A Petrographic and Geochemical Study of the Somesville Granite in the Cadillac Mountain Intrusive Complex: The Role of Basaltic Infusions in Silicic Magma ChamberProcesses

Kathleen J. Schuh
Department of Geology
The College of Wooster
Wooster, Ohio 44691

Introduction

The Silurian Cadillac Mountain intrusive complex on Mount Desert Island, Maine is an example of a composite pluton that has formed through multiple basaltic injections into a floored chamber of silicic magma.Although plutonic evidence for mixing and commingling of mafic and silicic magmas has been recognized for years, it has only recently been established that some intrusive complexes have originated in this way (e.g.,Wiebe, 1974, 1993; Michael, 1991; Chapman and Rhodes, 1992). The purpose of this study is to create a petrogenetic model for the role of the Somesville granite in this composite pluton and, in doing so, contribute to the understanding of magma chamber processes and the relationships between the plutonic record and volcanic activity

The Somesville granite, the smaller of the two felsic plutons on the island, intrudes the Cadillac Mountain granite. The unit forms an oval-shaped body between the gabbro-diorite unit in the north and southwestern areas of the complex and the eastern portion of the Cadillac Mountain granite. Samples were chosen across the mapped area of the Somesville granite in an attempt to acquire the most representative suite of rocks. Several descriptive petrologic and geochemical techniques were required for a comprehensive study of the coarse and fine-grained granite, as well as the silicic enclaves that occur in the coarse-grained unit.

Petrography

The Somesville granite exhibits two textural variations that display similar petrological characteristics.The two varieties of granite were characterized petrologically through thin section analysis and mineralogical point counting in hand sample and thin section. The entire unit of granite is characterized by three major phenocryst minerals: alkali-feldspar, quartz, and plagioclase feldspar (An_{30-15}). Biotite and rarely hornblende occur as the predominant mafic minerals, with accessory minerals including allanite, apatite, chlorite, fluorite, opaques, titanite, and zircon.The fine-grained, porphyritic variety of the granite occurs in contact with the gabbro-diorite unit and grades to the coarser grained Somesville. Perthitic alkali-feldspar appears as subhedral phenocrysts and as anhedral grains interstitial to plagioclase and quartz. Smaller equant quartz grains range from 0.5-5 mm, and plagioclase grains typically appear subordinate with sizes ranging from 0.2 to 3 mm.The largest of these grains of sodic plagioclase demonstrate complex patchy and oscillatory zoning that appears to record multiple episodes of resorption. Smaller plagioclase crystals often appear in clots and are most often found in association with hornblende. Granitic textures characterize the homogeneous fine-grained samples, while granophyric textures are common in the samples near the contact of the gabbro-diorite unit and in areas of contact between felsic dikes and the granite. Rounded crystals of K-feldspar rimmed by plagioclase are found in samples near the same contacts. Near contacts with the gabbro-diorite unit, small (1-5 cm), variably chilled and assimilated mafic inclusions are abundant. These inclusions contain partly resorbed xenocrysts of quartz and feldspar rimmed by hornblende and pyroxene. Enclaves are rare in this varietyoccuring only as small mafic clots ranging in size from <1 mm to 5 cm in diameter These enclaves largely resemble their host petrographically, but also contain clinopyroxene and hornblende in their fine-grained matrix.They often appear to be somewhat disaggregated. Larger silicic enclaves that occur in the coarse-grained variety of the unit are absent from the fine-grained rocks.

The coarse-grained variety of the granite occurs in the central and southwestern area of the complex, contained between the finer grained Somesville and the Cadillac Mountain granite to the east and south. The unit is typically homogeneous and massive with equigranular textures. Alkali-feldspar crystals account for 40-50% of these granites, with large perthitic anhedral-subhedral alkali-feldspar phenocrysts ranging in size from 0.5 mm to 10 mm. Quartz crystals make up 25-35 % of these rocks, and plagioclase feldspar (An30-15) accounts for the remaining 15-20%. Plagioclase grains are often intergrown, appear tabular to lath-like in shape, and vary in size from 1-4 mm. Sericitization is widespread and is preferential to the moreAn-rich zones in the plagioclase. Biotite, sometimes altered to chlorite, constitutes 2-5% of these granites. The remaining mafic mineral, hornblende, makes up no more than 3% of each sample. Diffuse inclusions very similar to the fine-grained variety occur in this coarser variety Clusters of very fine-grained (<0.1-0.3 mm) hornblende, plagioclase, and chlorite occur within these inclusions. Lage biotite crystals ranging in size from 0.2 to 2 mm are also evident.

