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Evolution and extinction of Permian fusulinid fauna in the Khao Tham Yai Limestone in NE Thailand

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ABSTRACT

The first detailed biostratigraphic investigation of a single limestone unit within the Khao Tham Yai Limestone shows it was deposited continuously in a shelf setting without any intercalation of clastic beds. It ranges from the Wordian (middle Middle Permian) up to the Wuchiapingian (lower Upper Permian). The limestone unit is divided in ascending order into three fusulinid zones, i.e. *Colania*, *Lepidolina* and *Codonofusiella* zones. The middle zone is characterized by an abundance of large-tested fusulinids characteristic of the *Lepidolina* Zone. Shell sizes of the fusulinid species in this zone display continuous rapid morphological change along a one-way evolutionary path from small, primitive species with simple structure to large, highly evolved species having a complicated wall structure. Fusulinid biostratigraphy in a single limestone unit elucidates evolution and extinction patterns of Permian fusulinids of the shallow-water Tethyan shelf area in the Indochina Block. Our study reveals that the boundary between the Guadalupian (Middle Permian) and Lopingian (Upper Permian) in the Khao Tham Yai Limestone is clearly defined as an abrupt change in the fusulinid assemblages from the elimination of large-tested Verbeekinids and Schwagerinids to the domination of small-shelled Schubertellids. The Schubertellids underwent slower evolutionary morphological change than earlier fusulinids and were decreasingly dominant through the Permian. A similar pattern of fusulinid evolution and extinction at the Guadalupian–Lopingian boundary occurs in shallow-water Tethyan shelf areas and mid-oceanic shallow-water environments in mid-Panthalassa. Eventually, even smaller fusulinids abruptly become extinct. Clastic deposits finally replace previous carbonate formations characterized by algae-foraminifera biota. It starts in the upper Middle Permian in the southern parts and spreads throughout the whole area in the lower Upper Permian in NE Thailand. These observations suggest possible correlation between the turning points of fusulinid evolution and global environmental change such as worldwide sea-level drop and its consequent effects.

1. Introduction

Upper Permian fusulinid faunas have been reported only from fragmentary limestones at a limited number of isolated localities in comparison with those of the Lower and Middle Permian in Thailand (e.g. Sakagami and Hatta, 1982; Ingavat, 1984; Ueno and Sakagami, 1991). Evolutionary patterns, development of provincialism, and the detailed timing of extinctions of Permian fusulinids have not been clearly documented in Thailand. Recently, Fontaine and Salyapongse (2001) described Khao Tham Yai and Khao Pa Khi limestones located in the Nam Nao district, about 360 km NNE of Bangkok, in NE Thailand (Fig. 1). They suggested the sedimentary sequence ranges from Murgabian or Wordian (Middle Permian) to possibly Lower Triassic based on stratigraphic relationships and fossils such as fusulinids and coral faunas, although the Triassic age was not confirmed by their subsequent work (Fontaine et al., 2002).

The abundance and the abnormal growth of selective fusulind fauna in the Khao Tham Yai Limestone (Fontaine and Salyapongse, 2001; Fontaine et al., 2002) attracted us to a biostratigraphic study of the limestone in order to provide direct evidence to resolve the evolution and extinction patterns of Permian fusulinids in Thailand. The sedimentary sequence of the area is composed of thick, fossiliferous limestones of the Khao Tham Yai ("Hill of the Large Cave"), clastic sequence with predominant shale in the valley east of Khao Tham Yai Limestone, and Khao Pa Khi Limestone poor in fossils farther to the east, in ascending order. Our attention was especially drawn to the abundance of the genus *Lepidolina* in the Khao Tham Yai Limestone. *Lepidolina* is a

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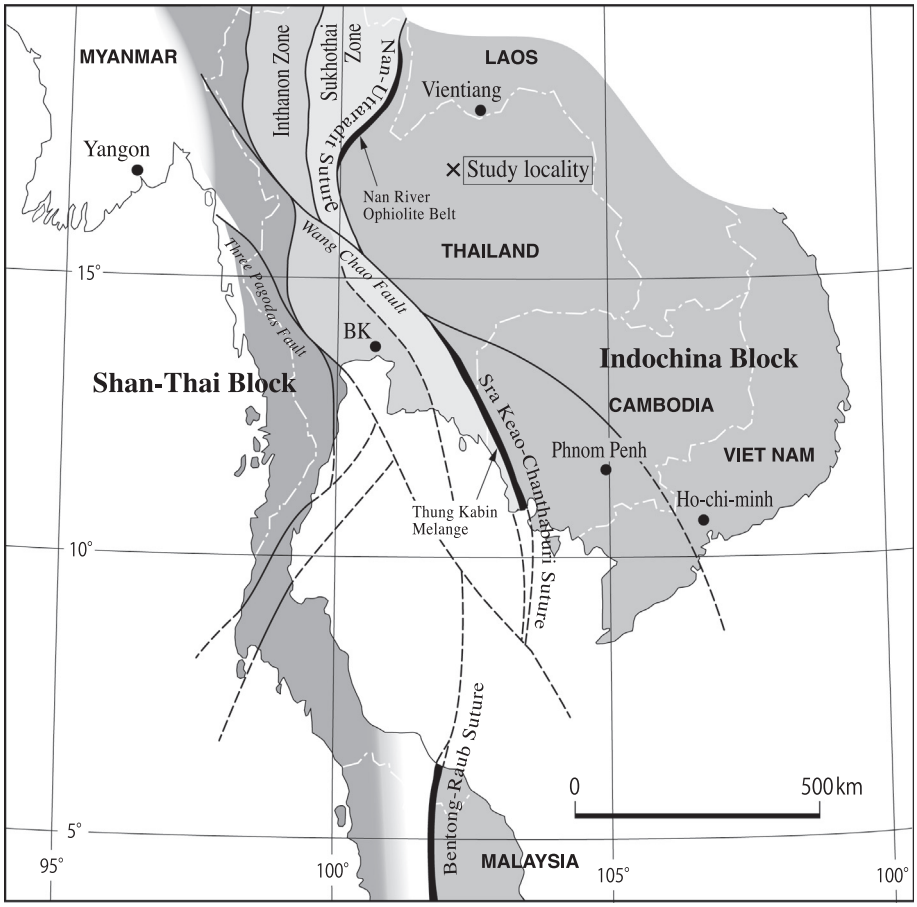

