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Diagenetic Evolution of Klapanunggal Limestone: A Vertical Profile from Cibinong, West Java

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Abstract
The Klapanunggal Formation in Cibinong, West Java, comprises a sequence of carbonate rocks that record a complex history of diagenetic alteration. This study investigates the vertical variation in diagenetic features within the limestone units, aiming to interpret their evolution through petrographic analysis. Samples from various stratigraphic levels were examined microscopically to identify key diagenetic processes including micritization, cementation, dissolution, and recrystallization. The results show distinct vertical patterns of diagenesis, suggesting varying diagenetic environments and fluid interactions through time. This vertical profiling provides valuable insights into the diagenetic evolution of the Klapanunggal Formation and contributes to a better understanding of carbonate reservoir quality in similar geological settings.

Keywords: Diagenesis, Limestone, Klapanunggal Formation, Cibinong, Vertical Profile, Petrography

1. Introduction

Carbonate rocks are highly susceptible to diagenetic processes that significantly modify their original textures, porosity, and permeability. These post-depositional changes can occur in various environments, including marine, meteoric, and burial settings, each leaving distinct petrographic signatures. Diagenesis plays a critical role in shaping the reservoir quality of carbonate rocks, influencing their capacity to store and transmit fluids. Therefore, understanding the nature and sequence of diagenetic processes is essential for both academic research and practical applications in petroleum geology, hydrogeology, and environmental geology. The Klapanunggal Formation, located in the Cibinong area of West Java, consists predominantly of thick limestone sequences deposited during the Neogene period in a shallow marine environment. These carbonate deposits have undergone multiple diagenetic episodes driven by sea-level fluctuations, tectonic uplift, and changes in groundwater regimes. Despite its geological significance, detailed diagenetic studies of the Klapanunggal Formation remain limited. This paper presents a vertical analysis of diagenetic features along a stratigraphic profile in Cibinong, aiming to document the spatial and temporal variability in diagenetic alterations and to reconstruct the diagenetic evolution of the formation. Such insights are not only valuable for regional geological understanding but also provide analogues for similar carbonate systems in Southeast Asia.

2. Geological Setting

The Klapanunggal Formation lies within the Bogor Basin, which is composed of sedimentary deposits predominantly of marine origin accumulated during the Neogene period. This basin developed as a result of the complex tectonic interaction between the Sunda Shelf and the southern convergent margin of Java, leading to significant subsidence that allowed for the accumulation of thick sedimentary sequences (Satyana, 2005; Setyawan, 2012). The limestone units within the Klapanunggal Formation are primarily composed of wackestone to packstone microfacies, often containing bioclasts such as benthic foraminifera, coral fragments, mollusks, and fragments of red algae, indicating deposition in a shallow marine environment (Flügel, 2004). Field and petrographic observations from the Cibinong area confirm these facies characteristics, with vertical successions displaying transitions in grain support, fossil content, and degree of micritization. Coral-algal boundstone structures are occasionally present, suggesting episodic colonization by reef-building organisms.

These carbonate sediments have been subjected to a range of diagenetic processes, including micritization, compaction, cementation, dissolution, and neomorphism. The spatial distribution and intensity of these processes vary vertically, offering a valuable record of the post-depositional evolution of the formation. According to Choquette and Pray (1970) [3], such diagenetic modifications in shallow marine carbonates are often governed by the interplay of eogenetic, mesogenetic, and telogenetic environments the tectonic history of West Java further influenced the diagenetic imprint on the Klapanunggal limestones.

