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REMARKS ON THE AGE OF THE LIMESTONES OF SOUTHEASTERN JAVA (INDONESIA)

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Key-words: Wonosari Formation, Foraminiferal assemblages, Biostratigraphy, East Indian Letter Classification, Miocene, Java.

Riassunto. Vengono esposti, sulla base delle associazioni di Foraminiferi, i risultati relativi alla datazione di campioni di calcare (Formazione Wonosari) prelevati nelle East Southern Mountains dell'Isola di Giava, Indonesia. Le associazioni contenute nei campioni esaminati, in riferimento alla East Indian Letter Classification, sono tipiche della parte inferiore del piano Tf. L'età risulta compresa tra le Zone N8 e N9 o appena più recente e corrisponde all'intervallo Langhiano-Serravalliano inferiore. I calcari a *Flosculinella bontangensis* delle East Southern Mountains di Giava, hanno la stessa età di quelli del margine australiano. Essi appartengono alla Zona N9 o all'intervallo stratigrafico compreso tra la Zona N9 e la parte basale di N10.

Abstract. The present paper deals with the age assignment of the limestones (Wonosari Formation) cropping out in the East Southern Mountains of South East Java (Indonesia), based on the foraminiferal assemblages observed in several limestone samples from that area. The assemblages are typical of Lower Tf stage; ages range from planktonic foraminiferal Zone N8 to Zone N9 or are slightly younger, corresponding to Langhian and earliest Serravallian in terms of Mediterranean stages. The limestones with *Flosculinella bontangensis* of the East Southern Mountains of Java, have the same age of those of the Australian margin. They correlate with Zone N9 or with a stratigraphic interval ranging from Zone N9 to basal N10.

Introduction.

A. Franchino and Sukandarrumidi (Gadja Mada University of Yogyakarta) carried out in 1983 a regional excursion to the East Southern Mountains of Java, from Yogyakarta to Banjuwangi, along an itinerary of approximately 1300 km west to east. Several limestone outcrops of Gunung Sewu and Gunung Kidul were visited and sampled. The study of the larger foraminiferal assemblages contained in the spot-

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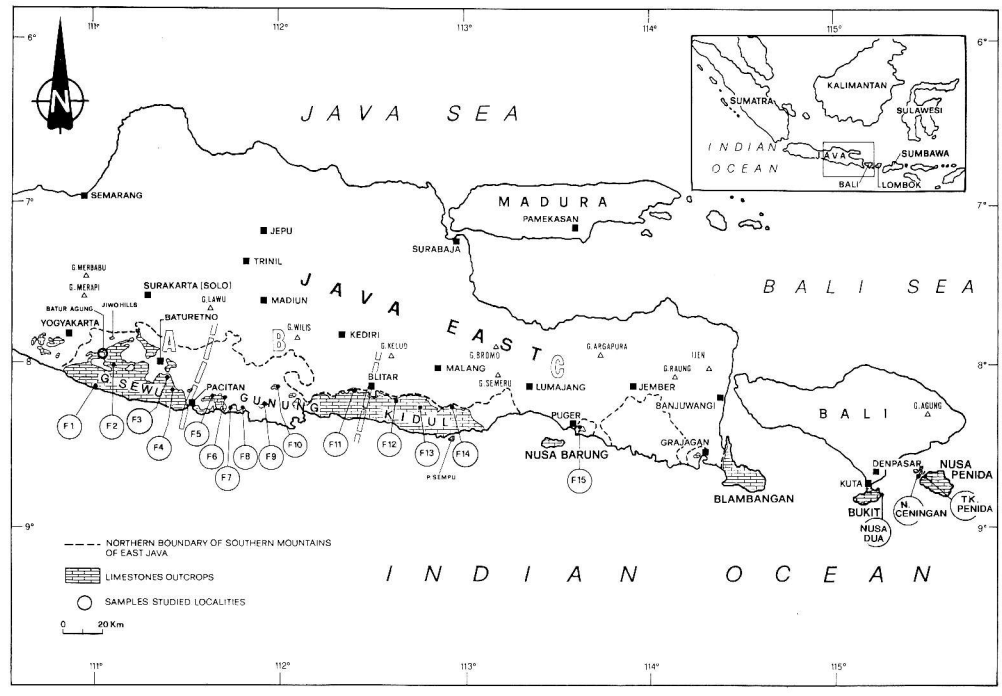

