Petrogenesis of granites in the Fosdick migmatite dome, Marie Byrd Land, West Antarctica

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Summary The Fosdick migmatite dome is composed of migmatitic paragneiss and orthogneiss, likely derived from the Swanson Formation and the Devonian Ford Granodiorite, respectively, and various granites. The granites are silicic (71-75 wt% SiO_2) and slightly peraluminous (1.0-1.2 A.S.I.), and may be grouped into K-rich and K-poor types. For the K-rich type, preliminary Nd isotope data permit partial melting of Ford Granodiorite as the source, which is supported by comparison between the whole-rock chemistry of the granites and glass compositions in melting experiments with an appropriate protolith. For the K-poor type, the particular source is not clearly defined at present, and these granites might be derived from either the Swanson Formation or the Ford Granodiorite by disequilibrium melting.

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Introduction

Migmatites and granites are widely distributed in the Fosdick migmatite dome in western Marie Byrd Land, West Antarctica. It is important to know the origin of the migmatite leucosomes and the granites to understand the evolution of the dome, particularly whether protoliths for gneisses within the dome represent source materials for leucosomes and some of the granites and whether some of the granites in the dome represent melt crystallized during ascent through a melt transfer zone. However, a detailed geochemical and isotopic study for these rocks in the dome has not been performed. In this work, we present geochemical and isotope data for granites in the dome and characterize the possible sources of the granites.

Geological background

The Fosdick Mountains form an 80x15km dome comprised of migmatitic paragneiss and orthogneiss, and various phases of granite. Outside the Fosdick Mountains, the Swanson Formation, a thick sequence of pre-Late Ordovician turbiditic mudstones and sandstones of low greenschist grade, is intruded by Devonian Ford Granodiorite. The Cretaceous Byrd Coast Granite intrudes both Swanson Formation and Ford Granodiorite. The protoliths for the paragneiss and orthogneiss within the dome are likely the Swanson Formation and the Ford Granodiorite, respectively (e.g. Siddoway et al., 2004 and references therein). Estimates for the intensive variables of dome-related metamorphism are ~720˚C and ~5 kbar, and the age of this metamorphism is ca. 115-96 Ma with rapid cooling during the interval ca. 101-94 Ma (Richard et al., 1994; Siddoway et al., 2004).

Recent geochronological investigations (Siddoway et al., 2006; Korhonen et al., this volume) have revealed new evidence of Devonian-Carboniferous metamorphism and melting suggesting that the migmatites and granites within the Cretaceous dome are the products of a polymetamorphic evolution. The earliest stage of metamorphism and partial melting of the Swanson Formation may have reached a thermal peak around 375 Ma, just prior to the intrusion of the Ford Granodiorite. This first cycle of metamorphism and magmatism is attributed to subduction-related events along the active continental margin of Gondwana. A second cycle of metamorphism and melting during the interval 119-96 Ma was generally contemporaneous with continental extension in the West Antarctic Rift System, and the intrusion of Byrd Coast Granite (Pankhurst et al., 1998) and mafic alkalic dikes (Siddoway et al. 2005). The proportion of migmatite and granite that relates to each of these events has not been determined.

Field relationships

Granites in the dome have a wide range of mineralogy and occur in a variety of structural settings. Five types of granite from across the Fosdick Mountains (Fig. 1) were analyzed as part of this study (Table 1). The structurally deepest rocks occur in the Ochs Glacier area, and one sample (K6-Mj01A) was collected from this area at Marujupu Peak. This garnet-bearing granite occurs as a 1 m-thick concordant dike intrusive into biotite gneiss. Another garnet-bearing granite was collected from Mt. Bitgood (K6-B27). This granite occurs as a massive coarse-grained K-feldspar granite with small (2-5 mm) euhedral pristine garnet and sillimanite schlieren defining a weak foliation. The granite is interlayered with orthogneiss and paragneiss on a large scale, but in detail it appears to be heterogeneous with evidence of possible mixing with melt derived from the host rocks. Mount Avers hosts syntectonic coarse-grained granite bodies 100s of meters in thickness (e.g. sample K6-A21B). These granites show little evidence for internal deformation, but the large-scale kinematics support models of Cretaceous oblique dextral translation (e.g. Luyendyk et al., 2003; Siddoway et al., 2005; McFadden et al., this volume). The summit of Mt. Iphigene hosts a massive body of medium-grained foliated granite (K6-I60). Xenoliths of foliated orthogneiss are common. The last granite analyzed in this study was collected from Thompson Ridge (sample K6-T35B). This granite is coarse-grained with xenoliths of residual paragneiss, and is very similar to the granodioritic gneiss at Mt. Richardson described by McFadden et al. (this volume).

