

Stratigraphy of the Lower Devonian sediments in the northwestern Shan Plateau, Myanmar

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Abstract: A new lithostratigraphic subdivision for the Lower Devonian sediments of the Pyin Oo Lwin Township, in northwestern Shan Plateau is proposed as the Zebingyi Formation (Pragian-Emsian) which comprises three members, stratigraphically from lower to upper, Khinzo Chung Limestone, In-ni Chung Limestone and Doganaing Chung Orthoquartzite. The type section is designated at the Zebingyi area and the Anisakan-Phaungdaw area, Pyin Oo Lwin Township is considered as a complementary section. The stratigraphy and lithofacies of the formation is studied in detail. Very rich micro- and macrofauna indicate a Lower Devonian (Pragian-Emsian) age and stratigraphically it is closely correlated with those of the same age from the neighbouring regions such as Malaysia, Thailand and China. The Zebingyi Formation as a whole is interpreted as pelagic to shallowing up locally with intertidal channel environment.

Keywords: Lower Devonian stratigraphy, Shan Plateau, Myanmar

INTRODUCTION

The Paleozoic strata of Myanmar were first described by La Touche (1913) who subdivided them into a lower dolomitic part “Lower Plateau Limestone” of Devonian age and an upper calcitic part, “Upper Plateau Limestone” of Carboniferous-Permian age. The undoubted oldest Devonian unit in the northwestern Shan Plateau (Figure 1) was recognized only after reidentification of the graptolite species, *Monograptus* cf. *M. recartonensis* Lapworth and *M. dubius* (Suess) which were previously regarded (La Touche, 1913) as the elements of Silurian age from the “Zebingyi Beds” at Pyintha, Pyin Oo Lwin Township. The former belongs to the *M. hercynicus* Perner group and the later was reidentified as *M. atopus* Bouček indicating an Early Devonian (Sieginian-Emsian) age for the “Zebingyi Beds” (Anderson *et al.*, 1969; Berry & Boucot, 1972).

Towards the top, the “Zebingyi Beds” merge into the “Lower Plateau Limestone” which was later named as the “Maymyo Dolomite Formation” by Amos (1975) without providing any characters of the stratotype. He proposed that

the largely dolomitic part of the Shan Plateau including the Zebingyi Beds should be called the “Shan Dolomite”, and that the local calcareous and shaly lenses such as those at Padaukpin and Wetwin should be regarded as members of the regional unit. The names “Zebingyi Beds” and “Maymyo Dolomite Formation” are unsatisfactorily defined in terms of modern stratigraphic practice. The lithostratigraphy of the Devonian sediments in the northwestern part of the Shan Plateau is thus in need of revision. In this paper, a new set of lithostratigraphic units is proposed for the Devonian sediments of the area in accordance with the international code of stratigraphical nomenclature (Hedberg, 1976).

PROPOSED DEVONIAN LITHOSTRATIGRAPHIC UNITS

The proposed stratigraphic subdivision for the Lower Devonian sediments of the Zebingyi and Anisakan-Paungdaw areas, Pyin Oo Lwin Township is given in Figure 2 (Devonian units in the northwestern part of the Shan Plateau). The Zebingyi Formation overlies conformably the Silurian Nyaungbaw Formation and the Maymyo Formation is overlain unconformably by the calcitic part of Permian Plateau Limestone.

ZEBINGYI FORMATION (REDEFINED UNIT)

La Touche (1913) first described the tentaculite-bearing argillaceous limestones in the Zebingyi area as “Zebingyi Stage”. It is exposed as a thin uninterrupted band along the western margin of the plateau approximately parallel to the road passing up to Pyin Oo Lwin (formerly Maymyo) from Mandalay. The unit is fairly rich in fossils such as dacroconarid tentaculites, brachiopods, trilobites, graptolites, corals, bryozoans and conodonts. It is given

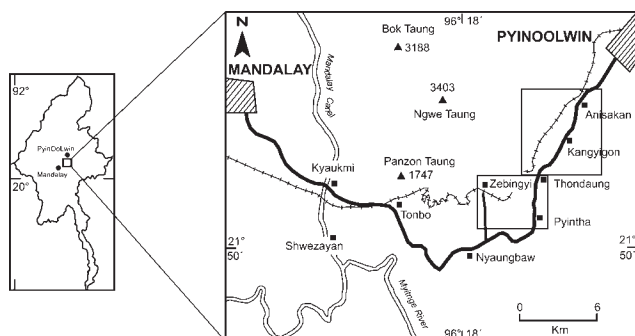


Figure 1: Location map of the Zebingyi-Anisakan area, Pyin Oo Lwin Township, Mandalay Division, Myanmar.

various stratigraphic names by the workers as Zebingyi Stage (Krishnam & Jacob, 1957), Zebingyi Series (Pascoe, 1959), Zebingyi Beds (Amos, 1975; Mitchell, 1977), Zebingyi Formation (without giving formal designation of the unit) (IGCP, 1980; Bender, 1983; Wolfart *et al.*, 1984).

Type section and thickness

Aye Ko Aung (2008) formally redefined the unit after Zebingyi village located at 4km north of the junction between the Mandalay-Pyin Oo Lwin Highway and the Zebingyi Road (GR 841541 in the one-inch topographic map (1:63, 360) 93C/5, Pyin Oo Lwin Township, Mandalay Division). The 112 m thick type section of the formation is newly selected at Doganaing Chaung, approximately 2.5 km south of Zebingyi village. The reference section of the formation, 102 m in thickness, is located near the junction of Pebin Chaung and Doganaing Chaung, (chaung = creek/stream in Myanmar language) at the shooting range of the Central Training Institute of Myanmar Police Force, Zebingyi village (Cho Oo *et al.*, 2005) (Figure 3).

Distribution

The Zebingyi Formation is fairly widely distributed in the Pyin Oo Lwin Township and northern Shan State (Aye Ko Aung, 2000). Apart from the type locality, it is well exposed in the vicinities of Letpangon, Naungwe, Pyintha, Thondaung, Kyaukphyadoe, Kyinganaing, Kangyigon, Anisakan, Phaungdaw, Kyadwinye, Naungkangyi, Medaw, all within the Pyin Oo Lwin Township.

In the southern Shan State, some good exposures of the Zebingyi Formation occur near Nyaungbin chaung,

northeastern part of Pindaya Township; Kywetaung and Momakha ranges, Lawksawk Township; Taungchun, Shwephone Pwint, Stubomika and Pinsin Chaung and a railway cutting from Shwenyaung to Taunggyi in Taunggyi Township; Hopong and Nyaung Shwe Townships (Wolfart *et al.*, 1984; Aye Ko Aung, 2010a). The Zebingyi Formation overlies the Nyaungbaw Formation (La Touche, 1913) of Early Silurian (Llandovery-Wenlock) age and underlies the Maymyo Formation (Aye Ko Aung, 2010b, 2011a,b) of Middle Devonian (Eifelian) and (Reed, 1908; Anderson *et al.*, 1969; Aye Ko Aung, 1995; Khaing Khaing San, 2005), (Givetian) (Khaing Khaing San & Aye Ko Aung, 2008); Late Devonian (Frasnian) (Aye Ko Aung *et al.*, 2010a,b) age. The Zebingyi Formation is unconformably overlain by the “Plateau Limestone Group” of Permian-Triassic age.