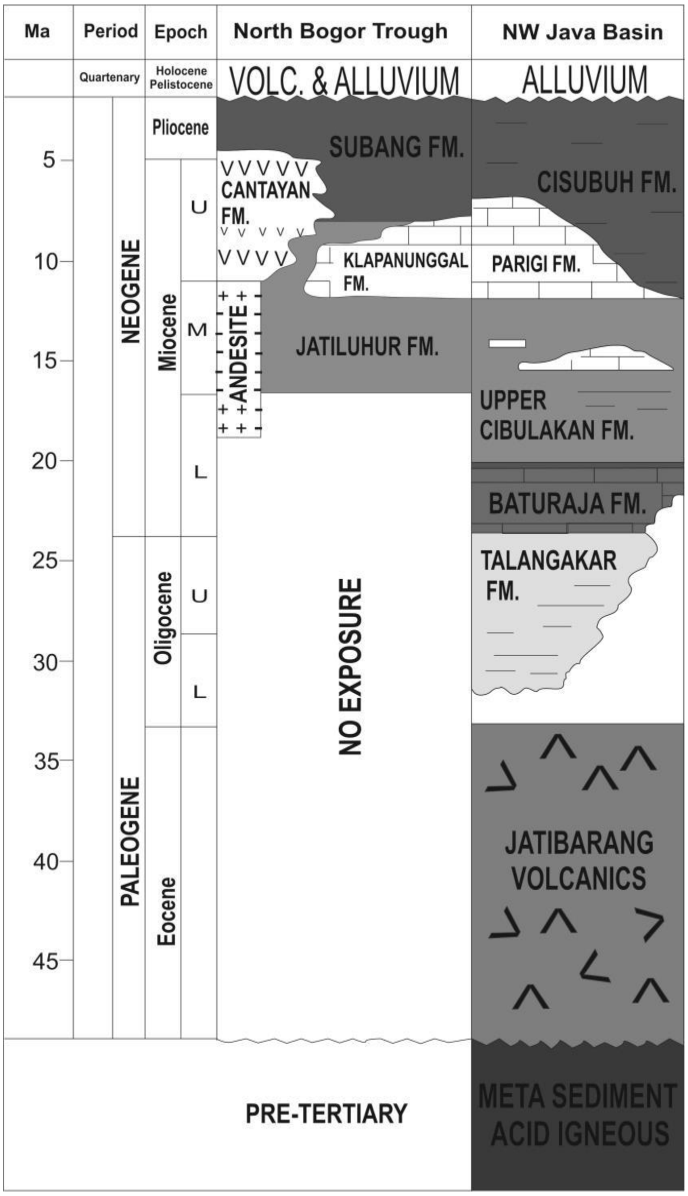
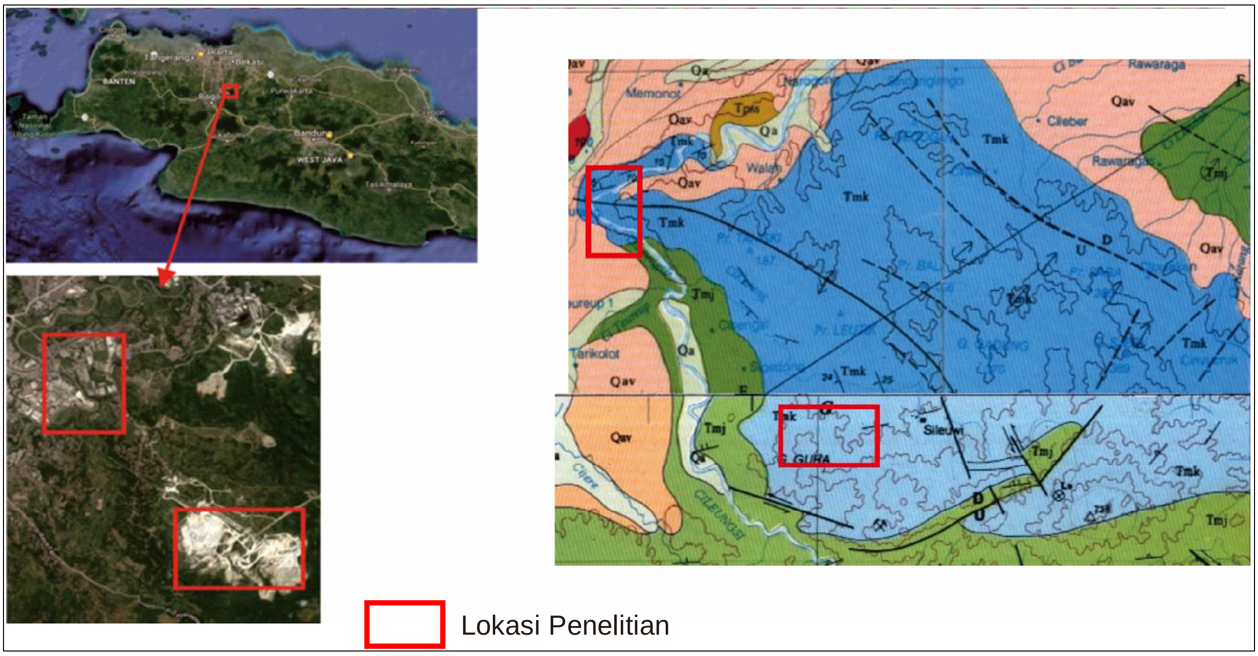


