

# THE PLIOCENE/PLEISTOCENE BOUNDARY, BASED ON CALCAREOUS NANNOFOSSILS, AND RELATED PALAEOCLIMATIC IMPLICATIONS, SOLO RIVER SECTION, NGAWI REGION, EAST JAVA, INDONESIA

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**Abstract:** Analysis of calcareous nannofossils has been carried out on samples from the Solo River section, Ngawi Region, East Java Basinal Area. The boundary between the Pliocene and Pleistocene was determined, based on the last occurrence of *Discoaster* and the simultaneous first occurrence of *Gephyrocapsa*, following Martini & Müller (1983). Van Gorsel & Troelstra (1981), who studied planktonic foraminifera from the same section, determined the same boundary on the first occurrence of *Globorotalia* cf. *G. truncatulinoides*. The present study shows that the Pliocene/Pleistocene boundary, as determined by planktonic foraminifera biostratigraphy, is approximately 1.8m stratigraphically higher than the boundary determined from nannofossil biostratigraphy.

Rahardjo (1999) concluded that the climate became cooler around the Pliocene/Pleistocene boundary, based on foraminifera and pollen from the central part of the East Java Basin: a similar conclusion is inferred from the present study.

## Introduction

Nannofossil analyses have been conducted on samples taken from the Solo River section. This section, located about 2km NE of Ngawi town, East Java Province, Indonesia, was measured along the bank of the Solo River (known locally as Bengawan Solo) (Figure 1). The section contains nannofossil assemblages of Pliocene to Pleistocene age. Van Gorsel & Troelstra's (1981) study of the planktonic foraminifera from the same section also identified the Pliocene/Pleistocene boundary. However, this is stratigraphically higher than the boundary as determined by nannofossils. This situation is discussed.

Correlation between foraminiferal and nannofossil biozonations around the Pliocene/Pleistocene boundary in Indonesia has already been carried out by several authors: e.g. Hasyim (1988) in the Kendeng Zone and Kapid (1991) in the Rembang Zone, although these reached differing biostratigraphical conclusions. The aim of this paper was to determine new information to allow a direct comparison between the two biozonations through this

