REVIEW ON THE PRE-PALEOZOIC TO EARLY MESOZOIC STRATIGRAPHY OF YE-NGAN TOWNSHIP, SOUTHERN SHAN STATE, MYANMAR

Aung Myo Zaw[1] & Aye Ko Aung

Abstract

The Pre-Paleozoic to Early Mesozoic rocks are well exposed in northwestern part of the southern Shan State. It is located about 13 km, NE of Ye-U, Ye-ngan Township, southern Shan State which lies in northwestern part of the Pindaya Range, located in the Eastern High Land (Shan-Tanintharyi Block). Ye-ngan Township is a geologically very well-known to a great number of geologists. The present paper focused on the newly defined Pre Paleozoic to Early Mesozoic stratigraphy with two types of approach; data collection in the field and literary work in the library. The Ye-ngan Township comprises seven type sections and four reference sections of the Pre-Paleozoic to Lower Mesozoic strata such as, Chaung Magyi Group (Late Neoproterozoic), Molohein Group (late Jiangshanian to Furongian), Lokepyin Formation (Trmadocian to Floian), Wunbye Formation (Darriwilian), Nan-on Formation (Katian/ Caradocian), Tanshauk Member (Hirnantian), Linwe Formation (Silurian-Lochkovian), Zebingyi Formation (Pragian-Emsian), Maymyo Formation (Eifelian-Frasnian), Thitsipin Formation (Early to Upper Permian), and Nwabangyi Dolomite Formation (late Upper Permian-Induan to Olenikian). Most of the Paleozoic rock units are fossiliferous in Ye-ngan Township the Upper Cambrian is represented by the Molohein Group, bearing saukiid trilobites. The Lokepyin Formation which contains small brachiopods. The Wunbye Formation includes the nautiloids, brachiopods, sponge and receptaculitid algae. The Nan-on Formation is rich in fossils, among with cystoids, orthid brachiopods, bryozoans, sponges and trilobite have been recorded. The Tanshauk Member yields brachiopods and trilobites. The Linwe Formation (in the limestone) includes nautiloids, crinoids, cystoids, ostracods, conodonts; trilobites and graptolites occurred in the siliciclastic horizon. Some Devonian outcrops of the Zebingyi Formation and? Maymyo Formation are narrowly exposed in the Myogyi area where there are [2]minor amounts of tentaculitids and ammonoids. There are so far no Carboniferous strata are discovered in this area. The Thisipin Formation contains rugose and tabulate corals, foraminifers mainly fusulinids, brachiopods, bryozoans, crinoids, gastropods and leaf fossils. The Nwabangyi Dolomite Formation has some fossils, ammonoids, conodonts, bivalves, and shark teeth. In completion of this works, detailed stratigraphic investigations are still needed in a matter of urgency.

Keywords: Pre-Paleozoic to Early Mesozoic stratigraphy, southern Shan State, Myanmar

Introduction

The first field trip to around Ye-ngan Township, especially Ye-U, Linwe, Thitsipin, Ingyi, Hsinsapya, Padongaing, Yechanbyin, Nwabangyi and Myogyi areas (Figure 1) was made by the authors. The field work was done with two purposes: Firstly, to let the students learn practically the stratigraphic characters of the type sections of the Pre Paleozoic to Early Mesozoic units in the western part of the southern Shan State formally established by Dr Myint Lwin Thein in 1973. The Paleozoic units designated in this area are, (1) Chaung Magyi Group (Pre Cambrian to ?Cambrian), (2) Molohein Group (late Middle to Late Cambrian), (3) Lokepyin Formation (Lower Ordovician), (4) Wunbye Formation (Middle Ordovician), (5) Nan-on Formation (Upper Ordovician), (6) Tanshauk Member (late Upper Ordovician), (7) Linwe Formation (Lower Silurian to early Devonian), (8) Zebingyi

[1] Department of Geology, Dagon University
[2] Department of Geology, Dagon University

Formation (Early Devonian) (9) possible Devonian unit (?Maymyo Formation), not mentioned in the previous reports, (10) Thitsipin Formation (Early to Upper Permian), and (11) Nwabangyi Dolomite Formation (late Upper Permian to Lower Triassic).

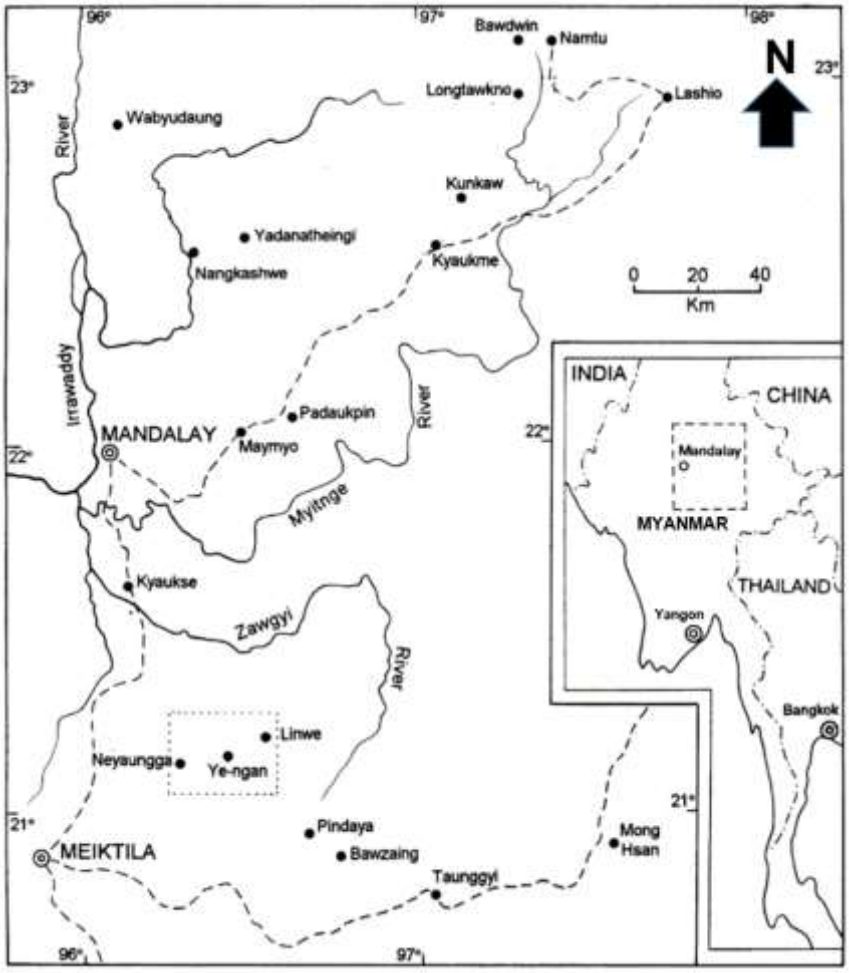

Figure 1. Locality Map of the study area, with dotted blocks showing the study area

Secondly, to achieve the biostratigraphic knowledge on basis of the Paleozoic to Early Mesozoic fossils as most stratigraphic units in this area are fairly fossiliferous which yield a variety of micro and macro fossils (foraminifers, fusulinids, conodonts, tentaculities, ostracods, corals, brachiopods, trilobites, bryozoans, cephalopods, graptolites and crinoids, receptaculitid algae, and leaf fossils). These faunas greatly assisted the geological mapping of the area which led to the understanding of the geological history of the western part of the southern Shan State.

