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Preface

An introduction to geodynamics and active tectonics in East Asia

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1. Introduction

This special issue contains a collection of 24 papers dealing with the geodynamics, geophysics and tectonics around the Philippine Sea Plate, especially near the Taiwan region. Most of the papers were presented in the 'Geodynamics and Environment in East Asia International Conference and fifth Taiwan–French Earth Science symposium (GEEA)' in Taitung (SE Taiwan), 24–29 November 2005. Seventy-seven oral presentations and Forty-two posters were presented in the GEEA meeting. Eight sessions were convened, including session A: plate boundary observation; session B: sedimentation and tectonics; session C: earthquake and seismotectonics; session D: geohazards; session E: neotectonics; session F: remote sensing and environmental observation; session G: Spratly tectonics and climate change; session H: quaternary environmental change in SE Asia. Previous Taiwan–French symposiums had been held in Taiwan (in 1984, 1995 and 2000), and in France (Paris in 1988, Montpellier in 1999). Proceedings had been published in Tectonophysics special issues (Angelier et al., 1986; Angelier, 1990; Lallemand and Tsien, 1997; Lallemand et al., 2001).

As the GEEA meeting venue was located in Taitung (a city in the south of the Longitudinal Valley), a three-day field trip was conducted in order to observe the structure and deformation of the convergent plate boundary between the Luzon volcanic arc (Coastal Range) and the Backbone Range (central mountain range of Taiwan) of the Eurasian Plate. Most of the stops deal with the outcropping Longitudinal Valley lithologies (e.g. Lichi Melange in Fig. 1) as well as the monitoring of the active Chishang fault displacement (Tapo and Chinyuan area). Rapid erosive and uplift rates are highlighted in the Hsiukuluan river which has deeply incised the central Coastal Range. A round trip to the small Lutao island ("green island", part of the Luzon Arc) (Fig. 2) offshore Taitung was to observe the geomorphology of the numerous uplifted Pleistocene marine terraces as well as the detailed volcano-stratigaphy of the Luzon volcanic arc. The field trip was finally ended by observing the brittle deformation of the south Backbone range in Taimali where three micro-tectonic stages are distinguished.

2. Eurasian and Philippine Sea plates

The tectonics of the East Asia is mainly controlled by three plates: India, Eurasian and Philippine Sea plates. The collision between the India and Eurasian plates since ca. 45 Ma (Lee and Lawver, 1995) has caused the uplift of the Himalaya belt and the extrusion of Indochina Block (Tapponnier et al., 1982). The results include the initiation of seafloor spreading of the South China Sea in Late Eocene (ca. 37 Ma) (Hsu et al., 2004). On the other hand, after the formation of the Luzon Arc the Philippine Sea Plate has approached the East Asian margin northwestward and finally has collided with the Ryukyu subduction zone since ca. 9 Ma (Sibuet and Hsu, 2004). The consecutive evolution has built the Taiwan mountain belt since about 3 Ma (Teng, 1990). The most active collision currently happens in central Taiwan and causes considerably gravitational instability (Hsu and Lo, 2004; Lo and Hsu, 2005). The actual plate boundary between the Eurasian Plate and the Philippine Sea Plate in East Asia is traced from Naikai Trough, Ryukyu Trench, Taiwan orogenic suture zone and Manila Trench. The tectonic interaction between these two plates has simultaneously resulted in numerous earthquakes. Moreover, if we examine detailed structures, heterogeneous characters still exist for different sites. For example, the opening history of the Okinawa Trough can be separated into several stages (Sibuet et al., 1998); especially, the Southern Okinawa Trough has opened just after the collisional sweep of the northern tip of the Luzon Arc against the southern Ryukyu Arc (Sibuet and Hsu, 2004). Consequently, the subducting Philippine Sea Plate in front of the Southern Okinawa Trough (i.e. the Huatung Basin) has exhibited a fast roll-back (Hsu, 2001). Most of the papers presented in this issue provide a good opportunity to better understand the tectonics of East Asia, particularly for the deformation and tectonics of the Taiwan mountain building belt and the Philippine Sea Plate.