In comparison to their hosts, the enclaves that occur in the two varieties of the granite contain higher percentages of mafics, including clinopyroxene which is absent from the host granite.Their matrix is composed of fine-grained (<.3 mm) plagioclase feldspar, biotite, and clinopyroxene. Phenocrysts of quartz and plagioclase occur but alkali-feldspar phenocrysts are absent. Quartz phenocrysts display rounded, resorbed edges and are cut by channel ways of mafic material (probably hornblende). These phenocrysts are comparable in size to those in the host granite, and are consistently rimmed by hornblende crystals.Two differing sizes of plagioclase crystals occur. The largest are phenocrysts (1-2 mm) which likely reflect the state at which crystallization proceeded before an eruption of the chamber occurred. The smaller crystals are usually less than 1mm in size and give evidence for abundant nucleation. Quench textures are abundant.

Geochemical Analysis

Eighteen of the thirty-one samples collected were analyzed for major and trace elements using both X-ray fluorescence (XRF) and the inductively coupled plasma technique (ICP): three of the fine-grained granite, eleven of the coarse-grained, and three of the silicic enclaves found in the coarse-grained unit.This data will be used to determine the possible origin of the Somesville granite, as well as its evolution and role in the intrusive complex.

All of the samples were plotted on the weight normative Q-Ab-Or classification diagram afterTuttle and Bowen (1958) and all were found to fall in the granite field. This was confirmed by the molecular normative An-Ab-Or diagram of Barker (1979) except for one sample 19A, which plotted as a granodiorite.This sample is discussed further below. Both the fine and coarse grained samples have between 72 to 77 weight % SiO_2.The three enclave samples demonstrate a range of 67 to 71 weight % SiO_2. Harker diagrams of oxides that exhibit a negative correlation with SiO_2 include CaO, Al_2O_3, MnO, MgO, TiO_2, and P_2O_5. The only harker diagram that exhibits a fairly strong positive correlation with SiO_2 is K_2O. The data demonstrates that the fine and coarse grained granite fall along the same compositional trends, indicating that they are related through fractionation processes (fig. 1). One of the coarse-grained samples, 19A, consistently had the highest TiO_2, MnO, MgO, CaO, Na_2O, P_2O_5, and Al_2O_3 and the lowest K_2O contents. It also demonstrated anomonously high concentrations of P_2O_5, Sr, Cr, Co, and Sc. This is likely due to the fact that the sample was taken at the contact of the gabbro-diorite unit and therefore was highly contaminated by mafics.

In order to establish their relationship, major and trace element data from the Cadillac Mountain granite (Webe, 1993) and the Somesville granite were plotted on variation diagrams together (fig. 2). On each plot the Cadillac Mountain granite occurs as a tight group between 72-74 weight % SiO_2. On the majority of the major element plots, several samples of the Somesville granite plot within this close grouping of Cadillac Mountain granite. Of those samples, three were taken from locations near the contact between the two units and three were fine-grained Somesville. For the remaining samples of Somesville granite, the Cadillac Mountain granite contained higher CaO, MgO, Na_2O, MnO, P_2O_5, and TiO_2 but lower K_2O. The Cadillac Mountain granite is also significantly higher in Ba, Ce, and Zr concentrations as compared to the Somesville granite. Fig. 2a demonstrates the relationship between the two for Zr concentrations v. weight % SiO_2.

Discussion

Petrographic relationships and textural features of outcrop scale observed at contact areas in the field demonstrate that the Somesville granite was affected by hybridization with mafics. The rapakivi textures in the granite near contacts with the gabbro-diorite unit noted above, as well the the quench textures visible in many of the samples, support the conclusion that significant undercooling has taken place.These relations indicate that the Somesville magma partially mixed with incompletely solidified mafic magma related to the gabbro-diorite unit. It is likely that the Somesville magma chamber was stratified with the finer-grained Somesville granite above the gabbro diorite unit and beneath the coarser-grained Somesville granite.