A number of the research papers and M.Sc, Ph.D Theses completed in the present area are, such as; Myint Lwin Thein (1973) re-classified the Lower Paleozoic units of the western part of the southern Shan State which includes the Ye-ngan, Ye-u, and Linwe areas. Garson *et al.* (1976) wrote a comprehensive report on the geology of the Neyaungga-Ye-ngan area. The geology of the Myogyi area was investigated by Ko Ko Myint (1989) in the frame of a M.Sc study and for the preparation of a detailed geological map of the area. Cocks and Zhen Ren Bin (1998) described and reviewed the brachiopod fauna of the Nan-on Formation. In the following years the undergraduate geology students

from the universities of Yangon and Taunggyi have made field mapping in the present area. Aye Ko Aung (2002) wrote a depermental unpublished paper, guide to the stratigraphy of the Ye-U, Linwe, Thisipin, and Nwabangyi areas, Ye-ngan Township, southern Shan State. Maung Maung and Aye Ko Aung (2005) described the first record of the late Silurian conodonts of the Linwe Formation, Ye-ngan Township, southern Shan State. Aung Myo Zaw (2014) mentioned *Ipciphyllum subtimoricum dilatum*, sub sp. nov from the Permian Thitsipin Formation, Pegin-Kyauktaw area, Ywa-ngan Township, Shan State (south). Aung Myo Zaw (2015) first described five coral species belonging to four genera *Yatsengia hangchowensis, Iranophyllum* sp. cf. *caracinophylloides*, *Ipciphyllum subelegans, Pavastehphyllum* sp., *Pavastehphyllum* (*Thomasiphyllum*) sp., from the Thitsipin Limestone of the Pegin-Linwe area, Ye-ngan Township, southern Shan State. Wernette *et.al* (2021) firstly systematically described the Cambrian Trilobite from Linwe-Padongaing areas. Aung Myo Zaw and Aye Ko Aung (2024) described a rugose coral new subspecies *Ipciphyllum subtimoricum dilatum,* of Middle Permian from Ye-U area, southern Shan State. Kyi Soe (1983), Ko Ko Myint (1989), Me Me Thein (2000), Tun Naing Zaw (2005), Maung Maung (2005), Aung Myo Zaw & Chit Thet Mon (2007), Kyi Kyi Maw (2010), Yin Min Htwe (2011) studied their M.Sc and Ph.D Theses in the present research area.

Regional Geological Setting

The area lies to the east of the great Shan Scarp and it occupies a large part of the plateau to the north and south-east of Ye-ngan consists of wide shallow valleys and broad low grassy hills formed by the Nwabangyi Dolomite Formation. The elevation is between 4000 and 4250 feet, dropping to about 3500 feet in some valleys. To the north-west and west Ye-ngan, the Natteik Limestone Formation forms more rugged and rocky country. The western margin of the area is bounded by the prominent Panlaung escarpment. The Panlaung valley is composed largely of Jurassic (Panlaung Formation, Loi-an Group), and questionable Cretaceous sediments (Kalaw Red Bed Formation). The area is bounded to the north by the dissected area covered with Chaung Magyi sedimentary rocks which forms an anticlinal structure (Yechanbyin anticline). The major folding of the area is dissected in the middle of the area, by Ingyi-Ingaung Fault. The block of the Lower Paleozoic sediments in the east of the area (Molohein Group, Lokepyin Formation, Wunbye Formation, Nan-on Formation, Linwe Formation, and a possible Devonian unit) is faulted (Karani Fault) against the "Plateau Limestone Group". The Cambrian rocks in the south-east corner of the area (Molohein Group) thrusted (?) against the other Lower Paleozoic units in the Linwe and Kyaukhnget areas (Figure 2).

Stratigraphy

The sequence of the rock units well exposed in this area is shown in (Figure 2). The sequence comprises five groups, seven formations, and two members of Precambrian to Early Triassic in age. All of the Lower Paleozoic (Cambrian to Silurian) units in the area were established by Myint Lwin Thein (1973).

Chaung magyi group

The group name is taken from Chaung Magyi river (locally named as Nampek river) flowing from north to south in the area to the east and north-east of Sedawgyi, in Madaya Township, Mandalay Region. The rock sequences in the type area was firstly mapped by Aye Ko Aung (1981). The Chaung Magyi rocks consists of a sequence of phyllite, slate, quartzite, and greywacke which is well exposed in the east and north-east of Sedawgyi. The different lithologies are recognized in the area north of Ye-U where the group consists of a series of slightly metamorphosed, folded sediments include brown, fine-grained, cross-laminated sandstones and mudstones, green argillites, and turbiditic sediments, forming a thickest unit in the group. The sedimentary structures strongly suggest that the sandstones are turbidites.

The Chaung Magyi Group is overlain unconformably by the Cambrian unit (in the type area) and? comformably (Yechanbyin area) the relationship with the older unit, in the present area, however, is indeterminable due to thick soil covering. Although no fossils have been recorded, the age of the group should be considered better be of Late Precambrian or Early Cambrian as it is unconformably overlain by the Late Cambrian saukiid trilobite- bearing sand unit of the Molohein Group of southern Shan State. According to Dew et.al (2019), based on the youngest detrital zircons present in sandstone samples from the western Yeywa Dome area, at least the upper part of the Chaung Magyi Group is of late Neoproterozoic age. The age of the Chaung Magyi Group is still controversial. Further detailed work is needed to better constrain stratigraphic, metamorphic and igneous ages associated with the Chaung Magyi Group.

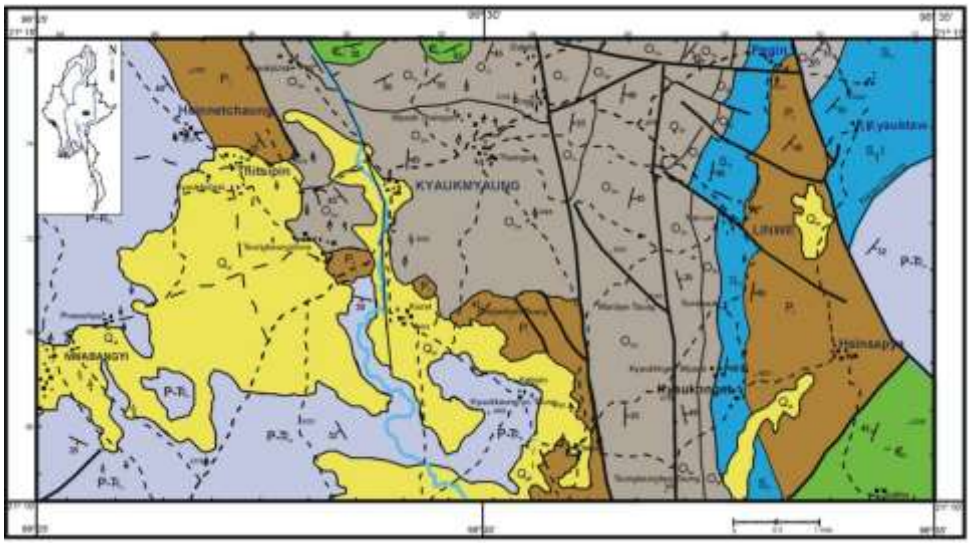

Figure 2. Geological map of the Nwabangyi-Kyauktaw area, Ye-ngan Township, southern Shan State (from, Garson *et.al* (1976); Kyi Soe (1983)

Molohein Group

The Group consists of a thick succession of orthoquartzites, siltstones, and sandstones. It is best exposed in the south-east corner of the area. The orthoquartzite unit of the Group (informally known as the Pandung Formation) in the vicinity of the Satthe village gradually passes upwardly into

whitish, pinkish, purplish, and yellowish brown micaceous sandstones and lenticular siltstones (Myetye Formation). In this tract, the fossiliferous horizon, which bears a great number of saukiid trilobites of the Padongaing area (Figure 3). The first Cambrian fossils to be formally described from Myanmar: *Eosaukia buravasi* (Myint Lwin Thein, 1973), which was previously reported but not figured; *Asioptychaspis asiatica*, previously known from North China; and *Asioptychaspis lata*, a new species endemic to Myanmar (Wernette *et.al* 2021). Considerable additional diversity may exist within the Myet-Ye Formation, which will permit further test of the above biostratigraphic and paleogeographic conclusions.The present faunas indicate the age of Lower to Middle Cambrian (Late Furongian).

