SILURIAN ROCKS IN THE KYAUKTAP AREA, SHAN STATE (SOUTH): THEIR SEDIMENTATION STYLE AND DEPOSITIONAL PROCESSES

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Abstract

The Silurian rocks in the Kyauktap area comprise seven distinct lithofacies, namely, flat laminated limestone, thin-bedded limestone interbedded with calcareous siltstone, purple phacoidal limestone, whitish grey shale and limestone interbedded unit, medium to thick-bedded limestone interbedded with argillaceous layers, grey phacoidal limestone and Kyauktap graptolite shale. There are nine carbonate microfacies in the Nyaunglwe section, ten microfacies in the Hle Lan section and nine microfacies in the Kyauktap phacoidal section. They are bioclastic rudstone, intraclastic bioclastic packstone, ostracod packstone, ferruginous ostracod packstone, bioclastic wackestone, argillaceous bioclastic wackestone, ferruginous bioclastic wackestone, argillaceous ostracod wackestone, nodular bioclastic wackestone, calcisphere bioclastic wackestone, dolomitized bioclastic wackestone, argillaceous limemudstone, limonitic limemudstone and ferruginous limemudstone. Nyaunglwe section is carbonate dominated unit and Hle Lan section is composed of whitish grey shale and argillaceous limestones in which bioturbated horizons are very common. Kyauktap phacoidal section is entirely grey nodular limestones and it grades into graptolite-bearing grey shales in the southern part of the area. Vertical and lateral variations of the lithofacies and microfacies suggest that the entire Silurian sequence represents a depositional continuum of shallow subtidal, deeper subtidal and slope.

Keywords: Silurian rocks, Kyauktap, Carbonate microfacies

Introduction

The Silurian rock units, comprising both carbonate and siliciclastic rocks, are extensively exposed on the southwestern Shan Plateau, particularly at the Pindaya Range, Bawsaing Range, Taunggyi Range and Loi-lem Range, etc. The present work aims to study sedimentology of the Siurian rocks which are well exposed at the Kyauktap area. The Kyauktap area is demarcated by Lat. 20º 47′ N to 20º 55′ N and Long.96º 45′ E to 96º 48′ E in one-inch

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topographic map no. 93 D/13 in Kalaw township. It is located about 10 miles at the east of Pindaya (Figure 1). It can easily be reached by the car.

Materials and Methods

The petrographic study was based on 130 samples obtained from the three studied sections.

Lithofacies of the Kyauktap Area

There are three measured sections in Kyauktap area from north to south namely Nyaunglwe section, Hle Lan section and Kyauktap phacoidal section in which seven distinct lithofacies can be observed: (1) flat laminated limestone, (2) thin-bedded limestone interbedded with calcareous siltstone, (3) purple phacoidal limestone, (4) whitish shale and limestone interbedded unit, (5) medium to thick-bedded limestone interbedded with argillaceous layers, (6) grey phacoidal limestone and (7) Kyauktap graptolite shales (Figure 2).

Flat laminated limestone

This lithofacies occurs at the Nyaunglwe section, and Hle lan section. The limestone is fine-grained and occurs in thin to massive beds of over ten feet (Figure 2a). Some of them are very hard, resistant and display a step-like appearance. The weathered surfaces are brown or grayish brown and smooth while the fresh surface displays a gray color. A few beds show lamination, and are poorly fossiliferous.

Thin-bedded limestone interbedded with calcareous siltstone

This lithofacies are encountered at the Nyaunglwe section. The limestones appears fine to medium-grained, light to medium gray with thin bedding (Figure 2b). Calcareous siltstone occurs in beds of ½ to 2 inches thick, and thin interbeds are usually consists of limestone. Siltstone beds are hard with blocky fractures, medium gray color where fresh, weathering to light brown color owing to oxidation of pyrite.

