A new definition of the Letter Stages in the Philippine Archipelago

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ABSTRACT: Long term study of larger foraminiferal biostratigraphy from the Philippine Archipelago, combined with research on supplemental spot samples, leads to a new definition of the East Indies Letter Stages for this region, ranging from a new Tertiary a0 stage to Tertiary h. The newly recognized units, in the form of local assemblage zones of larger foraminifera, are correlated to zonation in other shallow marine carbonate sequences in the eastern and central Tethys.

INTRODUCTION AND HISTORICAL BACKGROUND

The larger foraminifera (Foraminiferida) are the basis of for age and correlation of the Cenozoic sedimentary rocks from shallow carbonate-rich marine environments in the east Tethys region. This is essentially the modern East Indies or Indo-west Pacific region, whch includes Indonesia and the adjacent areas to the north and east. In 1927, Van der Vlerk and Umbgrove proposed a subdivision of the Cenozoic strata exposed in the East Indies by means of a Letter Classification for eight Tertiary "stages", actually zones, with the letters "a" to " h", plus a separate Quaternary, which they based on the ocurrence of 15 of the most important larger foraminifera taxa. By establishing the Letter Stages on local, independent criteria they avoided the confusion that would result from attempting to use the European epochs and ages for the Tertiary strata of the East Indies . Later, Leupold and Van der Vlerk (1931) created finer division of the Letter Stages based on the detailed biostratigraphy of sections in the Tertiary strata of eastern Borneo, mainly derived from studies by W. Leupold. In this new version of the Letter Stages, which used some 48 taxa of larger foraminifera, the four stages "e" through "h", covering upper Oligocene to Pliocene, were subdivided into eleven subzones, based both on larger foraminifera and the percentage of still living species of Mollusca, as contributed by K. Martin. In this way Leupold and Van der Vlerk's Letter Stages were expanded to cover the full span of Tertiary time according to the ranges of stratigraphically important larger foraminifera found in microfaunal assemblages. Unfortunately, they did not define the stage boundariers with stratotypes in type sections within the assemblage-bearing strata in eastern Borneo. Subsequently, Van der Vlerk (1948), van Bemmelen (1949, p. 87, table 13), Mohler (1948, 1949) and Van der Vlerk (1955) further revised the Letter Stages.

The Letter Stages are presently subdivided as follows: Tertiary a (a1, Paleocene, with genera *Miscellanea* and *Ranikothalia*; a2, lower Eocene, with genus *Flosculina*; and a3, middle Eocene), Tertiary b (upper Eocene), Tertiary c and d (lower Oligocene Rupelian); Tertiary e (e1-4, upper Oligocene Chattian, and e5, lower Miocene Aquitanian), Tertiary f (f1 or Tertiary f-lower, of lower Miocene age with genera *Miogypsinoides*, *Miogypsina* s.s., and *Nephrolepidina*, and *Tertiary* f2-3 or Tertiary f -upper, middle and upper Miocene, with genera *Miolepidocyclina* and *Miogypsina* s.s.), and Tertiary g/h (Pliocene).

The Letter Stages have long been used in the chronostratigraphic sense to date the Cenozoic sedimentary rocks in the east Tethys region in Borneo, Andaman Sea, Java Sea, Philippine Archipelago, Ogasawara Islands, Micronesia, Eniwetok and Bikini Atolls, and others (Cole 1954, 1957, 1963, 1969; Hanzawa 1957, p. 5-6; Adams 1965, 1970, 1984; Adams and Belford 1984; Matsumaru 1974, 1976, 1996; Matsumaru and Barcelona 1982; Hashimoto et al. 1977, 1978, 1979, 1980, 1981, 1982; Hashimoto and Matsumaru 1984; van Vessem 1978; Boudagher-Fadel and Banner 1999, and others). Adams (1984, p. 53-54, fig. 5) showed a major application of the Letter Classification from Tertiary c (Rupelian) to Tertiary g/h (Pliocene-Recent) based on 24 important larger foraminiferal genera, which were selected from the ranges of 137 taxa in the Philippines demonstrated by Hashimoto et al. (1977).

As part of a study for more than 40 years of the Cretaceous to Cenozoic larger foraminiferal biostratigraphy in the east Tethys region including Japan and Taiwan in collaboration with W. Hashimoto and colleagues, the author has reviewed the Letter Stages in the Philippines first presented by Hashimoto et al. (1977) and Hashimoto and Matsumaru (1984), that were based on 137 taxa and 145 taxa (respectively) of the most important larger foraminifera in this region. In this review, in order to make a comprehensive revision of the Philippine Letter Stages a better linkage is established between the larger foraminiferal biostratigraphy and the standard planktic foraminiferal zonations and/or radiometric ages, as well as the biostratigraphy in the western Tethys region (Matsumaru et al. 2010) and central Tethys region (Matsumaru and Sarma 2010). A stricter definition of boundaries for the the Letter Stages in the Cenozoic sedimentary rocks in which the samples of larger foraminifera were obtained is made more complicated by the geological problems created by the various depositional environments and tectonic histories of the region, not to mention the extensive reworking in the shallow water sediments where larger foraminifera occur, and by paleontological problems of misidentification of newly evolved and immigrant species (i.e. from the Caribbean region).

The purpose of this study is to introduce and describe new definition of the Letter Stages, based on revision of old data and introduction of new data gathered from the Philippines Archipelago up until the present day, together with the systematic description of the genera and species treated in the text. The illustration of will be published separately, because of space limitation (Text-figure 1).

BIOSTRATIGRAPHY AND NEW DEFINITION OF LETTER STAGES

The Letter Stages for the Philippines are re-defined in terms of 17 larger foraminiferal assemblage zones, in 16 divisions from Tertiary a0 to Tertiary h (Text-figure 2). Tertiary a0 is established as a new division, and Tertiary e is subdivided into 5 units, as Tertiary e1-2, Tertiary e3, Tertiary e4, Tertiary e5 lower and Tertiary e5 upper (Text-figures 2-3). The subdivisions of Tertiary e can be recognized as independent zones, based on evolution and ranges of species composing independent faunal assemblages of successive ages. The author, however, has not assigned separate letters to the independent stages in Tertuary e, in the same way as differentiating Tertiary a0 from Tertiary a1, because of long tradition for the use of Tertiary e in the Letter Stages.

Assemblage 1: *Broekinella arabica* Henson - *Coskinon rajkae* Hottinger and Drobne – *Idalina sinjarica* Grimsdale – *Miscellanea primitiva* Rahaghi – *Pseudolituonella* sp. (nov.) - *Rotalia trochidiformis* (Lamarck).

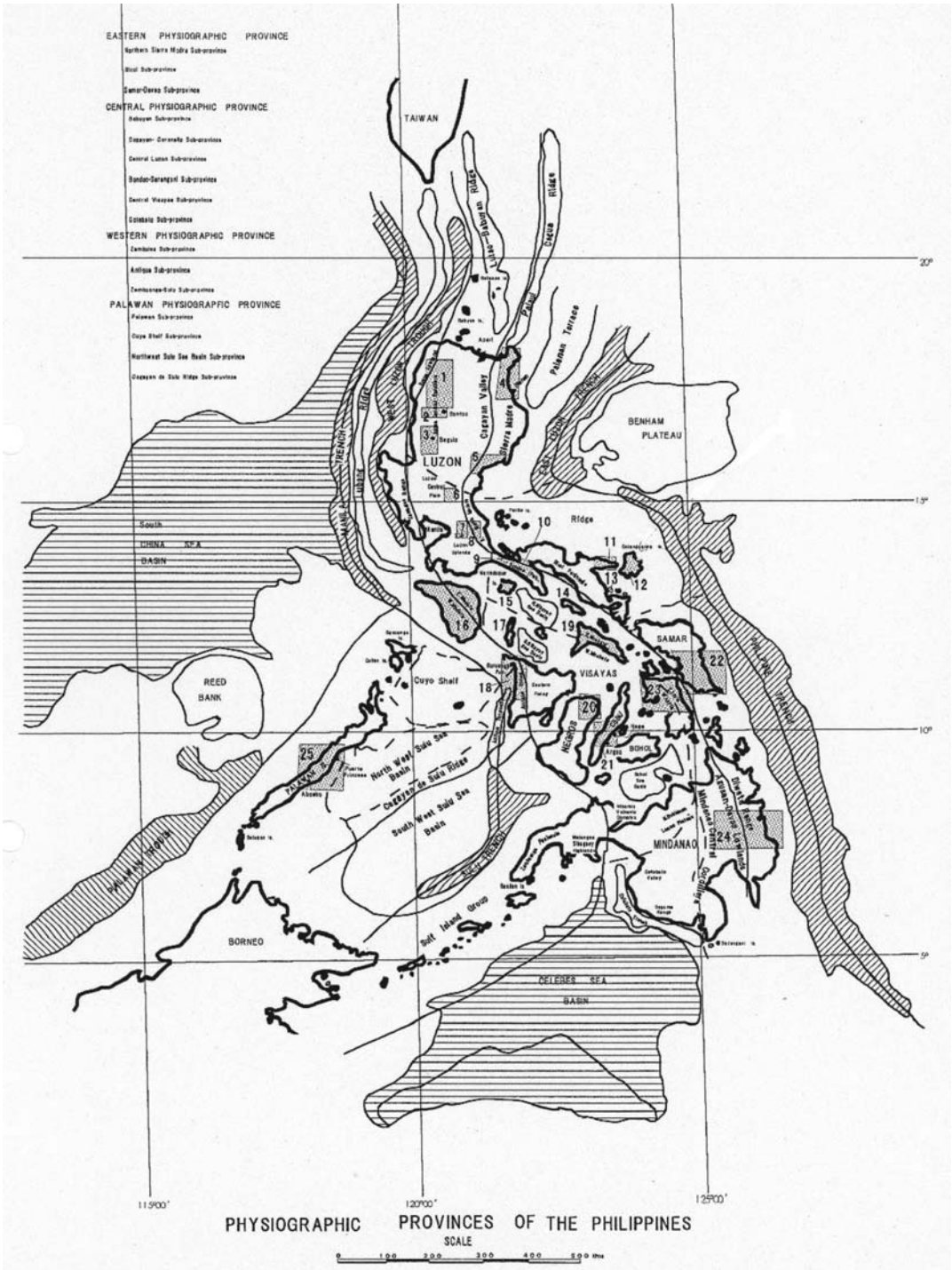
This defining taxa of this assemblage are found in the composite fauna in two type samples from two separate type sections, selected to compensate for the variation in environment in different regions. The first, Sample 7451105b of the lower Masungit Limestone, Maybangain Formation in the Pinugay Hill section, Mid-Luzon (Hashimoto et al. 1978a, figs. 2-3) yields *Idalina sinjarica, Miscellanea primitiva* Rahagi*, M.* spp*., Rotalia trochidiformis, Morozovella* ex gr. *M. pseudobulloides* (Plummer), *M. trinidadensis* (Bolli), *M.* ex gr. *M. conicotruncata* (Subbotina), *Planorotalites compressa* (Plummer). The second is sample G316 of the lower limestone of the Barcelona Group in the Taon River – Bislig River composite section, East Mindanao (Matsumaru 1974, text-fig. 2; RP - Japan Project 1972; H. Fuchimoto, Bishimetal Exploration Co. Ltd., oral communication). This sample yields *Broeckinella arabica*, *Crysalidina* sp., *Pseudolituonella* sp. nov., *Coskinon rajkae, Idalina sinjarica, Pfendericonus* spp., *Morozovella* ex gr. *M. pseudobulloides, M. trinidadensis,* and a new form of larger foraminifera. In addition to the above type samples, Assemblage 1 is known from sample CR37 of the Garchitorena Formation, Caramoan Peninsula, SE Luzon (Takizawa et al. 1996, fig. 2); sample 121006 of the lower Sipi Limestone, Catanduanes Island (Hashimoto and Matsumaru 1981a, text-fig. 2); and samples EN and I 4, both of the lower limestone of the Barcelona Group, East Mindanao (Matsumaru 1974, text-fig. 2 ; RP – Japan Project 1972). From these samples, we can also include the following in Assemblage 1: *Calcarina* sp. nov., *Chrysalidina* spp., *Coleiconus* spp., *Fabiania* spp., *Miscellanea primitiva* Rahaghi, *Miscellanea* spp. (possibly *M. primitiva*), *Kathina selveri* Smout, *Pfendericonus* spp., *Pseudolituonella* sp., and *Pseudochrysalidina* spp. As a result, Assemblage 1 represents a combination of faunal elements from both the Tethys region (i.e. *Broeckinella arabica*, and *Idalina sinjarica*) and the Caribbean region (i.e. *Coleiconus* spp.). It can also be correlated with planktonic foraminiferal zone P3 (Blow 1969; Berggren and Van Couvering 1974; Toumarkin and Luterbacher 1985) due to the presence of *Morozovella* ex gr. *M. pseudobulloides, M. trinidadensis, M.* ex gr. *M. conicotruncata*, and *Planorotalites compressa*.

