DEFORMATION OF ASIA AND ITS GLOBAL IMPACT

Pinxian Wang, Chun-Feng Li
State Key Laboratory of Marine Geology, Tongji University
Shanghai 200092, CHINA
E-mail: pxwang@tongji.edu.cn; cfl@tongji.edu.cn

Abstract

A series of IODP-ICDP joint drilling campaigns are proposed to cover the three major topics in the Asia-Pacific interactions: the Formation of the Pacific Plate and the South China Magmatic Province in the late Mesozoic, Asia without marginal seas in the early Cenozoic, and plateau uplift and reorganization of Asian fluvial system in the late Cenozoic.

Introduction

The new phase of IODP beyond 2013 will face the challenges of identifying scientific targets for deep-sea drilling. After 45 years of DSDP/ODP/IODP, there are not many sites left in the oceans where an ocean drilling program alone can answer major scientific questions. Rather, it requires a combination of IODP with other facilities such as deep-sea observation and continental drilling. Continent-ocean interactions between Asia and the Pacific will be the most appropriate topic for a joint effort of IODP-ICDP. Many important geological questions require dedicated inputs from a strong ally of scientists that have in mind both what have been learnt onshore and what are to be learnt offshore. For these purposes we strongly promote seamless collaborations between future ocean and continent drilling programs, and the deformation of Asia as a central scientific target requiring such collaboration.

Asian geology has been transformed by the late Mesozoic subduction of the paleo-Pacific Plate and in the Cenozoic by the uplift of the Tibetan Plateau and the formation of the western Pacific marginal seas. Ever since the closure of the Meso-Tethys in the late Mesozoic, Asia has become the area where interactions between the largest continent and largest ocean occur (Fig.1; Wang, 2004), and started to exert its global role in influencing climate and environments.

In this white paper we propose a set of three closely related scientific incentives that can potentially be better met in the next phase of the international ocean drilling program.

Formation of the Pacific Plate and the South China Magmatic Province

The large magmatic province in SE China (Fig. 2), with a 220,000 km^2 outcrop area of granitoids and volcanic rocks, have been dated to be from the middle Jurassic to the late Cretaceous (<180 Ma to 80 Ma) (Zhou & Li, 2000; Chen et al., 2008). The starting date of magmatic emplacement almost corresponds to the incipient formation age of the modern Pacific Plate (Bartolini & Larson, 2001). These extensive magmatic activities were accompanied by strong tectonic deformations and are considered as an evidence for reactivation of the cratonic lithosphere in the region. As a result, sea water had retreated perpetually from much of East Asia since the middle Jurassic. It has been hypothesized that the late Mesozoic activation in East Asia resulted from low-angle west-dipping subduction of the paleo-Pacific Plate and/or its subsequent foundering (Zhou & Li, 2000; Li & Li, 2007). Therefore, the late Mesozoic reactivation of East Asia and the early evolution of the Pacific Plate are apparently strongly coupled, and it must not be just a coincidence that the oldest crust of the modern Pacific has the same age as the most active magmatism in the Mesozoic East Asia.

The oldest crust of the Pacific Plate has been drilled so far at two ODP sites, ODP Site 801 drilling into the Bathonian crust of 167 Ma, and ODP Site 1149 into the Valanginian crust of 130 Ma (Révillon et al., 2002; Hauff et al., 2003). However, the focus was laid on plate subduction, and the Mesozoic history of the Pacific remains poorly constrained partly because of the "Jurassic magnetic quiet zone" that had hampered the use of magnetic chornology (Tivey et al., 2006). Now with high-resolution magnetic anomalies being recognized in the J-Cr Pacific crust, late Mesozoic sedimentary rocks can be recovered with better age controls at a set of sites in the oldest part of the present Pacific crust. Joint ocean and continental drilling in the Mesozoic part of the Pacific and South China Magmatic Province will help unveil much of the early history and geometry of the subducted part of the paleo-Pacific lithosphere as well as the reactivation mechanism of the South China Craton (Zheng & Wu, 2009), and address the missing link between the paleo-Pacific and East Asia tectonic and environmental histories.

