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A short note on the discovery of the bivalve *Euchondria* from the Carboniferous Kubang Pasu Formation of Pauh, Perlis

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Abstract: Bivalve taxa are rare from the fossil assemblage in the Carboniferous Kubang Pasu Formation. This study reports the discovery of the pectinid bivalve *Euchondria* sp. from the Kubang Pasu Formation exposed at Bukit Tuntung, Pauh, in Perlis state, NW Peninsular Malaysia. A single left valve is preserved in light grey shale and associated with previously reported Early Carboniferous (Viséan) ammonoids and the bivalve *Posidonia becheri*. The morphology and anatomy of the specimen is described. The genus *Euchondria* ranges from the Late Devonian to Permian which is consistent with its association with the Kubang Pasu Formation fossil assemblage of Viséan age. The fossil assemblage at Bukit Tuntung, which is relatively sparse compared to equivalent strata in western Perlis and dominated by thin-shelled bivalves and nektonic ammonoids indicates a relatively deeper marine depositional setting, which is consistent with the presence of turbidites.

Keywords: *Euchondria*, Carboniferous, Kubang Pasu Formation, Perlis, dysaerobic facies

INTRODUCTION

The Chepor Member of the Kubang Pasu Formation contains a rich and diverse marine shelly invertebrate fossil assemblage of Early Carboniferous (Mississippian) age (Hamada, 1968, 1969; Kobayashi & Hamada, 1973; Amir Hassan & Lee, 2003; Amir Hassan *et al*., 2014). Previously, the only known bivalve from the Chepor Member was *Posidonia becheri*, which is an important marker fossil for the unit, as well as for age-equivalent rocks of the Singa Formation in Langkawi (Sarkar, 1972; Basir, 2015). We here report the discovery of a relatively well-preserved specimen of the pectinid bivalve *Euchondria* sp. from the Chepor Member, Kubang Pasu Formation of Perlis, NW Peninsular Malaysia. The specimen was discovered in 2012 from an outcrop of light grey shale at Bukit Tuntung in Pauh, Perlis (Figure 1). This is the first reported occurrence of this genus from this unit known to the authors. This report includes a geological description of the outcrop, faunal content, discussion on the age of the unit and systematic description of the fossil specimen.

Geological setting

Perlis state in NW Peninsular Malaysia is predominantly underlain by sedimentary rocks ranging in age from the Ordovician to Triassic (Jones, 1981). The sedimentary strata are exposed as a regionally N-S striking fold belt. The geology of the western half of Perlis is better understood. The oldest rocks here are Ordovician – Devonian carbonates of the Setul Group, which also includes thin pelagic shale intercalations, i.e. the Tanjung Dendang and Timah Tasoh formations (Cocks *et al*., 2005; Lee, 2009). A thin but widespread Carboniferous (Tournaisian) chert unit unconformably overlies the Setul Group, i.e. the Telaga Jatoh Formation (Basir & Zaiton, 2011a, 2011b; Amir Hassan *et al*., 2014; Amir Hassan, 2021). This is then overlain by the clastic-dominated Kubang Pasu Formation, which underlies a significant area of the land surface of Perlis. Amir Hassan *et al*. (2014) subdivides the Kubang Pasu Formation into a Lower Carboniferous Chepor Member and a Lower Permian uppermost Kubang Pasu Formation. The Chepor Member has been interpreted as delta front – prodelta deposits with some glacial marine influence,

