SEQUENCE STRATIGRAPHY OF THE OLIGOCENE LIMESTONES EXPOSED AT HTONDAUNG AREA, THAYET TOWNSHIP, MAGWAY REGION, MYANMAR

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Abstract

The study area is situated in Thayet Township. The present work mainly emphasizes on the limestone bodies in the Okhmintaung Formation of the area. The carbonate rocks exposed at Thayet area contains stacked depositional cycles consisting of characteristic succession of sedimentary facies and facies associations. The stratigraphic succession starts on delta abandonment phases together with an erosional surface at the base of facies, *Grobigerina* packstone-grainstone facies in the lower part. Delta abandonment phase is indicated by the occurrence of swamp development and the subsequent formation of coal at the base of Limestone. Through the succession, repetitive of inner, middle and outer ramp facies associations are present, and then they are followed by an alternation of shale and sandstone facies at the top. The term "cycle boundary" was used to determine the fourth-order cycles. The individual cycles were numbered 1-5 and the same numbers were used for their respective boundaries. The fourth–order cycles (parasequence sets) can be recognized by environmental changes within section; by the graduality of the change in fauna and the co-occurrence or normal marine perforates and platform-interior imperforates, and a relatively large amount of planktonic foraminifera. The first level or base level 'C-1' of the Limestone shows the shallowing upward, start with basinal blue-grey shale, Globigerinid wackestone, Globigerinid packstone-grainstone, or *Lepidocyclina* packstone. The outer ramp sediment shifted just above outer ramp (basinal shale) sediment within the section. The cycle 'C-2' observes an outer to mid-ramp community of planktonic fauna in the lower part, and a gradual shift from a planktonic dominated fauna toward perforate larger benthic one of the mid-ramp in the upper. The cycle 'C-3' of the lower part consists of the retrogradation of the facies belts (from mid-ramp sediment to algal shoal of the inner ramp) marks the following TST aggradation and slow progradation of the corresponding HST. The cycle 'C-4' consists of bluish-gray shale with high amount of planktonic foraminifera (*Globigerina* sp., *Globotruncana sp., Nodosaria sp.*).The upper shows inner to mid-ramp sediments containing a rich perforate foraminifera (*Lepidocyclina* sp., *Operculina* sp.) packstone-grainstone containing coal and gypsum bearing shale. The base of the 'C-5' consists of yellowish brown calcareous shale with lime bands. The upper part shows middle to inner ramp sediments having rich in benthonic foraminiferal assemblages.

Keywords: carbonate rock, depositional cycles, ramp facies associations

Introduction

Location and Accessibility

The study area is located at about 4 miles southwest of Thayet Township. It lies between North Latitude 19° 15′ and 19° 18′ and East Longitude 95° 7′ and 95° 11′ within the one inch-map of 85 M/3. Being situated on the western bank of Ayeyarwady River, study area is accessible throughout the year. Location maps of Thayet area is shown in Figs. (1a).

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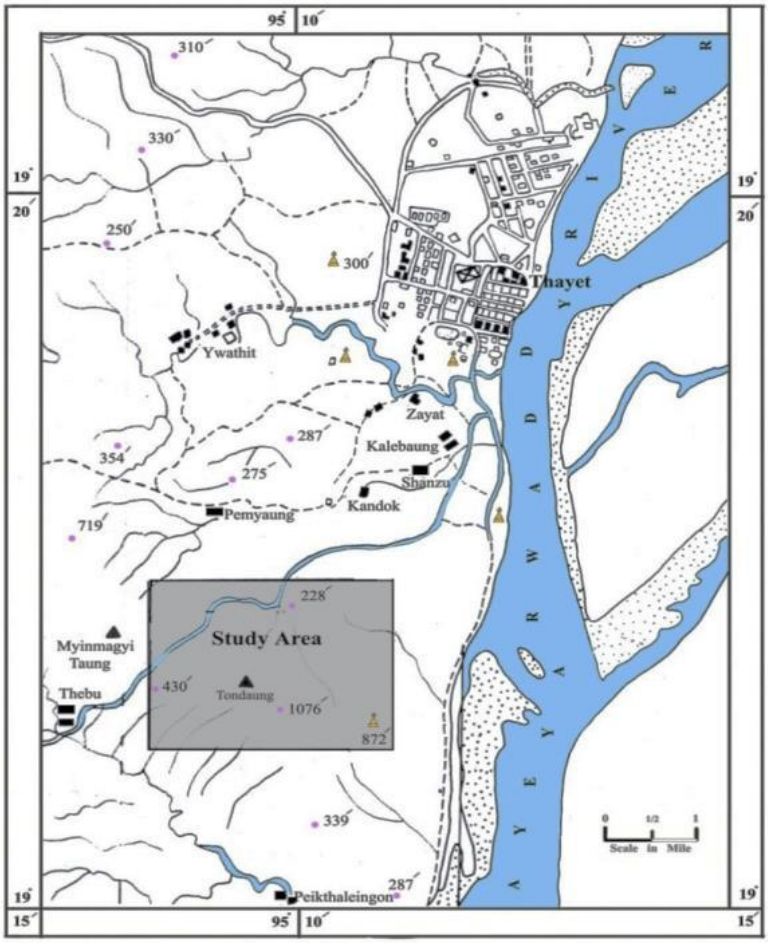