East Asia without marginal seas

A series of marginal seas separate the modern Asian continent from the Pacific, but most the basins were opened in the Oligocene-middle Miocene (~32-15 Ma). From the late Mesozoic until the end of Eocene, most of the marginal seas were nonexistent in the Western Pacific, and East Asia was under the direct impact of the subducting paleo-Pacific Plate. There are evidences for mountain ranges then developed in South China (Chen, 1995). Since the area covering the modern Tibetan Plateau was still inundated by the Tethys up to the Eocene, China must have had a west-tilting topography from the late Mesozoic till Eocene. The west-titling topography in China, and presumably all the East Asian continent, has profound impact on its environments and on continent-ocean interactions (Fig.3; Wang, 2004). As shown from computer modeling (Fig. 4), the Eocene climate in the region was prevailed by a planetary wind system, and the Asian monsoon was insignificant if not absent (Chen et al., 2000).

Entering the Cenozoic, the East Asian continental margin changed its tectonic regime from a collisional and compressive setting to experiencing severe continental margin rifting and break-up and the formation of western Pacific marginal seas. This episode of tectonic transform concurred with the collision between the Indian Plate and the Eurasia Plate, the final closure of the Tethys, the uplift of the Tibetan Plateau, the southeastward extrusion of Southeast Asia blocks, and the eastward retreat of the Pacific subduction zones. Due to this complex tectonic evolution in such a vast area, the cause and effect relationships between different tectonic events remain rather vague. Like the eastward younging in the late Mesozoic magmatism in South China, the Cenozoic rifting activity in the East Asian continental margin followed a similar pattern of eastward migration.

From offshore oil explorations, Paleocene and Eocene marine deposits have been discovered in the East China Shelf and the northern South China Sea. Together with numerous Paleogene marine sections in East Asian islands, these sequences yield an excellent opportunity for paleo-reconstruction of East Asia and the West Pacific before the formation of the marginal seas. In addition, the combined IODP-ICDP drilling of the Paleogene sequences will shed light on the "lost Eastern Tethys ocean basin" and the Tethys-Pacific connection (Heine et al., 2004). In general, a joint IODP-ICDP drilling in the marginal seas will provide continuous records of the afore-mentioned tectonic and paleogeographical transition.

Plateau uplift and reorganization of fluvial system

The Cenozoic evolution of East Asia is also hallmarked by the uplift of the Tibetan Plateau and the dramatic climatic and environmental consequences of this tectonic event. Unlike in the late Mesozoic when the highest plateau is located to the east due to the active subduction of the paleo-Pacific Plate, the Cenozoic era has witnessed the gradual change in the East Asian topography from declining westerly to declining easterly, and this has triggered, among many other important geological consequences, redistribution in the regional river system. Most of the largest river systems in East Asia today are radiating outwards from the Tibetan Plateau and adjacent areas (Fig. 1).

Thick early Cenozoic terrestrial sediments are found in most of the continental margin rifting basins offshore East Asia (Li et al., 2009), and they potentially provide the earliest information about the East Asia deformations. After the opening of the western Pacific marginal basins, primarily during the Oligocene and Miocene, rifting events were substituted by seafloor spreading, and a large portion of the materials carried by these large rivers can be transported directly into these marginal ocean basins after overfilling preexisting rifts. After the Miocene the East Asian continental margin experienced an accelerated subsidence and is overlain by thick marine sediments. Thus the complicated history of the Cenozoic evolution of East Asia and its aftermaths are well recorded in the western Pacific marginal basins, and these basins remain important drilling targets for the study of Asian deformation and evolution.

Scientific deep-sea drilling took place only in some of the Western Pacific marginal seas, particularly the Sea of Japan and the South China Sea and the latter has generated valuable sequences of the East Asian monsoon and erosion history (Wang and Li, 2009). A number of IODP proposals (#552, 595, 618, and 683) are devoted to the history of river systems draining the Asian continent. A Detailed Planning Group was organized by IODP in 2008 to address the theme of "Asian Monsoon and

Cenozoic Tectonic History" (Detailed Planning Group, 2008). However, we argue that such studies can be successful only through the combined efforts between IODP and ICDP.

