Constraining the Permian-Triassic boundary in the Gua Panjang Hill, Merapoh, Pahang state, Malaysia

Nelisa Ameera Mohamed Joeharry[1,*], Mohd Shafeea Leman[1,2], Che Aziz Ali[1,2] & Kamal Roslan Mohamed[1,2]

[1]Geology Programme, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 Bangi, Malaysia
[2]Institute for Environment and Development (LESTARI), Universiti Kebangsaan Malaysia, 43600 Bangi, Malaysia
*Corresponding author email address: nelisa166@yahoo.com

Abstract: The search for the critical Permian-Triassic Boundary (PTB) in Malaysia focuses on limestone hills in the Lipis district since the 1990s. The recent paleontological findings at Gua Panjang hill in Merapoh, Pahang state, has constrained the presence of PTB to be between 6.50 m to 9.00 m from the base of the logged section at the eastern cliff. Late Permian foraminifera such as *Colaniella* sp., *Ichtyofrondina* sp., and *Palaeotextularia* sp. were observed 6.50 m from the base of the logged section, where the microfacies is characterized as bioclastic grainstone deposited within a shallow open shelf environment during Late Permian. Located 2.50 m above the Late Permian horizon is a highly dolomitized horizon with the presence of earliest Triassic conodonts such as *Hindeodus parvus* and *Isarcicella staeschi*. Between the height of 6.50 m and 9.00 m, analyses on $\delta^{13}C$ and $\delta^{18}O$ of the whole rock composition have shown slight decrease in both isotopes to 1.18‰ (VPDB) and 18.23‰ (SMOW), respectively. However, a negative carbon isotope excursion, which is the signature in most PTB sections worldwide, was not observed in the Gua Panjang limestone section potentially due to the large-spaced sampling. Therefore, a high precision research on the 10.00 m logged section at the eastern cliff of the Gua Panjang hill is crucial to identify the precise position of the first PTB in Malaysia.

Keywords: Permian-Triassic Boundary, limestone, Gua Panjang, Merapoh, Lipis district, Pahang, Malaysia

Abstrak: Pencarian Sempadan Perm-Trias (SPT) yang kritikal di Malaysia telah tertumpu kepada singkapan-singkapan batu kapur di daerah Lipis sejak 1990an lagi. Penemuan paleontologi terkini pada bukit Gua Panjang di Merapoh, negeri Pahang, telah mengehadkan lokasi SPT pada ketinggian antara 6.50 m hingga 9.00 m daripada dasar log sedimen pada bahagian tebing timur Gua Panjang. Foraminifera Perm Akhir seperti *Colaniella* sp., *Ichtyofrondina* sp., dan *Palaeotextularia* sp. telah ditemui pada ketinggian 6.50 m daripada dasar log sedimen, di mana mikrofasies dikelaskan sebagai batu butir berbioklas yang diendap pada sekitaran pelantar cetek terbuka ketika Perm Akhir. Terletak 2.50 m pada bahagian atas jujukan Perm Akhir ini ialah jujukan yang hampir mengalami proses pendolomitan penuh dan mengandungi konodon-konodon Trias Awal seperti *Hindeodus parvus* dan *Isarcicella staeschi*. Di antara ketinggian 6.50 m hingga 9.00 m ini, analisis-analisis $\delta^{13}C$ dan $\delta^{18}O$ terhadap komposisi keseluruhan batuan telah menunjukkan sedikit penurunan pada kedua-dua isotop, masing-masing kepada nilai 1.18‰ (VPDB) dan 18.23‰ (SMOW). Namun, penurunan puncak karbon yang menjadi penunjuk bagi kebanyakan SPT di seluruh dunia, tidak ditemui pada singkapan batu kapur Gua Panjang berkemungkinan kerana jarak persampelan yang besar. Oleh itu, kajian terperinci terhadap 10.00 m singkapan yang dilog pada tebing timur bukit Gua Panjang ini adalah sangat penting bagi menentukan kedudukan sebenar SPT pertama di Malaysia dengan lebih tepat.

