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Adria seismicity and seismotectonics: Review and critical discussion

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ABSTRACT

We review the most recent advances in research on the seismicity and seismotectonics of Adria. A large number of earthquakes associated with this lithospheric block occur near the Adria boundaries and seismicity has been perhaps the first dataset to allow its identification as a specific lithospheric block. Adria also hosts significant intraplate seismicity, mostly concentrated in specific zones of intraplate brittle deformation, the most important being a deformation belt located at the Central Adriatic latitude and including the Gargano promontory and the Tremiti islands.

After a brief excursus on Adria seismicity, we address some relevant research points and open questions. Answers to such questions and, more in general, advances in research on Adria seismotectonics and seismicity will not only provide invaluable information for the seismic hazard assessment of this region, but also a precious tool to understand the current geodynamics of the Central Mediterranean.

1. Introduction

In this work we focus on Adria seismicity and related seismotectonics. The Adria foreland has been the object of intense investigations for over three decades, with results and hypotheses put forward by a large number of investigators (for a review, see Piccardi et al. (2011), with references). In this paper we will resume the main acquirements of these studies and we will address, in particular, the debated points and questions still open about the seismicity of Adria.

Adria is a block of continental lithosphere encircled by different fold-and-thrust belts that are part, as a whole, of the Alpine-Himalayan chain. These belts are the NE-verging Apennines, the S-verging "Sudalpino" (Alps back-arc belt; Doglioni, 1992), the SW-verging Dinarides and the W-verging Albanides (Dewey et al., 1973; Biju-Duval et al., 1977; Finetti et al., 1987; Roure et al., 2004). Therefore we can define Adria as that continental block which extends up to form the footwall of the sole thrust of all these orogenic wedges (Fig. 1A). As such, Adria is submerged for large part by the Adriatic Sea, but it is also locally exposed, for instance in Slovenia (Istria) and Southern Italy (Gargano promontory and Apulia region). Moreover, it is partly buried under siliciclastic foredeep deposits along the northeastern side of the Italian peninsula and in the Po plain (Bigi et al., 1992; Patacca and Scandone, 1989; Finetti, 2005; Fig. 1B).

A large number of earthquakes occur in proximity of the Adria boundaries and, as a matter of fact, seismicity has been one of the first datasets that allowed its identification as a specific lithospheric block. How Adria continues toward the south, however, has been and is still matter of a lively debate whose end-members are, on the one hand, that Adria is a promontory of the African Plate (e.g., Channell et al., 1979; Muttoni et al., 2001) and, on the other hand, that it is a totally independent microplate (e.g., Anderson, 1987; Anderson and Jackson, 1987; Platt et al., 1989). This variety of opinions is due to the lack of a well defined belt of seismicity univocally recognized as the southern microplate boundary, which makes different interpretative models equally viable (e.g., Mantovani et al., 2002).

Adria also hosts significant intraplate seismicity, mostly concentrated in a deformation belt located at the Central Adriatic latitude. This roughly E–W deformation belt, which includes the Gargano promontory and the Tremiti islands (Fig. 1B), has been considered the expression of a change of thickness in the Adriatic lithosphere, thicker to the south (Calcagnile and Panza, 1981; Favali et al., 1993; Doglioni et al., 1994). From a geodynamic point of view, this deformation belt has been interpreted as a right-lateral transfer zone accommodating higher roll-back velocities in the northern Adriatic slab with respect to the southern part (Doglioni et al., 1994). A more recent interpretation, however, emphasizes the role of the ongoing Africa–Eurasia plates NW–SE convergence

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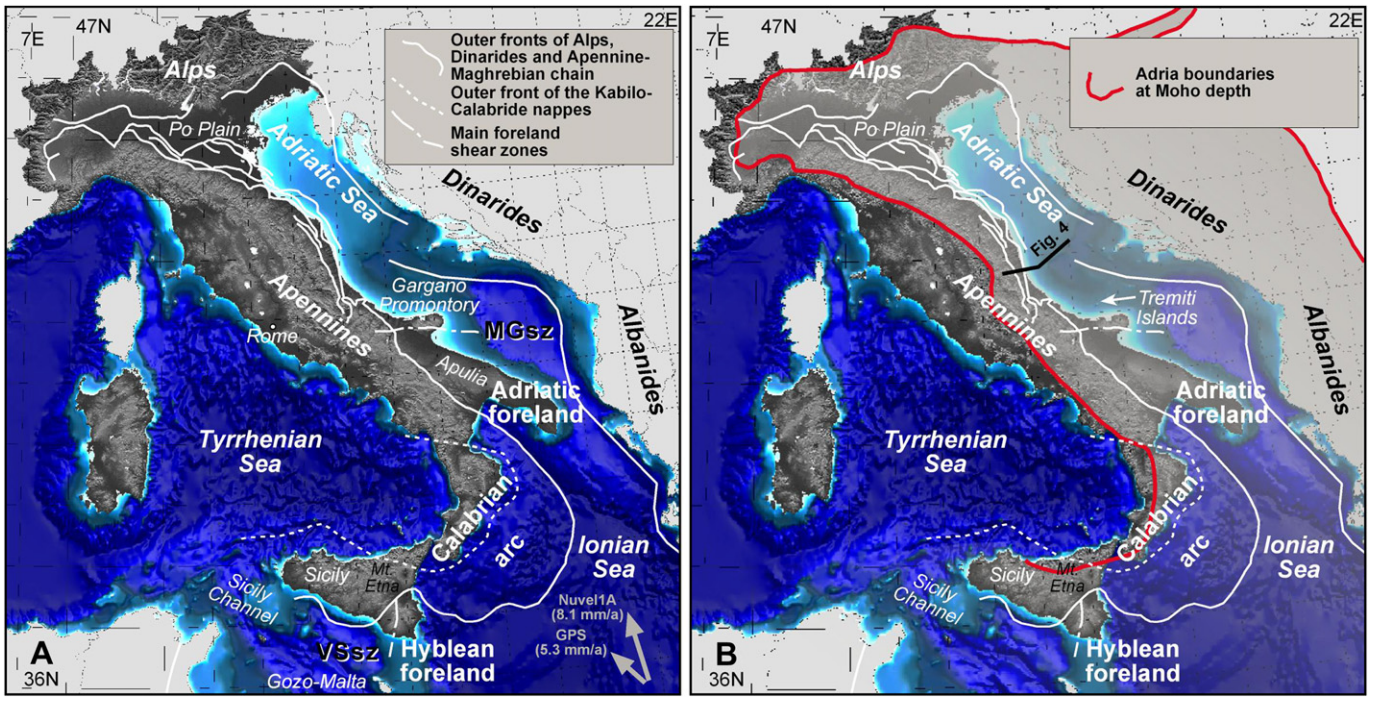

