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Petrogenesis and tectonic implications of Late Carboniferous A-type granites and gabbronorites in NW Iran: Geochronological and geochemical constraints

Hadi Shafaii Moghadam [a,b,*], Xian-Hua Li [a], Xiao-Xiao Ling [a], Robert J. Stern [c], Jose F. Santos [d], Guido Meinhold [e], Ghasem Ghorbani [b], Shirin Shahabi [b]

[a] State Key Laboratory of Lithospheric Evolution,, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100029, China
[b] School of Earth Sciences, Damghan University, Damghan 36716-41167, Iran
[c] Geosciences Dept., University of TX at Dallas, Richardson, TX 75083-0688, USA
[d] Geobiotec, Departamento de Geociências, Universidade de Aveiro, 3810-193 Aveiro, Portugal
[e] Geowissenschaftliches Zentrum der Universität Göttingen, Goldschmidtstraße 3, D-37077 Göttingen, Germany

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ABSTRACT

Carboniferous igneous rocks constitute volumetrically minor components of Iranian crust but preserve important information about the magmatic and tectonic history of SW Asia. Ghushchi granites and gabbronorites in NW Iran comprise a bimodal magmatic suite that intruded Ediacaran–Cambrian gneiss and are good representatives of carboniferous igneous activity. Precise SIMS U–Pb zircon ages indicate that the gabbronorites and granites were emplaced synchronously at ~320 Ma. Ghushchi granites show A-type magmatic affinities, with typical enrichments in alkalis, Ga, Zr, Nb and Y, depletion in Sr and P and fractionated REE patterns showing strong negative Eu anomalies. The gabbronorites are enriched in LREEs, Nb, Ta and other incompatible trace elements, and are similar in geochemistry to OIB-type rocks. Granites and gabbronorites have similar $\varepsilon_{Nd}(t)$ (+1.3 to +3.4 and −0.1 to +4.4, respectively) and zircon $\varepsilon_{Hf}(t)$ (+1.7 to +6.2 and +0.94 to +6.5, respectively). The similar variation in bulk rock $\varepsilon_{Nd}(t)$ and zircon $\varepsilon_{Hf}(t)$ values and radiometric ages for the granites and gabbronorites indicate a genetic relationship between mafic and felsic magmas, either a crystal fractionation or silicate liquid immiscibility process; further work is needed to resolve petrogenetic details. The compositional characteristics of the bimodal Ghushchi complex are most consistent with magmatic activity in an extensional tectonic environment. This extension may have occurred during rifting of Cadomian fragments away from northern Gondwana during early phases of Neotethys opening.

1. Introduction

A-type granites are generated in post-collisional and anorogenic settings associated with alkaline-type mafic rocks (Bonin, 2007; El Dabe, 2013). These occur mostly as bimodal magmatic suites accompanying post-collisional extension and/or anorogenic rifting (Bonin, 2004; Eby, 1992). Eby (1990) subdivided A-type granites into two groups according to their tectonic setting and chemistry; 1 — A_1 granites are fractional crystallization products of OIB-like mafic melts associated with intraplate settings or continental rifts; 2 — A_2 granites are partial melting products of juvenile continental crust and are commonly associated with post-collisional extension.

Large volumes of igneous rocks were emplaced as a result of Late Paleozoic subduction beneath Eurasia, which was followed by post-collisional high-temperature–low pressure (HT–LP) metamorphism and magmatism (Stampfli and Borel, 2002; von Raumer et al., 2009). Granites – especially A-type granites – are an important manifestation of this Late Paleozoic 'Hercynian' magmatism. Late Paleozoic alkaline rocks and A-type granites occur in the Eastern Pontides–Lesser Caucasus and NW Iran and give important clues on the geodynamic evolution of these regions during Carboniferous–Permian time (Fig. 1) (e.g., Okay et al., 2001; Topuz et al., 2010; Topuz et al., 2007; Rolland et al., 2011; Rolland et al., 2009). Late Paleozoic magmatism in Turkey is distributed mainly in Sakarya and in the Eastern Pontides (Dokuz et al., 2011; Meinhold et al., 2008; Okay et al., 1999, 2008). The Eastern Pontides contain numerous Hercynian domains, characterized by HT–LP metamorphic rocks (Dokuz et al., 2011; Topuz et al., 2010).