Lithology

In the Zebingyi area, the section comprises 112 m of dense black, earthy limestone separated by layers of light-coloured, purple, black shale and buff-coloured siltstone. The base is marked by the change from light to dark gray lime-mudstone intercalated with wavy calcareous silt bands, which is assigned to the upper part of the Nyaungbaw Formation, to fine-grained, hard, sometimes brecciated, well bedded lime-mudstone intercalated with fissile calcareous shale-siltstone of the Khinzo Chaung Limestone Member. The sequence of the Khinzo Chaung Limestone Member is overlain by whitish to light grey, flaggy, thin-bedded, partially dolomitized unit (In-ni Chaung Limestone Member). It is succeeded by thin-bedded, reddish brown orthoquartzite (Doganaing Chaung Orthoquartzite Member) (Figures 4 & 5). Kyaw Min & Aye Ko Aung (2010) first reported a new limestone unit of Emsian age in the upper part of the Doganaing Chaung Orthoquartzite Member. This Emsian Limestone Unit is located at approximately one kilometer north of Paung daw village, N 21° 59'E 96°26'(GR.971653). The unit is about 50 m (150 ft) thick in the section. The unit is narrow and only restricted to the area, at (GR.971653) on the Taungchun hill (Figure 6). The unit wedged out laterally so that its lateral extent cannot be traced.

The Emsian limestone unit is lithologically distinguishable from the Zebingyi Formation by the presence of clast supported conglomerates composed predominantly of clasts ranging in size from pebbles to gravels in places and is interpreted as a lime pebble conglomerate or bioclastic rudstone. This lithology is never recognized in the proper Zebingyi Formation as shown in Figure 7.

Stratigraphic relationship

The whole sequence of the Zebingyi Formation is unconformably overlain by a thick-bedded to massive, light to dark blue, calcitic, fairly fossiliferous and partially dolomitic Permian limestone unit which is equivalent to the Thitsipin Limestone Formation (Garson *et al.*, 1976) of the southern Shan State. The contact between the Zebingyi Formation and the underlying Nyaungbaw Formation seems

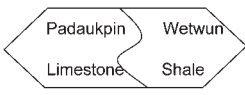
Devonian units in the northwestern part of the Shan				
		Age	Stratigraphic Units	
DEVONIAN	UPPER	Fammenian	Not yet reported	
		Frasnian	MAYMYO FORMATION	
	Givetian			
	Eifelian			
	MIDDLE			
	LOWER		Emsian	Doganaing chaung Orthoquartzite Member
		Pragian	ZEBINGYI FORMATION	
			In-ni chaung Limestone Member	
		Lochkovian	Khinzo chaung Limestone Member	

Figure 2: Proposed Devonian units of the northern Shan Plateau.

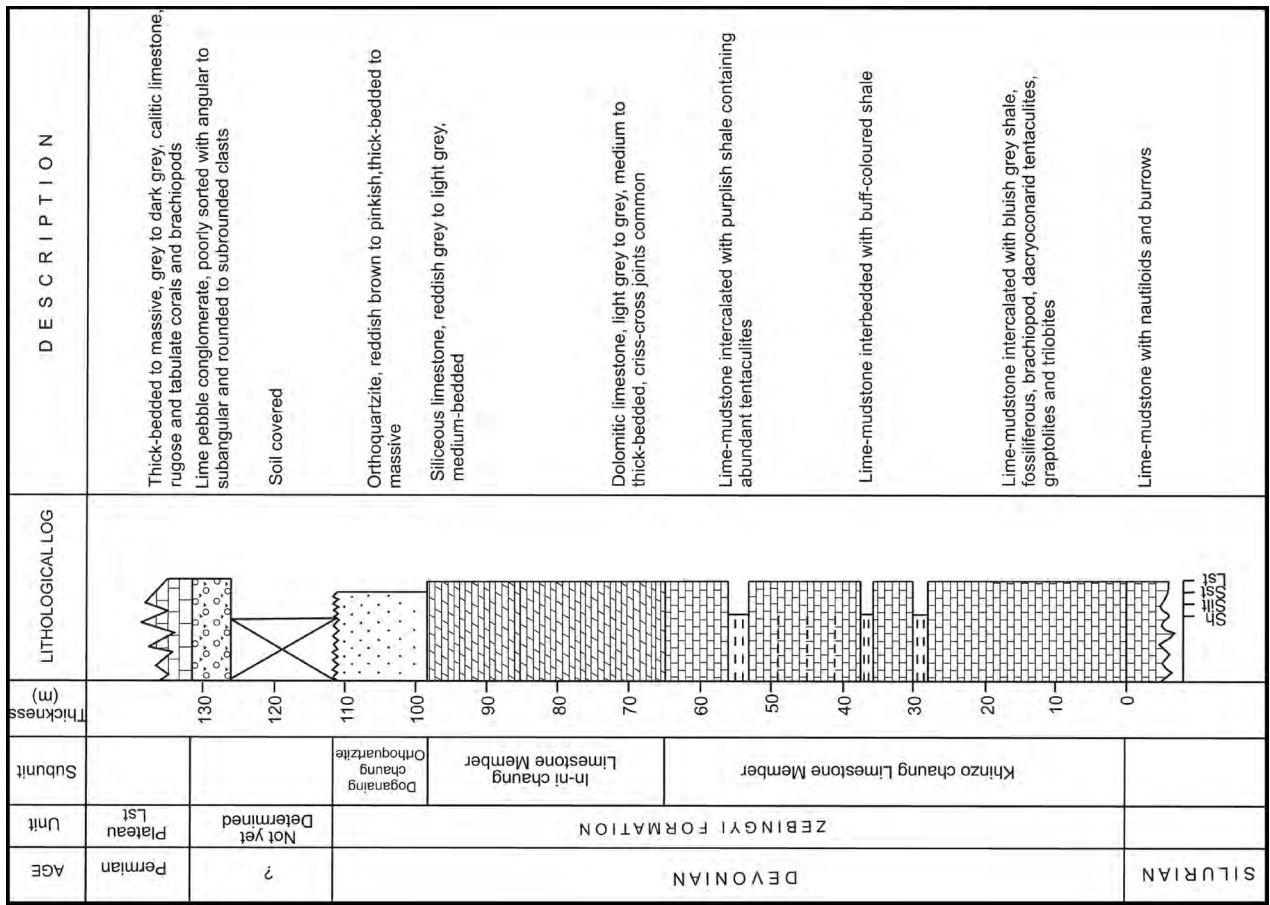


Figure 4: Log section of the Zebingyi Formation in the Zebingyi area (Aye Ko Aung, 2008).

