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New Paleocene–Eocene paleomagnetic results from the foreland of the Southern Alps confirm decoupling of stable Adria from the African plate

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ABSTRACT

From the “undeformed” foreland of the Southern Alps Paleocene through Early Miocene rocks, mostly biostratigraphically well-dated sediments with sub-horizontal bed attitude were collected for a paleomagnetic study from 23 geographically distributed localities. The samples were subjected to standard paleomagnetic measurements and evaluation. While the Miocene samples are unstable, most of the older localities yielded statistically well-defined paleomagnetic directions. These are interpreted as primary for the compact marls, supported by positive between-locality tilt and reversal tests. This large group of localities is characterized by CCW rotated declinations with respect to the present north. Combined with paleomagnetic directions of corresponding age from stable Istria, these allow definition of the APW for stable Adria for the 61.6–33.9 Ma interval, which is significantly displaced from the coeval segment of the African APW due to the decoupling of the former to the latter by a moderate CCW rotation. This post-Eocene final separation (exact age is not constrained directly, but estimated as end-of-Miocene) was preceded by a small CW rotation of Adria with respect to Africa, suggested by unchanged orientation of the former across the Cretaceous–Paleocene boundary, while the latter continued its CCW rotation.

1. Introduction

In recent years a systematic paleomagnetic study was carried out on geographically distributed Late Jurassic–Late Cretaceous localities from the foreland of the Southern Alps (Adige embayment), which belongs to stable Adria. The results were combined with coeval paleomagnetic results from another exposed area of stable Adria, which is in the Istria peninsula (Márton et al., 2008, 2010). The apparent polar wander (APW) path thus defined was displaced in a counter-clockwise (CCW) sense with respect to the African APW (Besse and Courtillot, 2002) by about 10°. This was interpreted as the resultant of a Latest Cretaceous CW and a post-Eocene CCW rotation, since the CCW rotation exhibited by Eocene rocks from stable Istria (Márton et al., 2003) was larger than the CCW rotation measured on the Late Cretaceous rocks from the same region.

In a pioneer work, Soffel (1972) investigated igneous rocks from the Euganei Hills, representing the foreland of the Southern Alps. This was followed by a number of papers dealing also with the paleomagnetism of the volcanites from other parts of the same foreland, the Berici and Lessini Mts (Soffel, 1974, 1975a, 1975b, 1975c). From the highly scattered paleomagnetic directions (the scatter was attributed to the secular variation of the Earth's magnetic field) he concluded that the area rotated in the CCW sense with respect to stable Europe during the Eocene–Oligocene volcanic activity. His data were re-interpreted by Channell et al. (1978), who, in the light of new K/Ar ages, argued that such rotation did not exist. At the same time Soffel (1978) pointed out that the “clearly” Oligocene and “clearly” Eocene overall mean paleomagnetic directions, which are based on well-grouped site mean directions (both accompanied by more scattered “satellite” directions) are statistically different and imply at least 20–30° CCW rotation between the Eocene and the Early to middle Oligocene.

The obvious purpose of the paleomagnetic investigations in such situation would have been to study the Paleogene sediments from the foreland of the Southern Alps, which did not happen till the present time. In this paper we are presenting new paleomagnetic results from the post-Cretaceous sediments of the Euganei Hills and also from the two other uplifted parts of the Adige embayment, the Lessini and Berici Mts. In addition, new results will be presented for some igneous rocks, outcropping close to studied sediments, basically to document that the sediments were not re-magnetized during the igneous activity.

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2. Geological setting

The Alpine belt originated from the Late Cretaceous to Present convergence between the Adriatic upper plate and the subducting European lower plate (e.g., Dal Piaz et al., 2003; Dewey et al., 1989; Kurz et al., 1998). It is composed of a Europe-vergent collisional wedge (Alpine domain *s.s.*) and a south-propagating fold-and-thrust belt (South Alpine domain) separated by a major fault system, the Periadriatic Lineament (Fig. 1).

During the first stages of the Alpine orogeny (Late Cretaceous–Early Paleocene), the central and western Southern Alps constituted the slightly deformed hinterland of the Europe-vergent Austroalpine-Penninic collisional wedge. From the Miocene onward (Neoalpine phase), the Southern Alps were shortened as a south-vergent fold-and-thrust belt, which developed as a retro-wedge (Castellarin et al., 2006; Doglioni and Bosellini, 1987).

The Southern Alps are subdivided into two main sectors (Lombardian and Venetian) by the NNE–SSW-trending Giudicarie belt (Fig. 1). In between the two sectors, the triangular swell of the Adige embayment comprising the Lessini and Berici Mountains and the Euganei Hills represents the "undeformed" foreland of the Southern Alps (Bigi et al., 1990; Castellarin et al., 2006; Fantoni and Franciosi, 2009) and thus the autochthonous core of the Adriatic plate.

Despite the Alpine shortening, the Southern Alps preserved the different paleogeographic units of the Mesozoic Adriatic passive margin. From east to west they are the Julian Basin, the Friuli Platform (part of the Adriatic Carbonate Platform, see Cati et al., 1989), the Belluno Basin, the Trento Platform and the Lombardian basin (e.g., Bertotti et al., 1993). The Trento Platform was drowned during the Middle Jurassic and became a seamount (Trento Plateau).