Figure 1 (a) Location map of the Thayet-Tondaung area.

Regional Geologic Settings

The present area is located in the Central Lowland. The Thayet areas near 19° 30′ North Latitude have most of the stratigraphic and structural characters of both the Central Basin and Pyay Embayment Basin. So, it is interpreted here that the Thayetmyo area, including the study area, may be regarded as a transitional area between the Central Basin and Pyay Embayment Basin belonging to the Central Cenozoic Belt consisting mainly of the Tertiary sediments (Aung Khin and Kyaw Win, 1969). More specifically, Thayet area and its environs are mainly composed of the rocks of the Lower Pegu Group (Oligocene), the Upper Pegu Group (Miocene) and Irrawaddy Formation (Pontian to Pliocene). As a result, the present study is mainly emphasized on the limestone bodies (carbonate rocks) of the area. It is exposed along the NW-SE striking in the Okhmintaung Formation. The stratigraphic units generally dip east with local variations near folds and faults. Structurally, NW-SE trending anticlinal and synclinal structures are dissected by faults. Lime hill is about one mile long in NW- SE direction and about a quarter mile wide, forming as an anticlinal structure plunging toward both NW and SE direction.

The core of anticline is occupied by the limestones and interbedded shales of the Okhmintaung Formation, forming the elevated part on the western bank of the Ayeyarwady River (Fig.1b & 1c).

Figure 1 (b) Land-sat image of the study area. (Source: Google Earth, 2008)

Methods of Study

The geology map is chiefly based on the work of the previous workers and one-million-scale map, and modification has been done wherever necessary. Besides, rock samples were taken for the purpose of making thin sections. Photographs and sketches were taken wherever necessary. Sequence stratigraphy of the limestone outcrops were measured in the field.