Assemblage 1 is assigned to Tertiary a0, a new division of the Leupold and Van der Vlerk Letter Stages, because it lacks the defining taxa of the younger Tertiary a1, i.e. *Miscellanea miscella* (d'Archiac and Haime) and *Ranikothalia nuttalli* (Davies) (Van der Vlerk 1955; Adams 1970; Hashimoto and Matsumaru 1984).

Geological age: Middle Paleocene (Selandian), and Letter Stage Tertiary a0.

Assemblage 2: *Daviesina danieli* Smout – *Kathina selveri* Smout – *Orbitoclypeus ramaraoi* (Samanta) –*Lockhartia haimei* (Davies) – *Miscellanea miscella* (d'Archiac) – *Ranikothalia nuttalli* (Davies) – *Alveolina vredenburgi* Davies.

The seven defining species of this assemblage are found in the composite fauna of three co-type samples that represent the variations in environmental conditions in different regions. The first, sample 7451105a of the lower Masungit Limestone, Maybangain Formation in the Pinugay Hill section, Luzon (Hashimoto et al. 1978, figs. 2-3) yields *Daviesina langhami* Smout, *Kathina mayor* Smout, *K. selveri* Smout, *Miscellanea primitiva*, *Orbitoclypeus ramaraoi, Ranikothalia nuttalli, Rotalia trochidiformis, Morozovella* ex gr. *M. pseudobulloides, M. trinidadensis, M*. ex gr. *angulata* (White), *M*. gr. *M. conicotruncata* (Subbotina), *M. velascoensis* (Cushman), *Acarinina mckannai* (White), *Planorotalites compressa*, *P. pusilla pusilla* (Bolli), and *Globigerina triloculinoides* Plummer. The second sample, no. 7682301 of the lower Sula Formation, Cagraray Island (Hashimoto et al. 1981, text-fig. 2) yields *Alveolina ellipsoidalis* Schwager, *A. vredenburgi* Davies, *Asterocyclina stellata* (d'Archiac), *Daviesina danieli* Smout, *Miscellanea globularis* Rahaghi, *M. primitiva*, and *Orbitoclypeus ramaraoi*. The third sample, MQ2 of the Talutunan-Tumicob Formation, Marinduque Island (Hashimoto and Sato 1969, fig. 28; Hanzawa and Hashimoto 1970, text-fig. 2; Hashimoto and Matsumaru 1984, p. 153) yields *Daviesina danieli, Lockhartia conditi* (Nuttall), *L. haimei* (Davies), *Miscellanea miscella, Orbitoclypeus ramaraoi, Ranikothalia nuttalli, Morozovella uncinata* (Bolli), *M. velascoensis, M*. ex gr. *M. aequa* (Cushman and Renz), and *Acarinina* spp. Assemblage 2 is also known from sample A422 of the Formation I, Caraballo Group, NE Luzon (RP – Japan Project 1976; Hashimoto et al. 1980, fig. 2); samples 31056 and 31057 of the tuffaceous limestone, Unisan Volcanics, Bondoc Peninsula, SE Luzon (Hashimoto and Matsumaru 1981a, text-fig. 4); sample CR35 and CR36 of the Garchitorena Formation, Caramoan Peninsula, SE Luzon (Takizawa et al. 1996, fig. 2); sample 7681902 of the lower Sula Formation, Cagraray Island (Hashimoto et al. 1981, text-fig. 2); sample WR154 of the Abrade Ilog Formation, near 2 km SW from Pocanil Point, Mindoro Island (Hashimoto and Sato 1969, fig. 25; RP –Japan Project 1982); and samples F538, E 12, I 9 and I 3 of the limestone of the Barcelona Group, East Mindanao (RP – Japan Project 1972; Matsumaru 1974, text-fig. 2). These additional samples add the following species to Assemblage 2: *Alveolina ellipsoidalis* Schwager, *A.* spp., *Asterocyclina incisuricamerata* Cole, *A. stella* (Gümbel), *Broeckinella arabica*, *Pseudolituonella* sp., *Coleiconus* spp., *Daviesina langhami* Smout, *D.* spp., *Glomalveolina* sp. nov., *Idalina sinjarica, Kathina major* Smout, *Lockhartia conditi* (Nuttall), *L.* spp., *Miscellanea globularis* Rahaghi, *M. primitiva, M.* spp.,



TEXT-FIGURE 1

Index map showing physiographic province in the Philippine Archipelago (BMG 1981) and study area, marked with dotted as follows: Nos. 1-3, Bontoc, North Luzon (Hashimoto 1939, 1975; Hashimoto and Sato 1969; RP-Japan Project 1980; Hashimoto and Matsumaru 1981); No. 4, Palanan, North Luzon (Hashimoto and Matsumaru 1975); No. 5, Caraballo Mountains, NE Luzon (RP-Japan Project 1976; Hashimoto et al. 1980); No. 6, Sibul, Mid-Luzon (Hashimoto and Sato 1969); No. 7, Montalban, Mid-Luzon (Hashimoto and Sato 1969; Hanzawa and Hashimoto 1970); No. 8, Pinugay Hill, Mid-Luzon (Hashimoto et al. 1978, 1979); Nos. 9-10, Bondoc Peninsula, SE Luzon (Hashimoto and Matsumaru 1981; Matsumaru and Barcelona 1982); No. 11, Caramoan Peninsula, SE Luzon (Hashimoto and Matsumaru 1981; Takizawa et al. 1996); No. 12, Catanduanes Island (Hashimoto and Matsumaru 1981); No. 13, Cagraray Island (Hashimoto et al. 1981); No. 14, Burias Island (Hashimoto 1981); No. 15, Marinduque Island (Hashimoto and Sato 1969; Hanzawa and Hashimoto 1970); No. 16, Mindoro Island (Hashimoto and Sato 1969; Hashimoto et al. 1976, 1977; RP-Japan Project 1982); No. 17, Tablas Island (Corby et al. 1951; Hashimoto and Sato 1969); No. 18, Panay Island (Hashimoto 1973); No. 19, Masbate Island (Corby et al. 1951; BMG, 2 1981); No. 20, Negros Island (Hashimoto et al. 1982); No. 21, Cebu Island (Hashimoto et al. 1978; Alcantara 1980); No. 22, Samar Island (Hashimoto and Matsumaru 1978); No. 23, Leyte Island (BMG 1981); No. 24, East Mindanao (RP-Japan Project 1972; Matsumaru 1974); and No. 25, Palawan Island (Hashimoto and Matsumaru 1982).

Operculina spp., *Orbitosiphon tibetica* (Douvillé), *Pseudochrysalidina* spp., and *Rotalia trochidiformis*.

Assemblage 2 is assigned to Tertiary a1, due to occurrence of *Miscellaneas miscella* and *Ranikothalia nuttalli.* With regard to the larger foraminiferal zones of the Meghalaya section of NE India, Tertiary a1 can be correlated with both the *Idalina sinjarica – Miscellanea primitiva – M. miscella – Kathina selveri – Lockhartia diversa* Smout Assemblage 1, and *Aberisphaera gambanica* Wan – *Daviesina khatiyahi* Smout – *Lockhartia haimei* (Davies) – *Miscellanea miscella – Ranikothalia nuttalli* Assemblage 2 of the late Paleocene (Thanetian) Lakadong Limestone (Matsumaru and Jauhri 2003; Matsumaru and Sarma 2010). In addition, Philippine Assemblage 2 contains planktic foraminifera from samples 7451105a, CR35, CR36, and MQ2 such as *Morozovella* ex gr. *M. pseudobulloides, M. trinidadensis, M. uncinata* (Bolli), *M*. ex gr. *M.angulata* (White), *M*. ex gr. *M. conicotruncata* (Subbotina), *M. verascoensis* (Cushman), *M*. ex gr. *M.aequa* (Cushman and Renz), *M*. spp., *Acarinina mckannai* (White), *A*. spp., *Planorotalites compressa, P. pusilla pusilla* (Bolli), *P.* ex gr. *P. chapmani* (Parr) and *Globigerina triloculinoides* Plummer. These planktic foraminifera indicate at least Zone P5 (Blow 1969; Berggren and Van Couvering 1974; Toumarkin and Luterbacher 1985). At the same time, while Assemblage 2 contains Tertiary a0 species such as *Broeckinella arabica, Miscellanea primitiva, Rotalia trochidiformis, Coskinon rajkae,* and *Idalina sinjarica*, the occurrence of new species such as *Lockhartia conditi* (Nuttall), *Daviesina langhami* Smout, *Kathina major* Smout, as well as the diagnostic species noted above, indicate a younger age than Assemblage 1.

Geological age: Late Paleocene (Thanetian), and Letter Stage Tertiary a1.

Assemblage 3: *Alveolina subpyrenaica* Leymerie – *Nummulites atacicus* Leymerie – *N. burdigalensis* (de la Harpe) – *N. globulus* Leymerie – *N. millecaput* Boubée –*Opertorbitolites douvillei* Nuttall.

