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Depositional setting and paleoenvironment of an alatoconchid-bearing Middle Permian carbonate ramp sequence in the Indochina Terrane

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ABSTRACT

A Middle Permian carbonate sequence at Khao Somphot in the south of the Khao Khwang Platform has been measured and analyzed. This sequence is characterized by prolific fossil content and large, bizarre alatoconchid bivalves. Nine major microfacies types are differentiated and consist of: algal-foram facies, fusuline facies, alatoconchid facies, lime mudstone/wackestone facies, laminated bindstone facies, fine-grained cortoid grainstone facies, coral biostrome facies, crinoidal packstone facies and carbonate breccia/conglomerate facies. Laminated bindstone, lime mudstone with fenestral fabric and algal foram facies represent loferites deposited in a restricted intertidal zone of an inner ramp. Fusuline grainstone and cortoid grainstone facies indicate sand shoals of an inner ramp. The fusuline wackestone/packstone and alatoconchid facies were deposited in a subtidal, below fair-weather wave base environment in the mid-ramp. The crinoidal facies, which overlies collapse breccia, possibly accumulated during transgression in the deeper part of the mid-ramp. Storm deposits are prevalent throughout as thin accumulates and as alatoconchid floatstone/rudstone (coquinite) layers and are common in mid-ramp setting. The Khao Khwang Platform probably evolved from a rimmed platform in the Early Permian to a ramp in the Middle Permian.

The general trend of $\delta^{13}C$ composition from both brachiopod shell and rock matrix from the lower part of the study section (Wordian) is significantly high. Moreover, the $\delta^{13}C$ signature from this interval is up to 8 VPDB‰, which suggests high productivity on the tropical Tethyan shelf of the Indochina Terrane. An abrupt negative shift in $\delta^{13}C$ in the late Wordian and late Capitanian indicating significant changes in paleoenvironment, productivity and the carbon cycle is probably contemporaneous with the Kamura event recorded from sediments of the mid-Panthalassa Ocean in Japan and elsewhere related to global cooling and a sea-level lowstand.

1. Introduction

The boundary of the Guadalupian and Lopingian (G–LB) is an important interval in geological history due to global cooling and a worldwide sea-level lowstand (Haq and Schutter, 2008; Isozaki, 2009; Kofukuda et al., 2014). This event led to mass extinction and was followed by the mass extinction at the end of the Permian. This double extinction event could be one reason why the global mass extinction around the P–Tr boundary is the largest in the Phanerozoic (Isozaki et al. 2007a, 2007b; Isozaki and Ajinović, 2009). Environmental change around the G–LB has been demonstrated by means of isotope ratios, sedimentary textures and fossil characteristics in the low paleolatitudes of Tethys and Panthalassa. During the Middle Permian, some major faunal groups including fusulines (Verbeekinidae), rugose corals (Waagenophyllidae) and bivalves (Alatoconchidae) reached their maximum size and abundance which provides a good regional stratigraphic marker. This large size and gigantism indicates the time of optimum environmental conditions prior to the decline in abundance and

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extinctions up-sequence around the G–LB (Ajinović et al., 2008; Isozaki and Ajinović, 2009).

In the last few decades, alatoconchid bivalves and their co-occurring giant faunas have been recorded in Lower–Middle Permian sequences in Afghanistan, Tunisia, Malaysia, the Philippines, Japan and Thailand. The paleoenvironment of these alatoconchid bivalves has been variously interpreted. They were originally regarded as reefal organisms (Termier et al., 1973) but were later interpreted as bank-dwelling fauna based mainly because of their morphology and the sedimentology of their habitat substrate (Yancey and Boyd, 1983). The large wing-like, flanged bivalves seem to prefer a loose/soft sediment surface rather than a reef-top environment which is supported by the observation that alatoconchid-bearing strata in Malaysia, Japan, Afghanistan, Tunisia and Croatia are all hosted in fine-grained sediments. In Malaysia and Tunisia, the rocks are light colored, poorly-sorted bioclastic packstones suggestive of moderate- to high-energy environments (Runnegar and Gobbet, 1975). By contrast, dark-gray lime mudstones/wackestones in Japan Afghanistan and Croatia indicate low-energy environments (Isozaki, 2006; Ajinović et al., 2008). In the Philippines, an alatoconchid accumulation has been interpreted as a laterally-limited biostrome (Kiessling and Flügel, 2000). Based on these observations and interpretations, it is suggested that alatoconchids preferred a fine-grained sediment substrate such as muddy sand or even stiff mud within low- to moderate-energy environments.

In central Thailand, along the Loei Foldbelt, more than 30 beds containing high concentrations of well-preserved alatoconchid, aberrant bivalves have been studied in the Middle Permian limestones at Khao Somphot. Prior to this study, little was known of these occurrences and their exceptional preservation. Field observations, carbonate petrography and stable isotopic analyses have been carried out in order to understand changes in depositional environments of this sequence and their relationship to biotic changes.