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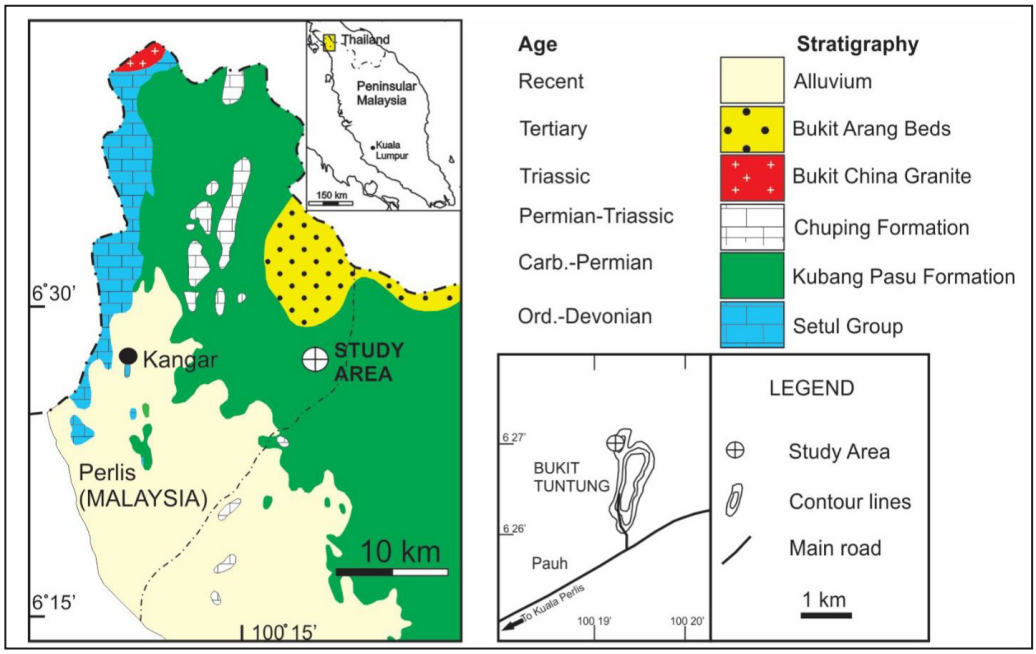

Figure 1: (A) Geological map of Perlis. The Telaga Jatoh Formation is only exposed at localized outcrops but is most likely extensive in the subsurface (modified after Jones, 1981). (B) Map showing locality of the fossil site.

while the uppermost Kubang Pasu Formation comprises calcareous sandstone with evidence of significant wave and storm reworking (Amir Hassan *et al*., 2013, 2014, 2017). No confirmed Upper Carboniferous strata have been identified throughout NW Peninsular Malaysia, suggesting the presence of a depositional hiatus between the two subunits of the Kubang Pasu Formation. The Kubang Pasu Formation is then successively overlain by Permian – Triassic carbonates of the Chuping Formation (Jones, 1981). Most of the Chuping Formation has been eroded, leaving only a narrow, N-S trending line of uplifted karst hills in the middle of Perlis.

The stratigraphy slightly changes in the eastern half of the state. Here as well as further south in north Kedah, carbonates of the Setul Group are absent and are replaced by age-equivalent slates of the Mahang Formation (Zaiton & Basir, 2000; Basir, 2010; Basir *et al*., 2010). However, the Mahang Formation is only exposed as uplifted slivers within fault zones and flower structures, which have been interpreted to be the product of strike-slip movement along the Bok Bak Fault (e.g. Zaiton & Basir, 2000). The Chuping Formation is also absent in eastern Perlis. Age-equivalent sedimentary rocks are present further east, within the adjacent state of Kedah, but these are comprised of turbidites and cherts of the Permian – Triassic Semanggol Formation (Burton, 1973; Ridd, 2013).

Perlis, along with other areas of the Western Belt of Peninsular Malaysia (i.e. Kedah, Perak, and Selangor) are part of the Sibumasu continental terrane, which rifted and drifted from Gondwana during the Permian (Metcalfe, 2011, 2013).

Sedimentology and palaeontology of the Chepor Member, Kubang Pasu Formation

The Chepor Member of the Kubang Pasu Formation contains a rich and diverse marine invertebrate fossil assemblage. Most of the fossils are preserved as decalcified internal and external moulds or pyrite replacements. Fossil taxa described from the unit includes cnidarians, brachiopods, trilobites, ostracods, crinoids, ammonoids and bivalves (Kobayashi & Hamada, 1966, 1973; Hamada, 1968, 1969; Sarkar, 1972; Jones, 1981; Amir Hassan & Lee, 2003; Amir Hassan *et al*., 2014; Basir, 2015). Transported fossil plants have also been reported, in close association with bivalves (Rasyidah *et al*., 2017). Reliable index fossils have been reported from the Chepor Member, including the ammonoids *Praedaraelites tuntungensis*, ?*Goniatites* sp. and *Delepinoceras* sp. (Amir Hassan *et al*., 2014; Amir Hassan & Becker, 2019) and the bivalve *Posidonia becheri* (Basir, 2015). These taxa indicate an Early Carboniferous (Viséan) age for the Chepor Member.