The six species above that define this assemblage are found in the type sample 7451215 of the upper Masungit Limestone, Maybangain Formation in the Tanay - Daraitan section, Pinugay Hill, Luzon Central Valley, Mid-Luzon (Hashimoto et al. 1979, figs. 1, 3). Assemblage 3 is also known in samples 7451213, 7451209 and 7451212 of the upper Masungit Limestone in the Tanay – Daraitan section, Pinugay Hill; sample 31055 of the tuffaceous limestone of the Unisan Volcanics, Bondoc Peninsula, SE Luzon (Hashimoto and Matsumaru 1981a, text-fig. 4; BMG 1981); samples CR42, CR44, CR51, CR75, and 6611806 of the Guihalo Formation, Caramoan Peninsula, SE Luzon (Hashimoto and Matsumaru 1981a, text-fig. 3; Takizawa et al. 1996, fig. 2); sample 7682302 of the upper Sula Formation, Cagraray Island (Hashimoto et al. 1981a, text-fig. 2). The other species that occur in Assemblage 3 are *Alveolina amarasiensis* (Henrici), *Alveolina* sp. nov., *A. ellipsoidalis* Schwager, *A. vredenburgi* Davies, *Assilina* sp. nov., *Asterocyclina incisuricamerata, Asterocyclina* sp. nov., *A. stella, A. stellata* (d'Archiac), *Daviesina danieli, D. khatiyahi, Fabiania cassis* (Oppenheim), *Glomalveolina levis* Hottinger, *Idalina sinjarica, Miscellanea miscella, M.* spp., *Nummulites amakusensis* Yabe and Hanzawa, *N. distans* Deshayes, *N. hongoensis* Hanzawa, *N. junbarensis* Matsumaru, *Operculina custugensis* Massieux, and *Orbitoclypeus ramaraoi*. Reworking of specimens from Tertiary a1 can be seen in this fauna.

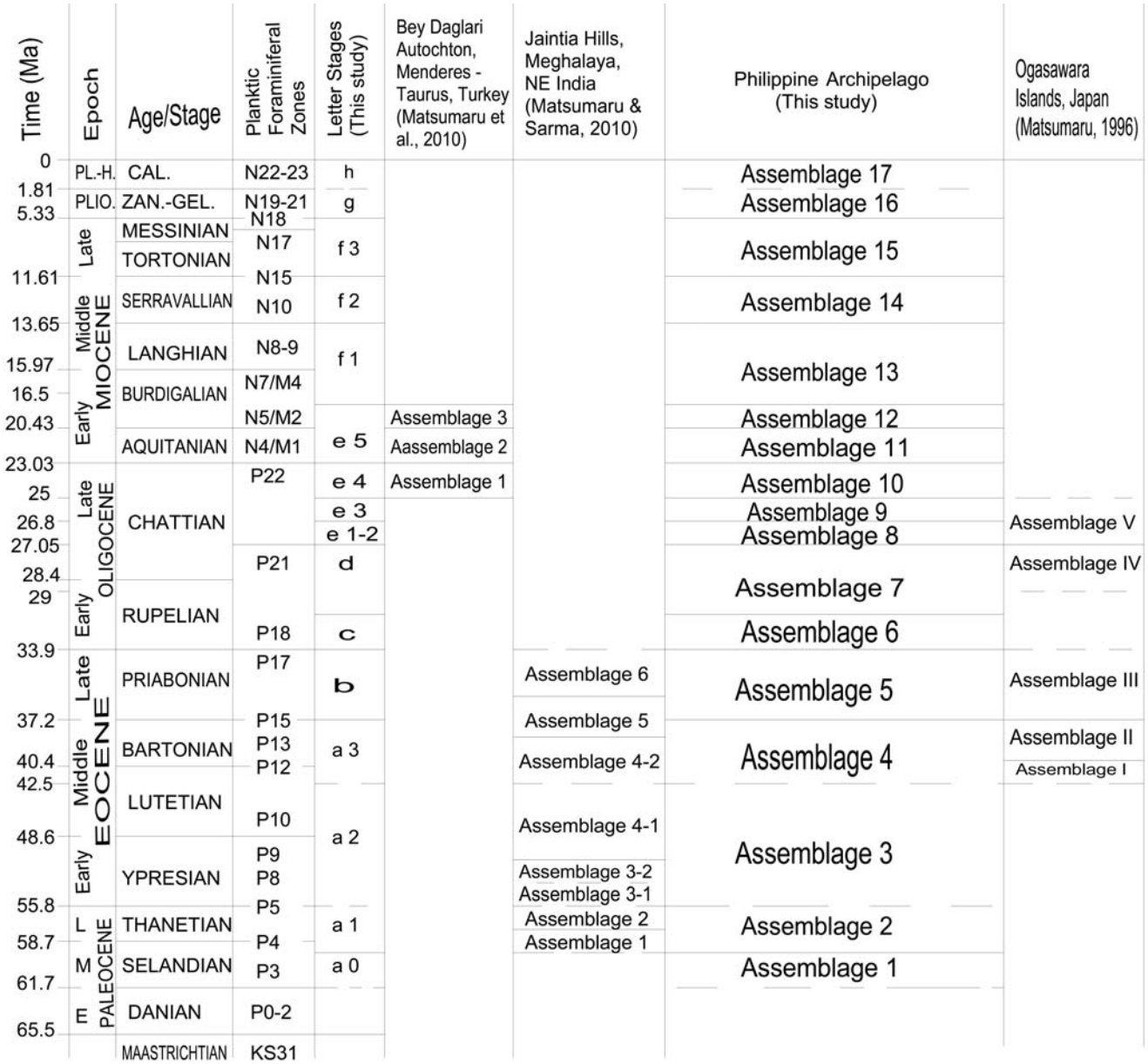
In the shallow water sequence of Meghalaya, NE India, Assemblage 3 is correlated to the *Alveolina oblonga* d'Orbigny – *A. schwageri* Checchia-Rispoli – *Assilina laxispira* de la Harpe – *A. placentula* (Deshayes) Assemblage 3-1 and the *Nummulites atacicus – N. globulus* Assemblage 3-2 of the Umlatdoh Limestone, and in addition to the *Alveolina elliptica nuttalli* Davies – *Nummulites beaumonti* d'Archiac and Haime – *N. gizehensis* (Forskål) – *N. perforatus* (Montfort) – *Orbitolites complanatus* Lamarck Assemblage 4-1 from the lower Prang Limestone (Matsumaru and Sarma 2010), according to the occurrence of *Nummulites atacicus, N. burdigalensis, N. globulus* and *N. millecaput* in all three Indian assemblages. Furthermore, Assemblage 3 from the Philippines contains planktic foraminifera in samples 7451212, 7451213, and 6611806 such as *Morozovella* ex gr. *M. aequa, M.* ex gr. *M. subbotinae* (Morozova), *Acarinina mckannai, A. nitida* (Martin), *A. primitiva* (Finlay), *A. soldadoensis soldadoensis* (Brönnimann), *A. broedermanni* (Cushman and Bermudez), and *Globigerina* ex gr. *G.lozanoi* Colom, and is thus partially correlative with P8 Zone (Blow 1969; Berggren and Van Couvering 1974; Toumarkin and Luterbacher 1985), which shares *M*. ex gr. *M. subbotinae, A. primitiva, A. soldadoensis soldadoensis,* and *A. broedermanni.*

Geological age: Late Early Eocene (Ypresian) to Middle Eocene (Lutetian), and Letter Stage Tertiary a2.

Assemblage 4: *Nummulites gizehensis* (Forskål) – *N. perforatus* (Montfort) – *N. ptukhiani* Kacharava – *N. striatus* (Bruguiere) – *Assilina exponens* (Sowerby).

The five defining species of this assemblage occur in a composite fauna derived from three type samples. The first is sample H502, Formation III of the Caraballo Group in the Kasibu section, NE Luzon (RP – Japan Project 1976; Hashimoto et al. 1980, fig. 2), which yields *Assilina exponens, Asterocyclina stella* (Gümbel), *Nummulites gizehensis* and *N. striatus*. The second sample, MQ28 of Taltunan-Tumicob Formation, Marinduque Island (Hashimoto and Sato 1969, fig. 28; Hanzawa and Hashimoto 1970, text-fig. 2; Hashimoto and Matsumaru 1984, p. 153) yields *Assilina exponens, Nummulites gizehensis, N. perforatus* and *Operculina* spp. The third *s*ample, F578 from limestone of the Koban Group, East Mindanao (RP – Japan Project 1972; Matsumaru 1974, text-fig. 2) yields *Alveolina* spp., and *Nummulites ptukhiani.* Assemblage 4 is also known in sample J310 of the Formation III of the Caraballo Group, NE Luzon (RP – Japan Project 1976; Hashimoto et al. 1980, fig. 2); sample 120902, top Sipi Limestone, Catanduanes Island (Hashimoto and Matsumaru 1981a, text-fig. 2); and sample YR2-025 of the Caguray Formation, Sablayan Group, Mindoro Island (RP – Japan Project 1982). These document the occurrence in this assenblage of *Assilina* spp., *Asterocyclina incisuricamerata, A. stella, A. stellata, Fabiania cassis, Operculina schwageri* Silvestri, and *O.* spp. Assemblage 4 is assigned to Tertiary a3, due to occurrence of *Nummulites gizehensis* and *N. perforatus* (Matsumaru 1996).

In regard to the Meghalaya section of NE India, Assemblage 4 is correlated with the *Nummulites acutus* Sowerby – *N. beaumonti* d'Archiac and Haimei – *N. gizehensis – N. millecaput – N. perforatus* Assemblage 4-2 and in part to *Nummulites perforatus – Operculina subformai – Pellatispira*



TEXT-FIGURE 2
Correlation chart between larger foraminiferal assemblages of the Philippine Archipelago in this study and those in former studies from Ogasawara Islands (Matsumaru 1996), Turkey (Matsumaru et al. 2010) and NE India (Matsumaru and Sarma 2010), and the Paleocene-Holocene Time scale (official website of ICS, 2004 and Berggren et al. 1995) with planktic foraminiferal zones (Blow 1969; Berggren and van Couvering 1974; Toumarkin and Leuterbacher 1985; Bolli and Saunders 1985; Berggren et al. 1995) and Letter Satges of a new definition. KS31: W. V. Sliter (1989)'s planktic foraminiferal zones.

madaraszi (von Hantken) – *P. orbitoidea* (Provale) Assemblage 5 of the middle and upper Prang Limestone, respectively (Matsumaru and Sarma 2010). Assemblage 4 of the Philippines is also correlated with the *Nummulites aturicus* Joly and Leymerie – *N. gizehensis* – *N. millecaput* Assemblage I of the Yusan Formation and *Nummulites pengaronensis* Verbeek – *N. perforatus* – *Alveolina elliptica* Assemblage II of the Okimura Formation, both of Haha-Jima, Ogasawara Islands, according to the occurrence of *Nummulites gizehensis* and *N. perforatus*, repectively (Matsumaru 1996). Volcanic rocks of the Yusan Formation are K-Ar dated to 42.5 Ma (Kaneoka et al. 1970), and the formation is conformably overlain by the Okimura Formation with the type section of *Orbulinoides beckmanni* (Saito), indicative of Zone P13 (Matsumaru 1996). Assemblage 4 is thus securely correlated to Zones P12 to P13, according to the stratigraphy, planktic zones and radiometric ages.

Geological age: Middle Eocene (Lutetian – Bartonian), and Letter Stage Tertiary a3.