INTRODUCTION

The transition from the Permian to Triassic period is marked by a catastrophic event known as the Permian-Triassic Mass Extinction (PTME). The PTME had destroyed approximately 90% marine life species (Chen & Benton, 2012; Erwin, 1994; Knoll *et al*., 2007; Raup, 1979) and 70% vertebrates families (Erwin, 1994; Maxwell, 1992). The peak extinction rate happened during or just after the Permian-Triassic Boundary (PTB), which is marked by the first occurence of conodont *Hindeodus parvus* in the Meishan section, South China (Yin *et al*., 2001), dated to be 252.28 Ma (Shen *et al*., 2011). Hundreds of Permian-Triassic sections have been studied worldwide, however the PTB section in Malaysia is yet to be confirmed.

The search for the first PTB in Malaysia started during the 1980s in the northern domain of the Western Belt, where Permian and Triassic conodonts were found in the Kodiang and Chuping limestone, Kedah state (Metcalfe, 1981; 1984; 1990; Metcalfe & Spiller, 1994). However, stratigraphic constrain on the PTB has not been reported in any publication.

Later, the search shifted to the Central Belt (Sone *et al*., 2008), where the Permian and Triassic faunas were reported within the same hill sections in Gua Bama, Gua Sei, Gua Panjang, and Gunung Senyum hills, Pahang state (Figure 1; Table 1) (Abdullah, 1993; Fontaine *et al*., 1988; Idris & Hashim, 1988; Leman, 1995; Lim & Abdullah, 1994; Metcalfe, 1995; Metcalfe & Hussin, 1995; Sone *et al*., 2004). Despite these various findings, the PTB search remains open as no specific horizon or interval was nominated.

This present study is focused on the Gua Panjang hill, Merapoh area, Lipis district, in Pahang state (Figure 1 and 2). This hill is located approximately 12 km south of the

Table 1: Prior findings of the Permian and Triassic fauna within the same limestone sections in Gua Bama, Gua Sei, Gua Panjang, and Gunung Senyum hills in the Pahang state.

	Gua Bama, Lipis district	Gua Sei, Lipis district	Gua Panjang, Lipis district	Gunung Senyum, Temerloh district
Triassic	Cephalopod *Sibyllonautillus bamaensis*	Conodont *Hindeodus parvus*, *Isarcicella isarcica*	Algal boundstone	Alga
	?Middle Triassic	Early Triassic	Triassic	Middle Triassic
	Sone *et al.* (2004)	Metcalfe (1995)	Abdullah (1993)	Fontaine *et al.* (1988)
Permian	Foraminifera *Globavulvulina* sp., *Tuberitina* sp., *Protonodosaria* sp.	Conodont *Hindeodus latidentatus*, *H. julfensis*, *H. changxingensis*	Conodont *Neogondolella rosenkratzi*	Conodont *Mesogondolella nankingensis*, *Neogondolella rosenkrazi*
	Late Permian			
	Lim & Abdullah (1994); Leman (1995)	Metcalfe (1995); Leman (1995)	Metcalfe & Hussin (1995)	Idris & Hashim (1988)

