Bull. Natl. Mus. Nat. Sci., Ser. C, 41, pp. 53–59, December 22, 2015

Calcareous nannofossil biostratigraphic study of the Pugo River section of Amlang Formation in the Luzon Central Valley Basin, Philippines

Jose Dominick S. Guballa[1] and Allan Gil S. Fernando[1]

[1] Nannoworks Laboratory, National Institute of Geological Sciences, University of the Philippines, Diliman, Quezon City, Philippines
E-mail: dominick_guballa@yahoo.com; agsfernando@yahoo.com

Abstract The study aims to establish the calcareous nannofossil biostratigraphy of an outcrop consisting of turbiditic sandstones and shales located along Pugo River, La Union in the Luzon Central Valley Basin, Philippines. Examination of the samples reveals a moderately- to well-preserved assemblage dominated by *Discoaster* and *Sphenolithus*. Based on the occurrence of *Discoaster berggrenii* in all of the samples, the nannofossil NN11A Zone is recognized. This suggests a late Tortonian (late Miocene) age for the investigated section. Biostratigraphic and lithologic correlation suggest that the Pugo River section is part of the Amlang Formation. The result of the present study, in addition, extends the base of the Amlang Formation to middle late Miocene.

Key words: Biostratigraphy, Amlang Formation, Luzon Central Valley Basin, Philippines, calcareous nannofossils

Introduction

La Union Province in Luzon Island occupies the northwestern portion of the Luzon Central Valley Basin (CVB), Philippines. Rock units identified in the basin include Eocene to Oligocene pelagic limestones and turbiditic clastics that are unconformably overlain by early to late Miocene sandstones, shales, and conglomerates, and Pliocene to Pleistocene clastic sedimentary rocks and limestones (Corby *et al.*, 1951; Amato, 1965; Lorentz, 1984; Peña, 2008).

Previous field investigations agree in recognizing the Aksitero Formation, Moriones Formation, Malinta Formation, Amlang Formation, Tarlac Formation, Cataguintingan Formation, Damortis Formation and Bamban Formation in the western portion of the CVB (Corby *et al.*, 1951; Amato, 1965; Lorentz, 1984; Peña, 2008). De Leon and Militante-Matias (1992) and De Leon *et al.* (1998) did comprehensive study of sections belonging to the Klondyke and Amlang Formations using calcareous nannofossil and foraminifera biostratigraphy, and established a middle Miocene to early late Miocene age for the Klondyke Formation and a late late Miocene age for the Amlang Formation. The details of the distribution and age assignment of units in the CVB, however, still need to be refined.

To contribute to the refinement of the stratigraphy and geology of the CVB, a fieldwork was held in 2014 in a turbiditic section along Pugo River, La Union. These exposures represent the lateral or distal extension of sedimentary formations exposed along the southwestern flanks of the Central Cordillera Region, which includes the well-studied but still poorly understood (in terms of stratigraphy) Baguio District (Peña, 1992). The study area was previously mapped as part of the Amlang Formation, although the exposed lithologies can be assigned either to the upper member of the Klondyke Formation (flysch-type thin intercalations of mudstones/shales and conglomerates and sandstone units;

De Leon *et al.*, 1991) or the Amlang Formation (rhythmic alternating deposits of sandstone and shale; De Leon *et al.*, 1991). The present study reports the calcareous nannofossil assemblage and corresponding nannofossil zone assignment of the Pugo River section, and will briefly discuss its implications regarding the depositional environment, stratigraphy and overall history of the area.