The fractionation of alkali feldspar and plagioclase occurred early, as indicated by their modal abundances in the unit. The geochemical relationships between the Somesville granite and the Cadillac Mountain granite demonstrate that the coarse grained Somesville granite is generally distinct from the Cadillac Mountain granite and may have differentiated from it (fig. 2b.,c.). This, coupled with the fact that the most silicic Somesville granite has chemical compositions that closely resemble the most silicic chilled granophyric liquids within the Cadillac Mountain granite (Wiebe, 1993), may indicate that the Somesville granite represents a partly crystallized highly evolved magma that is residual from the Cadillac Mountain granite.

Works Cited

Barker, F., 1979, Trondhjemite: Definition, environment and hypothesis of origin.*in:* Barker F. (ed.), Trondhjemites, dacites, and related rocks. Elsevier, Amsterdam, p.1-12.

Chapman, M., and J.M. Rhodes, 1992, Composite layers in the Isle au Haut Igneous Complex, Maine: Evidence for periodic invasion of a mafic magma into an evolving magma reservoir, J. Volcanol. Geotherm. Res., 51, 41.

Michael, P. J., 1991, Intrusion of basaltic magma into a crystallizing granitic magma chamber:The Cordillera del Paine pluton in southern Chile, Contrib. Mineral. Petrol., 108, 396.

Tuttle, O.F., and N.L. Bowen, 1958, The origin of granite in the light of experimental studies in the system $NaAlSi_3O_8$-$KAlSi_3O_8$-SiO_2-H_2O. Mem. Geol. Soc. Amer., No. 74.

Wiebe, R. A., 1993, The Cadillac Mountain Intrusive Complex, Mount Desert Island, Maine,*in press* J. Geol.

Wiebe, R. A., 1993, Basaltic Injections into Floored Silicic Magma Chambers: EOS, v 74, no. 1, p. 1-3.

Wiebe, Robert A. and Marshall Chapman, 1993, Layered gabbro-diorite intrusions of coastal Maine: basaltic infusions into floored silicic magma chambers: *in* Cheney and others, ed., Field Trip Guidebook for Northeastern United States: 1993 Boston GSA, Department of Geology and Geography, University of Massachusetts, Amherst, Massachusetts.

Wiebe, R. A., 1974, Coexisting intermediate and basic magmas, Ingonish, Cape Breton Island, J. Geol., 82, 74.

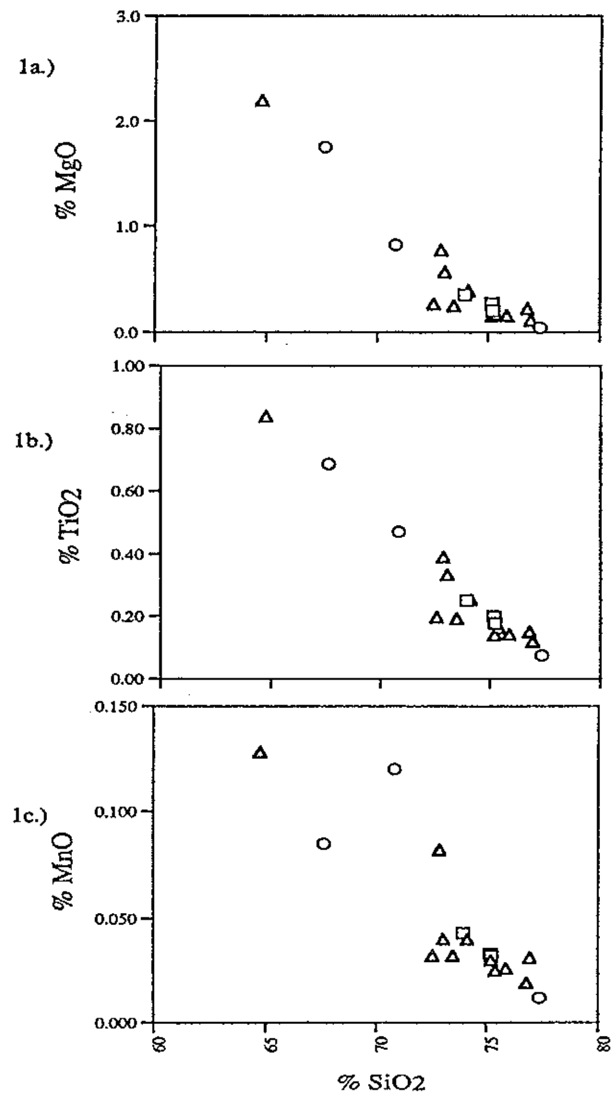

Figure 1. Harker diagrams of Somesville granite illustrating negative correlations with SiO_2 for a.) MgO, b.) TiO_2, c.) MnO.