Fig. 1 - Index map showing location of the collected samples and approximate distribution of Miocene limestone exposures in the East Southern Mountains of Java and some eastward islands. The subdivision into sectors (A, B, C) is conventional.

samples has allowed the chronostratigraphic setting of the outcrops which were assigned a Miocene age. Some assemblages resulted age-diagnostic because of the co-occurrence of larger and planktonic foraminifera. As regards the chronostratigraphic units, in this paper reference is made to the East Indian Letter Classification.

The study area is herein divided into three sectors, namely A, B, C, (Fig. 1), each with a pure conventional meaning. We do not consider the limestones outcropping immediately ESE of Yogyakarta and belonging to the Yogyakarta sub-basin (Suyanto & Roskamil, 1977) which have been already studied in detail by Kadar (1986). The Miocene limestones dealt with were grouped under the name Wonosari Beds (Bothe, 1929; Van Bemmelen, 1949) subsequently changed into Wonosari Formation (Marks, 1957). The name Punung Formation was used by Sartono (1964) for the limestones of Gunung Sewu (sector A); it is to be regarded as a local equivalent of Wonosari Formation.

The foraminiferal assemblages recovered from Nusa Dua (Bali) and the northwest coast of Nusa Penida Island are considered as well. In fact, the limestone belt of the East Southern Mountains of Java extends eastward to the islands of Bali, Nusa

Penida, Lombok and Sumbawa.

The results reported in the following pages are to be considered quite preliminary; they will serve as a base for future work on the Miocene deposits of that Indonesian region.

Geological setting.

The geological history of Java and the other eastward islands as far as Sumbawa, during the greatest part of the Cenozoic, coincides with that of the southern edge of the Sunda plate, and is linked to the subduction of the Indian oceanic plate beneath the Eurasian one. The features of this subduction system (trench, outer arc ridge, outer arc basin, volcanic arc and foreland basin) are developed there, from south to north, with particular clearness.

The above mentioned area lies on the transition zone between the present day active volcanic arc to the north and the outer arc basin to the south; the latter is the eastward continuation of the subduction system of Sumatra and western-central Java, extending to southeastern Java, Bali, Lombok and further eastward. The Indian Ocean floor is now sliding approximately northward beneath these island. The Cenozoic sedimentation occurred in the considered region at the junctures between the two plates; nevertheless, it has been relatively stable and continuous, and the rocks appear to have suffered limited deformation. Pre-Tertiary sediments and associated igneous and metamorphic rocks make up the basement. Unconformable Eocene conglomerates, sandstones, limestones and marls rest on top of it. Generally, no sedimentation occurred during the Oligocene. The Miocene deposits consist of limestones, marls and pyroclastic rocks.

Previous investigations.

By the end of the twenties several authors have dealt with the area considered in this paper, especially the Southern Mountains of Java and, at a lesser extent, the neighbouring islands to the east.

The Southern Mountains were first described by Bothe (1929) and a Miocene age was assigned to the limestones, based on their foraminiferal content (Umbgrove in Bothe, 1929). Leupold & Van der Vlerk (1931) divided the Upper Tertiary sequence of the area east of Yogyakarta into two parts separated by an unconformity. Van Bemmelen (1949), as regards the Southern Mountains in the area south of Solo, reported a Middle Miocene age for the larger foraminifera bearing limestones cropping out in that area. Marks (1957), in his Stratigraphic Lexicon of Indonesia, assigned the limestones a Te5 to Tf3 age.

