Lowermost Devonian conodonts from the Setul Group, northwestern Peninsular Malaysia

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Abstract: The Setul Group, which contains a thick Lower Ordovician to Early Devonian limestone succession, occurs in northwestern Perlis State and the Langkawi Islands, Peninsular Malaysia. We report a lowermost Devonian conodont fauna characterized by Flajsella stygia and Flajsella streptostygia from a limestone section near the small town of Kaki Bukit, in what was previously considered to be Ordovician limestone. The studied limestone corresponds to the youngest part of the Mempelam Limestone. Nine species of conodonts in six genera are systematically investigated herein, of which three species Dvorakia amsdeni, D. philipi and F. streptostygia are the first reports in the Peninsula Malaysia. The stratigraphic correlations of the rock are also briefly discussed.

Keywords: conodont, Lower Devonian, Malaysia, Mempelam Limestone, Setul Group

Introduction

The Sibumasu Terrane, which consists of allochthonous tectonic blocks derived from the vast paleocontinent of Gondwana, is one of the component forming modern Southeast Asia. The terrane geographically occupies parts of China, Myanmar, western Thailand, western Peninsular Malaysia, and northwest Sumatra (e.g. Metcalfe, 2011, 2013). Sibumasu separated from Gondwana in the late Paleozoic, then drifted north and collided with another Gondwana-derived block, the Indochina Terrane, in the early Mesozoic (e.g. Metcalfe, 2011, 2013). The Sibumasu Terrane formed as a result of separation and accretion and is characterized by widely distributed Paleozoic peri-continental deposits. In Malaysia, Paleozoic successions are exposed in the northwestern part of Peninsular Malaysia and the Langkawi Islands (Fig. 1). This paper focuses on the Ordovician to Lower Devonian Setul Group (Fig. 2) and lowermost Devonian conodonts are reported in the group.

Geological Setting

The Setul Group, which is characterized by a thick succession of fossiliferous limestone with minor intercalations of clastic and siliceous sedimentary rocks, crops out in the northwestern part of Perlis State and the eastern part of the Langkawi Islands of Kedah State, Peninsular Malaysia (Figs. 1, 2). The group was first described as the Setul Limestone Formation by Jones (1981), who use the name for a prominent thick limestone forming the rugged karst topography of the Setul Boundary Range in west Perlis. The limestone also occurs in the eastern part of the Langkawi Islands (Jones, 1981). He divided the formation into four units, the Lower Setul Limestone, Lower Detrital Member, Upper Setul Limestone and Upper Detrital Member, in ascending stratigraphic order. These units were given formation status by Cocks et al. (2005) and the Setul Limestone Formation was upgraded to the Setul Group by Lee (2009). The present subdivisions of the Setul Group are as follows (Meor, 2013): the Kaki Bukit Limestone, the Tanjong Dendang Formation, the Mempelam Limestone, and the Timah Tasoh Formation, in ascending stratigraphic order (Fig. 2). The Kaki Bukit Limestone is the Lower Setul Limestone of Jones (1981), and is mainly composed of gray, bedded, finely crystalline limestones with sporadic macrofossil-bearing horizons (Meor, 2013). The uppermost part of the limestone exposed on Langgun Island (Fig. 1) consists of reddish stylolitic and nodular limestones. Brachiopods, gastropod, cephalopods, trilobites, and conodonts reported from the limestone indicate an Ordovician (Floian–Hirnantian) age (Yochelson and Jones, 1968; Kobayashi and Hamada, 1978; Cooper, 1988; Cocks et al., 2005; Agematsu et al., 2008). The Tanjong Dendang Formation corresponds to the Lower Detrital Member of Jones (1981). The formation is a thin unit composed of dark-colored bedded quartzite, siltstone, shale, and occasional interbeds of chert (Cocks et al., 2005; Meor, 2013). A
Late Ordovician (Hirnantian) to early Silurian (Llandovery) age is confirmed by trilobites and abundant graptolites (Kobayashi and Hamada, 1964; Jones, 1973; Cocks et al., 2005). The Mempelam Limestone is the Upper Setul Limestone of Jones (1981); that limestone is not as massive as the Kaki Bukit Limestone. Conodonts, trilobites, and crinoids indicate an early Silurian (Llandovery) to earliest Devonian (Lochkovian) age (Igo and Koike, 1966, 1968, 1973; Lee, 2001; Cocks et al., 2005; Meor and Lee, 2005). The Timah Tasoh Formation is the Upper Detrital Member of Jones (1981): this formation is composed of dark-colored mudstones with occasional cherts. Tentaculitides and graptolites indicate an Early Devonian (Lochkovian to late Pragian or early Emsian) age (Jones, 1981; Meor et al., 2013; Fig. 2).