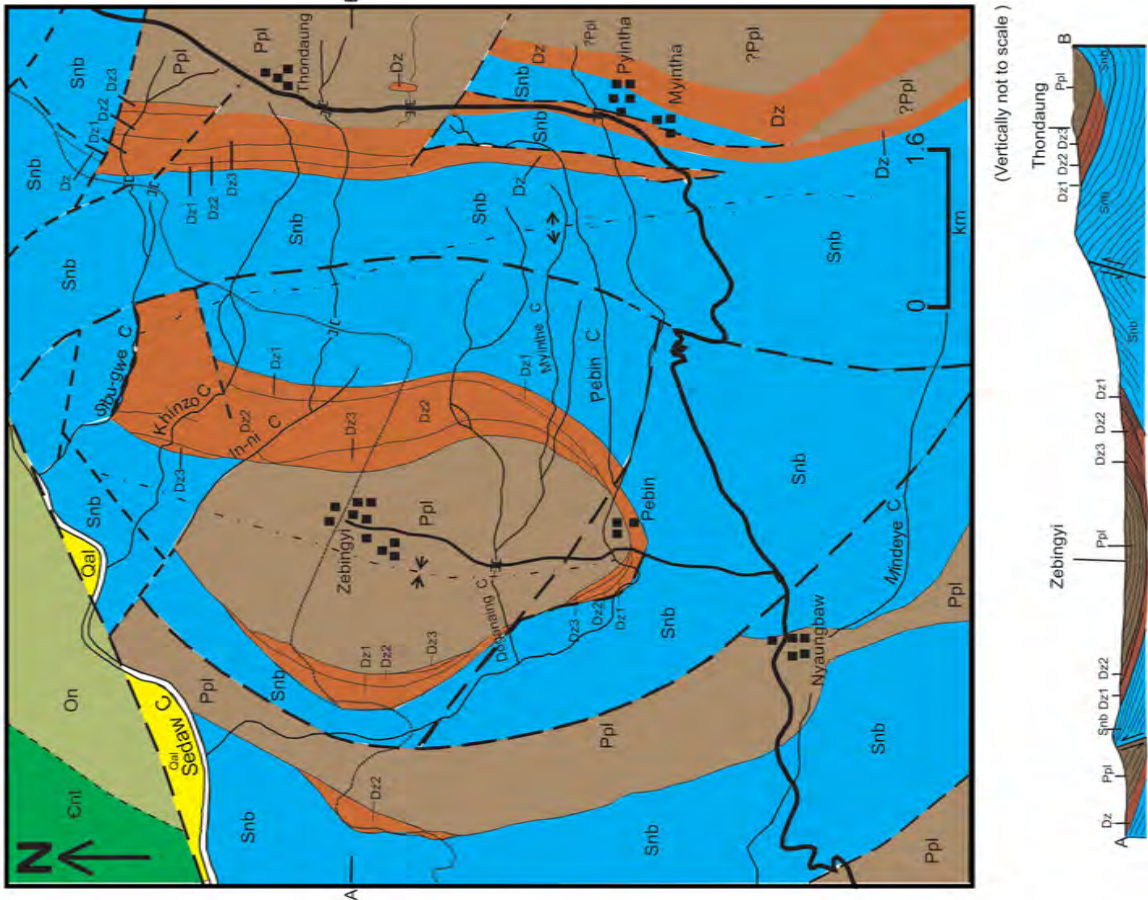


Figure 3: Geological map of the Zebingyi area (modified after Aye Ko Aung et al., 1982) and Cho Oo et al., 2005).

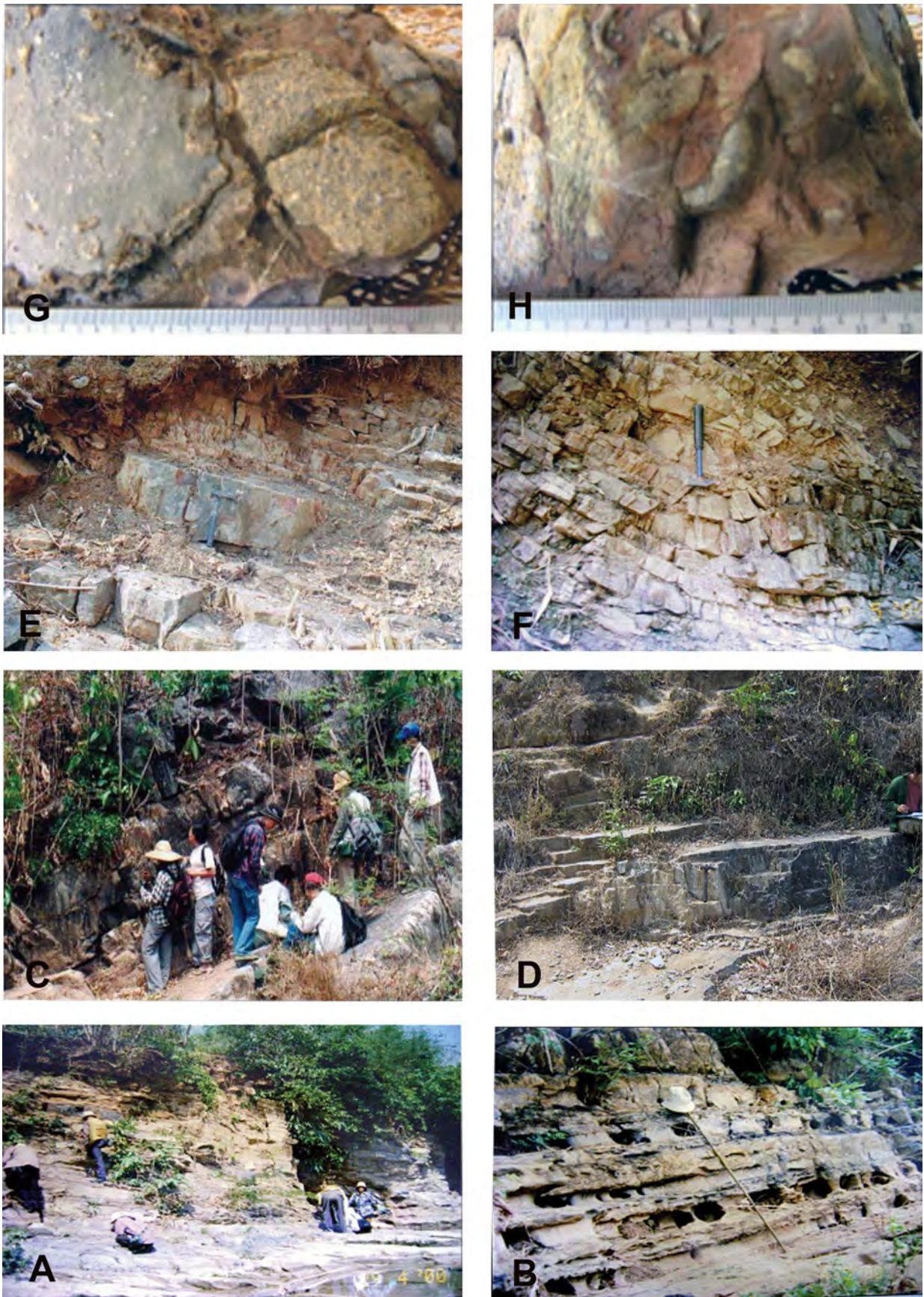


Figure 5: Outcrops of the Zebingyi Formation. A, B) Khinzo chaung Limestone Member. A) Pebin chaung. B) Khinzo chaung. C, D) In-ni chaung Limestone Member. C) Myinthe chaung. D) Thandaung. E, F) Doganaing chaung Orthoquartzite Member, Doganaing chaung. G, H) Emsian lime pebble conglomerate, Taungchun hill, Paungdaw.