Amir Hassan *et al*. (2014) (with some revisions in Amir Hassan, 2021) conducted a facies analysis of the Chepor Member based on several sections in western Perlis, i.e. at Guar Sanai and Utan Aji. The sections comprise thick mudstones interbedded with sandstones. The sandstones are fine- to medium-grained and tend to be tabular bedded. Sedimentary structures in the sandstones include scoured bases, load casts, mud rip-up clasts, basal mud clast conglomerates, cross-bedding, ripples, planar lamination and normal grading with Bouma sequences. Subordinate facies include diamictite beds and laminated beds penetrated by dropstones. The

depositional environment was interpreted to be a glacial-marine shelf/prodelta, with turbidites, wave/storm and current-generated bedforms.

RESULTS AND DISCUSSION

Geologic description of the Bukit Tuntung outcrop

Bukit Tuntung is a small N-S trending hill located approximately 25 km east of Kangar, Perlis. A large earth quarry operating at the hill has exposed Palaeozoic sedimentary strata. Several geological studies have previously been conducted at Bukit Tuntung (e.g. Basir, 2010; Basir *et al*., 2010). They reported the presence of extensive exposures of dark grey to green coloured slate of the Mahang Formation. The slate weathers to a red colour. The Mahang Formation was observed to be overlain by a thin unit of folded bedded chert containing Carboniferous radiolarians, which we recognize as the Telaga Jatoh Formation (Amir Hassan *et al*., 2014). This was then successively overlain by interbedded mudstone and sandstone of the Kubang Pasu Formation.

A small section of the outcrop at the northern end of the Bukit Tuntung quarry was studied (Figure 2). The section exposes the boundary between the Mahang, Telaga Jatoh and Kubang Pasu formations. The sedimentary strata have been structurally deformed. The section generally comprises vertical to steeply eastward dipping beds striking N-S. The eastern end of the section exposes tightly folded, thinly interbedded chert and black shales of the Telaga Jatoh Formation. The middle part of the section comprises grey to light grey shales of the Kubang Pasu Formation. The light grey shale contains shelly fossils of ammonoids and bivalves. The western end of the section exposes a N-S trending ridge of tightly folded sandstone. The sandstones tend to be tabular bedded, being either structureless, rippled or normal graded (medium- to fine-grained). The normal graded beds display Bouma sequences, with individual beds grading upward from structureless sandstone into parallel lamination, ripple cross-lamination and capped by shale. Groove casts are common at the base of beds. The sandstones are interpreted as turbidites.

Age of the strata at Bukit Tuntung, Pauh

The radiolarians *Stigmosphaerostylus variospina* (Won) and *Callela hexactina* Won have previously been reported from the chert beds of Bukit Tuntung, Pauh (Basir *et al*., 2010). The two taxa are typical of Tournaisian radiolarian assemblages found in the Telaga Jatoh Formation (Basir & Zaiton, 2001). The grey shale contains a shelly fossil assemblage, which includes the bivalve *Posidonia becheri**. This taxon is a very common fossil in the Chepor Member of the Kubang Pasu Formation and indicates an Early Carboniferous (Mississippian) age (Basir, 2015). Two ammonoid taxa have also been previously described from the shale, i.e. ?*Goniatites* sp. and *Praedaraelites tuntungensis*, which further constrains the age to Viséan (Amir Hassan *et al*., 2014). The new specimen of *Euchondria* in the grey shale is also consistent with these previous age determinations. *Euchondria* has a relatively long range, i.e. from the Late Devonian to Middle Permian (Newell, 1938; Newell & Boyd, 1995; Amler, 1995; Amler & Winkler Prins, 1999).

Palaeogeographic implications

Basir & Zaiton (2011a) recognized that there is a lateral W-E change in palaeoenvironment in the Chepor Member, Kubang Pasu Formation from shallow marine facies in Perlis to deeper marine facies in Kedah. A similar