Pindaya Group

Myint Lwin Thein (1973) introduced this Group as a formal stratigraphic unit, comprising essentially of thick-bedded, burrowed, pelletal or silty limestones with irregular silt specks or laminae, and the grey or yellow siltstones. The Group comprises three Formations (Lokepyin, Wunbye, and Nan-on) and one Member (Tanshauk). All of these rocks are well exposed in the Ye-Ngan Township. The lower limit of the group is the lower boundary of the Lokepyin Formation which in contact with the micaceous, pinkish or purplish sandstones of the Molohein Group and the upper limit is marked at the upper boundary of the Tanshauk Member of the Nan-on Formation. The type locality of the group is established at the north-western part of the Pindaya range, in Ye-ngan Township. The age of the Pindaya Group is regarded to be (Lower Ordovician to late Upper Ordovician).

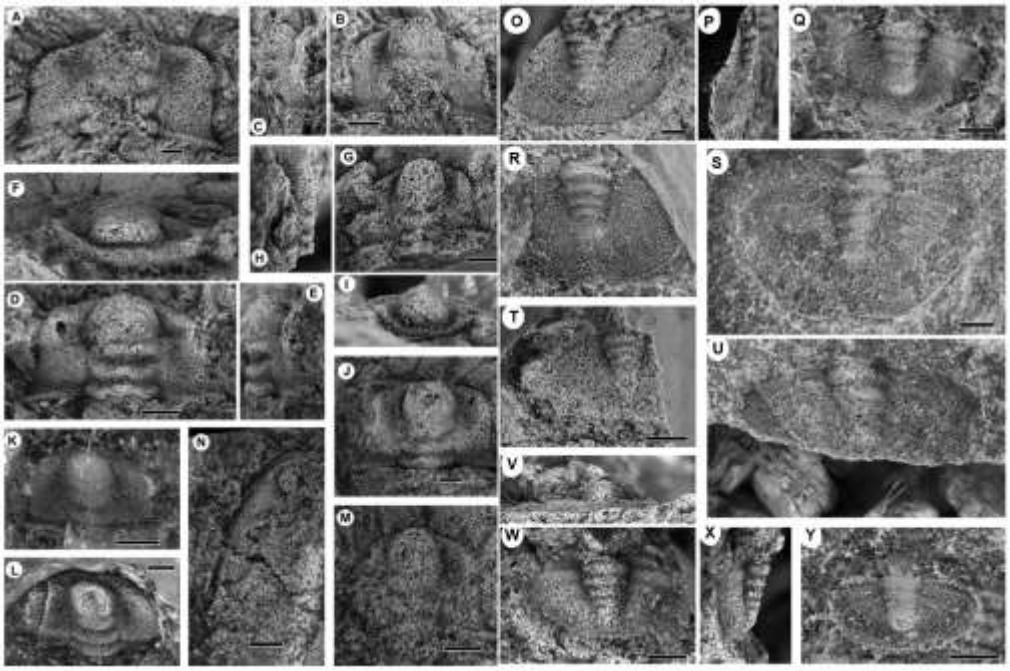

Figure 3. Late Cambrian trilobites of the Myet ye Formation, Molohein Group, Padongaing area, Ye-ngan Township, southern Shan State. A-M *Asioptychaspis lata* n. sp. all Cephalon. O-Y *Asioptychaspis lata* n. sp. all pygidium. All scale bars 2 mm.

Lokepyin Formation

Myint Lwin Thein (1973) first named this unit after Lokepyin village, 6km NE of Myaing, Ye-ngan Township, southern Shan State. This unit occurs at Theingon and Ingyi villages, located at about one mile east of Ye-U. It is also exposed at the road cutting between Kabyin and Kyaukhnget villages. It comprises a thick succession of medium- to thick-bedded, grey to buff, soft to indurated, micaceous siltstones. Subordinate rock types are yellowish, buff to greenish marl, and hard bands of micaceous and brownish sandstones interbedded with the yellowish siltstones that occur at the lower horizon. The carbonate content increases towards top of the unit and the upper boundary of the Lokepyin Formation is determined at the first appearance of limestone bed of typical Wunbye character. In this area the lower boundary is obscured due to thick soil cover. In the type area (Lokepyin village, about three miles north-east of Myaing, in Ye-ngan Township). The contact between this unit and the underlying micaceous siltstones of the Molohein Group is transitional. The unit yields abundant orthid brachiopods. Although no age determination of the fauna has been reported by the original author it should better be regarded, on basis of the stratigraphic position, as the age of Early Ordovician. The present authors trying to discover the conodonts fauna from the lime-mudstone of Lokepyin Formation at the Dalapin Village but no conodonts have been detected yet.

Wunbye Formation

The type section of this formation is established in this area between the point located at the eastern margin of the Ingyi village (GR 045 748) and the point (GR 078 728) of one-inch topographic map 93 C/12, situated at about one half mile north of western margin of Nan-on village. This formation has the largest distribution and thickness among the units exposed in this area. It occurs in the east and south-east of Ye-U, Ingyi, Theingon, and Wunbye Hill. In the type locality, the Wunbye Formation consists of a succession of thick-bedded limestones, siltstones, and dolomites. The limestones are finely crystalline, grey to bluish grey, sometimes oolitic and with pink, buff or yellow coloured silty materials in the forms of burrows, specks, pellets or irregular and regular laminations; burrow structure is most typical of these limestones. The minor siltstones are thin, medium- to thick-bedded, yellow to light grey and soft to indurated, sometimes thin bands of hard and light greenish siliceous claystone occur within the siltstones. The dolomite subunits are usually thick-bedded, often massive, but generally with laminations. The lithologies of the subunits of limestones, siltstones, and dolomites of the Wunbye Formation may vary from place to place. The lower and upper boundaries of the formation is marked by the first and last appearances of distinctive beds with the burrow structures or silty specks.

Faunally the formation is characterized by abundant orthid brachiopods, nautiloid cephalopods (*Actinoceras*, *Michelinoceras*, and *Wuthinoceras*), receptaculitid algae and stromatoporoids. The Wunbye fauna from Phyaukseikpin area, east of Kyaukse includes new species, *Michelinoceras burmese*, *M. kyaukse*, and *Actinoceras moeseini* identified by Myint Lwin Thein (1968), and receptaculitid algae, *Fisherites burmensis* by Rietchel and Niteckei (1984) indicates lower Middle Ordovician age of the Wunbye Formation. Niko & Sone (2014, 2015), reidentified the above nautiloid cephalopods from the Wunbye Formation as *Ordosoceras theini* sp. nov, *Armenoceras myanmarense* sp.nov, *Paratunkuskoceras* sp. *Wutinoceras moeseini* indicate the age of late Early or early Middle Ordovician (Floian or Dapingian) (Niko & Sone, 2014) (Figure 4). In 2015, they described

Gondwanan Nautiloid Cephalopods, *Sibumasuoceras langkawiense* (Kobayashi), *Ormoceras langkawiense, Tasmanoceras* sp. (Figure 5) which indicate late Middle Ordovician (Darriwillian).