to be gradational. However, the interbedded unit that shows a gradual change in lithology from the phacoidal limestone of the Nyaungbaw Formation to tentaculite-bearing fine-grained black lime-mudstone of the basal part of the Zebingyi Formation (Khinzo Chaung Limestone Member) is rarely observed in each measured section in the area. The phacoidal structure is noticeably decreased towards the top of the Nyaungbaw Formation and the boundary is well marked by the first appearance of tentaculites on medium-bedded limemudstone.

Fauna, age and correlation

The Zebingyi Formation contains abundant tentaculites (*Nowakia acuarina* (Richter) and *Styliolina* sp. suggesting an Early Devonian (Pragian) age. The graptolite fauna (*Monograptus atopus* Bouček and *Monograptus helmckei* Jaeger were described from the Zebingyi Formation, Pyntha area are suggestive of Early Devonian (Late Pragian-? Early Emsian) (Jaeger, 1983), and Zebingyi area of Late Pragian (Kyi Soe, 2000). The brachiopods (*Plectodonta* sp. cf *P. forteyi* Boucot & Cocks, *Clorinda* sp. cf *C. wongwannichi* Boucot & Cocks, *Lissatrypa* sp.) and trilobites (*Cornuproetus* sp. cf *C. sculptus* (Barrande), *?Illaenus* sp.) assemblage is very similar to that of the Lower Devonian (probable Lower to Middle Emsian) Pa Samed Formation of southern Thailand (Boucot *et al.*, 1999) and the Middle Emsian in Satun Province of southern Thailand (Fortey, 1989) (Figure 8).

A useful conodont species for age determination, *Eognathodus sulcatus* Phillip, which is the index form for the *sulcatus* Zone (Klapper & Johnson, 1980; Murphy *et al.*, 1981; Murphy, 1989; Mawson & Talent, 1994), was recovered by the first author in 2001 from the Khinzo Chaung Limestone Member of the Zebingyi Formation on Sitha-Ingyon road at the east of Kangyigon village (Figure 9).

Thus this level is referred to the *sulcatus* Zone of Pragian age. In the same section, (1.8 m) above the base a number of specimens of the trilobite species *Phacops taungtalonensis* Thaw Tint and Hla Wai which has been reported from the Siegenian or Pragian (Lower Devonian) limestone unit in Medaw area, Pyin Oo Lwin District (Thaw Tint & Hla Wai, 1970; Aye Ko Aung, 2001). Based on the presence of tentaculitids (*Nowakia acuarina* and *Styliolina* sp.), the Zebingyi Formation is correlated with the Lower Devonian Lower Detrital Member in the Langkawi Islands (Jones, 1981), Emsian Mahang Formation in Kampong Pahit, Perak (Burton, 1967), Emsian Timah Tasoh Formation (Meor Hakif & Lee, 2005), and late Pragian-early Emsian Jentik Formation at Guar Jentik, Perlis (Ong & Basir Jasin, 2007), northwest Peninsular Malaysia; earliest Emsian Pa Samed Formation of Satun area, southern peninsular Thailand (Boucot *et al.*, 1999; Agematsu *et al.*, 2006) and Wangjiacun Formation of China (Boucot, 2002).

The new facies of the Emsian unit which occurs at the top most part of the Zebingyi Formation (upper part of the Doganaing chaung Orthoquartzite Member), contains rugose corals: *Dohmophyllum graveyardense* Yu and Jell, *Tryplasma* sp., *Lythophyllum* sp., *Breviphrentis* sp.; and conodonts: *Ozarkodina prolata* Mawson, *?Eognathodus bipenatus* Bischoff & Ziegler (Figure 10). The rugose coral species, *Dohmophyllum graveyardense* Yu and Jell is common in the Late Emsian Db1 Member of the Burges Formation, Broken River Province, north Queensland, Australia (Aye Ko Aung, 1991). The species of the genera, *Tryplasma*, *Lythophyllum* and *Breviphrentis* are similar to those from the Lower Devonian (Emsian) rugosa of the Izarne Formation, Montagne Noire, South of France (Pedder & Feist, 1998). This faunal assemblage is not found in the proper Zebingyi Formation. The age of this fossil assemblage is confidently

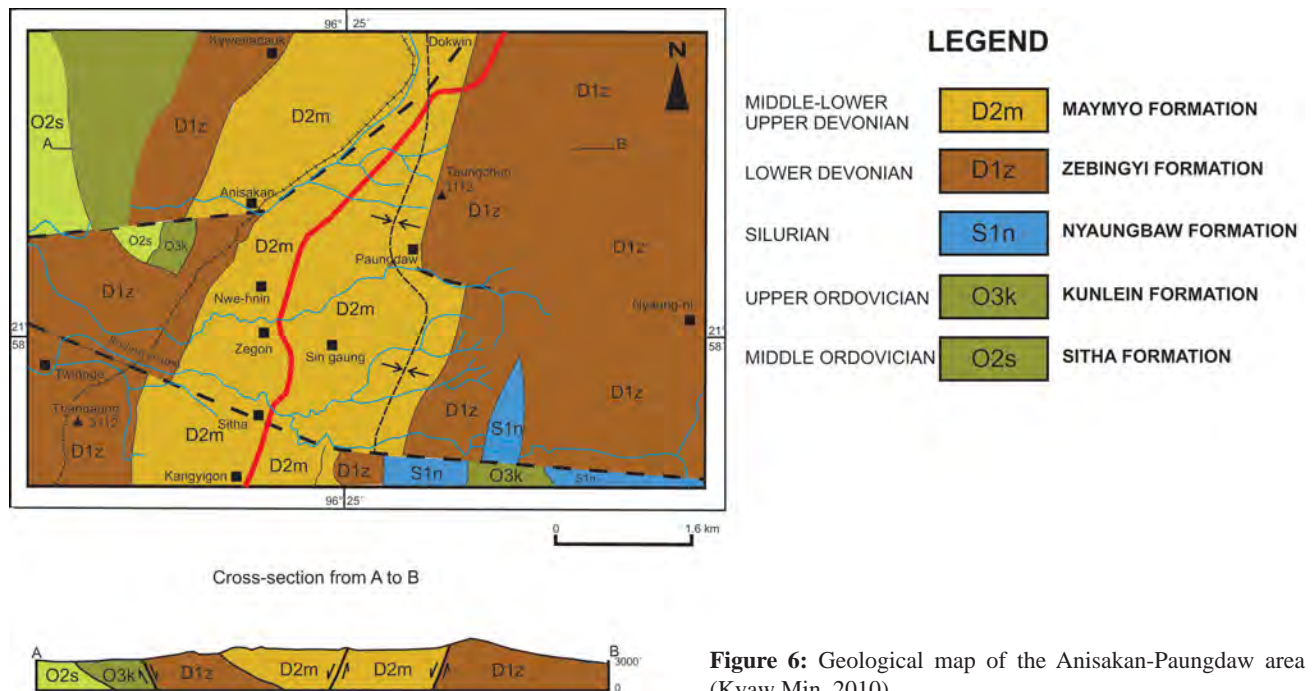


Figure 6: Geological map of the Anisakan-Paungdaw area (Kyaw Min, 2010).