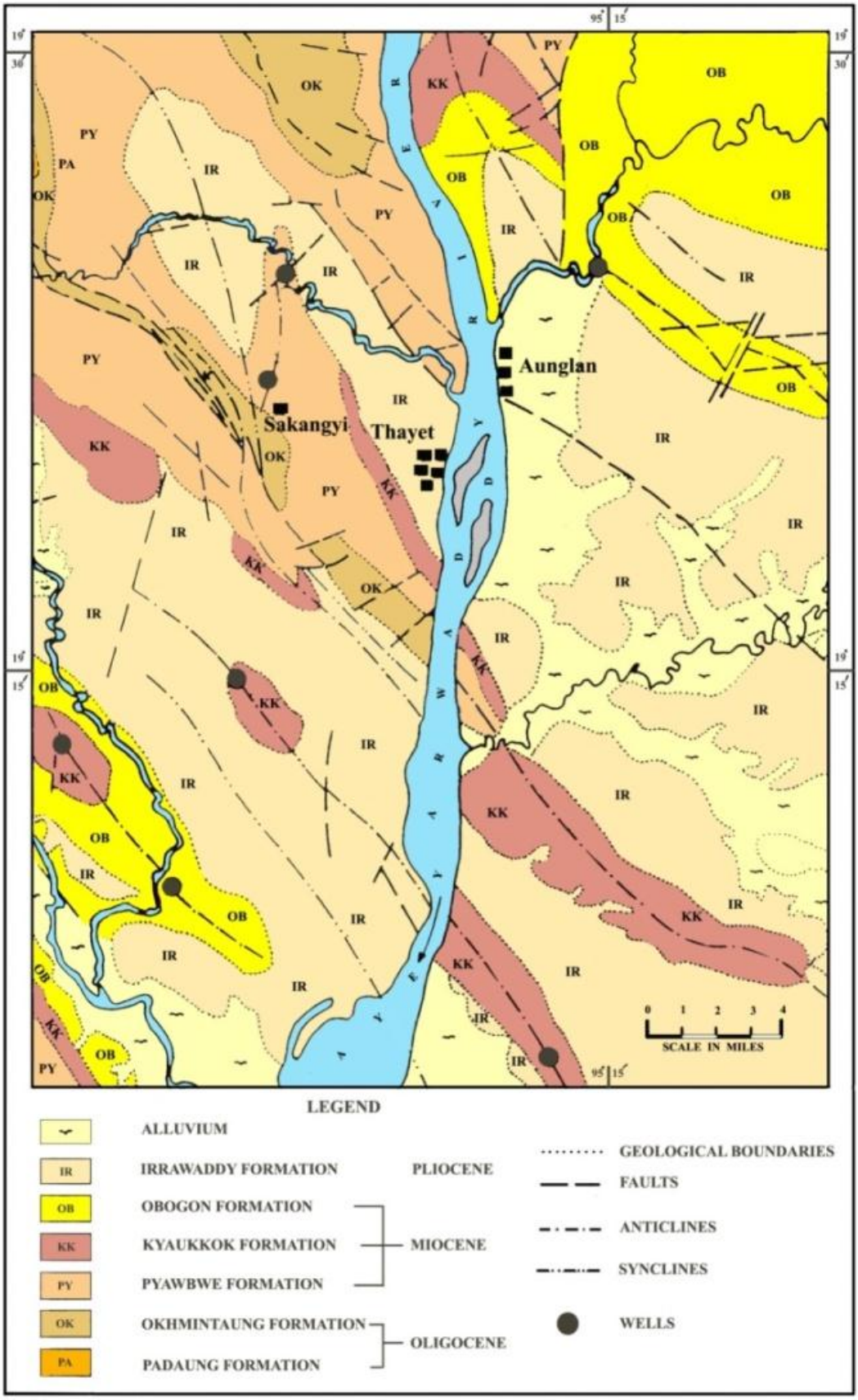


Figure 1 (c) Geological map of the Thayet-Tondaung area and its environs. (Modified from Chit Saing, 2003)

Result

Depositional Sequence and Cycle Boundaries and Transgressive Surfaces

In the present Tondaung area, the stratigraphic succession starts on delta abandonment phases together with an erosional surface at the base of facies *Grobigerina* packstone-grainstone facies in the lower part. Delta abandonment phase is indicated by the occurrence of swamp development and the subsequent formation of coal at the base of Tondaung Limestone (Fig.2).

Figure 2 (a-b) Yellowish gray shale containing coal layers exposed in Thayet area.

These carbonate facies are interrupted by fluvial incursion, based on the detailed measurements. Coal bearing shale beds indicate the shallow condition. The lower part of the succession indicates a marine transgression from fluvial through a tidal or estuarine to ramp environment with some fluctuations. Besides, foraminiferal fossils recorded from facies associations also support to confirm the marine transgression. The individual cycles were numbered 1-5 and it is here to say that the same numbers were used for their respective boundaries. Sequence boundaries in the Tondaung, are thought to be placed at the contact between progradation parasequence sets (Highstands) and retrograditional parasequence sets (Transgressive). It is apparent that the sudden superposition of transgressive beds upon prograding one is thought to represent a cycle boundary (CB). Based on this fact, in the Tondaung succession, the cycle boundaries are marked on the top surface of the shallowing and thickening upward cycle.. The indicator for the evidence of subaerial exposure is the presence of hardground surfaces (Fig.3).

