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Provenance analysis of the Miocene accretionary prism of the Hengchun Peninsula, southern Taiwan, and regional geological significance

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ABSTRACT

Petrographic analysis, detrital zircon U–Pb geochronology and Neodymium isotope are applied to the Middle-Late Miocene turbidite sequences in the Hengchun accretionary prism, southern Taiwan, to constrain the provenance and nature of sedimentation in the Manila subduction system. Both petrographic study and detrital zircon U–Pb ages show that the Middle-Late Miocene turbidite sequences were primarily derived from Mesozoic granites and volcanic rocks of the Cathaysian Block in SE China, which were transported southeastward via rivers like Minjiang and Jiulongjiang to the Taiwan area. This conclusion is further supported by Nd isotope analyses of shales intercalated within sandstone sequences showing negative εNd values (−13.3 to −10.5) of a continental origin. During the Late Miocene when global sea-level fell significantly, the SE China coastline shifted seaward to the eastern part of the present Taiwan Strait, which would have facilitated these continent-derived sediments being transported southeastward to the shelf-upper slope of the Chinese continental margin. These turbidite sequences were then deformed and accreted into the accretionary prism of the Hengchun Peninsula when the South China Sea oceanic lithosphere subducted eastward beneath the Philippine Sea Plate in the Late Miocene. Our study suggests that sedimentary deposition of the turbidite sequences in the Hengchun Peninsula could be strongly controlled by different river system supply, submarine channeling transport and fluctuations of sea-level.

1. Introduction

The Taiwan Island is located at the boundary between the Eurasian Plate and the Philippine Sea Plate (Fig. 1A). During the Early Cenozoic, the Eurasia continent in east China had experienced normal faulting to develop a series of NE-trending rift basins (Li and Rao, 1994; Huang et al., 2001). Among them the South China Sea oceanic lithosphere spread in Oligocene-Middle Miocene (32–17 Ma, Taylor and Hayes, 1983; 32–16 Ma, Briais et al., 1993; 31–20.5 Ma, Barckhausen and Roeser, 2004; 37–15 Ma, Hsu et al., 2004). Soon after cessation of oceanic spreading, the South China Sea oceanic lithosphere subsequently subducted eastward along the Manila Trench beneath the west-moving Philippine Sea Plate to develop the Hengchun Ridge accretionary prism and the Luzon arc–forearc basin (Fig. 1; Huang et al., 1992, 1997; Reed et al., 1992). The formation of this accretionary prism marks the transition of the Asian continental margin from the passive to active margin.

Sequences in the accretionary prism of the upper plate are sediments originally deposited on the subducting lower plate. During subduction, parts of these passive margin sediments are scraped off and accreted into the accretionary prism in the overlying upper plate (Cathy and Raymond, 1995; Clift and Vannucchi, 2004). Accordingly, the Miocene sequences in the accretionary prism of the Hengchun Peninsula were originally deposited on the passive Asian continental margin before they were accreted into the accretionary prism. Nowadays the Hengchun Peninsula is about 400 km away from the SE China mainland coast (Fig. 1A). Southward or southeastward paleocurrent measurements in the Hengchun Peninsula indicate that Miocene turbidite sequences were mostly transported from China continent to the northwest (Huang, 1984). However, northwestward paleocurrents are also reported

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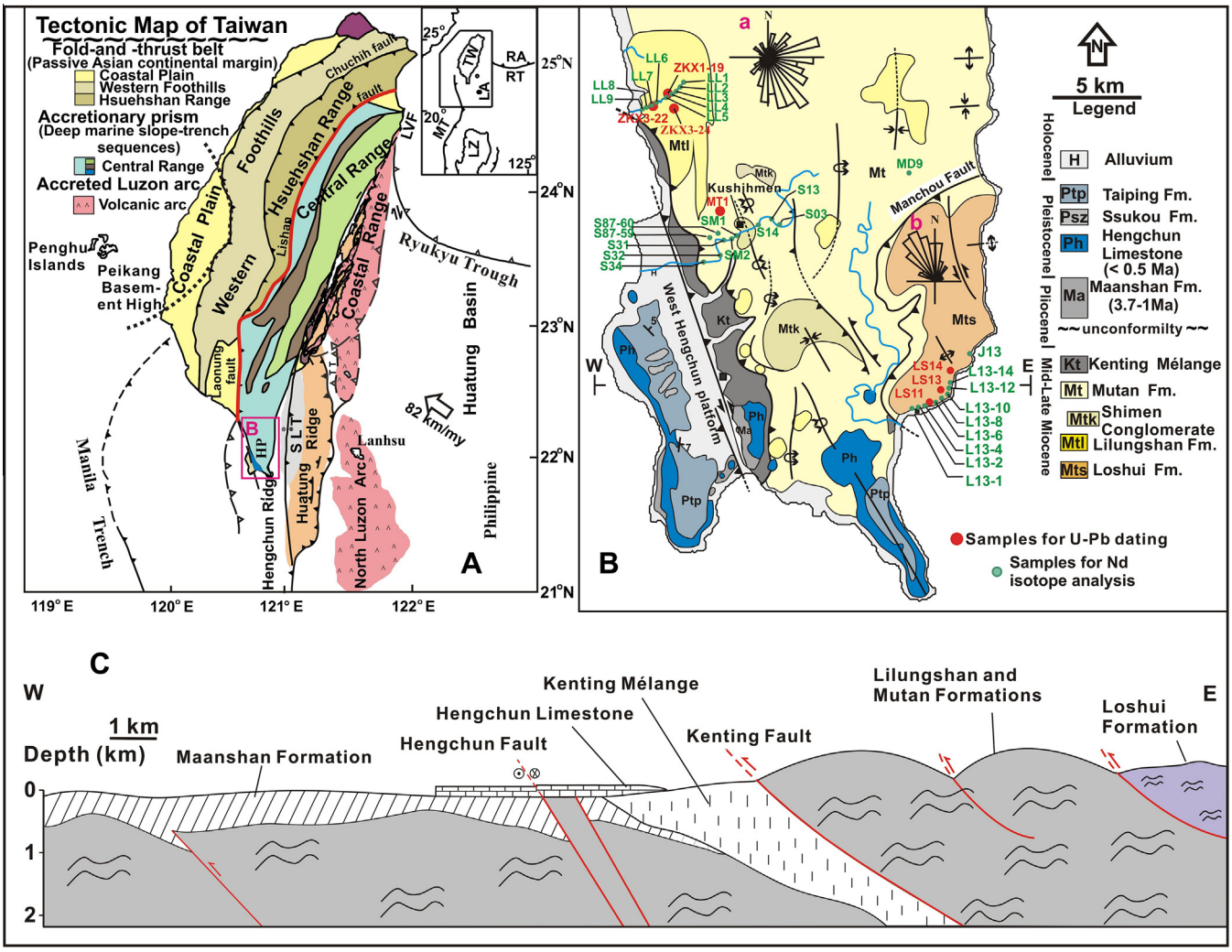