Study area

The Pugo River section is located on the southeastern portion of La Union Province

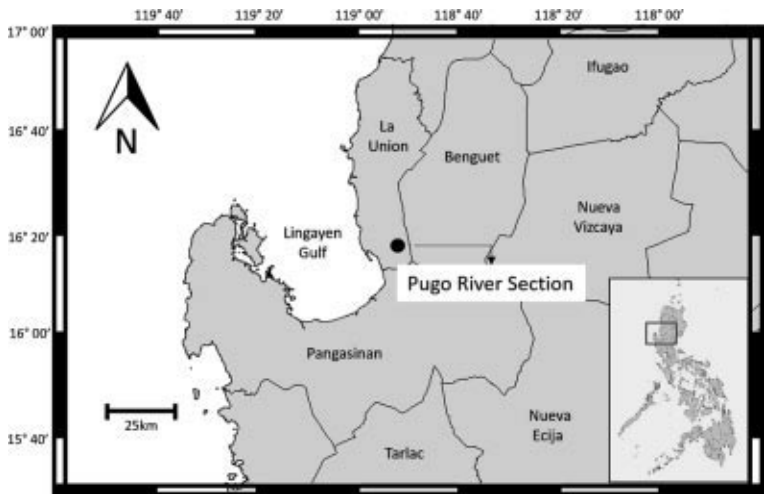

Fig. 1. Map of northern Luzon showing the location of the Pugo River Section in La Union Province, Philippines.

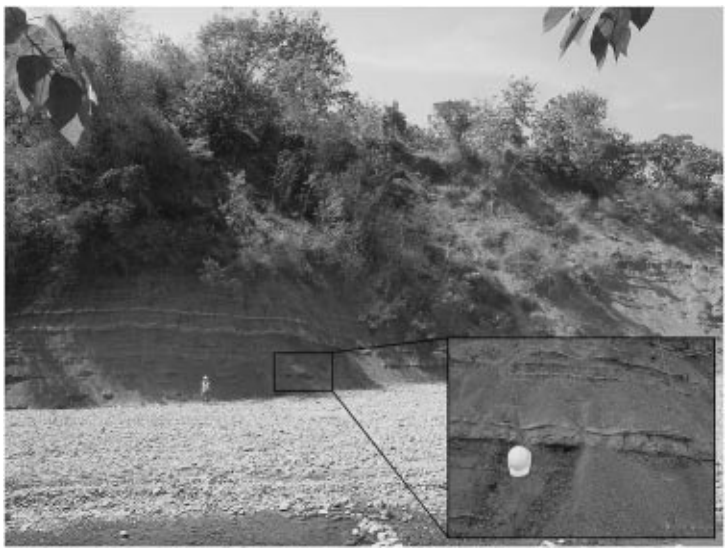

Fig. 2. Pugo River section in La Union Province. The outcrop is approximately 1 km in extent and 20 m in height. The dominant lithologies are mudstones and siltstones, with minor calcareous sandstone and marly layers. Image on the lower right shows a close-up view of the boxed portion of the outcrop.

within the CVB (Fig. 1). The basin is generally oriented along a N–S axis, with the western and eastern flanks of the southern portions stratigraphically distinct from each other. The eastern sedimentary units are dominated by volcanic sources and shallow marine deposits, while the western region is characterized by Neogene sediments dominated by Miocene turbidites (Aurelio, 2000). The Pugo River section belongs to the western flank of the CVB. As mentioned earlier, the section was mapped as part of the Amlang Formation, which consists of a lower member composed of thinly bedded gray shales interbedded with medium-grained sandstones, and an upper member that has a higher proportion of coarser-grained rocks (Lorentz, 1984; Peña, 2008).

The investigated section is composed of alternating layers of calcareous sandstones, siltstones, mudstones and marls (Fig. 2). The lower part of the section includes layers that contain coral fragments, pelecypods and other mollusk shells. In some layers, horizontal and vertical burrows were observed. The upper part of the section, on the other hand, is characterized by the occurrence of soft-sediment deformation structures such as convolute beddings/laminations. Tangential cross-bedding is also seen throughout the exposure. The attitude of the beds constantly dips to the northwest, with dip values ranging from 30° to 45° (Fig. 2).