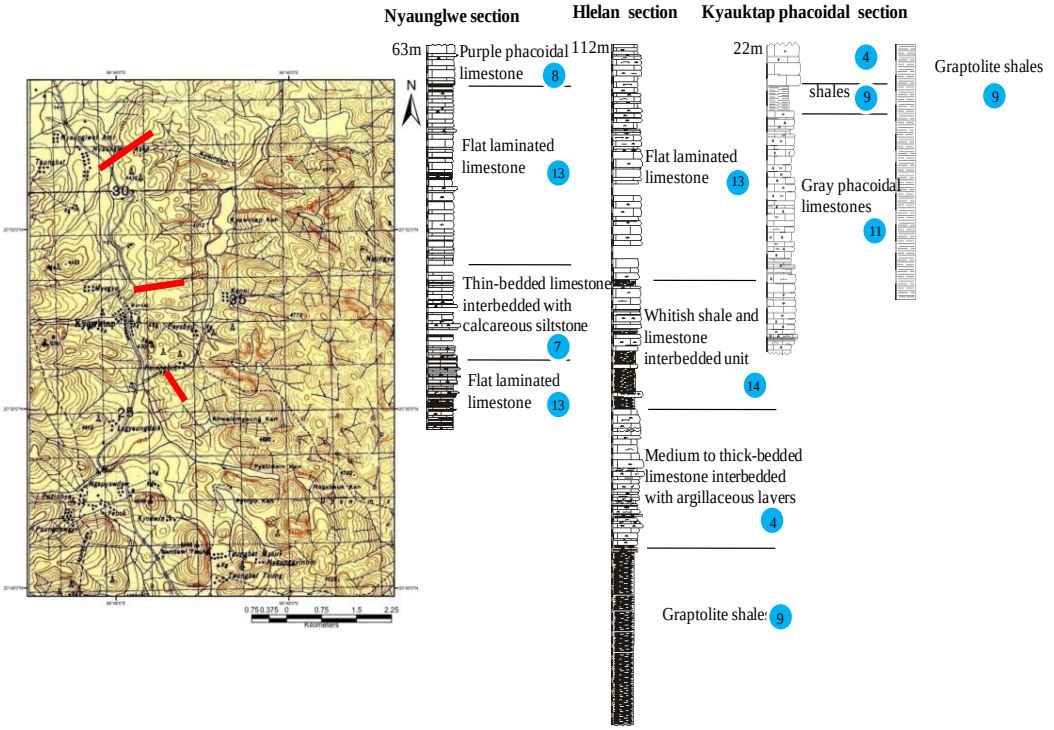


Figure 1: Map showing the locations of sections in the study area

Purple phacoidal limestone

This lithofacies can be observed at the top of the Nyaunglwe section. The limestone is medium grained, indurated, laminated with silt or mud specks showing phacoidal structure, which is aligned to the bedding plane, on the weathered surface (Figure 2c). The fresh surfaces are light to dark reddish brown and reveal a very wide variety of easily identifiable fossils.

Figure 2: Seven distinct lithofacies of Linwe Formation of the Kyauktap area
(a) Flat laminated limestone
(b) Thin-bedded limestone interbedded with calcareous siltstone
(c) Purple phacoidal limestone
(d) Whitish shale and limestone interbedded
(e) Medium to thick-bedded limestones interbedded with argillaceous layer
(f) Grey phacoidal limestone
(g) Kyauktap graptolite shale

Whitish shale and limestone interbedded units

This lithofacies is encountered at the middle part of Hle Lan section. This medium grained limestone occurs as thin to medium beds which are moderately resistant and fairly fossiliferous (Figure 2d). The shales are up to 4m thick, calcareous, fissile and contain scattered fragments of trilobite.

Medium to thick-bedded limestones interbedded with argillaceous layers

This lithofaies can be observed at the Kyauktap-Hlelan section. This medium-grained limestone occurs as thin to medium beds which are poorly resistant (Figure 2e). The weathered surfaces are light to dark gray or brown. The fresh surfaces are medium gray. The rocks are fairly fossiliferous.