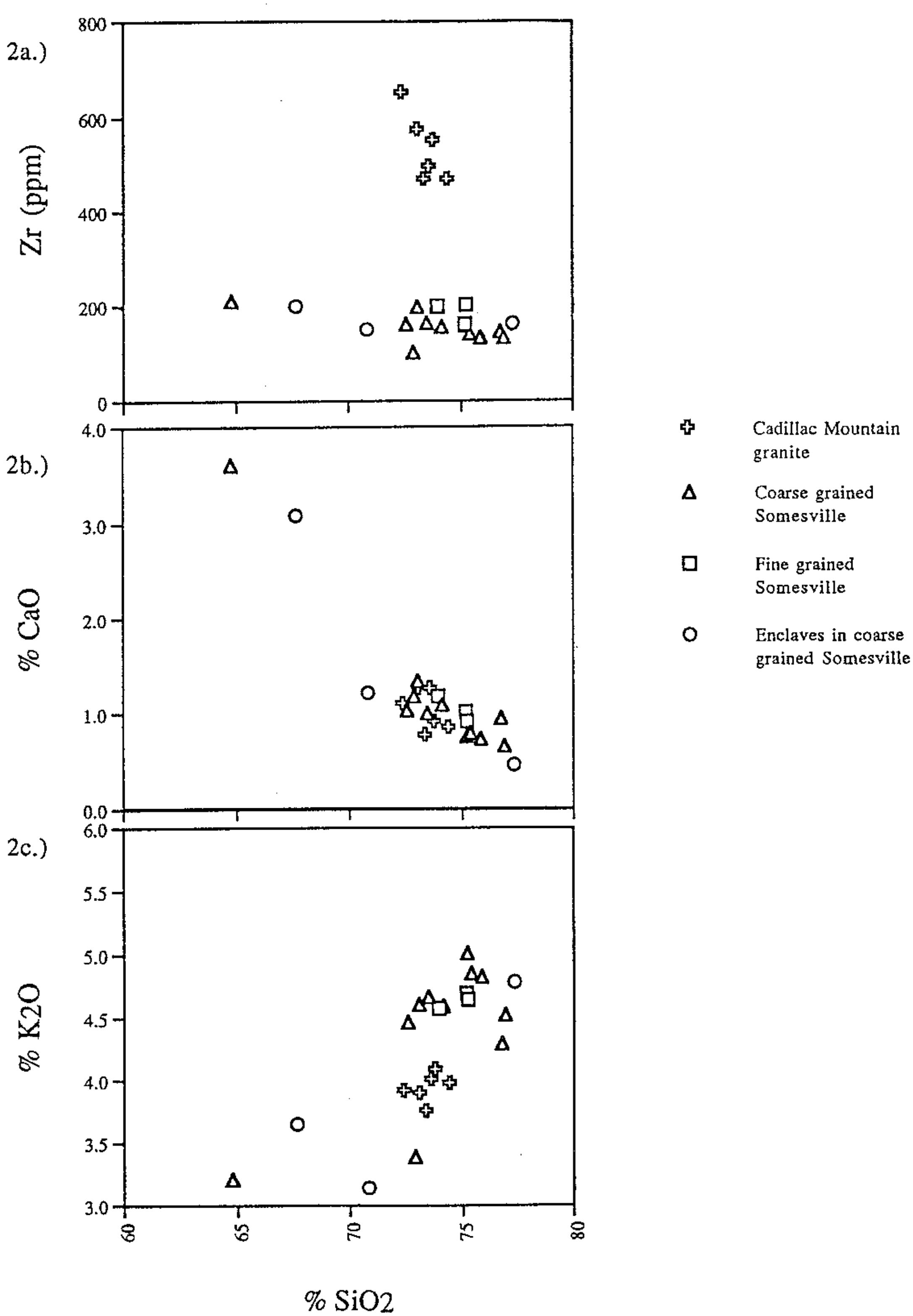

Figure 2. Harker diagrams illustrating various relationships between the Somesville granite and the Cadillac Mountain granite: a.) Zr v. SiO_2, b.) CaO v. SiO_2, c.) K_2O v. SiO_2.