Materials and methods

A total of 9 samples were collected along Pugo River for calcareous nannofossil analysis. These samples were collected from calcareous mudstone units that contain occasional planktonic foraminifera tests. Figure 3 shows a generalized stratigraphic column for the Pugo River section and the stratigraphic position of the samples.

Smear slides were prepared from these samples following standard sample preparation techniques (Bown and Young, 1998). These were examined under an Olympus BX51 polarizing microscope at 1000× magnification. Calcareous nannofossil specimens are identified up to the genus and/or species levels and were tallied and photographed. Relative abundances of calcareous nannofossil taxa were estimated from the categories of Bown (1998): very abundant (VA) - ＞25 coccoliths/field of view (FOV); abundant (A) – 6–25 coccoliths/FOV; common (C) – 1–5 coccoliths/FOV; few (F) – 1 coccolith/2–10 FOVs; rare (R) – 1 coccolith/11–50 FOVs; very rare (VR) – 1 coccolith/>50 FOVs.

Index markers were used to establish the nannofossil biostratigraphy of the section using the NN nannofossil zonation scheme of Martini (1971). Species were identified based on type specimens illustrated in Aubry (1984), Perch-Nielsen (1985) and Young (1998). Smear slide preparations and nannofossil microscopy were done at the Nannoworks Laboratory of the

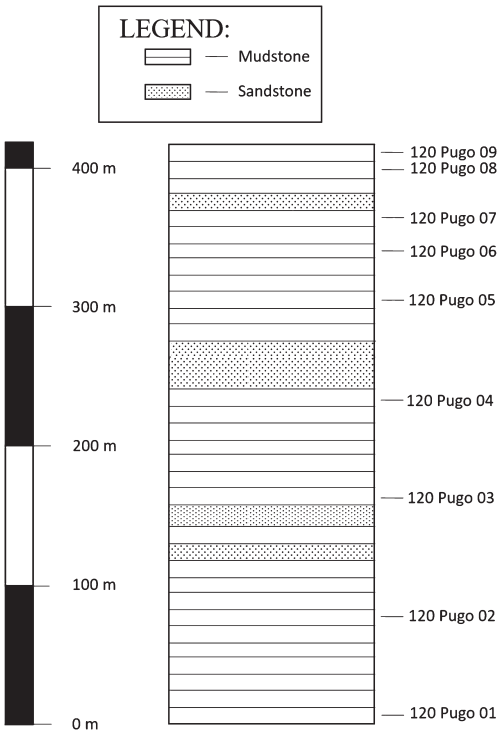

Fig. 3. Generalized stratigraphic column for the Pugo River Section in La Union Province. Relative stratigraphic positions of the samples are indicated in the column. The lithology of the outcrop is dominated by calcareous mudstones.

National Institute of Geological Sciences, University of the Philippines, Diliman, Quezon City (UP-NIGS).

Results and discussion

Table 1 lists all calcareous nannofossil taxa observed in each sample, and the corresponding age based on the assemblage and/or marker species present. Selected calcareous nannofossil taxa are illustrated in Figure 4.

Calcareous nannofossils observed in the Pugo River outcrop are rare to abundant, and are moderately- to well-preserved. Species richness varies from 12 to 16 species belonging to 12 genera, with Sample 120-Pugo-05 having the highest species diversity. The most common genera observed in all samples are *Reticulofenestra*, *Sphenolithus* and *Discoaster*. Reworked forms in the samples (as evidenced by recrystallization) include early to middle Miocene taxa like *Sphenolithus conicus* and *Cyclicargolithus floridanus*. Ascidian spicules and calcareous dinoflagellates (*Thoracosphaera*) were also observed in some of the samples.