The Cenozoic reorganization of Asian rivers is crucial for the establishment of the modern environmental settings in Asia, including the Asian monsoon system. Although numerous reconstructons have been published for the ancient fluvial system (e.g., Clark et al., 2004; Clift & Blusztajn, 2005), very little, if any, sedimentary records were available in the international literature from the river basins. A remarkable feature of the major rivers in East China and Siberia is the discrepancy in ages between river channels and their estuaries. All the deltas are dated at Pleistocene or late Pliocene, whereas the river channels are dated to be Paleogene and older, a fact supporting the hypothesis on the topographic reversal of East Asia (Wang, 2004).

The proposed topographic reversal has far-reaching consequences in global climate. Not only is the Asian monsoon related to the plateau uplift, but so is the formation of the boreal ice sheet. The major Siberian rivers are the main source of freshwater in the Arctic Ocean, but they came to affect the Arctic only after the uplift of central Asia. Since the fresh water supply is crucial for ice formation in the Arctic Ocean, the Asian deformation may have triggered the onset of the North Hemisphere glaciations (Wang, 2004).

We propose to drill the late Cenozoic deposits in the river deltas in the marginal seas and in river basins onshore. Only a joint effort of IODP and ICDP can test the hypothesis of Asian deformation and its climate impact. The IODP Proposal #683 has already set up an example of drilling onshore in the Yangtze River basin and offshore in the East China Sea. A systematic program of IODP-ICDP drilling will be needed to cover the broad area of East Asia.

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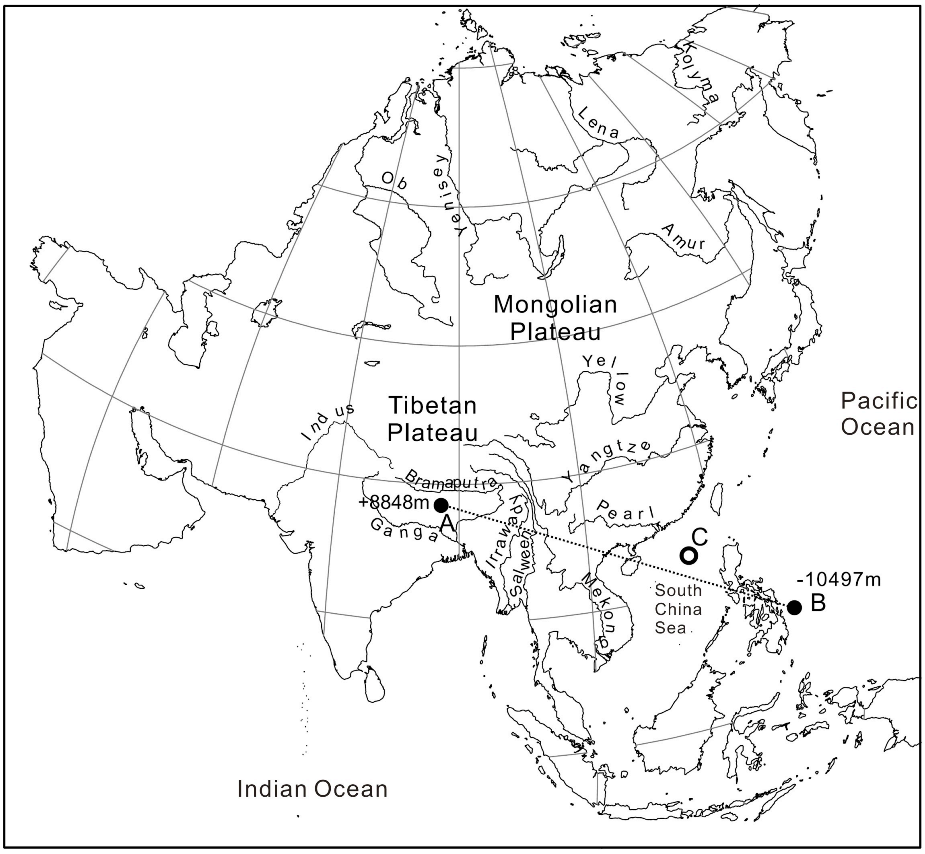

