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Provenance of Neoproterozoic sedimentary basement of northern Iran, Kahar Formation

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ABSTRACT

This article presents new data to understand the nature of the hidden crystalline basement of northern Iran and the tectonic setting of Iran during late Neoproterozoic time. The siliciclastic-dominated Kahar Formation represents the oldest known exposures of northern Iran and comprises late Ediacaran (ca. 560–550 Ma) compositionally immature sediments including mudrocks, sandstones, and conglomerates. This work focuses on provenance of three well preserved outcrops of this formation in Alborz Mountains: Kahar Mountain, Sarbandan, and Chalus Road, through petrographic and geochemical methods. Mineralogical Index of Alteration (MIA) and Chemical Index of Alteration (CIA-after correction for K-metasomatism) values combined with A–CN–K relations suggest moderate weathering in the source areas. The polymictic nature of Kahar conglomerates indicates a mixed provenance for them. However, modal analysis of Kahar sandstones (volcanic to plagioclase-rich lithic arkose) and whole rock geochemistry of mudrocks suggest that they are largely first-cycle sediments and that their sources were remarkably late Ediacaran, intermediate-felsic igneous rocks from proximal arc settings. Tectonic setting discrimination diagrams also indicate a convergent plate margin and continental arc related basin for Kahar sediments. This interpretation is supported by the phyllo-tectic to tectic composition and geochemistry of mudrocks. These results reveal the presence of a felsic/intermediate subduction-related basement (~600–550 Ma) in this region, which provides new constraints on subduction scenario during this time interval in Iran, as a part of the Peri-Gondwanan terranes.

1. Introduction

The tectonic evolution of Iran during the late Neoproterozoic time has been a matter of hot debate. The conventional model proposes late Neoproterozoic-Early Cambrian extension with possible rifting of peri-Gondwanan terranes away from Arabia and/or Iran (passive margin model; e.g., Stöcklin, 1968; Falcon, 1974; Samani, 1988; Berberian and King, 1981; Talbot and Alavi, 1996; Lasemi, 2001). The alternative model suggests a subduction zone boundary and contractional orogenic belt along the Gondwanan margin from Iran to the Himalayas (active margin model; e.g., Ramezani and Tucker, 2003; Hassanzadeh et al., 2008; Horton et al., 2008; Jamshidi Badr et al., 2013; Balaghi Einalou et al., 2014; Rossetti et al., 2015; Shafaii Moghadam et al., 2015).

Iran's oldest exposed strata consist of low metamorphic grade and immature siliciclastic rocks, collectively assigned to the "Tashk facies" (Ramezani and Tucker, 2003). The late Neoproterozoic Tashk facies is composed of a very thick series of greenish grey mudrocks and sandstones and has different names in different areas: for example the Kahar Formation in northern Iran, the Tashk Formation in central Iran, and the Morad Formation in southern Iran (Ramezani and Tucker, 2003). The lower contact of these formations is nowhere exposed (Ramezani and Tucker, 2003; Horton et al., 2008; Ghorbani, 2013). Nevertheless, little interest has been devoted to the provenance of these siliciclastic rocks; however, their provenance data can play a key role in determining the age and the nature of the hidden basement (Precambrian) rocks in Iran.

The provenance of siliciclastics can be tracked with a

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combination of mineralogical, geochemical, and radiometric (dating) methods (e.g., Bhatia, 1983, 1985a, b; Dickinson, 1985; Taylor and McLennan, 1985; Pettijohn et al., 1987; Roser and Korsch, 1988; McLennan and Taylor, 1991; Cox et al., 1995; Heins and Kairo, 2007; Etemad-Saeed et al., 2011; Armstrong-Altrin et al., 2012, 2013a, b; Armstrong-Altrin et al., 2015; Armstrong-Altrin, 2015). We present here a study of the provenance of the oldest sedimentary exposures in northern Iran, Kahar Formation. Our ultimate aim in studying the provenance of the Kahar siliciclastics is to develop further understanding of parent rocks (possibly hidden), tectonic setting of the source area and depositional basin, and also weathering in source area. For this purpose, we performed a systematic study of petrography and geochemical signatures of the Kahar siliciclastic rocks on three sections along E–W trend of the Alborz Mountains: the Kahar Mountain (type locality; Dedual, 1967), Sarbandan, and Chalus Road (Fig. 1A, B). Combining the data obtained by these diverse methods with geochronological data from previous studies provide valuable information regarding the provenance of Kahar sediments. The results can be used to clarify ambiguities about the tectonic setting of Iran during late Neoproterozoic time (passive or active margin models), and can also be helpful in the paleogeographic reconstruction of the northern margin of Gondwana.

2. Geologic framework

Although most Neoproterozoic paleogeographic reconstructions place the Iran plate along the northeastern margin of Gondwana (between Arabia and India plate; e.g., Stampfli and Borel, 2004), the question of Gondwanan or Peri-Gondwanan affinity of Iran still remains open. The Iranian plateau is made up of several structural units, on the basis of stratigraphy, magmatic rock, metamorphism, and orogenic events (Stöcklin, 1968; Davoudzadeh, 1997; Ghorbani, 2013). The main units include, from north to south, Alborz Mountains, Kopet Dagh, Central Iran, Sanandaj-Sirjan, Zagros, and Makran ranges. With the exception of Kopet Dagh, the units have similar late Neoproterozoic to Early Cambrian granitoids and granitic gneissic basement (from roughly 600 to 520 Ma) suggesting that a relatively uniform Neoproterozoic crust underlies much of Iran (Hassanzadeh et al., 2008).