Gray phacoidal limestone

This lithofacies are encountered at the Kyauktap section and is found as medium to massive beds, fairly resistant and very fossiliferous (Figure 2f). The weathered surface is light gray to medium gray and sometimes shows a fretted aspect. The fresh surface is light to dark gray, and displays dark rounded debris in a fine matrix.

Kyauktap graptolite shales

This lithofacies can be observed near Kyauktap Yekan and south of the Kyauktap village. It is more prominent in the southern part of the Kyauktap area. It attains up to 16.5 m thick in this area and extends as lateral facies into nodular limestone facies (Figure 2g). The shale is whitish, bluish gray, buff colored, partially tuffaceous and laminated with subordinate black slates. Many graptolites are present in this shale lithofacies.

Microfacies of the Kyauktap Area

Section measurements are conducted along three different sections in the Kyauktap area namely Nyaunglwe section, Hle Lan section and Kyauktap phacoidal section in which twelve microfacies are encountered (Figure 3).

Bioclastic rudstone

This microfacies is a mud-supported with abundant sand-size scattered organic debris (Figure 3a). The matrix consists of a reddish brown to light gray mosaic of micro-crystalline calcite stained by organic matter and pyrite pigments. The bioclastic material accounts for about 25-30 percent of the slide surface area and some grains show signs of compaction during early diagenesis. Cephalopod shells and trilobites constitute the majority of the larger bioclasts, while smaller particles are made of similar material together with ostracod valves, echnoid and some unidentifiable fragments. Cephalopod shells show some of the oldest preserved primary skeletal aragonite of nearly extinct externally-shelled of cephalopods. Trilobites are a part of a large trilobite fragment showing extinction patterns reflects the orientation of tiny prismatic crystals perpendicular to the carapace wall (Scholle *et al*., 2003).

Interpretation

Cephalopods are a diverse group of highly developed mollusks. Most were nektic creatures with moderate to high mobility; some were benthic, but still mobile, organisms. All modern and ancient forms are interpreted as fully marine. Although cephalopods are found washed into marginal marine settings, they are most common in open shelf and deeper-water deposits (Flugel, 2004). Their remarkable buoyancy controls, propulsion mechanisms, intelligence, and eyesight enabled the cephalopods to be formidable predators throughout their history (Scholle, 2003). In this way cephalopods were washed into open shelf.

Intraclastic bioclastic packestone

This microfacies is a mud-supported intraclastic bioclastic packstone with numerous sand-sized scattered organic fragments in microcrystalline calcite matrix (Figure 3b). Three types of intraclasts are present namely; crinoids, brachiopods and small thin ostracod clast; larger cephalopod with smaller calcified monoaxonic sponge spicules and calcisphers clast and crinoids with thin shell fragment clast. These intraclasts may be reworked because of the appearance of intraclsts outline. Interstitial spaces are filled by fine-grained detrital quartz and locally by void filled crystalline calcite.

Ostracod packstone

This microfacies is a grain-supported fabric with numerous sand-sized thin ostracod valve fitted in the microcrystalline matrix (Figure 3c). Fossil content averages 20 to 50 percent, and consists very largely of ostracods; some specimens consist of almost nothing except ostracods (Folk, 1962). The ostracods usually occur as unbroken and unbraded single valves, but there are some broken but unrounded fragments and some articulated complete shells. Much of the structures of ostracod valve are replaced by chert. Bioclasts are quite susceptible to this type of replacement. The effects of compaction are also noted.

Ferrugenous ostracod packstone

This microfacies is a grain-supported ferruginous ostracod packstone, containing sand-sized twinned ostracod floating in the matrix (Figure 3d). The fauna is very restricted with ostracod valve according for over 60 percent of all particles present. There is a sharp reduction in the frequency of crinoids, brachiopod shells, trilobite fragments and calcispheres. Twinning in ostracod valves usually develops as a result of burial or tectonic stress (Adams & MacKenzie, 1998). Ferrugenous material such as iron oxide, pyrite and limonite alternately are 10-15 percent in the fracture due to effect of compaction.

