U-Pb crystallization ages ranging from 53 to 47 Ma (Wackett et al., 2014). The Krestof Island pluton intruded older Albian-age accretionary wedge material to the north of the Crawfish pluton and is exposed over 80 km^2 (Fig. 1). Magmatic zircons from the Krestof pluton yield U-Pb crystallization ages of 52 Ma (Wackett et al., 2014). The spatial proximity (<75 km) of the coeval Crawfish Inlet and Krestof Island plutons offers an opportunity to assess the geochemical composition of multiple SBPB intrusive bodies within a small area.

METHODS

Standard beads and pellets for twenty-three (14 enclave, 9 host pluton) samples from the Crawfish Inlet and Krestof Island plutons were analyzed for major and trace elements by XRF and ICP-MS at the Washington State University GeoAnalytical laboratory. Sr and Nd isotopic data were collected at the Jackson School of Geosciences, University of Texas-Austin. Measured Sr isotopic ratios were corrected for ^{87}Rb by simultaneous analysis of ^{85}Rb and $^{87}Rb/^{85}Rb = 0.3860$, as well as for analytical fractionation using an exponential correction factor based on $^{88}Sr/^{86}Sr = 8.375209$. Measured Nd isotopic ratios were corrected for ^{144}Sm by simultaneous analysis of ^{147}Sm and $^{144}Sm/^{147}Sm = 0.206700$, as well as for analytical fractionation using an exponential correction factor based on $^{146}Nd/^{144}Nd = 0.7219$.

