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The discovery of a *Paleodictyon*-like trace fossil from the Late Cambrian Machinchang Formation in Pulau Jemuruk, Langkawi, Malaysia

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Abstract: Closely spaced polygonal *Paleodictyon*-like trace fossil was recently discovered in Late Cambrian Machinchang Formation at Pulau Jemuruk, Langkawi. Each polygon is bounded by six segments of ridges forming unique hexagonal framework. The Jemuruk fossil has an epi-relief origin, contrary to the hypo-relief burrow *Paleodictyon*. The Jemuruk trace fossils formed in relatively shallower marine environment compared with other known *Paleodictyon*. This study shows that the *Kinneyia* structure found in the same layer originated from these *Paleodictyon*-like trace fossils.

Abstrak: Surihan berbentuk poligon menyerupai *Paleodictyon* telah ditemui dalam batuan Kambria Akhir Formasi Machinchang di Pulau Jemuruk, Langkawi. Setiap ruang fosil surih ini disempadani enam segmen permatang membentuk kerangka heksagon yang menarik. Fosil Jemuruk berasalan epi-jasatimbul manakala *Paleodictyon* adalah sejenis korekan hipo-jasatimbul. Fosil surih Jemuruk terbentuk pada sekitaran laut lebih cetek berbanding dengan *Paleodictyon* yang diketahui. Kajian juga menunjukkan bahawa struktur *Kinneyia* yang ditemui dalam lapisan yang sama adalah berasal daripada fosil surih seakan *Paleodictyon* ini.

INTRODUCTION

The Machinchang Formation is perhaps the best described Cambrian rock formation in Malaysia. Despite being one of the oldest rock formation in the country, most of its rocks are neither strongly deformed nor highly metamorphosed. This phenomenon has attracted many geologists to visit and enjoy studying them, in particular some of their classical text book examples of sedimentary structures and trace fossils. First described by Jones (1961), the Machinchang Formation was named after the Mount Machinchang (see Jones, 1973) and surrounding hill ridges in the northwest of Pulau Langkawi (Fig. 1). The oldest part of the formation was recorded by Jones (1973) and Lee (1980a, 1983) in the core of the Machinchang anticline exposed in the Datai area. From the Datai area, the formation gets progressively younger toward the west to the Tanjung Chinchin and toward the east to the Teluk Kubang Badak. The transitional beds to the overlying Ordovician Setul Limestone are exposed at Tanjung Sabung, on the eastern coast of Teluk Kubang Badak.

Fossil occurrences in the Machinchang Formation have been reported by Jones (1961, 1981), Lee (1980a, 1980b, 1983), Yap (1980b) and Mohd Shafeea Leman (1997a, b). These reports are mostly concerning fragments of trilobites, brachiopods and trace fossils found on the rocky coast of Pulau Jemuruk and the nearby onshore coast of Teluk Kubang Badak. These authors could only suggest a tentative Late Cambrian age for the Pulau Jemuruk and Teluk Kubang Badak sequences which represent the uppermost part of the Machinchang Formation. Jones (1961,1968) suggested a Cambrian age for this formation based on correlation with the Tarutao Formation described (later) by Teroaka *et al.* (1982) from Ko Tarutao in southern Thailand. The later has a comparatively similar lithological sequence with the Machinchang Formation and is a northern extension of the Machinchang Formation beyond the Malaysia-Thailand border. The upper part of the Tarutao Formation has been assigned to late Cambrian based on trilobites described by Kobayashi (1957) from Ko Tarutao. Up till now, there are no fossil records in the older part of the formation. Thus, the actual age range of the Machinchang Formation and the

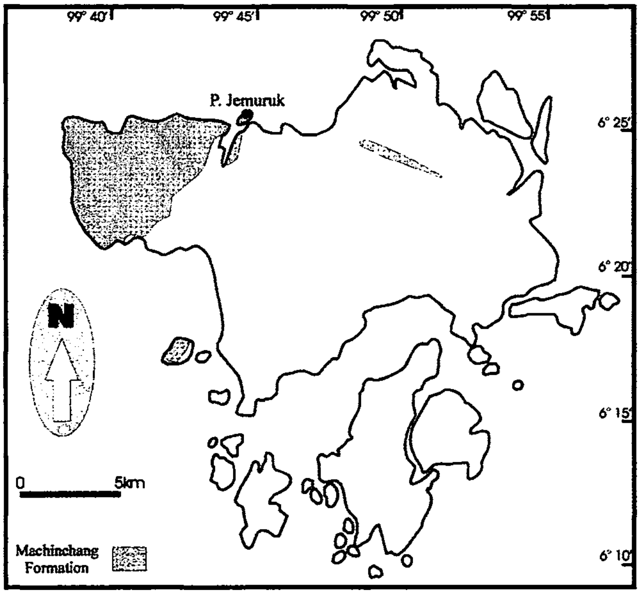

Figure 1. he distribution of the Machinchang Formation and the location of Pulau Jemuruk.

age of the supposedly oldest strata in Malaysia still remain unknown.