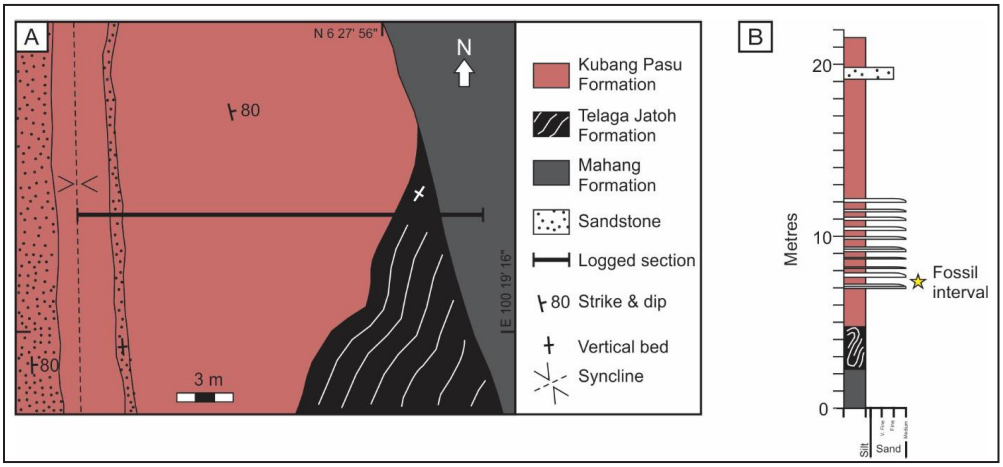

Figure 2: (A) Geological map of the study area at Bukit Tuntung, Pauh, Perlis state, NW Peninsular Malaysia. (B) Logged section at Bukit Tuntung. Location of section is marked in Figure A.

* Footnote: It should be noted that Basir (2015) claimed the nomenclaturally correct genus name of the bivalve to be *Posidonomya* instead of *Posidonia* due to the supposed homonymy with the seagrass *Posidonia* introduced earlier. ICZN rules, however, declare that the name of an animal taxon is not to be rejected merely because it is identical with the name of a taxon that does not belong to the animal kingdom. This implies that homonymy between plant and animal generic names is retroactively rejected.

pattern is also observed in older and younger strata, i.e. (i) where the platform carbonates of the Ordovician - Devonian Setul Group of Perlis transition into basinal deposits of the Mahang Formation in Kedah, and; (ii) where platform carbonates of the Permian – Triassic Chuping Formation in Perlis grades into turbidites and hemipelagites of the Semanggol Formation in Kedah (Ridd, 2013). The facies boundary is marked by a N-S trending zone just East of the Chuping hills in Perlis, which can be traced northward into Peninsular Thailand and southward into Kedah. This zone is referred to as the Rattaphum-Kodiang tectonic line and is interpreted as a zone of westward thrusting possibly related to the closure of the Paleo-Tethys during the Triassic (Ridd, 2013). The Chepor Member strata at Bukit Tuntung are located east of the Rattaphum-Kodiang line and several of its sedimentological and palaeontological characteristics support a deeper marine depositional environment interpretation. In terms of facies composition, the Bukit Tuntung strata are dominated by turbidites, which are typical of deeper marine settings. Additionally, groove casts at the base of sandstones indicate deposition by debris flow, slump or slide, which suggests a location along a shelf edge or slope (Peakall *et al*., 2020). In comparison, facies composition in successions of the Chepor Member westward of the Rattaphum-Kodiang line is more varied, which includes sandstones with cross-bedding, hummocky cross-stratification and wave ripples implying shallow marine conditions, mixed with diamictites and dropstones (Amir Hassan *et al*., 2014). Bouma sequences are also present but are subordinate facies and are closely associated with dropstones. This suggests that they were the product of gravity flows or suspension fallout from glacial/iceberg meltwater plumes (e.g. Vesely & Assine, 2006; Girard *et al*., 2012). The fossil composition of the Chepor Member at Bukit Tuntung is also significantly different from that in outcrops further west. At Bukit Tuntung, fossils are sparse and of low diversity, composed mainly of thin-shelled bivalves (*Euchondria* sp. and *Posidonia becheri*) and nektic ammonoids. Palaeoecologically, euchondriids are important index fossils as they are restricted to basinal environments with dysaerobic facies and have been found predominantly in grey and black shales (Amler & Winkler Prins, 1999). In contrast, the fossil assemblage in outcrops in western Perlis are rich in benthic fossils of relatively higher diversity, which is more consistent with a shallow marine setting, although *Posidonia becheri* and ammonoids are still present. This is not surprising, given the nektic, facies-independent nature of ammonoids and the pseudoplanktic interpretation for posidoniiform bivalves (Amler, 2009; Hoşgör *et al*., 2012).

