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The sequence of moderate-size earthquakes at the junction of the Ligurian basin and the Corsica margin (western Mediterranean): The initiation of an active deformation zone revealed?

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ABSTRACT

A new seismically active zone is found in the southern part of the Ligurian basin, 80-km west of Corsica (western Mediterranean). The activity began in February 2011 with a foreshock (M_L 4) and a mainshock (M_L 5.3) 5 days later, followed by numerous aftershocks. We first analyze the fore- and mainshock in detail. We compare the results obtained using classical methods (linear location in a 1D medium and focal mechanisms from P and S polarities) and new approaches (non-linear location in a 3D medium and waveform modeling for determining the seismic moment and the focal mechanism). Both methods provided similar results for location, depth (in the range of 6–13 km) and focal mechanisms, which reveal reverse faulting with nodal planes oriented N–S and NE–SW. We then locate 27 of the aftershocks in the 3D model and find a 10-km-long NE–SW alignment with a depth between 7 and 16 km. In 2012 and 2013, three other moderate-size events (M_L 3.8, 4 and 4.5) occurred and confirm that this zone is still active. The epicentral area is located in the oceanic domain of the Ligurian Basin. From analysis of the bathymetry and high-resolution multi-channel seismic profiles, no morphologic anomaly at surface and no inherited fault in the shallow ~4 km depth were imaged, which suggest that no significant deformation occurred in the area since 5 Ma. Thus, the structure(s) activated during the 2011–2013 sequence remain unknown. In light of these results, we point out a notable difference on both sides of the Ligurian Basin: the northern margin, close to the alpine chain, suffered strong earthquakes and large cumulated deformation since 5 Ma, while the southern margin, close to the Corsica–Sardinia continental block, is poorly deformed since 5 Ma.

1. Introduction

Between 2011 and 2013, according to the instrumental and historical catalogs, an unusual seismic activity occurred in the southern Ligurian Basin (Western Mediterranean), offshore western Corsica (Fig. 1 and Table 1). The first notable event (M_L 4.0) occurred on July 2nd, 2011, followed 5 days later by a larger event (M_L 5.3) widely felt in Corsica, south of France and Sardinia (http://www-dase.cea.fr/evenement/syntheses_resultat.php?n=-1&type_bulletin=proche&lang=fr). Hereafter in the paper, these events will be called foreshock and mainshock, respectively. They were followed by a sequence of smaller events that we consider as aftershocks. Then, 8 months later (April 2012), the zone was reactivated by a M_L 4.5 event, and again one year later by two events (M_L 4 and M_L 3.8).

From long term GPS measurements, we know that on a regional scale the junction between the southwestern alpine belt and the Mediterranean basin is a slowly deforming intraplate area (Nocquet and Calais, 2004; Serpelloni et al., 2007; Nocquet, 2012). Regional background seismicity consists of diffusely distributed low to moderate magnitude earthquakes (e.g. Larroque et al., 2001). Nevertheless, as in numerous intraplate settings with large inherited structures [e.g., the Rhine graben (Camelbeeck et al., 2007) and Central US (Bakun and Hopper, 2004)] stronger earthquakes may occur, as for instance in the Ligurian domain between the French–Italian Riviera and the Corsica–Sardinia block in 1887 and 1963 (Fig. 1).

At the time scale of the historical and instrumental seismicity, the low-to-moderate size events as well as the stronger earthquakes are mainly located in the northern part of the Ligurian Basin. In the southern part, the Corsica–Sardinia area, including the southern Ligurian Basin, exhibits a much lower level of seismicity, especially if we excluded the sequence under study (Fig. 1). Therefore, the 2011–2013 seismic sequence points towards a localized and peculiar seismogenic zone, the July 7th, 2011 event being the strongest instrumental event ever recorded in the area.

Regional studies of active faults and potential earthquakes representing a significant seismic and tsunami hazards have been focusing on the northern side of the Ligurian Basin, along the French–Italian