Table 1. Summary of mineralogical and geochemical characteristics of the granites in the Fosdick dome

Sample no.	Location	Main mineral constituents*	K_2O (wt %)	εNd (at 100Ma)
K6-Mj01A	Marujupu Peak	Qtz, Kfs, Pl, Bt, Grt	4.7	-4.8
K6-B27	Mt. Bitgood	Qtz, Kfs, Pl, Bt, Grt, Sil	5.5	-4.2
K6-A21B	Mt. Avers	Qtz, Kfs, Pl, Bt	5.7	-4.9
K6-I60	Mt. Iphigene	Qtz, Pl, Bt	3.1	-4.3
K6-T35B	Thompson Ridge	Qtz, Kfs, Pl, Bt	2.8	-3.2

* Mineral abbreviations are after Kretz (1983)

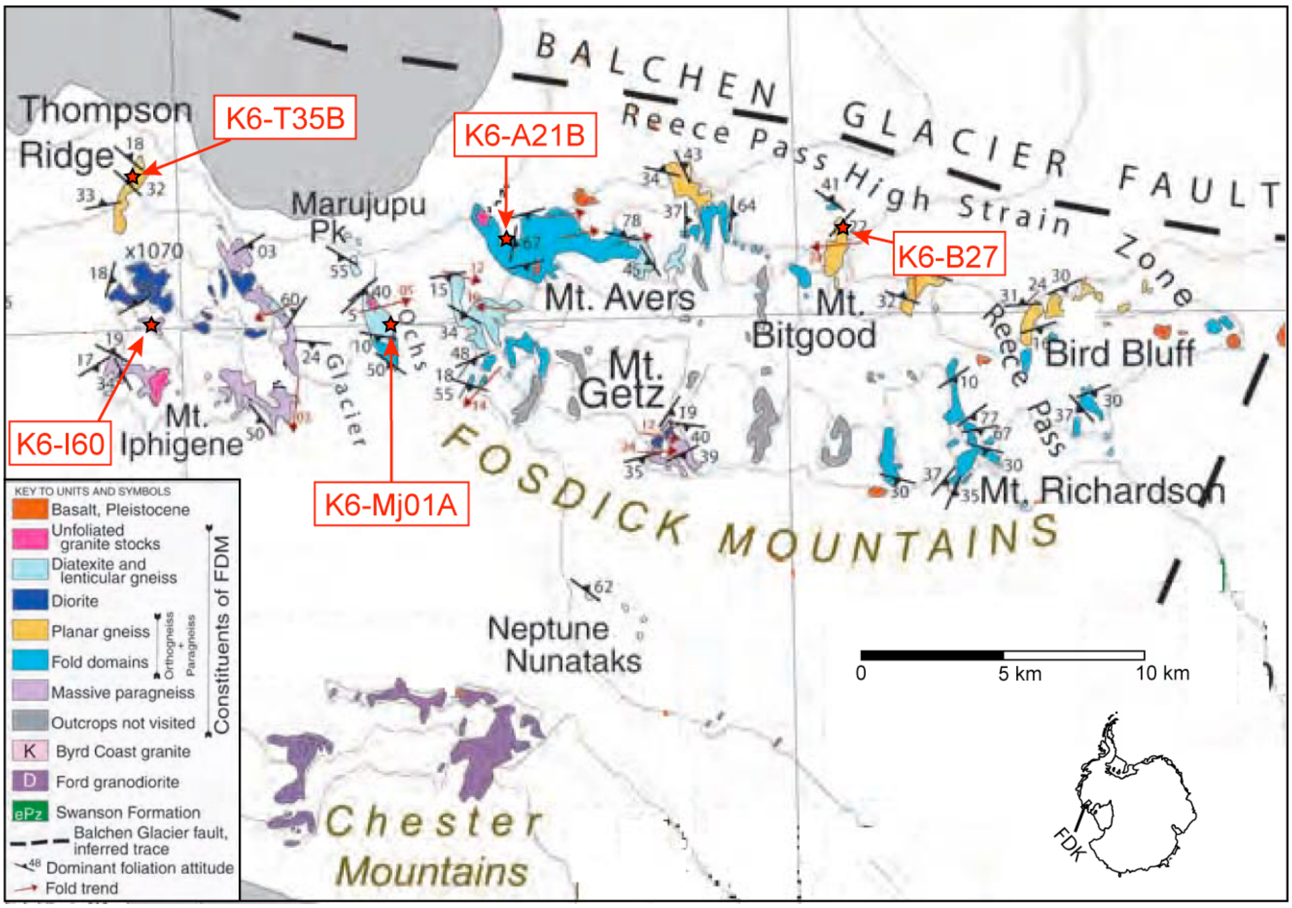

Figure 1. Sampling locations (red stars) of granites analyzed in this study (modified from Siddoway et al., 2004).

