









## F. Paleoclimate

On the Late Pliocene, generally, the climate changes from warm to cool and followed by shallowing upward. This event occurred after the first appearance of *Globorotalia tosaensis tosaensis* and before the occurrence of *Globorotalia truncatulinoides*, within the interval of 3 Ma [19] to 1.95 Ma [20]. The global cooling phase on the Pliocene has occurred from 3.35 to 2.3 Ma [21], [22].

In the Kali Ngliron/NL section (Figure 10), the cooling phase is observed from the upper *Mundu* Formation to the Tambakromo Member of the *Lidah* Formation (samples 25 to 8). Samples 8 to 25 show temperature fluctuation and are dominated by sub-tropic-transition faunas. This fact indicates the cooling environment occurred during this interval. Warmer temperature occurred when sample 9 (upperpart shales of the *Tambakromo* Formation) was deposited, which is marked by the increase of tropical fauna at the upper shales of *Tambakromo* Member of *Lidah* Formation.

## IV. CONCLUSION

Reworked fossils can be used to identify the lower and upper parts of sequence boundary N21 (SBN21). We identified the MFS of Sequence N21 using the Pick Abundance and Diversity (PAD) of planktonic and benthonic *forminifera*. We are also able to identify it by observing *benthonic* fossil association to indicate maximum *paleobathymetry*. The regression occurred in the N21 biozone, characterized by abrupt changes of *paleobathymetry* from the upper bathyal zone to near-shore environment. This regression produced an incised valley, which then had been filled by high energy cross bedded glauconitic Globigerinid Sands of Selorejo Formation during the transgression period. During the Pliocene, N-E Java Basin, the basin's ecology changed from open marine to semi-confined, which correlated to the deposition of middle-part blue shales Tambakromo Member of Lidah Formation.

## SUPPLEMENTARY MATERIALS

For easy reading, we deposited all figures and tables as supplementary materials as PNG figures and Powerpoint slide format [23].

## ACKNOWLEDGMENT

We are grateful to P3MI-ITB for the partial funding and Laboratory Micropaleontology Institut Teknologi Bandung for the technical support. We are also grateful to Rudi Lesmana and Rifky Ghifari for their contribution in preparing samples and figures.