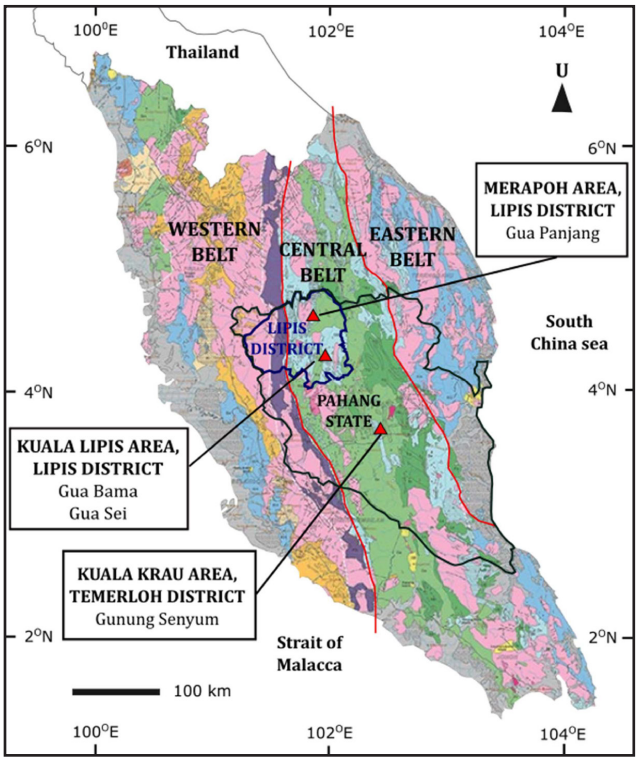

Figure 1: Gua Panjang, Gua Bama, Gua Sei, and Gunung Senyum hills are targeted locations for the study of the Malaysia PTB. This study only focuses on the finding in the Gua Panjang hill, Merapoh area.

Figure 2: The Gua Panjang hill is located at the south of the Merapoh village, Lipis district, as seen from the Central Spine Road (CSR) highway.

Merapoh village, and roughly 50 km north of the Gua Sei and Gua Bama hills. The Gua Panjang hill belongs to the Merapoh Limestone of the Gua Musang Group as described by Mohamed *et al.* (2016).

[Note: 15 km north of the Merapoh village is another limestone hill known as the Gua Panjang hill, located in the Gua Musang district, Kelantan state, where Igo *et al.* (1966) discovered late Early Triassic conodonts. This current study only focuses on the Gua Panjang hill of the Lipis district, Pahang state].

This paper discusses on the geology across the Late Permian - Early Triassic boundary at the Gua Panjang hill, in terms of sedimentology, paleontology, and geochemistry, and the possibility to constrain the position of the first PTB in Malaysia in the future.

METHOD

Ten rock samples were collected from the 10.00 m logged section at the eastern cliff of the Gua Panjang hill, Merapoh, Lipis district (Figure 2 and 3). The base of the logged section is located at the coordinate 4°35'5.62''N, 101°59'33.92''E. Samples weigh differently, ranging from 0.01 kg to 2.00 kg. Difficulty in collecting samples was due to the massive nature of the limestone and the danger of loose rocks from the cave ceiling. For petrographic study, thin section of rock samples were observed to determine microfacies and allochem compositions.

For paleontological study, rock samples were soaked in 10% acetic solution and filtered through 1.00 mm and 63.00 µm size sieves using the stacked sieve method. Filtered sediments were left to dry before individual conodonts were picked using a very fine brush under a microscope. Only one sample, at the height of 9.00 m, yields conodont specimens. Selected conodont specimens were sent to the UKM Electron Microscopy Laboratory for a Scanning Electron Microscopy (SEM) procedure.

For geochemistry study, small portions of selected rock samples were crushed, powdered, and sent to the University of Tasmania for $\delta^{13}C$ and $\delta^{18}O$ analyses. The whole rock analysis was chosen due to limited number of unaltered allochems and conodonts discovered.

SEDIMENTOLOGY AND PALEONTOLOGY

The Gua Panjang hill is made up of carbonates (limestone and dolostone) (Figure 3) while the surrounding low-lying area is predominantly made up of mudstone and shale, often highly tuffaceous (Leman, 1993; 1994). The limestone bed strikes in the NNW-SSE direction and dips 30°SW, suggesting that the Gua Panjang limestone overlies the tuffaceous shale unit to the east and possibly the well-known *Leptodus* shale to the south in the Sungai Yu - Sungai Toh area (Campi *et al*., 2002; 2005).

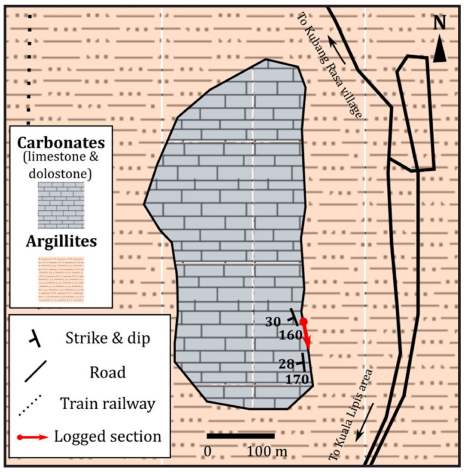

Figure 3: The geologic map of the Gua Panjang hill, Merapoh.