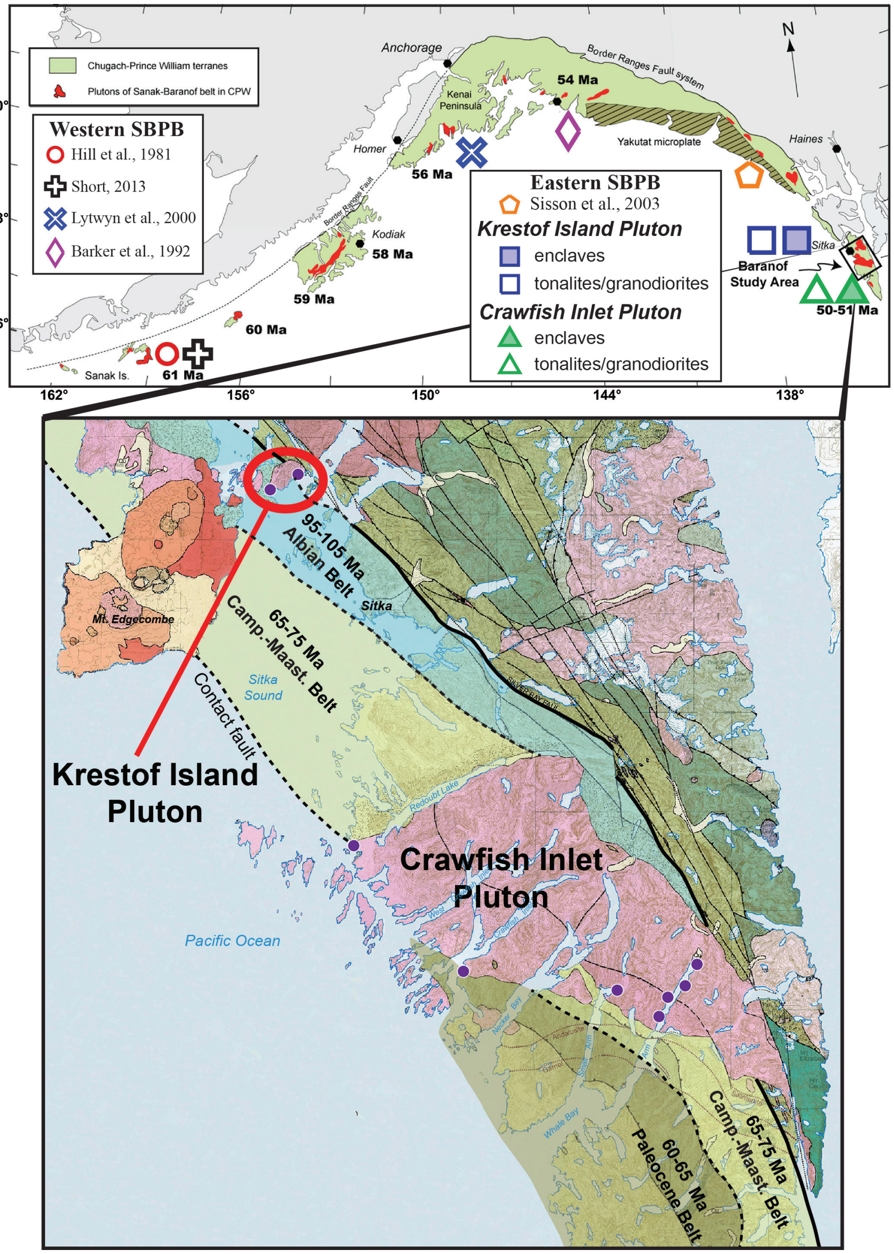

Figure 1. Simplified tectonic map (top) of southern Alaska showing location of the study area on Baranof Island within the CPW terrane. Symbols correspond to other geochemical studies of SBPB intrusive rocks. Inset (bottom) shows locations of the Krestof Island and Crawfish Inlet plutons on southern Baranof Island. Sample locations for this study are indicated by purple dots. Base map for Baranof Island modified from Karl et al., 2014 (in press).

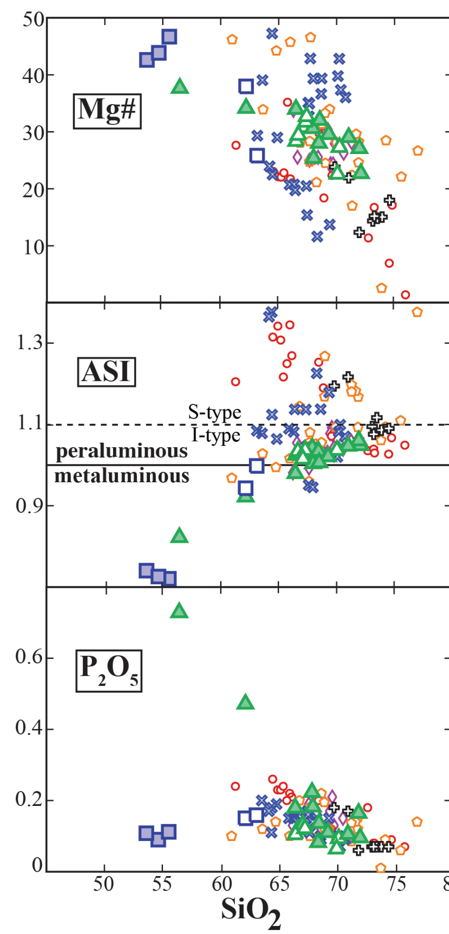

Figure 2. Mg#, aluminum saturation index (ASI), and P_2O_5 versus SiO_2 for enclaves and tonalites/granodiorites from the Krestof and Crawfish plutons, as well as other plutons from the SBPB. Symbols as in Figure 1.

PETROGRAPHY

Igneous rocks of the Crawfish and Krestof Island plutons consist predominantly of biotite tonalite and biotite-hornblende granodiorites based on petrographic observations and Ab-An-Or normative mineralogy (Barker, 1979). Most samples are hypidiomorphic, with euhedral plagioclase and anhedral ferromagnesian phases. Most rocks of the tonalitic suite exhibit seriate grain-size distributions, with some euhedral plagioclase grains displaying evidence for secondary hydrothermal alteration. Krestof Island samples are notably finer-grained and contain higher fractions of ferromagnesian phases and accessory opaque minerals than their Crawfish Inlet counterparts. None of the samples contain the appropriate mineral assemblage for Al-in-hornblende geobarometry (Hammarstrom and Zen, 1986). Zircon and apatite are common accessory phases, with chlorite commonly present as a show strong evidence for magmatic quenching processes, including acicular apatite and poikilitic and myrmekitic textures (Flood and Vernon, 1988; Vernon, 1990).