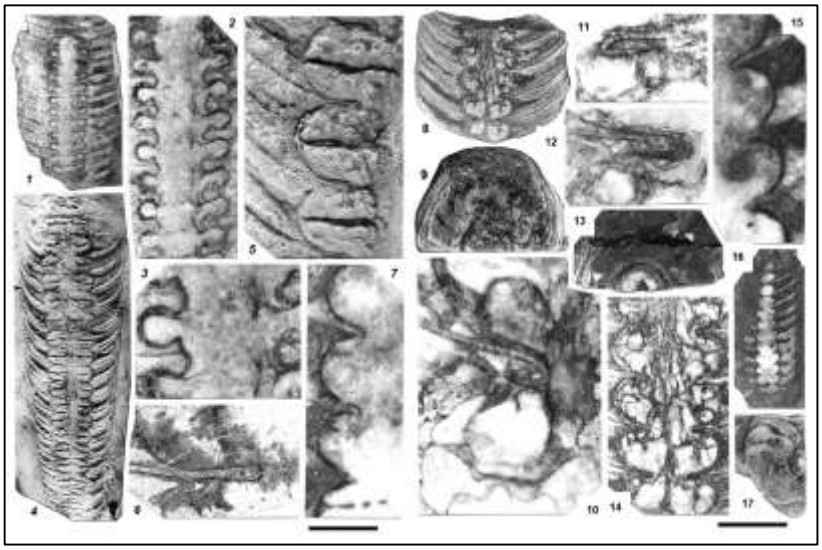

Figure 4. 1-3**,** *Ordosoceras theini* sp. nov., 4-6, *Armenoceras myanmarense* sp. nov.: 4, 5, holotype; 6, paratype, longitudinal thin section, showing details of septal neck. **7,** *Paratunkuskoceras* sp., Scale bar is 20 mm in Figure ; 8-12, 14**,** *Wutinoceras moeseini* (Thein, 1968); 13, *Armenoceras myanmarense* sp. nov., 15, 16, *Paratunkuskoceras* sp.; 17, *Ordosoceras theini* sp. nov., holotype, Scale bar is 30 mm

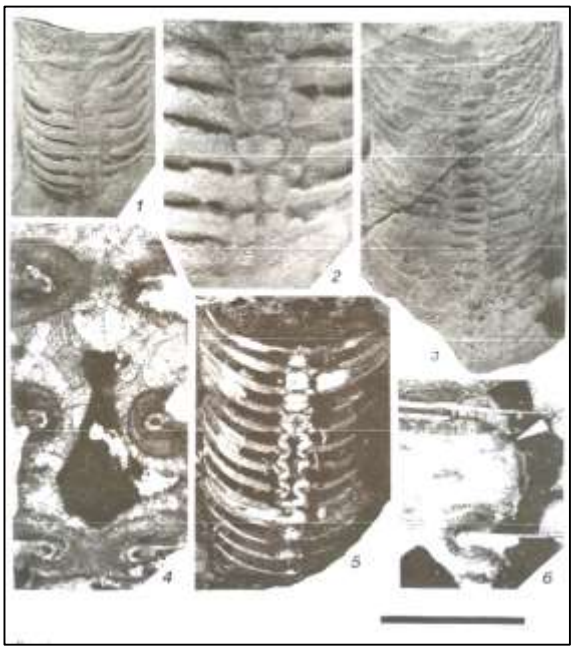

Figure 5. 1-6. *Sibumasuroceras lankawiensis* (Kobayashi, 1959). Middle Ordovician, Wunbye Formation, southern Shan State.

Nan-on Formation

The unit is named after Nan-on village, about one-mile south-west of Linwe village in Ye-ngan township. The type section of the unit is chosen at the area located between the grid coordinates of 078728 and 080728 (93 C/12) where both the upper and lower boundaries are being exposed. It has limited distribution in this area, extending southwardly to Tanshauk and Kyaukhnget areas. The Nan-on Formation at the type locality consists of yellow to buff or light orange, thin- to medium-bedded siltstones, mudstones, and claystones, generally subindurated to soft. Occasional occurrences of micaceous siltstone of light buff to whitish colour with pink or purple specks differentiate this unit from the yellow siltstones of the Wunbye Formation. In some areas, thin bands of laminated and argillaceous limestones occur interbedded with the siltstones. The lower boundary of the formation is marked at the contact of the siltstones with the top-most limestone bands of the Wunbye Formation which have burrow structures filled with silty materials, or silty laminations. The upper boundary, at the point of first appearance of purple band of the overlying Tanshauk Member. The Nan-on Formation is highly fossiliferous yielding abundant orthid brachiopods, cystoids, bryozoans, sponges, and trilobites. The brachiopod fauna of the Nan-on Formation was described and reviewed by Cocks and Zhen Ren Bin (1998). The fauna includes 31 genera, of which *Dirafinesquina* is a new genus, and *D. globosa* and *Leptellina (Leptellina)* minor are new species. The assemblage of the fauna indicates the age of Caradocian (Late Ordovician) (Figure 6).

Tanshauk Member

This unit is a member of the Nan-on Formation and was named after Tanshauk village, situated at about one-mile south of Nan-on village. The type section of the Tanshauk Member is located along the cart road situated at about one quarter of a mile north-west of Linwe village. This is also exposed at west of Nan-on and Pegin, at Tanshauk, and Kyaukhnget south villages. The member consists of purple or pink, soft, laminated, thin- to medium- bedded siltstones, calcareous shales and mudstones, the unit is characterized by its purple-coloured siltstones and shales. The lower boundary of the Tanshauk Member is determined at the horizon of the first occurrence of purple or pink shales or siltstones overlying the yellow or grey siltstones of the Nan-on Formation. The upper boundary is marked at the horizon of the last occurrence of purple siltstones or shales below the horizon of the first occurrence of phacoidal limestones or grey shales of the Linwe Formation. This member is correlated with the Hwe Maung Purple Shale Member of northern Shan State. This member is well exposed in the Pa-thin area, between Mandalay and Pyin Oo Lwin, Mandalay Region (Rong *et.al* 2020). Chen & Rong (2019) Discovered the brachiopods assemblage, *Xenocrania haimei* (Figure 7) that indicate the age of late Ordovician (Hirnantian). It is reasonable to take the age of Tanshauk Member of southern Shan State same as the Hwe Maung Purple Shale Member of northern Shan State.

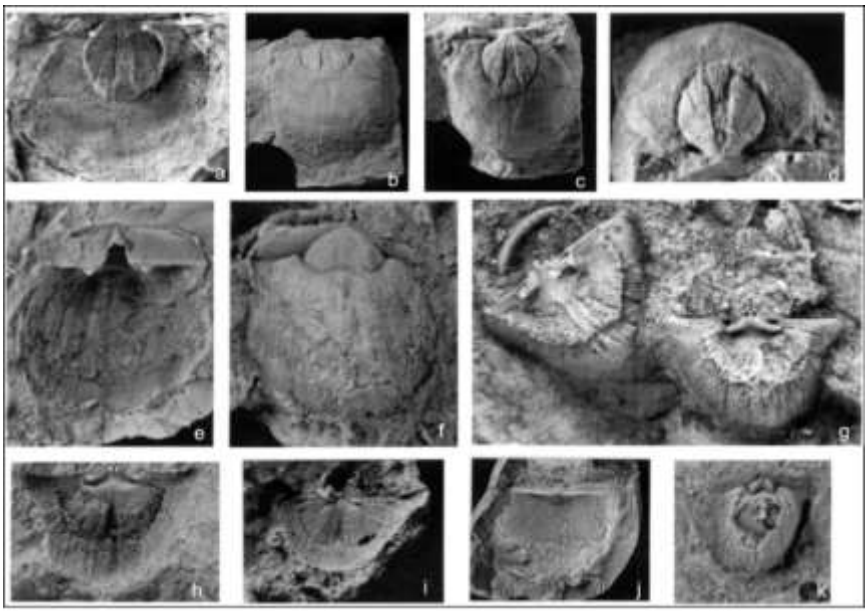

Figure 6. a-d, *Dirafinesquina globose* gen.et sp. nov. Linwe area. x2; e-k, *Leptellina* (*Leptellina*) *minor* sp. nov., Linwe area, x5. g-h, Holotype, x5 (Cocks and Zhen Ren Bin, 1998).