The presence of *Discoaster berggrenii* in all of the samples suggests that the Pugo River section can be assigned to the NN11A Zone. This corresponds to a middle late Miocene age [late Tortonian; ~8.6Ma to 7.25Ma (Cohen *et al.*, 2013)]. Based on the generalized stratigraphic column of the Central Valley Basin, the previously established base for Amlang Formation is late late Miocene (Fig. 5; Peña, 2008). The section, however, cannot be assigned to the late Miocene Malinta Formation for 2 reasons: (a) the lithological characteristics of the investigated outcrop do not conform to the description of Malinta Formation (which consists of a sequence of sandy shales, quartz sandstones and tuffaceous pebbly sandstones; Peña, 2008); and (b) the distribution of Malinta Formation is further south of the study area. De Leon *et al.* (1991; 1998) did nannofossil biostratigraphic investigations of several sections in Benguet and La Union Provinces and assigned the Klondyke and Amlang Formations to the NN5–NN10B and NN11 nannofossil zones, respectively. Based on the similarities in lithological characteristics (thinly-bedded gray shales interbedded with fine-grained sandstones)

Table 1. Calcareous nannofossil distribution and abundance in the Pugo River Section in La Union, Philippines. Abbreviations listed: Preservation – M = moderate, G = good; Abundance – VR = very rare, R = rare, F = few, C = common, A = abundant.

SAMPLE NUMBER	Preservation	Ascidian Spicules	*Calcidiscus leptoporus*	*Calcidiscus macintyrei*	*Coccolithus pelagicus*	*Cyclicargolithus floridanus*	*Discoaster berggrenii*	*Discoaster triradiatus*	*Discoaster variabilis*	*Discoaster* spp.	*Helicosphaera carteri*	*Pontosphaera multipora*	*Reticulofenestra minuta*	*Reticulofenestra pseudoumbilicus*	*Rhabdosphaera procera*	*Scyphosphaera* spp.	*Sphenolithus abies*	*Sphenolithus conicus*	*Sphenolithus moriformis*	*Syracosphaera* spp.	*Thoracosphaera* sp.	AGE
120-Pugo-09	M-G	VR	R	VR	R	VR	R	—	R	F	F	R	R	R	—	—	C	—	C	—	—	middle late Miocene (NN11A Zone)
120-Pugo-08	M-G	—	R	—	VR	VR	R	—	VR	R	R	R	F	F	—	—	C	—	C	—	—	
120-Pugo-07	M	—	F	R	F	R	R	—	VR	R	F	F	F	F	—	—	A	—	C	—	VR	
120-Pugo-06	M	—	VR	VR	VR	VR	F	—	—	R	F	R	F	F	—	—	C	—	C	—	VR	
120-Pugo-05	M-G	F	F	R	F	VR	F	—	R	F	F	F	F	C	VR	VR	A	—	A	VR	R	
120-Pugo-04	M	—	VR	VR	R	—	F	—	R	F	R	R	F	F	VR	—	A	—	A	—	—	
120-Pugo-03	M-G	R	VR	VR	R	—	R	—	—	F	F	R	F	C	VR	VR	A	—	A	—	—	
120-Pugo-02	M-G	VR	R	VR	R	VR	R	—	—	F	F	R	F	F	—	—	A	VR	A	—	—	
120-Pugo-01	M	—	R	R	—	VR	R	VR	R	R	F	R	R	F	—	—	A	—	C	VR	—	

