RECESSION OF THE SEA, CLIMATIC CHANGES, AND THE EARLIEST COLONIZATION OF JAVA NEAR THE PLIO-PLEISTOCENE BOUNDARY

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INTRODUCTION

Research about the evolution of the natural environment inhabited by *Homo erectus* in Southeast Asia faces several problems. One of the most important questions to solve is that of the impact of the so-called glacial periods upon the lower altitude landscapes: to what extent did grassy or even savanna-like formations expand in such equatorial areas?

We are approaching such questions by means of two complementary research programs being carried out on Java. The first is devoted to characterizing the ecological history of Java over the past three million years. Special attention is paid to Pleistocene fossil-bearing layers, including those of the well-known fossil hominid sites. This study has been mainly restricted to low altitude sites. From a palynological point of view there are still few results from such profiles in Southeast Asia, mainly because of the species richness and difficulties of identification. But this research, to which we shall restrict ourselves in this paper, is likely to be the most useful in understanding the environments of the *Pithecanthropus* sites.

Focused on a younger time-scale, the second program is recording data from lacustrine sediments dating from the last glacial maximum (*c*.18,000 BP) to historical times. The chronology of such deposits may be easily derived from radiocarbon dating, and pollen analysis is able to give a detailed picture of the consequences of the last major sequence of climatic changes. Knowledge of such consequences can then be applied for a better understanding of older periods.

The main target of this second program is thus paleoclimatic reconstruction. Our research is focused on the Ambarawa basin in central Java, at an altitude of about 500 m. This study opens new horizons for paleoclimatic research in Indonesia since previous scholars have usually restricted their work to very high altitude profiles. The data from these is mainly related to altitudinal shifts of vegetation zones and thus gives temperature changes only.

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Coming back to the first aspect of the research, we shall present the results in two parts. First comes a discussion of the main vegetation formations which can be inferred from the pollen diagrams, together with their ecological and climatic significances. Secondly, we present a specific example of this kind of research focused on the recession of the sea near Bumiayu in central Java and the understanding of the oldest colonization of Java by land mammals.

THE POLLEN ASSEMBLAGES AND THEIR SIGNIFICANCE

Experience leads us to recognize, in the very complex floral assemblages shown in the pollen diagrams, several important vegetal associations. Obviously, these associations are not completely identified vegetal formations from a botanical point of view. But their changing relative importances give good indications about paleoecological changes. Some can be used to describe major climatic trends:

The tropical rain forest, where we find, among others, the Dipterocarpaceae, the Fagaceae and the Podocarpaceae.

A more open forest group, which looks in several aspects like present Indonesian monsoon forest but is not in fact a true monsoonal climate association: Mimosaceae, Papilionaceae, Sapindaceae and some herbaceous taxa.

Isolated taxa, like *Podocarpus imbricatus*, which presently grow over 1500m. When found in fairly high proportions in lowland sediments such trees could point to a cooler climate than now.

We can also characterize several environments which are not climatically significant, but which can help us to recognize locally important geological or paleogeographical events. These include:

A group that points to an environment dominated by secondary vegetation, with reconquest pioneer taxa that grow after volcanic eruptions or persist during long periods of volcanic disturbance. Trees like *Casuarina* and herbs like *Imperata cylindrica* are important members of this group.

A beach formation group with Malvaceae (*Thespesia populnea, Hibiscus tiliaceus*), *Ipomaea pes caprae*, *Barringtonia*.

A mangrove forest group with Rhizophoraceae, *Avicennia, Excoecaria, Sonneratia*, etc.

A back-mangrove association (*Nypa, Sonneratia caseolaris*)

Lower altitude swamp forest, with many ferns (including *Stenochlaena palustris*), *Shorea albida* and the Ebenaceae.

THE BUMIAYU SERIES AND THE OLDER COLONIZATION OF JAVA

1. The Recession of the Sea and the Arrival of Land Animals

We know that the colonization of Java by land mammals could theoretically have taken place as soon as the first great eustatic drop of the sea level, thought to have happened just after the Gauss/Matuyama boundary, c.2.5 million years ago. But land mammals could not have colonized Java if the development of emerged lands was not sufficient.

The emergence of Java was of course partly linked to eustatic changes, but in a more important way to the uplift of the volcanic arc. Recession of the sea can be observed in stratigraphical sections in several areas of Java (Fig. 1): Bumiayu, south of Tegal, Kaliuter, Onto, Gemolong, Sangiran, Gunung Butak (Kedungbrubus, near Ngawi), and Perning west of Surabaya (A.M. Sémah 1986; Bandet *et al.* 1989). In all these sites, the emersion was immediately followed by colonization by mammals, whose fossils are found in the first continental layers.