Fig. 1. (A) General tectonic and stratigraphic map of Taiwan. From west to east, the geological divisions include: the Coastal Plain (CP), Western Foothills (WF), Hsuehshan Range (HR), Central Range (CR) (Hengchun Peninsula (HP)), Longitudinal Valley (LV) and Coastal Range (CoR) and Luzon Arc (LA). The submarine topography offshore of southern Taiwan includes a number of north–south trending submarine ridges and troughs (Hengchun Ridge; Southern Longitudinal Trough (SLT); Huatung Ridge; Taitung Trough (TT); Lutao-Lanshu Ridge)(Huang et al., 2006). Inset black arrows shows the direction of plate motion from Yu et al. (1997); (TW) Taiwan; (MT) Manila Trench; (RA) Ryukyu Arc; (RT) Ryukyu Trough; (LZ) Luzon Island; (LA) Luzon Arc. B: Simplified geological map of the Hengchun Peninsula showing the major units, sampling position referred in the text and the distribution of the Miocene accretionary prism sediments. Rose diagrams a and b in (B) represent the paleocurrent direction of Lilungshan and Mutan formations (a) and Loshui Formation (b), respectively (adapted from Huang, 1984; Cheng et al., 1984; Sung and Wang, 1986). (C) simplified geological map and cross section of the Hengchun Peninsula, southern Taiwan (modified after Chang et al., 2003; Shan et al., 2013).

in the Loshui Formation (N14-N15, ~11.6 to 9.8 Ma, rare planktonic foraminifera can be found) from the eastern coast of the Hengchun Peninsula (Huang, 1984; Cheng et al., 1984; Figs. 1B and 2). Consequently there are two contrast paleocurrents in the Hengchun Peninsula and raises a question about their sediment sources. Could these Miocene turbidite sequences, including upper fan conglomerates and well-preserved oyster/leave fossils, be transported for about 400 km from the Chinese continent to the Hengchun Peninsula in southernmost Taiwan? In addition to the Chinese continent would there also have other sources to provide sediments to the Hengchun Peninsula, for examples the Luzon arc–forearc to the east (Kirstein et al., 2010) or the proto-Taiwan to the north (Page and Lan, 1983; Clift et al., 2003).

To solve the controversial debates, petrographic analysis and detrital zircon U–Pb geochronology are applied to the Miocene sequences in the Hengchun accretionary prism to constrain the provenance and nature of sedimentation in the Manila subduction system. In addition, we also determine Nd isotopic values of the Miocene shales to test if they were derived from the SE China mainland or the Luzon arc. If the sediments were derived from the Luzon arc (εNd: +9.5 to −1.1), εNd values of the Miocene shales will be much less negative than those eroded from the Asian continent source (Goldstein and Jacobsen, 1988; Chen et al., 1990a,b).

2. Tectonic setting and stratigraphy

The Hengchun Peninsula in southern Taiwan represents the accretionary prism of the Manila subduction system. It extends southward to the offshore Hengchun Ridge between Taiwan and Luzon Islands and connects northward to the Central Range (Fig. 1; Huang et al., 1997). The Hengchun Peninsula-Central Range accretionary prism contacts the arc–forearc Coastal Range along the collision suture of the Longitudinal Valley fault system (LVF), which further extends southward to the collision suture basin (Southern Longitudinal Trough; SLT in Fig. 1; Huang et al., 2000). The volcanism of the northern Luzon arc starts from Middle Miocene (Yang et al., 1995) when the South China Sea oceanic lithosphere subducted eastward beneath the Philippine Sea Plate.