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Fig. 1. Photograph of the GEEA field trip participants. The picture is taken in the Longitudinal Valley corresponding to the eastern suture fault zone between the Eurasian plate and the Philippine Sea plate. Background shows the badlands of the marine Lichi melange where highly erosive features are remarkable.

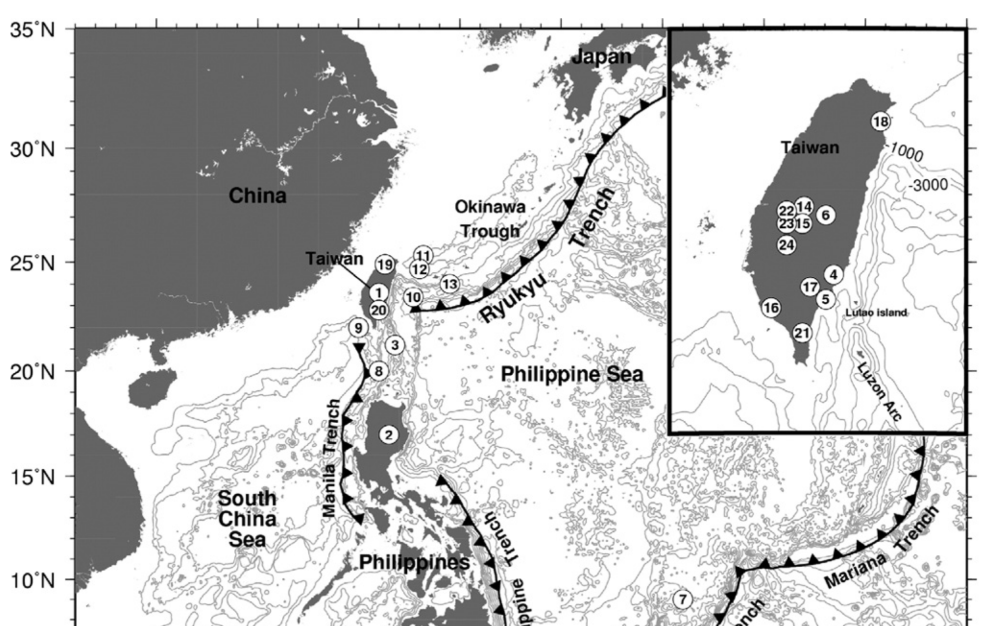

Fig. 2. Geodynamic context of East Asia where the Philippine Sea Plate subducts northward beneath the Ryukyu Arc and causes the back-arc rifting of the Okinawa Trough while the Eurasian Plate subducts eastward beneath the Luzon Arc. Numbers indicate the different papers in this issue.

3. Overview of the different papers

3.1. Tectonics of the western Philippine Sea Plate

The convergence between Philippine Sea Plate and Eurasian Plate in the region between Taiwan and Luzon islands is quite complex and is particularly influenced by the collision in the Taiwan orogen. Five papers related to the tectonics of the western area of the Philippine Sea Plate are presented in this issue.

By using seismic P wave arrival times, Wright (paper number 2 in Fig. 2, this issue) shows the P wave velocity of the upper/lower mantle transition zone beneath the Philippines region. Based on seismic reflection data, Ku and Hsu (paper number 8 in Fig. 2, this issue) present a paper addressing the morphological and structural features of the northern Manila Trench. Across the northern Manila Trench, the structural features can be divided into normal fault zone, proto-thrust zone and thrust zone. The Manila subduction zone in fact plays an important role in the South China Sea evolution and it could be the only location that can generate disastrous tsunami threatening coastal countries around the South China Sea. However, this location was not well studied. Wu et al. (paper number 3 in Fig. 2, this issue) have calculated the stress states from available earthquake focal mechanisms. Their results infer the variation of convergence characters and internal deformation in the westernmost Philippine Sea Plate.