Bioclastic wackestone

This microfacies is a mud-supported bioclastic wackestone which contains 5-15 percent of sand-sized organic debris floating in a fine-grained matrix (Figure 3e). Angular to subangular fragments of crinoid plates and columnals, brachiopod shells and ostracod valve constitute most of the larger sand-sized particles. The smaller particles are mainly of similar composition, together with calcisphere and bivalve shell fragments. There is a great faunal change within limestone bed horizon with a great decrease in the number of species of brachiopods. Thus, trilobites virtually disappear, appearing again only near the top of limestone bed. Most of the finer fragments of bioclasts set in the red hematitic clay matrix.

Argillaceous ostracod wackestone

This microfacies is a mud-supported argillaceous ostracod wackestone which consists of 10 to 20 percents of ostracod valves and some calcisphere masked in the matrix (Figure 3f). The ostracods usually occur as unbroken and unabraded single valves, but some are broken but unrounded fragments and some articulated complete shells. Ostracod fragments are less conspicuous and are probably obscured by other particles. There is a sharp reduction in the frequency of pelecypod shells, crinoids fragments, brachiopod shells and spines and sponge spicules.

Ferruginous bioclastic wackestone

This microfacies is a mud-supported ferruginous bioclastic wackestone which contains sand-sized organic debris set in a fine-grained matrix (Figure 3g). The bioclastic material accounts for about 10-25 percent of the slide surface area and some grains show traces of abrasion. Crinoids, ostracod valves and brachiopod shells constitute the majority of the larger bioclasts, while smaller particles are made of similar material together with cephalopod fragments and lithic pellets. Some fossils were apparently swiftly deposited with micrite after a strong and sudden current swash, there are many pockets and patches of spar in the 'matrix' adjoin shells.

Dolomitized bioclastic wackestone

This microfacies is a mud-supported dolomitized bioclastic wackestone containing 10-21 percent of sand-sized bioclasts floating in the microcrystalline calcite matrix (Figure 3h). Organic debris are usually scattered in a random fashion throughout the slide surface area. Crinoids arm plates, brachiopod shells and ostracod valves constitute the major bioclasts of this microfacies. The matrix may be crypto- to microcrystalline calcite is now seen as dolomitized micrite. Dolomite seems to have been incapable of attacking fossils, for some very delicate calcitic crinoids and ostracod valve have been unaffected although surrounded on all sides by dolomite which entirely replaces the surrounding micrite. If the surrounding limemud and some bioclast were unstable aragonite, this could be explained, as the calcitic fossils would be more difficult to dolomite (Folk, 1962).

Nodular bioclastic wackestone

This microfacies is a mud-supported nodular bioclastic wackestone with fine-grained matrix (Figure 3i). The bioclastic material accounts for about 15-20 percent of the slide surface area and some grains show signs of abrasion. Ostracods, crinoids and brachiopod shells constitute the majority of the sand-sized bioclasts, while smaller particles are made of similar material together with calcisphere and some unidentifiable fragments. Some shell fragments float in the matrix is also noticed.

Calcisphere bioclastic wackestone

This microfacies is a mud-supported calcisphere bioclastic wackestone in which 10-30 percent of organic material floating in fine-grained matrix. The silt-sized bioclasts are calcisphere, occurring in enormous numbers in some of the limestone beds; there are some concentrations of larger trilobite fragments, and other unidentified fossils. This horizon generally is thin and represents short-lived events relative to the other microfacies of the Linwe Formation.