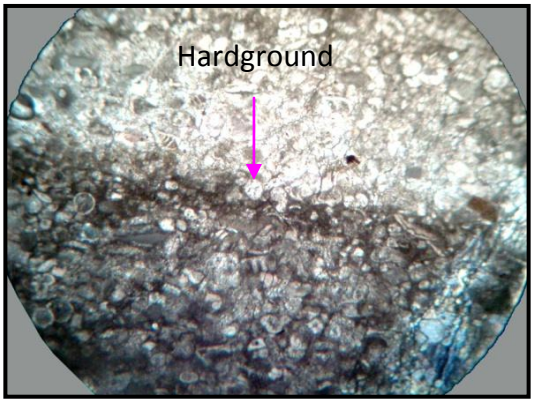


Figure 3 Photomicrographs of Globigerinid Wackestone containing *Globigerinia* and planar hardground with irregular surface probably formed by dissolution.

Features related to Transgression

Most cycle boundaries coinciding with transgressive surfaces especially occur at C1, C2, & C5 in which hard ground surfaces are developed. In the field, these surfaces can be easily visible by the presence of iron-stained surface and ionized bands (Fig.4a). Several of these surfaces combined with sequence display a horizon of intense burrowings suggesting the transgression period (Fig.4b). The edges of the burrows are well defined and sharp, suggesting a firm substrate.

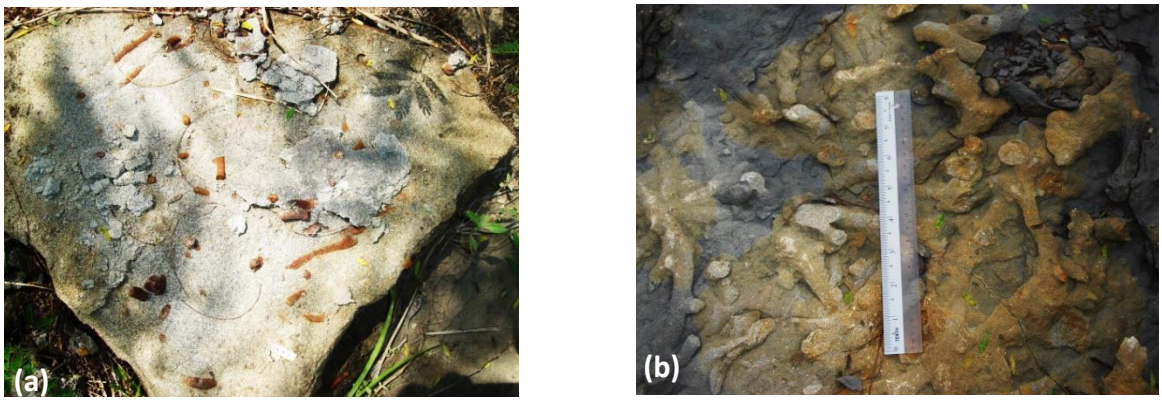


Figure 4 (a) Ionized bands and iron stain surface and (b) Intense burrowing in Oligocene Limestone.

Maximum Flooding Surface (mfs)

The marine flooding surface represent the time of maximum flooding on the ramp and is marked by shift from retrogradational to aggradational or progradational parasequence sets (Zwart et.al. 1994). The mfs coincides with maximum abundance of fossils (intense bioturbation) (Vail et al.1977). It is difficult to locate the position of mfs exactly within measured section. In this study, mfss have to be probably defined by using the changes in lithologic unit or in facies, the presence of intense bioturbation (Fig.5a,b), and transgression pointing at the beginning of progradation.