Northern Manila Trench terminates in southern Taiwan where the initial collision between the Luzon Arc and Eurasian margin begins. The uplift of the Taiwan mountain belt has accompanied the formation of the foreland basin in the west of Taiwan. The sedimentation off southwest Taiwan or northern South China Sea is described by Yu and Huang (paper number 9 in Fig. 2, this issue). The morphological features off southwest Taiwan such as canyons are also addressed.

Okino et al. (paper number 7 in Fig. 2, this issue) investigate the tectonics of the southern tip of the Parece Vela Basian, Philippine Sea Plate. Their study provides clues to fill in the gap of understanding the whole Parce Vela Basin and the Philippine Sea Plate tectonics.

3.2. Tectonics of Ryukyu subduction zone

Four papers in this issue address the tectonics of the southern Ryukyu subduction zone. Font and Serge (paper number 10 in Fig. 2, this issue) study the forearc tectonics of the southernmost Ryukyu subduction zone where the seismicity is severely clustered. They interpret the cluster of dense earthquakes is probably due to the subduction of oceanic relief. High angle splay fault in the accretionary prism of the southern Ryukyu subduction zone is suggested. Behind the southern Ryukyu arc, small scale seismicity in the southern Okinawa Trough, a back-arc basin, was poorly observed and studied. This area presents the distant limits of the earthquake observation networks for both the Central Weather Bureau (CWB) of Taiwan and Japan Meterological Agency (JMA) of Japan. Small earthquakes recorded by Ocean Bottom Seismometers (OBS) may fill this gap of observation. Results of Lin et al. (paper number 11 in Fig. 2, this issue) show a major northern limit of earthquakes distribution along the northern margin of the southern Okinawa Trough, while most of the earthquakes are linked to the E–W trending normal faulting due to the back-arc rifting. In the same area, Klingelhoefer et al. (paper number 12 in Fig. 2, this issue) present results from reflection and wide-angle seismic data and provide information about crustal and sediment thicknesses. Matsumoto et al. (paper number 13 in Fig. 2, this issue) show the result of ROV dives off southwest Ryukyu Arc. Their finding of submarine faults is suggested to be linked to the 1771 historic tsunami in southwest Ryukyu region.

3.3. Deformation and tectonics of the Taiwan orogen

Chen et al (paper number 1 in Fig. 2, this issue) statistically show the seismic deformation in the Taiwan region from a complete list of earthquake dataset. Their analysis especially suggests the potential regions of large earthquakes in Taiwan.

Eastern Taiwan is the place where the Philippine Sea Plate is actively colliding against the Eurasian Plate. In other words, the Luzon Arc hits on the Eastern Taiwan. As a result, the deformation is strong and the earthquakes are numerous. Cheng (paper number 4 in Fig. 2, this issue) uses a seismic tomographic technique to image the plate convergent zone in eastern Taiwan. His study provides information of understanding the collisional tectonics in a plate convergent zone. In the same geological context, there was a disastrous 2003 Chengkung earthquake in eastern Taiwan. Huang et al. (paper number 5 in Fig. 2, this issue) use dense seismic array and continuous GPS observations to examine the spatial and temporal variation of the fault rupture related to the Chengkung earthquake. Cheng et al. (paper number 17 in Fig. 2, this issue) have also shown the tectonic deformation because of the 2003 Chengkung earthquake in eastern Taiwan.

The active convergence between the Philippine Sea Plate and the Eurasian Plate implies that part of continental crust may subduct eastward in eastern Taiwan. The existence of an eastwards subducted slab in central Taiwan was debated. Lin's paper (paper number 6 in Fig. 2, this issue) shows the evidence of a subducted continental slab in central Taiwan. His also explains the situation of few related mantle earthquakes in terms of crustal strength. Malavieille and Trullenque (paper number 20 in Fig. 2, this issue) present an analogue modeling explaining the possible tectonic processes of the Taiwan orogeny.

