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Microseismicity and faulting in the southwestern Okinawa Trough

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Abstract

In November 2003, 15 ocean bottom seismometers were deployed in the southwestern Okinawa Trough. More than 3300 microearthquakes were located during the 10-days passive seismic experiment. The earthquake activity is characterized by the ceaseless occurrence of small earthquakes in the vicinity of all the instruments. The seismicity is essentially restricted to the central part of the Southwestern Okinawa Trough, except for one cluster of events situated in the southern part of it (cluster 2). The seismic activity terminates abruptly against the NE–SW trending prolongation of the Lishan fault. Most of the microearthquakes are aligned along the E–W trending normal faults, showing where the present-day active normal faulting occurs and how it accounts for the N–S extension in the Okinawa Trough. According to the P-wave velocity spectra estimated from some deep earthquakes located beneath the cross backarc volcanic trail area, the existence of a lower crustal/upper mantle magma chamber is confirmed by the presence of low frequency earthquakes in the 3–10 Hz bandwidth.

Keywords: Southwestern Okinawa Through; Microseismicity; Normal faulting; Extension; Backarc basin; Cross backarc volcanic trail

1. Introduction

The Okinawa Trough (OT) is a continental backarc basin currently opening behind the Ryukyu arc-trench system where the Philippine Sea plate (PH) subducts beneath the Eurasia plate (upper inset in Fig. 1). It can be considered as a complex area in which numerous geodynamic features interfere (backarc features, volcanic front, abnormal volcanism linked to the 123°E slab tear, previous geological trends). Refraction data acquired in the Okinawa Trough reveal that the crust is of continental origin and the crustal thickness along the trough axis increases from 15–18 km in the southern OT to 27–30 km in the northern OT (Lee et al., 1980; Iwasaki et al., 1990; Hirata et al., 1998; Sibuet et al., 1995). Based on the swath-bathymetric and seismic data, numerous normal faults were mapped by Sibuet et al. (1998) allowing to identify the two last phases of extension in the southwestern Okinawa Trough (SOT) with N150° directions of extension during the Pleistocene (2–0.1 Ma) and N170° during the late Pleistocene–Holocene phase of extension (0.1–0 Ma). The direction of present-day extension, estimated from the focal mechanism solutions of earthquakes occurring in the axis of the SOT, commonly strikes within 30° of the N–S direction (Dziewonski et al., 1981; Fournier et al., 2001; Kubo and Fukuyama, 2003). Two databases of GPS measurements in the Taiwan region (Yu et al., 1995 and 1997) and in the southern Ryukyu Arc (Heki, 1996; Imanishi et al., 1996) were combined by Lallemand and Liu (1998). These movements are relative to the South China Sea. The westernmost part of Ryukyu Arc, Yonaguni Island, is moving southward with a velocity 1.4 cm/yr faster than the north of Taiwan (Ilan Plan) which accounts for the Okinawa Trough opening processes. The volcanic front (dotted gray line in Fig. 1) extends from Japan to Taiwan. From Kyushu to Okinawa Island, it follows the active volcanoes of the Ryukyu Arc and progressively migrates inside the OT, following small subaerial active volcanoes located about 25 km west of the non-volcanic