Fig 1: Stratigraphic Coloum Of North Bogor Trough Basin & North West Java Basin

The uplift and exposure of the region during the Pliocene-Pleistocene promoted meteoric diagenesis, particularly evident in the upper parts of the limestone profile. This is reflected in the observed porosity variations and secondary mineral overprints found in thin section analyses (Tucker & Wright, 1990) [13]. The Cibinong area, situated within the central portion of the Bogor Basin, provides exceptional outcrop exposures along quarry walls and roadcuts. These allow detailed stratigraphic logging and sampling, facilitating the vertical profiling of diagenetic features. The integration of field observations, petrographic data, and stratigraphic framework supports a comprehensive understanding of the diagenetic evolution of these limestones.

3. Methodology

Field investigations were carried out in two vertical stratigraphic sections of the Klapanunggal Formation located in the Cibinong area, West Java. The first section lies within the industrial area of Indocement in the north, while the second is situated in a former open-pit quarry in the south. Both sections exhibit well-preserved carbonate outcrops, allowing for a comprehensive vertical assessment of diagenetic variations. A total of 32 limestone samples were collected systematically at intervals of 10–20 meters, with field notes recording lithological characteristics, fossil content, structural features, and stratigraphic relationships.



Source: Google Maps, Geological Map of the Jakarta Sheet and Bogor Sheet, 1992 & 1998

Fig 2: Research Location Map

All collected samples were processed into standard thin sections, stained with alizarin red S and potassium ferricyanide to differentiate calcite and dolomite and to highlight porosity types. Petrographic analysis was conducted using a polarizing microscope equipped with a digital imaging system. The observations focused on key diagenetic features, including micritization, syntaxial overgrowth, various cement types (equant, blocky, fibrous, bladed), dissolution-induced porosity (vuggy, moldic, intercrystalline), compaction features, neomorphism, and dolomitization. The spatial and textural relationships among these features were used to infer diagenetic sequences. Facies analysis was conducted to understand the depositional context of each sample. Using the classification systems proposed by Dunham (1962) and Embry & Klovan (1971), carbonate textures and fossil assembsslages were examined to categorize the samples into facies types such as packstone, wackestone, boundstone, rudstone, and mudstone. The vertical distribution of these facies provided a framework for interpreting the interaction between depositional processes and subsequent diagenetic overprints. The integration of stratigraphic, petrographic, and facies data enabled the reconstruction of the diagenetic evolution within each section. Cross-comparison between the northern and southern profiles allowed identification of spatial variability in diagenetic processes, including differences in cementation intensity, porosity development, and dolomite distribution. These interpretations were used to infer changes in diagenetic environments through time, particularly the transition from marine to meteoric and burial regimes.