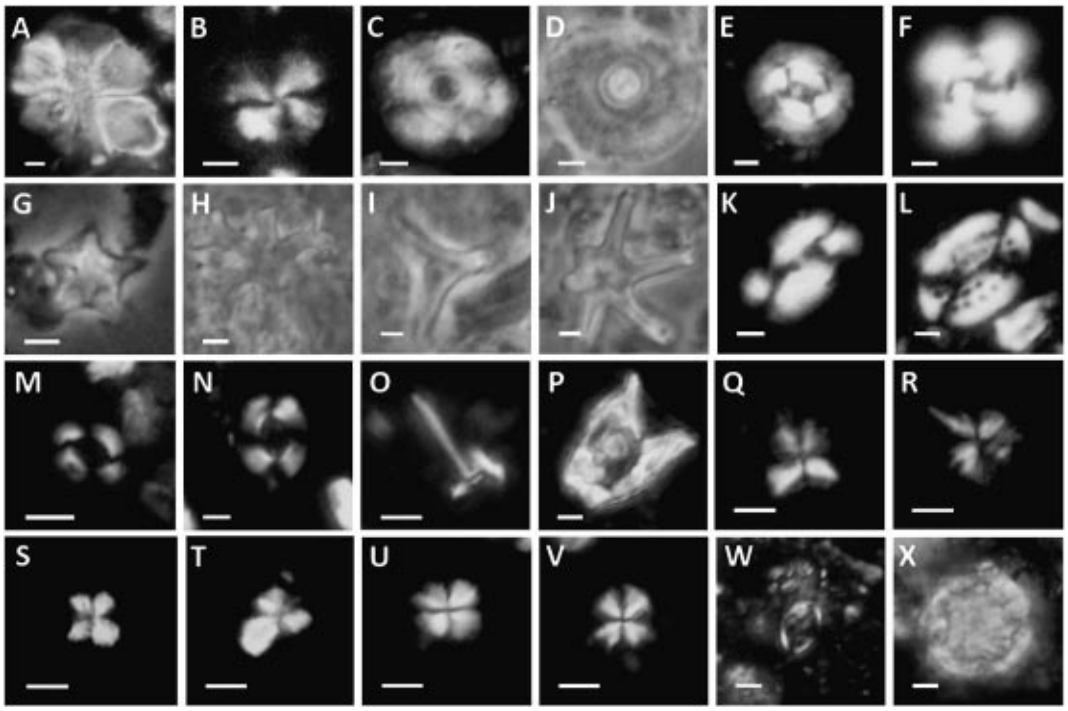

Fig. 4. Selected photomicrographs of calcareous nannofossils observed in the Pugo River section, La Union. XPL = cross-polarized image. PC = phase contrast image (scale bar = 2 microns). **A**. Ascidian spicule, XPL. **B**. *Calcidiscus leptoporus*, XPL. **C–D**. *Calcidiscus macintyrei*, XPL (C) and PC (D). **E**. *Coccolithus pelagicus*, XPL. **F**. *Cyclicargolithus floridanus*, XPL. **G**. *Discoaster berggrenii*, PC. **H**. *Discoaster variabilis*, PC. **I.** *Discoaster triradiatus*, PC. **J**. *Discoaster* sp., PC. **K**. *Helicosphaera carteri*, XPL. **L**. *Pontosphaera* sp., XPL. **M**. *Reticulofenestra minuta*, XPL. **N**. *Reticulofenestra pseudoumbilicus*, XPL. **O.** *Rhabdosphaera procera*, XPL. **P**. *Scyphosphaera pulcherrima*, XPL. **Q–R**. *Sphenolithus abies*, 0° (Q) and 45° (R), XPL. **S–T**. *Sphenolithus conicus*, 0° (S) and 45° (T), XPL. **U–V**. *Sphenolithus moriformis*, 0° (U) and 45° (V), XPL. **W**. *Syracosphaera* sp., XPL. **X**. *Thoracosphaera* sp., XPL.

and the nannofossil zone assignment (NN11), the present study confirms that the Pugo River section indeed belongs to the Amlang Formation. The result of the present study, in addition, confirms the gradational contact between the Klondyke and Amlang Formations as suggested by the "absence" of significant gap in the nannofossil biostratigraphic record, and extends the base of the Amlang Formation from late late Miocene to middle late Miocene (Fig. 5).