Fig. 1. Index map showing the study locality and the tectonic subdivision of Thailand and adjacent regions. Base map is from Barr and Macdonald (1991), Ueno and Igo (1997), Hada (2004) and Sone and Metcalfe (2008).

large-tested, highly evolved Verbeekinidae having a complicated wall structure (e.g. Ross, 1967; Ozawa, 1975; Kanmera et al., 1976). It is also among the most characteristic fusulinid faunas for paleobiogeographic and environmental interpretation, and represents one of the pre-extinction "last runners" of the large-tested fusulinids in the Middle to Upper Permian (e.g. Ross, 1967; Ishii et al., 1985; Ozawa, 1987).

Although *Lepidolina* has been known only from eastern Thailand (Toriyama et al., 1974; Pitakpaivan and Ingavat, 1980; Ingavat, 1984; Hada et al., 1999; Fontaine and Salyapongse, 1997, 2001; Fontaine et al., 2002), its abundance extends from eastern Thailand to western Cambodia (Ishii and Nogami, 1964; Ishii et al., 1969; Tien, 1979). *Lepidolina* characterizes shallow-water Tethyan shelf areas of the Indochina and South China continental blocks (e.g. Deprat, 1912; Sheng, 1963; Ozawa, 1970, 1975; Rui, 1983). Moreover, *Lepidolina* is a dominant species characterizing the exotic limestone blocks embedded within the Late Permian accretionary complex of Japan (Ishii et al., 1985; Ishii, 1990; Kanmera et al., 1990; Hada et al., 2001; Ota and Isozaki, 2006; Kasuya et al., 2012). In contrast, limestones within the accretionary complex were primarily derived from paleo-atoll complexes in mid-Panthalassa (e.g. Kanmera and Nishi, 1983; Sano and Kanmera, 1988; Ota and Isozaki, 2006). From the paleobiogeographic viewpoint, it is significant that *Lepidolina* formed fusulinid biogeographic territory the paleo-equatorial region in the East Tethys and mid-Panthalassa during the Middle Permian (e.g. Ross and Ross, 1983; Ishii et al., 1985; Sengör et al., 1990; Hada et al., 1996, 2001; Kobayashi, 1999; Kasuya et al., 2012). The continental shelf areas both in South China and in Indochina were located in the *Lepidolina* territory during the Middle Permian (Ishii et al., 1985; Hada et al., 2001; Kasuya et al., 2012).

We started geologic and paleontologic investigations of the Khao Tham Yai Limestone in 2005 in cooperation with the Geological Survey Division, Department of Mineral Resources of Thailand. We collected >180 limestone rock samples from the northern end and the northeastern part of a limestone hill that is continuously exposed and that is easily accessible to the east of Nam Nao Cave. Our study is based on field research and we conducted microscopic observation of >1800 thin sections. In this paper, we mainly describe the biostratigraphy of middle to upper parts of the Khao Tham Yai Limestone outcropping in our study area. This study is based upon the Tethyan Province fusulinid biostratigraphy that was established by numerous studies carried out in 1950–1970s (e.g. Kanmera, 1954; Sheng, 1963; Ozawa, 1975; Toriyama et al., 1975). In particular, we provide new data on unique fusulinid faunas found from the upper part of the Khao Tham Yai Limestone. These faunas exhibit the evolutionary pattern of the Middle Permian large-tested fusulinid faunas succeeded by small-shelled fusulinids across the Guadalupian–Lopingian (Middle–Upper Permian) boundary. Based on the foraminiferal fauna it is highly probable that the Khao Tham Yai Limestone ranges from Wordian (middle Middle Permian) to Wuchiapingian (lowermost Upper Permian).

2. Tectonic and geologic setting

Traditional understanding of the geotectonic and paleogeographic evolution of Southeast Asia suggests that mainland