EVIDENCE FOR EARLY FORMATION OF ANORTHOSITE IN THE EVOLUTION OF ARCHEAN GREENSTONES AT PIPESTONE LAKE, MANITOBA. W. C. Phinney, D. A. Morrison, SN4/NASA Johnson Space Center, Houston, TX 77058, D. E. Maczuga, LOCKHEED, 1830 NASA Rd. 1, Houston, TX 77058 and L. D. Ashwal, Lunar and Planetary Institute, 3303 NASA Rd. 1., Houston, TX 77058

Introduction

Archean anorthosites display a unique combination of texture and composition (1) and, therefore, should provide important information about processes involved in the early development of the Earth's crust and planetary crusts in general. There are several well developed units of Archean anorthosite in northern Manitoba (2) where exposures at Pipestone Lake (3), in particular, provide excellent field and petrographic relationships that bear on these processes.

Geologic Setting

For 19 km along the south shore of Pipestone Lake a sill-like arrangement of mafic igneous rocks, including anorthosite, occurs as a one kilometer wide strip between a volcanic-sedimentary greenstone belt to the north and a series of tonalites to the south, all in upper greenschist to amphibolite grades of metamorphism. Similar relations extend eastward for at least another 25 km (4). Similar anorthositic and gabbroic rocks in higher amphibolite and granulite grades of metamorphism extend for several 10's of kilometers to the southwest of Pipestone Lake and almost certainly represent the same rock units (5). The mafic igneous rocks cannot be intrusive into their current setting, however, because they are older than the surrounding rocks. Conglomerates in the sediments of the greenstone belt immediately to the north contain pebbles of the anorthosite and the tonalites immediately to the south develop numerous dikes that intrude the gabbros and anorthosite. The mafic igneous rocks thus appear to be the oldest unit in the area.

Within the mafic igneous unit there are: (a) large included blocks of megacrystic anorthosite (Fig. 1); some with layering defined by differing proportions of megacrysts to matrix (Fig. 2), (b) intrusive gabbroic units of various felsic/mafic ratios, some with layers of oxides, and (c) tiger-striped, gneissic anorthositic gabbro which is a more sheared and crushed version of type (b). The gabbros are clearly intrusive into the blocks of megacrystic anorthosite but contain scattered individual plagioclase megacrysts which may be concentrated into thin layers (Fig. 3). These megacrysts resemble both texturally and compositionally the large megacrysts in the blocks. In addition, similar megacrysts are common in the volcanic flows and dikes of most greenstone belts throughout this entire area (6). Thus there appears to be a petrogenetic relationship between the gabbros, volcanic rocks, and anorthosite blocks. Although ages have not been determined for the anorthosites and gabbros the dating of volcanic and tonalitic rocks indicate ages for the greenstone belts of about 2.7 b.y. and older (7).