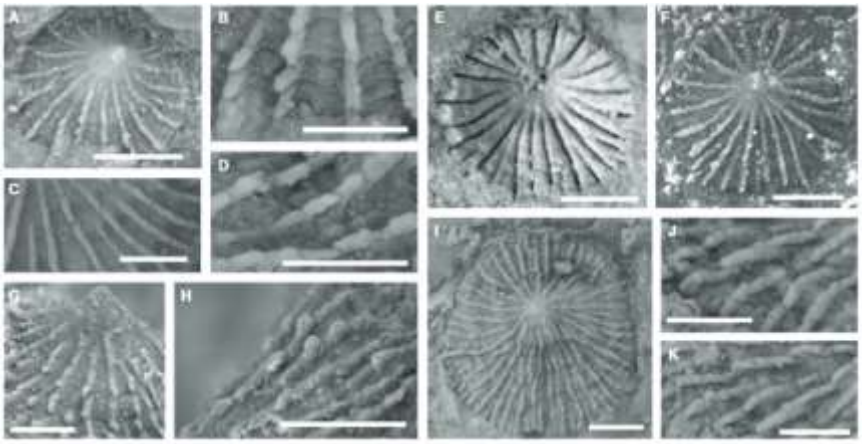

Figure 7. *Xenocrania haimei* (Reed, 1915). All specimens illustrated come from Hwe Mawng Purple Shale Member (Hirnantian), Mandalay Division, Myanmar.

Mibayataung Group

Myint Lwin Thein (1973) proposed this new stratigraphic unit which comprises essentially of phacoidally textured, pink, purple or bluish grey, argillaceous limestones (Linwe Formation), calcareous mudstones, buff-coloured mudstones, pink or purplish shales and slates (Wabya Formation), and orthoquartzites (Taungmingyi Member). The name of the group is taken from the Mibayataung Hill (GR 351 961 on topographic map 93/D11), situated at about 9 miles south-southwest of Heho. In exception of the Taungmingyi orthoquartzites the rock sequence of the group is well exposed at Linwe and Pegin areas. The lower limit of the group is marked at the last appearance of the purple or grey shale or siltstone of the Tanshauk Member which is the top of the Pindaya Group. The

upper boundary however, is placed at the base of possible Devonian unit or where it is absent, of the Thitsipin Limestone Formation of the "Plateau Limestone Group".

Linwe Formation

This unit is named after Linwe village in Ye-ngan Township, southern Shan State. The type section of the unit is located at and neighborhood of Linwe village (GR 085 725 on topographic map 93/C12), the total thickness of the unit at the type section is 1725 ft. (Myint Lwin Thein, 1973). In Linwe area the unit is widely distributed at Linwe and towards north, in the vicinity of Pegin village. Lithologically it is characterized by a thick succession of purple, pink, and grey-coloured limestones showing phacoidal structure on the weathered surface. Argillaceous limestones and calcareous mudstones constitute as minor account. Faunally straight and simple-cone nautiloid cephalopods (*Michelinoceras*) are locally fairly abundant in some outcrops of the calcareous mudstones or argillaceous limestones, crinoid stems and cystoid plates are quite often present but are of fragmentary nature. The Linwe limestone is easily distinguishable from the Ordovician Wunbye Limestone by having phacoidal character and purple or pink coloration. The latter distinctly has burrowed structure and lateral variation of the sedimentary facies is not common as in the Linwe Formation.

Myint Lwin Thein (1973) regarded the age of the Linwe Formation as Lower Silurian by judging from the graptolites and stratigraphic horizon. These graptolites were latter identified by Chit Sein (1998). The fauna indicates Early Silurian (Llandoverian) so that it is advisable to include all of the graptolite-bearing whitish silty shales (may be a member rank) into the Linwe Formation instead of taking as a separate unit that is the Wabya Formation. The youngest age for the Linwe Formation is now known to be accepted by the evidence of conodonts (*remscheidensis* Zone) (late Ludlovian to late Lochkovian), which is moving up into the Early Devonian by the presence of *Ozarkodina remscheidensis*, *Ozarkodina* sp., *Panderodus unicostatus*, *Dapsilodus obliquicostatus* (Figure 8) (Maung Maung & Aye Ko Aung 2005, 2009).

Wabya Graptolite Shale of the Linwe Formation

The mainly graptolite-bearing whitish, micaceous, silty, slaty shales well exposed at Wabya hill in Pindaya township are recognized as a new stratigraphic unit by Myint Lwin Thein (1973). The unit has limited distribution in the western part of the southern Shan state, Kyauktap, Mibayataung, Mwetaw Taung and Pegin areas.

The stratigraphic position of the unit is to be questioned as in places, it is sandawished between two phacoidal limestones of the Linwe Formation. In addition to that the shale unit may disappear laterally to be replaced by the phacoidal limestones showing lateral facies changes locally as well as regionally. The different faunal facies due to the above changes might as well pose problems in the stratigraphic correlation (e.g. *Michelinoceras* and crinoid species are common in phacoidal limestones whilst graptolites in shales). The age of the unit indicated by the graptolite faunas (orthograptids, climacograptids, glyptograptids, monograptids, and cyrtograptids) is of Early Silurian (Llandoverian to Wenlockian) (Figure 9).

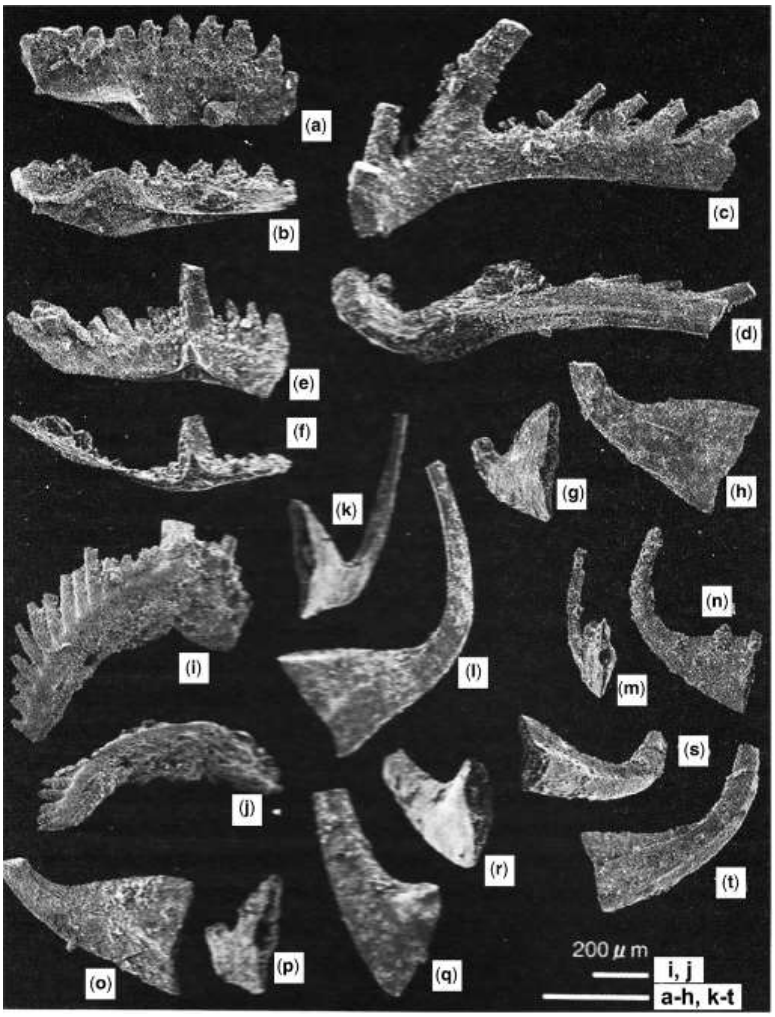

Figure 8. Early Devonian (Lohkovian) conodonts from the upper most part of the Linwe Formation, east of Pegin village, Ye-ngan Township, southern Shan State. (From Maung Maung, 2005; Maung Maung & Aye Ko Aung, 2005). 1) (a, b) *Ozarkodina remscheidensis* Ziegler; (c–f, i, j) *Ozarkodina* sp.; (g, h, k–r) *Dapsilodus obliquicostatus* Branson & Mehl; and (s, t) *Dapsilodus unicostatus* Branson & Mehl.