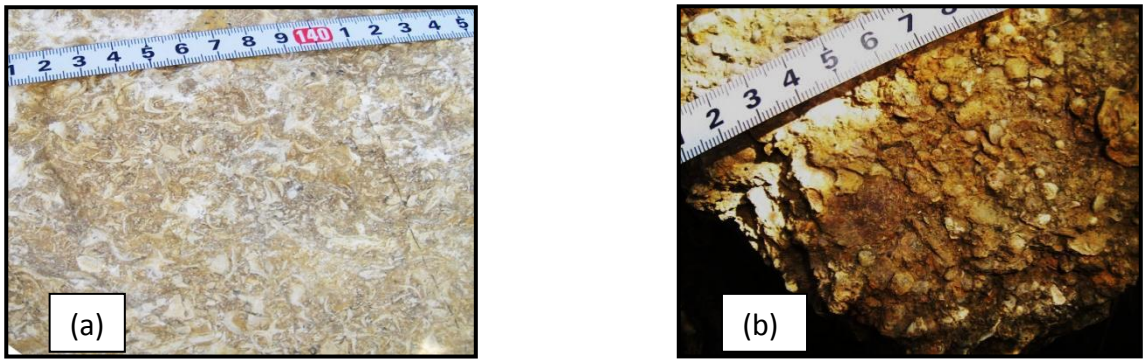


Figure 5 (a) Shell fragments in creamy limestone and (b) Pelecypods in buff color silty limestone at Tondaung mine, indicating maximum flooding surface.

System Tracts

Lack of Lowstand System Tracts

The lowstand systems tract may include two distinct parts, the lowstand fan (basin-floor submarine fan) and the lowstand wedge (Tucker et al.1993). In the present area, these features are missing or absent, so it is thought to be considered as lacking in lowstand system tract.

Transgressive System Tracts (TST)

It is characterized by retrogradational parasequence (deepening trend) of the ramp. It is underlain by the transgressive surface and overlain by the maximum flooding surface. In another way, the TST is bounded at the base by transgressive surface display features attributable to subaerial exposure (Fig.6). The basal surface of the TST is a marine flooding surface with the indication of abrupt deepening (Burchette et.al. 1990).

Highstand System Tract (HST)

Highstand Systems Tracts are defined by either aggradational or progradational parasequence sets. The mfs is the basal surface of the system tract (See also Fig.6). The top surface of the HST is transgressive surface as well as CB. The HST consists of an aggradational to progradational set of parasequences that overlies the maximum flooding surface and is overlain by the next sequence boundary. In Thayet-Tondaung area, HST cycle is described by shallow to deep subtidal facies. In measured section, HST is typified by both aggradational and progradational stacking patterns.

Cyclicity

It is observed that the carbonate ramp of Tondaung has a clear picture of cyclicity not only in megascopic but also in microscopic scales. The features that found on megascopic contain alternation of hard and soft lithologies and upward thickening or shallowing cycles (Fig. 7).

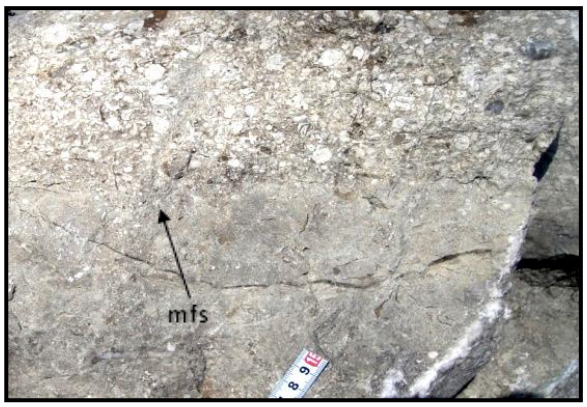


Figure 6 Intense bioturbation indicating the maximum flooding surface (mfs) at Thayet area.

Figure 7 Thickening upward cycle of buff color silty limestone at Thayet area.

Discussion

Cycles of the Thayet-Tondaung Section

Five cycles could be recognized in Thayet area (C1-C5), separated by cycle boundaries.

The first level (or) base level of cycle 'C-1' of the Tondaung Limestone shows the shallowing upward, start with basinal blue grey shale, Globigerinid wackestone, Globigerinid packstone grainstone, or *Lepidocyclina* packstone (Fig.8a). The lower part of the section is alternately composed of blue gray shale, forams wackestone-packstone and forams packstone-grainstone. The presence of planktonic foraminifera (*Globigerina*) is usually found in the shallow–deep transtitional fore reef zone.