During the complex collision between Europe and Adria, the inherited structural setting of the margins has controlled the final tectonic pattern along with the distribution of the sedimentary facies. The former Trento Plateau (to which the Lessini and Berici Mts and the Euganei Hills belong) reacted rigidly during the collision and was affected by block-faulting, which progressively reduced its extension. The uplifted blocks acted as centers of shallow-water carbonate sedimentation, which prograded and coalesced giving rise to the "Lessini shelf", a resurrected platform with scattered reefs, lagoons, islands and volcanoes (Bosellini, 1989), corresponding to the present-day Lessini and Berici Mts. The volcanic activity in the Lessini shelf is connected to Paleogene extension (De Vecchi et al., 1976). The main extensional structure is the NNW-trending Alpone-Agno graben located in the eastern Lessini Mountains and bounded to the west by the Castelvero normal fault (Fig. 2). The extensional deformation produced a widespread network of normal faults, either planar (domino style) or listric with low to moderate tilting of blocks (Zampieri, 1995). In the eastern Lessini Mts mafic and ultramafic rocks erupted during the Late Paleocene–Late Eocene, mainly in submarine environments. During the Late Eocene on the flanks of emerged volcanic ridges marine transgressive sediments were deposited ("Marne di Priabona"). The volcanic activity continued in the Early Oligocene east of Schio, in the Berici Mountains and in the Euganei Hills (De Vecchi et al., 1976).

After the Eocene the tectonic control on the accommodation space along with eustatic sea-level fluctuations produced strong variations of sediment facies and thickness, even on short distances. In the eastern Lessini and Berici Mountains the Lower Oligocene "Calcareniti di Castelgomberto" Formation (platform carbonates ca. 200 m thick) deposited on the Marne di Priabona or directly on the volcanics, where the Priabonian marls are missing. At the beginning of the Late Oligocene the Calcareniti di Castelgomberto carbonate platform became emergent and submitted to deep paleokarst development, testified in the eastern Lessini by cavities and dolines infilled by quartz sandstones (Frost, 1981). The unconformity is overlain by coralline algal rudstones ("Arenarie e Calcari di S. Urbano") of Late Oligocene age (Bassi et al., 2007). These are in turn overlain by marly and shaly sediments ("Marne argillose del M. Costi") of Early Miocene age (Bassi et al., 2008), which were also deposited in shallow-water environment, yet documenting the cessation of carbonate platform

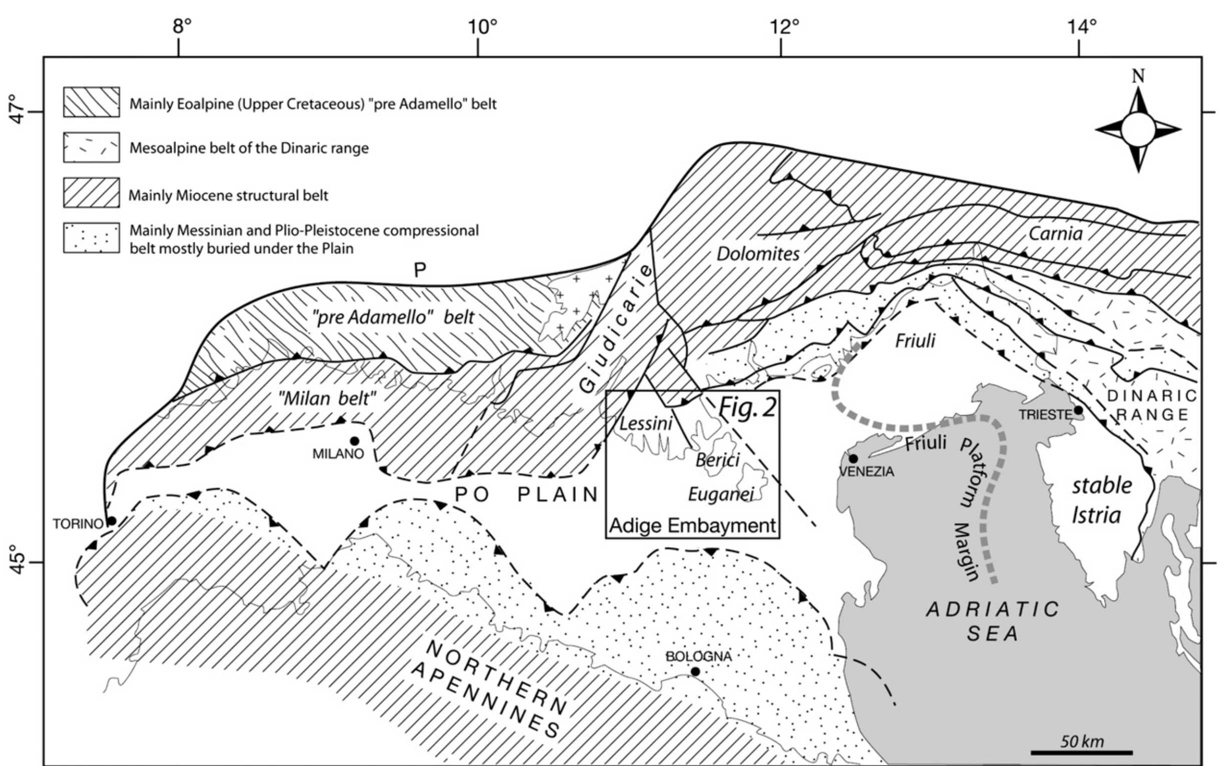

Fig. 1. Structural sketch of the Southern Alps, Northern Apennines and Northern Dinaric range with their partly common foreland areas (after Castellarin et al., 2006). The central inset shows the study area of Fig. 2, i.e. the Adige embayment.