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The tectonic evolution of western Central Iran seen through detrital white mica

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ABSTRACT

A first order survey of ^{40}Ar/^{39}Ar dating of detrital white mica from Jurassic to Pliocene sandstones has been carried out in order to reveal the tectonic evolution of blocks in Central Iran. The Central Iran block was believed to represent a stable Precambrian block. Our results indicate that: (1) Only a very small proportion of Precambrian but abundant Paleozoic and Mesozoic detrital white mica indicate the Phanerozoic, mostly Mesozoic age of metamorphic crust exposed in Central Iran. The oldest but scarce detrital white mica grains have ages ranging from 524 to 826 Ma heralding a Late Precambrian and Cambrian crystalline basement or cannibalism from older clastic successions. (2) Jurassic and Cretaceous sandstones from the west and east of the Chapedony fault yield different age spectra, with a dominance of Variscan ages (ca. 308–385 Ma) in the Biabanak unit west of the Chapedony fault compared to coeval sandstones from the block east of the Chapedony fault, where Variscan ages are subordinate and Cimmerian ages predominate. The micas from the Biabanak unit are most likely derived from the Variscan accretionary complex exposed in the Anarak–Jandaq areas further northwest. This result underlines the importance of a major block boundary identified as the Chapedony fault, which is in extension of a fault previously proposed. (3) Two stages of Cimmerian events are visible in our data set from Cretaceous and Paleogene sandstones, a cluster around 170 Ma and at ca. 205 Ma. These clusters suggest a two-stage Cimmerian evolution of the largely amphibolite-grade metamorphic Posht-e-Badam and Boneh Shurow complexes. (4) The youngest micas in Paleogene conglomerates have an age of ca. 100 Ma and are most likely derived from the base of the Posht-e-Badam complex. No record of the uplifted Eocene Chapedony metamorphic core complex has been found in Eocene and Pliocene clastic rocks.

1. Introduction

The ^{40}Ar/^{39}Ar dating technique has been applied to detrital K-bearing minerals, most commonly white mica, and less frequently biotite (Aalto et al., 1998), K-feldspar (Copeland and Harrison, 1990) and amphibole (Cohen et al., 1995). Of these, white mica has proved the most versatile and has played a key role in unravelling palaeogeographies and the time-scales involved in the sedimentary cycle in diverse geological settings (Kelley and Bluck, 1992; Renne et al., 1990). The success partly lies in the fact that white micas record the time at which the source block was experiencing temperatures of ca. 350–425 °C, and when in the sedimentary basin the eroded and deposited white micas are able to avoid complete or partial post-depositional setting.

With this study, we demonstrate some important advantages as well as some limitations of the ^{40}Ar/^{39}Ar white mica method. The approach has been systematically applied to various stratigraphic levels of Jurassic to Neogene sedimentary basins of the Central Iran area (Figs. 1–3). Only few studies exist from Iran using the ^{40}Ar/^{39}Ar white mica system. Here, we compile the first-order results, which demonstrate the usefulness of the ^{40}Ar/^{39}Ar dating approach to reveal tectonic processes. Our results demonstrate the systematic change of source compositions from Jurassic to Neogene basins. The new data allow significant refinement of the Paleozoic, Mesozoic and Cenozoic tectonic evolution of western Central Iran, which is part of the Mesozoic Cimmerides orogen (Sengör, 1979; Wilmsen et al., 2009). Only one study on dating detrital minerals of Iran exists, which presents U–Pb ages of detrital zircon from Neoproterozoic to Cenozoic sandstones (Horton et al., 2008). Our study is aimed to complement this study.

2. ^{40}Ar/^{39}Ar single-grain dating of detrital white mica

^{40}Ar/^{39}Ar dating of detrital white mica is a perfect tool (1) to demonstrate palaeogeographic relationships (e.g., Dallmeyer and Neubauer, 1994), (2) to constrain tectonic processes in the hinterland of sedimentary basins (Hodges et al., 2005; Kelley and Bluck, 1992); and (3) dynamics of sedimentary basins (Hodges et al., 2005; Najman et al., 2001). Dating is particularly useful when single grains are analysed, which avoids problems caused by mixing of different populations of