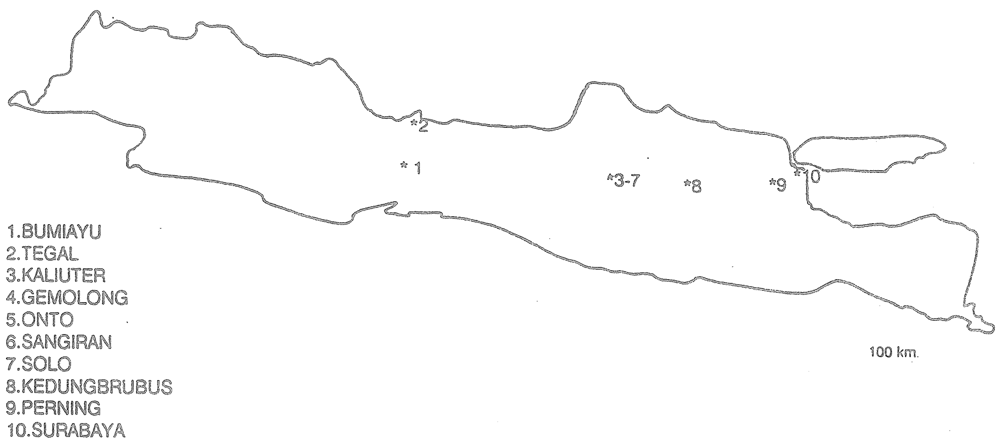

FIGURE 1: THE LOCATIONS OF TOWNS AND SITES MENTIONED IN THE TEXT

It is therefore important to know the chronology of the first appearance of continental conditions, and to describe the vegetal and climatic environments which dominated in Java during the marine to continental transition.

2. The Bumiayu Section and its Chronology

The section we studied in the Bumiayu area, at the junction between the Bogor anticlinal zone and the Northern Seraju mountains (which are themselves the westward extension of the Kendeng hills) is that of the Ci Saat syncline, one of the most complete in the area.

According to micropaleontological studies carried out on the thick marine series of Bumiayu, it seems that marine recessive conditions first appeared *c*.3.5 million years ago (Sumarso and Suparyono 1974). The youngest marine unit here is called the Kalibiuk