Assemblage 5: *Nummulites fabianii* (Prever) – *Spiroclypeus granulosus* Boussac – *Biplanispira mirabilis* (Umbgrove)

The three defining species above occur in the type sample MD117 of the Caguray Formation, Mindoro Island (RP – Japan Project 1982; Hashimoto and Sato 1969, fig. 25). Assemblage 5 is known in limestone samples h2144, h2155, BG6A, BG7, BG8, and BG12 within the pyroclastics of the Tineg Formation and/or Licuan Group, Bontoc area, North Luzon (RP – Japan Project 1980; Hashimoto and Matsumaru 1981, text-fig. 1); as well as samples G102 and I 19 of the Formation III of the Caraballo Group, NE Luzon (RP – Japan Project 1976; Hashimoto et al. 1980, fig. 2); limestone samples CT18, CT19, CT20, CT38, and CT39 of the olistostrome facies, Silat Point, Catanduanes Island (Hashimoto and Matsumaru 1981a, text-fig. 2); and samples TR2-005, WR41, MD115, and MD116, in the Bugusanga River section, and samples YR2-024, MD83, MD111, MD77, MD104, MD70, MD101, and MD100, in the Caguray River section, both of the lower Sablayan Group or Caguray Formation, Mindoro Island (RP – Japan Project 1982; Hashimoto and Sato 1969, fig. 25). The species that occur in the above samples allow further characterization of this assemblage as follows: *Pellatispira crassicolumnata* Umbgrove, *P. orbitoidea* (Provale), *P. madaraszi* (Von Hantken), *P. provalei* Yabe, *P. inflata* (Umbgrove), *Biplanispira absurda* Umbgrove, *Nummulites incrassatus* de la Harpe*, N. striatus* Bruguiere, *N. vascus* Joly and Leymerie, *Operculina saipanensis* Cole, *O. eniwetokensis* Cole, *O. schwageri, Heterostegina aequatoria* Cole, *H. saipanensis* Cole, *Cycloclypeus* spp., *Discocyclina dispansa* (Sowerby), *D. llarenai* Ruiz de Gaona, *Orbitoclypeus pygmaeus* (Henrici), *Asterocyclina stella, A. stellata, A. pentagonalis* (Deprat), *Borelis globosa* Matsumaru, *B. parvulus* Hanzawa, *B. pygmaeus* (Hanzawa), *Halkyardia minima* (Liebus), *Tayamaia marianensis* (Hanzawa), *Orbitogypsina vesicularis* Matsumaru, *O.* spp., *Discogypsina vesicularis* (Parker and Jones) *Amphistegina radiata* (Fichtel and Moll), *Sphaerogypsina globulus* (Reuss), *Acervulina inhaerens* Schultze, *Carpenteria* spp., *Fabiania cassis*, as well as new foraminiferal taxa.

Assemblage 5 is assigned to Tertiary b (Douvillé 1905; Van der Vlerk 1929; Leupold and Van der Vlerk 1931; Matsumaru 1996), due to coexistence of *Nummulites fabianii, Biplanispira mirabilis, B. absurd*a, *Spiroclypeus granulosus,* and *Borelis pygmaeus*. The following planktic foraminifera are also found in this assemblage: *Catapsydrax* cf. *C. dissimilis* (Cushman and Bermudez) in Sample MD117; *Globigerinatheka* cf. *G. index tropicalis* (Blow and Banner) and *Globigerina* ex gr. *G. ampliapertura* Bolli, in sample TR2-005; and *Globigerinatheka* cf. *G. index index* (Finlay) in sample h2144. As such these species indicate at least Zone 16-17 (Blow 1969; Berggren and Van Couvering 1974; Toumarkin and Luterbacher 1985). In the Sekimon Limestone, Haha-Jima, Ogasawara Islands, Assemblage 5 is correlated with the *Biplanispira absurda – Pellatispira provalei* Assemblage (Assemblage III) (Masumaru 1996) according to the common occurrence of *B. absurda* and *P. orbitoidea.* In the Meghalaya sequence of NE India, Philippine Assemblage 5 is partially correlated with the *Nummulites perforatus – Operculina subformai – Pellatispira madaraszi – P. orbitoidea* Assemblage 5 from the upper Prang Formation, and more so with the *Nummulites incrassatus – N. striatus – Pellatispira orbitoidea* Assemblage 6 from the Kopili Formation (Matsumaru and Sarma 2010), according to the common occurrence of *P. orbitoidea, N. incrassatusi* and *N. striatus.*

Geological age: Late Eocene (Priabonian), and Letter Stage Tertiary b.

Assemblage 6: *Nummulites fichteli* (Michelotti) – *Heterostegina duplicamera* Cole.

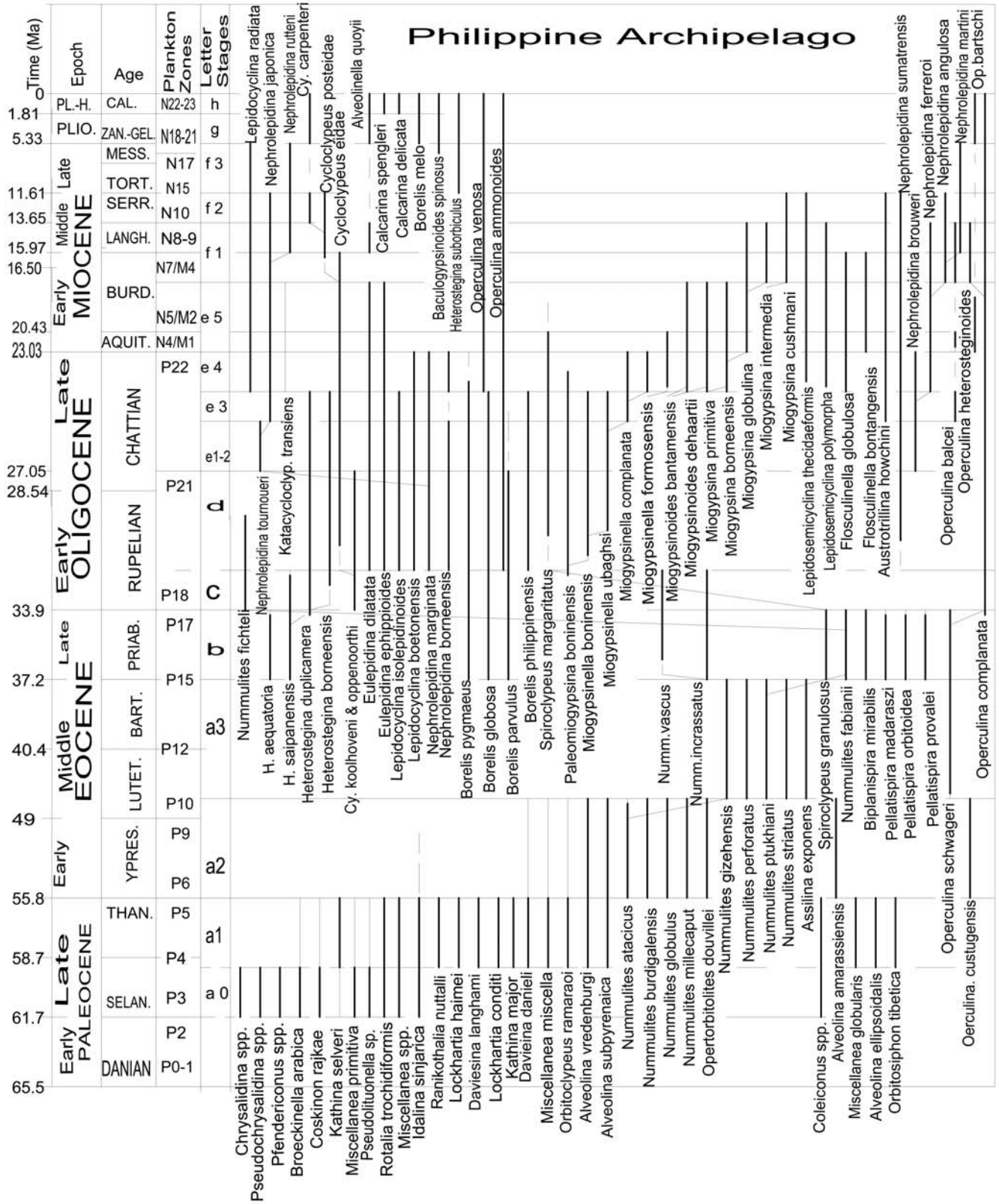
The two defining species above occur in the type sample B130 of the Mamparang Formation, NE Luzon (RP – Japan Project 1976; Hashimoto et al. 1980, fig. 2). Assemblage 6 is also known from other samples as follows: sample h2505 of the Tineg Formation, and sample B at Sagada Plateau, also probably from the Tineg Formation (former Sagada Limestone), Bontoc, North Luzon (RP – Japan Project 1980; Hashimoto and Matsumaru 1981b, text-fig. 1); in sample WR202 at the Bugsanga River section of the upper limestone of the Sablayan Group (Bandao Limestone) and sample 11479 at the Bugton Section of the lower Bugton Limestone, both of Mindoro Island (RP – Japan Project 1982; Hashimoto et al. 1977, fig. 1); and samples CB2, CB3, 7442623 and 7442624 of the lower Lutac Hill Limestone, Cebu Island (Hashimoto et al. 1978b, text-figs. 1-2), respectively. The other species occurring in the above samples further characterize the assemblage as follows: *Nummulites incrassatus, N. vascus, Operculina saipanensis, O. complanata* (Defrance), *Cycloclypeus koolhoveni* Tan, *C. oppenoorthi* Tan, *Borelis globosa, B. pygmaeus, B. parvulus, Halkyardia minima, H. bikininensis* Cole, *Heterostegina saipanensis, H. borneensis* Van der Vlerk, *H*. spp., *Peneroplis planatus* (Fichtel and Moll), *Amphistegina radiata*, *Sphaerogypsina globulus, Planorbulinella larvata* (Parker and Jones). Specimens of *Eorupertia boninensis* Yabe and Hanzawa and *Discocyclina* spp in these samples are regarded as reworked.

Assemblage 6 is assigned to Tertiary c, due to occurrence of *Nummulites fichteli,* which is found in the Borneo sequence (Douvillé 1905; Van der Vlerk 1929; Leupold and Van der Vlerk 1931). Ssample B130 also yields the planktic foraminifera *Paragloborotalia* ex gr. *P. opima nana* (Bolli), *Globigerina* ex gr. *G. sellii* (Borsetti), and *Globigerina* cf. G. *tripartita* Koch; these species indicate Zones P18-19 (Blow 1969; Bolli and Saunders 1985).

Geological age: Early Oligocene (Rupelian), and Letter Stage Tertiary c.

Assemblage 7: *Nummulites fichteli – Heterostegina borneensis – Eulepidina dilatata* (Michelotti) – *E. ephippioides* (Jones and Chapman) – *Lepidocyclina isolepidinoides* van der Vlerk– *Nephrolepidina marginata* (Michelotti) – *N. borneensis* (Provale) – *Borelis pygmaeus* (Hanzawa).

The eight species above that define this assemblage are found together in the type sample 11474 of the lower Bugton Limestone, Mindoro Island (Hashimoto et al. 1977, fig. 1). Assemblage 7 is also recognized in other samples, as follows: sample h2506, BG6B, and A of the Tineg Formation, Bontoc area and Sagada Plateau, North Luzon (RP – Japan Project 1980; Hashimoto and Matsumaru 1981b, text-fig. 1); sample B128 of the Mamparang Formation, NE Luzon (RP – Japan Project 1976; Hashimoto et al. 1980, fig. 2); limestone samples TR2-039 andTR2-029 of the Sablayan Group in the Mongpong River section, and samples WR203 and WR204 of the Bandao



TEXT-FIGURE 3
Biostratigraphic synthesized occurrence and phylogenetic relationship of main larger and important foraminiferal species from the Philippine Archipelago.