As for the Machinchang trace fossils, although their preservation is much better than the body fossils, their use for age determination is somewhat restricted. However, trace fossils are commonly very useful in interpreting the palaeoenvironment and palaeobathimetric conditions. Trace fossils were reported from Pulau Jemuruk by Lee (1980a, b, 1983), Yap (1980b) and Mohd Shafeea Leman (1997a, b). Ichnogenus *Paleodictyon* has been reported by Mohd Shafeea Leman (1997a, b) from the northwest of Pulau Jemuruk (Fig. 2) together with the *Kinneyia* structures reported earlier by Lee (1983). In an attempt to revise the Jemuruk ichnofossils, the author found that these polygonal structures might not be true *Paleodictyon*. This paper will describe and compare these *Paleodictyon*-like trace fossils with *Paleodictyon*.

TRACE FOSSILS OF PULAU JEMURUK

As mentioned earlier, trace fossils are the most abundant and most completely preserved fossils known from the Machinchang Formation. Most of the trace fossils were reported from Pulau Jemuruk and Teluk Kubang Badak. Lee (1980b) described the very interesting trace fossil *Dictyodora* from Pulau Jemuruk in which he distinguished them from some *Dictyodora* look-alike graptolites. Lee (1983) reported the presence of several trace fossils including *Dictyodora, Chondrites, Gordia, Neonereites, Diplichnites, Monomorphichnus* and *Dimorphicnus*. In this paper he also mentioned the occurrence of a *Kinneyia* structure which he interpreted as ripple-originated structures. Yap (1980) also wrote about the same *Dictyodora* and regarded it as the oldest Malaysian trace fossil. Mohd Shafeea Leman (1997a, b). recorded several other trace fossils from several localities in the northern coast of Pulau Jemuruk including *Phycodes pedum* Seilacher, *Teichichnus stellatus* Baldwin, *Palaeophycus*, *Dictyodora*, *Chondrites*, *Paleodictyon*, *Arenicolites*, *Planolites*, *Thallasinoides* and *Skolithos*.

Pulau Jemuruk is a small islet situated at the mouth of the Teluk Kubang Badak (Fig. 1). The geology is generally made up of medium- to fine-grained sandstone, siltstone and shale. The Pulau Jemuruk sequence is made up of at least two fining upward sequences (Fig. 3) from thick cross-bedded medium-grained sandstone to thinly inter-laminated fine-grained sandstone, siltstone and shale. These laminated shale and siltstone represented the flooding surface at the sequence boundary (Mohd Shafeea Leman, 1997a). Trace fossils are commonly sited within the thinly

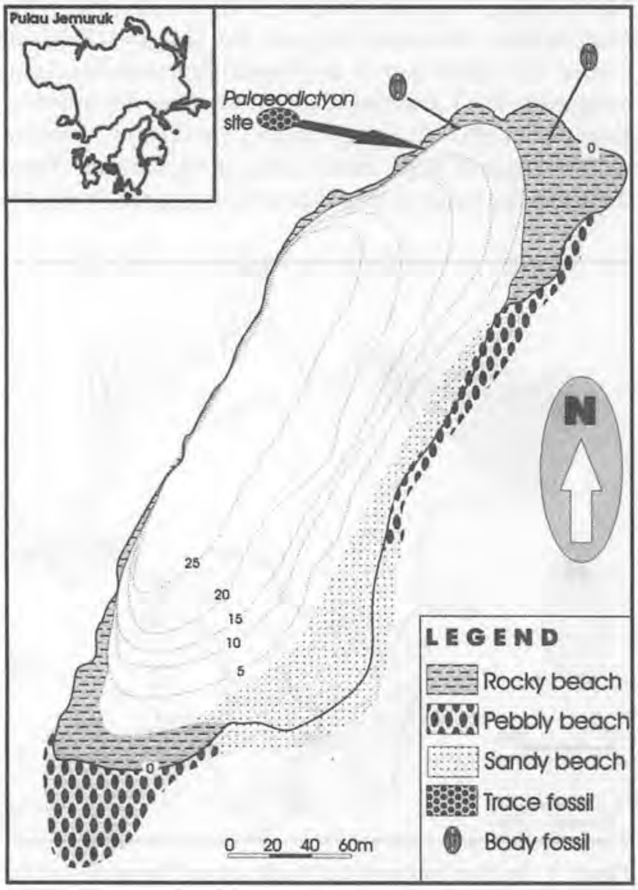

Figure 2. Pulau Jemuruk map showing the fossil site.

