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Integrated chronostratigraphy of an intra-arc basin: $^{40}Ar/^{39}Ar$ datings, micropalaeontology and magnetostratigraphy of the early Miocene Castelsardo basin (northern Sardinia, Italy)

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ABSTRACT

The chronostratigraphy of the lower Miocene deposits of northwestern Sardinia is refined in the Castelsardo Basin. The combination of new $^{40}Ar/^{39}Ar$ isotopic datings, 19 micropalaeontological datings (calcareous nannofossils, planktonic and large benthic foraminifers) and 16 palaeomagnetic polarity measurements led to a new chronostratigraphic framework. The continental deposits of the first megasequence (Valledoria and Casteldoria members) are possibly Aquitanian. The overlying marine sediments are early Burdigalian (*Vaginella depressa* Molasse). The marine transgression can be dated to around 19.7 Ma. Marine conditions ceased 18.83 ± 0.13 Ma, the age of the index aerial τ2 ignimbrite. The continental part of the second megasequence ("Lacustre" unit) is early-middle Burdigalian, between 18.8 and 18 Ma. The overlying marine part (Campulandu and Sedini members) is middle-late Burdigalian. The second marine transgression began in the earliest-late Burdigalian, during the Chron C5Dr reversal, at the time of the eustatic Bur 4 event.

The Castelsardo basin went through two main extensional tectonic episodes. The first one occurred as the Valledoria Member was deposited and possibly dates back to the Aquitanian. The second one occurred as the uppermost part of the *Vaginella depressa* Molasse was deposited during the early Burdigalian. The second extensional episode is related to a rapid rotation of Sardinia. Palaeomagnetic results confirm that Corsica and Sardinia acted as a single block which suffered a 28 ± 17° ccw rotation after ~19.2 Ma. The Castelsardo basin is held to be an Aquitanian–early Burdigalian intra-arc rift basin that later evolved in a thermally controlled subsident margin of the Ligurian–Provençal Basin during the middle-late Burdigalian.

1. Introduction

The Corsica-Sardinian Block (CSB) represents the southern margin of the Liguro–Provençal Basin (LPB) in the Western Mediterranean Sea (Fig. 1). The LPB is seen as a back-arc basin linked to an eastward retreat and roll-back of the subduction of the Neotethys oceanic plate under the European plate during the Africa–Europe convergence (Carminati et al., 1998a and 1998b; Gueguen et al., 1998; Séranne, 1999). This roll-back is responsible for the contemporaneous counterclockwise rotation of the CSB (Carminati et al., 1998a and 1998b; Gueguen et al., 1998; Séranne, 1999). Numerous studies have been carried out to determine the timing and path of this motion (e.g. De Jong et al., 1973; Montigny et al., 1981; Todesco and Vigliotti, 1993). From the most recent studies in central and southern Sardinia (Speranza et al., 2002; Gattacceca et al., 2007), it appears that after the rifting stage (late Oligocene to early Aquitanian, ~30–21.5 Ma), Sardinia rotated 45° counterclockwise with respect to stable Europe after 20.5 Ma. The precise age of the end of this rotation is difficult to assess. An age of 18–17.5 Ma has been suggested (e.g. Edel et al., 2001), but a more robust dataset (Deino et al., 2001) has shown that at 18 Ma Sardinia remained ~13° shy of its final position. Therefore,

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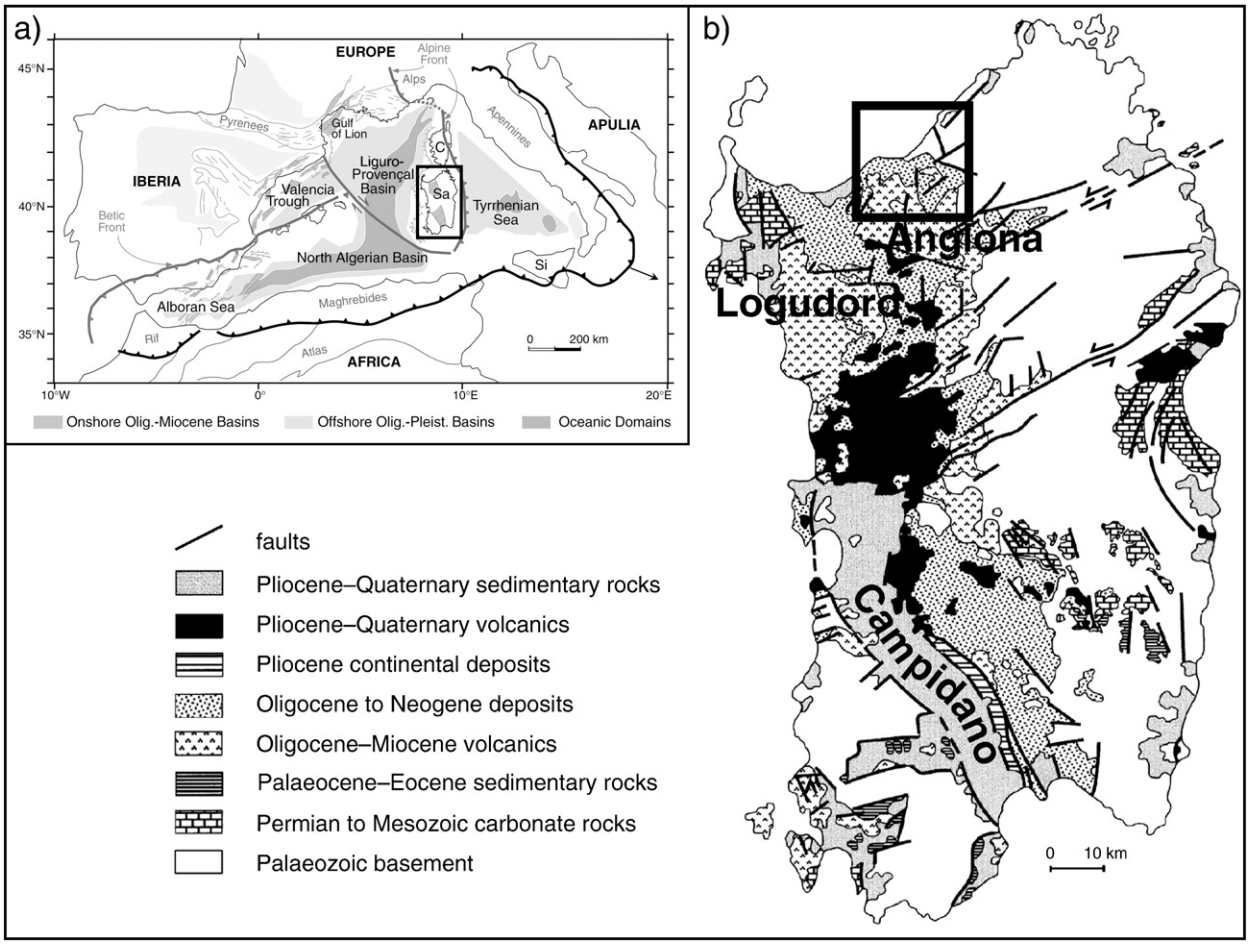

