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

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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

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 occurrence 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 (Metcalf, 1981; 1984; 1990; Metcalf & 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; Metcalf, 1995; Metcalf & 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...
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.

**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.

| Hill          | Permian          | Triassic          |
|---------------|------------------|-------------------|
| Gua Bama, Lipis district | Cephalopod *Sibyllonautilus bamaensis* | Conodont *Hindeodus parvus, Isarcicella isarcica* |
| Gua Sei, Lipis district | ?Middle Triassic | Early Triassic |
| Gua Panjang, Lipis district | Triassic | Abdullah (1993) |
| Gunung Senyum, Temerloh district | Algal boundstone | Fontaine *et al.* (1988) |

[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,
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).

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...
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 δ¹³C and δ¹⁸O analyses: samples from the height 0 m, 4.50 m, and 9.00 m. The δ¹³C (VPDB) value ranges from 1.18‰ to 3.41‰, while the δ¹⁸O (SMOW) value ranges from 18.23‰ to 20.48‰. Both analyses shows decreasing concentration from height 4.50 m to 9.00 m, where δ¹³C (VPDB) decreases from 3.41‰ to 1.18‰ while δ¹⁸O (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.](image1)

![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).](image2)

![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).](image3)
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. euryype* | 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 eastern 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 δ¹³C and δ¹⁸O 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 (¹³C and ¹⁸O) as the marine fauna with ¹³C and ¹⁸O 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 base 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 (δ¹³C, δ¹⁸O, δ³⁴S, and δ¹⁵N) and age geochronological data. Any significant isotope patterns, such as the well-known δ¹³C and δ¹⁸O 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 δ¹³C and δ¹⁸O 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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**REFERENCES**

Abdullah, N. T., 1993. The occurrence of Upper Permian foraminifers in Northwest Pahang. Warta Geologi, 19, 112.

Campi, M.J., Shi, G.R. & Leman, M.S., 2002. The Leptodus Shales of central Peninsular Malaysia: distribution, age and palaeobiogeographical affinities. Journal of Asian Earth Sciences, 20, 703–717.

Campi, M.J., Shi, G.R. & Leman, M.S., 2005. Guadalupian (Middle Permian) brachiopods from Sungai Toh, a Leptodus Shale locality in the Central Belt of Peninsular Malaysia Part1: Lower Horizons. Palaeontographica Abteilung A, 273(3–6), 97–160.