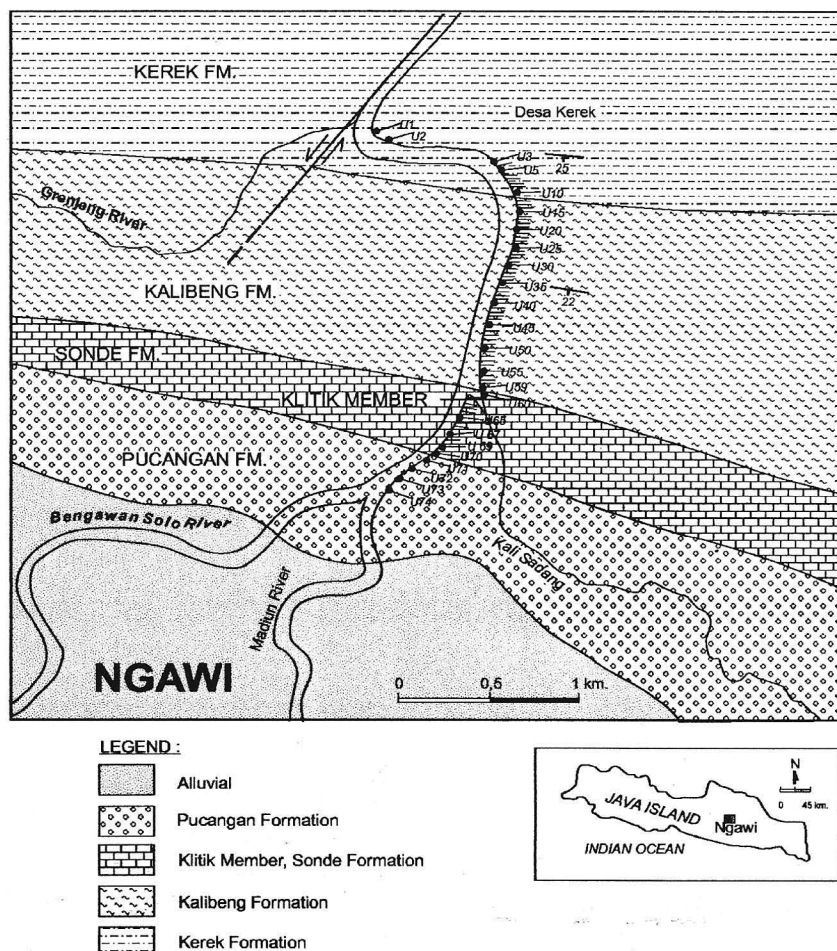
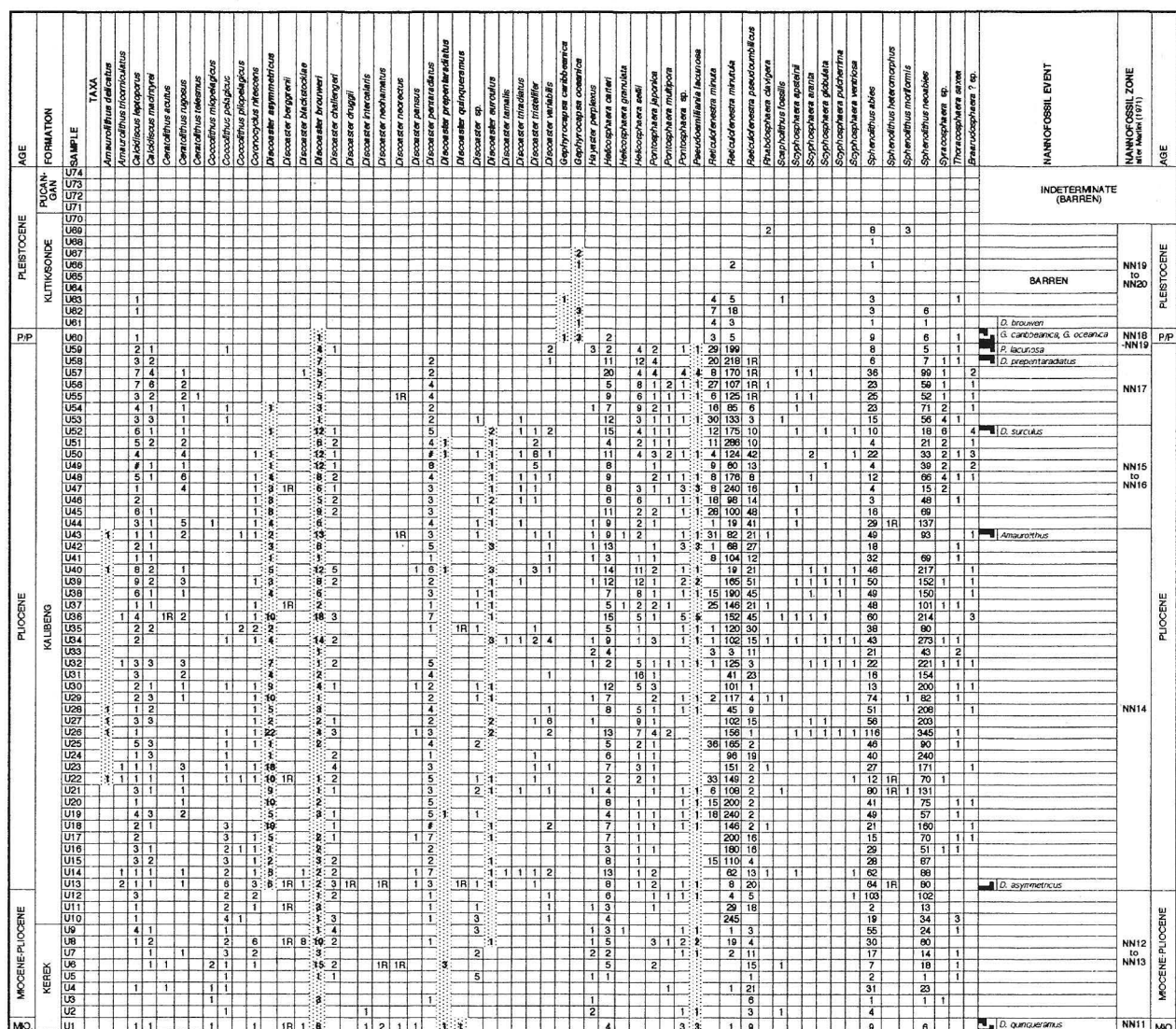


Figure 1: Location and geology of the Bengawan Solo River section, Ngawi Area, East Java.



**Figure 2:** Distribution of calcareous nannofossils, Solo River section, Ngawi Area, East Java. R = interpreted as reworked.

interval (nannofossil and plankton foraminiferal) in the same section. The Solo River section was selected because it comprises continuous marine sediments of Late Miocene to Pleistocene age, and thus contained the Pliocene/Pleistocene boundary.

## Methods and materials

The lithostratigraphic nomenclature used in this study follows that of Pringgoprawiro (1983), which is in accordance with the *Sandi Stratigrafi Indonesia* (Stratigraphic Code of Indonesia), but differs slightly from that used by van Gorsel & Troelstra (1981). In this study, the Kalibeng Formation is equivalent to the Lower Kalibeng Formation of van Gorsel & Troelstra (1981), whilst the Klitik Member, Sonde Formation, is equivalent to their Upper Kalibeng Formation. The uppermost part of the studied section belongs to the Pucangan Formation. Several key beds, or distinct lithological boundaries, were used as reference points.

