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AGE AND PETROGENESIS OF THE SHUMAGIN BATHOLITH IN WESTERN CHUGACH-PRINCE WILLIAM TERRANE, ALASKA

ALEXANDER K. SHORT, University of Minnesota Morris
Research Advisor: James F. Cotter

INTRODUCTION

The Shumagin batholith is part of the Sanak-Baranof plutonic belt in Southwest Alaska that extends approximately 2200km from Sanak Island in the west to Baranof Island in the east. (Hudson, 1979; Hudson et al., 1979; Hill et al., 1980; Bradley et al., 2000; Haeussler et al., 2003). Previous work has indicated that the crystallization ages of the Sanak-Baranof plutons young from west to east. The oldest pluton in the belt intruded the Upper Cretaceous flysch of the Chugach-Prince William accretionary complex at 61Ma (Bradley et al., 2003). The diachronous relationship of the Sanak-Baranof plutons has been interpreted both as having formed in place due to the subduction of an oceanic ridge (Bradley et al., 1993; Haeussler et al., 2003), and as having formed with the movement of the Chugach-Prince William terrain over a relatively immobile trench-ridge-trench triple junction (Cowan, 2003). These plutons are anomalous because they intrude the forearc and the diachronous age progression from the western end of the plutonic belt to the eastern end.

The origin of near-trench plutons has been well-studied and many workers conclude that this plutonic belt was generated by the interaction of a spreading ridge and subduction zone along the western North American margin (Hudson,1983; Sisson et al., 2003; Bradley et al., 2003; Kusky et al., 2003). The melting of the accretionary complex driven by interactions with sub-oceanic asthenosphere is suggested to have formed the Shumagin batholith.

In this study, with the new U-Pb dates of 61.7 + 0.7Ma and 62.6 + 0.7 Ma, I address and constrain the age and petrogenesis of the Shumagin Batholith, which deviates from the accepted diachronous age progression. The description of an inclusion of a metasedimentary xenocryst and accompanying geochemical analysis also suggest that these plutons intrude a forearc based on the sedimentary component in the melt.

GEOLOGIC SETTING

Widely spaced granitic plutons occur in a curvilinear belt more than 2000km long parallel to much of the continental margin (Hudson, 1979). The Sanak-Baranof Plutonic belt is the name given to this feature.

It is comprised of 61 to 50Ma biotite tonalite, granitic, and granodiorite plutons some of which are of batholith proportions. These plutons intrude the Mesozoic and Cenozoic accretionary prism known as the Chugach-Prince William terrane (Bradley et al., 2000).

The outer Shumagin Islands, an archipelago located 175-240km along strike from the southwestern end of the Sanak-Baranof plutonic belt, are underlain by upper Cretaceous turbidites intruded by early Tertiary granodiorite (Bradley et al., 2000). The islands are underlain by a thick sequence of interbedded sandstones and mudstones intruded by a granitic batholith. The Shumagin Formation itself can be divided into two facies and members of massive sandstone and mudstone rich graded beds, produced by turbidity currents, with many of the sandstone beds being derived from volcanic rock (Moore, 1975).