Limestones or limestones of the Sablayan Group in the Bugsanga River section, and samples 11473, 11475, 11477, 11483, 11469, 11478, and 11480 of the Bugton Limestones at Bugton section, all of Mindoro Island ((RP – Japan Project 1982; Hashimoto and Sato 1969, fig. 25; Hashimoto et al. 1977, fig. 1); samples 7442626, 7442627 and 7462628 of the Lutac Hill Limestone, Cebu Island (Hashimoto et al. 1978b, text-figs. 1-2); sample H14 of the Mangagoy Formation, East Mindanao (Matsumaru 1974, text-fig. 2); sample QZ4 of the Td limestone of Palawan Island (Hashimoto and Matsumaru 1982, text-fig. 1); and sample 7450707 of the Daram Formation, Samar Island (Hashimoto and Matsumaru 1978a, fig. 1), respectively. The occurrence species from above samples typifies the assemblage as the following: *Nummulites striatus, N. vascus, Operculina complanata, O. ammonoides* (Gronovius), *Heterostegina duplicamera, Cycloclypeus koolhoveni, C. oppenoorthi, C. eidae* Tan, *Lepidocyclina boetonensis* Van der Vlerk, *Spiroclypeus margaritatus* (Schlumberger), *Pararotalia mecatepecensis* (Nuttall), *Paleomiogypsina boninensis* Matsumaru, *Miogypsinella boninensis* Matsumaru, *M. ubaghsi* (Tan), *Lepidocyclina boetonensis* Van der Vlerk, *Nephrolepidina borneensis* (Provale), *N. sumatrensis* (Brady), *Borelis globosa, B. parvulus, B.* sp. nov., *B. philippinensis* Hanzawa, *Orbitogypsina vesicularis, Halkyardia bikininensis* Cole, *Discogypsina vesicularis*, *Planorbulinella larvata, Sphaerogypsina globulus, Neoplanorbulinella saipanensis* Matsumaru, *Amphistegina radiata, Acervulina inhaerens, Halkyardia minima, Fabiania* spp., *Lepidocyclina pustulosa* H. Douvillé, and *Linderina brugesi* Schlumberger. The last three species are regarded as reworked species.

The occurrence of the typically Caribbean species *L. pustulosa* is an indicator of important geographical significance. It is the second such report from the East Tethys region, after the occurrene of *Lepidocyclina* sp. in the Tertiary b of the Kopili Formation, Meghalaya, NE India that was assigned to *L. pustulosa* (Matsumaru and Sarma 2010, p. 550, pl. 3, fig. 11). In addition, sample QZ4 yields planktic foraminifera *Paragloborotalia* ex gr. *P. opima opima* (Bolli), indicating Zone P21 Zone of Blow (1969). Assemblage 7 is correlated with the *Eulepidina dilatata – E. ephippioides – Heterostegina borneensis* Assemblage (Assemblage IV) of Lower Minamizaki Limestone, Ogasawara Islands (Matsumaru 1996) according to occurrence of *Heterostegina borneensis, Eulepidina dilatata* and *E. ephippioides.* Also Assemblage 7 is correlated with samples of KPW58 of "Hsueshan Group", Southern Cross Mountain Highway, Taiwan (Hashimoto and Matsumaru 1975a), due to occurrence of *E. dilatata, L. formosensis,* and *N. fichteli.*

Geological age: Early Oligocene (Rupelian) to early Late Oligocene (Chattian), and Letter Stage Tertiary d.

Assemblage 8: *Heterostegina borneensis – Eulepidina dilatata – E. ephippioides – Lepidocyclina isolepidinoides.*

The defining four species above occur together in the microfauna found in the type sample 11467 of the upper Bugton Limestone, Mindoro Island (Hashimoto et al. 1977, fig. 1). Assemblage 8 is also known from the other samples as follows: samples A6 and H377 of the Columbus Formation, NE Luzon (RP – Japan Project 1976; Hashimoto et al. 1980); samples CLG7 and GMC18 of the Gumaca Formation, Bondoc Peninsula, SE Luzon (Matsumaru and Barcelona 1982, text-figs. 1-2); sample 11468 of the upper Bugton Limestone, Mindoro Island (Hashimoto et al. 1977, fig. 1); and sample 21760 of the Calagasan Formation, South Cebu (Alcantala 1980, fig. 2 near 21776 point), respectively. The following species from these samples also characterize this assemblage: *Operculina complanata, Heterostegina duplicamera, Cycloclypeus eidae, Spiroclypeus margaritatus, Pararotalia mecatepecensis* (Nuttall), *Paleomiogypsina boninensis, Miogypsinella boninensis, M. ubaghsi, Lepidocyclina boetonensis, Nephrolepidina marginata, N. borneensis, N. brouweri* (Rutten), *N. tournoueri* (Lemoine and R. Douvillé), *N. sumatrensis, Borelis globosa, B. pygmaeus, B. fusiformis, B. philippinensis, Planorbulinella larvata, Discogypsina sicularis, Sphaerogypsina globulus, Amphistegina radiata, Acervulina inhaerens, Marginopora vertebralis* Blainville, and *Sporadotrema cylindricum* (Carter). As such, Assemblage 8 is assigned to Tertiary e1-2, because Leupold and Van der Vlerk (1931) found both *Heterostegina borneensis* and *Lepidocylina isolepidinoides* in this stage, while Mohler (1949, fig. 3) found *Miogypsina ubaghsi* and *Lepidocyclina isolepidinoides* from Tertiary e1-4.

Assemblage 8 is partially correlated with the *Miogypsinella boninensis – Spiroclypeus margaritatus – Austrotrillina howchini* Assemblage (Assemblage V) of the Minamizaki Limestone, Chichi-Jima and Minami-Jima, Ogasawara Islands (Matsumaru 1996), due to occurrence of *H. borneensis, E. dilatata,* and *E. ephippioides*. However, the Assemblage V didn't carry *Miogypsinella ubaghsi* (Matsumaru 1996). Also Assemblage 8 is partially correlated with Tertiary beds in bore-holes at Eniwetok Atoll Drill Holes from 2687 to 1629 feet (Cole 1957b) and 2359.5 to 1723.5 feet in Bukini Atoll Drill Holes (Cole 1954), because of coexistence of *E. ephippioides* and *H. duplicamera.*

Geological age: Late Oligocene (Chattian), and Letter StageTertiary e1-2.

Assemblage 9: *Heterostegina borneensis – Spiroclypeus margaritatus* (Schlumberger) – *Eulepidina dilatata – E. ephippioides – Nephrolepidina sumatrensis* (Brady) – *Miogypsinella boninensis* Matsumaru – *M. ubaghsi* (Tan) – *M. complanata* (Schlumberger)

This assemblage is defined by the eight species above, found in the type sample 7682904 of the Trankalan Limestone, Negros Island (Hashimoto et al. 1982,text-fig. 1). Assemblage 9 is also known from other samples as follows: sample BG9 of the Tineg Formation (former Sagada Limestone), Bontoc, North Luzon (Hashimoto and Sato 1969, fig. 22); sample RZ4 of the Montalban Limestone, Mid-Luzon (Hashimoto and Sato 1969, fig. 22); sample A3 of the Columbus Formation, NE Luzon (RP – Japan Project 1976; Hashimoto et al. 1980, fig. 2); samples PTG9 and CLG1 of the Gumaca Formation (Matsumaru and Barcelona 1982, fig. 1), and sample 31058 of the limestone member of the Unisan Volcanics (Hashimoto and Matsumaru 1981a, text-fig. 4), both of Bondoc Peninsula, SE Luzon; samples Cebu 7, Cebu 8, Cebu 15, and Cebu 20 of the Cebu Formation (former Cebu Orbitoid Limestone), Cebu Island (Hashimoto et al. 1978b, text-figs. 1-2); sample 7683003 of the Trankalan Limestone and sample 7682902 of the Escalante Formation, both of Negros Island (Hashimoto et al. 1982, text-fig. 1); and samples F27, F28, and F29 in the Taon River and Bislig River composite section, and sample H106 at 25 km SW of

Boston, both of the Mangagoy Formation, East Mindanao (RP – Japan Project 1972; Matsumaru 1974, text-fig. 2), respectively. The other species in this assemblage, as found in these samples, are as follows: *Operculina ammonoides, O. balcei* Hashimoto and Matsumaru*, O. complanata, Heterostegina duplicamera, Cycloclypeus eidae, Pararotalia mecatepecensis, Paleomiogypsina boninensis, Lepidocyclina isolepidinoides, L. boetonensis, Nephrolepidina marginata, N. brouweri, N. japonica* (Yabe), *Austrotrillina howchini* (Schlumberger), *Borelis globosa, B. parvulus, B. pygmaeus, B. fusiformis, B. philippinensis, Discogypsina vesicularis, Planorbulinella larvata, Peelella boninensis* Matsumaru, *Amphistegina radiata, Sorites orbiculas* (Forskål), *Carpenteria proteiformis* Goës, *Sphaerogypsina globulus, Archaias* spp., *Eorupertia* spp., *Nummulites* spp., and *Pellatispira* spp. The specimens of the last three named taxa are regarded as reworked.

Hashimoto et al. (1982) considered the age of the Trankalan Limestone to be Te 2-3 to Te4 (Oligocene), while they considered that of the Escalante Formation to be Te4-5 (Oligocene – Miocene) due to occurrence of *Miogypsinella complanata*. On the other hand, Müller and Daniels (1981) regarded both the Escalante Formation, consisting of cs and subordinate pyroclastics, and the Trankalan Limestone, to be within planktic foraminifera Zone P22 and nannoplankton zone NP25. In this study, sample 7682902 of the Escalante Formation was found to contain the planktic foraminifera *Globigerina* cf. *G. tripartita* Koch and sample 7682904 of the Trankalan Limestone to yield *Globigerina* cf. *G. binaiensis* Koch, both of which indicate Zone P22 of Blow (1969). Sample PTG9 of the Gumaca Formation, Bondoc peninsula, SE Luzon yields *Globigerinoides* cf. *G. primordius* Blow and Banner, which also indicates Zone P22 Zone. The Assemblage 9 is partially correlated with the *Miogypsinella boninensis – Spiroclypeus margaritatus – Austrotrillina*i *howchini* Assemblage (Assemblage V) of the top Minamizaki Limestone, Chichi-Jima and Minami-Jima, Ogasawara Islands (Matsumaru 1996), according to occurrence of *Miogypsinella boninensis* and *Spiroclypeus margaritatus*, although *M. ubaghsi* and *M. complanata* are lacking from the typical assemblage. Assemblage 9 is partially correlated with Tertiary e limestone in bore-holes at Eniwetok Atoll Drill Holes at depth from 1599 to 1210 feet (Cole 1957b) and at Bikini Atoll Drill Holes at depth from 1671 to 1597.5 feet (Cole 1954), due to occurrence of *M. grandipustula* (Cole) and *M. ubaghsi.* Assemblage 9 is also partially correlated with limestone samples of KPW59 and KW17 of the "Hsueshan Group", Southern Cross Mountain Highway, Taiwan (Hashimoto and Matsumaru 1975, text-fig. 1), due to occurrence of *Heterostegina* sp.(assignable to *H. borneensis*)*, Lepidocyclina formosensis,* and *Eulepidina dilatata*, although here *Miogypsinella boninensis, M. ubaghsi* and *M. complanata* are lacking.

Geological age: Late Oligocene (Chattian), and Letter Stage Tertiary e3.

Assemblage 10: *Miogypsinoides formosensis* Yabe and Hanzawa – *M. bantamensis* (Tan) – *M. dehaartii* (van der Vlerk) – *Miogypsina primitiva* Tan - *Nephrolepidina ferreroi* (Provale) – *N. sumatrensis*.