The Iran–Anatolia region is a tectonically active plateau between the converging Arabian and Eurasian plates, which grew as a result of the northward subduction of the Neotethys Ocean beginning in Late Cretaceous time followed by collision between the two plates beginning in Miocene time (Berberian and King, 1981; Chiu et al., 2013; Moghadam

* Corresponding author at: Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100029, China. Tel.: +86 10 82998443; fax: +86 10 62010846.
E-mail address: hadishafaii@mail.iggcas.ac.cn (H.S. Moghadam).

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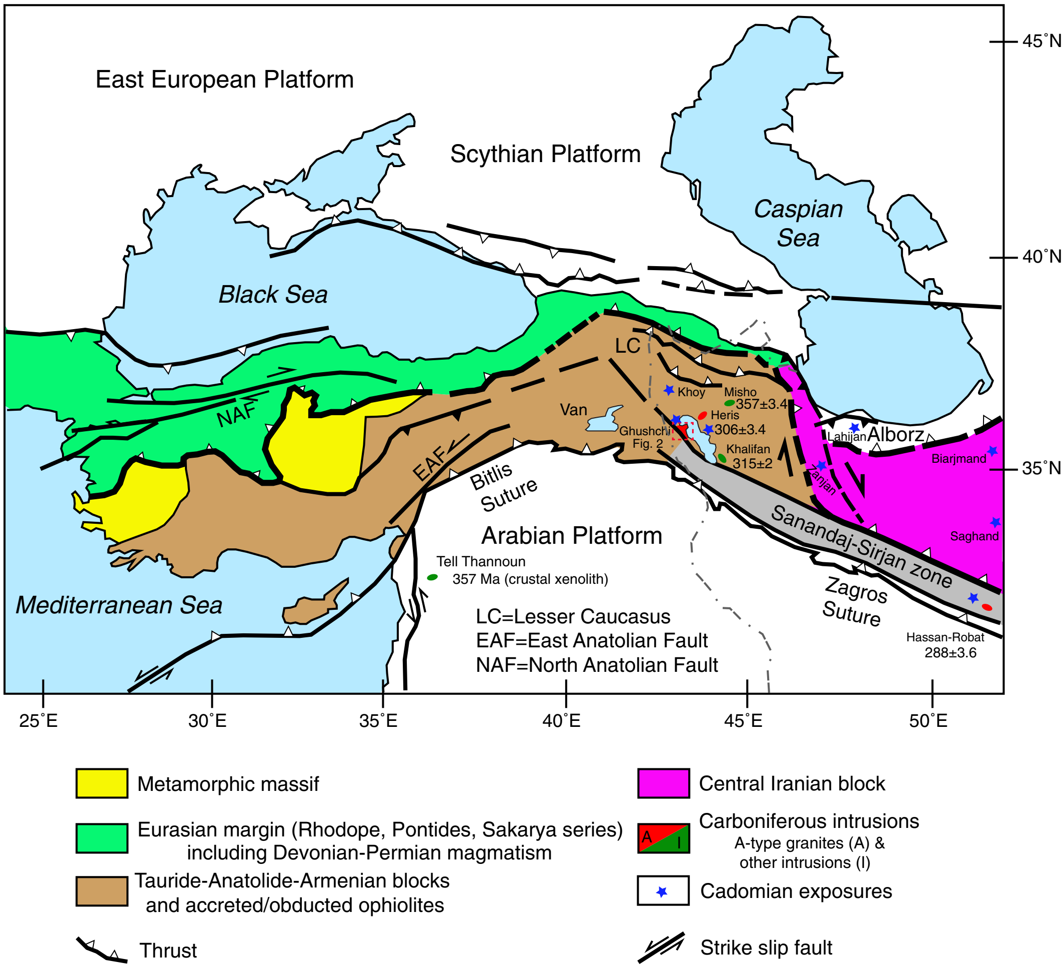