2. Geologic setting

Thailand consists of several distinctive tectonostratigraphic domains which include the Indochina Terrane (or Block), the Loei Foldbelt, the Sukhothai Foldbelt, the Inthanon Zone and the Sibumasu Terrane (Figs. 1 and 2). In the western portion of the Indochina Terrane, Permian limestones belonging to the Saraburi Group are exposed extensively along the north–south trending Loei Foldbelt to the west of the Mesozoic cover rocks of the Khorat Plateau (Fig. 1). Paleogeographically, the Permian in this belt consists of three major elements: the Khao Khwang Platform, the Pha Nok Khao Platform and the Nam Duk Basin located in the west, the east and middle of the belt, respectively (Wieldchowsky and Young, 1985). However, the paleogeographic and palinspastic relationships and the tectonic histories of the terranes, platforms and the basin remain controversial (e.g. Helmcke, 1985; Chutakositkanon et al., 1999; Chonglakmani and Helmcke, 2001; Metcalfe, 2002; 2011; Ueno and Charoentitirat, 2011; Burrett et al., 2014).

The Khao Khwang Platform consists of three main depositional environments: outer platform, platform interior and restricted platform. These environments can be further divided into nine depositional sub-environments (Wieldchowsky and Young, 1985). Carbonate sequences in this platform range in age from Asselian to Capitanian (Altermann, 1989; Chonglakmani and Fontaine, 1990; Fontaine, 2002). This Permian sequence conformably overlies Carboniferous rocks which comprise tuffaceous shales and sandstones and limestones. These Permo-Carboniferous sequences were deformed during the Late Triassic and are overlain unconformably by the Late Triassic basal conglomerate of the Huai Hin Lat Formation (Chonglakmani and Sattayarak, 1978; Fontaine et al., 1999) (Figs. 3 and 4). However, contact relationships between these sequences are not observed and need to be clarified.

The Khao Somphot Range consists mainly of approximately 1200 m of Saraburi Group limestone which, based on fusulines, range through the Cisuralian and Guadalupian (Fig. 3). Major environmental change and a sea-level lowstand are recorded in an approximately 200 m thick dolomite interval found between the Artinskian to early Guadalupian and late Guadalupian limestone conglomerates in the central part and eastern foot hills of the Khao Somphot Range, respectively (Wieldchowsky and Young, 1985; Altermann, 1989).

The alatoconchid-bearing limestones exposed in small hills east of Khao Somphot Range are, based on our new fusuline data, Murghabian–Midian (Wordian–Capitanian) in age (Fig. 3). This stratigraphic section forms part of the Khao Khwang Platform, and belongs to the Tak Fa Formation which is a correlative of the Khao Khwang Formation of the Saraburi Group in Saraburi and the Nam Mahoran and Pha Nok Khao Formations in the Loei and Phetchabun–Chayaphum areas, respectively (Nakornsri, 1981; Bunopas, 1983; Charoenprawat et al., 1984; Chonglakmani and Sattayarak, 1984; Hinthong et al., 1985) (Fig. 4). Conodonts in the carbonate sediments in the Tak Fa Formation were deposited in the Equatorial Warm Water Province close to South China during the Kungurian (late Early Permian) (Metcalfe and Sone, 2008).

Late Permian environmental change is indicated by paralic and non-marine deposits along the western margin of the Indochina Terrane. Plant and wood fossils are found in the Late Permian sequences in the Phetchabun area and further to the north along the Loei Foldbelt (Chonglakmani and Fontaine, 1990) (Fig. 2). A *Dicynodon* fauna is found in Late Permian terrestrial deposits from the north of the foldbelt in Laos (Battail, 2009; Bercovici et al., 2012). In contrast, in northern Thailand, a Late Permian marine sequence is found in the Ngao Group and is conformably overlain by marine sequences of the Triassic Lampang Group in the Sukhothai Foldbelt which is separated from the Loei Foldbelt by the ophiolitic Nan Suture (Bunopas, 1983; Chaodumrong and Burrett, 1997; Singharajwarapan and Berry, 2000) (Fig. 2).

3. Lithology of the study section

The study sequence is approximately 400 meters thick and consists mostly of medium to thick-bedded limestones exposed in two small hills in the eastern foothills of the Khao Somphot Range (Fig. 5). On the basis of field observations, lithologic and physiographic characteristics, seven lithostratigraphic units (Unit A–G) are recognized. They consist mainly of thin to medium-bedded limestones that are disrupted by limestone breccia and conglomerate at some intervals. The limestone beds are within a steeply dipping, homoclinal sequence that youngs to the east (Figs. 5 and 6). Fusuline stratigraphy indicates a Wordian–Capitanian age for the section and details are provided in the following section. Lithologic units are described below in ascending order.

Unit A consists predominantly of medium to thick-bedded limestones. These limestones are mainly intercalated with thin to medium-bedded argillaceous limestone and laminated limestone. Stratigraphic repetition of the shallowing-upward parasequences, is indicative of regular cyclicity. In addition, there are up to seven coquinite beds present in Unit A with alatoconchids in both life position and in displaced or reworked position (Fig. 6). Fusulines are mostly dispersed forming less than 10% of the rock volume, but in the lower part of this unit, they are found densely packed in single layers. Gastropods and brachiopods are also present in relatively high concentrations within single layers.

Unit B is characterised mainly by thick bedded fusuline-bearing limestone with some coral- and alatoconchid-bearing limestones.