4. Results and Discussion

Petrographic and field analyses conducted along two vertical stratigraphic profiles in the Klapanunggal Formation reveal significant diagenetic heterogeneity controlled by facies type, stratigraphic position, and exposure conditions. The northern section, located near the industrial complex of Indocement, is dominated by reefal boundstone facies with abundant platy and head corals. These boundstones exhibit massive structures and are characterized by early diagenetic features such as pervasive micritization and marine fibrous cement. Petrographic thin sections reveal the presence of primary marine cements lining large skeletal voids, indicating early stabilization in a high-energy shallow marine setting. As the profile progresses upward within the northern section, there is a gradual facies transition from boundstone to wackestone and packstone. These facies contain abundant foraminiferal fragments, with lower fossil diversity compared to the boundstones. Diagenetically, the packstone-wackestone intervals display minor dissolution features, limited vuggy porosity, and early-stage recrystallization (neomorphism) affecting micritic matrices and bioclasts. The cement types shift from marine fibrous to equant and blocky calcite cements, which commonly occlude intraparticle and interparticle pores. These cement types are typical of meteoric phreatic conditions, suggesting subaerial exposure and water-table fluctuations affecting the upper reef flank or slope environments. In contrast, the southern section, located in an abandoned quarry in the Nambo area, exhibits more advanced diagenetic overprinting.

Fig 3: Limestone Outcrop in Klapanunggal Area

The profile begins with packstone and wackestone facies containing larger foraminifera, coral fragments, and occasional algal debris. Dissolution is extensive in this section, with moldic, vuggy, and intercrystalline porosities developed along stylolites, fractures, and skeletal boundaries. Large solution cavities, interpreted as the result of karstification, are common, particularly in the middle to upper portions of the profile. Field observations confirm the presence of cavernous porosity and groundwater seepage features, suggesting prolonged meteoric exposure. Petrographic thin sections from the southern profile reveal strong evidence of neomorphism and multiple cement generations. Equant and blocky sparite infill moldic voids and vugs, while early fibrous and bladed cements, though rare, are preserved in some lower intervals. The presence of fibrous marine cements indicates initial shallow marine diagenesis prior to meteoric alteration. As the section progresses upward, extensive dolomitization becomes a dominant diagenetic process. Sucrosic dolomite crystals partially or completely replace micritic matrices and calcite cements. Dolomite textures suggest replacement dolomitization, likely driven by Mg-rich fluids during evaporative conditions or mixing-zone interactions. Vertical trends in porosity evolution also support the interpretation of sequential diagenetic stages. In the northern section, porosity is largely reduced due to early marine cementation and subsequent meteoric recrystallization. Vuggy porosity is sparse and usually associated with late-stage dissolution events. In contrast, the southern section exhibits an upward increase in secondary porosity, particularly vuggy and moldic types, followed by porosity occlusion due to late-stage dolomite and calcite cementation. Intercrystalline porosity also increases with dolomitization in the uppermost part of the southern profile. The contrast between the two profiles reflects not only stratigraphic position and facies architecture but also differential exposure to diagenetic regimes.