Devonian units of the Myogyi area

The Devonian units including Zebingyi Formation and ?Maymyo Formation are narrowly exposed in the Myogyi area, western part of the southern Shan State. The sequence consists of alternating purplish-red, unindurated calcareous siltstone and medium-bedded, light grey, argillaceous limestone with some ammonoids, gastropods, nautiloids, and ostracods. This Devonian sequence is tentatively considered as part of the Maymyo Formation since it overlies conformably the proper Zebingyi Formation of Pragian-Emsian age. This sequence requires future mapping. The Zebingyi Formation is recognized by the presence of a number of tentaculitids and the ?Maymyo Formation is of the presence of Late Devonian (Frasnian) ammonoids. The ammonoids include *Beloceras shidianese* Yang, *Tornoceras* cf. *contractum* Glenister (Figure 10). (Aye Ko Aung *et.al* 2010)

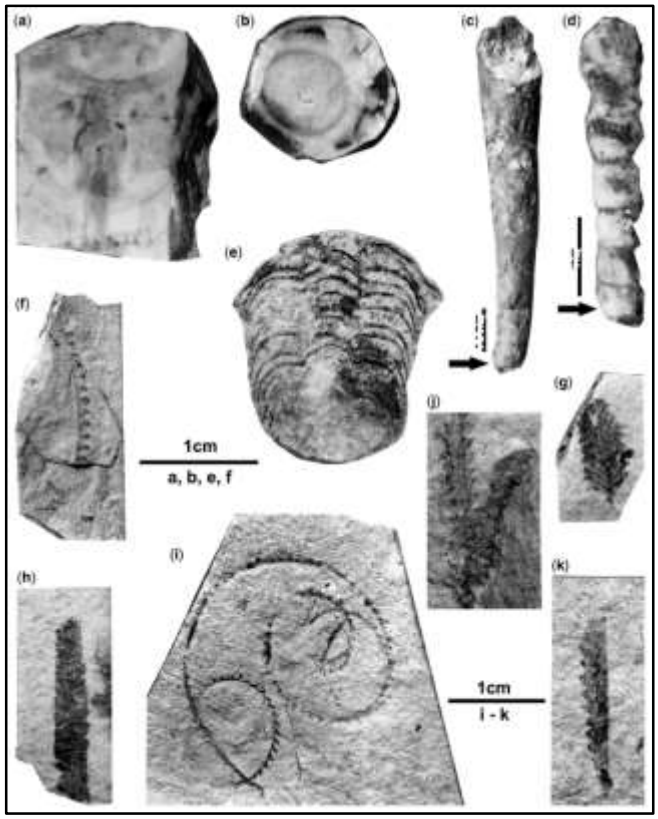

Figure 9. Silurian fossils of the Linwe Formation. (a-d) *Michelinoceras* sp.: (a) longitudinal section; (b) transverse section; and (c, d) surface specimens; (e) indeterminate dalmanitid; (f) *Monograptus priodon* (Bronn); (g) *Phyllograptus* sp.; (h)*Normalograptus normalis* (Lapworth); (i)*Cyrtograptus* sp.; (j) *Neoglyptograptograptus* sp.; and (k) *Pristiograptus variablis* (Perner).

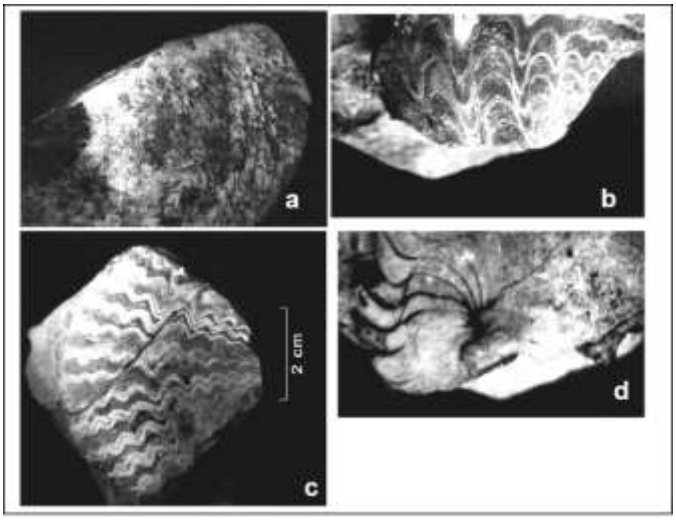

Figure 10. Late Devonian ammonoids of the Maymyo Formation, Myogyi area, Ye-ngan Township, (a-c) *Beloceras shidianense* Yang; (d) *Tornoceras* cf. *contractum* Glenister.

Thitsipin Limestone Formation

The unit was firstly named by Garson *et al*. (1976) after Thitsipin village, north of Ye-ngan. The formation is well exposed at the type area and the areas to the east and south-east of Pegin and Linwe villages. The largest outcrops of the unit are in the east of the Linwe area where more than half of the outcrop has been intensely dolomitized, resulting brecciation. The outcrop of which is easily distinguishable from the undolomitized or non-brecciated calcitic part of the formation. The undolomitized portion of the unit consists entirely of limestones. Five coral species belonging to four genera *Yatsengia hangchowensis*, *Iranophyllum* sp.cf. *caracinophylloides*, *Ipciphyllum subelegans*, *Pavastehphyllum* sp., *Pavastehphyllum* (*Thomasiphyllum*) sp., are discovered from the Thitsipin Limestone Formation (Aung Myo Zaw 2014) (Figure 11). At the base of the Pegin Pagoda Hill, a nearly ten-meter-thick sequence of well-bedded, dark grey, crinoidal limestone and micritic limestone is well exposed. In this interval, a typical Middle Permian foraminifer, *Multidiscus padangensis* is recovered (Aung Myo Zaw 2024). Middle Permian Limestone exposures of Pegin area and Htam sang area are closely similar not only lithology but also fauna occurrences (Aung Myo Zaw, 2023). Garson *et al.* (1976) divided the Thitsipin Limestone into three main facies: a massive limestone facies with abundant big brachiopods; a massive cherty limestone facies; and a well-bedded calcarenite facies.

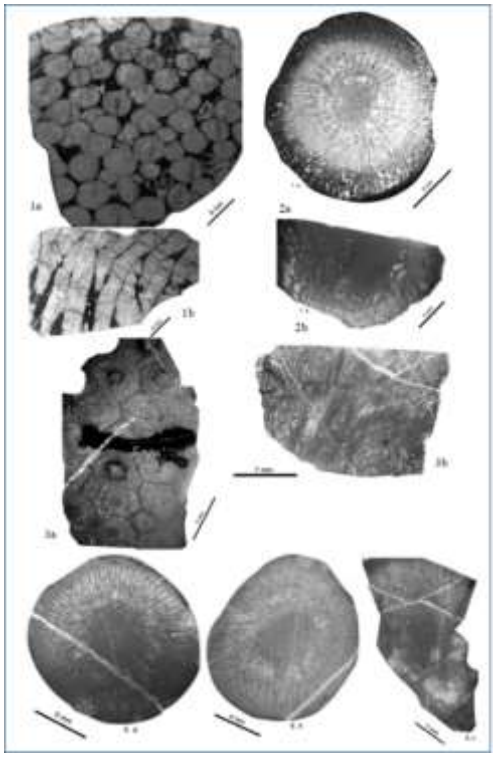

Figure 11. Permian corals of the Thitsipin Formation, Pegin-Linwe area, Ye-ngan Township.1a-*Yatsengia hangchowensis* ; transverse section,1b) *Yatsengia hangchowensis*; longitudinal section, 2a) *Iranophyllum* sp.cf *carcinophylloides*; transverse section, 2b) *Iranophyllum* sp.cf *carcinophylloides*; 3a) *Ipciphyllum subelegans*; transverse section, 3b) *Ipciphyllum subelegans*; longitudinal section, 4a, b) *Pavastehphyllum* sp.; transverse section, 4c) *Pavastehphyllum* sp.;longitudinal section.