The innumerable conical hills constituting the characteristic scenario of the Gunung Sewu (western part of the East Southern Mountains) were investigated in great detail by Sartono (1964). He established the Punung Formation, divided into

alternating limestone facies (7 members) and clastic facies (6 members) reflecting non-volcanic and volcanic periods respectively. The Punung Formation was assigned a Tf1-Tf3 age.

The large scale oil and gas exploration during the last 20 years, especially the seismic surveys and exploratory drilling made by Pertamina and foreign oil Companies, has enormously improved the knowledge on the geology of Indonesia. In the offshore area of Southern-Central Java, approximately 25 km SSW of the coastline and 50 km from Yogyakarta, two wells named Alveolina (ALV1) and Borelis (BOR1) were drilled by SHELL in deep water (Bollinger & De Ruiter, 1975). The ALV1 well encountered a sedimentary sequence consisting of deep marine Pliocene clay overlying some 300 meters of shallow marine Middle Miocene limestones, these latter resting unconformably on Late Oligocene tuff and clay.

Some excursion itineraries carried out in 1976 and 1977, in the frame of a joint Indonesian-Japanese research program, partially covered some areas near the southern coast of Java, in particular the Gunung Sewu (between Baturetno and Pacitan) and the area south of Malang. The subsequent extensive special publication (Utung & Sato, 1978) reported on the micropaleontological study of some spot-samples; the age assignments are within a time interval extending from Upper Te (Early Miocene) to Lower Tf (Middle Miocene).

As regards more recent studies, mention is to be made of the extensive one by Kadar (1986) on the Neogene planktonic foraminiferal biostratigraphy of South-Central Java, and of the investigations carried out in Bukit Peninsula (Bali) by Robba et al. (1986), in Lombok by Franchino et al. (1988), in Sumbawa by Barberi et al. (1987).

The foraminiferal assemblages.

As regards the stratigraphic ranges of the recognized larger foraminifera, and their framing within the current biostratigraphic and chronostratigraphic scales, we make reference to Adams (1970, 1984) and to Chaproniere (1981, 1984a, 1984b) for information concerning the Indo-West Pacific region and Australia respectively. Figure 2 shows the stratigraphic setting of the examined lithotypes compared to that of the limestones cropping out in the island east of Java.

East Southern Mountains, Sector A. Some limestone spot-samples were collected in four different localities (F1 through F4; see Fig. 1) in the karstic area of Gunung Sewu, between its western extremity and Pacitan. Two distinctive larger foraminiferal assemblages have been identified.

The first assemblage (samples F1, F2, F4) is contained in boundstones with *Melobesiae.* It is characterized by *Lepidocyclina (Nephrolepidina)* cf. *howchini* Chapman & Crespin, *Lepidocyclina (Nephrolepidina)* spp., *Amphistegina* cf. *hauerina* d'Orbigny, *Gypsina* sp., *Sphaerogypsina globula* (Reuss), *Borodinia septentrionalis* Hanzawa, *Homotrematidae, Miliolidae.* This assemblage quite likely is attributable to Zone N8 or