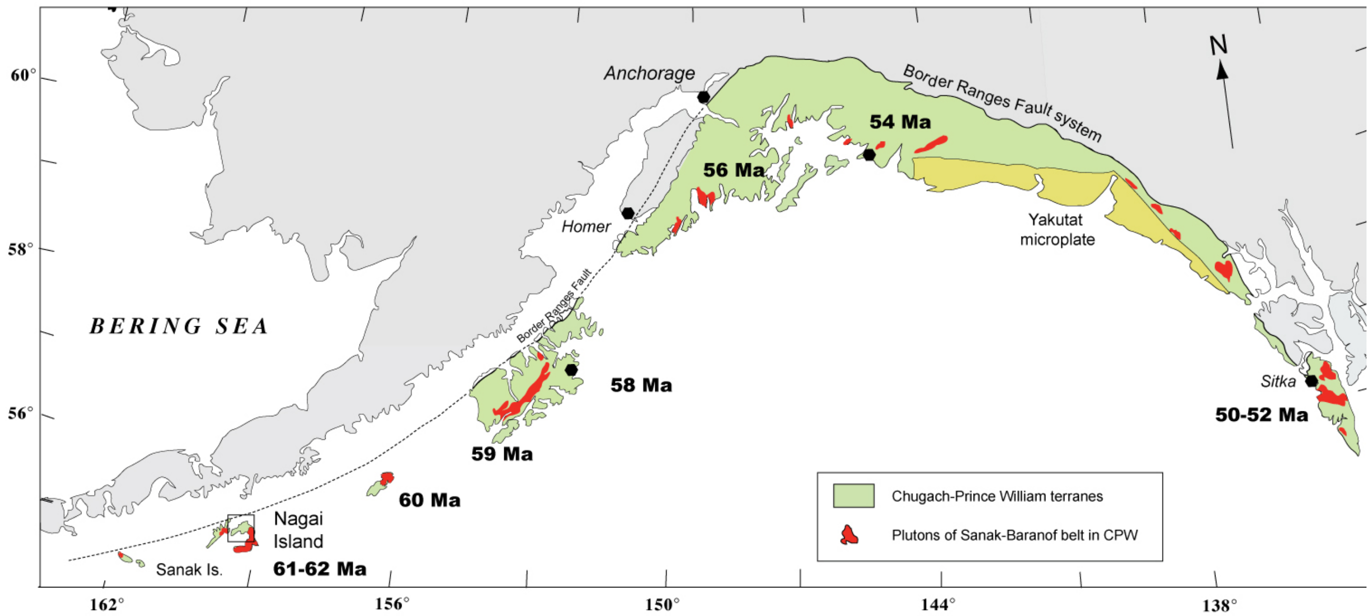

Figure 1. Generalized geologic map of southern Alaska showing the location and age of the plutons in the Sanak-Baranof Plutonic belt. Map modified from Bradley (2003).