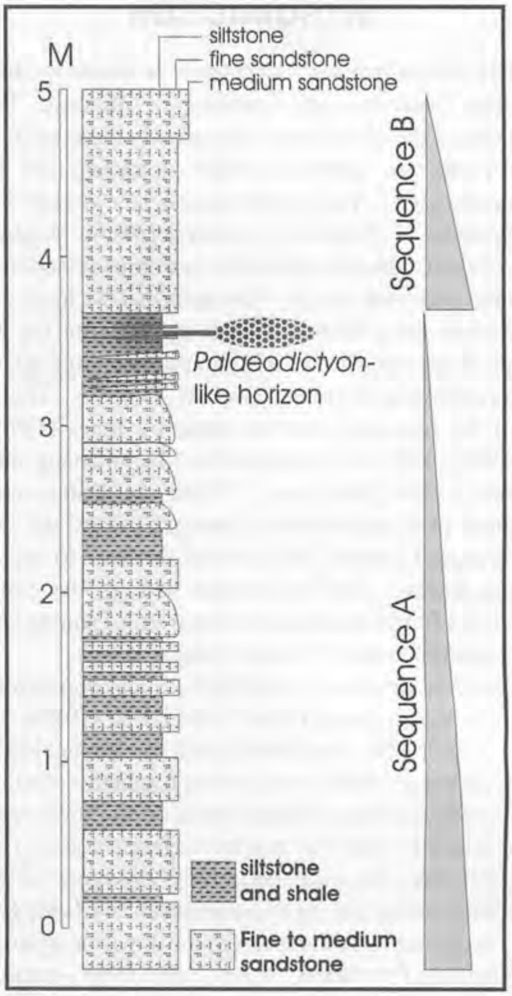

Figure 3. Sedimentological log showing the position of the fossil bed.

bedded and inter-laminated unit on top of the lower sequence, namely the sequence A. The *Paleodictyon*-like trace fossils in the current study were found in the topmost horizon of the Sequence A (see Fig. 3), where the *Kinneyia*-like structures are also abundant.

PALEODICTYON-LIKE TRACE FOSSIL

The studied fossils found in thinly laminated fine-grained sandstone and siltstone. They are epi-relief traces made of networks of ridges, systematically arranged to form small polygonal space in between them (Fig. 4). Most of the polygons are hexagonal in shape, often stretched in a unilateral direction. The top of these polygons formed a shallow depression. The distant between parallel ridges range from 2.2 to 3.0 mm for the compressed axis, from 3.0 to 3.5 mm for the stretched axis. The ridges are made of fine-grained sandstone, ranging in width from 1.0 to 1.5 mm. The crests of the ridges are smoothly rounded, but some ridges have rather flattened crest. No vertical tubes are known.

COMPARISON

Affinity

The Jemuruk ichnofossil has a very similar network pattern to *Paleodictyon (Glenodictyum) minimum* Sacco described by Seilacher (1977) from the Upper Cretaceous of northern Spain. They both have small regular hexagonal polygon with relatively broad ridges. The hexagonal pattern of *Paleodictyon (Glenodictyum) minimum* Sacco is among the most consistently constructed *Paleodictyon*. Regularly and closely spaced *Paleodictyon* found by Yap (1980a, b) from the Early Miocene deep water Temburung Formation in Labuan may belong to the same species. The *Paleodictyon (Glenodictyum) imperfectum* Seilacher found by Yap (1980c) from the Permo-Carboniferous flysch deposit in Maran area, on the other hand, has somewhat larger polygons and their polygons are not perfectly hexagonal in shape. Seilacher (1977), Carney (1981) and Bromley (1996) related *Paleodictyon* to the farming habits or trap mechanisms of deep marine bottom dwellers.

Referring back to the Treatise of Invertebrate Paleontology written by Hantzschel (1975), the genus *Paleodictyon* Meneghini should be described as a honeycomb-like network of ridges in hypo-relief. Seilacher (1977) later described it as graphoglyptid traces, i.e. meandering open mud burrows which became uncovered and immediately sand-casted by low velocity turbidity current deposits. Therefore, the tunnel ridges are most likely to be preserved at the basal section. The Jemuruk trace fossils are seen on the bedding surface and therefore most probably representing an epi-relief trace fossils. Furthermore, the meandering nature of the ridges is not well demonstrated. Thus, the Jemuruk polygonal structures cannot likely belong to *Paleodictyon*. They should belonged to a different group of trace fossil, the affinity of which is still not known.