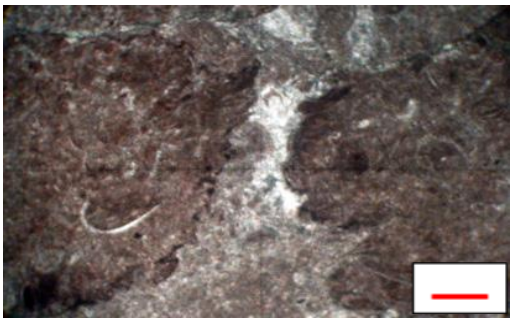
Argillaceous limemudstone

This microfacies is almost pure mud-supported limemudstone with less than 10 percent of organic debris. Organic fragments are limited to central canal of crinoids, small brachiopods shell fragments, and more rarely ostracod valves. The fecal pellets are usually subrounded and small in some slides. The matrix is crypto to microcrystalline, pink to reddish brown calcite, colored by hematite and organic matter. Angular grains of silt-sized quartz are common in this microfacies.

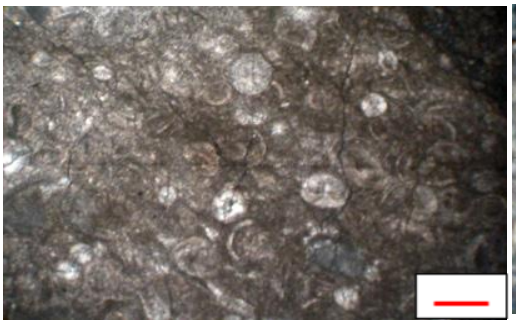
Ferrugenous limemudstone

This microfacies is a mud-supported ferruginous limemudstone with 4-7 percent of the slide surface area and some grains shows sign of abrasion. 10-25 percent of ferruginous material are also noticed in this microfacies. The ferruginous materials are iron-oxide in some slides and limonite or pyrite in other slides. Angular to subangular silt-sized grains of quartz are scattered through the slide surface area. Crinoids and brachiopod shells together with siliceous sponge spicules are major constituent in this microfacies.