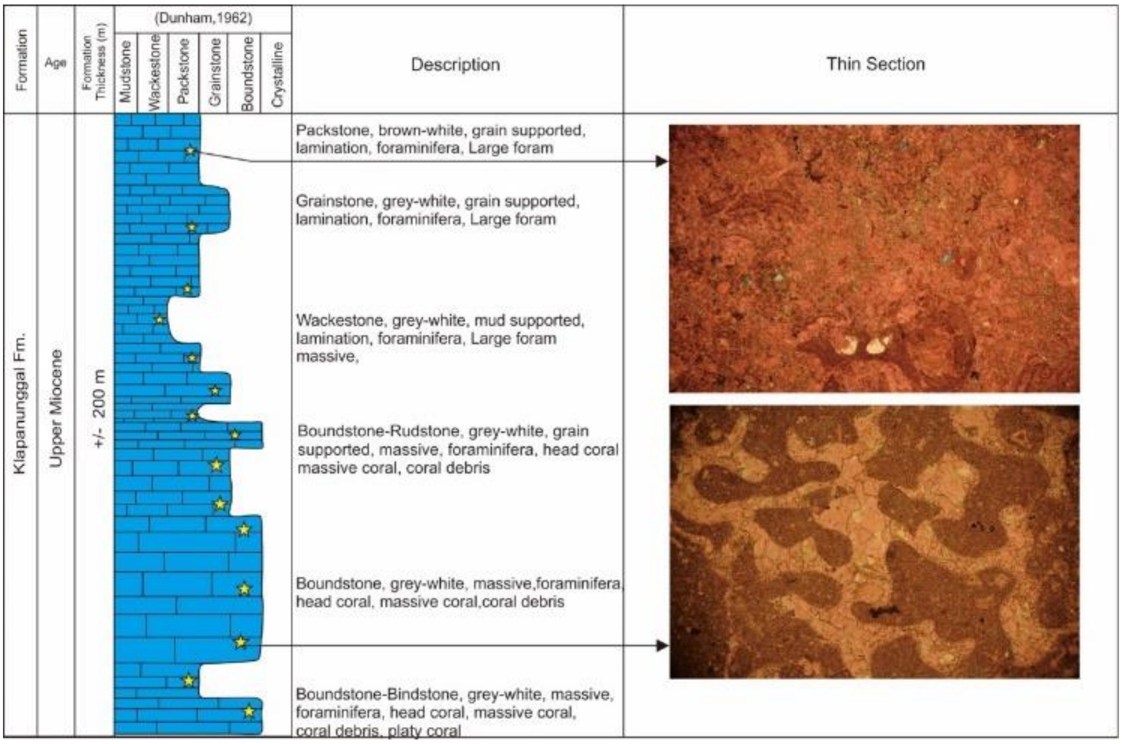


Fig 4: Outcrop profile of lithology and petrographic of limestone

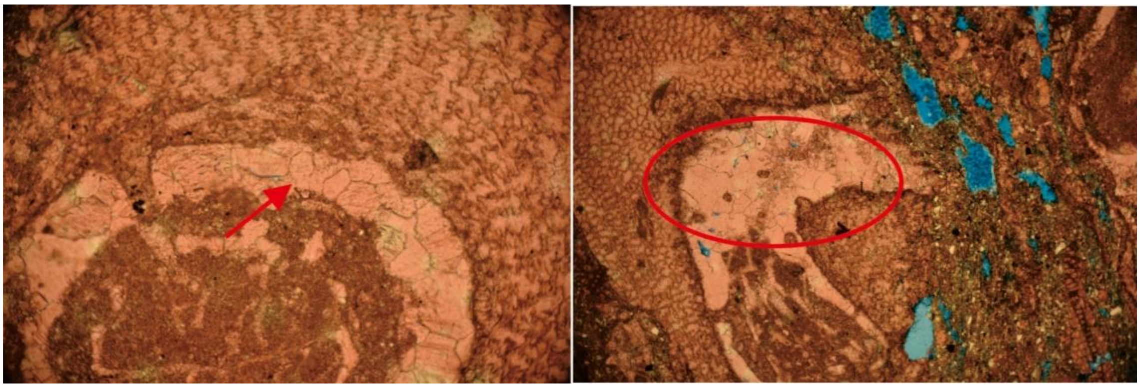


Fig 5: Photomicrograph of bindstone limestone thin section from the northern traverse showing the presence of equant and blocky cement (red arrows), as well as evidence of neomorphism (right photo).

