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Westward advance of the deformation front and evolution of submarine canyons offshore of southwestern Taiwan

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ABSTRACT

This study analyzes both 2D and 3D seismic images around the Palm Ridge area offshore of southwestern Taiwan to understand how the deformation front shifted westward and how tectonic activities interact with submarine canyon paths in the transition area between the active and passive margins. Palm Ridge is a submarine ridge that developed on the passive China continental margin by down-dip erosion of several tributaries of Penghu Canyon; it extends eastward across the deformation front into the submarine Taiwan accretionary wedge. The presence of proto-thrusts that are located west of the frontal thrust implies that the compressional stress field has advanced westward due to the convergence of the Philippine Sea Plate and Eurasian Plate. Since the deformation front is defined as the location of the most frontal contractional structure, no significant contractional structure should appear west of it. We thus suggest moving the location of the previously mapped deformation front farther west to where the westernmost proto-thrust lies. High-resolution seismic and bathymetric data reveal that the directions of the paleo-submarine canyons run transverse to the present slope dip, while the present submarine canyons head down slope in the study area. We propose that this might be the result of the westward migration of the deformation front that changed the paleo-bathymetry and thus the canyon path directions. The interactions of down-slope processes and active tectonics control the canyon paths in our study area.

1. Introduction

As an accretionary wedge grows, new thrust faults develop in front of the wedge, and the deformation front (thrust front) is replaced by newly developed thrusts through time. While the deformation front is advancing, a proto-thrust zone may develop in the footwall of the frontal thrust. A proto-thrust zone is usually a transition between the normal fault and thrust zones and is the location of the next frontal thrust. Proto-thrusts have been observed in many subduction systems over the world, such as Manila (Ku and Hsu, 2009), Nankai (Karig and Lundberg, 1990; Leggett et al., 1985), and Cascadia (Cochrane et al., 1994; Adam et al., 2004). With the proto-thrusts developing, a previously extensional environment turns into a compressional one and thus leads to both structural and sedimentary alterations.

Submarine canyons are incised into shelf and slope settings in continental margins and are conduits for transporting orogenic sediments to the deep sea (Nittrouer and Wright, 1994). Studies from various continental margins around the world suggest that canyon paths can be greatly affected by tectonic activities in tectonically active zones (Clark and Cartwright, 2011; Mountjoy et al., 2009; TuZino and Noda, 2007; Yu and Hong, 2006), whereas those in passive margins cannot (Harris and Whiteway, 2011). However, few studies discuss the role of tectonics on canyon evolution near the transition between active and passive continental margins.

Situated in the incipient arc-continent collision zone, the accretionary wedge offshore SW Taiwan was formed by oblique arc-continent collision between the Luzon arc and the China continent (Huang et al., 1997; Liu et al., 1997), which is different from other accretionary wedges that have been created by subduction processes, such as the ones at the Naikai and Cascadia subduction zones. The migration of submarine canyon paths in the area on land and offshore SW Taiwan has been revealed by several studies (Lee et al., 1995; Fuh et al., 1997, 2003; Yu and Hong, 2006), and some authors suggest that it is a result of the growth of the Taiwan orogenic wedge (Yu and Hong, 2006). Their studies note that the submarine canyon paths offshore SW Taiwan have migrated southwestward through time. Yu and Hong (2006)

