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Shell Bed Identification of Kaliwangu Formation and its Sedimentary Cycle Significance, Sumedang, West Java

Identifikasi Lapisan Cangkang dan Signifikansi Siklus Sedimentasinya pada Formasi Kaliwangu, Sumedang, Jawa Barat

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AbstrAct

Kaliwangu Formation cropping out around Sumedang area contains mollusk fossils dominated by gastropods and bivalves. In terms of sequence stratigraphy, each sedimentary cycle generally consists of four shell bed types: Early Transgressive Systems Tract (Early TST) deposited above an erosional surface or sequence boundary, that is characterized by shell disarticulation, trace fossils, gravelly content, no fossil orientation direction, and concretion at the bottom; Late Transgressive Systems Tract (Late TST) identified by articulated (conjoined) specimen in its life position, that shows a low level abration and fragmentation, adult specimen with complete shells, and variation of taxa; Early Highstand Systems Tract (Early HST) characterized by adult taxa that was found locally in their life position with individual articulation, juvenile specimens frequently occured; Late Highstand Systems Tract (Late HST) determined as multiple-event concentrations, disarticulated shell domination, and some carbon or amber intercalation indicating terrestrial influence. Shell bed identification done on this rock unit identified nineteen sedimentary cycles.

Keywords: shell bed, sedimentary cycle, sequence stratigraphy, Kaliwangu Formation, West Java

Sari

Formasi Kaliwangu yang tersingkap di sekitar wilayah Sumedang mengandung fosil moluska yang didominasi oleh gastropoda dan bivalvia. Berdasarkan kerangka sikuen stratigrafi, pada setiap siklus sedimentasi umumnya terdapat empat jenis lapisan batuan yang mengandung cangkang moluska, yaitu: Transgressive Systems Tract Awal (TST Awal), batuan diendapkan di atas bidang erosi atau batas sikuen, ditandai dengan disartikulasi cangkang, fosil jejak, kandungan kerakal, tidak ada orientasi arah dari fosil-fosilnya, dan konkresi pada bagian bawah lapisan; Transgressive Systems Tract Akhir (TST Akhir) diidentifikasi oleh kehadiran artikulasi cangkang dalam posisi hidupnya, yang menunjukkan tingkat abrasi dan fragmentasi cukup rendah, spesimen dewasa dengan cangkang utuh, dan variasi taksa; Highstand Systems Tract Awal (HST Awal) ditandai oleh kehadiran fosil dewasa yang ditemukan setempat-setempat dalam posisi hidupnya pada keadaan individual artikulasi, sering dijumpai kehadiran fosil moluska yang masih muda (juvenile); Highstand Systems Tract Akhir (HST Akhir) ditandai oleh multiple-event concentrations (perselingan), cangkang disartikulasi umum dijumpai, dan sisipan karbon atau amber yang menunjukkan adanya pengaruh terestrial. Identifikasi lapisan cangkang yang dilakukan pada setiap lapisan unit batuan ini teridentifikasi sembilan belas siklus sedimen berdasarkan karakteristik lapisan cangkang.

Kata Kunci: *lapisan cangkang, siklus sedimen, sikuen stratigrafi, Formasi Kaliwangu, Jawa Barat*

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INTRODUCTION

In this paper, the shell bed study was using taphonomic analysis, where taphonomy is a study of geological activity happened after the death process of organisms, and transformed into fossils. Mollusk fossil data were used to interpret its sequence stratigraphic depositional element. Sequence stratigraphic element studies based on shell bed analysis were done by several authors such as: Cantalamessa *et al.* (2005), Kondo *et al.* (1998), Parras and Casadio (2005), Aditya *et al.* (2008), and Aswan (2009).

The shell bed study was based on mollusk fossil content within outcrops of Pliocene Kaliwangu Formation, along Cikandung and Cipedes Rivers, Sumedang, West Java. The studied area is the northeastern part of Sumedang town, West Java as shown in Figure 1.

The present study is a part of a join-research focused on unraveling the palaeodepositional history ofthe marine Pliocene strata in West Java. The aims of the study are to: (a) constraint the lower part ofthe Kaliwangu Formation within a sequence stratigraphic framework by means of integrated paleontological, sedimentological, and stratigraphic observations of shell bed concentrations associated with key stratal surfaces; and (b) provide the distinctive characteristics of shell beds in this area. The scarcity of Late Tertiary shallow marine deposits preserved onshore in Java will develop an interest ofthis locality where strata ofthis temporal span are well exposed and easily accessible.