**Location of the study section**

Kaki Bukit, from which the name of the Kaki Bukit Limestone is derived, is a small town located approximately 20 km north of the state capital town of Kangar in Perlis State. Metcalfe (1980) and Jones (1981) confirmed Ordovician age of the limestones around Kaki Bukit from reports of age-indicative fossils such as brachiopods, gastropods, cephalopods and conodonts. Because of these studies, the limestone of the boundary area has been regarded as being of Ordovician age without detailed biostratigraphic studies. The limestones investigated in this study (N6°40′17″ E100°11′50″) crop out along a roadcut between Kaki Bukit and Wang Kelian (Fig. 1.B). The study section contains gray, bedded limestone with regular interbeds of thin, dark-colored mudstone layers (Fig. 1.C). The beds strike NS to N 30°E and dip 30–40°E. A total of 14 samples were collected from outcrop at approximately 0.5–1.0m intervals (Fig. 3). Study of limestone thin sections using an optical microscope indicated that the rocks are mudstone/wackestone in the classification of Dunham (1962). The limestones contain bioclasts such as ostracods, fragmented bivalves, trilobites and crinoids with fine-grained quartz in micritic matrix.
mented bivalves, trilobites, and crinoids with fine-grained quartz in a micritic matrix (Fig. 1.D). The microfacies represents a low-energy environment (Flügel, 2010).

**Conodont biostratigraphy**

Limestone samples weighing 1.0–1.5 kg were dissolved in 10% acetic acid. Undissolved residues were washed and sieved, and approximately 500 conodonts were recovered in total. Although most of the obtained conodonts are poorly preserved, a total of nine species belonging to six genera were identified: *Belodella resima* (Philip), *B. anomalis* Cooper, *Dvorakia amsdeni* Barrick and Klapper, *D. philipi* (Drygant), *Pseudooneotodus beckmanni* (Bischoff and Sannemann), *Flajsella stygia* (Flajs), *F. streptostygia* Valenzuela-Rios and Murphy, *Oulodus* sp. and *Wurmiella excavata* (Branson and Mehl). These taxa represent a cosmopolitan earliest Devonian (Lochkovian) conodont fauna. A conodont-biostratigraphic subdivision of the Lochkovian Stage was first suggested by Klapper (1977) and Klapper and Johnson (1980) based on faunas of the North American Cordillera. This first zonal scheme, which includes the hesperius, eurekaensis, delta, and pesavis zones is not globally applicable, as it has invalidity concerning the pesavis Zone as pointed out by Valenzuela-Rios and Murphy (1997). Valenzuela-Rios and Murphy (1997) divided the Lochkovian Stage into three divisions (lower, middle, and upper parts) and subdivided the middle part into three zones based on the first appearance of Ancyrodelloides species (*A. omus α–A. eleanorae Zone, A. eleanorae–A. trigonicus Zone, and A. trigonicus–Criteriognathods pandora β Zone*, in ascending order) in western North America and Europe. The latter two zones were supplemented by the occurrence of Flajsella species. *Flajsella schulzei* first appears in the *A. eleanorae–A. trigonicus Zone* and *F. stygia* and *F. streptostygia* are recognized in the *A. trigonicus–C. pandora Zone* (Valenzuela-Rios and Murphy, 1997). Recent research on the conodont biostratigraphy of the Carnic Alps also confirmed that both *F. stygia* and *F. streptostygia* are associated with the trigonicus Zone of Corradini and Corriga (2012). The trigonicus Zone is correlated with the *A. trigonicus–C. pandora Zone* of Valenzuela-Rios and Murphy (1997). Therefore, our conodont fauna is indicative of the *A. trigonicus–C. pandora β Zone* in the middle Lochkovian Stage (Fig. 3).