Fig. 1. (a) Simplified tectonic sketch of the western Mediterranean, modified based on the works of Gueguen et al. (1998) and Rollet et al. (2002). (b) Simplified summary of Sardinian geology modified based on the work of Casula et al. (2001) Inset depicts the Anglona region under study. C: Corsica; Sa: Sardinia; and Si: Sicily.

the end of the rotation probably occurred between 16 and 15 Ma. It is interesting to note that 30°of rotation occurred between 20.5 and 18 Ma (late Aquitanian to middle Burdigalian). This implies high oceanic spreading rates during this period (up to 9 cm yr^{-1} in the southernmost part of the LPB; Gattacceca et al., 2007). The western part of the island of Sardinia was seen either as a single intracontinental rift or as numerous intra-arc basins. The intracontinental rift (dating back to the Oligocene–Miocene) crosses the island with a 200 km N–S trending depression named the "Sardinian Rift" or "Sardinian Trough" linked to the LPB rifting (e.g. Cherchi and Montadert, 1982; Casula et al., 2001; Cherchi et al., 2008). The intra-arc basins are characterized by multiphase extension and transtension, with several orientations of normal and strike–slip faults (e.g. Carmignani et al., 1995; Oggiano et al., 1995; Lecca et al., 1997 Sowerbutts, 1997, 2000; Monaghan, 2001). Northwestern Sardinia, i.e. the Anglona region (Fig. 1), is thought to link the so-called Sardinian Rift to the Corsican southern margin of the LPB (Gennesseaux et al., 1989).

This study is focused on the Castelsardo (Fig. 2) basin, because the most complete Oligocene–Miocene sedimentary sequence from northern Sardinia outcrops there (Maxia and Pecorini, 1969). Due to the occurrence of numerous volcanic flows interbedded within the sediments, this basin has also been extensively studied for palaeomagnetic purposes (53 sites; synthesis in Todesco and Vigliotti, 1993 and more recent work of Gattacceca et al., 2007). These indicate a significant 30° counterclockwise rotation of Sardinia relative to Europe, taking into account the declinations yielded by ignimbrites from various stratigraphic levels of the sedimentary series. However the chronostratigraphy of the Castelsardo basin remains poorly constrained because of biostratigraphical uncertainties and large K/Ar age ranges (synthesis in Sowerbutts, 2000). These uncertainties prevent straightforward correlations between palaeomagnetic data and the geomagnetic polarity time scale (GPTS), as well as a precise estimation of the rotation of northern Sardinia. Thus this study presents precise dating of some volcanic key-levels that provides a good opportunity to accurately assess the kinetics of rotation. This new geochronological investigation is reinforced by a study of calcareous nannoplankton and planktonic foraminifers and by additional palaeomagnetic data. The new integrated stratigraphy presented here allows a refinement of the tectonostratigraphic and palaeogeographic evolutions of northern Sardinia in relation to the rotation of the CSB.

2. Geological outline of the Castelsardo basin

In the Anglona region of northwestern Sardinia, the Porto-Torres and Castelsardo Basins are the two main half-grabens (Fig. 2). They both continue offshore in the Asinara Gulf and onto the large continental platform between Corsica and Sardinia where a third basin, the Bonifacio Basin, is located (Fig. 2). The evolution and type of the sedimentary infilling are comparable within these three basins. Subduction related volcanism occurred mainly along the major bounding faults (Fig. 2; Thomas and Gennesseaux, 1986 Gennesseaux et al., 1989; Rollet et al., 2002).

The Castelsardo Basin is a 284 km^2 half-graben bounded by two main normal NNW–SSE trending faults (Tramontana and Viddalba faults; Fig. 3). Its basement is composed of Hercynian igneous and metamorphic rocks, Mesozoic sedimentary rocks and of some Cenozoic andesitic domes and subordinate lavas. The latter correspond to the Lower Andesitic Series of the Sardinian volcanic lithostratigraphy, roughly dated between 28 and