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Offshore Oligo-Miocene volcanic fields within the Corsica-Liguria Basin: Magmatic diversity and slab evolution in the western Mediterranean Sea☆

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ABSTRACT

The European and Corsica–Sardinia margins of the Ligurian Sea (western Mediterranean) have been affected by a geochemically diverse igneous activity, offshore and onshore, since the Eocene. This magmatism occurred in a global subduction-related framework. On the European side, the oldest Tertiary magmatism dated at ca. 35 Ma was mainly calc-alkaline. It included the emplacement of plutonic bodies of adakitic affinity, such as the quartz microdiorite laccolith locally referred to as “esterellite”. Younger magmatic events on-land within the whole Ligurian domain were mostly medium-K or K-rich calc-alkaline. Miocene volcanic activity was important in Sardinia, where andesites and ignimbrites were erupted during several magmatic cycles. In Corsica, it was minor although it emplaced lamprophyres near Sisco at 15 Ma.

Dredging and diving cruises conducted in the Ligurian Sea during the last thirty years allowed us to collect a number of submarine samples. We discuss here their geochemistry (major and trace elements) and their whole-rock K–Ar ages and mineral ^{40}Ar–^{39}Ar plateau ages. Around 15 Ma, minor amounts of adakitic lavas were emplaced off southwestern Corsica, in the deepest part of the Liguria-Corsica Basin. They rested over the thinnest southwestern Corsica Hercynian continental crust. Closer to the coast, contemporaneous calc-alkaline rocks erupted on a less thinned crust. The adakitic events could be indicative of either the final stages of active subduction, or alternatively of a slab tearing linked to the southeastern retreat and steepening of the slab. The latter event could be connected with the end of the Corsica–Sardinia block drifting and its correlative eastern collision.

Younger volcanic effusions, dated at 14–6 Ma, occurred mostly northwest and north of Corsica. K-rich calc-alkaline basalts, shoshonites and K-rich trachytes were emplaced during this period, and alkali basalts erupted as early as 12 Ma in Sardinia. In the Toulon area, alkali basalts dated at 7–6 Ma represent the last onshore activity just before the Messinian crisis, and the Pliocene alkali basaltic outpouring in Sardinia. We propose to link these latter volcanic events to the development of a slab window in a post-collisional tectonic framework.

1. Introduction

The Mediterranean domain represents a wide, geodynamically active area where the Cenozoic convergence between the African and Eurasian plates resulted in a complex spatial and temporal tectonic pattern. Between Alps-Provence and Corsica, a highly thinned continental crust on the deep part of the margins underlies the Ligurian Sea, while an oceanic-type crust is present in its narrow central part. Corsica and Sardinia islands are underlain by a “typically” Variscan bowl-shaped continental crust (Galson and Mueller, 1986).

☆ This work is dedicated to the memory of our colleague Henriette Lapierre, Professor at Grenoble University, who died in January 2006. She was an important contributor to our initial project.

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During the Neogene, the western Mediterranean domain and its margins evolved through a complex succession of NW-directed subductions, back-arc openings and collisions, involving slab tearings and detachments (Réhault et al., 1984; Von Blanckenburg and Davies, 1995; Gueguen et al., 1998; Carminati et al., 1998a,b; Faccenna et al., 2004; Lucente et al., 2006; Carminati et al., 2010; Lustrino et al., 2011).

The magmatic activity linked to these complex geodynamic patterns led to the emplacement, both onshore and offshore, of geochemically diverse volcanic and plutonic associations. These include MORB-type and back-arc oceanic basalts (Beccaluva et al., 1990), from calc-alkaline to ultrapotassic lavas (Peccerillo, 2005), plutonic and volcanic rocks of crustal anatectic origin (Zeck et al., 1998) and alkali basalt series (Oyarzun et al., 1997; Lustrino and Wilson, 2007). These complex rock associations occur throughout the whole Mediterranean domain, e.g. in the Betic Cordilleras (Zeck, 1996; Benito et al., 1999), the Maghreb alpine chain (Maury et al., 2000), the Apennines-Calabrian-Sicilian domain and the Eolian arc and Tuscany (Hawkesworth and Vollmer, 1979; Savelli, 1988; Lustrino et al., 2011).

Within the Liguro-Provençal Sea and its margins as well as on the Sardinia-Corsica block, a Neogene magmatic evolution from medium-K calc-alkaline towards K-rich calk-alkaline lavas was followed by the emplacement of alkali basaltic lavas in the Toulon area (France) and in Sardinia (Coulon, 1977; Montigny et al., 1981; Dostal et al., 1982; Aguilar et al., 1996; Morra et al., 1997; Gattacceca, 2001; Gattacceca et al., 2007; Lustrino et al., 2007a,b). In Corsica, the only evidences are the Sisco lamprophyre at Cap Corse and the ignimbritic tuffs of Balistra (Bellon, 1976) and the Tre Paduli, Francolu, and Maore (Ottaviani-Spella et al., 1996, 2001; Ferrandini et al., 2003). The geochronology and geochemistry of this onshore magmatic activity, which has been related to the drifting of the Sardinia-Corsica block, are relatively well documented (Bellon and Brousse, 1977; Wilson and Bianchini, 1999; Savelli et al., 1979; Savelli, 1988, 2002; Oudet et al., 2010; Lustrino et al., 2011).

In comparison with onshore igneous rocks, the literature data on the offshore volcanics from the Ligurian Sea are nearly completely missing. The present paper is based on the study of the dredging and diving cruises carried out by French scientific institutions that sampled a large number of volcanic rocks during the three last decades in the Corsica-Liguria Basin. Our new data highlight the tectono-magmatic processes,which controlled the Tertiary evolution of the northwestern Mediterranean domain.