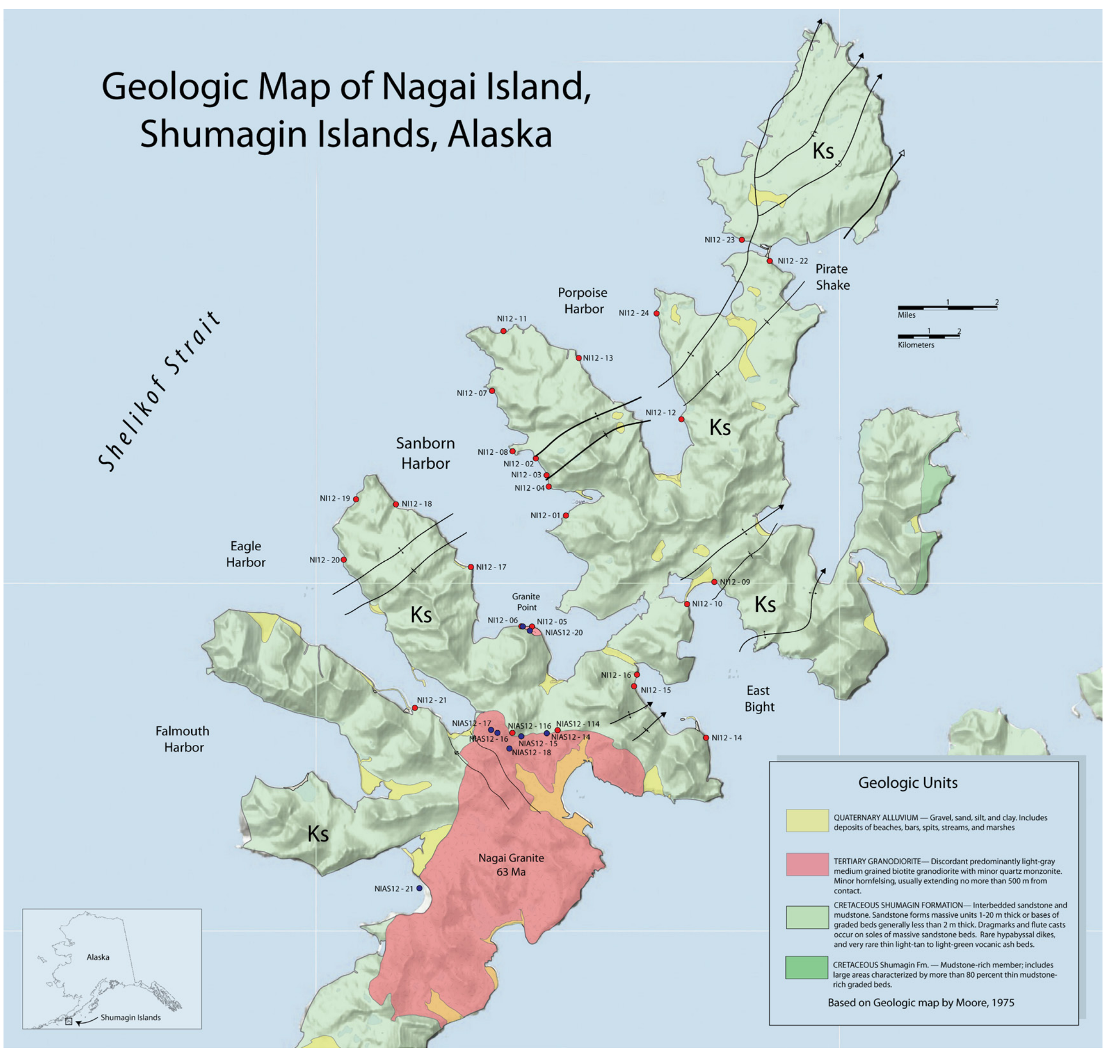

Figure 2. Geologic map of Nagai Island displaying new sample site locations of newly dated intrusive rocks.

METHODS

Eleven samples of the Shumagin Batholith were taken, including: five samples of granite, one intermediate enclave, one mafic enclave, two hornfels samples, one leucocratic granite sample, and one melanocratic granite sample. Six samples of surrounding country rock, five of sandstone and one of shale, were also taken. U-Pb igneous zircon ages were obtained by radiometric dating of zircon grains from two samples taken from the Shumagin batholith, NI12-05 and NIAS12-21. Zircon grains were separated using the standard separation techniques of crushing, grinding, Wilfley table separation and density separation. Zircons were then dated by LA-MC-ICPMS at the Arizona LaserChron Center (Gehrels et al., 2008). This involves the ablation of zircon grains where the ablated material was then analyzed by a Nu HR ICPMS. Where possible, core and rim ages were taken. Twenty-four and twenty-five grains were dated in each sample respectively, and in each sample set there was one inherited core was identified and left out of the overall age calculation.

To assist in determining the origin of the granitic melts, whole rock geochemistry was conducted, on each of the sixteen samples of the batholith, and six samples of surrounding country rock comparing major and trace elements on the granites and the surrounding sandstones and shales. Standard beads and pellets were analyzed for major and trace elements using the XRF at Macalester College.

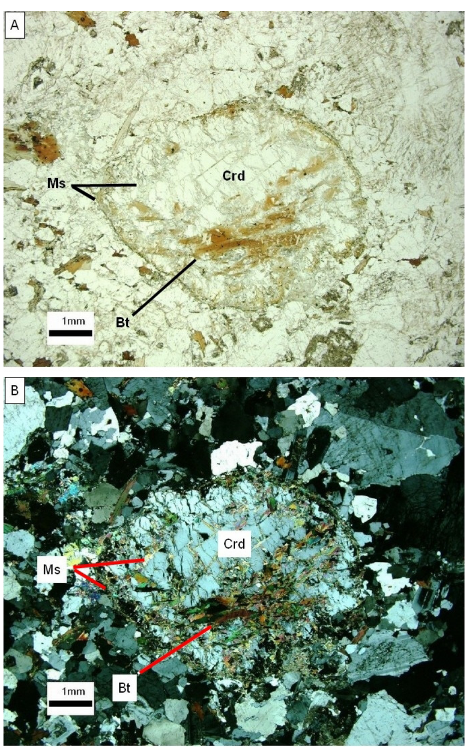

Figure 3. Photomicrographs of xenocrystic Cordierite in NIAS12-16A, a granitic sample, approximately 6mm across. A) Cordierite xenocryst in plane-polarized light (ppl). B) Cordierite xenocryst in crossed polarized light (xpl). Note muscovite reaction rim surrounding xenocryst and the anhedral shape of the xenocryst, along with biotite and muscovite inclusions.

PETROGRAPHY AND GEOCHEMISTRY

The Shumagin Batholith is homogeneous, coarse grained granodiorite that is rich in biotite and notably it has an absence of hornblende. There is also separate sodium and potassium rich phases of feldspar in thin section indicating high water content during crystallization. This high water content has resulted in a perthitic texture present in the samples further suggesting a slow cooling of the granitic intrusion.

Through geochemical analysis, each sample was plotted paraluminous with an index, according to their Aluminum saturation index (ASI; Frost et al., 2001) vs SiO2, of greater than one which also suggests a sedimentary component in the melt. Support for the inclusion of a metasedimentary component in the petrogenisis of the batholith, proposed by Hill et al. (1981), was found in thin section analysis of the granitic samples collected. Thin section analysis of these granitic samples suggests the inclusion of a sedimentary component through the inclusion of a large metasedimentary xenocryst of Cordierite.