The six defining species of this assemblage occur together in the microfauna found in type sample 7682905 of the Escalante Formation, Negros Island (Hashimoto et al. 1982, text-fig. 1). Assemblage 10 is also known from other samples as follows: sample No.1 of the Palanan Limestone at Palanan, North Luzon (Hashimoto and Matsumaru 1975b, text-fig. 2); samples c2711 and c2712 of the Alaba Formation at Kabugao, North Luzon (RP – Japan Project 1980); sample RZ3 of the Montalban Limestone, Mid-Luzon (Hashimoto and Sato 1969, fig. 22; Hanzawa and Hashimoto 1970); samples A107 and A2 of the Palali Formation, NE Luzon (RP – Japan Project 1976; Hashimoto et al. 1980, fig. 2); sample PTG5 of the Gumaca Formation, Bondoc Peninsula, SE Luzon (Matsumaru and Barcelona 1982, fig. 1); sample 7681903 of the Sula Formation and sample 7681904 of the lower Coal Harbour Limestone, both of Cagraray Island (Hashimoto et al. 1981, text-fig. 2); samples MQ15, MQ16 and MQ17 of the lower Torrijos Formation, Marinduque Island (Hashimoto and Sato 1969, fig. 28; Hanzawa and Hashimoto 1970, text-fig. 2); limestone sample MD7 of the upper Sablayan Group (or Baco Group) near Pocanil Point and sample 7212101 of the Paclasan Limestone at north Bugton Point, both of Mindoro Island (Hashimoto and Sato 1969, fig. 25; Hashimoto et al 1977, fig. 1); sample 7682906 of the Escalante Formation, Negros Island (Hashimoto et al. 1982, text-fig. 1); samples F498, H260, F512, and G315 of the Bislig Formation, East Mindanao (Matsumaru 1974, text-fig. 2); and sample 745713 of the Daram Formation, Samar Island (Hashimoto and Matsumaru 1978a, fig. 1), respectively. The other species from the above samples that occur within this assemblage are: *Operculina ammonoides, O.venosa* (Fichtel and Moll), *O. complanata, Cycloclypeus eidae, C. indopacificus* Tan, *Katacycloclypeus transiens* Tan, *Spiroclypeus margaritatus, Heterostegina borneensis, Pararotalia mecatepecensis, Miogypsinella complanata, Miogypsina borneensis* Tan, *Boninella* sp.nov., *Lepidosemicyclina thecidaeformis, L. polymorpha* Rutten, *L. indonesiensis* (Tan), *Eulepidina dilatata, E. ephippioides, Lepidocyclina radiata* (Martin), *Nephrolepidina marginata, N. brouweri, N. borneensis, N. japonica, N. verbeeki* (Newton and Holland), *Austrotrillina howchini, Flosculinella globulosa* (Rutten), *Borelis pygmaeus, Kanakaia marianensis* Hanzawa, *Tayamaia marianensis, Planorbulinella larvata, Discogypsina vesicularis, Sphaerogypsina globulus, Neoplanorbulinella saipanensis, Halkyardia bikiniensis, Amphistegina radiata, Planorbulinella larvata, Marginopora vertebralis* Blainville, *Carpenteria proteiformis, Acervulina inhaerens, Sorites orbiculus, Homotrema rubrum* (Lamarck), *Borodinia septentrionalis* Hanzawa, *Paleomiogypsina boninensis, Lepidocyclina boetonensis,* and *Eorupertia boninensis* (Yabe and Hanzawa). The last three species are regarded as reworked.

Assemblage 10 is assigned to Tertiary e4, according to the occurrence of *Nephrolepidina ferreroi* and *Miogypsinoides dehaartii* (Leupold and Van der Vlerk 1931). Assemblage 10 can also be correlated to the fauna of Zone 5 of the lower Kita Daitojima Limestone, Kita-Daito-Jima, Japan (Hanzawa 1940, Zone 5: 431.67 – 394.98 m) due to occurrence of *Miogypsinella borodinensis* Hanzawa, presently assigned to *Miogypsinoides formosensis* (Matsumaru et al. 2010, p. 452). Zone 5 has a Sr isotope age 24.3 to 23.5 Ma (Ohde and Elderfield 1992). Assemblage 10 is also correlated with the *Miogypsinoides formosensis – M. bantamensis – M. dehaartii – Miogypsina primitiva – Spiroclypeus margaritatus* Assemblage (Assemblage 1) of the Küçükköy Formation, Bey Dağlari Autochton, Menderes – Taurus Platform, Turkey, due to the occurrence of

Miogypsinoides formosensis, M. bantamensis and *M. dehaartii* (Matsumaru et al. 2010).

Geological age: Late Oligocene (Chattian), and Letter Stage Tertiary e4.

Assemblage 11: *Cycloclypeus eidae* Tan – *Miogypsinoides dehaartii* – *Miogypsina globulina* (Michelotti) – *Lepidosemicyclina thecidaeformis* (Rutten) – *Nephrolepidina ferreroi* – *N. sumatrensis* – *Flosculinella bontangensis* (Rutten)

The seven defining species of this assemblage are found together in the type sample 7681908 of the upper Coal Harbour Limestone, Cagraray Island (Hashimoto et al. 1981, text-fig. 2). Assemblage 11 is also known from other samples as follows: samples Nos. 3 and 4 of the Palanan Limestone at Palanan, North Luzon (Hashimoto and Matsumaru 1975b, text-fig. 2); sample BG 1 of the Zigzag limestone at Bontoc, North Luzon (Hashimoto 1939; Hashimoto and Sato 1969, fig. 22); sample No. 19 of the Angat Formation, Mid-Luzon (Hashimoto and Sato 1969, fig. 22); sample C56 in the Bokad section, samples K732, B102 and B395 in the Didlpla section, and spot sample A29 in the Caraballo Mountains, all of the upper Palali Formation, NE Luzon (RP – Japan Project 1976; Hashimoto et al. 1980, fig. 2); sample 7681905 of the upper Coal Harbour Limestone, Cagraray Island (Hashimoto et al. 1981, text-fig. 2); samples MQ12, MQ14, and MQ20 of the Torrijos Formation (Hashimoto and Sato 1969, fig. 28; Hanzawa and Hashimoto 1970, text-fig. 2); sample YR09 in the Mongpong River section, sample HR206 in the Bugsanga River section, samples MD112, MD112a, and MD113 in the Cagraray River section, and samples TR2-127 and TR2-137 between the Bansud River and Tangon river, all of the upper Sablayan Group or Tangon Formation, Mindoro Island (RP – Japan Project 1982; Hashimoto and Sato 1969, fig. 25; Hashimoto et al. 1977, fig. 1); sample Cebu 23 of the Malbog Formation "near Uling", Cebu Island (Hashimoto et al. 1978b, text-figs. 1-2); sample PN20 of the Fragante Formation, Panay Island (Hashimoto 1973, text-fig. 1); sample 7683001 of the Trankalan Limestone, Negros Island (Hashimoto et al. 1982, text-fig. 1); samples C58, E25, and E26 of limestone lenses of the Kalagutay Group in the Sita River and Pilang River composite section, East Mindanao (RP – Japan Project 1972; Matsumaru 1974, text-fig. 2); sample PLN8 of the Masbate Formation, Masbate Island (BMG 1981); and samples 745608 and 745609 of the Daram Formation, Samar Island (Hashimoto and Matsumaru 1978a, fig. 1), respectively.

The other species in these samples characterize this assemblage as follows: *Operculina ammonoides, O. bartschi* (Gronovius), *O. complanata, O. balcei, O. venosa, Heterostegina* spp., *Cycloclypeus indopacificus, Katacycloclypeus transiens, Spiroclypeus margaritatus, Miogypsinoides bantamensis, Miogypsina primitiva, M. borneensis, Lepidosemicyclina polymorpha, L. indonesiensis, L. musperi* (Tan), *Eulepidina dilatata, E. ephippioides, Lepidocyclina radiata* (Martin), *Nephrolepidina japonica, N. verbeeki, Austrotrillina striata* Todd and Post, *Flosculinella fusiformis* Hashimoto and Matsumaru, *F. globulosa* (Rutten), *Borelis philippinensis, Austrotrillina howchini* (Schlumberger), *Kanakaia marianensis, Tayamaia marianensis, Discogypsina vesicularis, Sphaerogypsina globulus, Planorbulinella larvata, Neoplanorbulinella saipanensis, Peneroplis planatus, Orbitogypsina globulus* Matsumaru, *Amphisorus hemprichii* Ehrenberg, *Amphistegina radiata, Miniacina miniacea, Acervulina inhaerens, Carpenteria proteiformis, Sorites orbiculus, Marginopora vertebralis, Homotrema rubrum, Sporadotrema cylindricum, Archaias* spp., *Paleomiogypsina boninensis,* and *Eorupertia* spp. The last two species are regarded as reworked.

Assemblage 11 is assigned to Tertiary e5 lower, due to the occurrence of *Miogypsinoides dehaartii, Miogypsina globulina, Lepidosemicyclina thecidaeformis* and *Flosculinella bontangensis,* all of which are reported from the lower Tertiary e5 of Beboeloeh Lagen/Formation by Leupold and Van der Vlerk (1931). Assemblage 11 is correlated with the fauna of lower Zone 4 of Kita-Daito-Jima, from ca. 360 to 302.31 m in the Kita-Daitojima Limestone (Hanzawa 1940), due to occurrence of *Miogypsinoides bantamensis, M. dehaartii, Miogypsina borneensis,* and *Spiroclypeus margaritatus*. This level is dated by Sr isotope analysis between 23.1 to 21.1 Ma (Ohde and Elderfield 1992). Assemblage 11 is also correlated with the *Miogypsinoides bantamensis – M. dehaartii – Miogypsina primitiva – M. borneensis – M. globulina – Spiroclypeus margaritatus* Assemblage (Assemblage 2) of the Karabayir Formation, Bey Dağlari Autochton, Menderes – Taurus Platform, Turkey, according to the occurrence of *Miogypsinoides dehaartii* and *Miogypsina globulina* (Matsumaru et al. 2010). In addition, Assemblage 11 is correlated with the fauna of *Miogypsinoides formosensis, Nephrolepidina taiwanensis* Yabe and Hanzawa, and *Cycloclypeus communis* Martin from the Kungkuan Tuff and Tailiao Formation in the Lower Kaizan Beds, Taiwan, due to occurrence of *M. formosensis* (Yabe and Hanzawa 1930). The planktic foraminifera *Globigerina binaiensis* Koch, *G. ciperoensis* Bolli, and *Globigerinita dissimilis dissimilis* (Cushman and Bermudez) were described by Huang (1979) from the lower part of the Kungkuan Tuff, which is diagnostic of planktic foraminifera Zone N5 of Blow (1969) and Aquitanian age.

Geological age: Early Miocene (Aquitanian), and Letter Stage Tertiary e5 lower.