In the field, 10.00 m of the eastern hill section was logged, starting from the basal section at the coordinate 4°35'5.62"N, 101°59'33.92"E (Figure 4). In the field, the first 4.50 m of the logged section comprises of visible alternates between light gray limestone with greenish gray limestone. Petrographic observation of thin sections does not reveal any obvious differences between these different colored bandings, except for the presence of 80 to 200 microns-sized clasts of volcanic glass within the greenish gray limestone. The greenish coloration is possibly contributed by the presence of chloritic pyroclasts of the Pahang Volcanic Series as described by Richardson (1950). Allochem compositions are very low, which is between 5% to 25%, in this carbonate mudstone and bioclastic wackestone microfacies.

At the height of 6.50 m, the presence of the Late Permian foraminifera such as *Colaniella* sp., *Palaeotextularia* sp., and *Ichthyofrondina* sp. (Figure 5) in bioclastic grainstone suggests the deposition in an open shallow marine platform. The allochem composition is 40% with a more diverse fauna. Observation of thin sections from the height of 7.00 m to 10.00 m have shown a nearly full dolomitization of limestone, which is now categorized as a dolostone. A single sample at the height of 9.00 m yields five species of early Triassic conodonts including *Hindeodus parvus erectus*, *H. parvus parvus*, *H. latidentatus latidentatus*, *H. latidentatus*