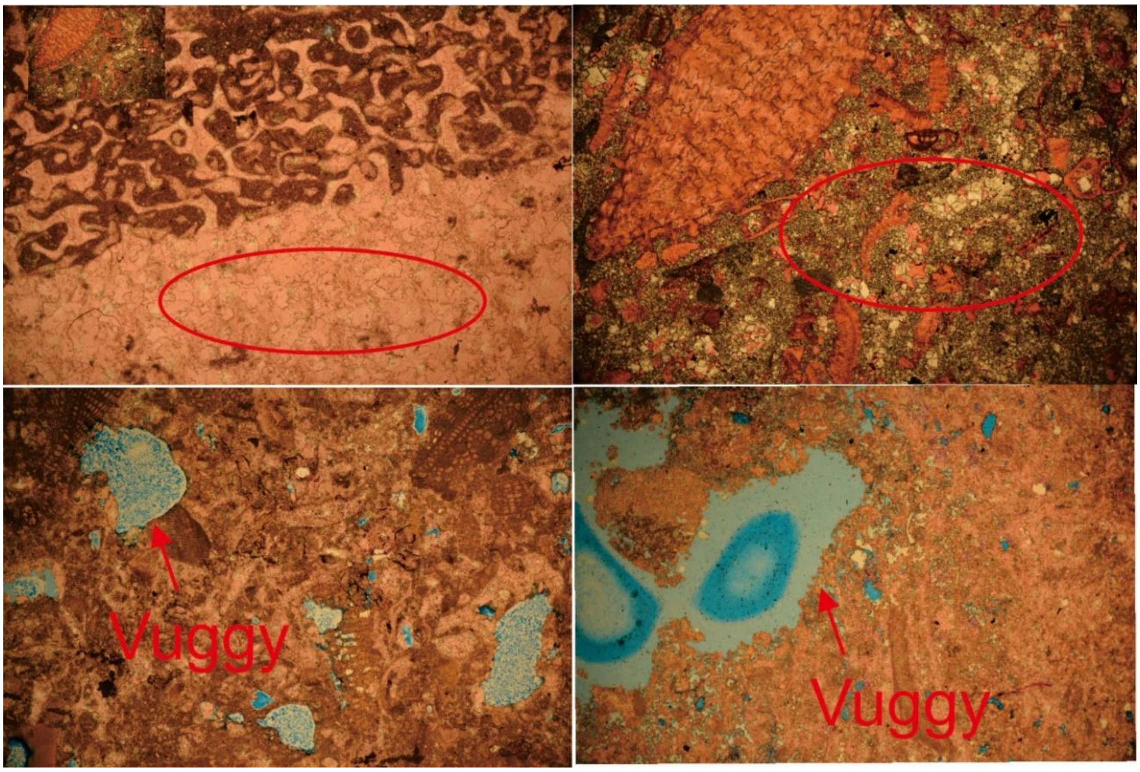


Fig 6: Thin section of limestone from the southern traverse, exhibiting a packstone-wackestone texture, showing the presence of equant and blocky cement (top left photo), significant dolomitization (top right photo), and secondary porosity indicated by the presence of vuggy porosity.

The northern profile, with limited karst features and more pervasive early marine cements, represents a relatively stable shallow marine to meteoric diagenetic transition. The southern profile, however, underwent more complex and intense diagenetic overprinting, with strong indicators of meteoric vadose exposure, karstification, and burial modification. These patterns are consistent with a model of sequential diagenesis progressing from eogenesis (marine) to telogenesis (meteoric exposure) and mesogenesis (burial), as described by Choquette and Pray (1970) [3] and Tucker (1990). Tectonic uplift and sea-level changes during the Miocene–Pliocene likely played a crucial role in shaping these diagenetic regimes. The structural setting of the Bogor Basin and the presence of fractures and faults may have facilitated meteoric water circulation and vertical fluid migration, enhancing dissolution and cementation patterns. This is supported by the frequent observation of fracture-associated porosity and the alignment of karst features along structural trends.