Interestingly, the occurrences of these polygonal structures are closely associated with the *Kinneyia* structures described by Lee (1983). The current study shows that the Jemuruk *Kinneyia* structures were in fact developed as a result of the breaking of selected segments of the ridges. Figure 4b shows some of the ripple-like structures on exposed surfaces while on fresh surfaces (Fig. 4a) the polygons are very well preserved. In most cases the alignment of the ridges are parallel to the bedding strike.

Palaeoenvironment and Palaeobathimetry

Paleodictyon is commonly associated with the deep marine basinal zone of abyssal depth. Crimes (1975) noted that this ichnogenus represents the most distal ichnofacies, dominated by horizontal forms. Seilacher (1967) grouped all these deep marine forms into the *Nereites* ichnofacies, and Rhoads (1975) described these ichnofacies as azoic because of its anoxic (very low or no oxygen) environment, with sedimentation mostly of turbidites. As graphoglyptid trace fossils, *Paleodictyon* were originally developed as open mud-burrows, thus they required low velocity turbidity current for them to be uncovered and immediately sand-casted. This phenomenon has been well illustrated by Seilacher (1977) for various graphoglytid trace fossils including *Paleodictyon*.

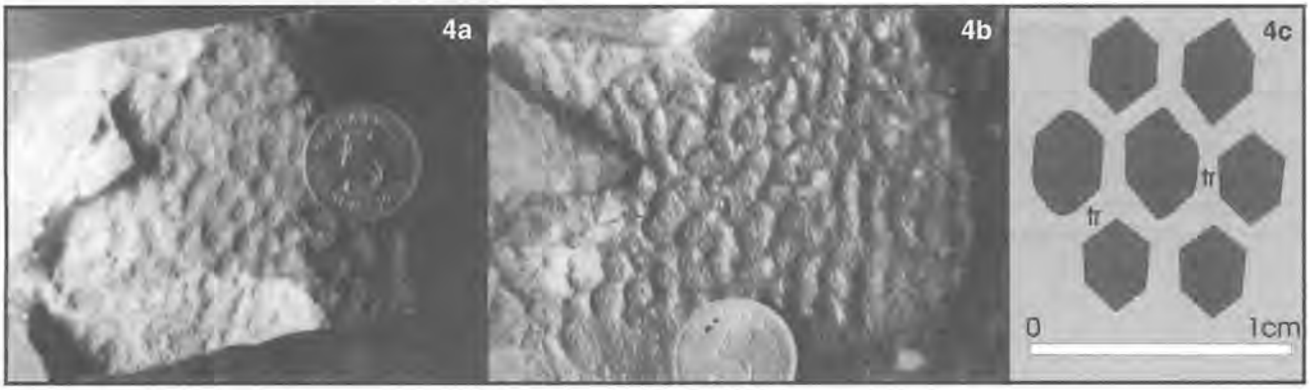

Figure 4. Photographs (a, b) and sketches (c) of *Paleodictyon (Glenodictyum) minimum* Sacco; tr – tunnel ridge (bar scale is 1cm).

Jones (1961, 1968, 1973, 1981) and Lee (1980a, 1983) described the Machinchang Formation as mainly of shallow marine deposit. However, Mohd Shafeea Leman (1997a) suggested that the fine-grained sediments at Pulau Jemuruk might have been deposited in a relatively confined depositional environment. Perhaps during the maximum marine transgression this confined environment might reached its maximum water depth, but there is still lack of evidence to support the presence of turbidity current in Jemuruk Island. Therefore the possibility for any graphoglyptid burrow to survive normal bottom current deposition seems to be unlikely. Limited mudstone poses another problem for the *Paleodictyon*-making creature to lived and grazed. Therefore, these *Paleodictyon*-like trace fossils most probably are new type of trace fossils and probably deposited in shallower marine environment than that of *Nereites* Ichnofacies. Other trace fossils also indicate a relatively shallower depositional environment.

CONCLUSION

In terms of their structural layout, the studied trace fossil resembles *Paleodictyon (Glenodictyum) minimum* Sacco found widespread in deep marine Cretaceous through Early Tertiary. However, the Jemuruk trace fossils have a different origin and lived in different palaeoenvironment compared with other known *Paleodictyon*. The Jemuruk trace fossils are an epi-relief traces while *Paleodictyon* has a hypo-relief origin. *Paleodictyon* was originated in the deep marine environment while the Jemuruk trace fossil horizons were deposited in a shallow marine environment. The supposed Kinneyia structures found in the same layer are believed to be erosional product of these *Paleodictyon*-like trace fossils.

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