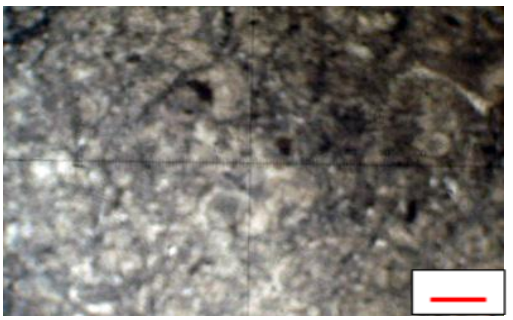
(a) Bioclastic rudstone



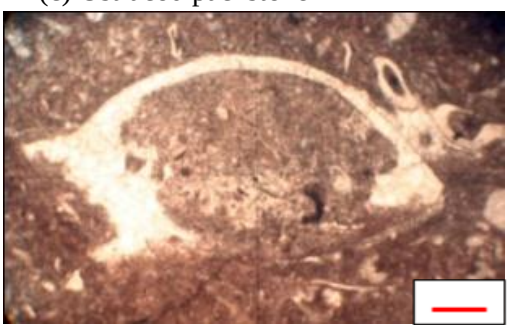
(b) Intraclastic bioclastic packstone



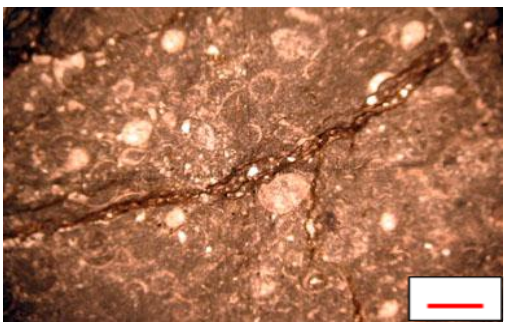
(c) Ostracod packstone



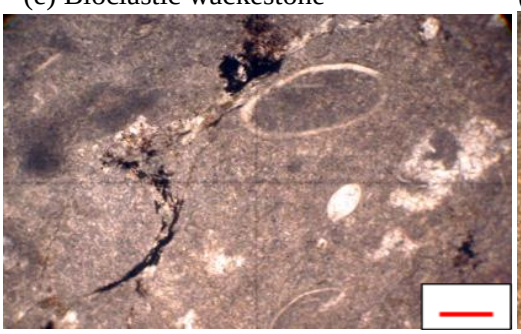
(d) Ferrugenous ostracod packstone



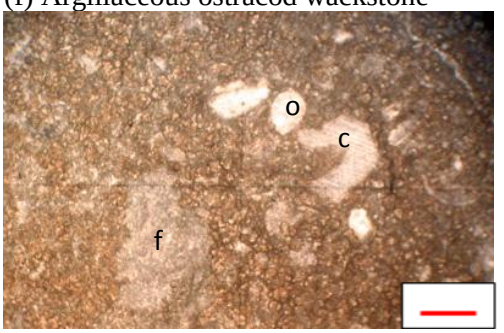
(e) Bioclastic wackestone



(f) Argillaceous ostracod wackstone



(g) Ferrugenous bioclastic wackestone



(h) Dolomitized bioclastic wackestone

Figure 3: (a-h) Microfacies of the Kyauktap area (scale bar = 200 µm)

Results

The limestones from the Kyauktap area comprises Kyauktap graptolite shales, gray phacoidal limestones, some purple phacoidal limestones in Nyaunglwe section, limestones with argillaceous seams and some limestones with pressure solution seams. The regional structural trend of the Kyauktap area is the same as the Linwe-Pegin area, nearly N-S and shale contents are more prominent in the southern part. The bioclastic materials of Kyauktap phacoidal section are more flourished than northern Nyauglwe section. The bioclastic materials are crinoids, trilobites, ostracods, brachiopods, calcisphere, etc. These bioclastic materials are very similar to base section of Wabya Formation. Larger bioclastic fragments can be encountered at some horizon and then smaller fragments of bioclasts are also observed. Gray phacoidal limestones from Kyauktap area are rich in bioclastic materials. Limestones with argillaceous seams are rich in mainly ostracods and some crinoids, and trilobites.

Vertical and lateral facies relationships represent argillaceous and ferruginous materials are alternatives. Among these, Nyaunglwe section which is northern part of study area is more limemud, argillaceous and ferruginous than Hlelan and Kyauktap phacoidal sections. Moreover, ostracoda are more abundant in the northern part. Some horizon is rich in ostracod and others rich in larger bioclastic materials. Three types of iron are present; pyrite, limonite and iron oxides. Typically, subtidal and tidal-flat facies are extensively interbedded through many vertical and lateral transitions. Typical lithofacies are lime mudstone, muddy peloidal packstone and wackestone and bioclastic wackstone (Moore *et al.*, 1983). The Hle Lan section (middle part) in which argillaceous contents are more abundant than ferruginous materials. Moreover, nodular microfacies and bioclastic materials are also more common because of the lower part of this section are interbedded with graptolite shales. The thin bed of calcisphere and larger fragments of trilobite are encountered in one horizon indicates the deposition of sediment under storm condition.

Kyauktap phacoidal section, southern part of study area, is only bioclastic wackestone and limemudstone. Phylloid algae is observed at the lower part of section indicate the deposition in shelf setting. Moreover the

reversible nature of calcite and quartz in some horizon seem to indicate sea level fluctuation during deposition. Ferruginous horizon can be observed alternately in the lower part of the section while argillaceous horizon in the upper part. Larger bioclastic materials, brachiopods, crinoids, trilobites and bivalve, are encountered in the lower part of the section that may be the deposition in an open marine during sea-level transgression (Figure 4). The presence of small amounts of replacement dolomite in some limestone horizon indicates that there would have been times of lowered sea level or prolonged droughts the salinity. Intraclasts limestones in the upper part of shale horizon may be deposited in subtidal channals during storms.

