



Crustal deformation at the southernmost part of the Ryukyu subduction (East Taiwan) as revealed by new marine seismic experiments

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ABSTRACT

The southernmost part of the Ryukyu subduction, where the Philippine Sea Plate is subducting under the Eurasian Plate, is known to be a very seismically active region of transition from a north-dipping subduction along the Ryukyu subduction to an SE–NW collision along the Taiwanese orogenic wedge. In this paper, we will focus on the Ryukyu forearc area close to Taiwan where the deformation is paroxysmal. In order to decipher the nature of the seismic deformation in this region, a three month passive experiment, combining 22 Ocean Bottom Seismometers and 51 onland stations, has been led. Starting from an a-priori heterogeneous model, we have obtained 801 well-located earthquake hypocenters, a precise P-wave tomography model and 14 focal mechanisms. The seismicity along the Ryukyu forearc is mainly located not only in the vicinity of the Interplate Seismogenic Zone (ISZ) but also within both the subducting PSP and the overriding plate. Seismicity within the upper-plate is essentially localized east of Nanao basin where NW–SE extension occurs, and northwest of the Heping basin where strike-slip dominates. As revealed by both the P-wave velocity structure and the newly derived seismicity, we argue that a sub-vertical step offsetting the subducting PSP around 10 km may support the presence of a trench-parallel tear. The PSP also undergoes extension in its upper part that is probably caused by buckling and slab pull. The P-wave velocity structure reveals three other major features: (1) a continuity between the Central Range and the Ryukyu Arc with a shallower Moho (~30 km depth) between ~122.3°N and ~122.5°N along the Ryukyu Arc, (2) high P-wave velocities along the eastern side of the Central Range and, (3) two bodies with similar high crustal velocities (6.5–7.0 km/s) at 12–18 km depths, embedded within the Ryukyu arc basement, just north of Heping Basin and north of the Nanao Basin.

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1. Introduction

The Ryukyu Subduction zone between Kyushu Island (Japan) and Taiwan is known to have generated only a few large thrust interplate earthquakes during the period of 1900–2010 at its two extremities (Heuret et al., 2011; Shiono et al., 1980), i.e., in the northern part offshore SW Japan and close to Taiwan west of 124°E (Fig. 1a and b). No evidences of major $M_W > 8.0$ historical shallow earthquakes have been reported (Abe, 1981; Kanamori, 1986) suggesting that the plate interface is seismically weakly coupled (Kanamori, 1971; Pacheco et al.,

1993; Peterson et al., 1984; Ruff and Kanamori, 1983). The southernmost part of the Ryukyu Subduction system, in particular between Taiwan and the Gagua Ridge, is a region of transition between an oblique subduction (Ryukyu) and an active collision (Taiwan orogen) (Kao et al., 1998b). This region results from the meeting and ~5 My evolution along the South China passive margin, of two subductions with opposite polarity: the east-dipping Eurasian Plate (EP) of the Manila Subduction and the northwest-dipping Philippine Sea Plate (PSP) of the Ryukyu Subduction, respectively to the south and northeast of Taiwan (Chai, 1972; Lallemand et al., 2001; Suppe et al., 1984; Teng, 1990; Tsai et al., 1977; Wu, 1978; Yen, 1973) (Fig. 1). Offshore, east of Taiwan and in the transitional domain between subduction and collision along the Ryukyu forearc, the high level of seismicity characterizes a paroxysmal deformation (Chen et al., 2009; Hsu, 1961; Kao et al., 1998b; Tsai, 1986; Wang, 1998; Wang and Shin, 1998; Wu,