Seventy-four samples were prepared as smear-slides. The nannofossil zones of Martini (1971) were

applied. Specimens were randomly counted using a grid pattern.

## Results

The Kerek, Kalibeng and Klitik Formations are of Late Miocene to Pleistocene age (see range-chart, Figure 2). Fifty-seven species were recorded, and ten nannofossil biozones applied (NN11 to NN20), although only the Pliocene-Pleistocene zones (NN18-NN19) are discussed in detail. The Pliocene/Pleistocene taxa are illustrated in Plate 1. Fully-authored and –referenced lists of nannofossil taxa can be found in Perch-Nielsen (1985) or Bown (1998).

### Discussion – the Pliocene/Pleistocene boundary

Authors such as Martini (1971), Okada & Bukry (1980) and Perch-Nielsen (1985) have placed the Pliocene/Pleistocene boundary (approximately) between NN18 and NN19. They determined that the last occurrence (LO) of *Discoaster* occurred in the latest Pliocene, and could be used to approximate the Pliocene/Pleistocene boundary. Hasyim (1988) and Kapid (1991), however, found that

*Discoaster* was present in Pleistocene sediments in East Java. Rio (1974 in Haq et al., 1977) also inferred that specimens of *Discoaster brouweri* were present in the Early Pleistocene. Previous authors have regarded such occurrences as reworking, and argued that these should not be used as biostratigraphic markers. Instead, they have used the first occurrence (FO) of *Gephyrocapsa* to define the Early Pleistocene.

The designation of the Pliocene/Pleistocene boundary by Rio (1974 in Haq et al., 1977) at the LO of *Discoaster brouweri* in the presence of *gephyrocapsids* (*Gephyrocapsa oceanica* and *Gephyrocapsa caribbeanica*) was applied to the present study, this co-occurrence being observed in Sample U60. Samples from U61 upwards are devoid of *Discoaster*. Van Gorsel & Troelstra (1981) concluded that the Pliocene/Pleistocene boundary coincided with the N21/N22 Planktonic Foraminifera Zone boundary, indicated by the FO of *Globorotalia* cf. *G. truncatulinoides* and the LOs of *Globoquadrina altispira*, *Globigerinoides obliquus extremus* and *Globigerinoides fistulosus*. It thus appears, from a comparison of the two studies, that van Gorsel & Troelstra's (1981) boundary is approximately 1.8m above that determined herein.

The discrepancy between the foraminifera- and nannofossil-derived Pliocene/Pleistocene boundaries may be explained by one of two factors.

The sampling interval of the foraminifera study was of lower resolution than that of the nannofossil study, especially around the boundary between the Kalibeng and Klitik Formations. If the sampling had been more detailed, it is possible that *Globorotalia* cf. *G. truncatulinoides* might have been found below the recorded level, and thus its FO might be closer to the level of the LO of *Discoaster*. Thus, the discrepancy may not be significant.

However, Rio's (1974 in Haq et al., 1977) study of the Catanzaro section, southern Italy, found that the FO of *Globorotalia* cf. *G. truncatulinoides* was almost coincident with the LO of *Discoaster* and the FOs of *Gephyrocapsa caribbeanica* and *Gephyrocapsa oceanica*, whilst in his study of the Le Castella section, he found the FO of *Globorotalia* cf. *G. truncatulinoides* 2m above the nannofossil-defined boundary. Thus, the likely sequence of biostratigraphic events through the boundary interval appears to be: LO *Discoaster*, (nannofossil boundary), FOs *G. caribbeanica* and *G. oceanica*, (planktonic foraminifera boundary), FO *G. cf. G. truncatulinoides*.

#### Palaeoclimatic implications

Herein, the Pliocene/Pleistocene boundary is quantitatively indicated by a drastic decrease in nannofossil abundance. Cool-water species, such as *Coccolithus pelagicus*, *Gephyrocapsa caribbeanica* and *Hayaster perplexus*, are relatively more abundant in this interval than warm-water taxa, such as *discoasters* and *Ceratolithus rugosus*, and the latter do not occur at all in the Pleistocene sediments. Okada & McIntyre (1979) and Haq (1980) determined that *G. caribbeanica* is typical of temperate to polar regions, whilst Bollmann (1997) found it to have a tolerance of 5° to

21°C, with its maximum abundance at 13° to 19°C. The Solo River data may thus indicate a climate cooling scenario from the Pliocene to Early Pleistocene.