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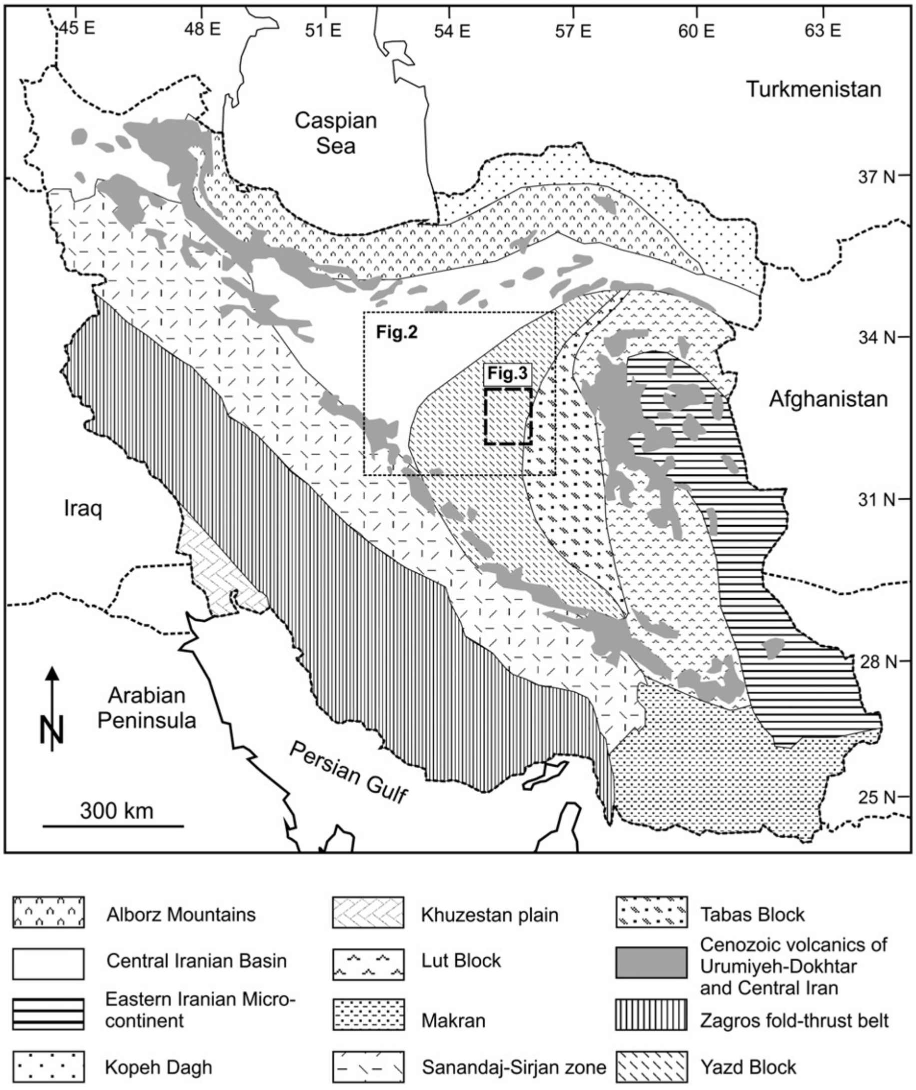

Fig. 1. Simplified geological map of Iran; black dashed rectangles show the position of study area (Figs. 2, 3).

different age (Copeland and Harrison, 1990; Najman et al., 2001; Neubauer et al., 2007).

The argon isotopic system of detrital white mica has been shown to be very resistant against mechanical and chemical weathering and sedimentary transport and is, therefore, very suitable for ^{40}Ar/^{39}Ar dating of detrital material (e.g. Clauer, 1981; Mitchell and Taka, 1984). In contrast, biotite is highly accessible to weathering and occurs only in minor amounts in clastic successions (see review in Rieser et al., 2005).

Detrital white mica within clastic sediments originates from either pelitic metamorphic or plutonic source rocks, which were formed in the middle and lower levels of the continental crust. However, metamorphic source rocks like micaschist and gneiss predominate as only S-type granitoids comprise a significant proportion of white mica among plutonic rocks. Such S-type granitoids constitute a maximum of ca. 5–20% in present-day exposed plutonometamorphic basement, and its modal content of white mica is low (up to a maximum of ca. 5%) compared to micaschist (ca. 50–70%) and gneiss (ca. 5–20%). Consequently, white mica from metamorphic rocks should predominate, in average, the detrital mica population of sandstones. Furthermore, recycling of detrital white mica from older clastic successions could potentially contribute to the detrital white mica age populations although this effect was never investigated in detail.

In low-grade metamorphic units, below metamorphic temperatures of ca. 400 to 450 °C, white mica is generally fine-grained (<200 μm) and is increasingly coarse-grained above this temperature up to ca. 580–600 °C where white mica finally breaks down to K-feldspar and alumino-silicate (e.g., Spear, 1993). As isotopic data are generally obtained from grain sizes between 200 and 500 μm, the dated white mica originate generally from temperatures levels of 400–600 °C within the crust. In metamorphic units, white mica includes muscovite, paragonite and celadonite (or phengite) and mixtures between these end members (Rieder et al., 1998).

According to experimental data, ^{40}Ar/^{39}Ar and K–Ar ages of white mica monitor the cooling of the crust of the hinterland below temperatures of 425 ± 25 °C (Harrison et al., 2009). In the past a range from about 350 to 450 °C was postulated as the approximate closure temperature of the argon isotopic system within white mica within regional metamorphic terrains (Hames and Bowring, 1994; Kirschner et al., 1996). The argon retention temperature is complicated by additional factors (Villa, 1998). These factors are, among others, duration of heating, cooling rate, grain size, deformation like kinking, and hydrothermal alteration.

Usually, laser-probe single-grain ^{40}Ar/^{39}Ar dating using a high-resolution gas mass spectrometer can yield total fusion age, which is equivalent to a conventional K–Ar age of the single grain. In appropriate cases, provided a relatively large grain size (200–500 μm), even a step-heating experiment can be performed, which allows the recognition of a thermal overprint on even a single grain. To detect a possible in-situ