The increase in abundance of *Pontosphaera* spp. and *Scyphosphaera* spp. in samples 120-Pugo-04 and 120-Pugo-05 is interesting, as these two genera are considered shallow marine (shelfal) forms (Perch-Nielsen, 1985). The samples where these genera were observed are located below and above a thick sandstone unit, in an otherwise mudstone-dominated section (Fig. 3). The occurrence of large benthic foraminifera in the lower section of the outcrop, as well as the occurrence of ascidian spicules, supports the shallow marine depositional setting of the lower section of the Pugo River outcrop. These observations, however, do not correlate well with the lithological and sedimentological features observed in the outcrop and, thus, could have been transported to a deeper marine setting. As indicated by graded bedding, cross bedding and convolute bedding/lamination features, the sediments could have been transported by turbidity currents, from a shelfal marine environment to a deeper portion of the slope. These observations

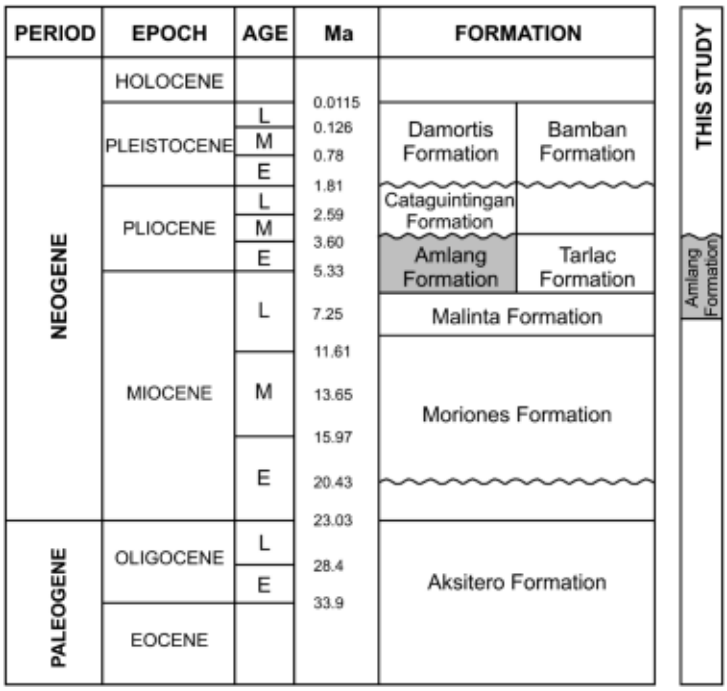

Fig. 5. Generalized stratigraphic column of the Central Valley Basin. The Pugo River section corresponds to the lower Amlang Formation based on lithological and sedimentological characteristics. Based on the results of the calcareous nannofossil biostratigraphic study of the section, the base of the Amlang Formation is extended from late late Miocene to middle late Miocene. Figure modified from Peña (2008).

support the suggestion of De Leon *et al.* (1991) that the Amlang Formation was deposited in a bathyal environment.

Conclusions

1. The presence of *Discoaster berggrenii* in the Pugo River outcrop suggests that the section investigated is within the NN11A Zone, which is equivalent to late Miocene age. This would assign the section to the lower member of the Amlang Formation (Figure 5), and would extend the base of the Amlang Formation from late late Miocene to middle late Miocene.
2. The established nannofossil zonation for the Pugo River section supports the gradational contact with Klondyke Formation, whose upper lithologic units were assigned to the NN10B zone (De Leon *et al.*, 1991; 1998). The nannofossil zone assignments of the two formational units suggest the "absence" of significant gap in the nannofossil record.
3. The Pugo River section is interpreted to have resulted from turbidity currents based on lithological, fossil assemblage and sedimentary structure characteristics (Lorentz, 1984; Tumanda, 1984; Peña, 2008). The presence of shallow (shelfal) marine environment indicator taxa like *Pontosphaera*, *Scyphosphaera* and ascidian spicules in the samples, therefore, suggest that these shallow water components were transported to a deep marine setting (i.e., in the bathyal environment as suggested by De Leon *et al.*, 1991).

Acknowledgements

We would like to thank Nannoworks Laboratory and UP-NIGS for the use of facilities needed for the completion of this short project. We

would also like to thank the Geology 120 Stratigraphy students of UP-NIGS (Class 2013–2014) for providing the data used for the generalized stratigraphic column of the Pugo River Section. Dr. Tomoki Kase of the National Museum of Nature and Science (Tokyo, Japan) is also acknowledged for reviewing the initial draft of the manuscript.

