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Age and petrogenesis of Na-rich felsic rocks in western Iran: Evidence for closure of the southern branch of the Neo-Tethys in the Late Cretaceous

Fatemeh Nouri [a], Hossein Azizi [b,*], Jan Golonka [c], Yoshihiro Asahara [d], Yuji Orihashi [e], Koshi Yamamoto [d], Motohiro Tsuboi [f], Ryo Anma [g]

[a] Geology Department, Faculty of Basic Sciences, Tarbiat Modares University, Tehran, Iran
[b] Mining Departments, Faculty of Engineering, University of Kurdistan, Sanandaj, Iran
[c] AGH University of Science and Technology, Faculty of Geology, Geophysics and Environmental Protection, Al. Mickiewicza 30, 30-059 Krakow, Poland
[d] Department of Earth and Environmental Sciences, Graduate School of Environmental Studies, Nagoya University, Nagoya 464-8601, Japan
[e] Earthquake Research Institute, University of Tokyo, Tokyo 113-0032, Japan
[f] Department of Applied Chemistry for Environment, School of Science and Technology, Kwansei Gakuin University, Sanda 669-1337, Japan
[g] Graduate School of Life and Environmental Sciences, University of Tsukuba, Ibaraki 305-8572, Japan

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ABSTRACT

Intermediate to felsic volcanic and granitic rocks with high Na_2O concentrations (5.2–9.1 wt.%) are widely distributed in the Harsin area along the Zagros thrust zone in western Iran. Most of these rocks are classified as low-potassium tholeiite, display affinity with oceanic plagiogranite and contain somewhat high Na content and low concentrations of K_2O, Al_2O_3, Rb, Sr and Ca. Thus, we prefer to apply the term Na-rich felsic rocks to this complex. U–Pb dating yielded ages of 94.6 ± 2.7 Ma (2σ) from baddeleyite and 95.0 ± 2.4 Ma (2σ) from zircon grains, indicating that the complex crystallized in the Late Cretaceous. Based on the mineral compositions, the crystallization occurred at low pressures (mostly <2 kbar) and low temperatures (<750 °C). High initial ratios of $^{143}Nd/^{144}Nd$ (0.51288–0.51304) and positive values of εNd(t) (+7.0 to +11.5) are consistent with those of mid-oceanic ridge basalt (MORB). During collision of the Arabian plate and Biston-Avoraman block in the Late Cretaceous, an increasing geothermal gradient was responsible for partial melting of altered mafic rocks and for producing the Na-rich felsic rocks in the Harsin area. The presence of these types of rocks along the main Zagros fault indicates local collisions. These collisions were caused by southwestward subduction under the Arabian plate in the southern branch of the Neo-Tethys. This event was the first stage of the Zagros collision, which was followed by collision of the Arabian and Iranian plates during the Eocene through Neogene.

1. Introduction

Volcanic and plutonic rocks of intermediate to felsic composition are concentrated in the upper continental crust and along active continental margins, although minor amounts of felsic rocks have been reported in oceanic basins (Malpas, 1979; Aldiss, 1981; Niu et al., 2002; Koepke et al., 2004, 2005, Koepke et al., 2007; Wilson et al., 2006; Wanless et al., 2010; Wolff et al., 2013). Various mechanisms have been proposed for the emplacement of felsic rocks in oceanic basins: (1) magma differentiation (Coleman and Donato, 1979; Aldiss, 1981; Lippard et al., 1986; Niu et al., 2002), (2) partial melting of gabbroic rocks (Malpas, 1979; Gerlach et al., 1981; Spray and Dunning, 1991; Koepke et al., 2004, 2005, Koepke et al., 2007; Wolff et al., 2013), (3) magma immiscibility (Philpotts, 1982; Sato, 1978; Ulrich and Borsien, 1996; Natland and Natland and Dick, 2001), (4) assimilation and partial melting (Michael and Schilling, 1989; Wilson et al., 2006), (5) mixing of released and residual melts (Wanless et al., 2010), and (6) melting of low-K tholeiite (Nakajima and Arima, 1998).

Mafic and ultramafic rocks dominate the Zagros suture zone in western Iran as a remnant of Neo-Tethys branches (Fig. 1 a, b). These rocks are referred to as the Zagros ophiolites (Stöcklin, 1968; Ricou, 1971; Delaloye and Desmons, 1980; Desmons and Beccaluva, 1983; Berberian, 1995; Agard et al., 2005; Allahyari et al., 2014). Based on the distribution of these ophiolites, the main Zagros fault (MZF) is regarded as a suture zone between the Arabian and Iranian plates (Stöcklin, 1968, 1974; Ricou, 1971; Braud, 1980; Delaloye and Desmons, 1980; Desmons and Beccaluva, 1983; Berberian, 1995; Agard et al., 2005; Paul et al., 2006; Shafaii Moghadam and Stern, 2011; Mouthereau et al., 2012; Whitechurch et al., 2013; Allahyari et al., 2014).

However, a large volume of mainly felsic volcanic, sub-volcanic and granitic rocks crop out near the northern side of the Gamassiab River in

* Corresponding author. Tel.: +98 871 6660073.
E-mail address: Azizi1345@gmail.com (H. Azizi).