GEOCHEMISTRY

Compositions of host pluton and enclave samples range from 62-70 wt% SiO_2 and 53-72 wt% SiO_2, respectively. All evolved (> 66 wt% SiO_2) enclaves and host tonalities/granodiorites from the Crawfish Inlet pluton are peraluminous (Fig. 2). All samples from the Krestof Island pluton (both enclaves and host tonalite/granodiorite) are metaluminous (Fig. 2). In contrast, the vast majority of other SBPB rocks are peraluminous, and many plot within the S-type field (Fig. 2). The least evolved enclaves (<66 wt% SiO_2) have Mg# ≥ 35, where as host tonalites/granodiorites

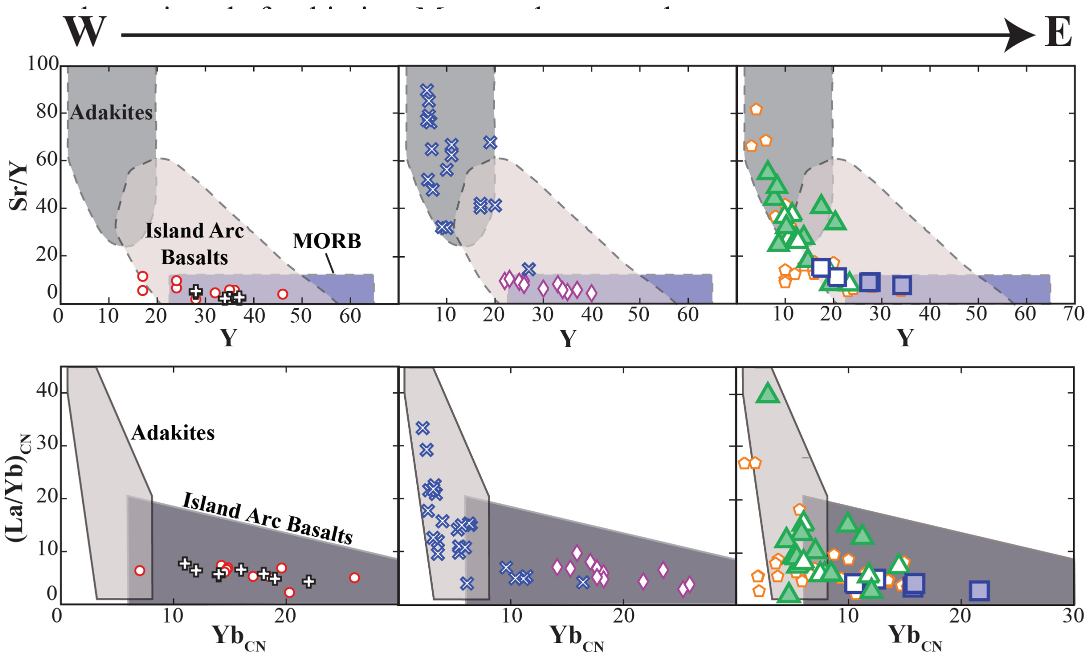

Figure 3. Sr/Y vs. Y and $(La/Yb)_{CN}$ vs. Yb_{CN} for SBPB plutons, from west to east. Fields for adakites, island arc basalts, and MORB are after Drummond and Defant (1990). Symbols as in Figure 1.

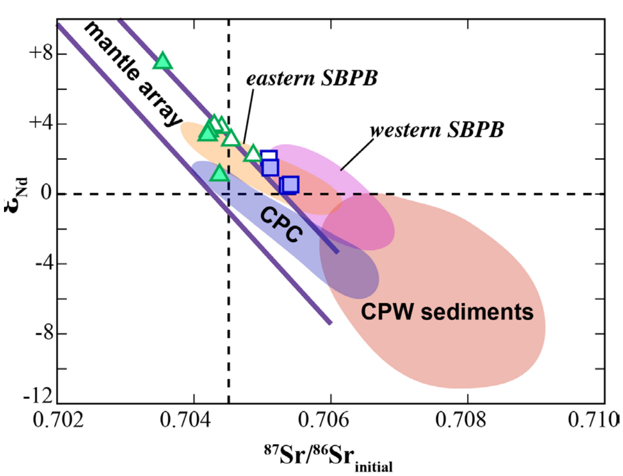

Figure 4. ε_{Nd} vs. $^{87}Sr/^{86}Sr_{initial}$ diagram for enclaves and tonalites/granodiorites from the Crawfish and Krestof plutons. Fields for eastern SBPB, western SBPB, northern Coast Plutonic Complex (CPC), and CPW sediments are shown for comparison and are referenced as follows: eastern SBPB – Sisson et al., 2003; western SBPB – Barker et al., 1992; northern CPC – Arth et al., 1988; CPW sediments – EarthChem and references therein. Dashed lines indicate estimated Bulk Earth composition (DePaolo and Wasserburg, 1976). Mantle array after McCulloch and Perfit (1981).

and more evolved enclaves exhibit consistently lower Mg#.