SYSTEMATIC PALAEONTOLOGY

Class BIVALVIA Linnaeus, 1758
Subclass AUTOBRANCHIA Grobben, 1894
Infraclass PTERIOMORPHIA Beurlen, 1944

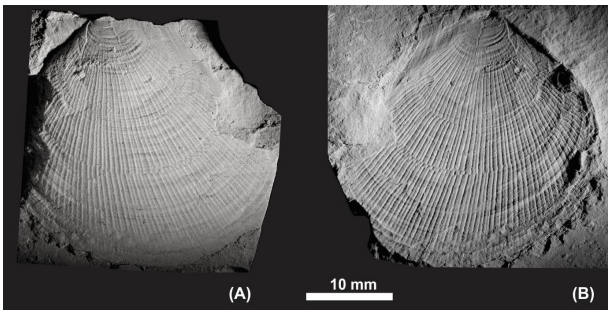

Figure 3: *Euchondria* sp. from the Carboniferous Kubang Pasu Formation of Bukit Tuntung, Pauh, Perlis, NW Peninsular Malaysia (UMBTP003). Specimen is a left valve. (A) Internal mould; (B) Counterpart external mould.

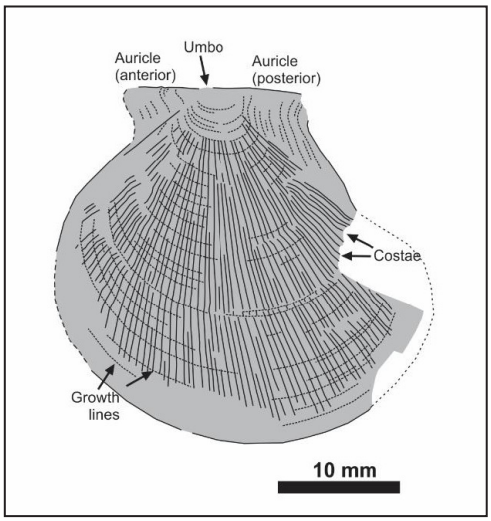

Figure 4: Diagrammatic sketch of the *Euchondria* sp. specimen from the Carboniferous Kubang Pasu Formation of Bukit Tuntung, Pauh, Perlis, NW Peninsular Malaysia. The main anatomical features described in this paper are labelled.

Order PECTINIDA Gray, 1854
Superfamily EUCHONDRIOIDEA Newell, 1938
Family EUCHONDRIIDAE Newell, 1938
Genus *Euchondria* Meek, 1874
Euchondria sp. (Figure 3 and Figure 4)

Material:

One specimen (left valve internal mould, incomplete, and counterpart external mould) from light grey shale of the Kubang Pasu Formation at Bukit Tuntung, Pauh, Perlis, NW Peninsular Malaysia (Catalogued as UMBTP003 in the collection of the Department of Geology Faculty of Science, Universiti Malaya).

Description:

(Left valve only): Shell small; valve retrocrescent (prosocline), higher than long, characteristically obliquely oval in outline with distinct posteroventral expansion. Shell very thin, irregularly broken due to compaction. Umbo triangular, pointed, but beak not completely preserved,

slightly anterior to midline, umbonal angle about 90°. Anterior auricle lobate, separated by narrow auricular sulcus, anterior margin convex, anterior auricular sinus shallow concave. Posterior auricle triangular, acuminate, less distinctly separated, slightly longer than anterior auricle, but acute posterior end broken off, its posterior margin concave and ventrally merging with posterior margin of disc in a nearly straight line. Anterior, ventral and posterior margin of disc smoothly rounded. Ornamentation multicostate: primary costae very thin, filiform, secondary and tertiary costae intercalate at various distances from umbo, at height (H) = 10 mm *ca*.12 primary costae and 10 secondary in 10 mm length of the growth line, at H = 20 mm *ca*. 7 primary, 6 secondary and 8 tertiary costae in 10 mm length of the growth line; width of interspaces unequal, generally and typically wide, flat. Growth lines sharp, very closely spaced, developed only in interspaces, giving the exterior shell surface a characteristic reticulate appearance. Anterior auricle with growth lines only, posterior auricle with 5 or 6 thin, faint indistinct costae. Interior: The characteristic crenulation of the hinge margin is not preserved (broken off). Dimensions: Length estimated to be 30 mm (most posterior margin not preserved), H=32 mm.