Geochemistry

We have obtained XRF whole-rock major and trace element compositions for paragneiss, orthogneiss and granites in the Fosdick migmatite dome (Fig. 1) as well as very low grade Swanson Formation from outside the dome. The major and trace element compositions of paragneiss and orthogneiss are comparable to those of the Swanson Formation and the Ford Granodiorite (Weaver et al., 1991), respectively, consistent with the previous interpretation about protoliths of the gneisses (Fig. 2a). The granites within the dome are silicic (71-75 wt% SiO_2) and slightly peraluminous [1.0-1.2 of alumina saturation index (A.S.I.)]. K-rich (4.7-5.7 wt %) and K-poor (2.8-3.1 wt %) types are distinguished among the granites (Table 1). In terms of normative mineralogy, the K-rich types plot in the granite field in an An-Ab-Or diagram and the K-poor types plot close to the trondhjemite and granodiorite fields (Fig. 2b).

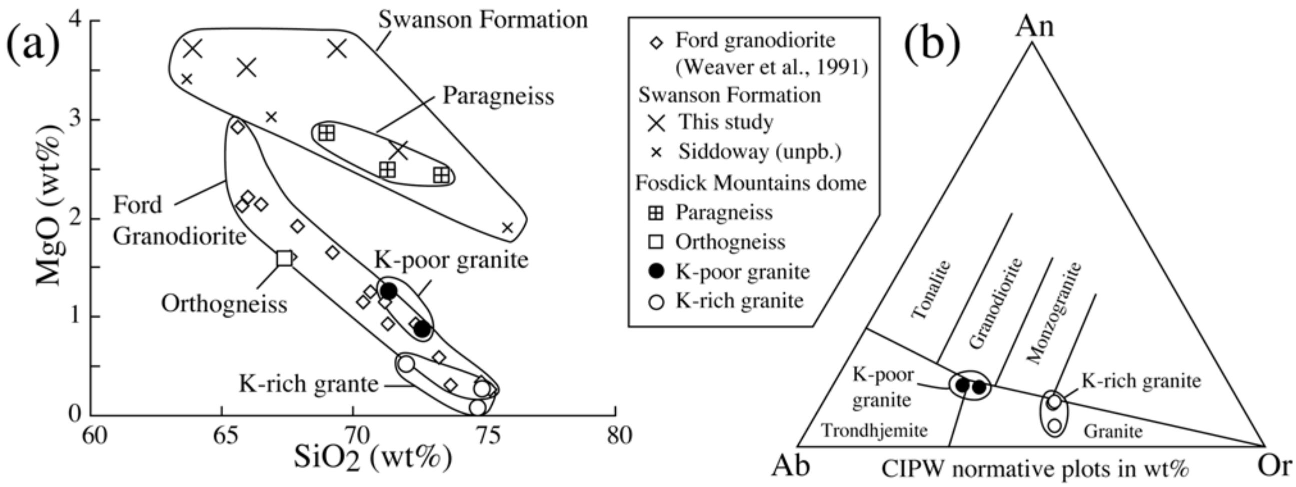

Figure 2. SiO_2 vs MgO diagram for the rocks of Fosdick dome, Ford Granodiorite and Swanson Formation (a) and An-Ab-Or normative ternary diagram of the granites in the Fosdick dome (b). Samples of Swanson Formation indicated with small x symbol come from glacial erratics from moraines in the Fosdick Mountains, whereas those with large X symbol were acquired from outcrops in the central and southern Ford Ranges.

The major element compositions of the granites are compared with experimental glasses generated from starting materials with compositions similar to the Ford Granodiorite (Skjerlie and Johnston, 1993) and the Swanson Formation (Koester et al., 2002). The experimental glass composition of Skjerlie and Johnston (1993) is comparable to the bulk chemical compositions of the K-rich granite types (Fig. 3). In contrast this glass composition has lower CaO and higher K_2O contents than the K-poor granite types (Fig. 3). The experimental glass composition of Koester et al. (2002) is characterized by higher A.S.I. (1.4-1.9) than both types of granite.