GEOLOGICAL SETTING

Pliocene marine sedimentary rocks in Java were mainly preserved in offshore depocentres. However, while sedimentation still continues beneath the modern sea level, some margins of coastal basins have

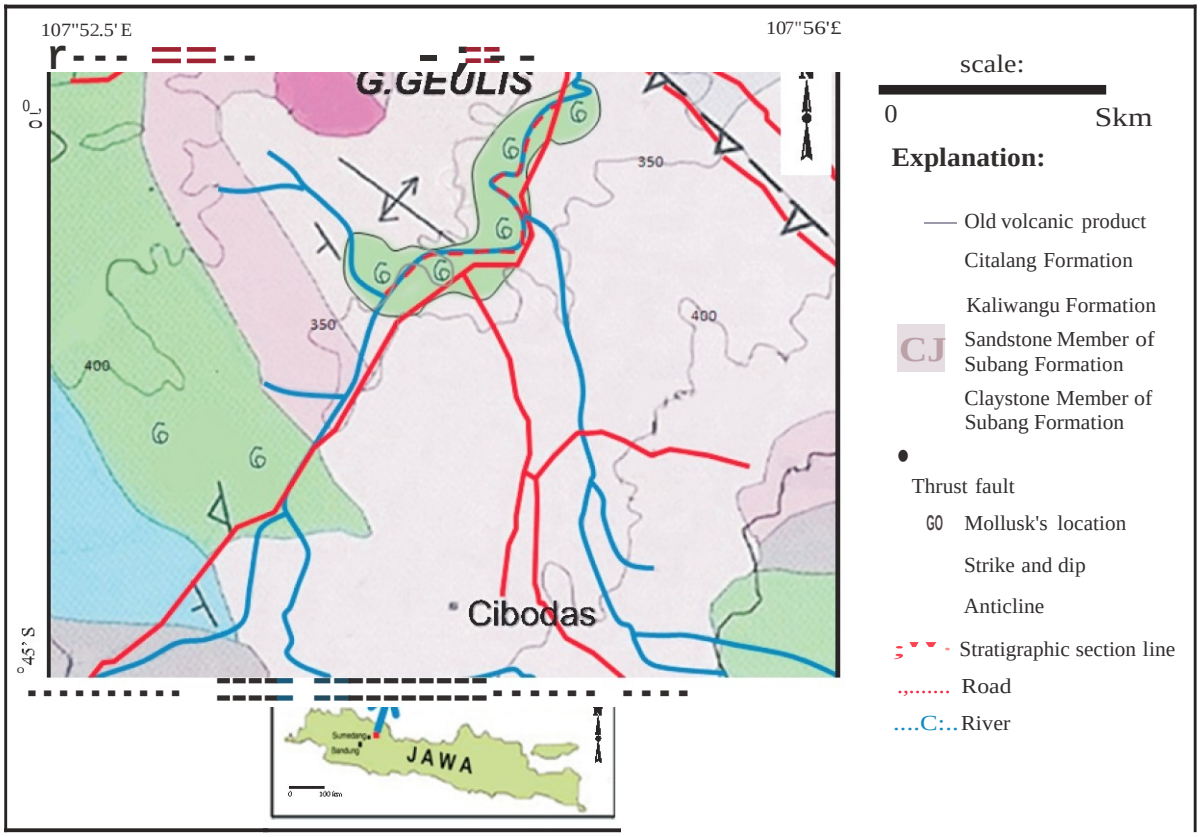


Figure 1. Geologic map of the studied area showing stratigraphic section lines (red dashed line) along Cipedes and Cikandung Rivers. Index is Java map showing the researched area locality in the northeastern part of Sumedang Town.

undergone a gentle Plio-Pleistocene uplift, generated excellent coastal exposures of the Pliocene siliciclastic successions. The Kaliwangu Formation was deposited in the eastern part ofBogor Basin (Martodjojo, 2003) (Figure 2), where the Bogor Basin occupies the south of Jakarta coastal plain and continue to the west- east along Bogor, Purwakarta into Burniayu in Central Java. The Kaliwangu Formation is one of the significant accumulations of mainly Neogene shallow marine strata exposed on land but there are just a few studies about the mollusk contents such as the one written by Aswan and Zaim (1998) and Unggul (2009). The outcrops represent a critical interval and a valuable reference section (Rijani, 2009), where environmental changes and glacio-eustatic evolutions that affected this part ofWest Jawa during Pliocene can be recognized (Aswan *et al.*, 2008).

MATERIALS AND METHODS

Two stratigraphic sections located in Cikandung and Cipedes Rivers were measured and described. Both sections are in Tanjungkerta Subregency, Surnedang Regency or at coordinates around 107° 44'00" E to 107° 40'20" E and 06° 56'00" S to 06° 53'30" S. The sedimentologic study was based on 83 m in stratigraphic thickness from Cikandung River and 72 min stratigraphic thickness at Cipedes River. Strike of these rock layers are almost to the NW with 17° to 30° dip. Observation of the sections includes descriptions of lithology, sedimentary structures, and paleontological aspects. Based on these features, some taphonomic facies were recognized and grouped according to their vertical and lateral arrangement in several facies associations. Facies were initially identified and characterized in the field. Mollusk fossil concentrations were classified following Kondo *et al.* (1998) and Aswan (2006), considering their stratigraphy, inferred histories of accumulation, and position within the depositional sequence. Thus, several features were recorded, including stratigraphic (thickness, lateral extent, geometry, stratigraphic contacts, association with significant surfaces, and position within depositional sequence), sedimentologic (type of matrix, associ-