On the basis of their lithology and age, the limestones of the study section are correlated with the Mempelam Limestone of the Setul Group. Previous works provided the age of the Mempelam Limestone spanning the late Llandovery (early Silurian) to the middle Lochkovian (earliest Devonian; e.g. Agematsu and Sashida, 2009a). Lochkovian–late Pragian or early Emsian graptolites have been reported from the Timah Tasoh Formation; that formation is stratigraphically and provides an upper
age limit for the limestone (Cocks et al., 2005; Meor, 2013). Agematsu and Sashida (2009a) reported *F. schleicheri*, *F. sigmostygia*, and *F. stygia* from the uppermost part of the Mempelam Limestone on Langgun Island (Fig. 1), Langkawi. These age indicators are slightly older than our conodont fauna, which is characterized by *F. stygia* and *F. streptostygia* in Perlis State. Hence, this result reveals that the limestones in this study are the youngest part of the Mempelam Limestone; additionally, the Mempelam Limestone undoubtedly crops out near the town of Kaki Bukit. Additionally, an unnamed Devonian fossiliferous red mudstones that overlie the Setul Group have been reported from near Wang Kelian (Lee and Azhar, 1991). These results imply that Devonian strata are distributed more widely in the border area than previously known.

**Stratigraphic correlation**

On the basis of Ordovician stratigraphic correlation between southern Thailand and the northwestern part of Peninsular Malaysia, Agematsu and Sashida (2009b) suggested that both areas had been included within a single sedimentary basin that they called the Tarutao–Langkawi basin (Fig. 4). These two regions were associated throughout the Paleozoic (Cocks et al., 2005; Lee et al., 2009). Our results show that the age of the uppermost part of Mempelam Limestone in the boundary region in Perlis is extended to the late middle Lochkovian, slightly younger than in the Langkawi Islands. The results of this study are consistent with those of previous studies and confirm their age indications. In the Siluro–Devonian part of southern Thailand, the Kuan Tung Limestone underlies the Pa Samed Formation: these units are lithologically correlated with the Mempelam Limestone and the Timah Tasoh Formation, respectively (Cocks et al., 2005) (Fig. 4). Fortey (1989) described an Emsian trilobite fauna from the upper part of the Kuan Tung Limestone. The Pa Samed Formation is mainly composed of siltstones and mudstones with occasional fossil-bearing layers; Agematsu et al. (2006) reported Emsian tentaculitids from the lower part of the formation. The lithological shift from the Mempelam Limestone to the Timah Tasoh Formation in the northwestern part of Peninsular Malaysia represents a Lochkovian environmental change in the southern part of depositional basin. In southern Thailand, a similar shift is recognized from the Kuan Tung Limestone to the Pa Samed Formation during the Emsian age. These results suggest that the environmental change may have occurred later towards the north in the southern part of depositional basin that was present in the area at that time.

**Conclusion**

We report a lowermost Devonian conodont fauna characterized by *F. stygia* and *F. streptostygia* from limestones of the Setul Group near the town of Kaki Bukit, Perlis State. The limestones were previously considered to be part of the Ordovician Kaki Bukit Limestone. This study reveals the presence of Devonian limestones corresponding to the youngest part of the Mempelam Limestone near the border with Thailand. On the basis of stratigraphic correlation of southern Thailand and the northwestern part of Peninsular Malaysia, the Early Devonian lithological shifts occurred later towards the north in the single depositional basin that was present in the area at that time.

**Systematic Paleontology**

The studied conodont collection is deposited at the Doctoral Program in Earth Evolutionary Science, Graduate School of Life and Environmental Sciences, University of Tsukuba, Japan with repository numbers EESUT-ty0002-0506. The prefix EESUT denotes Earth
Evolutionary Science, University of Tsukuba. Element occurrences are listed in detail in Table 1.

