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Geological and geochemical aspects of a Devonian siliceous succession in northern Thailand: Implications for the opening of the Paleo-Tethys

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ABSTRACT

The opening of the Paleo-Tethys are reconstructed, including the depositional setting and redox conditions, based on an analysis of radiolarian fossils and the geochemistry of a Devonian siliceous succession in the Chiang Dao area of northern Thailand. The succession is subdivided into the following five rock types (in ascending stratigraphic order): black shale (Lower Devonian), siliceous shale (Middle Devonian), tuffaceous chert and tuff (Middle/Upper Devonian), and chert (Upper Devonian). The succession was deposited in continental margin and pelagic environments between the Sibumasu Block and the Indochina–North China blocks. The concentrations of terrestrial-derived elements (Al_2O_3, TiO_2, Rb, and Zr) suggest that the succession (except for the chert) was supplied with terrigenous material and volcanic ash from the adjacent continent, deposited within a SiO_2-rich environment. Geochemical indicators of redox conditions (total organic carbon and the Th/U ratio) reveal a gradual change from anoxic to oxic oceanic conditions between the black shale and chert. Taking into account the interpreted depositional setting and redox conditions, the initial Paleo-Tethys developed as a small, closed anoxic–suboxic oceanic basin during the Early to Middle Devonian, located close to the continental margin. Black shale and siliceous shale were deposited in the basin at this time. Opening of the Paleo-Tethys started around the Middle and Upper Devonian boundary, marked by voluminous volcanic activity. The tuffaceous chert was deposited under oxic conditions, suggesting that ash and pumice within the chert were derived from a continental source. After the Late Devonian, the Paleo-Tethys developed as a deep, broad ocean in which pelagic chert was deposited.

1. Introduction

The Paleo-Tethys, which opened in response to Devonian separation of the North China, South China, Indochina and Tarim blocks from Gondwana, occupied a large area around the equator from the Devonian to Triassic, where carbonates, chert, and basalt were deposited in a pelagic domain (e.g., Metcalfe, 1999, 2006). These Paleo-Tethyan rocks, characterized by an ocean plate stratigraphy (OPS), were subducted beneath the Indochina Block during the Permian–Triassic (Metcalfe, 2002; Wakita and Metcalfe, 2005; Hara et al., 2009); however, the depositional environment and style of Paleo-Tethys opening have yet to be clarified.

Here, the tectonics of the opening of the Paleo-Tethys were reconstructed, focusing on a Devonian siliceous succession that was located in the convergence zone of Paleo-Tethyan rocks within the Inthanon Zone, northern Thailand. This Devonian to Lower Carboniferous siliceous succession has been described as chert in previous studies and is informally named the 'Fang Chert' where it occurs in northern Thailand (e.g., Bunopas, 1981; Sashida et al., 1993; Wonganan and Caridroit, 2005; Wonganan et al., 2007). In the Chiang Dao area of northern Thailand, black shale is exposed at the base of the succession, bearing Early Devonian graptolites (Kobayashi and Igo, 1966; Jaeger et al., 1968, 1969). The succession from black shale to chert records the change in depositional environment related to opening of the Paleo-Tethys (Randon et al., 2006). In addition, the similar Devonian siliceous succession with graptolite-bearing black shale has been reported in the western Yunnan area of south China along the convergence zone of the Paleo-Tethyan rocks (Feng and Liu,