Petrography

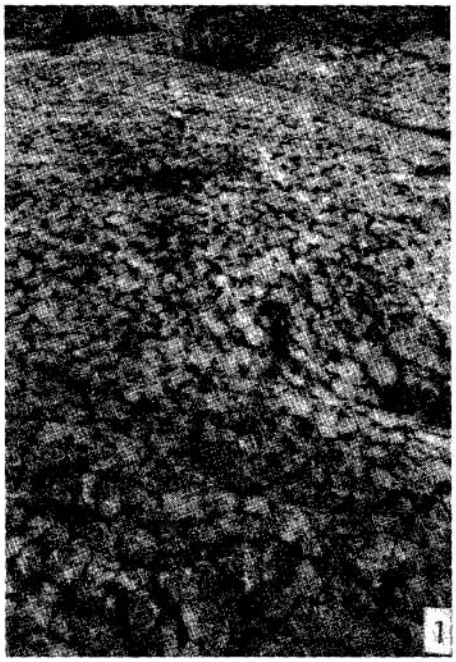
The blocks of megacrystic anorthosite consist mainly of large (generally 5 to 8 cm, but up to 10 cm), roughly equidimensional, euhedral, compositionally homogeneous plagioclase crystals that occur in a matrix consisting most commonly of mafic minerals; mainly amphibole and chlorite. Although a few similar plagioclase megacrysts occur in the gabbros, the large majority of plagioclase in the gabbro is lathy to platy and ranges from a few to several millimeters long. Mafic minerals in the gabbros are generally amphiboles and, rarely, biotite, oxides, and/or clinopyroxene. Similar but finer grained anorthositic gabbro with lathy plagioclase occurs rarely within the megacrystic blocks as thin layers (Fig. 4) or patches of matrix (Fig. 2). Varying degrees of alteration to epidote and chlorite occur in all rock types. Most textures display evidence of shearing and recrystallization but in most cases the primary texture is largely preserved. Plagioclase compositions vary systematically among major textural types. The lathy plagioclases of the gabbros are An_{50-60} whereas the large plagioclase megacrysts in the anorthosite blocks are about An_{80}. Plagioclase megacrysts in the gabbros have An_{75-80} cores with zoning from the An_{60}'s to An_{45}. Lathy plagioclase in the layers and patches of anorthositic gabbro in the megacrystic blocks is An_{63-67}.

Petrogenesis

The anorthosite inclusions are crystal segregations and not likely to represent liquids. The calcic and homogeneous compositions of the megacrysts indicate nearly isothermal crystallization. Although the blocks of megacrystic anorthosite are intruded by the gabbros there is evidence that the blocks are merely older segregations from the same parental melt that produced the gabbros. For example, anorthositic gabbro with lathy plagioclase, in a few instances, occurs as thin layers or patches of matrix in the megacrystic blocks and megacrysts similar to those in the large blocks occur occasionally within the intrusive gabbros but display thin rims that approach the more sodic compositions of the lathy plagioclase in the gabbro. Neither type of megacryst is in equilibrium with its lathy matrix plagioclases. The differences in composition between megacrysts and lathy plagioclases require significant crystal fractionation between them (8). It is also apparent from anorthositic layering in the intrusive gabbros and highly anorthositic patches of lathy gabbro in the megacrystic blocks that the lathy plagioclase component also forms crystal segregations. Thus there is a sequence: (1) isothermal crystallization to form plagioclase megacrysts in both size-sorted and unsorted units, (2) separation of plagioclase megacrysts from coprecipitating mafics, (3) significant crystal fractionation, (4) entrainment or mixing of megacrysts with the more fractionated liquid, and (5) production of lathy feldspathic gabbroic segregations. As in many other occurrences of Archean megacrystic anorthosites there are no complementary mafic segregations in the area. Furthermore, the plagioclase texture in these megacrystic blocks and in similarly textured anorthositic complexes elsewhere is not like that of plutonic gabbroic intrusions known to have fractionated within conti-

nental or oceanic crust such as the Bushveld, Stillwater, Kiglapait, Great Dike or ophiolite complexes. Also the bulk compositions of megacrystic anorthositic complexes are significantly different from those of gabbroic intrusions (1). Phinney (1) has proposed ponding of relatively dense melts at the base of the crust as a mechanism for separating mafic from felsic components. Crystallization of the ponded melt would allow the more dense mafic minerals to sink while the less dense plagioclase would float or be suspended in the melt until it is rafted upward at a later time either after fractionation has developed a lower density melt or tensional stresses and rifting have provided a means of access for the melt into the upper crust. Alternatively, separation of anorthosites from ultramafics must be done tectonically for which there is no field evidence.

The evidence from this occurrence provides further arguments for the important role of large bodies of melt in the evolution of planetary crusts and mantles, and particularly the importance of relative densities between major rock units and large masses of melt as well as between melts and fractionating crystals. Also, the complex textural relationships of multiple plagioclase segregations formed at different stages of fractionation has important implications for interpretation of processes that could produce variations in individual lunar or meteorite samples.



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