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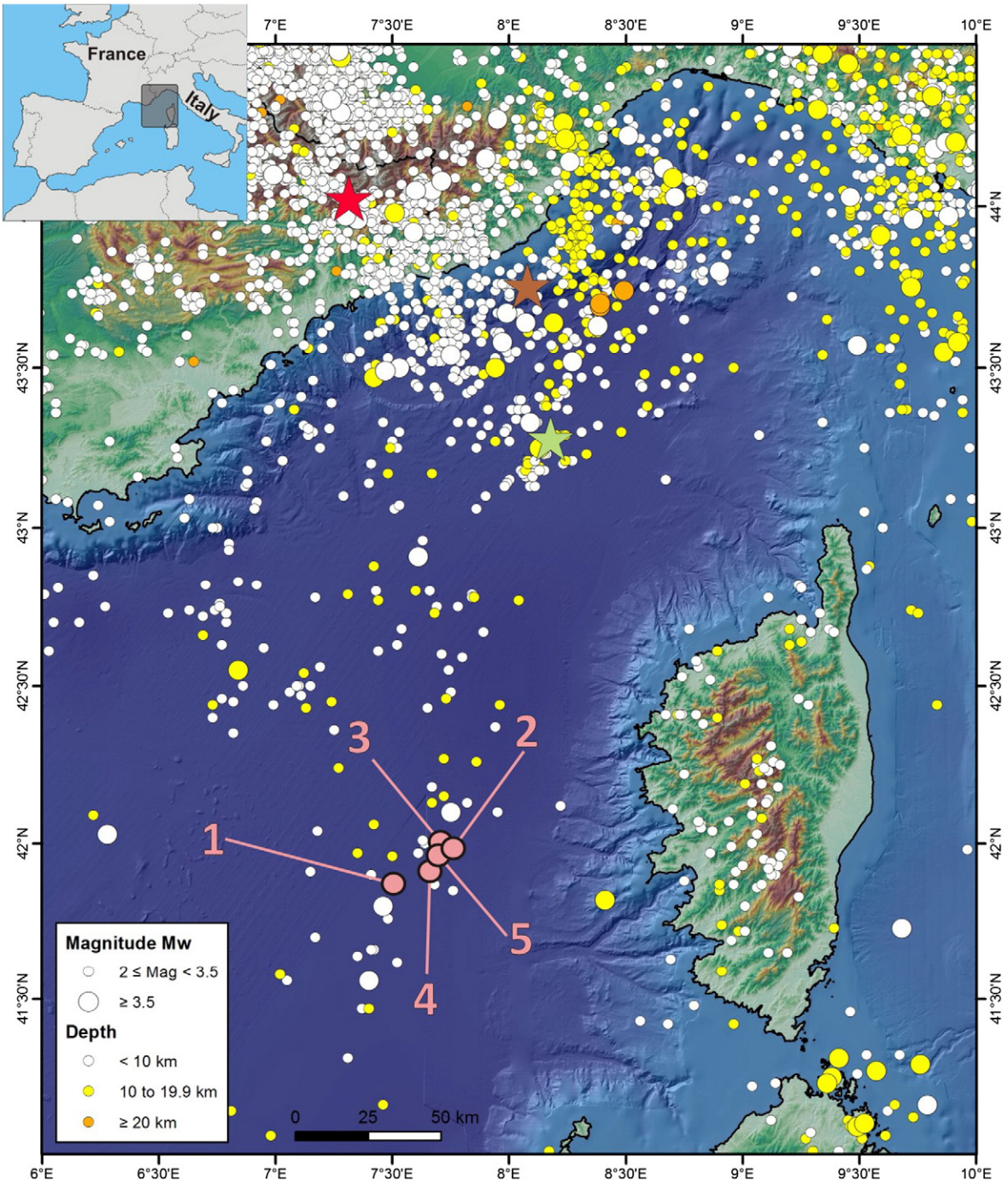

Fig. 1. Instrumental seismicity map from the DASE/LDG catalog (January 1980–June 2011; DASE/LDG network has available seismic stations since 1976 in Corsica). The stars correspond to large historical earthquakes (red: 1564/07/20, epicentral Intensity VIII MCS; brown: 1887/02/23, M_w 6.7–6.9; green: 1963/07/19, M_w 6.1). The pink dots correspond to the 2011–2013 seismic sequence offshore western Corsica (location from DASE/LDG, numbers refer to Table 1).

Table 1
Epicenters and magnitudes from LDG bulletin (http://www-dase.cea.fr/evenement/syntheses_resultat.php).

	Date	hh:mm	Magnitude (M_L)	Epicenter
1	2011/07/02	14:43	4.0	41.81°N–7.51°E
2	2011/07/07	19:21	5.3	41.95°N–7.70°E
3	2012/03/04	03:47	4.5	42.03°N–7.66°E
4	2013/04/05	07:25	4.0	41.85°N–7.64°E
5	2013/04/06	21:10	3.8	41.94°N–7.65°E

Riviera (Courboulex et al., 2007; Ioualalen et al., 2014). The potential hazard posed by earthquakes in the southern Ligurian Basin has never been addressed before. Here, we first characterize the sequence of events in 2011 with refined locations, depths, and focal mechanisms.

We focus most of our attention on the M_L 5.3 mainshock (2011 July 7th, M_L 5.3), which was recorded by numerous regional broadband stations with good azimuthal coverage from Spain to Italy. Nevertheless, constraining the source parameters of this and other such moderate-size earthquakes located offshore with stations farther than 90 km is quite challenging. To address this difficulty, we explored the hypocenter locations using both 1D and 3D regional velocity models, and the focal