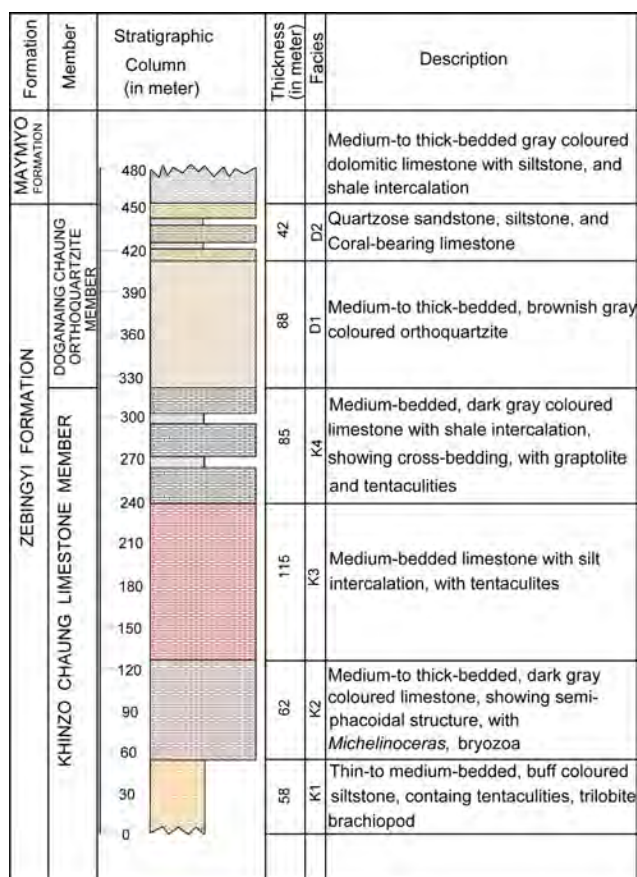


Figure 7: Log section of the Zebingyi Formation, Anisakan-Paungdaw area (Kyaw Min, 2010).

identified by the presence of conodonts, “*Ozarkodina*” *prolata* Mawson, not known earlier than Emsian (Early Devonian) worldwide. The lower part contains a useful conodont of zonal form, *Eognathodus sulcatus* Philip, which indicates *sulcatus* Zone of Pragian age. Thus the time span of the Zebingyi Formation in the Pyin Oo Lwin Township, as a whole, is regarded as Pragian to Emsian. The relationship between new Emsian facies of the Zebingyi Formation or Doganaing chaung Limestone Member where the former is absent, and the overlying Plateau Limestone of Permian age is fairly sharp. After deposition of the upper part of the Zebingyi Formation, it is followed by thick carbonate sequences with unconformable contact.

Lithofacies of the Zebingyi Formation

A comprehensive report on the microfacies analysis of the Zebingyi Formation in the Zebingyi area, Pyin Oo Lwin Township was published by Han Khan Pau *et al.* (1993). They identified seven microfacies of the Zebingyi Formation: (1) fossiliferous micrite-mudstone, (2) microsparite-mudstone, (3) siliciclastic micrite-mudstone, (4) tentaculitid biomicrite-wackestone/peckstone, (5) biopelmicrite-wackestone/peckstone, (6) biopelmicrosparite-wackestone/peckstone and (7) packed algal biomicrite-grainstone. Kyaw Min (2010) gave a comprehensive report on the lithofacies descriptions of the Zebingyi Formation in the Phaungdaw area, Pyin Oo Lwin Township. In this report the sedimentary petrology

of the Zebingyi Formation in the Anisakan-Paungdaw area is described using the classification from Dunham (1962) and Pettijohn (1957). The former is adopted for description of hand-specimens and the latter is used for that of the siliciclastic sediments.

1. Black calcareous shale

Thin-to medium-bedded, black calcareous shale is common at the base of the formation. Tentaculites and graptolites were seen at the bedding plane surfaces, in places, intercalated with thin limestone layers. *Michelinoceras* sp. is also abundant in this shale which is 15 m thick. Microscopically silt sized quartz grains are disseminated in the carbonaceous groundmass (Figure 12C).

2. Buff coloured calcareous siltstone

Buff coloured, fossiliferous siltstone showing fine-grained angular to rounded quartz (35%) and mica fragments (less than 5%) cemented with ferruginous matrix (60%) under the microscope (Figure 12A).

3. Lime mudstone (subphacoidal lime mudstone)

It is macroscopically named as argillaceous lime-mudstone, commonly found with irregular silt laminations displaying subphacoidal or subnodular structure, well preserved and large *Michelinoceras* sp. are still common (Figures 8L-N). Microscopically, this limestone comprises lime-mud (matrix) about 90% of the total rock volume. Some thin-shelled bioclasts are occasionally present and are usually tentaculites. Opaque iron oxide mineral appears in dark colour contains less than 5% (Figure 12B).

4. Bioclastic wackestone

This grey limestone is rich in tentaculites and brachiopods. Most of the allochems (50% of the total volume) are tentaculites and thin shelled bivalves and they are filled with granular calcite cement. Texturally, the scattered quartz grains (30%) are subangular to rounded, loosely packed and poorly sorted in the limemud matrix (20%) (Figure 12C).

This lithofacies may be subdivided into two more subfacies on the abundance of particular type of allochems such as, tentaculitid wackestone, bryozoan wackestone and mottled wackestone (Figure 12D).

5. Wavy bedded packstone

This facies is characterized by its undulated bedding not only on the bedding plane but in the thin sections. Anhydral silt-sized detrital quartz grains (30%) are found scattered in the micritic matrix. Transverse-sections of tentaculitid are commonly observed as elongated outlines (Figure 12B).

