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Cretaceous–Eocene provenance connections between the Palawan Continental Terrane and the northern South China Sea margin

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ABSTRACT

The plate kinematic history of the South China Sea opening is key to reconstructing how the Mesozoic configuration of Panthalassa and Tethyan subduction systems evolved into today's complex Southeast Asian tectonic collage. The South China Sea is currently flanked by the Palawan Continental Terrane in the south and South China in the north and the two blocks have long been assumed to be conjugate margins. However, the paleogeographic history of the Palawan Continental Terrane remains an issue of uncertainty and controversy, especially regarding the questions of where and when it was separated from South China. Here we employ detrital zircon U–Pb geochronology and heavy mineral analysis on Cretaceous and Eocene strata from the northern South China Sea and Palawan to constrain the Late Mesozoic–Early Cenozoic provenance and paleogeographic evolution of the region testing possible connection between the Palawan Continental Terrane and the northern South China Sea margin. In addition to a revision of the regional stratigraphic framework using the youngest zircon U–Pb ages, these analyses show that while the Upper Cretaceous strata from the Palawan Continental Terrane are characterized by a dominance of zircon with crystallization ages clustering around the Cretaceous, the Eocene strata feature a large range of zircon ages and a new mineral group of rutile, anatase, and monazite. On the one hand, this change of sediment compositions seems to exclude the possibility of a latest Cretaceous drift of the Palawan Continental Terrane in response to the Proto-South China Sea opening as previously inferred. On the other hand, the zircon age signatures of the Cretaceous–Eocene strata from the Palawan Continental Terrane are largely comparable to those of contemporary samples from the northeastern South China Sea region, suggesting a possible conjugate relationship between the Palawan Continental Terrane and the eastern Pearl River Mouth Basin. Thus, the Palawan Continental Terrane is interpreted to have been attached to the South China margin from the Cretaceous until the Oligocene oceanization of the South China Sea. In our preferred paleogeographic scenario, the sediment provenance in the northeastern South China Sea region changed from dominantly nearby Cretaceous continental arcs of the South China margin to more distal southeastern South China in the Eocene.

1. Introduction

The eastern margin of Eurasia was above the long-lived Panthalassa subduction zone consuming the Izanagi and Pacific plates during the Mesozoic (Müller et al., 2016). Since the Late Cretaceous this convergent setting along the South China margin has become diachronously and episodically replaced by continental rifting (Franke et al., 2014; Morley, 2016). Subsequent oceanic opening of the South China Sea (SCS; Fig. 1) in the Oligocene–Early Miocene has been traditionally viewed as a consequence of either the strain transfer from southeastward extruding Indochina along the Red River Fault (Fig. 2a; Briais et al., 1993; Leloup et al., 2001) or slab pull derived from subducting a hypothetical Proto-SCS beneath Borneo (Fig. 2b; Taylor and Hayes, 1983; Hall, 2002). Palawan, an island of the Philippines to the south of the SCS, exposes Upper Paleozoic to Mesozoic metamorphic and sedimentary rocks (Fig. 1a) that clearly show an Asian mainland origin based on paleomagnetism and provenance analysis (e.g., Almasco et al., 2000; Suzuki et al., 2000; Suggate et al., 2014). The continent-derived nature of these rocks is distinct from that of the

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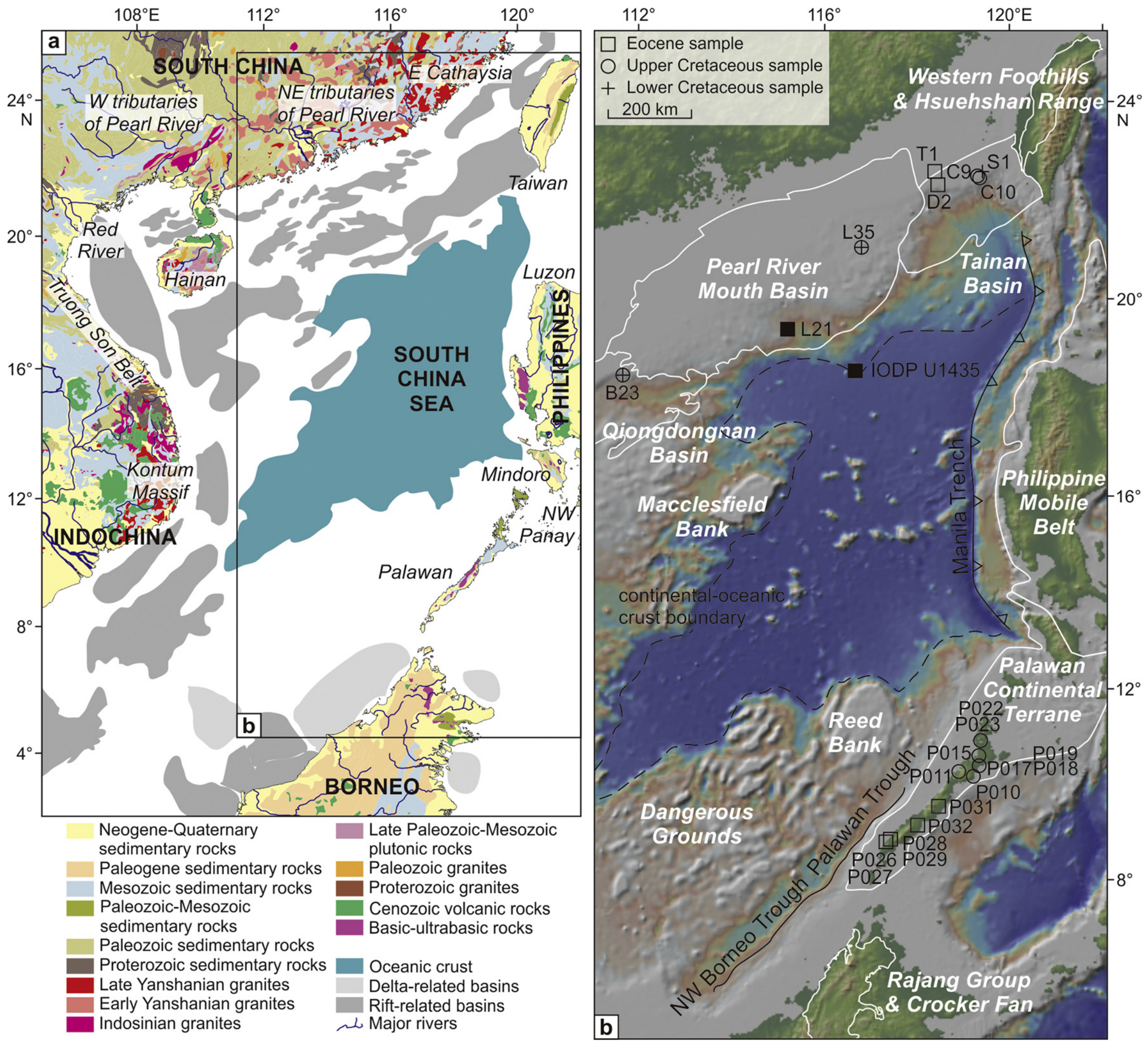