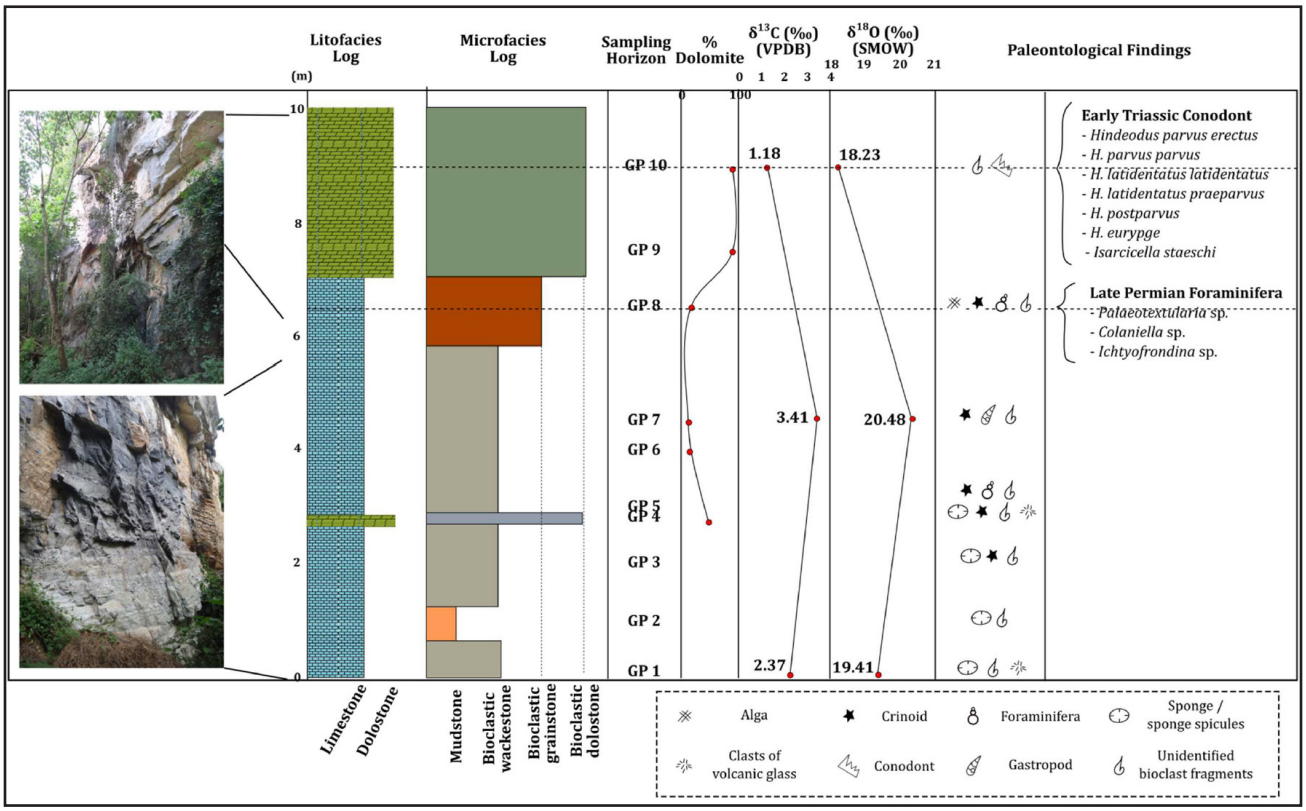

Figure 4: Summary of litofacies, microfacies, latest paleontological findings, and isotopes data of the 10.00 m logged section at the eastern foothill of the Gua Panjang hill.

praeparvus, *H. postparvus*, *H. eurypge*, and *Isarcicella staeschi* (Figure 6). The abundance of specimens is listed in Table 2. The full systematic descriptions of conodonts are described in Joeharry *et al*. (2018).

The finding of the Late Permian foraminifera at the height of 6.50 m and the Early Triassic conodonts at the height of 9.00 m constrains the presence of the PTB in Malaysia to be within this 2.50 m height interval (Figure 4; Figure 7).

GEOCHEMISTRY

In this early study on the isotope of the Gua Panjang hill, only three samples were selected for $\delta^{13}C$ and $\delta^{18}O$ analyses: samples from the height 0 m, 4.50 m, and 9.00 m. The $\delta^{13}C$ (VPDB) value ranges from 1.18‰ to 3.41‰, while the $\delta^{18}O$ (SMOW) value ranges from 18.23‰ to 20.48‰. Both analyses shows decreasing concentration from height 4.50 m to 9.00 m, where $\delta^{13}C$ (VPDB) decreases from 3.41‰ to 1.18‰ while $\delta^{18}O$ (SMOW) decreases from 20.48‰ to 18.23‰.

DISCUSSION

In the Lipis district, the presence of *Colaniella* sp. is an indicator of the Late Permian outcrop. Prior to this study, Colaniella-bearing limestone were reported from Gua Bama (Lim & Abdullah, 1994), Gua Sei (Leman, 1995), and Gua Panjang (Metcalfe & Hussin, 1995) hills. At the Gua Bama hill, the horizon containing the collaniellid foraminifera at the eastern foothill (Lim & Abdullah, 1994) is overlain by a massive unfossiliferous limestone until the peak of the hill, where an algal rich limestone harboring a ?Middle Triassic nautiloid *Sybillonautilus bamaensis* was reported (Sone *et al.,* 2004; 2008). At the Gua Sei hill, despite the

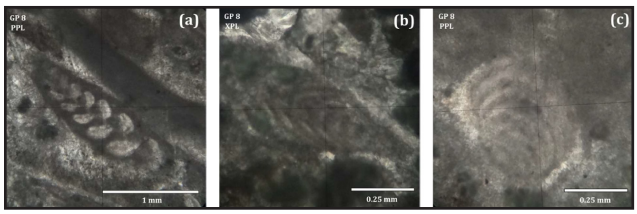

Figure 5: Late Permian foraminifera at the eastern side of the Gua Panjang hill, Merapoh. (a) *Palaeotextularia* sp.; (b) *Colaniella* sp.; (c) *Ichtyofrondina* sp.