Van Gorsel & Troelstra (1981) concluded that a cold or glacial period had occurred in the Early Pleistocene, based on foraminiferal data. More recently, Rahardjo (1999) studied pollen and planktonic foraminifera of the Mojokerto area, about 100km E of the present study area. Both of the localities belong to the East Java Basinal Area. Rahardjo (1999) concluded that there was a drastic climatic cooling during the Early Pleistocene, indicated by the extinction of *Stenochlaenioides papuanus*, a warm-climate pollen, and characterised by the distinct increase of gramineae. Thus, the present data may support this hypothesis.

#### Conclusions

The Pliocene/Pleistocene boundary has been identified in the Solo River section, using the LO of *Discoaster* and the FO of *Gephyrocapsa*. This level is 1.8m below the level of the boundary determined by planktonic foraminifera (van Gorsel & Troelstra, 1981) which may be due to differences in sampling resolution, or may indicate that the sequence of events across the boundary interval are: LO *Discoaster*, (nannofossil boundary), FOs *G. caribbeanica* and *G. oceanica*, (planktonic foraminifera boundary), FO *G. cf. G. truncatulinoides*.

The relatively high abundances of cool-water nannofossil taxa (*Coccolithus pelagicus*, *Gephyrocapsa caribbeanica*, *Hayaster perplexus*), may indicate cooling conditions across the Pliocene/Pleistocene boundary in this region.

In order to establish a reference section for the Tertiary/Quaternary biostratigraphy of Java, it is proposed that research should be continued and expanded in the region of the Solo River.

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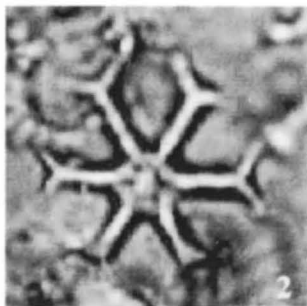
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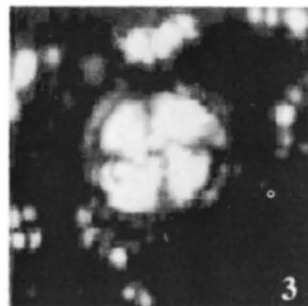
# PLATE 1



*D. brouweri*  
(U50) Neg.# F4-20, PC



*D. challenger*  
(U50) Neg.# F4-21, PC



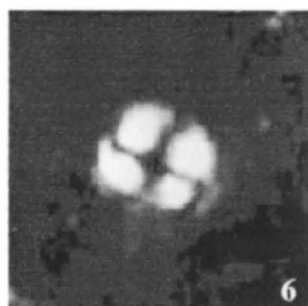
*C. macintyre*  
(U1) Neg.# F4-4, XP



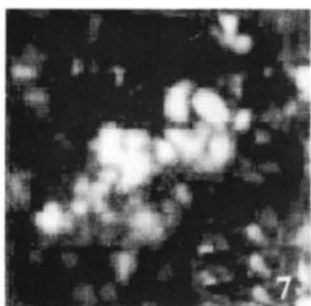
*C. acutus*  
(U36) Neg.# F3-15, XP



*C. telesmus*  
(U55) Neg.# F4-28, XP



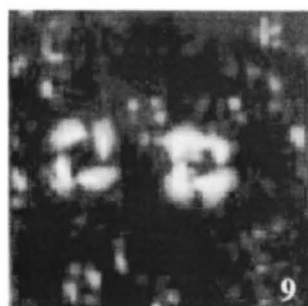
*C. pelagicus*  
(U22) Neg.# F2-13, XP



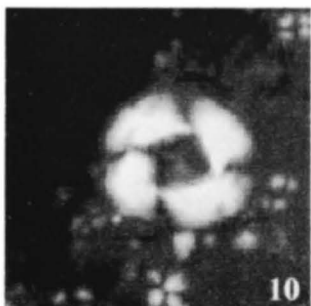
*G. caribbeanica*  
(U63) Neg.# F5-1, XP



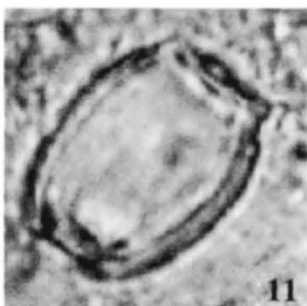
*G. oceanica*  
(U63) Neg.# F6-7, SEM  
x5400



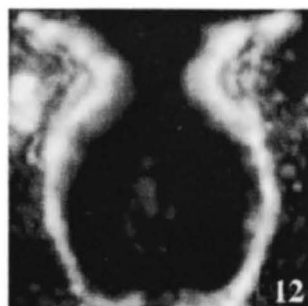
*P. lacunosa*  
(U47) Neg.# F4-15, XP



*R. pseudoumbilicus*  
(U11) Neg.# F1-34, XP



*S. aranta*  
(U39) Neg.# F3-21, PC



*S. ventriosa*  
(U22) Neg.# F2-215, XP