Remarks:

The discovered specimen possesses characteristics which are diagnostic of the genus *Euchondria* (*sensu lato;* Waterhouse, 2008), including the overall morphology and ornamentation with intercalate radial costae crossed by fine, very closely spaced growth lines, although the characteristic crenulate hinge line is not preserved. In euchondriids, right and left valves do not necessarily match because the marginal portion of right valves may not be entirely calcified during the animal's lifetime. Due to compaction of the pelitic sediment, the very thin shell is irregularly broken and the radial ornamentation very slightly distorted, features well known from many other localities (Yates, 1962; Rathmann & Amler, 1992; Hutchinson & Stumm, 1965; Amler & Winkler Prins, 1999). Difficulties are caused by the different ornamentation of right and left valves (discordance) and the lack of a preserved hinge plate (Amler & Winkler Prins, 1999). Unfortunately, recovery of a single left valve does not allow for more specific identification.

Euchondriids are widespread among Carboniferous bivalve faunas worldwide, but very often misunderstood due to the difference of right and left valves, discussed in detail, e.g. by Rathmann & Amler for *Aprathipecten aprathensis* (Rathmann & Amler, 1992). Euchondriids were described by various authors in the past as species of either *Aviculopecten, Acanthopecten,* or *Pecten,* but in most cases these were misinterpreted and/or misidentified as discussed by Amler & Winkler Prins (1999) for the "European" species from occurrences of the northern Palaeotethys.

Without comprehensive revision and without having seen most of the respective material, Waterhouse (2008) subdivided some of the species previously assigned to *Euchondria* into the genera *Velbertia* Waterhouse, 2008, *Pellucipecten* Waterhouse, 2008, *Callytharrachondria* Waterhouse, 2008, *Aprathipecten* Waterhouse, 2008 as well as *Euchondria sensu stricto* based on subtle characters in ornamentation and shell outline. Although valid according to ICZN rules, this procedure requires more detailed analyses. Consequently, we retain our assignment of the present specimen to *Euchondria sensu lato*. Previously, the only known bivalve from the Kubang Pasu Formation was *Posidonia becheri*. However, it should be noted that the bivalves *Pterinopecten, Aviculopecten* and *Allorisma* have been reported from the Carboniferous Khuan Klang Formation in adjacent southern Thailand, which is the lateral equivalent of the Chepor Member (Malaysian-Thai Working Group, 2009).

Palaeoecologically, euchondriids are important index fossils as they are restricted to basinal environments with rather dysaerobic facies and have been found predominantly in grey and black shales of Carboniferous age, e.g. the Kulm Facies of central Europe and intra-platform basins of the Carboniferous Limestone Facies of western Europe (Amler, 2006).

CONCLUSIONS

The fossil bivalve *Euchondria* is reported for the first time from the Chepor Member, Kubang Pasu Formation of Bukit Tuntung in Pauh, Perlis, NW Peninsular Malaysia. This new fossil discovery furthers our understanding of the biostratigraphy and depositional setting of the Kubang Pasu Formation. *Euchondria* has a long stratigraphic range (Late Devonian – Middle Permian) but its presence within grey shales containing the bivalve *Posidonia becheri* and the ammonoids ?*Goniatites* sp. and *Praedaraelites tuntungensis* is consistent with a Carboniferous (Mississippian, Viséan) age. The sparse, ammonoid and bivalve-dominated fossil assemblage at Bukit Tuntung and the presence of turbidites and possible debris flow/slide structures are consistent with a deeper marine depositional setting relative to the more benthic fossil-dominated strata of the Chepor Member of western Perlis.

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AUTHORS CONTRIBUTION

MHAH designed the study, carried out fieldwork, prepared the specimen and contributed to data interpretation.

AKAA carried out fieldwork, collected field data and collected the specimen.

MRWA taxonomically described and identified the specimen, as well as contributed to data interpretation.

DECLARATION OF COMPETING INTERESTS

The authors MHAH, AKAA and MRWA declare no conflicts of interest related to the publication. MHAH is affiliated with the Department of Geology, Faculty of Science, Universiti Malaya and is the corresponding author. AKAA was an undergraduate student at the Department of Geology, Faculty of Science, Universiti Malaya when the study was completed. MRWA is affiliated with the Faculty of Mathematics and Natural Sciences, Institute of Geology and Mineralogy, University of Cologne. There are no financial or personal relationships that could be perceived as conflicts of interest.

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