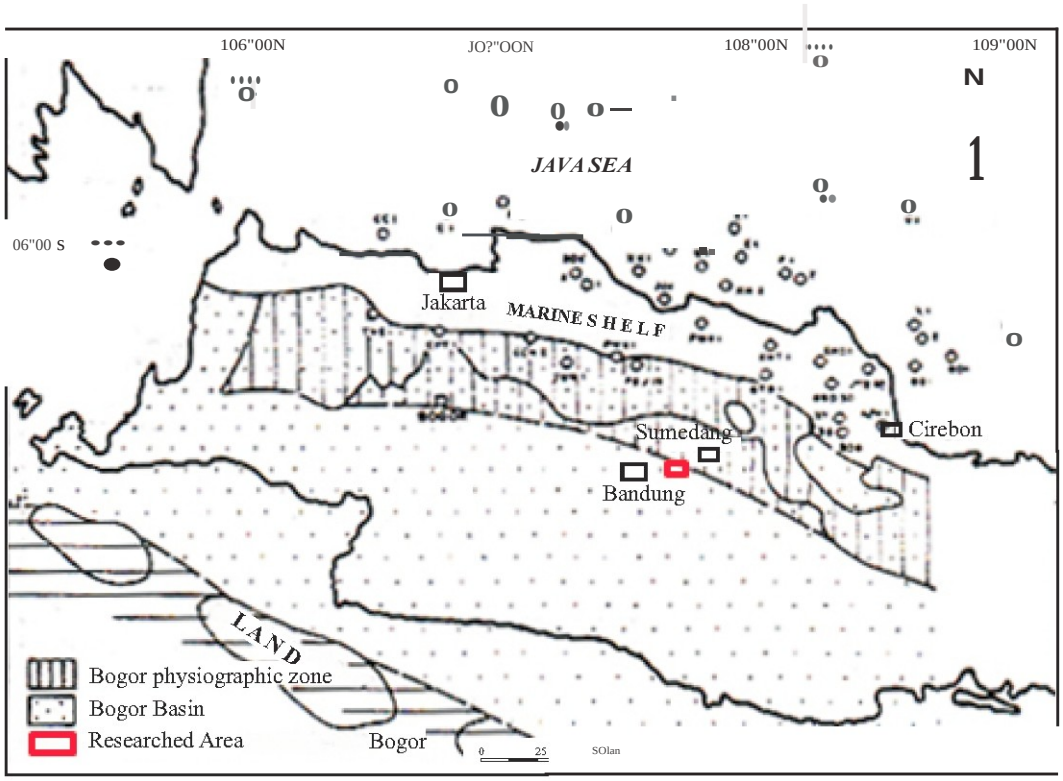


Figure 2. Red box in the Bogor Basin map indicates the studied area (Martodjojo, 2003).

ated physical and biogenic sedimentary structures), palaeoecological (taxonomic composition, life habits), and taphonomic (orientation, fragmentation, abrasion, disarticulation, encrustation, bioerosion) features.

The identification of mollusk fossils obtained from the studied area shows that the Cikandung River contains: *Zaria angulata* Sowerby, *Placuna placenta* Linnaeus, *Paphia (Calliotapes) vandermeermohri* Oostingh, *Corbula cheribonensis* (Oostingh), *Anadara (Anadara) tambacana* (:tvlARTIN), *Nassarius (Zeuxis) verbeeki* (MARTIN) *Oliva (Anazola) gibbosa* (MARTIN), *Siphonalia paradoxica crassicostata* :tvlARTIN, *Terebra* sp., *Chlamys* sp., and *Natica* sp. Meanwhile in the Cipedes River section, there were *Zaria angulata* Sowerby, *Placuna placenta* Linnaeus, *Paphia (Calliotapes) vandermeermohri* Oostingh, *Paphia cheribonensis* Oostingh, *Corbula (Anisocorbula) socialis* :tvlARTIN, *Anadara (Anadara) tambacana* (:tvlARTIN), *Nassarius (Zeuxis) verbeeki* (:tvlARTIN), *Murex (M.) lebacanus* MARTIN, *Oliva* sp., and *Arca* sp. The fossil contents between these two river sections have different characteristics that may be due to the environmental changes during sedimentation.

CHARACTERISTIC OF SHELL BEDS

Sequence stratigraphic unit terminologies according to taphonomic characteristics used in this study were based on Cantalamessa *et al.* (2005) and Parras and Casadio (2005). Both references were used as a standard due to its appropriate sedimentary cycle characteristics from the outcrop, which is especially not the content of Lowstand system tract layers.