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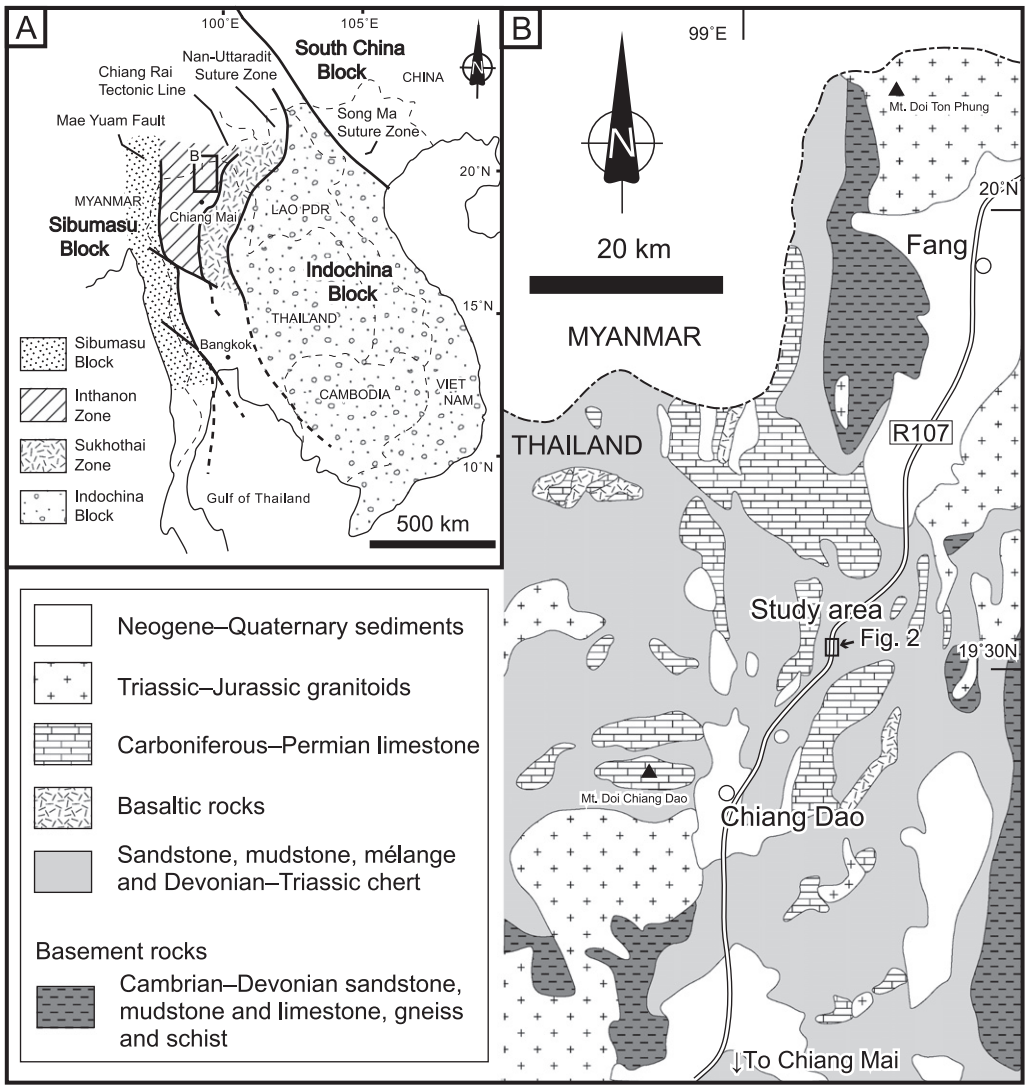

Fig. 1. Geology of the Chiang Dao area in northern Thailand, and surrounding area. (A) Tectonic map of Thailand and the surrounding region. (B) Simplified geological map of the Chiang Dao area. The map is based on the Geological Map of Thailand (1:1,000,000), published by Department of Mineral Resources (1999).

1993; Wang et al., 2003, 2006). The characteristic succession is an important sediment for the understanding of the depositional environment at the initial Paleo-Tethys.

The aim of this paper is to reconstruct the depositional environment during the opening of the Paleo-Tethys, as recorded in the Devonian siliceous succession around the Chiang Dao area, northern Thailand. The reconstruction is based on new lithological observations and radiolarian fossil data, geochemical analyses, measurements of total organic carbon (TOC), and analyses of Th/U ratios. Geochemical analyses of siliceous rocks are useful in terms of understanding the depositional setting and redox conditions (e.g., Adachi et al., 1986; Murray, 1994; Kametaka et al., 2005). In particular, analyses of TOC and Th/U are commonly employed to clarify redox conditions in the paleo-ocean (e.g., Stein, 1986; Wignall and Twitchett, 1996; Algeo and Maynard, 2004). By combining information on the depositional setting and redox conditions for the Devonian siliceous succession, along with age control provided by radiolarian fossils, we reconstruct the opening and development of the Paleo-Tethys.

2. Geological outline of northern Thailand

A tectonic scheme has recently been proposed for northern Thailand (Ueno and Hisada, 2001; Ueno, 2003; Sone and Metcalfe, 2008; Kamata et al., 2009), based on Paleozoic and Mesozoic biostratigraphy and paleo-biogeography (e.g., foraminifers and radiolarians), as well as correlations between northern Thailand and the western Yunnan area of south China. In this scheme, northern Thailand is divided into the following four geotectonic units (from west to east): the Sibumasu Block, the Inthanon Zone, the Sukhothai Zone, and the Indochina Block (Fig. 1). The Devonian siliceous succession analyzed in the present study is located within the convergence zone of Paleo-Tethyan rocks in the Inthanon Zone.

The Sibumasu Block, which is eastern part of Cimmerian continent, is characterized by a Gondwanan stratigraphy, including a Lower Carboniferous hiatus, Upper Carboniferous to Lower Permian glaciogenic diamictites with Gondwanan fauna and flora, and Middle–Upper Permian platform carbonates (Metcalfe, 1988, 2006; Ueno, 2003).

The Inthanon Zone, originally proposed by Barr and Macdonald (1991), is characterized by Paleo-Tethyan oceanic rocks, pre-Devonian basement rocks, and Late Triassic and Early Jurassic S-type granitoids and gneissic rock. The Paleo-Tethyan rocks consist of pelagic Carboniferous–Permian seamount-type carbonate rocks (the Doi Chiang Dao Limestone) associated with basaltic rocks, Middle Devonian–Middle Triassic radiolarian chert, and mélange-type rocks related to subduction of the Paleo-Tethys beneath the Indochina Block