Family Belodellidae Khodalevich and Chernikh, 1973

Genus Belodella Ethington 1959

**Belodella anomalis** Cooper, 1974

*Belodella anomalis* Cooper (1974), pl. 1, figs.1-10, text-fig. 1e; Cocks (1999), pl. 4, figs. 5, 6; Farrell (2003), pl. 1, figs. 5, 6, 12, 15, 16, text-fig. 4; Farrell (2004), pl. 1, figs. 1–17, text-fig. 4.

**Remarks.** Farrell (2004) described the morphology of the Sa, Sb, Sc, Sd and T elements of this species. Only a single Sd element, which is characterized by its strongly curved anterior denticulated ridge of the new description of Farrell (2004) was obtained from the study area.

**Occurrence.**—The Sd element of *Belodella anomalis* was recovered only from sample KB-5 from the lower part of the studied limestone.

**Belodella resima** (Philip, 1965)

*Belodella resima* Philip, 1965, pl. 8, figs. 15–17.

*Belodella resima* Telford (1975), pl. 1, figs.13–16; Mawson and Talent (1994), pl. 4, figs.1–4, 8, 9; Farrell (2003), pl. 1, figs. 14–21; Farrell (2004), pl. 2, figs. 6–13.

**Remarks.**—Anderson (2003) morphologically classified the Sa, Sb, Sc, Sd, “tortifom” and M elements based on well-preserved specimens. We follow that classification scheme and the Sa and Sb elements are recognized in this study. The Sa element is an untwisted symmetrical element. The Sb elements are similar to the Sa element except that the cusp is twisted to one side.

**Occurrence.**—*Belodella resima* is common throughout the studied interval. Elements of the species were abundant from the samples kk-8, 10 in the middle and upper part of the limestone.

Genus Dvorakia Klapper and Barrick, 1983

**Dvorakia amsdeni** Barrick and Klapper, 1992

*Dvorakia amsdeni* Barrick and Klapper (1992), pl. 2, figs. 11, 15–19.

**Remarks.**—The lack of surface ornamentation and the presence of a broad anterior keel and inner anterolateral costa easily distinguish *D. amsdeni* from other species. This species is morphologically composed of Sd, Sb1, Sb2, Sc and tortifom elements, as suggested by Barrick and Klapper (1992). In this study, Sd and Sb1 elements are obtained. The Sb1 element is similar to the symmetrical Sd element except that the cusp is slightly twisted. This is the first report of this species from the Setul Group and from Peninsular Malaysia.

**Occurrence.**—Specimens of *Dvorakia amsdeni* are present in the middle to upper part of the studied limestone.

**Dvorakia philipi** (Drygant, 1974)


*?Paltodus philipi* Drygant (1974), pl. 1, figs. 21, 29.

**Remarks.**—The small keels and anterolateral costa distinguish this species from *D. amsdeni*. This species was morphologically classified by Barrick and Klapper (1992) into Sd, Sb1 and Sb2 elements. We obtained Sb1 and Sb2 elements in this study. The Sd element is tall,
with an asymmetrical subtriangular cross section and twisted cusp. The Sb2 element has hook-like curvature of the distal part and cusp. This is also the first report of this species from the Setul Group and from Peninsular Malaysia.

**Occurrence.**—Specimens of *Dvorakia philipi* are present in the lower to upper part of the studied limestone.

Family Spathognathodontidae Hass, 1959
Genus *Flajsella* Valenzuela-Ríos and Murphy, 1997

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**Flajsella stygia** (Flajs, 1967)

Fig. 5.9

*Spathignathodus stygius* Flajs (1967), pl. 5, figs. 16, 17.

*Ozarkodina stygia* Lane and Ormiston (1979), pl. 1, figs. 45, 46, pl. 2, figs. 10, 11.

*Flajsella stygia* Valenzuela-Ríos and Murphy (1997), fig. 8, 26–28, fig. 9, 26–30.

**Remarks.**—Valenzuela-Ríos and Murphy (1997) defined this species based on the Pa element. Apart from the Pa element, only element available for reconstruction is the Pb element. Only Pa elements were recognized in the studied limestone. This species is distinguished by the almost straight anterior blade of the Pa...
element that is highest near the anterior end. The posterior blade has a few small denticles with an undenticated space behind the cusp of the Pa element. The species is an effective age indicator of the middle Lochkovian Stage.