Enclaves from the Crawfish Inlet and Krestof Island plutons exhibit differences in their minor and trace element compositions. Crawfish enclaves have higher P_2O_5 (Fig. 2), TiO_2 (not shown), Sr/Y, and $(La/Yb)_{CN}$ ratios (Fig. 3) than Krestof enclaves. Some workers have suggested that a systematic depletion in REE exists from western to eastern SBPB intrusive bodies (Farris and Paterson, 2009). However, my review of all available REE data revealed no clear spatial relationship. But there appears to be differences in Sr/Y vs. Y and $(La/Yb)_{CN}$ vs. Yb_{CN} across the belt (Fig. 3). Plutons in the western belt exhibit low Sr/Y and $(La/Yb)_{CN}$, whereas SBPB rocks occurring further east (including the Crawfish) display higher Sr/Y and $(La/Yb)_{CN}$ ratios (Fig. 3). Although the Krestof pluton is proximal to and coeval with the Crawfish (Fig. 1), Krestof enclaves and host tonalites/granodiorites plot in the same field as western SBPB plutons (Fig. 3).

In general, trace element and REE profiles for the Crawfish and Krestof tonalites/granodiorites (not shown) are similar to those of the accretionary wedge sediments they intrude. Other workers observed similar geochemical relationships for other SPBP plutons and the sediments they intrude, and therefore concluded that the sediments were important sources for those SBPB magmas (Hill et al., 1981; Barker et al., 1992; Harris et al., 1996; Sisson et al., 2003b).

All Crawfish and Krestof samples (both enclaves and host tonalites/granodiorites) plot near or within the mantle array on an ε_{Nd} vs. $^{87}Sr/^{86}Sr_{initial}$ diagram (Fig. 4). Sr and Nd isotopic compositions of the enclaves from the Crawfish and Krestof plutons provide further evidence that they are geochemically distinct (Fig. 4). Enclaves from the Krestof pluton have similar isotopic compositions to their host tonalites/granodiorites, but the Crawfish enclaves have higher ε_{Nd} and lower $^{87}Sr/^{86}Sr_{initial}$ (Fig. 4). Fields for eastern SBPB, western SBPB, northern Coast Plutonic Complex, and CPW sediments are shown in Figure 4 for reference. The Sr and Nd isotopic compositions of the Crawfish and Krestof suites suggest less involvement of accretionary wedge sedimentary material compared to other SBPB and Coast Plutonic Complex rocks.

PETROGENETIC MODELING

Studies focusing on the geochemistry of the SBPB intrusive rocks have attributed their distinct chemical signatures to either assimilation-fractional crystallization and/or partial melting of accretionary sedimentary and lower crustal material (Hill et al., 1981; Barker et al., 1992; Harris et al., 1996; Lytwyn et al., 2000; Bradley et al., 2003). Trace element

