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Composition, provenance and source weathering of Mesozoic sandstones from Western-Central Mediterranean Alpine Chains

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ABSTRACT

Forty-two Mesozoic sandstone samples from three different sedimentary successions of the Internal Domains along the Western-Central Mediterranean Alpine Chains (Betic Cordillera, Rif Chain and Calabria-Peloritani Arc) were chemically analyzed to characterize their composition and the degree of weathering in the source area(s). The Rif Chain sandstones have SiO_2 contents higher than those of the Calabria-Peloritani Arc and Betic Cordillera sandstones, whereas Al_2O_3 contents are higher in the Calabria-Peloritani Arc sandstones rather than in the Rif Chain and Betic Cordillera sandstones. The indices of compositional variability (ICV) of the studied samples are generally less than 1, suggesting that the samples are compositionally mature and were likely dominated by recycling. Recycling processes are also shown by the Al–Zr–Ti diagram indicating zircon addition and, thus, recycling processes. The Chemical Index of Alteration (CIA) values are quite homogeneous for the Calabria-Peloritani Arc (mean = 76) and Betic Cordillera sandstones (mean = 55), whereas the Rif Chain sandstones are characterized by CIA values ranging from 54 to 76. The CIW and PIA values are high for all the studied sandstones indicating intense weathering at the source areas. The different values of weathering rates among the studied sandstones may be related to variations of paleoclimatic conditions during the Mesozoic, that further favored recycling processes. Thus, these differences among the studied samples, may be related to an increase in continental palaeoweathering conditions and sediment recycling effects from the Middle Triassic to the earliest Jurassic due to rising humidity. In addition, regional tectonic movements promoted structural changes that allowed sedimentary recycling and subsidence, which in turn caused diagenetic K-metasomatism. These processes could significantly affect the CIW and PIA weathering indices, which likely monitor a cumulative effect, including several cycles of weathering at the source. The source areas are mainly composed of intermediate-felsic rocks with minor, but not negligible, mafic supply, as suggested by provenance proxies.

1. Introduction

Mesozoic continental redbeds from the Internal Domains of the Western-Central Mediterranean Alpine Chains are important stratigraphic markers and indicators of the paleogeographic, paleotectonic and paleoclimatic conditions controlling continental basins developed in relation to early stages of rifting which lead to the break-up of the Pangea (e.g., Roep, 1972; Martín-Algarra et al., 1995; Perri, 2008; Perri et al., 2005, 2008a, 2008b, 2011a, 2011b, 2012a, 2013; Mongelli et al., 2006; Perrone et al., 2006; Aldinucci et al., 2008; Critelli et al., 2008; Zaghloul et al., 2010). These studies show the importance of Mesozoic redbeds since they preserve key geodynamic signatures from Pangea break-up to Tethys opening and its closure during growth of the Alpine circum-Mediterranean Chains.

The geochemistry of the sandstones give information about the composition, provenance, tectonic setting and source rock weathering. The geochemical composition of clastic sedimentary rocks is related to a complex interplay of many variables, such as provenance, weathering, transportation and diagenesis. The distribution of major and trace elements is used to reconstruct the source area composition and the degree of weathering, and the diagenetic processes (e.g., Cullers, 1994; Condie et al., 1995; Bauluz et al., 2000; Perri et al., 2008a, 2011a, 2011b, 2012a, 2013; Mongelli et al., 2006; Critelli et al., 2008; Caracciolo et al., 2011; Zaghloul et al., 2010). These determinations are based on the different behavior of the elements during erosion and sedimentation, in order to preserve the characteristic trace-element distribution of the source rocks. Thus, the chemical variations may explain and predict the sedimentary evolution and geological processes affecting clastic sediments and, thus, the relationship developed between source area and sedimentary basin.

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In the present paper we discuss about the composition of sandstone samples from the Internal Domains of the Western-Central Mediterranean Alpine Chains (Betic Cordillera, Rif Chain and Calabria-Peloritani Arc) and the relationships with the associated basement rocks characterizing the Mesomediterranean Microplate (e.g., Guerrera et al., 1993, 2005; Perri et al., 2011a, 2013; Mongelli et al., 2006; Perrone et al., 2006; Aldinucci et al., 2008; Critelli et al., 2008; Zaghloul et al., 2010). The main purpose of this study is to evaluate the major and trace element geochemistry of the Mesozoic sandstone samples from three different sedimentary successions (Betic Cordillera, Maghrebian Rif and Calabria-Peloritani Arc) in order to infer their composition, provenance, and weathering intensity.

2. Geological setting

The Betic Cordillera, the Maghrebian Chain (Rif, Tell and Sicily) and the Calabria-Peloritani Terranes are the main three Alpine systems bordering the Central-Western Mediterranean (Fig. 1). These chains are linked by the Gibraltar Arc and the Calabria-Peloritani Arc, two main tectonic features that connect different chains and reveal gradual change of convergence from one chain to another (e.g., Guerrera et al., 1993).

The Gibraltar Arc has two arms composed of the Betic Cordillera (southern Spain) and the Rif Chain (northern Morocco), which land-locked the Alboran Basin situated in the internal part of the arc. The mountain front of the Gibraltar Arc originated from the Early Miocene collision of the Alboran Domain with the South-Iberian and Maghrebian paleomargins, involving Mesozoic to Cenozoic platform and basinal sedimentary sequences (e.g., Perrone et al., 2006 and references therein).