Sequence stratigraphic elements which could be determined are:

TST (Transgressive System Tract)

Transgression happens when sediment supply falls or accommodation space rises caused by the relative rise in sea level. Surface where the water level reaches a maximum landward position is known as a maximum flooding surface (Posamentier *et al.*, 1988; Van Wagoner *et al.*, 1988). Sequence boundary is the surface that divides distinctly lowstand and transgressive system tract which is also known as a transgressive surface (Posamentier *et al.*, 1988).

Early TST

Early TST (Figures 3 and 4) starts on a ravinement surface or sequence boundary. Because of the distinct erosional surface at their base, shell disarticulation, trace fossils, and gravelly content, there is no taxa orientation and concretion layer. Shell content, as mentioned previously, is interpreted as a reworked residue of previous deposited sediments (Parras and Casadio, 2005). Cantalamessa *et al.* (2005) also noted that concretion could also be a marker for this early TST.

Figure 3. Early TST unit indicated by trace fossils and reworked shell (in the red ellipse) within a concretion layer.

Figure 4. Early TST unit indicated by *Placuna placenta* concretion attached to the sandstone (in the red circle) within concretion layer.

Late TST

Late TST (Figure 5) deposit is a hiatal concentration that happened due to the continuing sea level rise. Late TST is identified by an articulated (conjoined) specimen as its living position, showing low level of abration and fragmentation, adult specimen with complete and variation of taxa, and some barren layers. This concentration was accumulated when a high rate production of biogenic hard parts as a result of accommodation space addition and a low sediment rate. Therefore, the water condition almost contains no suspension deposits and the mollusks could grow perfectly (Parras and Casadio, 2005).

Figure 5. Late TST unit shown by *Zaria angulata* as its living position (in the red ellipse) where its long axis parallel to the original horizontal sediment position.

HST (Highstand System Tract)

HST deposited after Maximum Flooding when sea level continued to rise at a slower condition compared to during TST. This condition caused a relative sediment supply to change to be similar with the accommodation space rate. Usually, during this stage transgression phase end and starts to the regression phase. In this regression phase "the sediment supply versus accommodation space factor" increased, particularly in the beginning of Late HST.

EarlyHST

In the Early HST (Figures 6 and 7) deposit usually individually adult taxa in life position, juvenile dominated, few fragmented and disarticulated shells, carbon or coal layers were found spottedly. The condition ofthis phase caused mollusks not to grow perfectly and usually they were found as juvenile fossils, due to the environmental situation which began to change into a turbid condition (Parras and Casadio, 2005).

Figure 6. Early HST unit revealed disarticulated *Paphia cheribonensis* (in the red ellipses).

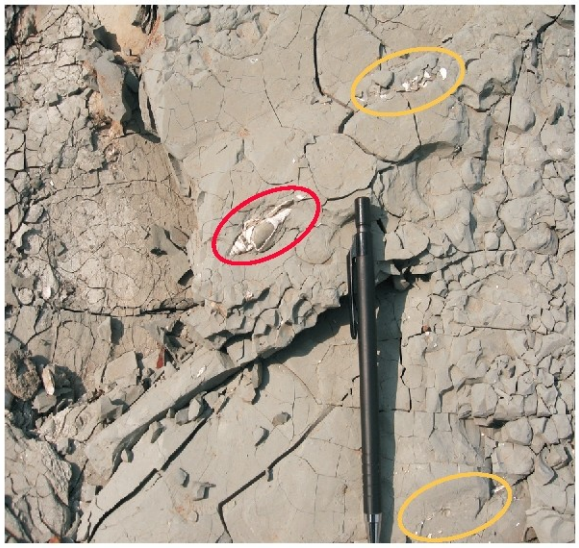


Figure 7. Early HST unit revealed *Nassarius* sp. and fragmented mollusk (in the red and yellow ellipses).

Late HST

The peak ofHST (Figure 8) that associated with a highstand condition of sea level is usually characterized by multiple-event concentrations, such as repeated series of abundant fragmented shell fossil layer and relative barren fossil layer (Parras and

Figure 8. Late HST unit sediments show a multi-event concentration of intercalation between shell layer and nonshell layer, alternating *Zaria* sp. (see arrows for more detail).

Casadio, 2005). In this study, this sequence stratigraphic element was characterized by multiple event concentrations observed, living position mollusks locally found where the long axis of gastropods are parallel to the original horizontal position of the sediment, disarticulated and fragmented shell domination, and some carbon or amber intercalations which indicate a terrestrial influence.

DISCUSSION

Several points about the taphonomic relationship of each shell type concentration and the sedimentary cycle from the studied area need to be taken into account in its interpretation:

The Early TST (Figures 3 and4) occurred above the erosional limit or sequence limit (sequence boundary). Distinct characteristics of this system observed from the studied areas were the presence of disarticulation, bioturbation, gravel mixing (coarse sediment layer on finer layer), and high frequency of unoriented mollusk fossil fragmentation. They originated from previous deposition with indeterminable taxa, intense abrasion indication generally diminishing upwards, amber finding and concretion varying in size and shape which follow bedding direction. In Cikandung (Figure 9) and Cipedes River (Figure 10) observation tracks, this Early TST was found on cycle number 1, 3, 4, 8, 10, 11, 12, 13, and 19, and on cycle number 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 36, and 40 respectively.