Nwabangyi Dolomite Formation

Garson *et al*. (1976) first used the name after the village of that name situated in Ye-ngan township. It wide spreadly outcrops in north and north-west of Nwabangyi village and outside the study area the unit is extensively distributed in Pindaya, Heho, Shwenyaung, and Taunggyi townships. Garson *et al*. (1976) recognized four main facies in the formation: thin- bedded foraminifera limestone; laminated and turbiditic limestone; sedimentary breccia; and light and dark grey, fine-grained limestone.

In Myogyi area the Nwabangyi Dolomite Formation is chiefly composed of dolomitite carbonate rocks with the common features of surficial shattering and brecciation. In the present area, however the rock sequence consists of grey intraformational oligomitic conglomerate in combination with sedimentary breccia, bedded, grey lithic packstone, thin to medium bedded bioclastic wackestone with ammonoids, brachiopods, conodonts and shark fossils and thinly bedded, grey, tyrbiditic and dolomitic packstone-grainstone. The ammonoid-bearing unit crops out extensively in the Myogyi area which is situated approximately 20 km southeast of Kyaukse town, Mandalay Region. It is located at the triple junction of Kyaukse-Myitha and Ye-ngan townships.

The ammonoids species are identified as, *Ussurflemingites* cf. *abrekentisis* Shigeta & Zakharov; *Ussurflemingites* cf. *primoriensis* Shigeta & Zakharov; *Arctoceras* cf. *subhydaspis* (Kiparisova) (Figure 12), and a nautiloid species *Trematoceras* cf. *subcampanile* (Kiparisova); conodonts, *Neospathodus pakistanensis* Sweet, Neo. Dineri Sweet (Figure 13); and shark teeth, *Acrodus* cf. *cuneocostatus* Cuny, Rieppel & Sander, *Polyacrodus* sp.indet., *Hybodus* sp. and Placoid scale of Euselachii order, family., gen. et sp. indet, from the sequence. These faunas indicate Lower Triassic (Induan-Olenekian).

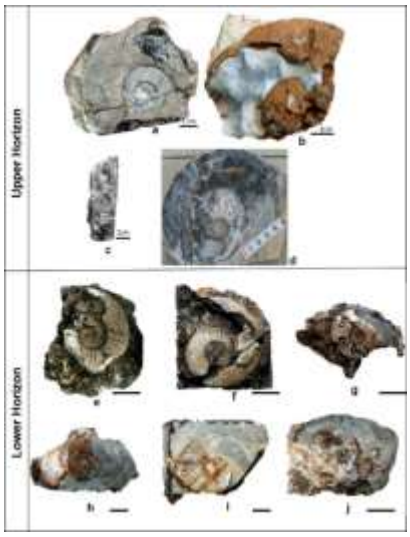

Figure 12. a) *Ussuriflemingites* cf. *primoriensis* Shigeta & Zakhrov, 2009; b, d) *Arctoceras* cf. *subhydaspis* Kiparisova, 1961; c) *Trematoceras* cf. *subcampanile* Kiparisova, 1954; Upper Horizon of the Nwabangyi Dolomite Formation, Myogyi area; e-j) *Paleokazakhstanites* cf. *ussuriensis* Zakharov, 1968; Lower Horizon of the Nwabangyi Dolomite Formation; scale bar=1cm for all figures.

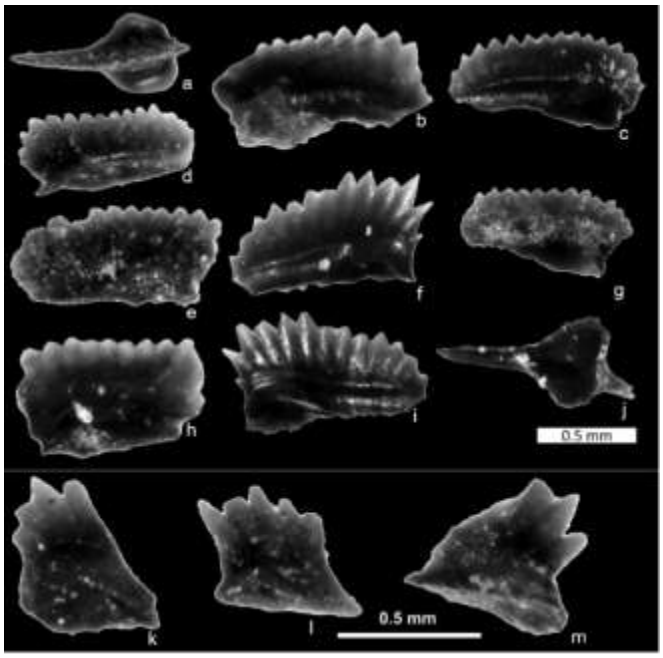

Figure 13. a-j *Neospathodus pakistanensis* SWEET; k-m *Neospathodus dieneri* SWEET, Nwabangyi Dolomite Formation, Myogyi area, Ye-ngan Township, southern Shan State.

Conclusions

Based on the experience in the study of Pre-Paleozoic to Early Mesozoic stratigraphy in southern Shan State, it is known to be believed that most of the rock units require comprehensive revision. The age of the Chaung Magyi is reviewed as Precambrian-Cambrian (Aye Ko Aung & Cocks, 2017) and Late Neoproteozoic-? Cambrian (Dew *et.al*., 2019). The existence of Late Cambrian trilobites has been acknowledged since 1970's, but no formal descriptions of such fossils have been published. Wernette *et.al* (2021) provide such descriptions of some trilobites from Molohein Group's "Myet-Ye Formation" from the Linwe area, Ye-ngan Township of the southern Shan State. Three species from two genera are reported: *Asioptychaspis lata* n.sp.Wernette, *A.asiatica* Zang & Jell, and *Eosaukia buravasi* Kobayashi. These fossils indicate Furongian (Lower to Middle Cambrian) stage 10. The Early to Middle Ordovician nautiloids are identified by Niko & Sone (2014, 2015) provide new species: *Ordoceras theini* n.sp. Niko & Sone, (Floian or Dapingian, late Early-early Middle Ordovician), *Armenoceras myanmarensis* n.sp. Niko & Sone (Darriwillian, early Middle Ordovician), *Wutinoceras moeseini* (Thein) Niko & Sone (late Early Ordovician), two species of Gondwanan cephalopods: *Sibumasuoceras langkawiensis* (Kobayashi) (Dariwillian). The Nan-On Formation consists abundant brachiopods (*Dirafinesquina globose* gen.et sp. nov. & *Leptellina* (*Leptellina*) *minor* sp. nov., suggests Late Ordovician (Katian/Caradocian). Latest Ordovician (Hirnantian) Tanshauk Member, revealing typical *Hirnantia* Fauna. The Silurian Linwe Formation is revised with the evidence of conodont fauna, *Ozarkodina remcheidensis*, an important zone fauna which indicates the age of Early Devonian (Lochkovian). In the Devonian system, Late Devonian (Frasnian) unit,

previously not known in the Shan State is recognized in the Myogyi area, Ye-ngan Township, southern Shan State. It is evidenced by the recovery of the Late Devonian (Frasnian) ammonites (*Beloceras* sp.). There are so far no Carboniferous strata found in the present study area. The Permian rocks are the most widely distributed in the Shan Plateau. They are rather fossiliferous, comprising corals, foraminifers, brachiopods, bryozoans, and crinoids, which are very useful tool for stratigraphic correlation locally as well as regionally with the neighboring countries such as, Thailand, Malaysia, and Yunnan. The Early Triassic (Induan-Olenikian) boundary bed is recognized in the Myogyi area by the occurrence of ammonoids (*Ussuriflemingites* cf. *primoriensis*) and conodonts (*Neospathodus pakistanensis*), which are useful tools for global correlation.