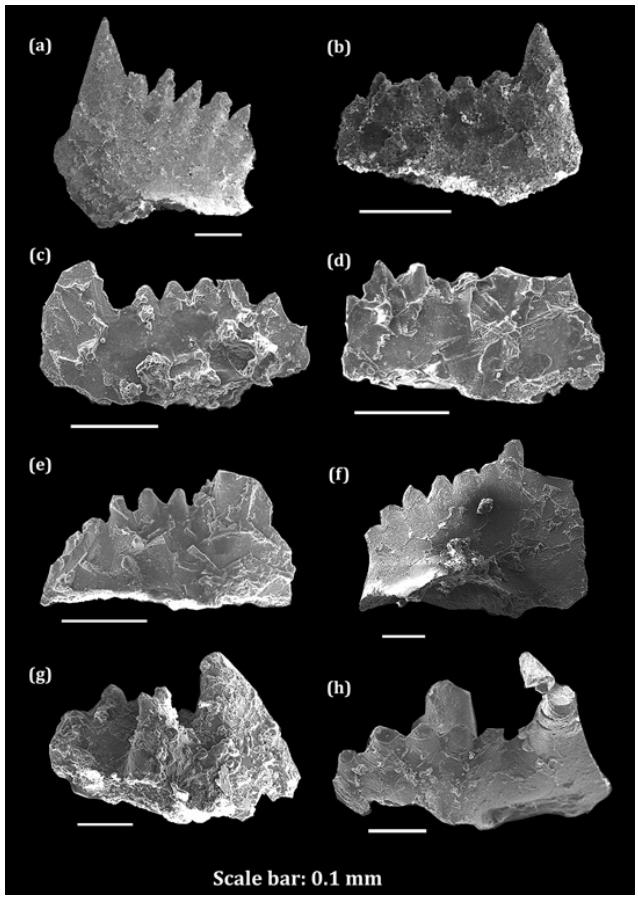

Figure 6: Early Triassic conodonts at the eastern side of the Gua Panjang hill, Merapoh. (a) *Hindeodus parvus erectus*; (b) *H. parvus parvus*; (c) *H. latidentatus latidentatus*; (d) *H. latidentatus praeparvus*; (e) *H. postparvus*; (f) *H. eurypge*; (g & h) *Isarcicella staeschi*. The image of *Hindeodus parvus* and the systematics of these findings are published in Joeharry *et al*. (2018).

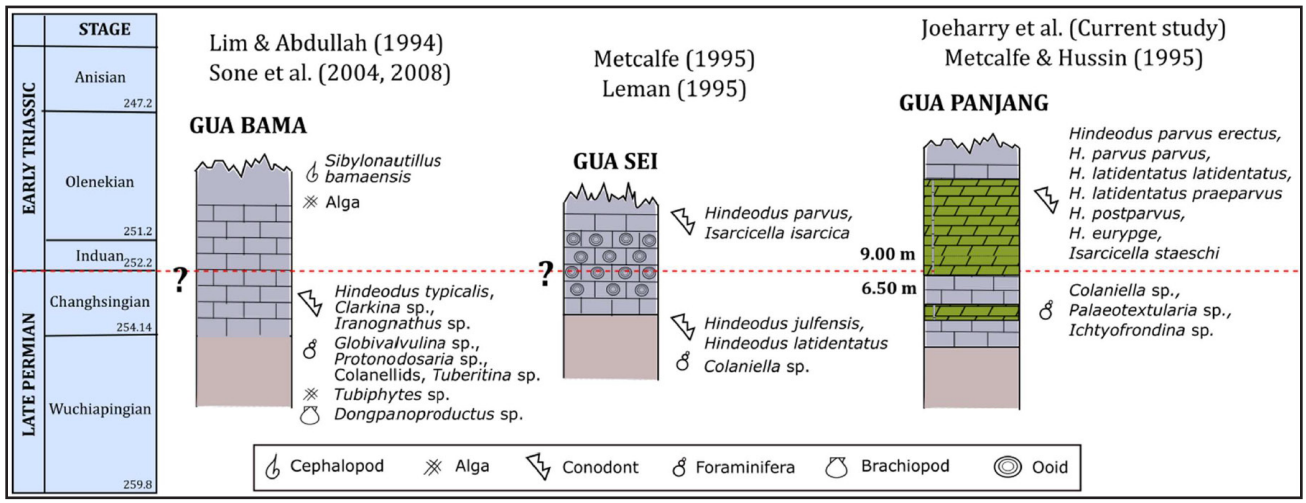

Figure 7: Summary of the PTB search in the Lipis district to date. Data modified from Lim & Abdullah (1994), Leman (1995), Metcalfe (1995), Metcalfe & Hussin (1995), and Sone *et al*. (2004, 2008).

Table 2: Abundance of conodont specimens in the 9.00 m height from the base of the logged section. Only one sample yields conodont specimens. The specimens, labeled as UKM-KGP, are stored in the Paleontology laboratory, Universiti Kebangsaan Malaysia.