Assemblage 12: *Cycloclypeus eidae – Miogypsina globulina – Lepidosemicyclina thecidaeformis – L.polymorpha – Nephrolepidina ferreropi – N. sumatrensis*

The six diagnostic species of this assemblage occur together in the type sample C57 from the upper Palali Formation, NE Luzon (RP – Japan Project 1976; Hashimoto et al. 1980, fig. 2). Assemblage 12 is also known from other samples as follows: sample Nos. 2 and 6 of the Palanan Limestone, North Luzon (Hashimoto and Matsumaru 1975b, text-fig. 2); sample BG15 of the Zigzag Limestone, North Luzon (Hashimoto and Sato 1969, fig. 22; Hashimoto 1975); sample AG3 of the Angat Formation, Mid-Luzon (Hashimoto and Sato 1969, fig. 22; Hanzawa and Hashimoto 1970); sample C57 of the upper Palali Formation, NE Luzon (RP – Japan Project 1976; Hashimoto et al. 1980, fig. 2); sample MQ19-1 and MQ28? of the Torrijos Formation, Marinduque Island (Hashimoto and Sato 1969, fig. 28; Hanzawa and Hashimoto 1970, text-fig. 2); sample PP61 of the St. Paul Limestone, Palawan Island (Hashimoto and Matsumaru 1982, text-fig. 1); and sample PLN2 of the Masbate Formation, Masbate Island (BGM 1981), respectively. The other species that occur within this assemblage are as follows: *Operculina ammonoides, O. complanata, O. venosa, Cycloclypeus indopacificus, Katacycloclypeus transiens, Miogypsinoides dehaartii, Miogypsina primitiva, M. borneensis, Lepidosemicyclina indonesiensis, Eulepidina dilatata, E.*

ephippioides, Lepidocyclina radiata, Nephrolepidina japonica, N. verbeeki, Austrotrillina howchini, A. striata, Flosculinella bontangensis, F. globulosa, Kanakaia marianensis, Tayamaia marianensis, Neoplanorbulinella saipanensis, Discogypsina vesicularis, Planorbulinella larvata, Amphisorus hemprichii, Amphistegina radiata, Sphaerogypsina globulus, Acervulina inhaerens, Sorites orbiculus, Linderina brugesi, and Eorupertia boninensis. The occurrence of the last two species is probably based on reworked specimens.

Assemblage 12 is assigned to Tertiary e5 upper due to the occurrence of *Miogypsinoides dehaartii* and *Miogypsina globulina*, and the absence of genus *Spiroclypeus*, which is probably unknown from the upper Boeboeloh Lagen/Formation (Leupold and Van der Vlerk 1931). Assemblage 12 is correlated with the fauna of Zone 4 upper from 302.31 to 209.26 m in the Kita-Daitojima Limestone, Kita-Daito-Jima (Hanzawa 1940) due to occurrence of *Miogypsinoides dehaartii* and *Miogypsina borneensis*. The Sr isotope age of this zone is from 21.1 to 18.8 Ma (Ohde and Elderfield 1992). Assemblage 12 is also correlated with the *Miogypsinoides dehaartii – Miogypsina borneensis – Miogypsina globulina – Miolepidocyclina burdigalensis* Assemblage (Assemblage 3) of the Karakuştepe Formation, Bey Dağlari Autochton, Menderes – Taurus Platform, Turkey, due to occurrence of *Migypsinoides dehaartii, Miogypsina borneensis,* and *M. globulina* (Matsumaru et al. 2010).

Geological age: Early Miocene (Burdigalian), and Letter Stage Tertiary e5 upper.

Assemblage 13: *Cycloclypeus posteidae* Tan – *Miogypsina globulina – M. intermedia* Drooger – *Lepidosemicyclina thecidaeformis – Nephrolepidina ferreroi*.

The five defining species of this assemblage occur together in the type sample MQ10 of the upper Torrijos Formation, Marinduque Island (Hashimoto and Sato 1969, fig. 28; Hanzawa and Hashimoto 1970). Assemblage 13 is also known from other samples as follows: sample 120 of the Kennon Limestone?, along National Road No. 4, Ilocos Sur Province, Bontoc, North Luzon (Hashimoto 1939, p. 401); sample F31 of the Natbang Formation, NE Luzon (RP – Japan Project 1976; Hashimoto et al. 1980, fig. 2); samples A9, MA11, and SML10 of the Atimonan Formation, Bondoc Peninsula, SE Luzon (Matsumaru and Barcelona 1982, fig. 1); samples MQ6, and MQ19-2 of the upper Torrijos Formation, Marinduque Island (Hashimoto and Sato 1969, fig. 28); samples CB9 (= Cebu 9), Cebu 18, Cebu 28, Cebu 38, Cebu 51, Cebu 52, and Cebu 54, all samples belonging to the Mt. Uling Limestone, placed at station CB9, about 2km west of Uling, Cebu Island (Hashimoto et al. 1978b, text-figs. 1-2); samples TB35, TB40, and TB45 of the Bogoliano Limestone, Tablas Island (Corby et al. 1951; Hashimoto and Sato 1969, fig. 29); samples MH5 and MH6 of the San Pascual Formation, Burias Island (Hashimoto 1981, tab. 7); samples MBG1 and MBG10 of the Mountain Maid Limestone, Masbate Island (Corby et al. 1951; BMG 1981, p. 126); samples E10, E28, and BTF2F of limestone lenses of the Kalagutay Group, which is correlated to the Agtuucanon Formation, in the Sita River and Pilang River composite section, East Mindanao (RP – Japan Project 1972; Matsumaru 1974, text-fig. 2); and samples QZ10-1 and QZ10-2 of the upper St. Paul Limestone?, Palawan Island (Hashimoto and Matsumaru 1982, text-fig. 2), respectively. The species occurring in the same samples as the defining species are as follows: *Operculina ammonoides, O. complanata, O. heterosteginoides* (Defrance), *O. balcei, Heterostegina* spp., *Miogypsina cushmani* Vaughan, *Lepidosemicyclina polymorpha, L. indonesiensis, L. musperi, Lepidocyclina radiata, Nephrolepidina japonica, N. sumatrensis, N. angulosa* (Provale), *N. rutteni* (Van der Vlerk), *N. martini* (Schlumberger), *N. verbeeki, Austrotrillina howchini, Flosculinella bontangensis, F. fusiformis, F. globulosa, Alveolinella quoyii* (d'Orbigny), *Neoplanorbulinella saipanensism Planorbulinella larvata, Tayamaia marianensis, Pseudorotalia schroeteriana* (Carpenter, Parr and Jones), *Sorites orbiculus, Amphisorus hemprichii, Discogypsina vesicularis, Orbitogypsina vesicularis, Sphaerogypsina globulus, Acervulina inhaerens, Amphistegina radiata, Miniacina miniacea, Marginopora vertebralis, Homotrema rubrum, Carpenteria proteiformis, Borodinia septentrionalis, Sporadotrema cylindricum, Cycloclypeus eidae, Spiroclypeus margaritatus,* and *Nephrolepidina brouweri*. The occurrence of the last three species is probably based on reworked specimens.

Assemblage 13 is assigned to Tertiary f1, due to occurrence of *Cycloclypeus posteidae, Miogypsina globulina, M. intermedia*, and *Alveolinella quoyii*. The last species was identified as *Alveolina boscii* (Defrance) in Tertiary f1 by Leupold and Van der Vlerk (1931).

Assemblage 13 is divided into two parts according to occurrence of *Flosculinella bontangensis,* which is present in samples TB35, E10 and BT2F, and absent in samples 120, F31, A9, MA11, SML10, MQ6, MQ10 (the type sample), MQ 19-1, CB9, MH5, MH6, MBG1, MBG10, QZ10-1 and QZ10-2. The difference from the first to the second group is due to a change in salinity between hypersaline lagoon (45 to 56 ‰) to normal ocean salinity (36 to 40 ‰) (Murray 1973; Chaproniere 1975; Matsumaru 1978), in a stratigraphic succession. The normal marine samples A9, MH5, MBG1 and QZ10-1 yield the planktic foraminifera *Paragloborotalia* cf. *P. mayeri* (Cushman and Ellisor), *Praeorbulina glomerosa* (Blow), *Praeorbulina sicana* (de Stefani), *Globigerina* cf. *praebulloides* Blow, and *Globigerinoides* cf. *G. obliquus* Bolli, indicative of Zone N8-9 of Blow (1969), but a final assignment is deferred by the author pending analysis of more samples.

Assemblage 13 is correlated with the fauna of Zone 3 from the Kita Daitojima Limestone, Kita-Daito-Jima, according to the occurrence of *Cyclolcypeus communis* (presently recognized as *C. eidae* by Hanzawa 1957, p. 49), *Miogypsina polymorpha* (Rutten), *Nephrolepidina tournoueri* and *Trillina howchini* Schlumberger in Zone 3 from 209.26 to ca. 123 m (Hanzawa 1940). This succession has been dated by Sr isotope analysis to between18.8 and 15.5 Ma (Ohde and Elderfield 1992).

Geological age: Early Miocene (Burdigalian) to Middle Miocene (Langhian), and Letter Stage Tertiary f1.

Assemblage 14: *Cycloclypeus posteidae – Nephrolepidina rutteni* (Van der Vlerk) – *N. martini* (Schlumberger) – *N. angulosa* (Provale).

The four defining species of this assemblage occur together in the type sample Cebu 30 of the Toledo Formation, Cebu Island (Hashimoto et al. 1978b, text-figs. 1-2). Assemblage 14 is also known from other samples as follows: samples BG2 of the Mirador Limestone, Bontoc, North Luzon (Hashimoto and Sato 1969; Hashimoto 1975); samples B53, D20, K16, and F28 of

the Macde Limestone, NE Luzon (RP – Japan Project 1976; Hashimoto st al. 1980, fig. 2); sample MD106 of limestone lenses of the Socorro Group in the Cagraray River section, Mindoro Island (Hashimoto and Sato 1969, fig. 25; RP – Japan Project 1982); sample Cebu 29 of the Toledo Formation, Cebu Island (Hashimoto et al. 1978b, text-figs. 1-2); sample TB42 of the Bogoliano Limestone, Tablas Island (Corby et al. 1951; Hashimoto and Sato 1969, fig. 29); and sample PWC 5 of the Mountain Maid Limestone, Masbate Island (Corby et al. 1951), respectively. The other species that occur in this assemblage, as found in the above samples, are as follows: *Operculina ammonoides, O. balcei, O. complanata, O. venosa, Heterostegina* spp., *Cycloclypeus carpenteri* Brady, *Miogypsina cushmani, Lepidosemicyclina thecidaeformis, Lepidocyclina radiata, Nephrolepidina japonica, N. sumatrensis, Austrotrillina howchini, Sorites orbiculus, Planorbulinella larvata, Discogypsina vesicularis, Marginopora vertebralis, Rotalia* spp., *Homotrema rubrum, Amphistegina radiata, Carpenteria proteiformis, Acervulina inhaerens, Sphaerogypsina globulus, Archaias* spp., and *Sporadotrema cylindricum*.

Assemblage 14 is assigned to Tertiary f2, due to occurrence of *Nephrolepidina angulosa, N. sumatrensis, Miogypsina cushmani* and *Lepidosemicyclina thecidaeformis*, which occur in Tf2 in the Balikpapan-Lagen (Balikpapan Formation) of Borneo according to Leupold and Van der Vlerk (1931). The Toledo Formation (samples Cebu 29 and Cebu 30) yields the planktic foraminifera *Orbulina universa* d'Orbigny and *Dentoglobigerina* cf. *D. altispira* (Cushman and Jarvis), which ranges from Zones N9-19 of Blow (1969). Assemblage 14 is correlated with the fauna of Zone 3 upper between ca. 123 to 116.41 in the Kita Daitojima Limestone, Kita-Daito-Jima (Hanzawa 1940), due to occurrence of *Acervulina inhaerens, Amphistegina radiata, Carpenteria* sp., and *Sphaerogypsina globulus.* While none of these are conclusively diagnostic of Assemblage 14, this level is dated from 13.65 to 11.61 Ma by Sr isotope analysis (Ohde and Elderfield 1992).