Acknowledgements

We would like to express our gratitude to the Myanmar Academy of Arts and Science for allowing us to be able to publish this paper. We are also grateful to Rector of Dagon University, Professor Dr Thar Tun Maung, Pro-Rectors, Dr Myo Min, Dr San San Hmwe, and Dr San San Lwin for their encouragement. Many thanks are also due to staffs of Geology Department, Dagon University for their help at various stages of this research especially to Professor Dr. Aung May Than, Head of Department of Geology, Dagon University for her encouragement, suggestions and discussions.

References

Aung Myo Zaw, 2014. *Ipciphyllum subtimoricum dilatum*, sub sp. nov from the Permian Thitsipin Formation, Pegin-Kyauktaw area, Ywa-ngan Township, Shan State (south). *Universities Research Journal* 6, 5, 219-226.

Aung Myo Zaw, 2015. Systematic Study of the Permian Rugose Corals from the Thitsipin Formation, Pegin-Linwe area, Ywa-ngan township, Shan State (south), Myanmar. *Universities Research Journal* 7, 4, 249-268.

Aung Myo Zaw, 2023. The New Peri Gondwana coral fauna and sediments from the Htam Sang area in the Shan Plateau, Myanmar. Abstract volume, 6th paper reading session, *The International Conference on Substantial Scientific Collaboration of Ocean and Earth Sciences between Myanmar and China (SSCOE-2023)*.

Aung Myo Zaw, 2024. Middle Permian (Murgabian) Foraminifers faunas of the Thitsipin Formation, Pegin area, Ywa-ngan Township, southern Shan State, Myanmar. *Dagon University Research Journal*. Vol. 15, no.1.

Aung Myo Zaw and Aye Ko Aung, 2024. A new middle Permian rugose coral subspecies (Waagenophyllidae) from the Shan Plateau, Myanmar (in press; *Warta Geology, University of Malaya*).

Aung Myo Zaw and Chit Thet Mon, 2007. Geology of the Pegin-Linwe area, Ye-ngan Township, southern Shan State. Unpublished Honours Report. Department of Geology, Dagon University. 163p.

Aye Ko Aung, 1981. Geology of Kainggyi-Gwegyaung-Hnone area, Madaya and Naungkio Townships. Unpublished M.Sc Thesis, Mandalay University, Department of Geology, 125p.

Aye Ko Aung, 2002. Guide to the stratigraphy of the Ye-U, Linwe, Thitsipin, and Nwabangyi areas, Ye-ngan Township, southern Shan State, Myanmar. Unpublished Research Paper, Department of Geology, Dagon University. 13p.

Aye Ko Aung, Becker, R.T. and Ko Ko Myint, 2010. First record of Frasnian (Upper Devonian) sediments and ammonoids from Myanmar. Sub-commission on Devonian stratigraphy, *Newsletter*, 25-35.

Chit Sein, 1998. Systematic and stratigraphic palaeontology of Silurian fossil assemblges (Graptolites) of Wabya, Kyauktap and Mibayataung areas, southern Shan State. Unpublished M.Sc Thesis, Department of Geology, University of Yangon, 104p.

Chen, D., Rong, J.Y., 2019. A new craniid brachiopod genus from the terminal Ordovician Hirnantia fauna of Myanmar and South China. *Palaeontology* 5, 521–535

Cocks, L.R.M. and Zhan Ren-Bin, 1998. Caradoc brachiopods from the Shan States, Burma (Myanmar). *Bull. Nat.Hist.Mus.Lond*. (Geol) 54(2), 109-130.

Dew, R., C., C.K. Morley, Tin Aung Myint and A. Collins, 2019. Age and provenance of the Chaung Magyi Group, Yeywa Dome, Myanmar, based on U-Pb dating of detrital zircons. *Journal of Asian Earth Sciences* Vol. 184(2019) 103967

Garson, M. S., A. H. G. Mitchell, and B. J. Amos, 1976. The geology of the area around Neyaungga and Ye-ngan, southern Shan State, Burma. *Overseas Geol. Miner. Res*. Mem. Institute of Geological Society, London. 2, 1-70.

Kobayashi, T. 1959. On some Ordovician fossils from northern Malaya and her adjacence. *Journal of the Faculty of Science, University of Tokyo*, Section 2, Geology, Mineralogy, Geography, Geophysics, vol.11, pt. 4, pp.387-407, pls. 24-27.

Ko Ko Myint, 1989. Geology of the Myogyi area, Ye-ngan Township. Unpublished M.Sc Thesis, Department of Geology, University of Mandalay, 131p.

Kyi Kyi Maw, 2010. Stratigraphy and carbonate sedimentology of the Thitsipin Limestone. Unpublished Ph.D. Thesis, University of Yangon.

Kyi Soe, 1983.Paleozoic faunal study and biostratigraphy of Yegyanbyin-Linwe area, Ye-ngan Township southern Shan State, unpublished M.Sc Thesis, University of Yangon 358 p.

Maung Maung, 2005. Siluro Devonian Sequence and event stratigraphy of the Pindaya and Bawsaing areas, southern Shan State. Unpublished Ph.D. Thesis, Department of Geology, University of Mandalay, 237p.

Maung Maung and Aye Ko Aung, 2005. The first record of the Late Silurian Conodonts of the Linwe Formation, Pegin area, Ye-ngan Township, southern Shan State. *3rd Research Paper Reading Session, Myanmar Geosciences Society* (MGS), 14 p.

Maung Maung and Aye Ko Aung, 2009. The first record of the Late Silurian Conodonts of the Linwe Formation, Pegin area, Ye-ngan Township, southern Shan State. *Journal of Myanmar Geosciences Society* (MGS), vol2. No.1.

Me Me Thein, 2000. The carbonate petrology and microfacies of Carbonate rocks of the Linwe area, Ye-ngan Township, southern Shan State (unpublished) M.Sc Thesis, Yangon University ,Department of Geology135 p.

Myint Lwin Thein, 1973. The lower Paleozoic stratigraphy of the western part of the southern Shan State.*Geol. Soc. Malaysia Bull* No.6, 143-163.

Niko, S., and Sone, M., 2014. Actinocerid cephalopods from the Ordovician of Myanmar, and their paleobiogeographic implications for northern Gondwana. *Paleontological Research*, 18, 94-103.

Niko, S., and Sone, M., 2015. Gondwana nautiloid cephalopods from the Ordovician of Myanmar. *Paleontological Research*, 19 (4), 228-293.

Rietschel, S. and Nitecki, M. H., 1984. Ordovician receptaculitid algae from Burma. *Palaeontology*, vol. 27, p. 4, 15-420.

Rong, J.Y., Kyi Pyar Aung., Zhan R.B., Huang, B., David A.T.H, Chen, D., Zhou, H., Zhang, X, 2020. The latest Ordovician Hirnantia brachiopod fauna of Myanmar: Significance of new data from the Mandalay Region. *Paleoworld* Vol. 29(2020)1-30.

Tun Naing Zaw, 2005.The stratigraphy, Petrology and detailed structure of the Linwe-Pegin area, Ye-ngan Township, southern Shan State. Unpublished M.Sc Research project, Department of Geology, Dagon University, 184 p.

Wernette, Shelly J., Hughes, Nigel C., Mirow, Paul M., Aye Ko Aung, 2021. The first systematic description of Cambrian fossils from Myanmar: Late Furongian trilobites from the southern part of the Shan State and the early Palaeozoic palaeogeographical affinities of Sibumasu. *Journal of Asian Earth Sciences* 214 (2021) 104775.

Yin Min Htwe, 2011. Sedimentology of the Silurian Rocks of the Pindaya and Bawsaing Ranges, Shan State (south), Unpublished PhD Thesis, University of Yangon, 174p.