Late TST (Figure 5) is the barren concentrations occurring due to the continuation of sea level rise on a low energy water environment. This system could be recognized in the studied areas by the presence of life position fossils, where long axis of gastropod fossils are parallel to the original horizontal sediment position, or articulation (conjoined) of each taxa, low fragmentation with intact, mature, and more varieties of fossils indicating low level abration as well as barren layer finding. In the Cikandung River observation track (Figure 9), this Late TST was found on cycle number 11 and 13; whilst in the Cipedes River Track, the Late TST occurs on cycle number 20, 25, 26, 27, 28, 29, and 35.

In the Early HST (Figures 6 and 7) a mixing between juvenile and adult individual mollusk fossils was commonlly found. When the sea water level began to fall, mollusks could not completely develop due to early sediment saturation on the environment (Parras and Casadio, 2005). On this condition, adult mollusk fossils were generally laid on their life position to form individual articulation, while the presence of dominated juvenile mollusk fossils occasionally indicates rapid sedimentation processes. The shells were disarticulated and fragmented. In the Cikandung River observation track (Figure 11), this system was found on cycle number 1, 3, 5, 7, 9, 10, 11, 12, 13, 15; whereas in the Cipedes River one, the system occurs on cycle number 19, 21, 27, 28, 29, 34, 37, and40.

The Late HST (Figure 8) peak was characterized by the repeated events (multiple-event concentrations) when the shell orientation was relatively parallel to the empty fossil layers generally dominated by disarticulated adult mollusk fossils that might indicate that there a very rapid accretion had taken place. Carbon insertion might also be found, as the sea water fall which could be associated with coarse grain sediments in Cikandung (Figure 11) and Cipedes River (Figure 12) observation paths, especially on cycle number 4, 7, 11, 12, 16, and 17; and 20, 24, 28, and 37 respectively.