6. Quartz arenite

This unit only occurs in the uppermost part of the Zebingyi Formation. It represents the Doganaing Chaung Orthoquartzite Member and is mainly composed of well bedded, greenish gray coloured arenite. (Figures 5E-F). It is composed of detrital quartz grains of three different



Figure 8: Macrofossils of the Zebingyi Formation. A.) *Nowakia acuaria* (Richter); B, C) *Monograptus atopus* Bořček; D, E, F) Odontopleurid trilobite gen. et sp. indet.; G, H) *Phacops taungtalonensis* Tint & Wai; I) ?*Calymene* sp.; J) *Plectodonta* sp. cf. *forteyi* Boucot & Cooks; K) *Clorinda* sp. cf. *wongwannichi*; L, M, N) *Michelinoceras* sp.; O) *Bivalvia* gen. sp. indet.

sizes (fine, medium and coarse) with varied colour, brown, yellowish brown, and grey, locally ferruginous, and silica cements are major component of this rock unit. Coarse-grained, subangular to rounded, poorly sorted, monocrystalline quartz grains (95%) are cemented with silica (5%), and they are loosely packed. No fossil was found in this unit (Figure 12F).

7. Bioclastic rudstone (Lime pebble conglomerate)

This unit is mainly composed of gray coloured lime pebble conglomerate. The various sizes and types of clasts are dominant in this unit. (Figures 5G-H). The intraclasts of a lime pebble conglomerate range from fine-sand size to gravel size. In this unit, grading, stratification and

recognizable fabric was not observed. The fauna assemblage of corals, bryozoans, conodonts and others shell fragment is dominant in the matrix (Figure 12G).

Based on the presence of allochem and orthochem, four major lithologies have been recognized, intramicrite, intrabiomicrite, pelmicrite and biomicrite according to the types of clasts. Most of the lithoclasts are peloidal grainstone. It is a bioclastic rudstone (Embry & Klovan, 1971) or lime pebble conglomerate.

Depositional environment

In the east Pyntha area, Pyn Oo Lwin Township, the Late Silurian thick sequence of cherty limestone and overlying marl beds is an evidence of relatively deep conditions during the Late Ludlovian-Pridolian time. However, the beginning of Lochkovian time was marked by sudden shallowing, possibly not amounting to continental conditions, of the sea in which a large amount of clastic sediments, mainly quartz grains and ferruginous materials are flushed in. In this part of Myanmar, there has been no evidence of any structural or stratigraphic discordance and there is complete conformity between the Upper Silurian and the basal Devonian beds (Thaw Tint & Hla Wai, 1970).

Zebingyi area

In the Zebingyi area, westernmost part of the Pyn Oo Lwin Township, however, the lower part of the Zebingyi Formation (Khinzo Chaung Limestone Member), which is characterized by the tentaculitid biomicrite-wackestone/packstone microfacies, contains significant amounts of allochems, mud-supported to grain-supported, and large sized tentaculitids, brachiopods and ostracods that suggest a stable, relatively deeper water environment (Heckel, 1972). Scarcity of laminae and presence of broken fossil fragments could be attributable to bioturbation, indicating oxygenating bottom conditions and slow deposition. The occurrence of a few intraclasts suggests that the bottom sediments were affected by intermittent storms (Hang Khan Pau *et al.*, 1993).

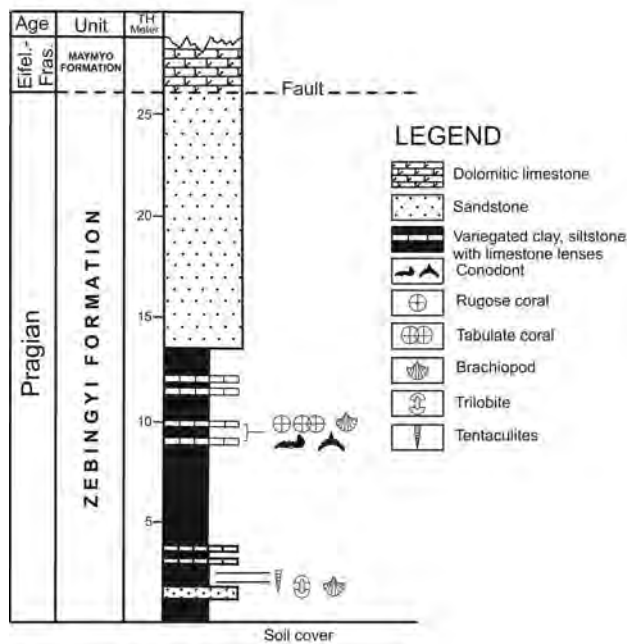


Figure 9: Measured section on Sitha-Ingyi road, Pyn Oo Lwin Township (Aye Ko Aung, 2001).

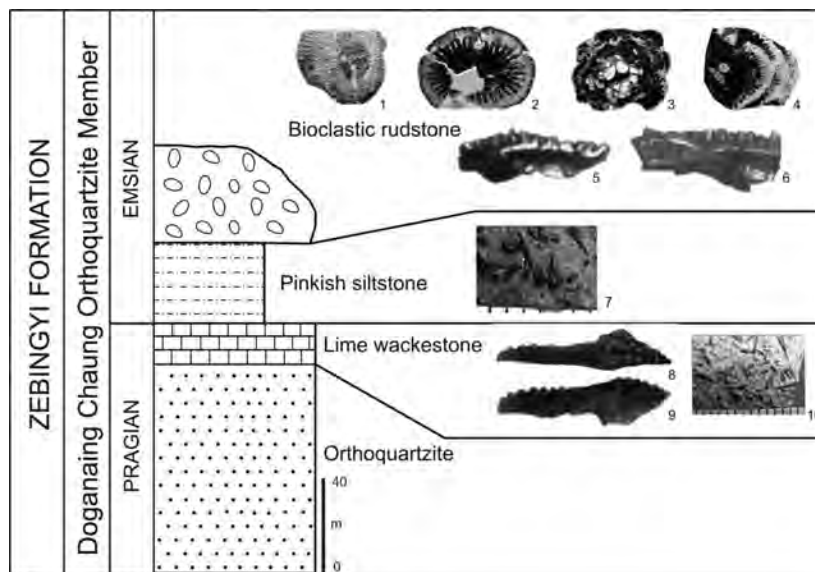


Figure 10: Generalized section of the Zebingyi Formation in the Paungdaw area. a) *Dohmophyllum graveyardense* Yu & Jell; b) *Tryplasma* sp.; c) *Lithophyllum*; d) *Breviphrentis* sp.; e) *Ozarkodina prolata* Mawson; f) *Ozarkodina* sp.; g) Tentaculitids; h, i) *Eognathus sulcatus* Phillip; j) Tentaculitids.