Name of specimens	Abundance
Hindeodus parvus erectus	2
H. parvus parvus	1
H. latidentatus latidentatus	2
H. latidentatus praeparvus	3
H. postparvus	2
H. eurypge	3
Isarcicella staeschi	4
Unidentified P elements	3
Unidentified S elements	9

finding of the Late Permian and Early Triassic conodonts (Metcalfe, 1995), no specific height constrain of the PTB was named. Therefore, this 2.50 m interval constrain between the Late Permian fossil record and the first appearance of the Earliest Triassic fossil record at the eastern Gua Panjang hill (Joeharry *et al*., 2018) should represent the closest possible Malaysia PTB location. Figure 7 summarizes the present state of knowledge on the PTB in the Lipis district.

From the base of the logged section, the change from bioclastic wackestone with low allochem composition of crinoid fragments and sponge spicules towards the uppermost Permian colaniellid-bearing bioclastic grainstone indicates changes in the depositional environment from a relatively deep to a shallower open shelf. This is evident that Lipis Sea is shallowing upwards during the latest Late Permian. Further changes towards the earliest Triassic conodont-bearing bioclastic dolostone should strengthen the evidence of an end-Palaeozoic regression in this area. This is consistent with the discovery of Triassic conodonts in oolitic limestone of the Gua Sei hill in the Kuala Lipis area by Metcalfe (1995), which was also defined as the deposition within a shallow marine setting. In addition, the overlying Middle Triassic to Upper Triassic Gunung Rabong formation, and the Upper Triassic to Jurassic period Koh formation show deposition of continental deposit.

Preliminary whole rock isotope analyses on $\delta^{13}C$ and $\delta^{18}O$ show slight decrease in both isotopes to 1.18‰ (VPDB) and 18.23‰ (SMOW), respectively. The decrease of both isotope values are similar to other PTB sections worldwide, where the phenomenon is driven by the deposition of more lightweight isotopes (^{12}C and ^{16}O) as the marine fauna with ^{12}C and ^{16}O in their tests composition went into extinction. However, the carbon isotope excursion, which is the fundamental signature in most PTB sections worldwide, is not observed in the study area. Large-spaced sampling and selecting only limited rock samples for isotope analyses are possible causes of the absence of the negative isotope excursion or any distinct pattern during the Permian to Triassic transition.

FUTURE WORKS

Further research on the 10.00 m logged section at the eastern foothill of the Gua Panjang hill, starting from the basal coordinate 4°35'5.62''N, 101°59'33.92''E, is important to understand the paleontology and geochemistry of the Late Permian - Early Triassic setting and the PTME in the Merapoh area. A much narrow-spaced sampling within the 2.50 m PTB constrain is critical to properly define the First Appearance Datum (FAD) of *Hindeodus parvus*, hence the precise location of the PTB. The finding of this FAD can be substantiated with more isotope analyses ($\delta^{13}C$, $\delta^{18}O$, $\delta^{34}S$, and $\delta^{15}N$) and age geochronological data. Any significant isotope patterns, such as the well-known $\delta^{13}C$ and $\delta^{18}O$ negative excursions, are valuable in the study of the PTME in the Merapoh area.

The finding of the Permian to Triassic period transition will not only mark the first official PTB location in Malaysia, but will attract more geologists worldwide on this newly discovered PTB section. This high scientific value, together with the beautiful karstic landscape of the northwest Pahang will help the nomination of the Lipis district as the national geopark candidate and possibly into the UNESCO Global Geoparks list.

CONCLUSION

Based on the finding of the Late Permian foraminifera and the Early Triassic conodonts, the possible location of the Malaysia PTB is constrained to 2.50 m, between the height of 6.50 m and 9.00 m of the logged section at the eastern cliff of Gua Panjang hill, Merapoh. Microfacies changes indicate continuous regression towards the Permian to Triassic transition. Preliminary isotope analyses show decrease in both $\delta^{13}C$ and $\delta^{18}O$ values. In the future, more narrow-spaced samplings might lead to important discovery such as the FAD of *Hindeodus parvus* and the carbon isotope negative excursion of the PTME in the Merapoh area.

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