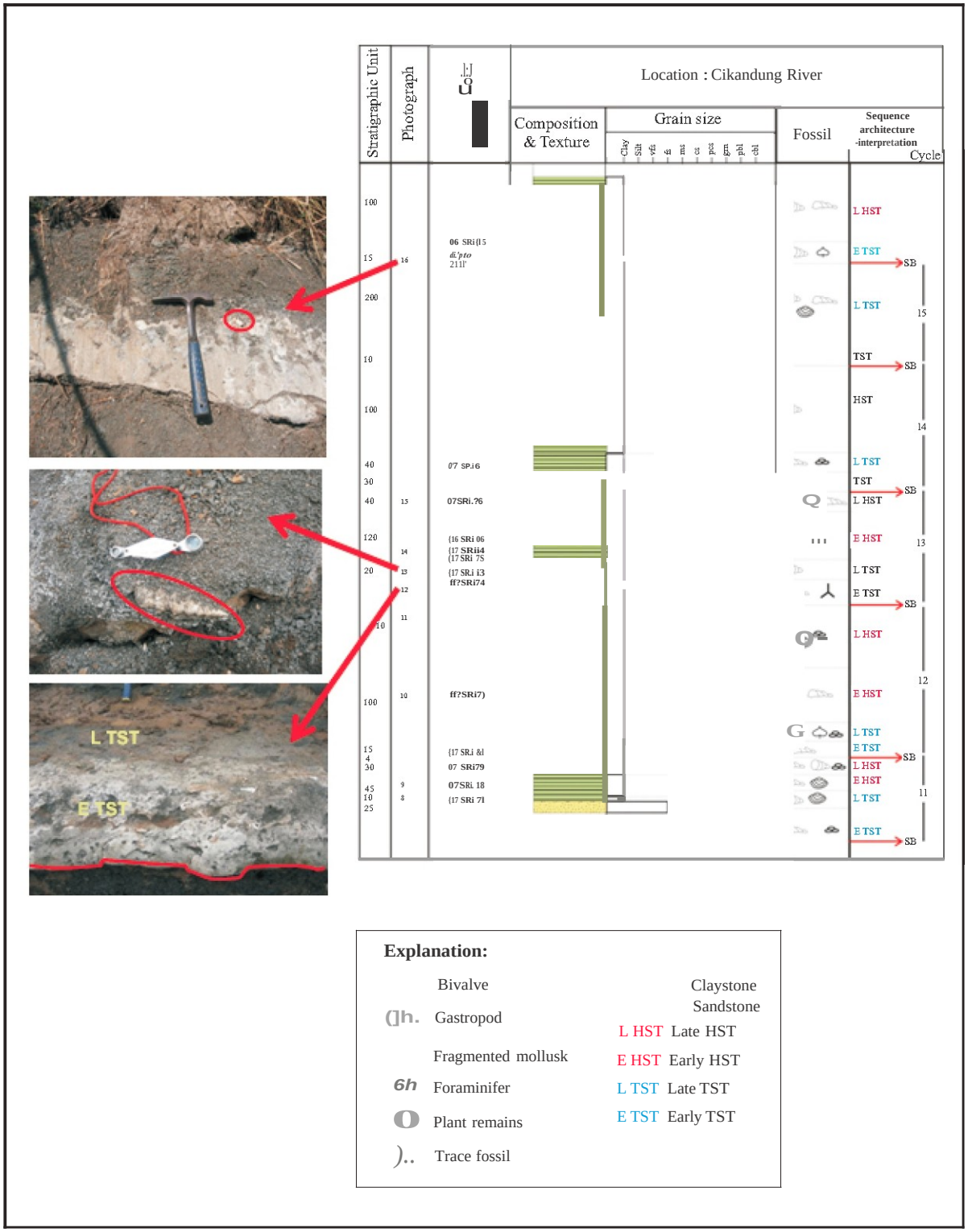
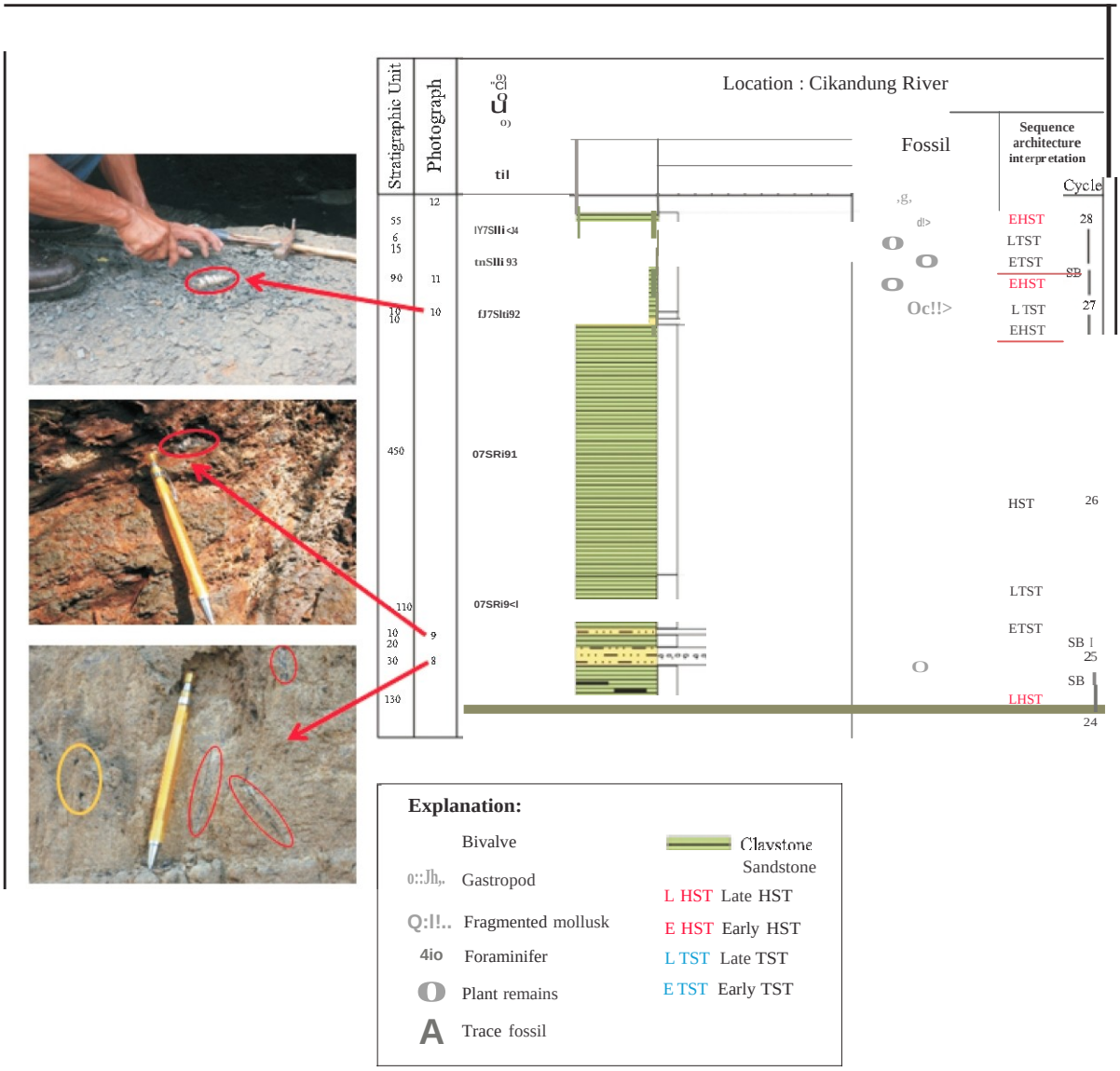


Figure 9. Stratigraphic column shows Early and Late TST intervals along the Cikandung River.