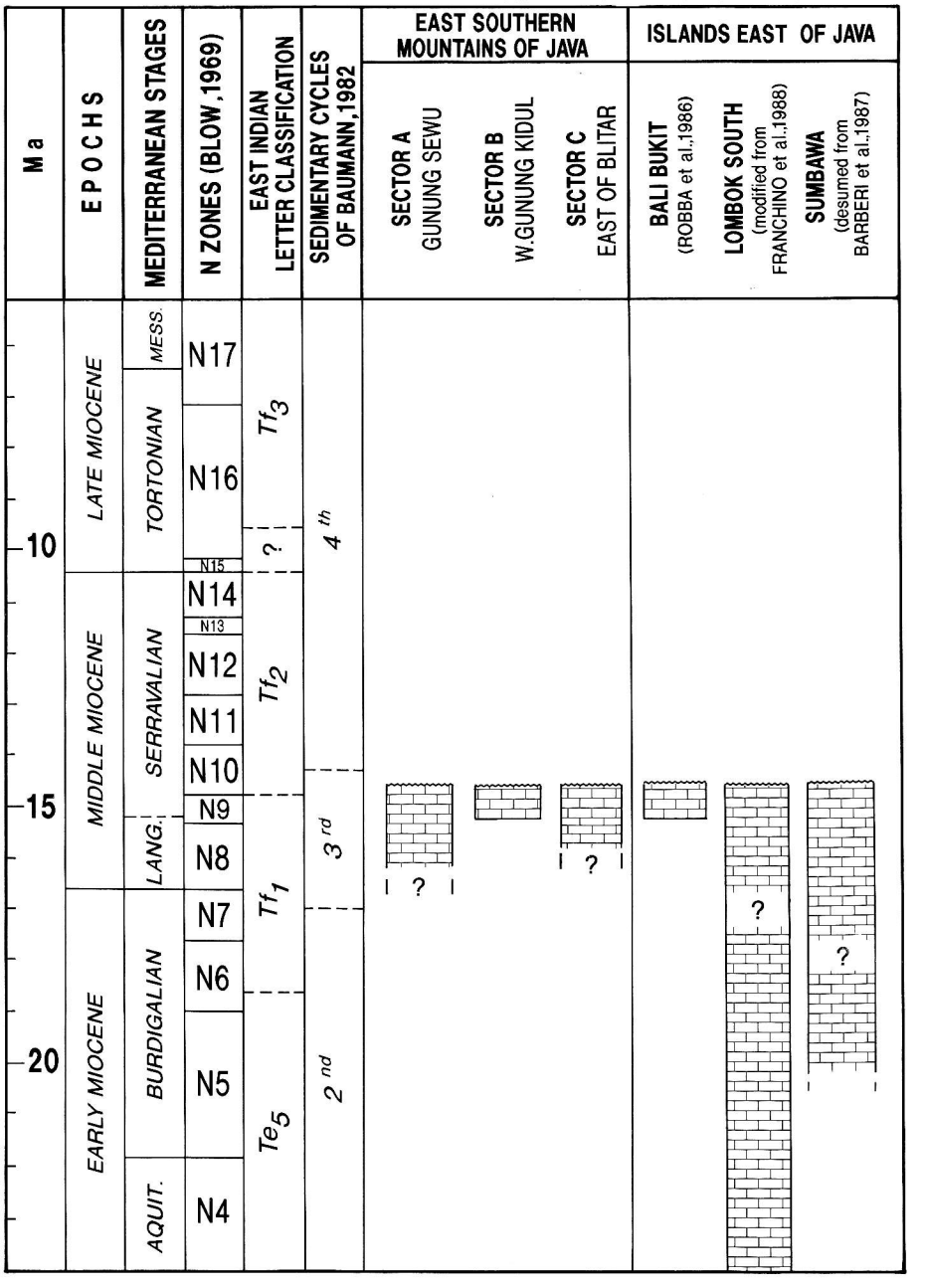

Fig. 2 - Stratigraphic setting of the limestones of the three sectors compared to that of the limestones outcropping in the islands east of Java.

basal N9 (Langhian) that means a Tf1 age.

The second assemblage (sample F3), recovered from a partially recrystallized packstone-wackestone, is dominated by planktonic foraminifera: *Praeorbulina glomerosa* Blow, *Orbulina suturalis* Brönnimann, *Orbulina universa* d'Orbigny, *Globoquadrina altispira* Cushman & Jarvis and abundant *Globigerinidae*. Co-occurring benthic foraminifera are: *Miogypsina* (*Lepidosemicyclina*) cf. *thecidaeformis* (Rutten), *Sphaerogypsina globula* (Reuss), *Cibicides* sp., *Brizalina* sp., *Guttulina* sp., *Nodosariidae, Rotaliidae*. The assemblage can fall within Zone N9 or be slightly younger (Early Serravallian), thus suggesting a Tf1 age, possibly transitional to Tf2. It is of note that an assemblage including *Flosculinella bontangensis* (Rutten) was found by Kadar & Natori (1978, sample JC6) in the same locality and level of our sample F3.