The active collision also causes the strong convergence and deformation in west-central Taiwan. A direct consequence is the occurrence of the Chi-Chi earthquake in 1999. The Chi-Chi earthquake has caused a serious damage in Taiwan and is also a milestone of geological and geophysical studies in Taiwan (eg. Kao and Chen, 2000). The drilling of the Chelungpu fault zone down to about 2 km is one of the important follow-up research activities (Ma et al., 2006). Hung et al. (paper number 15 in Fig. 2, this issue) have analyzed the physical properties of the core and indicated the 1111 depth as the rupture site during the Chi-Chi earthquake. Besides, the focal mechanisms and seismotectonic stress related to the Chi-Chi earthquake is presented by Mozziconacci et al. (paper number 22 in Fig. 2, this issue), while the landslides triggered by the Chi-Chi earthquake and their characteristics are introduced by Tseng et al. (paper number 23 in Fig. 2, this issue) and Dong et al. (paper number 24 in Fig. 2, this issue). Mebarki (paper number 14 in Fig. 2, this issue) compares the Peak Ground Accelerations attenuation and error models of the 1999 Chi-Chi earthquake in Taiwan.

Comparing to the active collision in the eastern Taiwan, the northern Taiwan is under a post-collisional extension regime. The most prominent example is the opening of the Ilan Plain in the southernmost Okinawa Trough. Using geodetic information from 34 sites in the Ilan Plain, Hou et al. (paper number 18 in Fig. 2, this issue) show the crustal deformation of the southernmost Okinawa Trough. The southeastward extrusion of the southern Ilan Plain is concluded. Angelier et al. (paper number 19 in Fig. 2, this issue) also present extrusion model for the Ilan Plain. Moreover, the deformation of the Pingtung Plain in the southern Taiwan is also explained by an extrusion model where the crust moves southwestward. Likewise, the geological phenomenon may reflect different phases of deformation of the convergence. Chang et al. (paper number 21 in Fig. 2, this issue) demonstrate folding, faulting and rotation of the structural geology in southern Taiwan. The SW Taiwan has been expected to be an area that may potentially generate big earthquakes in Taiwan. Huwan et al. (paper number 16 in Fig. 2, this issue) use geodetic measurements and SAR (Synthetic Aperture Radar) technique to monitor the deformation of the Tainan area in SW Taiwan and demonstrate the potential hazard.

4. Perspectives and conclusions

This special issue contains most of the papers presented at 5th Taiwan–France earth science conference and GEEA conference. Most of papers address the tectonic problems in and around Taiwan. Some papers address the Philippine Sea plate, the Ryukyu subduction zone and the Manila subduction zone. Their results shed light on the understanding of the geodynamics and active tectonics in East Asia. However, there are still several places needed to be explored in the near future. For example, the structures and tectonic evolution of the northern part of the South China Sea, from the Asian continental margin in the west to the Manila Trench in the east near the Luzon Island, are not very clear (Hsu and Sibuet, 2004). The study of the Manila subduction zone is especially important in the sense that it may generate large tsunami-earthquakes along the Manila Trench and damage the coastal countries surrounding the South China Sea. On the other hand, the Philippine Sea Plate near the Taiwan–Philippine region is not clear either. This region is related to the formation of a fossil transform fault zone along the Gagua Ridge (Hsu et al., 1998) and is associated with the East Philippine Trench.

In the north, the northern margin of the Okinawa Trough and the East China Sea obviously demand more attention, especially the tectonic evolution related to the southern Okinawa Trough. As a matter of fact, the scientific co-operations through bilateral or multiple countries become more and more important. The joint studies are especially significant for the areas where the economic exclusive zones (EEZ) are overlapped by different countries.

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Shu-Kun Hsu
Institute of Geophysics, National Central University, Chung-Li 32001, Taiwan
Corresponding author.
E-mail address: hsu@ncu.edu.tw.

Benoit Deffontaines
Laboratoire de Géomatériaux et Géologie de l'Ingénieur, 5 Bd Descartes, F-77454 Marne-la-Vallée Cedex 2, France
E-mail address: Benoit.Deffontaines@univ-mlv.fr.