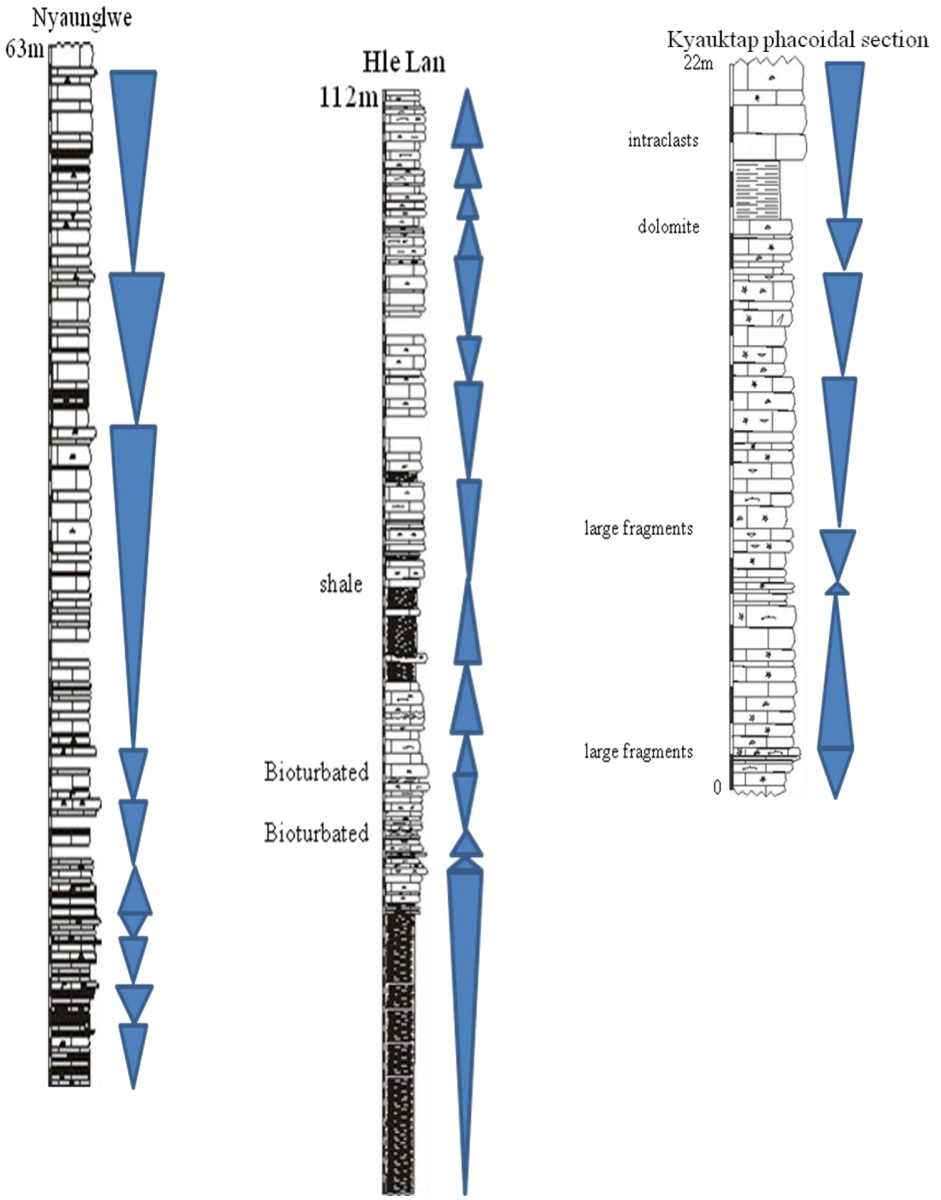


Figure 4: Vertical stacking pattern of deposition in three sections

Discussion

Cephalopods are considered for deposition of these limestones. Most cephalopods were nektic creatures with moderate to high mobility; some were benthic, but still mobile, organisms. All modern and ancient forms are interpreted as fully marine. Although cephalopods are found washed into marginal marine settings, they are most common in open shelf and deeper-water deposits. Purple phacoidal limestones are 2-5m thick sequence that occurred in the upper part of the section and purple colour due to iron-rich in the Naunglwe. Grey phacoidal limestones are normal salinity and 10 to 22 m thick. Thus vertical and lateral variations of the lithofacies and microfacies suggest that the entire Silurian sequence represents a depositional continuum of shallow subtidal, deeper subtidal and slope.

The marine transgression reached its maximum by late Silurian time, and deep water clastic sedimentation became more widespread (Hutchison, 1989). There are two types of transgressions namely slow transgressions and rapid transgressions. The slow transgression associated with internal cycles of

carbonate successions which do not interrupt the production of carbonates. The rapid transgressions associated with terminal cycles of carbonate successions which lead to the drowning of carbonate platforms and the change from carbonate to clastic systems. In this way, purple phacoidal limestone is overlained by graptolite shale is the indication of the sediment is overlain by shale and sea-level fluctuations during Silurian time.

Conclusion

The study area is located at the northwestern and southern parts of the Pindaya Range, Shan State (south) in topographic map no. 93C/12 and 93D/9. Five distinct lithofacies and fourteen microfacies in the Linwe-Pegin area and five distinct lithofacies and fourteen microfacies in the Yegyanzin-Wabya area are noticed. The purple phacoidal limestones occur at the base and gray phacoidal to typical nodular limestones occur at the top of the section. Abrupt shift of fossil in some stratigraphic level indicate the environmental control during sedimentation of Silurian sediments. Many of the transgressive surfaces are marked by fossil diversity in measured stratigraphic section.

