Textural Evolution of Volcanic Rocks: Investigating Magma Rheology, Petrology, and Eruptive Processes

Gabbroic Shergottite Northwest Africa 6963: An intrusive sample of Mars‡

Justin Filiberto1,*, Juliane Gross2, Jarek Trela1† and Eric C. Ferré1

1Department of Geology, Southern Illinois University, 1259 Lincoln Drive, MC 4324, Carbondale, Illinois 62901, U.S.A.
2Department of Earth and Planetary Sciences, The American Museum of Natural History, Central Park West at 79th Street, New York, New York 10024, U.S.A.

Abstract

Meteorite Northwest Africa (NWA) 6963 was classified as a basaltic shergottite based on mineralogy, but here we show that it is a gabbroic rock with a quartz-alkali feldspar intergrowth that represents a late-stage granite melt. NWA 6963 contains clinopyroxene and maskelynite grains up to 5 mm in length, with minor ferroan olivine, spinel, ilmenite, mellilitite, apatite, Fe-sulfides, and high-Si glass. NWA 6963 also contains areas of quartz and alkali-feldspar intergrowths up to ~1 mm in size. Based on mineral abundances and textural analysis, we suggest that NWA 6963 is an intrusive rock similar to a terrestrial gabbro. Infiltration of the martian crust by young gabbroic bodies would suggest that estimates of crustal composition, density, and thickness based on the surface chemistry alone would be problematic and the martian crust may be even more heterogenous than is seen from orbit alone. Investigations of crater walls, where intrusive crustal rocks would be exposed, are needed to discover the launch sites of the shergottites and the full heterogeneity of the martian crust.

Keywords: Mars, gabbro, SNC meteorite, shergottite, intrusive, micro-graphic, granite

Introduction

Martian meteorites are classified, depending on mineralogy, as shergottites, chassignites, nakhlites, and ALH84001 (McSween and Treiman 1998; Bridges and Warren 2006). Shergottites represent the largest and most diverse group of martian meteorites and are further subdivided into basaltic, olivine-phryic, and lherzolitic. Basaltic shergottites are dominated by clinopyroxene and plagioclase with no forsteritic olivine (McSween 1994; Goodrich 2002; Treiman 2003; Bridges and Warren 2006). Those shergottites containing forsteritic olivine are classified as olivine-phryic shergottites (McSween 1994; Goodrich 2002; Treiman 2003; Bridges and Warren 2006). Both basaltic and ol-phryic shergottites are thought to be extrusive rocks similar to terrestrial basalts (McSween 1994; Zuber et al. 2000; Bridges and Warren 2006; Gross et al. 2011). Lherzolitic shergottites are coarse-grained olivine-pigeonite cumulate rocks and are intrusive in nature (Goodrich 2002; Bridges and Warren 2006). Shergottites are also classified based on rare earth element bulk chemistry and isotopic signatures into enriched, intermediate, and depleted categories (Jones 1989, 2003; Treiman 2003; Bridges and Warren 2006; Filiberto et al. 2012). Shergottite NWA 6963 has previously been classified as an enriched basaltic shergottite (Meteoritical Bulletin 2013; Wilson et al. 2012), but based on mineral abundances, textural analysis, and quartz-alkali feldspar intergrowths, we suggest it represents an intrusive rock similar to a terrestrial gabbro.

* E-mail: filiberto@siu.edu
† Present address: Virginia Tech, Department of Geosciences, 4044 Derring Hall (0420), Blacksburg, Virginia 24061, U.S.A.
‡ Special collection papers can be found on GSW at http://ammin.geoscienceworld.org/site/misc/specialissuelist.xhtml.

Samples and Methods

Meteorite Northwest Africa (NWA) 6963 was found at an undisclosed location in Morocco in 2011, represents numerous partly fusion-crusted broken stones that together make up 8–10 kg (Meteoritical Bulletin 2013), and was classified as a martian shergottite meteorite based on its bulk composition, mineral chemistry, and oxygen isotopes (Wilson et al. 2012). For this study we purchased a 1.201 g part slice of the meteorite from Martin Altmann and Stefan Ralew of “Chladni’s Heirs,” cut and polished a section of it into a thick section, and confirmed that it matched the mineralogy and textural description in the meteoritical bulletin (Meteoritical Bulletin 2013). Backscattered electron (BSE) images and X-ray element maps were taken with the Cameca SX100 electron microprobe (EMP) at the American Museum of Natural History (AMNH). The BSE images and X-ray element maps were used to determine the textural characteristics and the modal mineral abundance of this sample using techniques described by Maloy and Treiman (2007).

Comparison with Terrestrial and Lunar Gabbros

Mineralogy

Mineralogically, NWA 6963 is composed of 65 ± 5% pyroxene (25 ± 5% augite and 40 ± 5% pigeonite), 30 ± 5% maskelynite (shocked plagioclase), with minor ferroan olivine, spinel, ilmenite, mellilitite, apatite, Fe-sulfides, and quartz-alkali feldspar intergrowths, which is similar to many basaltic shergottites (e.g., McSween 1994; McSween and Treiman 1998; Bridges and Warren 2006). The two pyroxenes are in equilibrium and give a high-temperature crystallization of ~1250 °C and low temperature of ~1000 °C calculated from Andersen et al. (1993). Olivine is fayalitic (~Fo80) suggesting that this mineral was a late-stage crystallization product.

Terrestrial gabbros are typically composed of 30–75% plagioclase, 15–50% clinopyroxene with minor magnetite, amphibole, biotite, chrome-spinel, olivine, and/or quartz (e.g., Carmichael et al. 1974; Hopper and Smith 1996; O’Driscoll et al. 2008), which is similar to NWA 6963. However, NWA 6963 contains