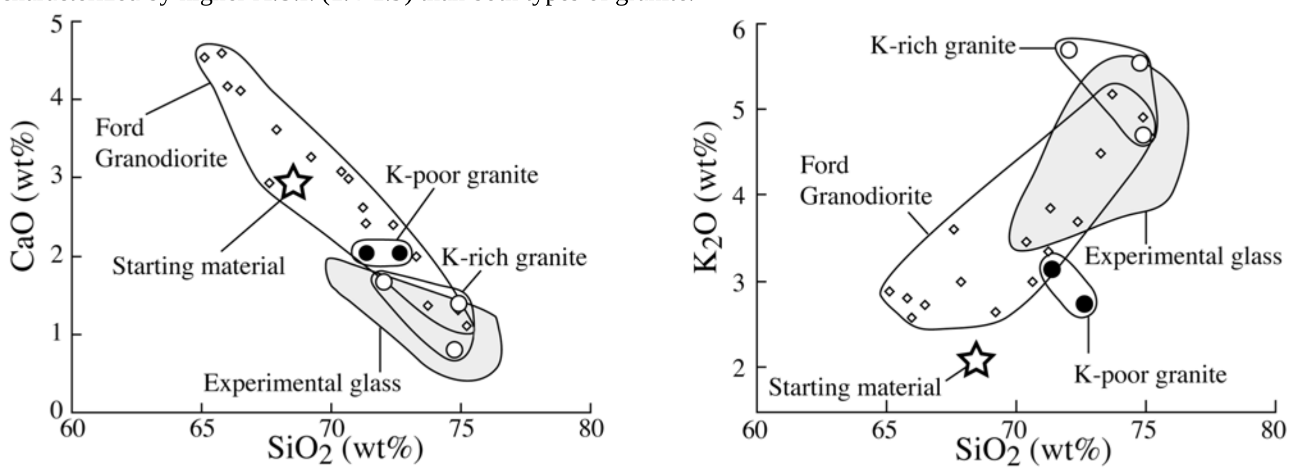

Figure 3. Comparison of granites in the Fosdick dome with experimental glass compositions of Skjerlie and Johnston (1993). Star indicates starting material composition in the experiments, which is comparable to the Ford Granodiorite. Shaded area represents experimental glass compositions.

Nd isotopes and origin of granites

The Nd isotope compositions of rocks are recalculated to 100 Ma and 365 Ma because there is evidence for high temperature metamorphism and partial melting events at these times (Siddoway et al., 2006; Korhonen et al., this volume) (Fig. 4). The εNd values of both types of granite are significantly more positive than those of Swanson Formation and paragneiss at both times, which precludes an origin of the granites by equilibrium partial melting of the Swanson Formation. The K-rich granites have εNd values comparable to those of Ford Granodiorite (Weaver et al., 1992) and orthogneiss, suggesting that the K-rich types may have formed by partial melting of the Ford Granodiorite, consistent with the geochemistry and the experimental data discussed above. The εNd values of the K-poor granites are more positive than those of Ford Granodiorite. However, partial melting of crustal sources with a high degree of Nd isotope disequilibrium is suggested as a possible process by previous studies (e.g. Zeng et al. 2005), and this process will be addressed in our future work. Additional isotope and trace element geochemistry are necessary to evaluate the origin of the K-poor types. However, our present data suggest that the K-rich granites could have been formed by partial melting of the Ford Granodiorite, which represents the protolith of the orthogneisses within the dome. Thus, the K-rich granites might represent melt crystallized during ascent through a melt transfer zone.

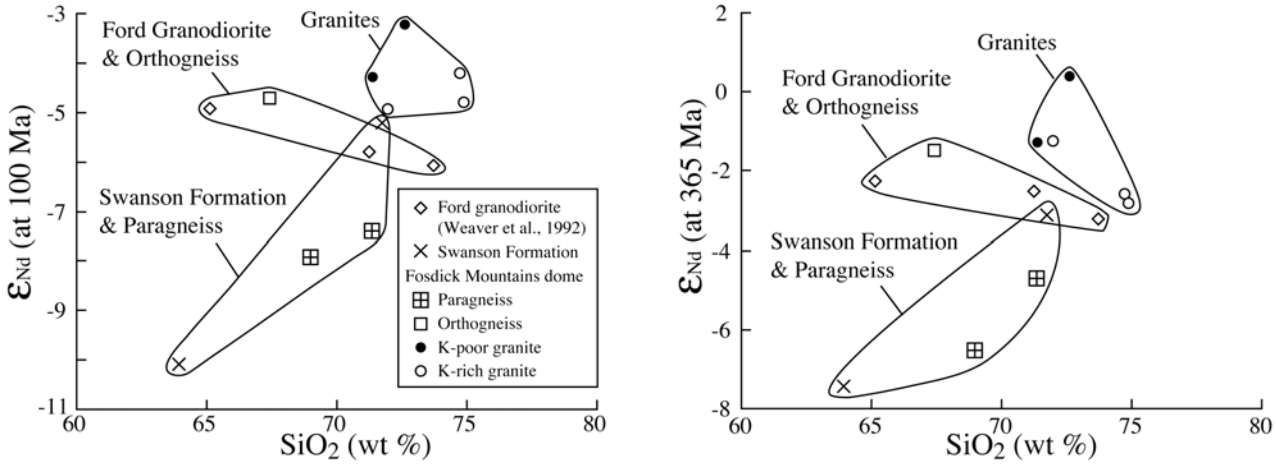

Figure 4. SiO_2-εNd diagrams calculated at 100 Ma and 365 Ma.

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