The inner portion of the Betic Cordillera is composed of thrust slices at its front (Frontal Units) plus an antiformal stack of nappe complexes named, in ascending tectonic order, Nevado–Filabride, Alpujarride and Malaguide complexes (Fig. 2A). In particular, the Malaguide Complex is the highest tectonic element of the Betic Internal Domain and; it mainly consists of pre-Ordovician to Upper Carboniferous siliciclastic, siliceous and metasedimentary (slate, phyllite and quartzite) sequence including thin carbonate lenses and conglomerate bodies with some clasts of acid plutonic rocks, strongly deformed during the Variscan Orogeny (Martín-Algarra et al., 2009 and references therein) unconformably covered by a Meso-Cenozoic sedimentary succession that starts with Triassic continental redbeds (Pseudoverrucano-type; Perrone et al., 2006) (Fig. 3A and B). The Malaguide Triassic continental facies belt changed laterally to marine carbonate sediments with Alpine lithofacies of the Alpujarride Complex and of the Frontal Units. The Malaguide Triassic redbeds have been formally grouped into the Saladilla Formation (Roep, 1972; Martín-Algarra et al., 1995). This formation is generally made of quartzose conglomerates, overlain by sandstones and mudstones (siltstones and claystones) with vivid red colours (mainly from purple red to orange red, but also pinkish, yellowish, or whitish, rarely greenish) (Fig. 4). It also includes some conglomerate with carbonate clasts, calcareous sandstone, dolostone, limestone, marl and gypsum, and is locally intruded by deca-to hectometric bodies of basic subvolcanic rocks (Geel, 1973; Martín-Algarra, 1987; Martín-Algarra et al., 2000, 2009). The thickness of the whole formation changes notably among different outcrops but, in the Malaguide succession from Sierra Espuña reaches a lot of hundred of metres.

The Internal Nappes of the Rif Chain constitute, from bottom to top, superimposed structural complexes named the 'Dorsale Calcaire', Sebtide and Ghomaride Complexes, which are identical, respectively, to the Frontal Units, to the tectonically highest Alpujarride units and to the Malaguide Complex of the Betic Cordillera (Suter, 1980 and references therein) (Fig. 2A). In particular, basement rocks supporting a thin Alpine Meso-Cenozoic cover, severely reduced by erosion, characterize the Ghomaride Complex (Fig. 3C and D). This complex is made up of an unmetamorphosed or slightly metamorphosed pre-Alpine basement, deformed by the Hercynian orogenesis (Chalouan and Michard, 1990; Zaghloul et al., 2010 and references therein) and consisting of Palaeozoic slates, phyllites, metarenites and metalimestones, ranging in age from Ordovician to Carboniferous; the uppermost beds are represented by Mid-Carboniferous sandstones and conglomerates of Culm facies (Baudelot et al., 1984; Zaghloul et al., 2010 and references therein). The Alpine Meso-Cenozoic cover sedimentary cover is composed of continental redbeds (Pseudoverrucano-type; Perrone et al., 2006) overlain by undated dolomites and then Lower Jurassic, shallow-marine, white massive limestones, only a few tens of metres thick (Fig. 4) (Maate, 1996; Maate et al., 1991). These continental redbeds belong to the Saladilla Formation, defined by Martín-Algarra et al. (1995) and Maate (1996) for the Western Betics and also for the Rifian Ghomarides.

The Calabria-Peloritani Arc is a fault-bounded exotic terrane connecting the NW–SE-trending Southern Apennines with the

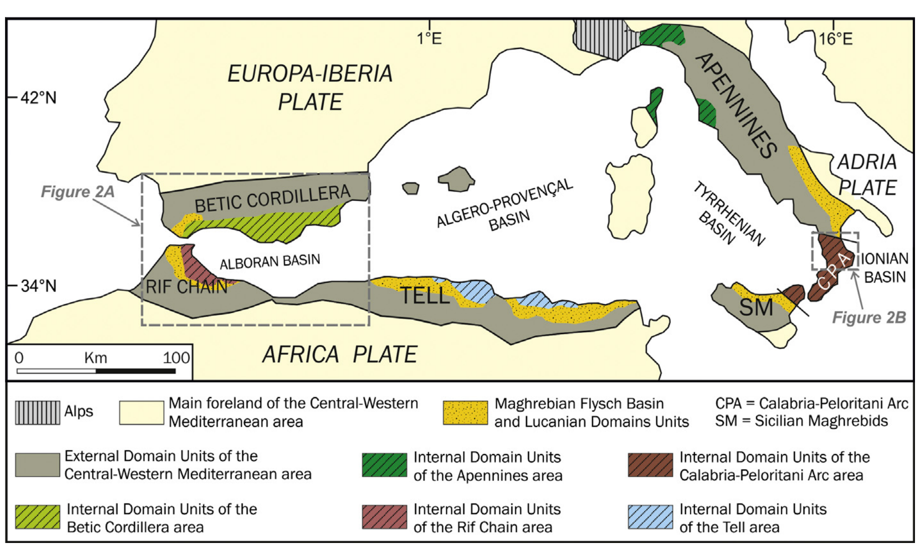

Fig. 1. Geological sketch map of the Alpine Chains in the Central-Western Mediterranean Region (modified and redrawn after Perrone et al., 2006).