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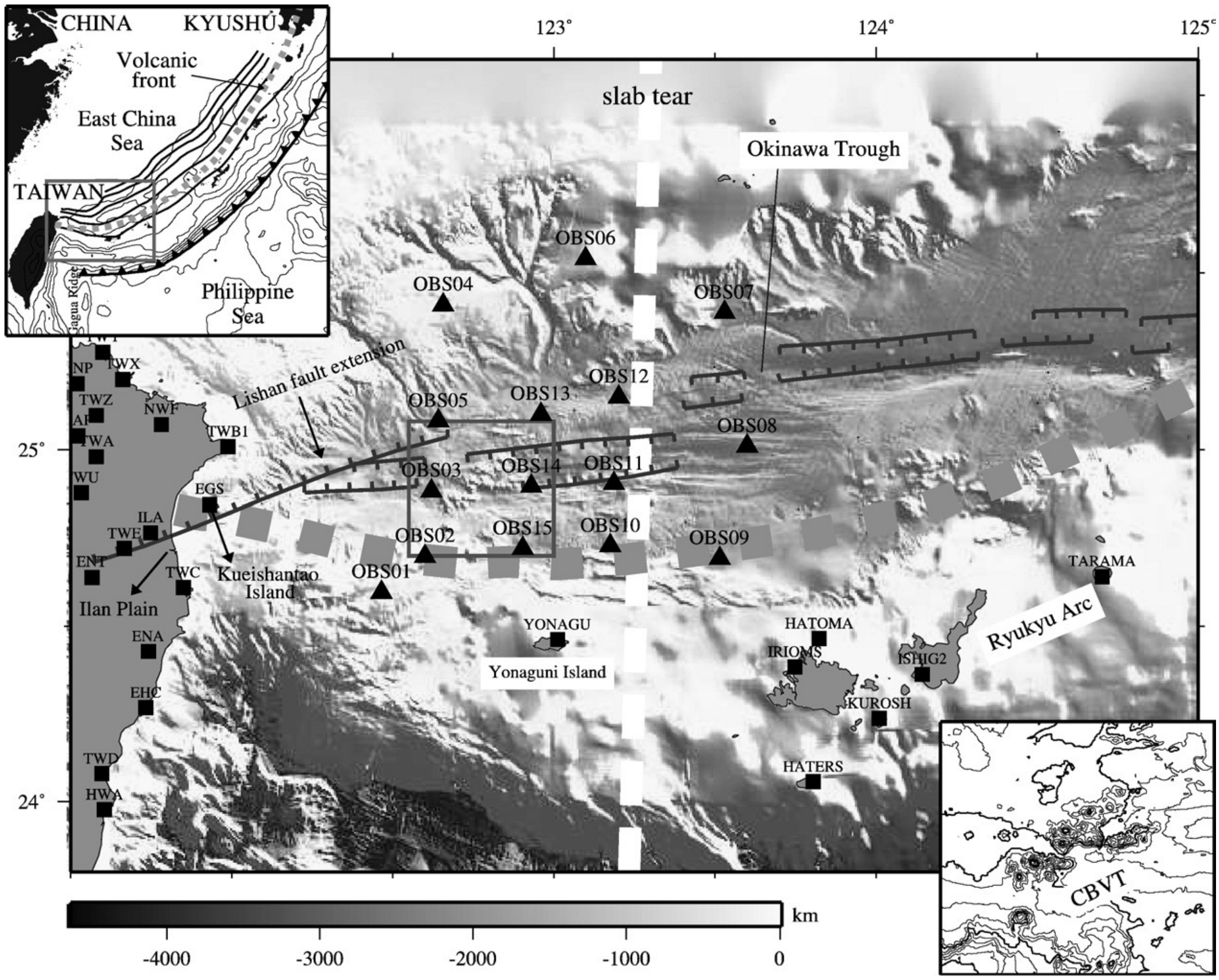

Fig. 1. Shaded bathymetry in the northwestern corner of the Philippine Sea plate extracted from Sibuet (in prep.). The location of the Lishan fault extension and Okinawa Trough normal faults are from Sibuet and Hsu (2004). Locations of the 15 OBS (black triangles) used during the 2003 experiment and surrounding land stations (black squares). The white dashed line shows the location of the slab tear (Lin et al., 2004a and b). In the upper left corner, the general map of the Ryukyu subduction zone with slab depths every 50 km and location of the volcanic front (dashed line). In the lower right corner, detailed bathymetry (isobathic spacing, 100 m) of the cross backarc volcanic trail (CBVT) (Sibuet et al., 1998) located in the gray square box.

arc. Southwest of Okinawa Island, it migrates inside the OT, follows numerous seamounts associated with high amplitude magnetic anomalies (Hsu et al., 2001), then cuts across the cross backarc volcanic trail (CBVT), which consists of a cluster of about 70 seamounts located west of 123°E longitude (lower inset in Fig. 1) and finally ends 10 km offshore of Taiwan in Kueishantao Island (Sibuet et al., 1998; Chung et al., 2000). According to seismicity data (Engdahl et al., 1998) and depths of magnetic basement (Lin et al., 2004a), a slab tear was identified along the 123.2°E meridian (Fig. 1). Based on Vp, Vs and Vp/Vs tomographic images, an excess of partial melting identified along the slab tear is at the origin of the abnormal CBVT volcanism (Lin et al., 2007). The Lishan fault is a major feature of Taiwan, which separates the Hsuehshan Range from the Backbone Range (Ho, 1986; Lee et al., 1997). It continues in the Ilan Plain (Hsu et al., 1996) and in the westernmost part of the SOT and was identified up to 122.6°E longitude (Sibuet et al., 1998). Its existence was suspected east of 122.6°E but not firmly established due to the lack of seismic reflection data. The Lishan fault and its OT prolongation seem to be a major crustal or even lithospheric feature which offset the tensional features of the SOT and Ilan Plain.

Thus, the SOT is located in a complex geologic setting that can be better understood if we are able to constrain its deep crustal structure. As this region is a seismically active area, the idea is to look at the hypocenter distribution in order to better understand the geological context. In the past, the SOT seismicity was established by using only land seismic stations recordings. The depth accuracy of offshore seismic activity analyzed from existing land data was often poor, even if seismological data from the two Taiwanese and Japanese networks of land stations are coupled (Hsu, 2001; Nakamura et al., 2003). Because of this limitation, a passive ocean bottom seismometer (OBS) experiment performed in this area is a good way to increase the resolution of earthquake data.

2. Data acquisition

The passive seismic OBS experiment was conducted from November 19 to December 1, 2003. 15 OBSs were deployed in