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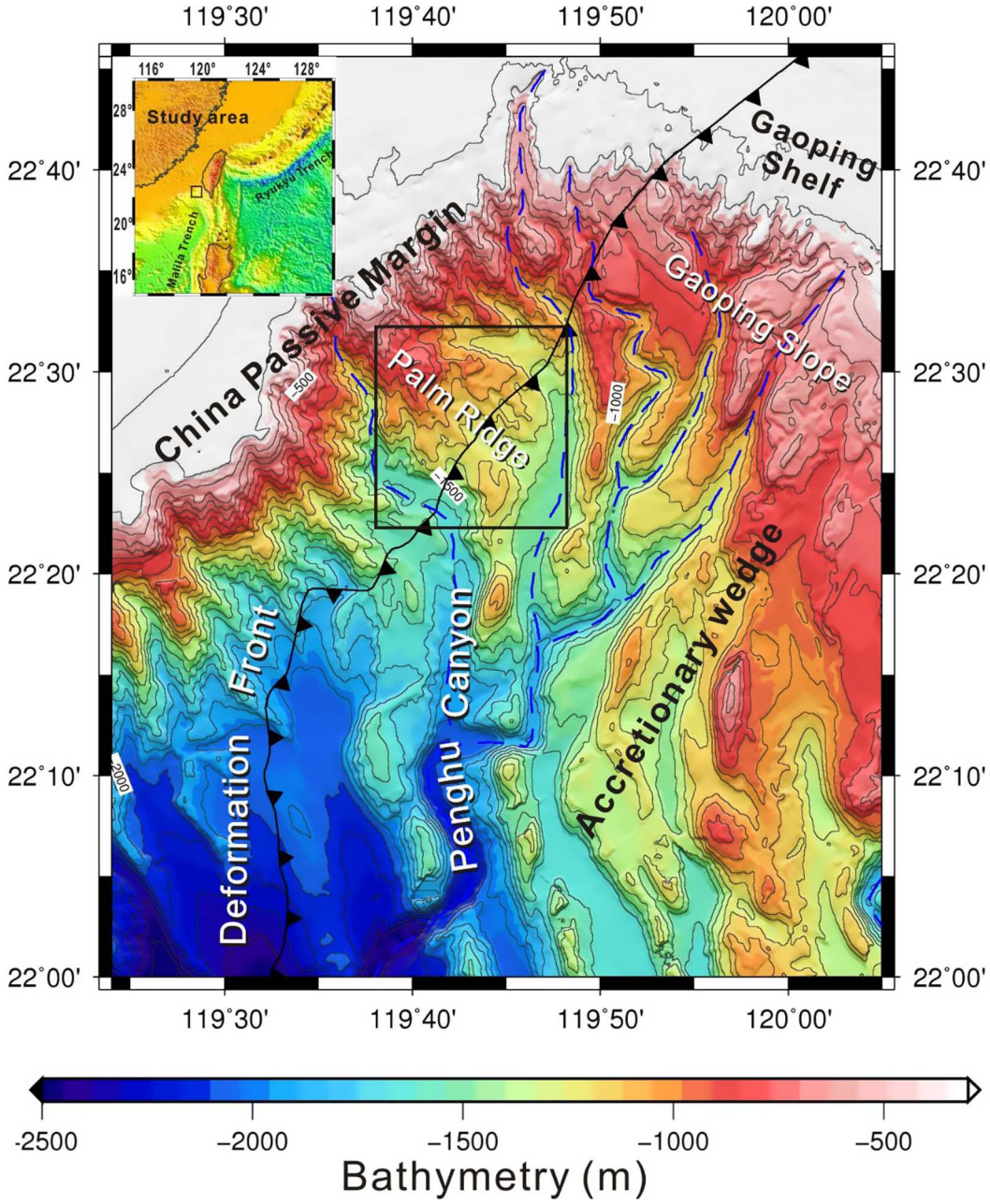

Fig. 1. Bathymetric map of the study area showing the locations of Palm Ridge, the deformation front of Lin et al. (2008) (black line with teeth) and submarine canyons (dashed blue lines). The deformation front separates the China passive margin to the west and the active accretionary wedge to the east. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

further suggest that the shifting axes of Late Pliocene–Pleistocene canyons from onshore SW Taiwan to the present-day position of Penghu Canyon reflect evolving foreland basins with a longitudinal canyon transport system progressively migrating southwestward. Nevertheless, how the deformation front has been shifted and how the canyon paths have been changed are still not clear.

The aim of this study is to understand how the growth of the submarine Taiwan accretionary wedge has changed the structural styles and thus the canyon paths in the transitional zone between the active and passive margins. To better characterize these issues, we have conducted both 2D and 3D seismic surveys to investigate Palm Ridge in the upper reach of Penghu Canyon across the deformation front offshore SW Taiwan (Fig. 1) for both tectonic and sedimentary interests. Palm Ridge is a topographic high surrounded by tributaries of Penghu Canyon; it covers both the China passive margin and the submarine Taiwan accretionary wedge. After distinguishing and mapping the features based on 2D and 3D seismic images (see Fig. 2 for seismic line distribution), the locations of the regional structural and sedimentary features, such as buried canyon deposits, anticlinal ridges and faults, are compiled, and their characters are described and interpreted. Finally, we propose a geological model to illustrate the change of structural styles observed and the possible canyon evolution in our study