Cordierite is a characteristic of many paraluminous felsic igneous rocks (Clarke, 1995). The assimilation of Cordierite is explained through the inclusion of country rock that becomes entrapped in the melt during the intrusion of silicate magma. Partial melting of pelitic material under lower pressures in the middle to upper crust results, in many cases, in the formation of Cordierite in the same peritectic reaction that forms the paraluminous melt phase (Clarke, 1995). The presence of Cordierite, together with other complementary geological and petrological observations, can be considered to be a diagnostic feature of assimilation and, for this reason, the formation of Cordierite has received considerable attention in the study of granitoids (Juan Diaz Alvarado et al., 2011). The inclusion of large metasedimentary xenocrysts of Cordierite also confines the depth of crystallization of the batholith to where Cordierite, at relatively low temperature and

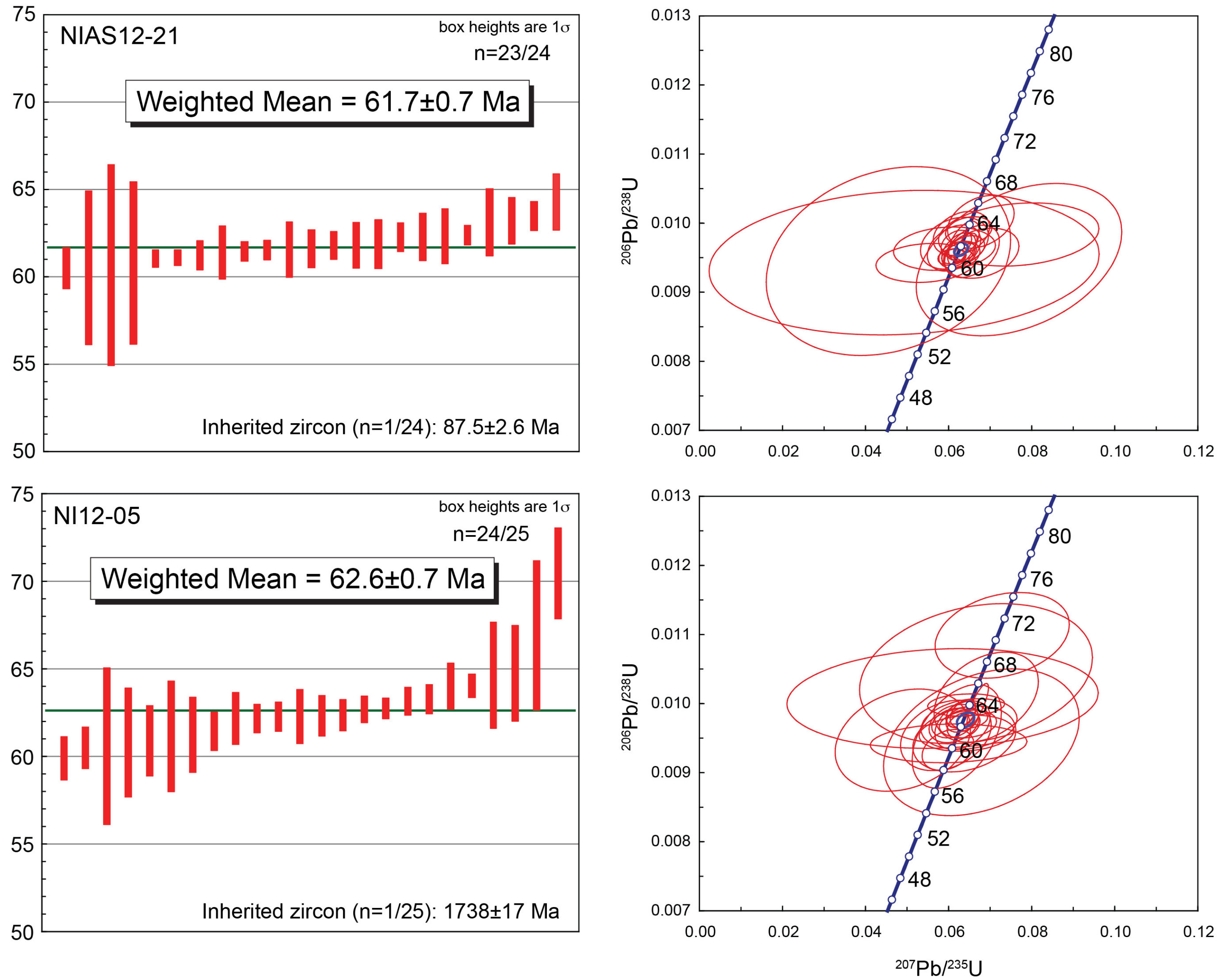

Figure 4. U/Pb zircon weighted mean and concordia diagrams from the Shumagin batholith. A)Unnamed Bay south of Falmouth Harbor (NIAS12-21). B) Granite Point in Sanborn Harbor (NI12-05). Weighted mean and concordia diagrams calculated using Isoplot (Ludwig, 2003).

pressure, is stable. Ascent brings those melts into the stability field of cordierite. Surrounding country rock was hot enough to fully reset fission tracks, (>300°C), and the delay in cooling ages from intrusion (62 Ma) to cooling (45-50 Ma) would suggest that intrusion occurred with ambient temperatures of around 200°C (Deluca, this volume).