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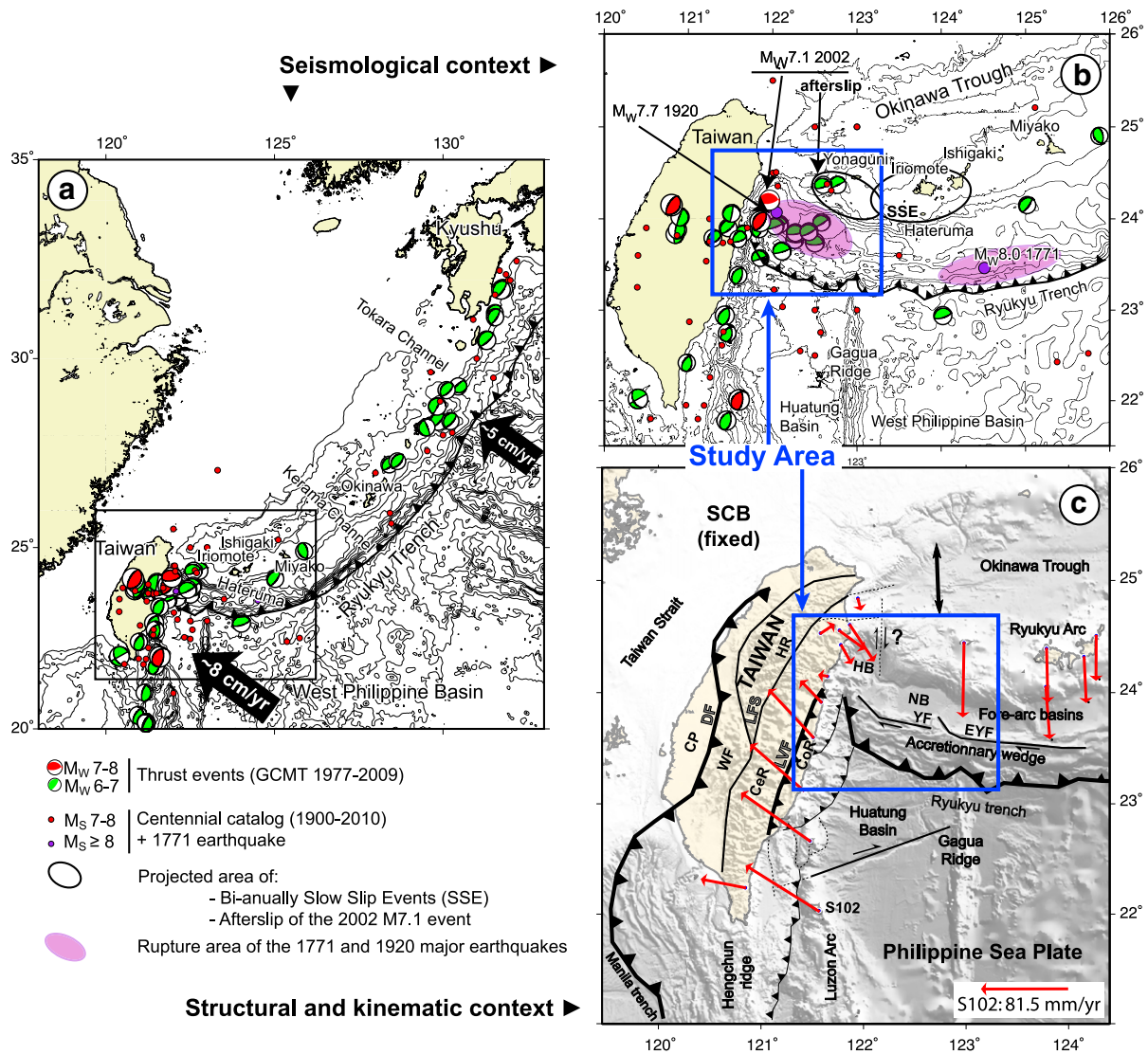


Fig. 1. Tectonic settings. a: Thrust events along the Ryukyu subduction zone during the period 1977–2009 and major earthquakes ($M_s > 7$) during the period 1900–2010. b: Close-up view of the southernmost part of the Ryukyu subduction. Known slip area of Slow Slip Events (SSE) and two larger earthquakes known (1771, 1920) are also added in purple. c: Structural and kinematic context. GPS velocity field comes from Hsu et al. (2009). CP: Coastal Plain, DF: Deformation Front, WF: Western Foothill, LFS: Lishan Faults system, CeR: Central Range, LVF: Longitudinal Valley Fault, CoR: Coastal Range, HB: Hopping Basin, NB: Nanao Basin, YF: Yaeyama Fault, EYF: East Yaeyama Fault. S102 is the reference of the GPS station on Lanyu Island supposed to represent the velocity of the non-deformed PSP.

1978) (Fig. 2). There, more than 10 major events with magnitude between 7 and 8 occurred since the beginning of the last century but the source of each of them is not known (Theunissen et al., 2010). Efforts to image this area, mainly based on active seismic offshore (reflection and refraction) or passive seismic using onland seismic stations, have led to divergent interpretations. Previous studies were non-conclusive regarding the geometry and mechanism of offshore active faults (e.g., Font and Lallemant, 2009). Responses to key questions are still outstanding: how is the deformation accommodated offshore northeast Taiwan? What are the type and the origin of the seismicity along the Ryukyu forearc? What is the nature of the forearc domain? Is the subduction interface close to Taiwan likely to generate a major earthquake?

In this study, before to answer the questions, we aim to image the seismic wave velocity structure to describe tectonic features and to characterize the geometry and deformation type of offshore active faults in order to contribute to the determination of large event

sources. This work carries out a 3D approach that uses an a priori 3D P-wave velocity model and 3D hypocenter determination as initial inputs to perform the tomographic inversion and focal mechanism determination. East of Taiwan, some studies have provided earthquake location and seismic tomography to image and understand the seismic deformation pattern offshore. Many of them used a combination of seismic stations located on Taiwanese and Japanese islands in order to better highlight the area offshore (Chou et al., 2006, 2009; Font and Lallemant, 2009; Font et al., 2004; Hsu et al., 2001; Kao and Rau, 1999; Lin et al., 2004; Wu et al., 2008, 2009b). However, in all these studies, no Ocean Bottom Seismometer (OBS) has been used to improve the azimuthal coverage, resulting in poorly resolved crustal structures (especially at shallow depth) and large uncertainties on hypocenter position (especially the depth). Only Lin et al. (2007) have used a combination of OBS deployed during 12 days in the Okinawa basin and permanent stations to study the micro-seismicity in the back-arc basin. To improve azimuthal coverage and P-wave velocity structure

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