## REFERENCES

- [1] J. R. Beerbower, 'New Perspectives in Paleontology', *J. Geol. Educ.*, vol. 11, no. 3, pp. 95–97, 1963.
- [2] K. C. Maguire, D. Nieto-Lugilde, M. C. Fitzpatrick, J. W. Williams, and J. L. Blois, 'Modeling species and community responses to past, present, and future episodes of climatic and ecological change', *Annu. Rev. Ecol. Evol. Syst.*, vol. 46, pp. 343–368, 2015.
- [3] D. E. Irawan and R. Kapid, 'A review on paleoenvironment suitability for hominid fossils and other early vertebrate faunas: a case from Pucangan and Kabuh Formations, Central and East Java, Indonesia', *Sci. Res.*, Jun. 2017, doi: 10.14293/s2199-1006.1.sor-life.ah9puy.v1.
- [4] C. S. Kenyon, 'Distribution and Morphology of Early Miocene Reefs, East Java Sea', *Indones. Pet. Assoc.*, pp. 215–238, 1977.
- [5] H. Pringgoprawiro, 'Biostratigrafi dan Paleogeografi Cekungan Jawa Timur Utara: Suatu Pendekatan Baru', PhD Thesis, Institut Teknologi Bandung, Bandung, 1983.
- [6] P. Baumann, 'Depositional Cycle on Magmatic and Back-Arc: An Example from Western Indonesia', *Rev. L'Institute Francais Pet.*, vol. 37, no. 1, pp. 3–17, 1982.
- [7] A. Muin, 'Contribution a la Geologie du Bassin Nord Oriental de l'Il de Java, Indonesia: Sedimentologie d'un Bassin d'Arrier Arc', PhD Thesis, Universite Scientifique et Medicale de Grenoble, France, 1985.
- [8] L. Samuel and M. Johannes, 'Perlapisan silang-siur sebagai penunjuk arah arus purba di Daerah Utara Cepu, Jawa Tengah', in *Ann. Conv. XIth IAGI*, Yogyakarta, 1986.
- [9] R. Kapid, 'Le mio-pliocene marin du nord-est de java, indonesie. Biostratigraphie qualitative et quantitative des foraminiferes et du nannoplanton', PhD Thesis, Reims, France, 1991.
- [10] D. Djuhaeni, 'Stratigraphie Sequentielle Des Series Sedimentaires Marines du Neogene et du Pleistocene dans Region de Cepu, Bassin Nord-Est de Java', Disertasi Doktor, Universite Claude-Bernard du Lyon-I, France, 1994.
- [11] D. Djuhaeni, 'Efek Tektonik dan Eustasy Terhadap Perkembangan Sikuen: Suatu contoh pada Endapan Miosen Atas \_ Plestosen di Daerah Cepu, Cekungan Jawa Timur Utara', in *Prosiding PIT-IAGI*, Bandung, 1996.
- [12] D. Djuhaeni, 'Signifikansi Aplikasi Konsep Sikuenstratigrafi pada Endapan Berumur Neogen dan Plestosen di Daerah Cepu, Cekungan Jawa Timur Utara', *J. Teknol. Miner. -ITB*, 1996.
- [13] D. Djuhaeni, 'Hubungan antara Fluktuasi Paras Muka-laut Relatif dan Biostratigrafi pada Endapan Neogen dan Plestosen di Daerah Cepu, Cekungan Jawa Timur Utara', *J. Teknol. Miner. -ITB*, 1996.
- [14] D. Djuhaeni and S. Martodjojo, 'Studi Batupasir Selorejo Daerah Cepu, Jawa Tengah', in *Proc. XIXth. Ann. Conv. IAGI*, Bandung, 1990, pp. 162–179.
- [15] D. S. Tolderlund and A. W. Bé, 'Seasonal distribution of planktonic foraminifera in the western North Atlantic', *Micropaleontology*, pp. 297–329, 1971.
- [16] J. R. Haynes, *Foraminifera*. Springer, 1981.
- [17] W. H. Blow, 'Late Middle Eocene to Recent planktonic foraminiferal biostratigraphy', in *Proceedings of the first international conference on planktonic microfossils*, 1969, vol. 1, pp. 199–422.
- [18] H. G. Billman and M. Scrutton, 'Stratigraphic correlation in Indonesia', 1976.
- [19] J. D. Hays, T. Saito, N. D. Opdyke, and L. H. Burckle, 'Pliocene-Pleistocene Sediments of the Equatorial Pacific: Their Paleomagnetic, Biostratigraphic, and Climatic Record', *GSA Bull.*, vol. 80, no. 8, pp. 1481–1514, Aug. 1969, doi: 10.1130/0016-7606(1969)80[1481:PSOTEP]2.0.CO;2.
- [20] T. Saito, P. R. Thompson, and D. Breger, *Systematic index of Recent and Pleistocene planktonic foraminifera*. University of Tokyo Press, 1981.
- [21] J. Van Gorsel and S. Troelstra, 'Late Neogene planktonic foraminiferal biostratigraphy and climatostratigraphy of the Solo River section (Java, Indonesia)', *Mar. Micropaleontol.*, vol. 6, no. 2, pp. 183–209, 1981.
- [22] R. Stainforth, J. L. Lamb, H. Luterbacher, J. H. Beard, and R. M. Jeffords, 'Cenozoic planktonic foraminiferal zonation and characteristics of index forms', 1975.
- [23] K. A. Maryunani, R. Kapid, D. Djuhaeni, W. D. Santoso, and D. E. Irawan, 'Supplementary material - Pliocene to Pleistocene Stratigraphy of Rembang Zone, North East Java Basin, Indonesia', *Zenodo*, Nov. 2019, doi: 10.5281/zenodo.3525453.
- [24] Adinegoro, 'Stratigraphic Studies by the Indonesian Petroleum Institute', Lemigas, United Nation Escope, CCOP Technical Bulletin, 1973.
- [25] Hasjim, N., 'Le Neogene Marin Du Nord Est De Java, Indonesie. Etude Biostratigraphique (Foraminiferes et Nannoplanton)'. GEOMEDIA Fons-Troubado Chemin du Four 13100 Aix en Provence, France, 129 pp, 6 pl, 1988.