Fig. 1. (a) Geological map of Southeast Asia surrounding the SCS region. (b) Topographic map of the study area showing sample locations. Rift basins in the northern SCS margin, the PCT, the Philippine Mobile Belt, as well as the Eocene tectono-sedimentary units of West Taiwan and North Borneo are schematically outlined with white lines. The localities of commercial borehole L21 and IODP Site U1435 are also marked. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Philippine Mobile Belt to the northeast which comprises a complex collage of island arcs and ophiolites (Fig. 1). Thus, Palawan as a component of the Palawan Continental Terrane (PCT) has long been supposed to start drifting along with the seafloor spreading processes in the SCS region (Holloway, 1982). However, the Late Mesozoic–Early Cenozoic paleogeographic history of the PCT remains controversial, especially with regard to its pre-drift location along the South China margin and the timing of drift initiation.

Ideally, the PCT's pre-drift location can be indirectly determined by reconstructing the SCS seafloor spreading history. This reconstruction process, however, is hampered by the SCS oceanic lithosphere that subducted eastward along the Manila Trench since the Miocene, and in addition, magnetic anomalies in the SCS are difficult to interpret due to strong post-spreading volcanism and ridge jumps (Fig. 1b; Taylor and Hayes, 1983; Briais et al., 1993; Sibuet et al., 2016). Attempts have been made towards a full-fit reconstruction by restoring the paleo-continental and oceanic crust boundary (e.g., Bai et al., 2015), but still involve significant uncertainties, particularly in defining the initial basement thickness and spatial distributions of conjugate margins. In these previous kinematic reconstructions, the proposed conjugate margins of the PCT include the Tainan Basin (e.g., Taylor and Hayes, 1983) and the Pearl River Mouth Basin (e.g., Sibuet et al., 2016), but these hypotheses have still not been verified by any independent evidence.

The controversy over the timing of drift initiation hinges on the interpretation of the tectonic nature of the Palawan Trough (Fig. 1b). In earlier tectonic reconstructions using either the extrusion model or the slab pull model, the PCT drifted southward in response to the Oligocene opening of the SCS (Figs. 2a and 2b; Holloway, 1982; Taylor and Hayes, 1983; Briais et al., 1993; Hall, 2002). The Palawan Trough has been accordingly assumed to be a bathymetric expression of extensional faults related to the Early Cenozoic rifting, and its contiguous juxtaposition with the Northwest Borneo Trough seems coincidental (Fig. 1b; Schlüter et al., 1996). Alternatively, the Northwest Borneo–Palawan Trough may represent an ancient trench marking a southeastward subduction of the Proto-SCS lithosphere beneath both Palawan and North Borneo (Hutchison, 2010; Cullen, 2014), which requires that the PCT was already located on the south side of the Proto-SCS during the Eocene (Fig. 2c). Thus, the PCT has been proposed to have been split off from the South China margin as early as the latest Cretaceous when the Proto-SCS formed presumably as a backarc basin to its northwest above the Izanagi subduction zone (Morley, 2012; Zahirovic et al., 2014). In this model, kinematic reconstruction of the Cenozoic PCT is inevitably sketchy because of the uncertainty associated with the now-vanished Proto-SCS crust.

Sediment provenance data can play a critical role in testing the paleogeographic and tectonic models described above. While pre-