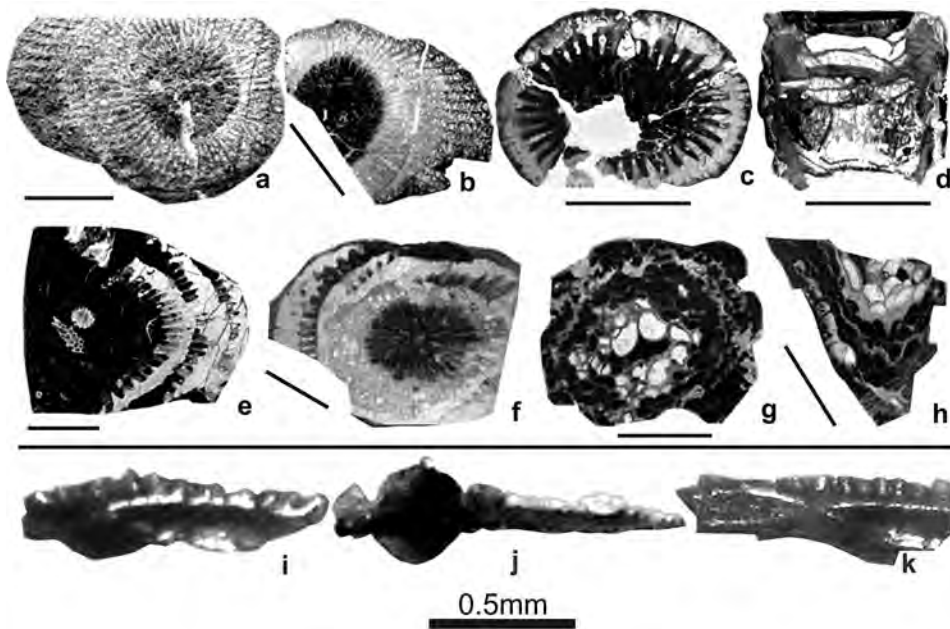


Figure 11: Macro and micro fossils of the Emsian lime pebble conglomerate of the Zebingyi Formation. a, b) *Dohmophyllum graveyardense* Yu & Jell, transverse sections; c, d) *Tryplasma* sp., c) transverse section, d) longitudinal section; e, f) *Breviphrentis* sp., transverse sections; g, h) *Lithophyllum* sp., g) transverse section, h) longitudinal section (scale bar = 1 cm); i, j) *Ozarkodina prolata* Mawson, i) upper view, j) lower view; k) *Ozarkodina* sp., lateral view.

The above condition is followed by the shallowing upward sequence (In-ni chaung Limestone Member) and red soil on the top of this unit indicates probable subaerial exposure to an oxidizing environment. The quartzose sandstone unit (Doganaing Chaung Orthoquartzite Member), in the upper part, is typical of shallow marine environment.

Anisakan-Phaungdaw area

The depositional environment for the Zebingyi Formation in the Anisakan-Paungdaw area is rather different from that of the Zebingyi area as suggested by Hang Khan Pau *et al.* (1993). The depositional system of mixed carbonate-clastic sediments indicates stratigraphically open-up and shut-down of clastics deposits, accumulated along with carbonate depositional system during the Devonian period. This whole depositional scenario reflects the rhythmic sea-level changes causing interbedding of clastics and carbonates. Consequently, marine transgression and regression may be presumed during the whole depositional history (Wilson, 1975).

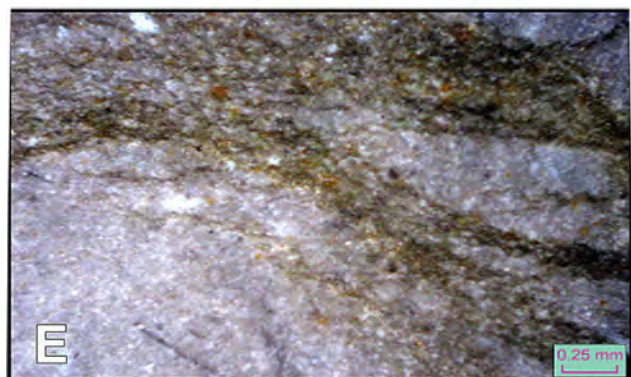
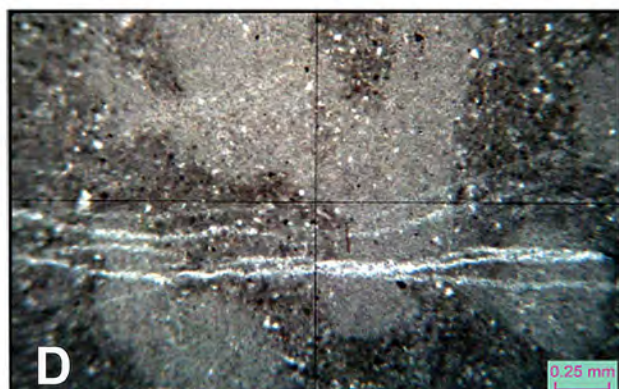
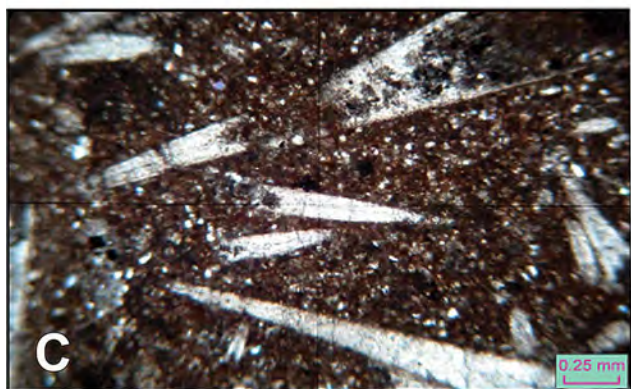
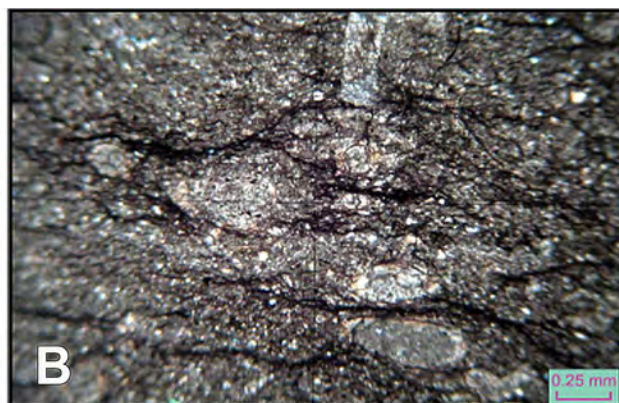
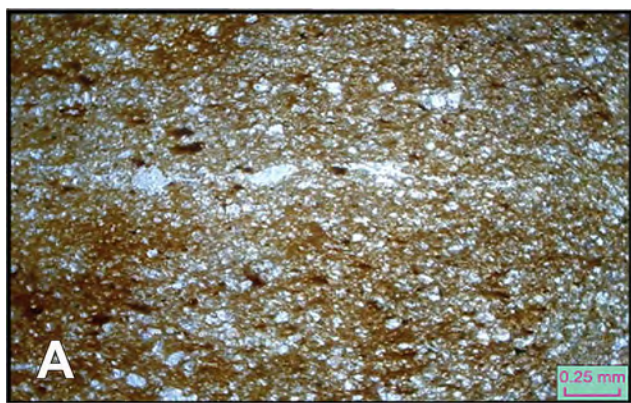
In the Khinzo chaung Limestone Member, the presence of burrow structures and mottled structures (bioturbation) in siltstone and wackestone respectively suggests deposition in a shallow marine intertidal-subtidal environment. This is supported by the presence of low angle cross-bedding (Figures 12I-J) and much of shallow marine fauna of brachiopods, bivalves, trilobites and bryozoans in the wackestone. The silt sized quartz disseminated in the wackestone (Figure 12 E), may be derived from coastal dune and beach, sand reworked in the shallow marine environment (especially shallow shelf and intertidal areas) (Wilson, 1975).