The Alborz Mountains, which contain our study localities, lie parallel to the southern margin of the Caspian Sea and form the northern margin of the Central Iran zone (Ghorbani, 2013). This mountain belt is the result of different tectonic events: from the Late Triassic Cimmerian orogeny, resulting from the collision of the Iranian block with Eurasia, to the present day stage of intra-continental deformation related to the convergence between the Arabian and Eurasian plates (Zanchi et al., 2006). The oldest rocks in the Alborz Mountains (northern Iran) belong to the Ediacaran siliciclastic-dominated Kahar Formation (Ghorbani, 2013).

2.1. Kahar Formation

The Kahar Formation, originally described by Dedual (1967) in the Kahar Mountain, central Alborz Ranges, represents northern Iran's oldest known exposures of Neoproterozoic sedimentary rocks (Stöcklin et al., 1965; Dedual, 1967; Ghorbani, 2013). It consists of more than 1000 m of grey to greenish mudrocks with subordinate intercalations of greywackes, carbonates, and volcanic materials. The geographic extent of the Kahar Formation is limited to northern Iran but its correlative successions, such as the Tashk and Morad formations, are recognized to the south in Saghand and Kerman regions, respectively (Stöcklin et al., 1965; Ramezani and Tucker, 2003). The basal contact of the Kahar Formation is not exposed anywhere; however, it is generally conformably overlain by the late Neoproterozoic rocks, especially alternating shales and carbonates of the Soltanieh Formation (Stöcklin et al., 1965; Dedual, 1967; Ghorbani, 2013). The Soltanieh Formation definitely contains the Precambrian–Cambrian boundary in its middle part, near the top of the Lower Shale Member (Hamdi et al., 1989; Kimura et al., 1997; Ciabeghodsi et al., 2005). In some places such as Zanjan area, the Kahar Formation has been affected by low grade metamorphism. In this area, metamorphism of Kahar sediments was enhanced by ca. 550–600 Ma granitoid intrusives, such as Sarv-e Jahan ($^{206}Pb/^{238}U$ age of 599 ± 42 Ma), Moghanlou ($^{206}Pb/^{238}U$ age of 548 ± 27 Ma), and Doran ($^{206}Pb/^{238}U$ age of 2.8 ± 1 Ma and 567 ± 19 Ma) granites (Hassanzadeh et al., 2008).

The depositional ages assigned to the Kahar Formation range from 600 to 550 Ma, on the basis of Rb–Sr and detrital zircon U–Pb data, palynomorphs, stromatolites, chemostratigraphy, and also

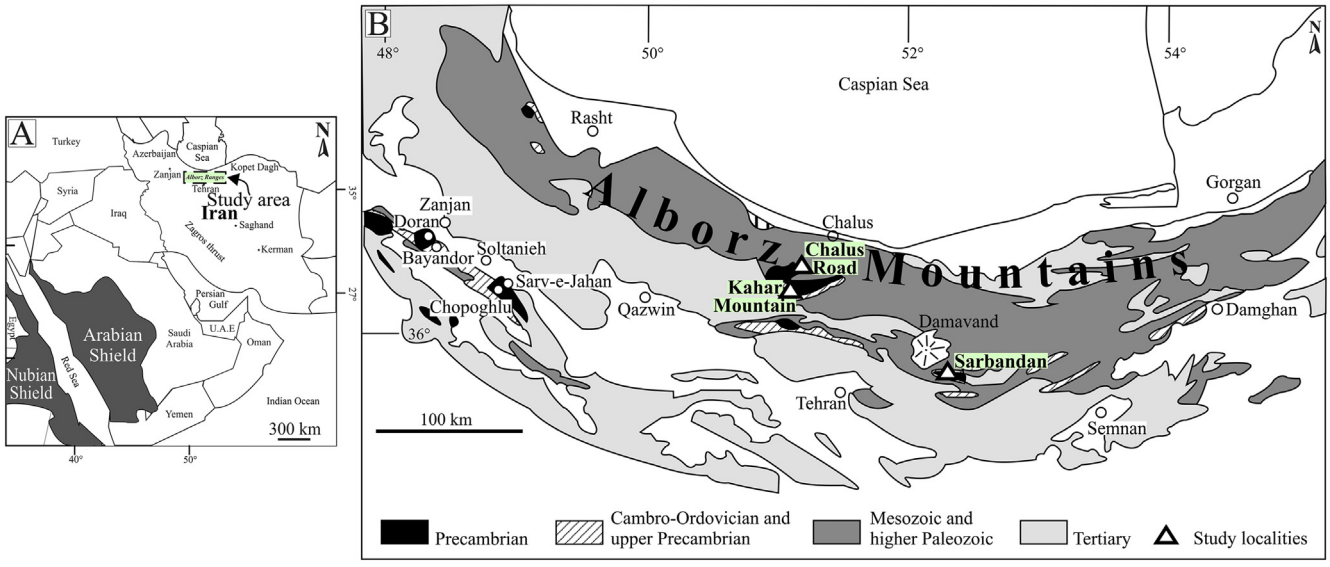

Fig. 1. (A) Location of study sections (northern Iran) in the Middle East near the juvenile Neoproterozoic crust of the ANS. (B) Generalized geological map of Alborz Mountains, from Zanjan to Damghan (modified after Stöcklin et al., 1964). Triangles indicate our study areas.