The cycle 'C-2' observed in the basal part, predominance of an outer to mid-ramp community of planktonic fauna, and in the upper part a gradual shift from a planktonic dominated fauna toward perforate larger benthic one of the mid-ramp. The lower part is interpreted as a TST whereas the upper part as a HST. The boundary between the lower and upper part is marked by a sharp, sudden change in fauna and lithology; gray packstone containing abundant planktonic (*Globigerina)* is substituted by creamy skeletal lime sand with predominance of perforate (L*epidocyclina* sp, *Amphistegina* sp.) The faunal assemblages suggest that there were no effective burrier present, the boundary and change in fauna at the TST/HST transition (mfs).

The cycle 'C-3' of the lower part consists of retrogradation of the facies belts (from mid-ramp sediment to algal shoal of the inner ramp) marks the following TST aggradation and slow progradation of the corresponding HST.

The lower part of the sequence starts with carbonaceous shale overlain by well bedded *Lepidocyclina* packstone- grainstone to red algae foraminifera grainstone. The lower part is regarded as TST on the outer ramp, basinal shale; the upper part is interpreted as a HST deposition in an inner ramp algal shoal and capped by iron-staining packstone (Fig. 8b) and meteroic diagenetic.

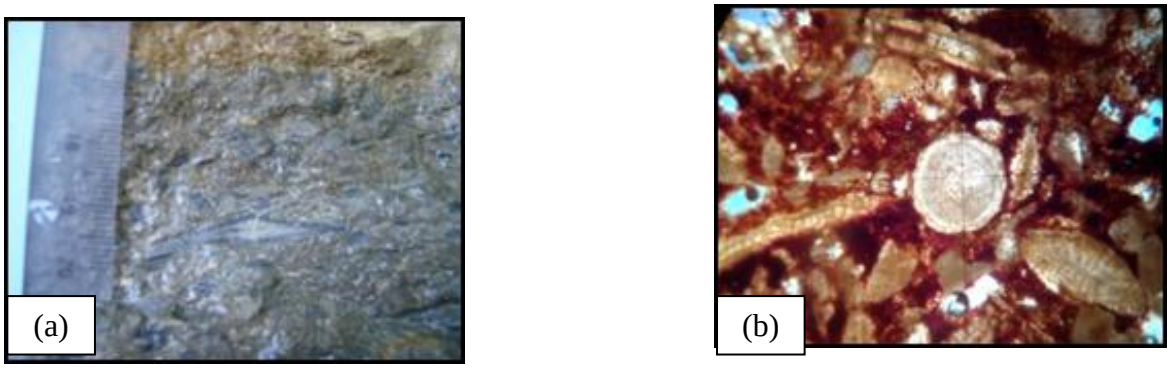


Figure 8 (a) Light grey, thick-bedded limestone containing abundant Lepidocyclina exposed in the middle part of measured section. **(b)** Photomicrographs of ironized bioclastic grainstone in which iron cement is coating on the detrital grains. Scale bar is 0.1mm.

The basal sequences of the cycle 'C-4' consist of bluish gray shale with high amount of planktonic foraminifera (*Globigerina* sp, *Globotruncana* sp ,*Nodosaria* sp).The upper shows inner to mid-ramp sediment contain a rich perforate foraminifer (*Lepidocyclina* sp, *Operculina* sp) packstone-grainstone, containing coal, and gypsum bearing shale. This associations is typical of deltic and marginal marine fauna of gastropod, pelecypod and bryozoan, echinoderm etc.),

separated by coastal marine shale, delta plain organic clay and coals, mark local transgerssive phase related to local delta lobe abandonment.