GEOCHRONOLOGY

For this study, the two of the sixteen samples of granite that were used for U-Pb dating were collected on the island of Nagai. Where possible core and rim ages were recorded for zircon grains, these analyses revealed two inherited cores, one of which was an early Precambrian grain dated at 1737.6 + 17Ma, which is odd given the extremely low number of Precambrian grains in the flysch of the Chugach terrane (Roe et al., this volume).

The first of the Nagai samples, NIAS12-21, included the dating of 24 euhedral magmatic zircons with a range of dates from approximately 55Ma to 66Ma with a weighted mean of 61.7 + 0.7. The second sample, NI12-05, included the dating of 25 zircon grains with a range of dates from approximately 56Ma to 74Ma and a weighted mean of 62.6 + 0.7Ma. We interpret these weighted means to be the crystallization age for these samples. The ages of these zircons from both samples were concordant and together indicate a mean crystallization age of approximately 62 Ma.

DISCUSSION AND CONCLUSIONS

The crystallization ages of the Sanak-Baranof plutons trend younger from west to east, from ca 61Ma at the western end, Sanak Island, to ca 50Ma at the eastern end, Baranof Island (Bradley et al., 2003). For the Sanak pluton there are eight previously published K/Ar (biotite) and Rb/Sr (mineral/whole-rock isochron) dates that range from 57.4+2.9 to 60.7+1.8 Ma, there is one outlier K/Ar muscovite age of 65.6+3.3 Ma which is eliminated by the new U/Pb date (Bradley et al., 2000). There has been a little use of U/Pb dating, which has been accepted as more reliable than the previous methods. Based upon two fractions of magmatic zircons Bradley et al. (2000) obtained an average U/Pb date of 61.1+0.3 Ma, which is assumed to be the most reliable. Emplacement of the Sanak-Baranof belt later terminates at an age of 50Ma at the eastern end on Baranof Island.

This new U-Pb age of approximately 62 Ma of the batholith presents a challenge to the newly accepted age of the Sanak Island whose age has been recently suggested to be 61.1 + 0.3 Ma, by Bradley et al. (2000), rather than the previous estimate of 66Ma. This is because a younger age for the Sanak pluton would suggest that magmatism at the very western end of the belt commenced after the crystallization of the Shumagin Batholith and contradicts a diachronous age relationship among the plutons of the Sanak-Baranof belt.

Previous work (Hudson et al., 1979; Hill et al., 1980; and Barker et al., 1992) suggests based on age, Rb-Sr and petrologic relationships, that these plutons formed from partial melting of the CPW. Mineral isochrons using unaltered minerals yielded 87Sr/86Sri = 0.70534 + 10 for the Shumagin batholith. These data support the formation of plutons through a mixture of sub-oceanic asthenosphere and a crustal component (Hill et al., 1981).

A commonality between the different models for petrogenisis of the batholith is the exposure of the crustal component through contact with exposed sub-oceanic asthenosphere. This exposure would occur through either the slab window formed by the subduction of a mid ocean trench or coastwise motion over the triple junction. This exposure would have driven the melting of the hydrated underside of the crust. This would create conditions for the mixing of both magma and crustal component. Ultimately this mixing would form the array of granodiorite, granitic and tonalite petrology that makes up the vast majority of the geochemistry of the comprising plutons. Thus far current geochemical analysis indicates a crustal component through the trace element signature of the surrounding country rock, specifically the shales, which are nearly identical to the batholith in trace element.

The new average U-Pb date of approximately 62 Ma for the Shumagin batholith contradicts a diachronous age relationship at the western end of the Sanak-Baranof plutonic belt at the western end. This contradiction is specifically between the age of the Sanak Pluton age and the new Shumagin age which predates the Sanak pluton now by 1.1Ma according to U-Pb dates presented by Bradley et al., 2003. The geochemistry and petrography of the batholith is consistent with that of crystallization of the batholith through the melting of the CPW terrane and subsequent mixing with upwelling mantle.

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