Figure 1. Map of Asia. Note that all large rivers originate in the Central Asian plateaus. Solid circles mark the highest peak in the world (A, Zhumolongma or Everest in the Himalayas, 8848 m altitude) and one of the deepest ocean trenches (B, Philippine Trench, water depth 10,497 m), presenting nearly 20 km of vertical contrast in topography within a horizontal distance of ~ 4000 km. Open circle (C) shows location of ODP Site 1148. (Wang, 2004)

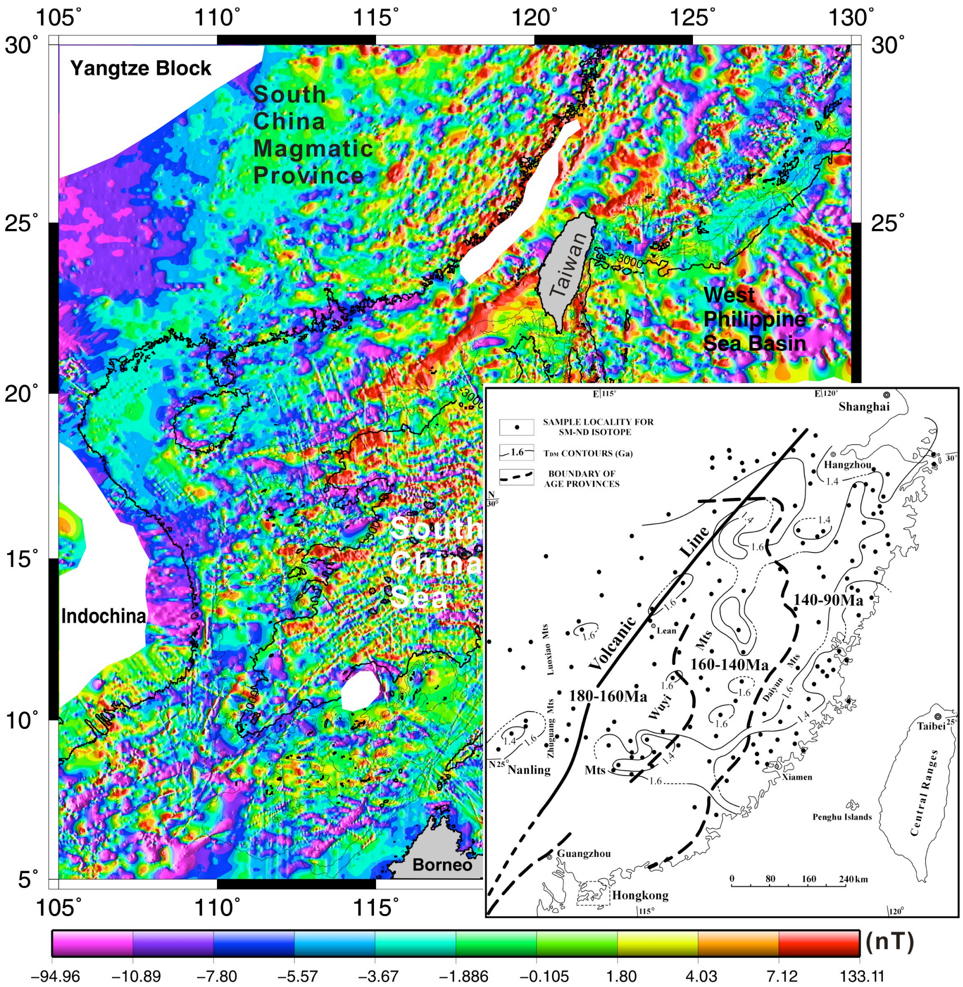

Figure 2. (Upper left) Magnetic anomaly map showing the South China Magmatic Province (Li et al., 2007). (Lower right) Provincial distribution and temporal migration of Late Mesozoic igneous rocks and Nd TDM contours in the South China Magmatic Province [age provinces and TDM contours after Zhou and Li (2000) and Shen et al. (2000)].