**Occurrence.**—Only present in sample kk-6 from the lower part of the studied limestone.

**Flajsella streptostygia** Valenzuela-Rios and Murphy, 1997

Fig. 5.10

**Ozarkodina stygia** Lane and Ormiston (1979), pl. 2, figs. 23, 28.

**Flajsella streptostygia** Valenzuela-Rios and Murphy (1997), fig. 9, 1–4, 26–37.

**Remarks.**—Valenzuela-Rios and Murphy (1997) defined this species on the basis of observations of the Pa element. They recognize that the species possesses Sa and M elements and some candidates for Pb elements. Only Pa elements were obtained in the present study. This species is distinguished from other species by the small basal cavity of the Pa element. The species is an effective age indicator of the middle Lochkovian: this is the first report of this species from the Setul Group and from Peninsula Malaysia.

**Occurrence.**—This taxon is present in the middle part of the studied limestone.

**Wurmiella excavata** (Branson and Mehl, 1933)

Fig. 5.12, 5.13

**Ozarkodina excavata excavata** Simpson and Talent (1995), pl. 8, figs. 16–25; pl. 9, figs. 1–24; Dongal (1995), fig. 4G–J; Miller (1995), pl. 1, fig. 8; Talent and Mawson (1999), pl. 4, figs. 1, 3–4; pl. 5, figs. 1–4; pl. 6, figs. 19–22; pl. 7, fig. 14; pl. 9, figs. 8, 9; pl. 11, figs. 12–14; pl. 12, figs. 1–4; Farrell (2003), pl. 6, figs. 10–21.

**Wurmiella excavata** Murphy et al. (2004), fig. 2, 29–36; Corriga and Corradini (2009), fig. 4, C; Corradini and Corriga (2010), pl. 2, figs. 9–25; Slavik and Carls (2012), Fig. 3, B, D, G, M; Corradini et al. (2016), pl. 3, fig. 14, 15.

**Remarks.**—The genus *Ozarkodina* was recently subdivided into several new genera by Murphy et al. (2004). The genus *Wurmiella* was proposed by them and includes the "excavata Group" of *Ozarkodina*. The Pa element of this species differs from *W. tuma* in the density of denticles on the blade and from *W. wurmi* in lacking a ledge at the base of the denticle. As well as the Pa elements of *W. excavata*, we obtained fragmentary Pb, Sa, Sb, Sc, and M elements of Ozarkodiniiforms which probably belonging to *W. excavata* or *Flajsella* species.

**Occurrence.**—Specimens of *Wurmiella excavata* are present in the lower to upper part of the studied limestone. Element of this species were most abundant in sample kk-6 in the middle part of the limestone.

Family Unknown

**Genus Pseudooneotodus Drygant, 1974**

**Pseudooneotodus beckmanni** (Bischoff and Sannemann, 1958)

Fig. 5.4


**Pseudooneotodus beckmanni** (Bischoff and Sannemann): Drygant (1974), p. 67, pl. 2, figs. 34–39; Mawson and Talent (1994), fig. 153–L; Talent and Mawson (1999), pl. 13, figs. 1–7; Zhang and Barnes (2002), p. 33–34, figs. 17.21, 17.22, 17.25, 17.26; Corradini et al. (2003), pl. 1, fig. 8; Albanesi et al. (2006), fig. 5.K, 5.L; Corradini (2007), pl. 1, figs. 1–7; Corriga and Corradini (2009), fig. 6, D, E; Slavik and Carls (2012), fig. 3, UB, DD, D; Berkyova (2009), fig. 10, A–D; Corriga et al. (2014), fig. 5, L; Corradini et al. (2016), pl. 3, fig. 18.

**Remarks.**—Barrick (1977) reconstructed the apparatus of *Ps. beckmanni* as comprising one-denticle squat elements and slender conical elements. However, due to the different geographical and stratigraphic distributions of these elements, this species was thought to have a unimembrate apparatus, with uncertain positions of each element (Corradini, 2007). The specimens examined in this study support the idea of Corradini (2007).

**Occurrence.**—Specimens of *Pseudooneotodus beckmanni* are present in the middle to upper parts of the studied limestone.

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