The crinoidal limestones, phacoidal (nodular) limestones of Linwe Formation and whitish grey shales with many graptolites of Wabya Formation are encountered in Yegyanzin-Wabya area. In addition, the nodular limestones are encountered during Paleozoic (Silurian – Devonian) and Mesozoic (Jurassic – Cretaceous). This is the indication of global sea-level transgression with which nodular forming processes are related. Many of the features related to transgression include the abrupt disappearance of multiple species of graptolites in the shales; cephalopods, trilobites, echinoids, brachiopods, ostracod etc in the limestones; and the abrupt appearance of several new species of these groups.

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References

Adams, A.E., & MacKenzie, W.S., (1998), *A Colour Atlas of Carbonate Sediments and Rocks under the Microscope*, Manson Publishing, London, 180p.

Bencini, A. & Turi, A., (1974), Mn distribution in the Mesozoic rocks from Lima valley, Northern Appennines, *Journal of Sedimentary Petrology*, v.44(**3**), p.774-782.

Dunham, R.J., (1962), Classification of carbonate rocks according to depositional texture, in Ham, W.E. (Ed.): Classification of Carbonate Rocks. *American Association of Petroleum Geologists Memoir*. 1, p.108-121.

Flugel, E., (2004), *Microfacies Analysis of Limestones*: analysis, *interpretation and application*, New York, Springer-Verlag, Berlin Heidelberg, 976p.

Myint Lwin Thein , (1973), The Lower Paleozoic Stratigraphy of Western Part of the Southern Shan State, Burma: *Geological Society of Malaysia*, Bull. 6, p.143-163.

Scholle, P.A. & Ulmer-Scholle, D.S., (2003), *A Colour Guide to the Petrography of Carbonate Rocks*, AAPG, Memoir 77, 474p.

Yin Min Htwe, (2011), Sedimentology of the Silurian rocks of the Pindaya and Bawsaing ranges, Shan State (south), *PhD Thesis*, University of Yangon (Unpublished), 162p.