References

Amato, F. L. (1965) Stratigraphic paleontology of the Philippines. *Philippine Geologist*, **19** (1): 1–24.

Aubry, M. P. (1984) *Handbook of Cenozoic Calcareous Nannoplankton*, *Book 1: Ortholithae (Discoasters)*. 266 pp. Micropaleontology Press, The American Museum of Natural History, New York.

Aurelio, M. A. (2000) Tectonics of the Philippines, revisited. *Journal of the Geological Society of the Philippines*, **55** (3–4): 119–183.

Bown, P. R. (1998). *Calcareous Nannofossil Biostratigraphy*. 314 pp. British Micropaleontological Society Publications Series, Chapman and Hall/Kluwer Academic Publishers, London.

Bown, P. R. and Young, J. R. (1998) Techniques. In: Bown, P. R. (Ed.), Calcareous Nannofossil Biostratigraphy. British Micropaleontological Society Publications Series, Chapman and Hall/Kluwer Academic Publishers, London, pp. 16–28.

Cohen, K. M., Finney, S. C., Gibbard, P. L. and Fan, J.-X. (2013) The ICS international chronostratigraphic chart. *Episodes*, **36**: 199–204.

Corby, G. W., *et al.* (1951) Geology and oil possibilities of the Philippines. *Republic of the Philippines*, *Department of Agriculture and Natural Resources*, *Technical Bulletin*, **21**: 1–363.

De Leon, M. M. and Militante-Matias, P. J. (1992) Calcareous nannofossil biostratigraphy of the western part of Tarlac Province, Central Luzon Basin. *Journal of the Geological Society of the Philippines*, **47** (1–2): 35–92.

De Leon, M. M., Tamesis, E. V., and Militante-Matias, P. J. (1991) Calcareous nannofossil study of the Klondyke Formation section along kilometer posts 278-251, Marcos Highway, Baguio City-Pugo, La Union Province. *Journal of the Geological Society of the Philippines*, **46** (3-4), pp. 35–49.

De Leon, M. M., Militante-Matias, P. J., and Tamesis, E. V. (1998) Calcareous nannofossil biostratigraphy of the submarine fan sequence of the Klondyke and Amlang Formations in Benguet and La Union Provinces, Philippines. *Journal of the Geological Society of the Philippines*, **53** (3–4): 89–141.

Lorentz, R. A., Jr. (1984) Stratigraphy and sedimentology of Late Neogene sediments on the southwest flank of Luzon Central Cordillera, Philippines. *Philippine Geologist*, **38** (2): 1–24.

Martini, E. (1971) Standard Tertiary and Quaternary calcareous nannoplankton zonation. In: Farinacci, A. (Ed.), *Proceedings of the Second Planktonic Conference*, *Roma*. Edizioni Tecnoscienza, Roma, pp. 739–785.

Peña, R. E. (1992) A review of the stratigraphy of Baguio District. *Journal of the Geological Society of the Philippines*, **47** (3–4): 151–166.

Peña, R. E. (2008) Lexicon *of Philippine Stratigraphy*. pp. 364. The Geological Society of the Philippines, Inc., Manila.

Perch-Nielsen, K. (1985) Cenozoic Calcareous Nannofossils. In: Bolli, H. M., Saunders, J. B., and Perch-Nielsen, K. (Eds.), Plankton Stratigraphy. Cambridge University Press, Cambridge, pp. 428–554.

Tumanda, F. (1984) Biostratigraphic study of the Rosario Formation. *Philippine Geologist*, **38**(2): 25–34.

Young, J. R. (1998). Neogene. In: Bown, P. R. (Ed.), Calcareous Nannofossil Biostratigraphy. British Micropaleontological Society Publications Series, Chapman and Hall/Kluwer Academic Publishers, London, pp. 225–265.