2. Northwestern Mediterranean magmatic events

2.1. Onland magmatism in SE France, Corsica and Sardinia

Tertiary magmatic rocks are present mainly in the emerged part of the northern Ligurian margin. They are well-known since the XIXth century, especially the “porphyre bleu de l’Estérel” or “estérellite” (Michel Lévy, 1898), a quartz-bearing microdiorite forming a thick laccolithic complex near Le Drammont. Basaltic to andesitic pyroclastic deposits cropping out around Villeneuve-Loubet were described by Brousse and Lefèvre (1990). Finally, andesitic and dacitic pebbles occur in volcanogenic breccias interbedded within the Eocene sedimentary rocks in the Saint-Antonin syncline, located to the north of Nice (Féraud et al., 1995; Boyet et al., 2001).

The first published K–Ar age at 26.2 ± 1.2 Ma (Bellon and Brousse, 1971) concerned the andesites exposed between Biot and Grasse. Complementary ages carried on lavas collected at Tourettes sur Loup, Juan-les-Pins and La Vanade, are bracketed between 32.5 and 30.8 Ma (Bellon, 1981). More recently, two pyroclastic levels sampled during the Monaco railway tunnel engineering works were dated at respectively 27 ± 0.8 and 18.7 ± 0.8 Ma (Ivaldi et al., 2003). ^{40}Ar–^{39}Ar ages for Le Drammont microdiorites and for the Saint-Antonin andesites range from 33 to 31 Ma (Féraud et al., 1995). Similar plateau ages (31–30 Ma) have been measured on Alpine plutons such as Traversella and Biella (Ruffet, unpublished data) and nearby bodies of similar ages (32–29 Ma; Buergi and Kloetzli, 1990; Romer et al., 1996). Andesitic to dacitic pebbles from a volcanoclastic unit interbedded within an Early Oligocene (Priabonian-Rupelian) marine formation at the Baratus pass, in the vicinity of St Auban, have been dated at 29.6 ± 0.5 and 29.0 ± 0.5 Ma (Montenat et al., 1999).

Northwest of Aix en Provence, at Beaulieu, two Miocene volcanic events emplaced a calc-alkaline lava flow and an alkali basaltic flow, respectively (Gueirard, 1964), which have been considered later as transitional to alkaline by Dautria and Liotard (1990). The Formation de Beaulieu, which includes coastal deposits overlain by lacustrine limestones, is subcontemporaneous of this volcanic complex. ^{40}Ar–^{39}Ar dating of a basaltic sample taken in the quarry site, previously studied by Baubron et al. (1975), yielded a plateau age of 17.5 ± 0.3 Ma, which can be correlated with N6 + N7 biozones dated in the neighbouring marine sediments and the paleomagnetic chrone C5Dn (Aguilar et al., 2003). It is consistent with the previous K–Ar age of ca. 18.2 ± 0.5 Ma (Baubron et al., 1975). North of Toulon, alkali basaltic flows dated at 6.97 ± 0.24 and 6.30 ± 0.22 Ma (Bellon, unpublished data) represent the last volcanic event known in Provence (Coulon, 1967; Gouvernet et al., 1997).

The important Neogene magmatic activity documented in Sardinia may be divided in two main periods. The first one occurred between 32 and 15 Ma with a peak between 22 and 18 Ma, and the second one emplaced alkali basalts between 12 and 0.1 Ma (Lustrino et al., 2007a,b). In Northeast Corsica, lamproitic dykes intruding the “Schistes lustrés” unit yielded a whole rock K–Ar age of 13.75 Ma (Bellon, 1976, age corrected according to constants in Steiger and Jäger, 1977) and a Rb–Sr age of 15 Ma (Féraud et al., 1977). Their emplacement is related to that of K-rich and shoshonitic lavas in Sardinia.

2.2. Offshore Corsica-Liguria Basin volcanism

Offshore volcanism appears relatively scattered within the Corsica-Liguria basin, which comprises the Ligurian Sea and its submarine margins. However, two main volcanic fields are distinguished in Fig. 1. The first one, the southwestern Corsica volcanic field, is located in the prolongation of the central Sardinia rift, while the second one, the northwestern Corsica volcanic field, is located south of Genoa Gulf and along the Central Ligurian Sea. This latter field underlines the N10°–20° trending foot of the Corsica continental margin and Liguria Central Basin.

A large set of pre-existing data and studies have been considered in our study. It includes previous geological samplings, bathymetric and geophysical data, large transverse magnetic anomalies southwest of Corsica (Bayer et al., 1973), dredged samples in the Ligurian basin (Réhault et al., 1974), identification of reflectors of the Ligurian margins (Bellaiche et al., 1974), and studies of the relationships between tectonics, volcanism and sedimentation (Gennesseaux et al., 1989). A first synthetic map (Sartori et al., 1982) was based on data obtained on cored samples during drillings and on lavas dredged or sampled in situ in the western Mediterranean. Additional data include (i) the first K–Ar dating of dredged lavas from the “Tristanite Ridge” (Réhault, 1981; Réhault et al., 1985), (ii) K–Ar and ^{40}Ar–^{39}Ar ages of columnar-jointed lavas in SW Corsica (Bellon et al., 1985), (iii) dating of submarine volcanoes (Monte Doria complex and Genoa Gulf central volcano), south of Genoa Gulf (Fanucci et al., 1993), and finally (iv) the trace element geochemistry and ^{40}Ar–^{39}Ar ages of calc-alkaline volcanism in southwest Corsica (Rossi et al., 1998).