Chen, Z.Q. & Benton, M. J., 2012. The timing and pattern of biotic recovery following the end-Permian mass extinction. Nature Geoscience, 5(6), 375-383.
Erwin, D.H., 1994. The Permo-Triassic Extinction. Nature, 367, 231-236.
Fontaine, H., Khoo, H.P. & Vachard, D., 1988. Discovery of Triassic fossils at Bukit Chuping in Gunung Sinyum area and at Kota Jin, Peninsular Malaysia. Journal Southeast Asian Earth Science, 2, 145–162.
Idris, M.B. & Hashim, C.N., 1988. An Upper Permian Fossil Assemblage from Gunung Sinyum and Gunung Jebak Puyoh Limestone, Pahang. Warta Geologi, 14(5), 199–203.
Igo, H., Koike, T. & Yin, E.H., 1966. Triassic conodonts from Kelantan, Malaya. Geology and Palaeontology of Southeast Asia, 2, 157-177.
Knoll, H. K., Bambach, R. K., Payne, J. L., Pruss, S. & Fischer, W.W., 2007. Paleophysiology and end-Permian mass extinction. Earth and Planetary Science Letters, 256, 295-313.
Joeharry, N.A.M., Leman, M.S., Ali, C.A. & Mohamed, K.R., 2018. Earliest Triassic conodonts of Gua Panjang, Merapoh, and its bearing towards Permian-Triassic Mass Extinction in Malaysia. Sains Malaysiana, 47(7), 1423-1430.
Leman, M.S., 1993. Upper Permian brachiopods from northwest Pahang. Proceedings of International Symposium on Biostratigraphy of mainland Southeast Asia, Chiang Mai, 1, 203-218.
Leman, M.S., 1994. The significance of Upper Permian brachiopods from Merapoh area, northwest Pahang. Bulletin of the Geological Society of Malaysia, 35, 113-121.
Leman, M.S., 1995. The significance of Permian volcanic activity towards faunal development in Padang Tengku area, Pahang. Sains Malaysia, 24, 17-28.
Lim, K.K. & Abdullah, N.T., 1994. Development of Permian Volcanics Limestone Succession at Gua Bama, Pahang Darul Makmur. Warta Geologi, 20(3), 243–244.
Maxwell, W.D., 1992. Permian and Early Triassic extinction of non-marine tetrapods. Palaeontology, 35(3), 571-583.
Metcalfe, I., 1981. Permian and early Triassic conodonts from northwest Peninsular Malaysia. Bulletin of the Geological Society of Malaysia, 14, 119–126.
Metcalfe, I., 1984. The Permian-Triassic Boundary in Northwest Malaya. Warta Geologi, 10(4), 139–147.
Metcalfe, I., 1990. Triassic conodont biostratigraphy in the Malay Peninsula. Bulletin of the Geological Society of Malaysia, 26, 133–145.
Metcalfe, I., 1995. Mixed Permo-Triassic boundary conodont assemblages from Gua Sei and Kampong Gu, Pahang, Peninsular Malaysia. CFS Courier Forschungsinstitut Senckenberg, 182, 487–495.
Metcalfe, I. & Spiller, F. C. P., 1994. Correlation of the Permian and Triassic in Peninsular Malaysia: New data from conodont and radiolarian studies. Proceedings of the International Symposium on Stratigraphic Correlation of Southeast Asia, Bangkok, 129.
Metcalfe, I. & Hussin, A., 1995. Implications of new biostratigraphic data for stratigraphic correlation of the Permian and Triassic in Peninsular Malaysia. Bulletin of the Geological Society of Malaysia, 38, 173–177.
Mohamed, K.R., Joeharry, N.A.M., Leman, M.S. & Ali, C.A., 2016. The Gua Musang Group: A newly proposed stratigraphic unit for the Permo-Triassic sequence of Northern central Belt, Peninsular Malaysia. Bulletin of the Geological Society of Malaysia, 62, 131-142.
Raup, D. M., 1979. Size of the Permo-Triassic Bottleneck and Its Evolutionary Implications. Science, 206, 217-218.
Richardson, J.A., 1950. The Geology and Mineral Resources of the Neighbourhood of Chegar Perah and Merapoh, Pahang, Federated Malay States. Geological Survey Department Federation of Malaya, Ipoh, 162 p.
Shen, S.Z., Crowley, J.L., Wang, Y., Bowring, S. A., Erwin, D. H., Sadler, P.M., Cao, C.Q., Rothman, D.H., Henderson, C.M., Ramezani, J., Zhang, H., Shen, Y., Wang, X.D., Wang, W., Mu, L., Li, W.Z., Tang, Y.G., Liu, X.I., Liu, L.J., Zeng, Y., Jiang, Y.F. & Jin, Y.G., 2011. Calibrating the End-Permian Mass Extinction. Science, 334(6061), 1367–1372.
Sone, M., Leman, M.S. & Metcalfe, I., 2004. Triassic nautiloid Sibyllonautilus from Gua Bama, Peninsular Malaysia and its regional stratigraphic implications. Alcheringa, 28(2), 477–483.
Sone, M., Metcalfe, I. & Leman, M.S., 2008. Search for the Permian-Triassic boundary in central Peninsular Malaysia: Preliminary report. Permophiles, 51, 32-33.
Yin, H.F., Zhang, K.X., Tong, J.N., Yang, Z.W. & Wu, S.B., 2001. The Global Stratotype Sections and Points (GSSP) of the Permian-Triassic boundary. Episodes, 24, 102-114.