East Southern Mountains, Sector B. The spot-samples (F5 through F11) collected in the western part of Gunung Kidul area, from Pacitan to south of Blitar, mostly are from packstones often with *Melobesiae*, and provided a fauna similar to the previous one.

The following larger foraminifera are present: *Flosculinella bontangensis bontangensis* (Rutten), *Lepidocyclina (Nephrolepidina)* cf. *howchini* Chapman & Crespin, *Lepidocyclina (Nephrolepidina)* sp., *Miogypsina (Lepidosemicyclina) thecidaeformis* (Rutten), *Gypsina howchini* Chapman, *Borodinia septentrionalis* Hanzawa, *Operculina* cf. *complanata* (Defrance), *Heterostegina* sp., *Cycloclypeus* sp., *Amphistegina hauerina* d'Orbigny, *Sorites* sp., *Marginopora vertebralis* de Blainville, *Parrellina craticulariformis* Wade, *Miliolidae, Rotaliidae, Discorbidae* and several *Homotrematidae* including *Biarritzina* cf. *carpenterliformis* (Halkyard) and *Sporadotrema* sp. Less abundant planktonic foraminifera were observed as well: *Orbulina suturalis* Brönnimann, *Orbulina universa* d'Orbigny, *Globigerinoides trilobus* (Reuss), *Globoquadrina* spp. and *Globigerinidae*. The fauna suggests a N9-basal N10 (Early Serravallian) zonal assignment and points toward a Tf1 age, probably transitional to Tf2.

East Southern Mountains, Sector C. Spot-samples were collected in three localities of Gunung Kidul, east of Blitar (F12, F13, F14) and from the isolated outcrop near Puger (F15a, F15b). Similarly to sector A, the limestones (mostly packstones) yielded two distinctive assemblages.

The first (samples F12, F13, F15a) includes *Lepidocyclina (Nephrolepidina)* cf. *howchini* Chapman & Crespin, *Lepidocyclina (Nephrolepidina)* sp., *Miogypsina (Lepidosemicyclina)* sp., *Sphaerogypsina globula* (Reuss), *Gypsina* cf. *howchini* Chapman, *Marginopora vertebralis* de Blainville, *Sorites* sp., *Heterostegina* sp., *Operculina* sp., *Amphistegina* cf. *hauerina* d'Orbigny, *Austrotrillina howchini* (Schlumberger), *Miliolidae, Rotaliidae, Discorbidae, Homotrematidae*. Although poorly represented, some planktonic foraminifera were recognized such as *Praeorbulina transitoria* Blow, *Globigerinoides* sp. and *Globigerinidae*. The fauna can be referred to Zone N8 or basal N9 (Langhian), and establishes a Tf1 age.

The second assemblage (samples F14, F15b) is dominated by larger foraminifera as well and includes *Lepidocyclina (Nephrolepidina)* cf. *howchini* Chapman & Crespin, *Lepidocyclina (Nephrolepidina)* sp., *Miogypsina (Lepidosemicyclina)* cf. *thecidaeformis* (Rutten), *Gypsina* spp., *Sorites* sp., *Amphistegina* sp., *Operculina* sp., *Austrotrillina howchini* (Schlumberger), *Miliolidae, Rotaliidae, Homotrematidae.*

Samples 327 and 333 of Kadar & Natori (1978), collected in the same locality of our sample F14, were generically assigned an Upper Te (Lower Miocene) to Lower Tf (Middle Miocene) age, on the basis of larger foraminiferal assemblages containing *Flosculinella* sp. The fauna of sample F14 strongly suggests a N9 or basal N10 zonal assignment, and points toward a Tf 1 age possibly transitional to Tf2 for those fossil bearing layers.

