Lithos 284–285 (2017) 545–559

Contents lists available at ScienceDirect

Lithos

journal homepage: www.elsevier.com/locate/lithos

Neoproterozoic Rosetta Gabbro from northernmost Arabian–Nubian Shield, south Jordan: Geochemistry and petrogenesis

Ghaleb H. Jarrar [a,*], Robert J. Stern [b], Thomas Theye [c], Najel Yaseen [a], Victoria Pease [e], Nathan Miller [f], Khalil M. Ibrahim [d], Cees W. Passchier [g], Martin Whitehouse [h]

[a] Geology Department, The University of Jordan, P.O. Box 13633, 11942 Amman, Jordan
[b] Geosciences Department, U. Texas at Dallas, ROC 2.1, 800 W. Campbell Rd, Richardson, TX 75080, USA
[c] Institut fuer Mineralogie und Kristallchemie, Universtität Stuttgart, Azenberg 18, D-70174 Stuttgart, Germany
[d] Department of Earth Sciences and Environment, The Hashemite University, Zarqa, Jordan.
[e] Department of Geological Sciences, Stockholm University, SE-10691 Stockholm, Sweden
[f] The University of Texas at Austin, Jackson School of Geosciences, 2275 Speedway Stop C9000, Austin, TX 78712-172, USA
[g] Institute of Geological Sciences, Johannes-Gutenberg University, Mainz, Germany
[h] Swedish Museum of Natural History, Box 50007, SE-10405 Stockholm, Sweden

ARTICLE INFO

Article history:
Received 12 January 2017
Accepted 15 May 2017
Available online 21 May 2017

Keywords:
Appinite
Rosetta Gabbro
Water-rich magma
Amphibole microchemistry
LA–ICP-MS
Arabian–Nubian shield

ABSTRACT

An Ediacaran mafic intrusion of south Jordan is a distinctive appinitic igneous rock with a possibly unique texture, characterized by spherical clots up to 40 mm in diameter composed of amphibole cores from which plagioclase euhedra radiate; we call it the Rosetta Gabbro. It is exposed as a small (ca. 750 m^2) outcrop in the Neoproterozoic basement of south Jordan. A second outcrop of otherwise similar gabbro is located about 400 m to the north of the Rosetta Gabbro, but it lacks the distinctive texture. The Rosetta Gabbro could represent a magma pipe. It intrudes the Aqaba Complex (~600 Ma) granitoids and metasediments of the Janub Metamorphic Complex (633–617 Ma). The gabbro is an Ol- to QZ tholeiite with the following chemical characteristics: SiO_2 = 46.2–47.8 wt.%; Al_2O_3 = 16.4–17.7 wt.%, TiO_2 = 1.70–2.82 wt.%, Na_2O = 1.27–2.83 wt.%. K_2O = 0.82–1.63 wt.%; Mg# 58–63; Σ REE = 70–117 ppm; La/Yb ~6 to 8; and Eu/Eu* = 1.05–1.2. The investigated gabbro has the geochemical features of a continental flood tholeiitic basalt emplaced in a within-plate tectonic setting. Two varieties of amphiboles are found: 1) large, 3–5 mm, brown ferri-titanian-tschermakite $(K_{0.09}Na_{0.28})(Na_{0.20}Ca_{1.80})(Mn_{0.04}Fe^{3+}{}_{1.1}Mg_{2.34}Fe^{2+}{}_{0.90}Ti_{0.29}Al_{0.22})(Al_{1.85}Si_{6.15})O_{22}(OH)_{1.95}$ of the calcic amphibole group which is riddled with opaques; and 2) acicular yellowish-light green ferrian-magnesiohornblende $(K_{0.04}Na_{0.153})(Ca_{1.755}Na_{0.245})$ $(Fe^{3+}{}_{0.66}Mn_{0.01}Fe^{2+}{}_{1.01}Mg_{3.03}Ti_{0.06}Al_{0.22})(Al_{1.03}Si_{6.97})O_{22}(OH)_{1.95}$. Scattered flakes of phlogopite also occur. Tabular radiating plagioclase ($An_{64–79}$) are complexly twinned, with broad lamellae that show no zoning. Laser-ablation ICP-MS analyses of amphibole and plagioclase reveal considerable variation in trace element abundance, in spite of more subtle major element variations except for TiO_2 in amphibole. The REE in the amphibole shows an order of magnitude variation with a concave-downward pattern and a positive Eu anomaly Eu/Eu* = 0.6–2, though far less pronounced compared to the Eu/Eu* = 5–45 of plagioclase. The 3D dandelion-like texture of the rosettas is broadly similar to "Chrysanthemum Stone", which is a diagenetic growth in sedimentary rock, but we can find no description of similar textures in igneous rocks. The formation of the rosettas is thought to reflect loss of magmatic water resulting in supersaturation of plagioclase, which grew rapidly around amphibole and may have floated in the magma. This implies magmatic evolution in shallow (10 to 12 km deep) crust where temperatures were nevertheless in the range of ca. 750 to 900 °C.