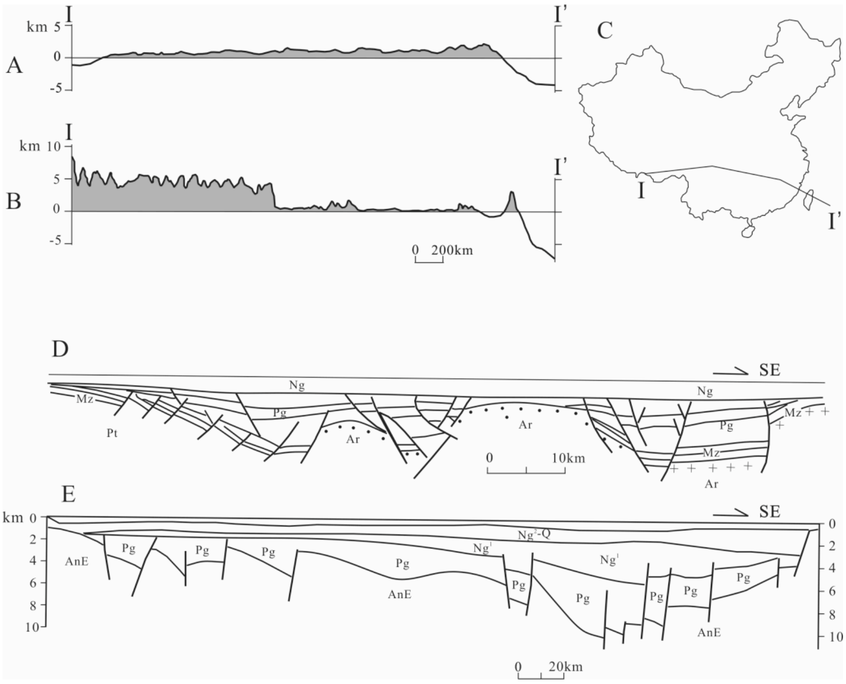

Figure 3. Mid-Cenozoic tectonic changes in China. Upper panel shows a comparison of Paleogene and Neogene topographic transects of China, with grey areas indicating land above sea level. (A) A hypothetical transect of Southern China (I-I') during the Eocene about 50 Ma. (B) Modern transect (I-I') showing east-tilting topography. (C) Location of the transect I-I'. Lower panel displays two typical transects of Cenozoic basins in eastern China showing Paleogene sediments deposited during active extension and Neogene sediments formed during regional thermal subsidence: (D) the Liao River Mouth Basin, Northeast China; (E) the East China Sea Shelf Basin (Wang, 2004).

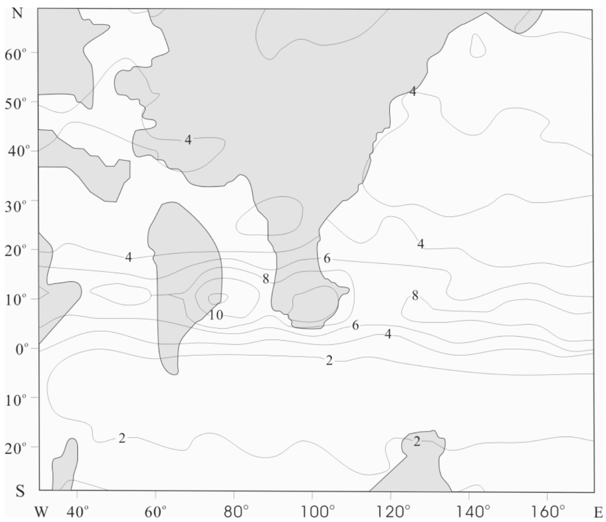

Figure 4. Simulated precipitation distribution in early Eocene Asia (after Chen et al., 2000)