Figure 1. A) Schematic structural map of Adria and surrounding chains. Gray arrows in the lower right corner show the convergence vectors between Africa and Eurasia according to the Nuvel1A model (DeMets et al., 1994) and to the GPS pole of rotation proposed by D'Agostino and Selvaggi (2004) (modified from Di Bucci et al. (2010)). B) Adria boundaries at crustal depth (from Bigi et al. (1992), Di Stefano et al. (2009), de Leeuw et al. (2012)).

(DeMets et al., 1994; Ward, 1994; Hollenstein et al., 2003; McClusky et al., 2003; Marotta and Sabadini, 2008) in controlling the seismotectonics of this deformation belt (Di Bucci and Mazzoli, 2003; Valensise et al., 2004; Di Bucci et al., 2010). Finally, some investigators (but not all; see, for instance, Devoti et al., 2008) suggest that the deformation belt in the Central Adriatic be the boundary between two microplates, one including the Po Plain and the northern Adriatic Sea, the other one extending from the Apulia promontory to the Ionian Sea up to the Hyblean foreland, in southern Sicily (Oldow et al., 2002; D'Agostino et al., 2008).

2. Instrumental seismicity and related seismotectonic setting

It is now widely accepted that Adria is characterized by its own seismicity, different and recognizable from that occurring in the surrounding fold-and-thrust belts (e.g., Chiarabba et al., 2005b; Di Bucci et al., 2010, with references). As shown by instrumental data (ISIDE Working Group, 2012), seismicity within the Adria block displays hypocentral depths ranging within almost the whole crustal thickness, and following the inflection of the plate at the footwall of the orogenic wedges fronts, where it deepens beneath the surrounding chains. In addition, recent deeper earthquakes in the Northern Apennines have been interpreted within a model based on high-resolution teleseismic tomography which suggests a delamination of the Adria lithosphere; such property would be characteristic of its northern part only and would be due to an initial thickness smaller than in the southern part (Giacomuzzi et al., 2011, 2012).

Starting from the north, we observe that part of Adria is interposed between the Northern Apennines and the Southern Alps and is buried under the sedimentary infill of the Po Plain (Figs. 1 and 2). Here background seismicity is very limited, but earthquakes of moderate magnitude (up to M ≈ 6) accompanied by few minor events occasionally occur within the entire crustal thickness (ISIDE Working Group, 2012), which is in the order of about 30–35 km (Brandmayr et al., 2010). Following the aforementioned Adria inflection under the chains, the hypocentral depth can be larger and even exceed 60 km, as in the case of the 27 January 2012, M 5.4 Parma earthquake, located beneath the Northern Apennines fold-and-thrust belt (ISIDE Working Group, 2012). These relatively deep earthquakes display compressional focal mechanisms, which can be interpreted as an expression of active interaction between Adria and the overlaying Apennines chain. In other parts of the Po Plain, however, active deformation within Adria can be relatively shallower resulting also in earthquakes with different kinematics, both extensional and strike-slip. On top of this part of Adria, the outermost thrusts of the Southern Alps and Northern Apennines are responsible for intra-wedge moderate yet damaging earthquakes, such as those that occurred in Emilia Romagna (20 May and 29 May 2012, M_L 5.9 and 5.8 respectively; ISIDe Working Group, 2012).

Moving toward the east the orogenic wedges surrounding Adria become more distant from each other, leaving a wider part of this block as a typical foreland area, partly submerged by the Adriatic Sea and partly exposed in the Istria peninsula (Bigi et al., 1992). In this part of Adria, earthquakes are few and small, depicting a tectonically stable region. As already anticipated in the introduction, this stability characterizes large parts of the Adria foreland, whose tectonic activity and seismicity are concentrated only along specific shear zones.

Along the southwestern and northeastern margins of the Adria block seismicity occurs at the footwall of the Apennines and Dinarides orogenic wedges, deepening beneath these chains similarly to what is observed in the Po Plain. Available focal mechanisms of deep earthquakes display compressional kinematics with WSW–ENE maximum horizontal stress axis. Along the Italian peninsula these events have been interpreted as evidence for the ongoing motion of the Apennines basal thrust on top of Adria (Lavecchia et al., 2004). This interpretation, however, has to be matched with the inactivity of the leading edge of the same thrust,