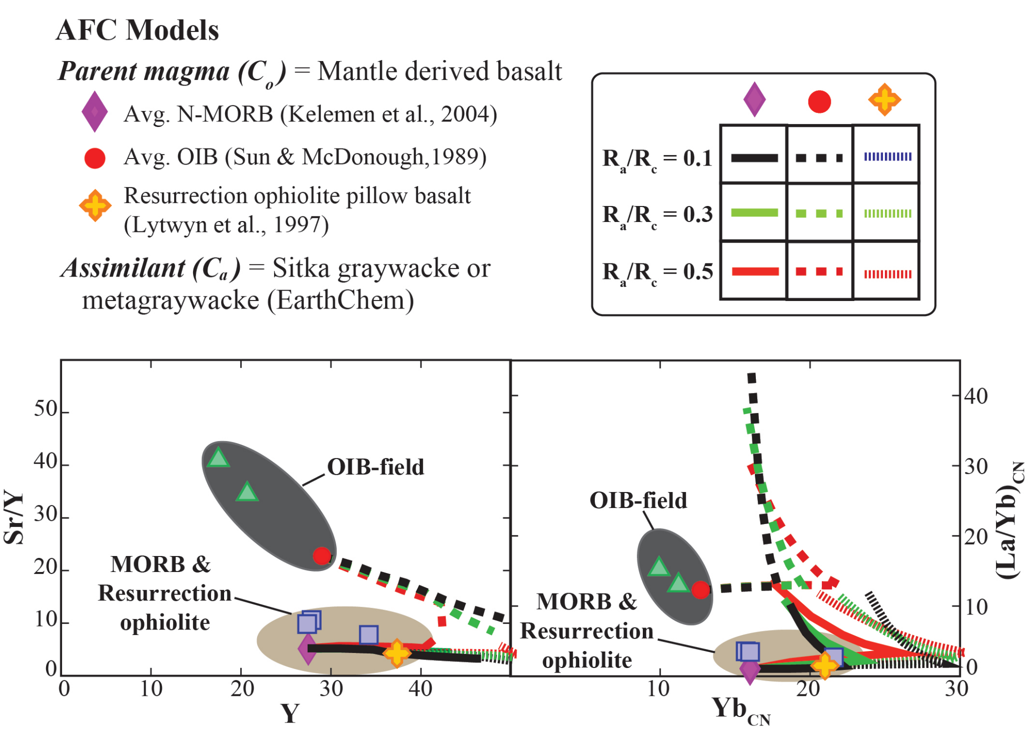

Figure 5. Modeled AFC compositions (solid and dashed lines) using various mantle-derived basaltic parental magmas and CPW sedimentary assimilants (Sitka greywacke or metagraywacke). Ocean island basalt (OIB) and MORB fields from GEOROC and EarthChem. Resurrection ophiolite compositions are from Lytwyn et al., 1997. R_a/R_c = rate of assimilation/rate of crystallization. Models based on equations of DePaolo (1981).

models after DePaolo (1981) were used to evaluate whether compositions of the least evolved Crawfish and Krestof enclave magmas could be produced from various mantle-derived basalt parental magmas via assimilation-fractional crystallization (AFC) of CPW sediments/lower crust. Modeled compositions of contaminated magmas generated in these AFC models generally do not match the trace element signatures of the enclaves (Fig. 5). Rather, the least evolved enclaves display characteristics similar to compositions of the mafic parental magmas assumed in the models (Fig. 5). This suggests enclave magmas were relatively uncontaminated, an observation supported by the Sr and Nd isotopic data (Fig. 4). Future modeling will test whether more evolved enclaves and host tonalites/granodiorites can be derived from the least evolved enclaves via AFC processes involving sedimentary and/or lower crustal material.

DISCUSSION

The Crawfish Inlet and Krestof Island plutons are hosts to relatively uncontaminated magmatic enclaves, as evidenced by their quenched mineral textures and primitive trace element and isotopic compositions (Figs. 4 and 5). Despite the spatial and temporal proximity of the Crawfish and Krestof intrusions, the least evolved enclaves occurring in these intrusive bodies have trace element and Sr-Nd isotopic characteristics that indicate distinct mantle sources. Additionally, Sr and Nd isotopic compositions for both enclaves and host tonalities/granodiorites of the Crawfish and Krestof plutons suggest minimal input from accretionary wedge materials. This observation is further supported by trace element models, in which the least evolved enclaves exhibit similar compositions to their assumed mafic parental magmas. These findings are in contrast to other studies (Hill et al., 1981; Barker et al., 1992; Harris et al., 1996; Lytwyn et al., 2000; Bradley et al., 2003) that call upon significant involvement of accretionary sediments in the petrogenesis of SBPB and Coast Plutonic Complex intrusive bodies. In addition, the systematic variations in Sr/Y and $(La/Yb)_{CN}$ across the SBPB suggest a changing role of amphibole and/or garnet as fractionating or residual phase(s) during the genesis of SBPB magmas.

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