5. Conclusion

Based on the vertical profile analysis of the Klapanunggal Limestone Formation in Cibinong, this study reveals a complex and multi-phase diagenetic evolution. The early diagenetic processes were dominated by micritic precipitation and biogenic binding, particularly involving red algae, which played a crucial role in the initial formation of the carbonate sediments. Subsequent diagenetic stages involved mineral replacement and the development of sparitic cement, indicative of advanced recrystallization phases. These diagenetic alterations caused significant variations in porosity and permeability, directly impacting the reservoir potential of the limestone. Furthermore, geochemical changes observed during diagenesis provide insights into the paleoenvironmental conditions and fluid interactions over geological time. This comprehensive understanding of the diagenetic history is essential for accurate geological interpretation and has important implications for natural resource exploration and management in the Cibinong area and the greater West Java region.

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6. References

1. Abdurrokhim, Ito M. The role of slump scars in slope channel initiation: a case study from the Miocene Jatiluhur Formation in the Bogor Trough, West Java. J Asian Earth Sci. 2013;73:68-86.
2. Achdan A, Sudana D. Peta Geologi Lembar Karawang, Jawa [map]. Bandung (ID): Pusat Penelitian dan Pengembangan Geologi; 1992. Scale 1:100 000.
3. Choquette PW, Pray LC. Geologic nomenclature and classification of porosity in sedimentary carbonates. AAPG Bull. 1970;54(2):207-50.
4. Effendi AC, Kusnama, Hermanto B. Peta Geologi Lembar Bogor, Jawa [map]. Bandung (ID): Pusat Penelitian dan Pengembangan Geologi; 1998. Scale 1:100 000.
5. Hilmi F, Haryanto I. Pola struktur regional Jawa Barat. Bull Sci Contrib. 2008;6(1):57-66.
6. Jambak MA, Syafri I, Isnaniawardhani V, Benyamin, Rodriguez H. Facies and diagenetic level of the Upper Cibulakan and Parigi Formation, in Randegan and Palimanan area. Indones J Geosci. 2015;2(3):157-66. doi:10.17014/ijog.2.3.157-166.
7. Martodjojo S. Evolusi Cekungan Bogor [dissertation]. Bandung (ID): Institut Teknologi Bandung; 1984.
8. Patmosukismo S, Arpandi D. The Cibulakan Formation as one of the prospective stratigraphic unit in the North-West Java Basinal area. In: Proceedings of the 4th Annual Convention Indonesian Petroleum Association; 1975; Jakarta. p. 181-210.
9. Praptisih, Kamtono. Carbonate facies and sedimentation of the Klapanunggal Formation Cibinong, West Java. Indones J Geosci. 2014;1(3):175-83.
10. Pulunggono A. Tertiary structural features related to extensional and compressive tectonics in the Palembang Basin, South Sumatra. In: Proceedings of the 15th Annual Convention Indonesian Petroleum Association; 1986; Jakarta. p. 187-213.
11. Scholle PA, Ulmer-Scholle DS. A color guide to the petrography of carbonate rocks: grains, textures, porosity, diagenesis. Tulsa (OK): American Association of Petroleum Geologists; 2003. (AAPG Memoir; 77).
12. Solihin M, Abdurrokhim, Jurnaliah L. Biozonasi foraminifera planktonik di lintasan Sungai Cipamingkis, daerah Jonggol, Provinsi Jawa Barat. Bull Sci Contrib. 2016;14:55-62.
13. Tucker ME, Wright VP. Carbonate sedimentology. Oxford (UK): Blackwell Scientific Publications; 1990.
14. Turkandi T, Sidarto, Agustyanto DA, Purbo-Hadiwidjojo MM. Peta Geologi Lembar Jakarta dan Kepulauan Seribu, Jawa [map]. Bandung (ID): Pusat Penelitian dan Pengembangan Geologi; 1992. Scale 1:100 000.
15. Walker RG, James NP, editors. Facies models: response to sea level change. St. John's (NL): Geological Association of Canada; 1992.

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