Figurel 0. Stratigraphic column shows Early and Late TST intervals along the Cipedes River.

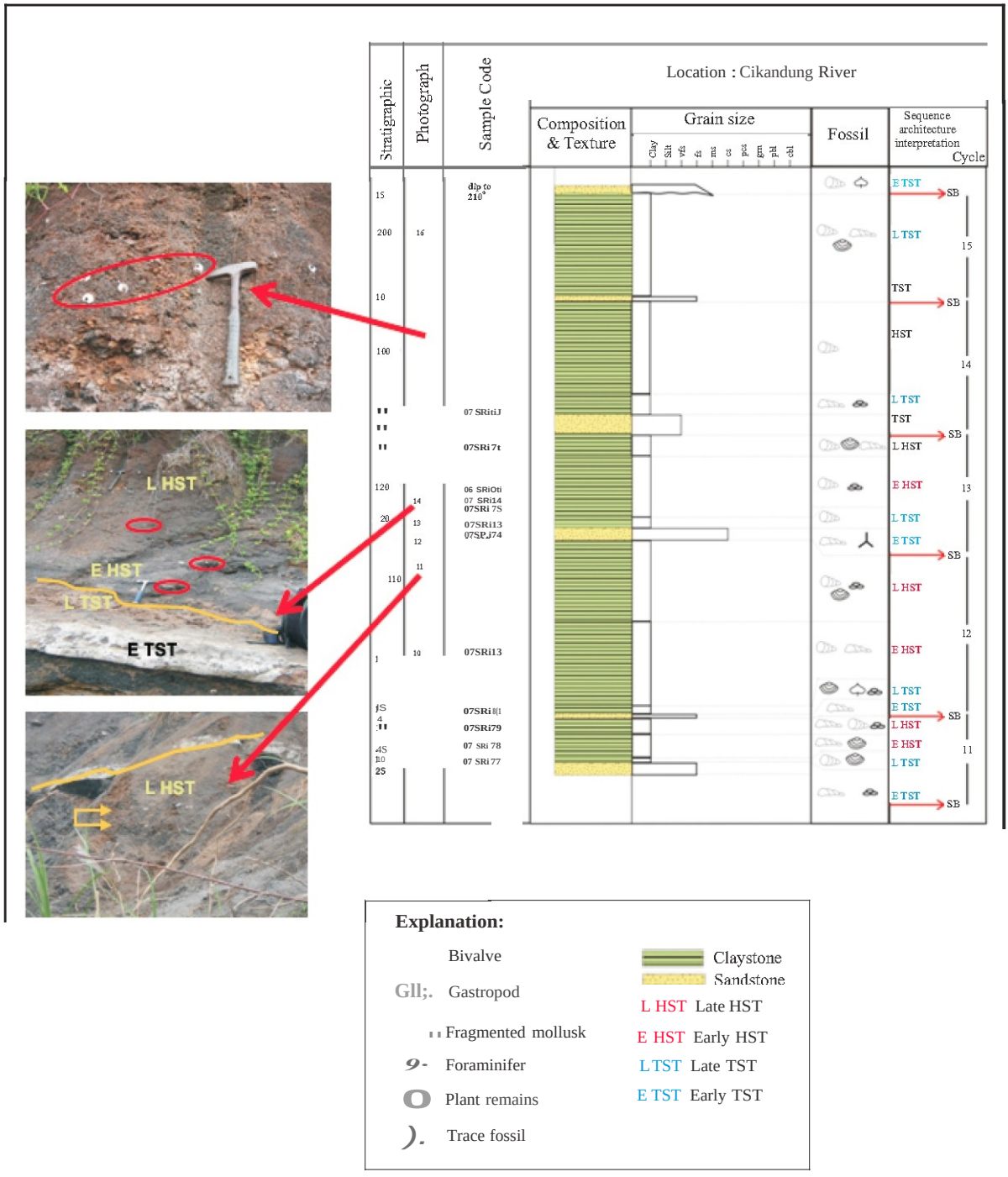


Figure 11. Stratigraphic column shows Early and Late HST intervals along the Cikandung River.