The In-ni Chaung Limestone Member chiefly constitutes dolomitized lime mudstone (dolomitized micrite). It is believed to have formed in the supratidal environment. (Reeckmann & Friendmann, 1991).

The Doganaing Chaung Orthoquartzite Member, mainly composed of the quartz arenite may represent a barrier beach facies. The upper part of Doganaing Chaung Orthoquartzite Member has been reported to be a new Emsian facies (Kyaw Min & Aye Ko Aung, 2010). It consists of lime pebble conglomerates composed of pebble-to cobble-sized limestone clasts, bioclasts, sand and silt intraclasts and terrigenous material (silt and mud), indicating a channel lag deposits (Einsele, 1992) whereas the intraclasts of pebble conglomerate support the evidence of existing intertidal conditions. Thus the whole setting of depositional environment of the Zebingyi Formation (both Zebingyi and Aniskan areas) might well be interpreted as pelagic to shallowing up locally with intertidal channel environment.

DISCUSSION

The newly proposed stratigraphic subdivisions of Early Devonian sediment comprise redefined unit of the Zebingyi Formation which has been known as a Silurian unit for a long time previously. The present work is being carried out on basis of a thorough revision of the stratigraphic position of the Zebingyi Formation. The fauna evidences of the formation strongly suggest it is the oldest Devonian unit in Myanmar. The formation composed of mixed carbonate-siliciclastic sediments is divisible into three members in ascending order, Khinzo Chaung Limestone Member, Inni Chaung Limestone Member and Doganaing Chaung Orthoquartzite Member. The Zebingyi Formation is widely distributed in Pyin Oo Lwin Township located in the northwestern part of the Shan Plateau. It is well exposed in two major areas: the Zebingyi area, a locality of stratotype and the Anisakan-Phaungdaw area. Although both areas may share principle lithologies, the depositional setting is somewhat different from each other. The carbonate depositional environment of the Zebingyi Formation in the Zebingyi area is based on



the work by Hang Khan Pau *et al.* (1993). He suggested deposition in a typical deep-water, low energy environment below wave base which was locally affected by intermittent storms. The upper part of the formation, however, shows some sedimentary evidence of fluctuating currents and a shallowing-upward depositional environment.

In the Anisakan-Phaungdaw area, located a few kilometers east of the Zebingyi area, the presence of medium scale, low-angle cross bedding and mottled structure (bioturbation) in wackestone and burrows in siltstone suggests deposition in a subtidal environment. It is followed by the deposition mainly of arenaceous material indicating a beach environment. The deposition was not terminated by then as evidenced by the presence of a new Emsian lime pebble conglomerate facies, which is not found in any other areas in the Shan Plateau. This special type of sedimentation presumably continued until the end of Emsian. Thus it is advisable, on the depositional setting of the Zebingyi Formation in the Early Devonian, that the formation was deposited fairly deep pelagic to shallow marine, subtidal, intertidal (Khinzo Chung Limestone Member) and supratidal environments (In-ni Chung Limestone) throughout in the early stage which was subsequently followed by greater amount of siliceous, arenaceous input of beach material which was locally followed by the deposition of channel lag sediments (Doganaing Chung Orthoquartzite Member) under intertidal channel condition.

CORRELATION WITH OTHER PARTS OF SOUTHEAST ASIA

The Zebingyi Formation is conveniently correlated with others of Early Devonian age from neighbouring regions such as Thailand and Malaysia. A number of divergent macrofaunas found in the formation show strong affinity with those of these localities. The tentaculitid-bearing beds yielding *Nowakia-Styliolina* fauna including *Nowakia acuaria* have been reported from the Fang area, Sri Sawat area, Trang area and Satun area in Thailand (Agematsu *et al.*, 2006). In Peninsular Malaysia, the carbonaceous shale containing rich tentaculites, *Nowakia acuaria*, and *Styliona* sp. indicating an Emsian age have been reported from the Timah Tasoh Formation of Pulau Langgun and Perlis (Meor Hakif & Lee, 2005) and the Mahang Formation of Kedah and northwest Perak (Burton, 1967).

The lithology of Myanmar Lower Devonian sequence is closely correlated with that of the Satun area, southern Peninsular Thailand, composed of shale, mudstone,

limestone and sandstone (Agematsu *et al.*, 2006) and this sequence has been correlated with the Devonian Pa Samed Formation by Wongwanich *et al.* (1990). Homologous to the Pa Samed Formation in the south are carbonaceous, laminated shales of the Timah Tasoh Formation in Perlis, Peninsular Malaysia. The Timah Tasoh Formation is actually the southern extension of the mid-Paleozoic sequence in Thailand. In conclusion, the Zebingyi Formation (Myanmar), the Pa Samed Formation (Thailand), the Timah Tasoh Formation (Perlis) and the Mahang Formation (central Kedah and northwest Perak) are interpreted as the basal facies characterized by the deposition of black shale containing dactyloconarid tentaculites and graptolites. In contrast to any other Lower Devonian facies in Southeast Asia, in Myanmar, there is an intertidal channel facies which is locally developed in the uppermost part of the Zebingyi Formation in the Anisakan-Phaungdaw area, Pyin Oo Lwin Township.

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Figure 12: Photomicrographs, A-F. (All cross polars except A). A) Angular to rounded, fine-grained quartz scattered in lime-mud matrix and transverse section of tentaculites filled with calcite in the buff coloured siltstone (lithofacies 2), (PPL). B) Microwavy to nodular bedded, transverse and oblique sections of tentaculites filled with micrite in packstone (lithofacies 5). C) Longitudinal sections of conical shaped tentaculites filled by sparry calcite cements and detrital quartz grains set in ferruginous matrix in calcareous shale (lithofacies 1). D) Discolouration and sharp edge molted structures, small, parallel calcite veins and detrital quartz grains set in lime-mud matrix of molted wackestone (lithofacies 4). E) Subphacoidal argillaceous thin layers set in lime-mud matrix in the argillaceous lime-mudstone (lithofacies 3). F) Medium-grained, angular to rounded, poorly sorted, moderately packed quartz arenite (lithofacies 6). G) Polished section showing pebble to gravel sized limeclast, silt to sand sized lithoclasts and bioclasts in the bioclastic rudstone (lithofacies 7). H) Burrows in the Khinzo Chung Limestone Member. I, J) Low angle cross-bedding in the wackestone of the Khinzo Chung Limestone Member.

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