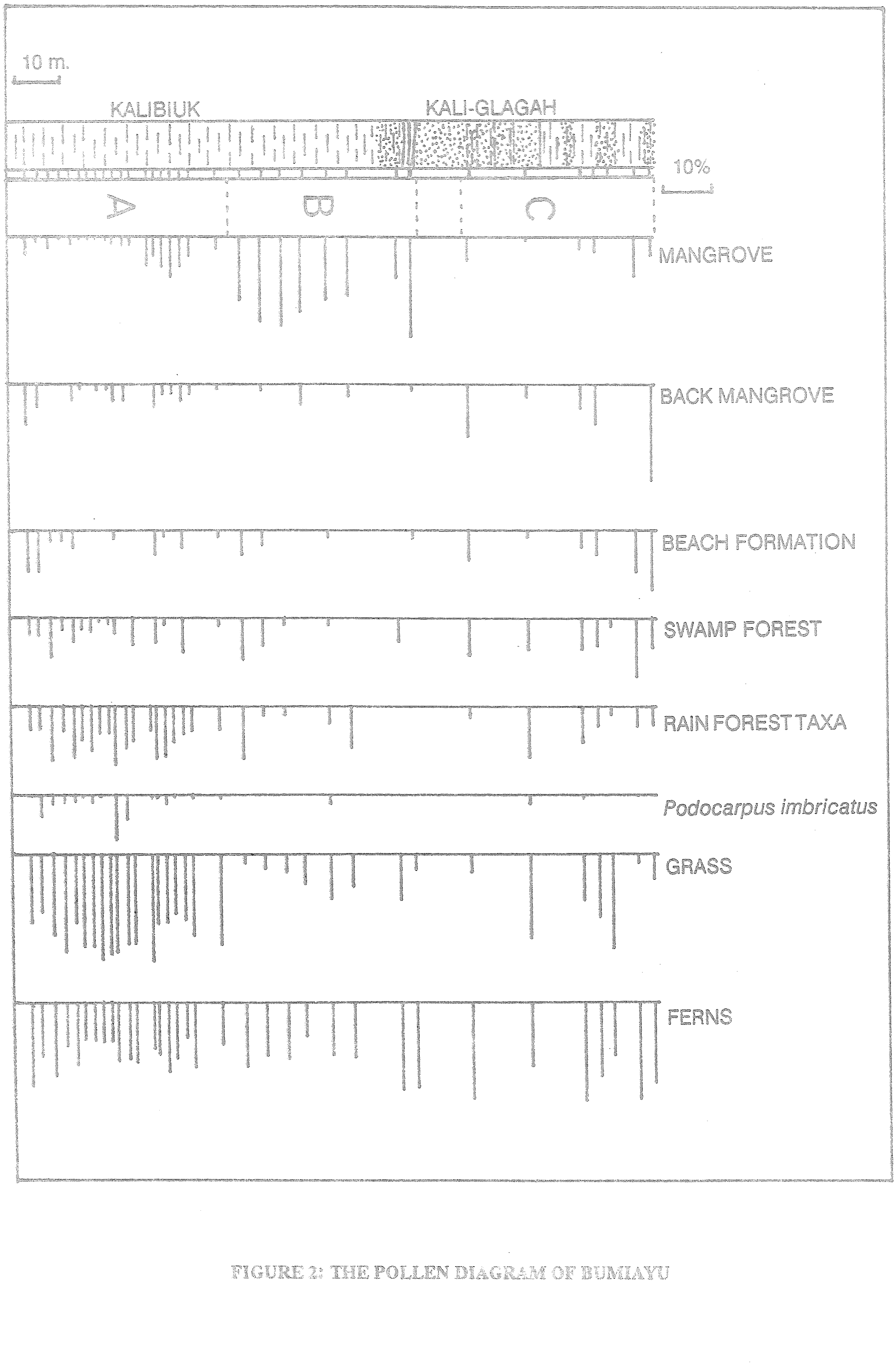

FIGURE 2: THE POLLEN DIAGRAM OF BUMIAYU

formation. The uppermost part of the Kalibiuk clays contains littoral molluscs and sea urchins and records several signs of emersion such as oxydized concretions. The Kalibiuk formation ends in the Ci Saat syncline with a lignitic bank.

The following Kali-Glagah, Mengger and Gintung units conformably overlie the Kalibiuk formation. Several hundred meters thick, they show alternation between conglomeratic layers, fluviatile sands and black clays with freshwater molluscs. Most of the deposits are derived from the erosion of volcanic structures.

The most ancient mammal fossil-bearing horizons are found near the transition between the Kalibiuk and Kali-Glagah formations. Some of these were excavated by Ter Haar and Zwierzycki at the beginning of this century (Ter Haar 1929; Van der Maarel 1932).

No radiometric dating is available yet for the Bumiayu area. Interpretation of the palaeomagnetic analysis (F. Sémah 1986) suggests a correlation of the higher Kalibiuk beds (reversed) with the lower part of the Matuyama chron (*c.*2.5-2.3 million years ago), and the lower part of the Kali-Glagah series with the normal events which occured between 2.15 and 1.8 million years ago (Réunion and Olduvai).

3. Interpretation of the Pollen Diagram (Fig. 2)

The Bumiayu pollen diagram extends over the upper Kalibiuk layers and the lower Kali-Glagah beds. Its interpretation is based on the evolution of the basic vegetation groups which were listed above.

The mangrove forest association exists all through the studied section implying nearness of the coastline. We can divide the diagram into three zones. In *Zone A*, the marine clays show rather high percentages of mangrove pollen. These percentages increase in *Zone B*, with a maximum value in the lignitic layer. We are here actually within the mangrove forest, along the coast. In *Zone C*, whose lithological facies is already a continental one, we still find mangrove elements, together with many back mangrove taxa which usually grow along estuaries. Their presence proves that the shoreline remained close. We can follow smaller oscillations marked by the ingression of estuarine forms. These interpretations are also supported by the persistence all through the section of two other littoral groups, namely the beach formation and the swamp forest.

Behind the littoral formations, Zone A indicates the presence of a rain-forest-like background on the hills. We find no evidence for the development of an open forest and thus conclude that humid conditions existed. Zone A is also rich in herbaceous taxa (Poaceae, Cyperaceae) and ferns. The frequency of *Podocarpus imbricatus* might point to a cooler climate than present.

In Zone B, the mangrove forest pollen acts as a screen covering other pollen groups. Using an adapted computer software we can get a recalculated diagram which excludes the main mangrove taxa and gives us a picture of the background vegetation. Both diagrams (the normal and the recalculated one) can be used for interpretation. Differences with Zone A comprise the abrupt disappearance of *Podocarpus imbricatus*. The decrease of Cyperaceae and ferns points to a drier climate. Eventually, Zone C shows, behind the mangrove and littoral formations, the recurrence of humid conditions with rain forest developing on the hills.

Throughout Zones B and C, characteristic pioneer plants point to disturbance of the vegetal environment by the volcanic activity conspicuously recorded in the sediments.

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