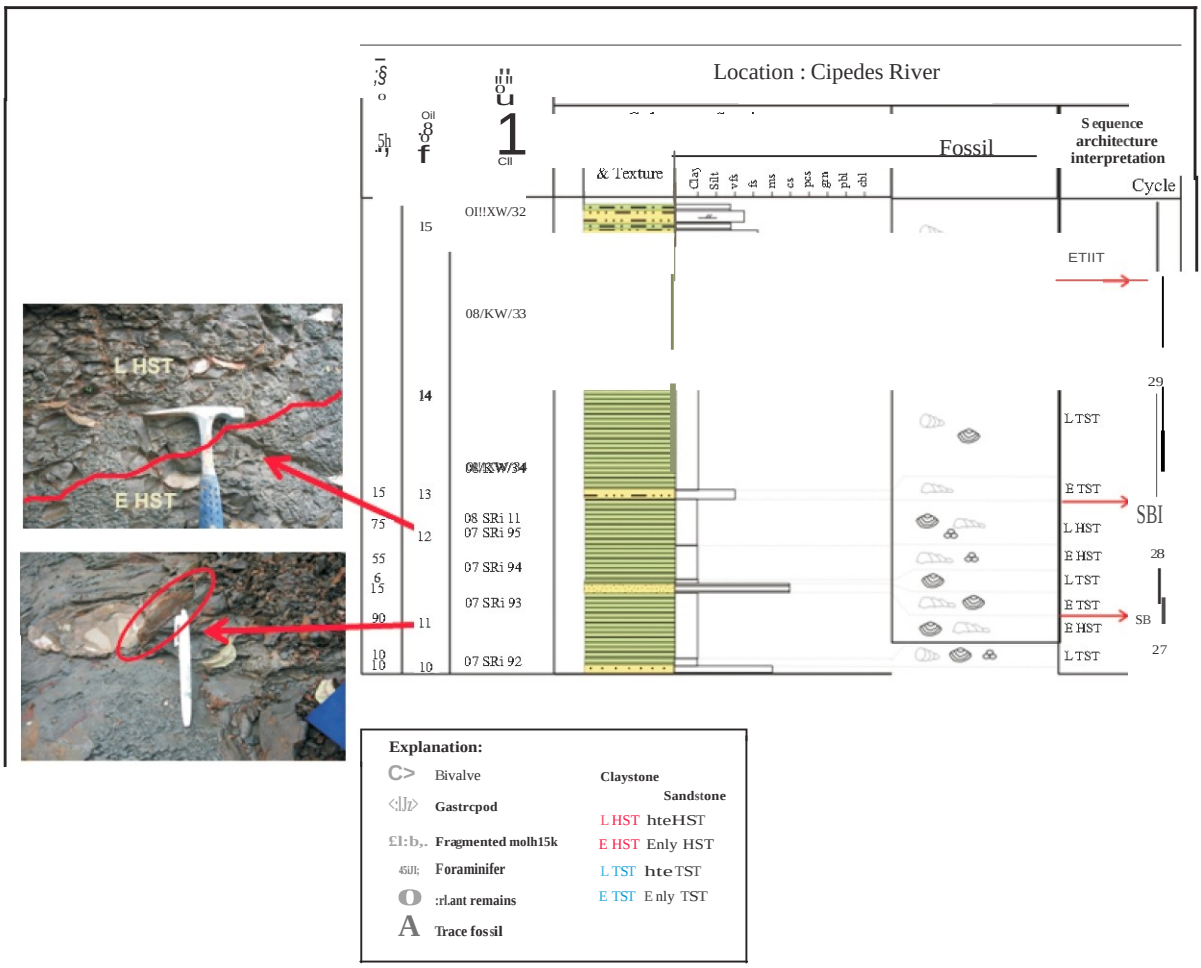


Figure 12. Stratigraphic column shows Early and Late HST intervals along the Cipedes River.

These four element repetitions show its sedimentary cycles of the formation. In this study, nineteen cycles from the Cikandung River and twenty cycles from the Cipedes River can be identified. Both sections are continued stratigraphically from the lower part into the upper part of Nyalindung Formation and developed 40 total cycles.

The short time period represented by the section and the thin units (many are not thicker than 2 m) indicates that the main cause of the cyclicity was orbitally induced climate change, representing Milankovitch-scale cycles of 41,000 years.

Understanding detailed sedimentary cycle analysis as done in this study is useful in determining the total volume of a rock unit, such as calculation of reservoir potential in case of monotonous sedimentary rock unit.

CONCLUSIONS

Kaliwangu Formation shell bed characteristics were observed, and its sedimentary cycle significance in terms of sequence stratigraphy are:

1. Early Transgressive System Tract (Early TST) deposited above the sequence boundary, is characterized by shell disarticulation, trace fossils, gravelly content, no taxa orientation, and concretion.
2. Late Transgressive System Tract (Late TST) is

identified by articulated (conjoined) specimen in life position showing a low level of abration and fragmentation, adult specimen with complete shells and variation of taxa, and some barren layers.

3. Early Highstand System Tract (Early HST) showing adult taxa locally in their life position and individual articulation, is dominated by juvenile, few as fragmented shells, with carbon or coal layers spottedly.
4. Late Highstand System Tract (Late HST) determined as multiple-event concentrations, is locally found parallel to the long axis of gastropods present on the original sediment surface, disarticulated shell domination, and some carbon or amber intercalations indicating a terrestrial influence.

Based on each sequence stratigraphic element abovementioned, its repetition represents each sedimentary cycle of the identified nineteen cycles from Cikandung River and twenty cycles from Cipedes River. They are included as the sixth order.

Detailed sedimentary cycle analysis by determining the sequence stratigraphic elements as done in this study is useful in determining the total volume of a massive sedimentary rock, such as calculation of reservoir potential in case of monotonous sedimentary rock unit.

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