Geological age: Middle Miocene (Serravallian), and Letter Stage Tertiary f2.

Assemblage 15: *Heterostegina suborbiculus* d'Orbigny – *Nephrolepidina rutteni* .

The two defining species of this assemblage, above, are found in the type sample Cebu 25 of the Maingit Formation, Cebu Island (Hashimoto et al. 1978b, text-figs. 1-2). Assemblage 15 is also known from sample BHK 4 of the Hondagua Formation, Bondoc Peninsula, SE Luzon (Matsumaru and Barcelona 1982, fig. 1); sample Cebu 27 of the Maingit Formation, Cebu Island (Hashimoto et al. 1978b, text-figs. 1-2); and sample MBG 2 of the Mountain Maid Limestone, Masbate Island (Corby et al. 1951), respectively. The other species from these same samples are *Operculina ammonoides, O. complanata, O. venosa, Lepidocyclina radiata, Nephrolepidina martini, Planorbulinella larvata, Baculogypsinoides spinosus, Calcarina* spp., *Amphistegina radiata, Asterigerina* spp., *Acervulina inhaerens,* and *Miniacina miniacea.* The number of diagnostic species is reduced because of the low diversity of larger foraminifera of this age in the Philippine Archipelago, which reduces its value for the Letter Stages. Assemblage 15, nevertheless, can be assigned to Tertiary f3, due to the limited occurrence and range of *Nephrolepidina rutteni*. In Japan, *Nephrolepidina japonica* forma III from the Shimoshiroiwa and Kaden Formations, Izu Peninsula has been more recently assigned to *Nephrolepidina rutteni* Van der Vlerk (as. *Lepidocycluna* (*Trybliolepidina*) *rutteni*) and placed in Zone N17 of Blow (1969) (Matsumaru 1971, p. 110, fig. 33, Matsumaru 1981, Matsumaru 1992).

According to Leupold and van der Vlerk (1931) the Tertiary f3/Tertiary g boundary is defined by the last occurrence of *Nephrolepidina rutteni,* as the last occurrence of lepidocyclines, while Adams (1985) showed the last occurrence of *Nephrolepidina* is within the early Pliocene (Zanclian), based probably on the composite section at Sealark Hill, the type locality of the Lami Limestone, Viti Levu, Fiji (Adams et al. 1979). In the original descruption of Whipple (1934), the type Lami Limestone yields *Eulepidina dilatata, E. formosa, Cyclolepidina suvaensis* Whipple (now assigned to *Lepidocyclina radiata*), and *Cycloclypeus neglectus* (correctly assigned to *C. posteidae,* in that it has 10 nepionic septa), but not *C. postindopacificus* Tan as stated by Adams et al. (1979). While *Cycloclypeus posteidae* is found before the Pliocene (Text-figure 3), Whipple assigned the microfauna of the type Lami Limestone to Tertiary e ("Old Miocene"). The Lami Lime assemblage is comparable to the fauna desribed by Cole (1945; 1960) from the Futuna Limestone, Lau Islands, Fiji, which includes *Lepidocyclina radiata*, *Nephrolepidina rutteni, N. martini, Cycloclypeus eidae, C. indopacificus* Tan, *Katacycloclypeus annulatus, K. martini, K. transiens,* and *Miogypsina neodispansa* (Jones and Chapman), which Cole assigned to Tertiary f (lower Miocene). The occurrence of *Lepidocyclina radiata* in the type Lami Limestone of Fiji is not clear evidence that this species persisted until the lower Pliocene, because the material seems to include many reworked specimens. In this study, sample BHK 4 from SE Luzon yields *Baculogypsinoides spinosus*, a species from the latest Miocene, while Sample MBG 2 from Masbate Island yields the planktic foraminifer *Candeina* cf. *C. nitida* d'Orbigny, which ranges from Zone N17-N23 (Blow 1969). Assemblage 15 is also correlated with the fauna of Zone 2, from the section between116.41 to 103.49m in the Kita Daitojima Limestone, Kita-Daito-Jima, with occurrence of *Acervulina inhaerence, Sphaerogypsina globulus, Amphistegina radiata, Homotrema rubrum, Sporadotrema cylindricum, Miniacina miniacea, Sorites marginalis* (Lamarck), and *Carpenteria proteiformis* (Hanzawa 1940). This section is dated from 11.61 to 5.33 Ma by Sr isotope anaylsis (Ohde and Elderfield 1992).

Geological age: Late Miocene (Tortonian to Messinian), and Letter Stage Tertiary f3.

Aseemblage 16: *Baculogypsinoides spinosus* Yabe and Hanzawa – *Amphistegina radiata*.

The two defining species of this assemblage occur together in the type sample Cebu 2 of the Barili Limestone, Cebu Island (Hashimoto et al. 1978b, text-figs. 1-2). Assemblage 16 is also known from samples BYG 1 of the lower Malumbang Formation, Bondoc Peninsula, SE Luzon (Matsumaru and Barcelona 1982, text-figs. 1-2); samples Cebu 46, Cebu 2, and Cebu 44 of the Barili Formation, Cebu Island (Hashimoto et al. 1978b, text-figs. 1-2); samples LMN 10, VLB 9, and BHY 2 of the Dolores Formation, Leyte Island (BMG 1981); sample PWC 16 of the Masbate Limestone, Masbate Island (Corby et al. 1951; BMG 1981); and sample QZ10-3 of the Alfonzo XIII Formation, Palawan Island (Hashimoto and Matsumaru 1982, text-fig. 1), respectively. Species occurring together with this assemblage in the above samples are as follows: *Operculina bartschi,*

O. complanata, O. venosa, Heterostegina suborbicularis, Cycloclypeus carpenteri, Borelis melo (Fichtel and Moll), *Alveolinella quoyii, Planorbulinella larvata, Amphisorus hemprichii, Sorites orbiculus, Acervulina inhaerens, Carpenteria proteiformis, Sphaerogypsina globulus, Lepidocyclina radiata, Nephrolepidina rutteni*, and *N. martini.* The presence of the last three species is probably based on reworked specimens, as evidenced by fragmentary condition.

Assemblage 16 is assigned to Tertiary g, due to absence of *Nephrolepidina rutteni* as stated by Leupold and Van der Vlerk (1931). Sample Cebu 46 yields the planktic foraminifera *Globorotalia* ex gr. *G. miocenica* Palmer, *G.* ex gr. *G. menardii* (d'Orbigny), and *Globigerinoides* spp., characteristic of Zone N19 or N19-N21 (Blow 1969), of Pliocene age. Also, Assemblage 16 is correlated with the fauna of Zone 1 found in the section between 103.49 and 9.7 m in the Kita Daitojima Limestone, Kita-Daito-Jima, according to the occurrence of *Acervulina inhaerens* and *Amphistegina radiata* (Hanzawa 1940). This section is dated by Sr isotope analysis to be between 5.33 to 1.81 Ma (Ohde and Elderfield 1992), essentially the entire Pliocene (Berggren and Van Couvering 1974). In addition, Assemblage 16 is correlated with the fauna containing *Operculina lucidisutura* Cole (= *O. complanata*)*, O. ectilata* Cole (= *O. venosa*)*,* and *Cycloclypeus postindopacificus* from the Tertiary g Barrigada Limestone of Guam, which Cole (1963) correlated with the Janum Formation of Guam, a deep-water facies yielding *Operculina rectilata* and *Cycloclypeus postindopacificus.* The Janum Formation also contained *Nephrolepidina martini* in a small pebble, which Cole regarded as reworked.

Geological age: Pliocene (Zanclean to Gelasian), and Letter Stage Tertiary g.

Assemblage 17. *Calcarina spengleri* (Gmelin) – *Calcarina delicate* Todd and Post

The defining species of this assemblage are found in the type sample TB17 of the Colasi Limestone, Tablas Island (Corby et al. 1951; Hashimoto and Sato 1969, fig. 29; Hanzawa and Hashimoto 1970). Assemblage 17 is also known from samples BYG 3, BYG 4, BHK 7, and PRS 7 of the upper Malumbang Formation, Bondoc Peninsula, SE Luzon (Matsumaru and Barcelona 1982, text-figs. 1-2); samples PN 21 and PN 23 of the St. Cruz Formation, Panay Island (Hashimoto 1973, text-fig. 1); and samples VLB 12, AGM 3, BHY 5, and BHY 6 of the Dolores Formation, Leyte Island (BMG 1981), respectively. The other species found with this assemblage in the above samples are as follows: *Operculina ammonoides, O. bartschi, O. complanata, O. venosa, Heterostegina suborbiculus, Cycloclypeus carpenteri, Alveolinella quoyii, Bacylogypsinoides spinosus, Rotalia* spp., *Amphistegina radiata, Planorbulinella larvata, Sorites orbicularis, Acervulina inhaerens, Sphaerogypsina globulus,* and *Nephrolepidina rutteni¸* the last of which is regarded as based on reworked specimens. Van der Vlerk and Umbgrove (1927) and Leupold and Van der Vlerk (1931) did not consider that the stages above Tertiary f, following the extinction of *Nephrolepidina rutteni,* contain a diagnostic fauna of larger foraminifera. The type sample, TB 17, also yields the planktic foraminifera *Globigerinoides* cf. *G. immaturus* Leroy, *Globorotalia* cf.*G. crassaformis* (Galloway and Wissler), and *G.* ex gr. *G. pseudomiocenica* Bolli and Bermudez. While the last of these species is probably a reworked Miocene form, the other two species are known to occur together from upper Miocene/Pliocene to Recent (Blow 1969, Bolli and Saunders 1985). Assemblage 17 is partly correlated to fauna from limestone samples taken in the Ryukyu Group, Japan, due to presence of *Baculogypsinoides spinosus, Baculogypsina sphaerulata* (Parker and Jones), *Calcarina spengleri, C. delicata,* and *Cycloclypeus carpenteri* (Matsumaru 1976, 1986). The 14 sections in the Ryukyu Group of Hateruma-Jima, Okinawa Prefecture, is dated from 300 to 100 Ka by Th230/U234 radiometric analysis (Omura 1983). Although Assemblage 17 is based on poorly diagnostic larger foraminifera of low diversity, it can be calibrated with the help of associated planktic foraminifera, startigraphic analysis and radiometric dating.

Geological age: Pleistocene to Holocene, and Letter State Tertiary h.

CONCLUSIONS

The primary goal of this study was accurate correlation of the biostratigraphical sequence of larger Foraminifera in the Philippine Archipelago with planktic foraminiferal zonation and radiometric age determinations. While success was limited by poor preservation and exposure of shallow water, carbonate-rich formations in many parts of this region as well as the effects of local tectonic activity, the author has nevertheless been able to take advantage of decades of work by colleagues to make detailed study of biostratigraphic and spot samples in 25 different areas in the Philippines Archipelago (Text-figure 1). As can be seen from Text-figures 2 and 3, the Letter Stages for this region can now be identified in terms of 17 larger foraminiferal assemblage zones for the 16 divisions of the East Tethyan Letter Stages, from the newly prosposed Tertiary a0 to Tertiary h. Further foramniferal biostratigraphic research is required, however, to improve the new Letter Stages by identifying stratotypes for their exact boundaries.

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