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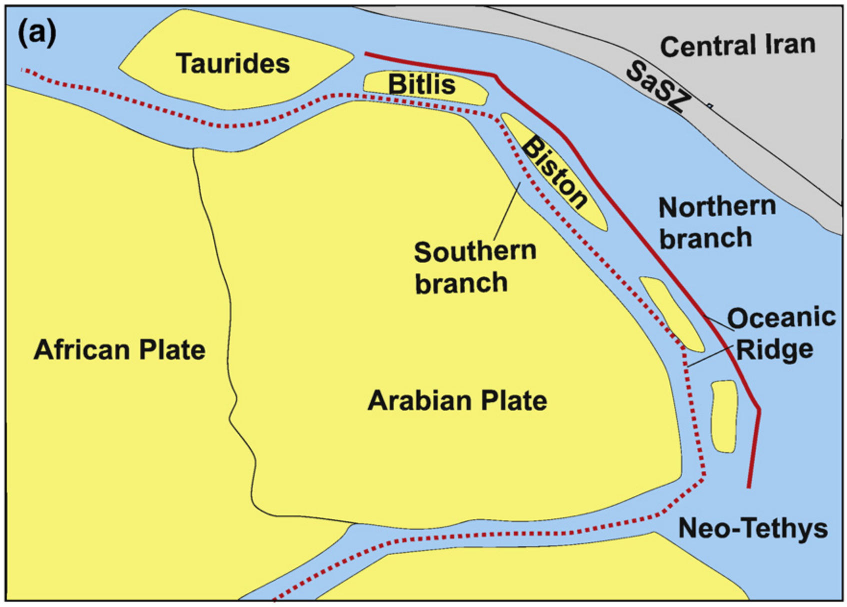

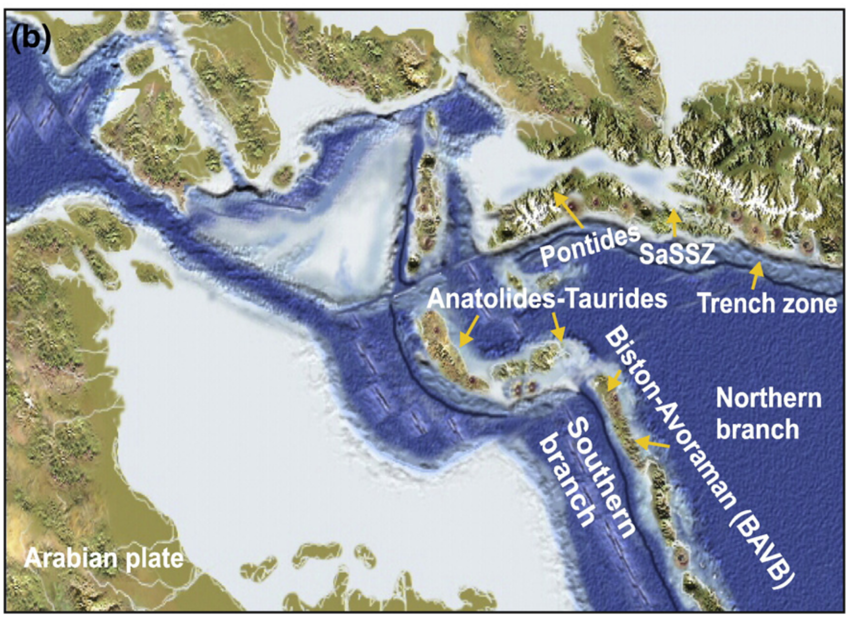

Fig. 1. (a) Simplified paleogeographic map of the Neo-Tethys in the Early Cretaceous. The Taurides–Anatolides and Biston-Avoraman blocks are shown as separate continental blocks in the Neo-Tethys Ocean (modified from Jassim and Goff (2006); Topuz et al. (2013)). (b) Mediterranean paleogeography during the Early Cretaceous (110 Ma), modified after http://jan.ucc.nau.edu/~rcb7/globaltext.html. The Anatolides–Taurides (AT) block and Biston–Avoraman block (BAVB) extended northwest-southeast between the northern and southern Neo-Tethys branches. During this period, the Sanandaj Sirjan Zone (SaSZ) and Pontides formed active zones in the northern Neo-Tethys branch.

Harsin (Figs. 2b and 3). Braud (1978), as shown on the geologic map of Kermanshah, classified these rocks as Eocene gabbro and dioritic rocks, and Shahidi and Nazari (1997) believed these rocks to be part of a Zagros ophiolite complex that originated in a mid-ocean ridge during the Cretaceous Period (Fig. 3). However, Braud (1978); and Shahidi and Nazari (1997) did not report the chemical compositions, ages and descriptions of these rocks. Our field and laboratory research shows that these rocks are mainly to felsic volcanic-subvolcanic and granitic rocks without any relation to the Zagros ophiolite. They were exhumed along the Zagros suture zone near the northern Gamassiab River and were cut by gabbroic rocks near the northern Gamassiab River (Fig. 3).

High Na_2O and low K_2O concentrations characterize these rocks. They are likely to be related to plagiogranite and quartz keratophyre or keratophyric rocks (Brown et al., 1979; Leo, 1985; Li et al., 1990; Savu, 2011) in an ophiolite complex that were produced by partial melting of hydrated gabbros (Malpas, 1979; Gerlach et al., 1981; Spray and Dunning, 1991; Koepke et al., 2004, 2005, Koepke et al., 2007; Wolff et al., 2013). However, the large volume of felsic rocks and a chemical composition that differs from normal plagiogranite in an oceanic ridge, which were reported in the Tethys ophiolite (Amri et al., 1996; Borsi et al., 1996; Floyd et al., 1998; Luchitskaya et al., 2005; Jiang et al., 2008; Rollinson, 2009), indicate another possibility for the source and evolution of these rocks in the Zagros suture zone.

The field relationships, chemical compositions, ages and tectonic setting of these rocks are the subject of this study. The goals of this study, therefore, were (1) to report the absolute U–Pb dating of rare minerals such as baddeleyite and heavy minerals such as zircon and apatite; (2) to report the geochemistry and tectonic setting of these rocks based on new data from the mineral chemistry, whole-rock chemical compositions and isotope ratios and (3) to propose a new geodynamic