Nusa Dua (Bali) and Nusa Penida. The limestone samples from Nusa Dua (east of Bukit Peninsula of Bali) yielded assemblages composed of *Amphistegina* sp., *Cycloclypeus* sp., *Planorbulinella* sp., *Orbulina* sp., *Globigerinoides* sp. and co-occurring abundant calcareous algae. Since the fauna is not age-diagnostic, a generic Mid-Late Miocene age may be supposed.

Some limestone samples have been collected in the locality of Teluk Nusa Penida (also called Crystal Bay), on the NW coast of the island of Nusa Penida, and on the northern extremity of Nusa Ceningan islet (near Tanjung Glumpang). The fossil contents consist of very abundant calcareous algae *(Corallinaceae)* and foraminifera. The microfauna includes *Amphistegina* sp., *Gypsina* spp., *Lepidocyclina* sp., *Heterostegina* sp., *Cycloclypeus* sp., *Planorbulinella* sp., *Acervulinidae, Homotrematidae, Globigerina* spp., *Globigerinoides* sp. In the lack of significant forms, again a Mid-Late Miocene age is inferred.

Concluding remarks.

The age of the considered limestones cropping out in the East Southern Mountains of Java ranges from Zone N8 to N9 or basal N10, that means a Lower Tf age. In terms of Mediterranean stage ages, this time interval correlates with Langhian and earliest Serravallian. The limestones are attributable to the third depositional cycle of Baumann (1982). Zone N9 has been ascertained in other sequences of the islands east of Java (Fig. 2). All these limestones are, quite possibly, not younger than Zone N9 or basal N10. It is to be noted, in this respect, that a significant regressive phase occurred all over the Sundaland, corresponding to zones N10-N11 (Baumann, 1982).

Flosculinella bontangensis, found in the limestones of the East Southern Mountains of Java, often co-occurs with *Orbulina universa;* a very typical larger foraminiferal association includes *Flosculinella bontangensis bontangensis, Lepidocyclina (Nephrolepidina)* cf. *howchini* and *Miogypsina (Lepidosemicyclina)* cf. *thecidaeformis* etc. (Pl. 42). In various localities of the considered area, *Flosculinella bontangensis* is recorded from layers directly overlying limestones with *Praeorbulina* and *Orbulina su-*

turalis, and the same quite possibly occurs in the island of Sumbawa (Barberi et al., 1987). Similar evidence has been reported on for various sectors of the Australian margin where, in the lower part of Zone N9, a hiatus is recognizable between the *Praeorbulina* bearing layers and the overlying beds with *Orbulina* and a *Flosculinella-Austrotrillina* assemblage (McGowran, 1979). In Australia, *Flosculinella bontangensis bontangensis,* typical of the *Austrotrillina howchini-Flosculinella bontangensis* association, is reported to range within a stratigraphic interval not older than Zone N9; these levels are topped by an unconformity (Chaproniere, 1975, 1981, 1984a, 1984b). This unconformity is present in the examined area as well and corresponds to the regional unconformity that truncates the carbonate sequences represented in Fig. 2. Accordingly, the limestones with *Flosculinella bontangensis* of the East Southern Mountains of Java are inferred to have an age same as that of the just mentioned Sumbawan and Australian levels. They are framed within a stratigraphic interval extending from Zone N9 to basal N10 which correlates with the earliest Serravallian.

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PLATE 42

Bioclastic packstone with: F, *Flosculinella bontangensis bontangensis* (Rutten); L, *Lepidocyclina (Nephrolepidina)* cf. *howchini* Chapman; M, *Miogypsina (Lepidosemicyclina)* cf. *thecidaeformis* (Rutten); A, *Amphistegina* sp.; H, *Homotrematidae;* O, *Orbulina universa* d'Orbigny. Sample F11, Gunung Kidul, East Southern Mountains of Java; x 25. The assemblage falls within Zone N9 or N9 to basal N10 and points toward an earliest Serravallian age.


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