Fig. 1. Sketch geological map of the Caucasus–Turkey and NW Iran regions with emphasis on the distribution of Hercynian magmatism (modified after Rolland et al., 2011).

et al., 2014a). Because of abundant younger rocks (mostly due to Cenozoic volcanism and sedimentation) in Iran, Late Paleozoic igneous rocks are rarely exposed except rare plutons in NW Iran such as Khalifan, Hassan-Robat and Heris granitoids and the mafic Misho intrusion (Fig. 1) (Advay and Ghalamghash, 2011; Alirezaei and Hassanzadeh, 2012; Bea et al., 2011; Saccani et al., 2013) (Fig. 1).

In this paper we present the first detailed petrologic and geochronologic study of an excellent representative of Late Paleozoic igneous activity in the region: the Ghushchi intrusive complex of NW Iran. Our studies include: 1) a detailed investigation of A-type granite and associated OIB-like gabbronorite in terms of mineral and whole rock geochemistry; 2) U–Pb zircon dating of intrusive rocks and their host basement rocks; and 3) bulk rock Sr–Nd and zircon Hf isotope geochemistry. Based on these results, we evaluate the petrogenesis of Late Carboniferous Ghushchi complex A-type granites and OIB-gabbronorites and explore the tectonic implications of this intrusion.

2. Geological setting

2.1. Regional geology

NW Iran and adjoining areas, including NE Turkey and Lesser Caucasus, is a complex zone with a core of Late Neoproterozoic–Early Cambrian crust (ca. 500–600 Ma). These "Cadomian" fragments are stitched together by Paleozoic and Mesozoic sutures and covered by huge expanses of Cenozoic volcanic rocks (Shafaii Moghadam and Stern, 2014).

Northern Iran–southern Eurasia is remarkable for the presence of Paleozoic sutures and associated subduction-related magmatic rocks. In southern Eurasia, the Paleotethys Ocean opened in Early Paleozoic time and closed during Triassic time, resulting in Eo-Cimmerian deformation in northern Iran and Afghanistan followed by Middle–Late Jurassic compression (Boulin, 1991; Zanchetta et al., 2013; Zanchi et al., 2006). Paleotethys opening is reflected in widely distributed alkali to tholeiitic continental flood basalts (Soltan–Meidan basalts), felsic–mafic plutons (with ages of ca. 460 Ma; Shafaii Moghadam and Stern, 2014) and dolomites, evaporites and terrigenous sediments in the Ordovician Ghelli to Lower Devonian Padeha Formations of northern Iran (Aharipour et al., 2010; Stampfli et al., 2001). New zircon U–Pb dating of Masshad 'ophiolite' in NE Iran also reveals evidence of Paleotethys subduction during Devonian time; ca. 380–382 Ma (Moghadam et al., 2014b).

The study area in NW Iran consists of Cadomian basement, Paleozoic platform sediments, and Paleozoic to Triassic igneous rocks, like the geologic succession of central Iran (Alavi, 1991; Berberian and King, 1981). The Late Neoproterozoic Kahar Formation consisting of metasediments and meta-igneous (felsic) rocks is common in NW Iran, Central Iran, as well as in the Alborz and Sanandaj–Sirjan Zones, and is overlain by Cambrian–Ordovician sedimentary rocks including (from bottom to top) (Berberian and King, 1981): (1) Cambrian Soltanieh dolomites with sandstone intercalations; (2) Cambrian Barut sandstones; (3) Ordovician Zagun–Lalun sandstones and quartzites; and (4) Ordovician Mila sandy limestones with shales and marls.

Ediacaran–Cambrian (Cadomian) metamorphosed igneous rocks (orthogneisses) and meta-sediments are also present in NW Iran. The trace of Early Carboniferous rifting to open Neotethys is also recorded