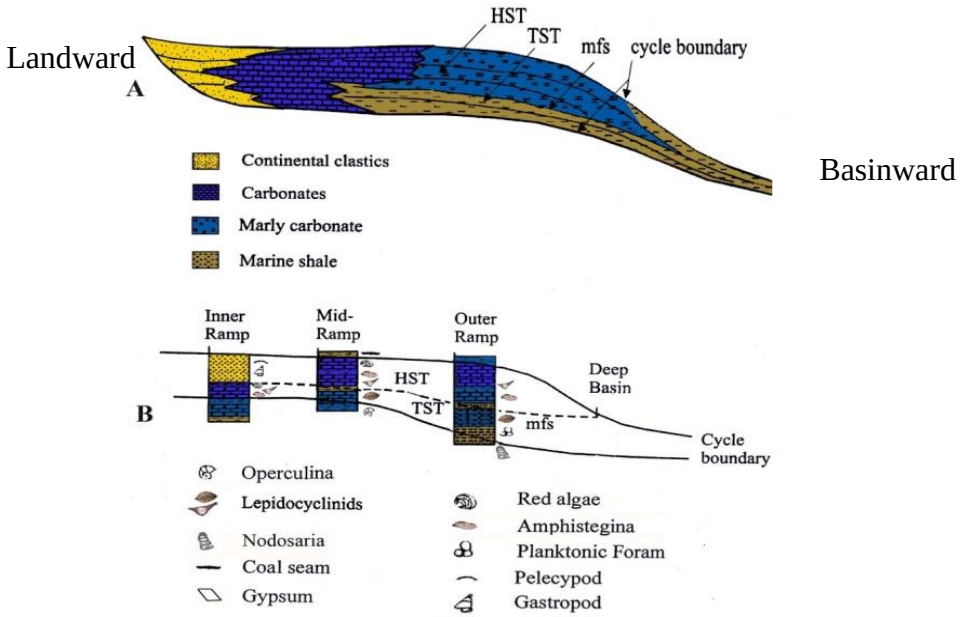
The base of the cycle 'C-5' consists of yellowish brown calcareous shale with lime bands. The upper part shows middle to inner ramp sediments containing rich benthonic foraminiferal assemblages indicating a sharp sudden change boundary between lower and upper. In contrast, the yellowish brown calcareous shale of middle ramp is substituted by well bedded sandy packstone to grainstone with abundant benthic foraminifers, pelecypods and gastropods fossils. Then, carbonates were deposited following a transgression brought about by compaction of overlying deltic sediments. Considering the base of middle ramp is interpreted as a TST and the upper inner - ramp is interpreted as HST.

After that, mixing of siliciclastic-carbonate facies is formed at the top of the Tondaung section. A mixed siliciclastic-carbonate facies point out that siliciclastic facies prograded basinward or progradational parasequence sets of the late highland.

Model of Sequences

The observed sedimentary cycles in Htondaung area were interpreted with a sequence stratigraphic ramp model (Fig.9). This model is derived from sequence staratigraphic ramp models (Vail et.al 1977) but highly modified for the specific conditions observed in Tondaung area.

Once fourth-order depositional sequence is shown with system tracts and associtated facies distribution in Fig.9a. Three simplified sections through one cycle are displayed for the outer ramp, the mid-ramp and the inner ramp. The three depositional systems combine to form five sequences are observed in Thayet-Htondaung area (see also Fig. 9b).



TST - Trangressive Systems Tracts, HST - Highstand Systems Tracts, mfs – Maximum flooding surface

Figure 9 Empirical Model for a depositional fourth order cycle on the carbonate ramp of Tondaung area. (a) Distribution of facies in system tracts and (b) three typical sections for inner, middle and outer ramp (Not to scale).

Summary and Conclusion

The Thayet- Tondaung section shows a clear cyclicity on megascopic scale. Five fourth-order shallowing upward, parasequence cycles can be recognized by environmental changes within the section. In the description of the section, deepening trends (retrograditional stacking) are considered Transgressive systems Tracts (TST), shallowing trends (progradational stacking) are held to be Highstand System Tracts (HST), and the change from deepening towards shallowing is interpreted as maximum flooding surface (mfs). The sudden superposition of transgressive beds upon prograding one as thought to represent a Cycle Boundary (CB). Cycle boundaries recognized in this study were initially identified abrupt shift from shallowing trend to deepening trend response to increase in water depth and the lowstand systems tract is missing. As a result, this study focused on depth trends to identify stacking patterns. Progradational stacking was indicated by a net shallowing upward trend through a series of parasequences. Retrogradational stacking is despite upward shallowing within each of component parasequences. Many of the cycle boundaries that coincide with transgressive surface have hardground developed on them, usually with pyrite and iron-stained surface, and surface display a horizon of intense burrowing. The three depositional systems combine to form five sequences are observed in Thayet area.

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