1. Introduction

The Neoproterozoic basement complex of Jordan forms the northernmost extremity of the Arabian–Nubian Shield (ANS) and crops out over an area of about 1400 km^2 east, northeast and north of the Gulf of Aqaba as far as the southern shore of the Dead Sea (Fig. 1A) (Bender, 1968). The ANS is one of the largest exposures of juvenile continental crust that has been formed as a consequence of plate tectonic processes. It evolved as the northern segment of the Neoproterozoic East African Orogen (EAO, 900–530 Ma) that extends from south to north for about 6000 km (Stern, 1994). It is generally regarded as a collage of juvenile volcanic arc terrains and associated ophiolite remnants which were amalgamated during the assembly of Gondwana (e.g. Johnson et al., 2004; Meert, 2003; Stern, 1994). During the East African Orogeny, the ANS experienced multiphase deformation and

* Corresponding author.
E-mail address: jarrargh@ju.edu.jo (G.H. Jarrar).

http://dx.doi.org/10.1016/j.lithos.2017.05.008
0024-4937/

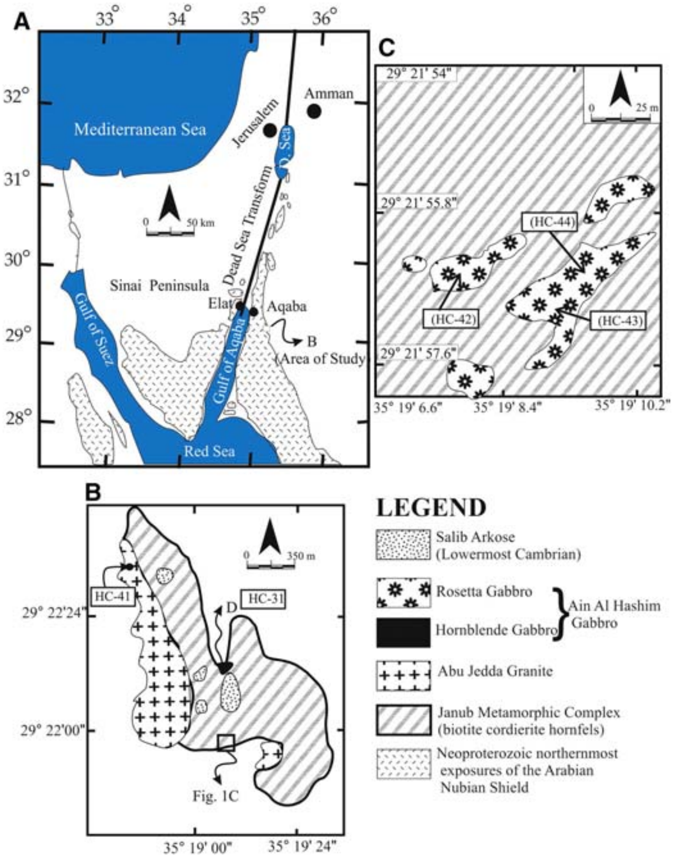

Fig. 1. A. The northernmost outcrops of the Arabian–Nubian Shield. B. Part of the Janub Metamorphic Complex which hosts the investigated gabbroic stocks (Ain Alhashim gabbro). C. A detailed map of the Rosetta Gabbro locality. The gabbroic bodies shown in B and C are not mappable at the scale of Ayn-Al Hashim map (map 3048I; scale 1:50,000); thus they were not shown on this map.

metamorphism, ranging in grade from greenschist to upper amphibolite facies conditions (e.g. Abu-El-Enen and Whitehouse, 2013; Jarrar et al., 2013a). This was accompanied and followed by extensive plutonic and subordinate volcanic activity (Jarrar et al., 2003).

We document an interesting new occurrence of appinites from the ANS of southernmost Jordan. Appinite is defined as including melanocratic hornblende-rich syenite, monzonite, or diorite. In a recent review, Murphy (2013) discussed the role of water in the generation, emplacement, and crystallization history of mafic to felsic magmas and noted that a common feature of appinites is that they reflect crystallization from unusually water-rich mafic magmas. Appinites occur as stocks, pipes, dikes and sills and commonly form soon after the cessation of subduction. These rocks are genetically related to hornblendites and spessartite lamprophyres. Murphy (op.cit) suggested a broader definition for appinite suites as "a group of coeval plutonic and or hypabyssal rocks, ranging from ultramafic to felsic in composition, in which hornblende is the dominant mafic mineral and typically occur both as large prismatic phenocrysts and in the finer grained matrix".

The Rosetta Gabbro of southernmost Jordan is an appinite, but one with an unusual spheroidal texture that has not previously been reported. Spheroidal textures, generally referred to as globules, orbs, ocelli, varioles, and rapakivi are reported from diverse igneous lithologies; nevertheless, their origins remain a matter of debate (e.g. Ballhaus et al., 2015 and references therein). Liquid immiscibility has been advocated as a mechanism to explain spheroidal textures in some igneous rocks. Ballhaus et al. (2015) proposed that globular and orbicular textures my result from exsolution of a fluid phase at elevated temperature and pressure from H_2O saturated mafic magmas.

We present new field observations and U–Pb zircon geochronology which constrain the age of the Rosetta Gabbro. In addition, petrography, major, trace and rare element chemistry, including laser ablation inductively coupled plasma mass spectrometric (LA–ICP-MS) mineral chemistry of amphibole and plagioclase, are used to evaluate the Rosetta Gabbro appinitic suite along with its peculiar magmatic texture. The major and trace element compositions of the whole rocks and constituent minerals are used to constrain how the Rosetta Gabbro formed. Our results contribute to understanding the diversity of igneous structures and textures and how these form in water-rich mafic magmas.