

Palynological investigations in the Danau Tempe depression, southwest Sulawesi (Celebes), Indonesia

1 INTRODUCTION

The geological history of Sulawesi (Celebes) shows a combination of geological activities like uplifts, tectonic fractures, foldings, volcanic eruptions and erosion. What in Tertiary times was a string of islands, became, as a result of uplift and volcanic activities, the island of Sulawesi as it is known now. The northern part still shows volcanic activities whereas the southwestern arm has been more stable for a considerable time. The latter area includes the Danau Tempe depression which in the south is bordered by a mountain complex, the highest peak of which is the 2,870 m high Lompobatang, a volcano which has been extinct since Tertiary times (van Heekeren 1972:65). To the east and to the west this depression stretches to the sea and to the north it is bordered by the mountains of Central Sulawesi.

Three lakes are situated in the Tempe depression: Danau Sidenreng, Danau Tempe and Danau Buaja. In wet periods they cover large parts of the depression forming extensive shallow lakes, as was the case in 1980 when samples for this study were collected. In dry periods the lakes are reduced in size and a system of rivers connecting the lakes shows up (Wichmann 1890:951 and Tab. II). A molasse ridge (Tcm on the geologic map of Indonesia, Ujung Pandang sheet, 1975) just east of Danau Tempe divides the depression in two parts. South of Sinkang the river Cenrana cuts through this formation and forms the drainage from Danau Tempe via a flat alluvial plain to the Gulf of Bone. Part of this plain is the Rawa Lampulung area which in 1980 was flooded too.

With the aim of studying the Late Quaternary vegetation history in the Danau Tempe area by pollen analysis, in June 1980 borings were carried out by the Biologisch-Archaeologisch Instituut (Groningen, Netherlands), in co-operation with the Pusat Penelitian Arkeologi Nasional (Jakarta, Indonesia).

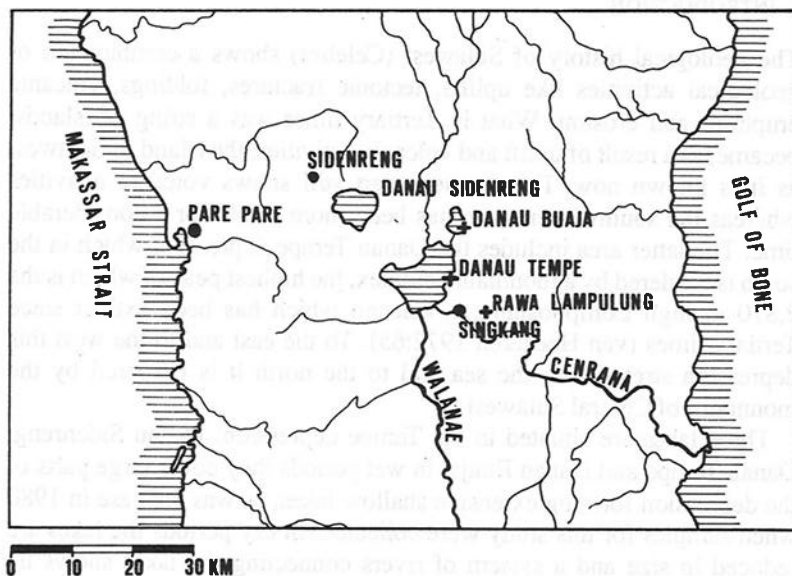
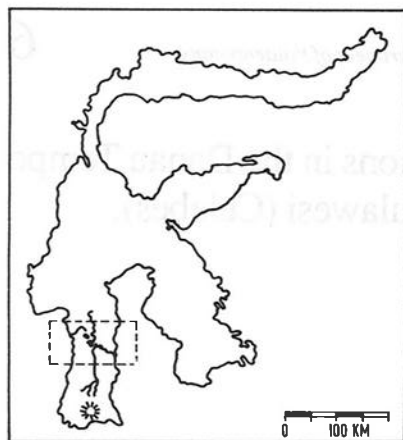


Figure 1. Coring sites (+) in Southwest Sulawesi

Sediment cores were obtained from three sites: Rawa Lampulung, c. 4 km east of Singkang, Danau Tempe, c. 5 km northwest of Singkang and Danau Buaja, c. 16 km north of Singkang (Fig. 1).

2 ACKNOWLEDGEMENTS

The palynological investigations were carried out at the request of Dr G.J.

Bartstra of the Biologisch-Archaeologisch Instituut (Groningen, Netherlands) who is involved in archaeological studies on Java and Sulawesi. He was responsible for the preparation and the organisation of the fieldtrip.

Participants in (a part of) the fieldwork were Mrs Drs Netty A. Polhaupe (Direktorat Geologi, Bandung), Basoeki (Pusat Penelitian Arkeologi Nasional, Jakarta), Burhanuddin and Dammar (Pendidikan dan Kebudayaan, Singkang), Petrus Kanna (Permuseuman Sejarah dan Kebudayaan, Ujung Pandang) and Prof Dr W. van Zeist and Drs I.-L.M. Stuijts (both of the Biologisch-Archaeologisch Instituut, Rijksuniversiteit Groningen, Netherlands).

Drs I.-L.M. Stuijts and Mr H. Woldring assisted in solving problems of identification of the pollen grains. Radiocarbon determinations were carried out at the Isotope Physics Laboratory of the Rijksuniversiteit Groningen under the direction of Prof Dr W.G. Mook.

The pollen diagrams were drawn by Mr W.J. Dijkema and Mrs G. Entjes-Nieborg typed the successive drafts of the manuscript. Miss A.L. Brindley corrected the English text.

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3 SAMPLING AND SAMPLE TREATMENT

3.1 The coring

The sediments were cored in water, up to 3.5 m deep, using a Dachnowsky sampler with an inner diameter of 3.6 cm and a useful length of 25 cm. The borings were carried out alternately in two holes and usually casings were used. The working platform was formed by two praws tied together and anchored in the sediment, with bamboo poles.

In the field the core segments were wrapped in polythene sheeting and sealed. Subsequently, before shipping to the Netherlands, they were also wrapped in aluminum foil and sealed again.

3.2 The sites (fig. 1)

3.2.1 Rawa Lampulung

Rawa Lampulung, on the map indicated as a swamp area, showed up as a shallow lake. Two borings were carried out at a short distance from each other, c. 300 m from the border of the temporary lake which at that place was about 2.40 m deep. The following lithology was recorded in m below the water surface:

- 0 – 2.40 water
- 2.40 – 2.60 sediment too soft to collect
- 2.60 – 4.90 dark blue-grey clay
- 4.90 – 4.95 transition zone
- 4.95 – 5.80 peaty clay
- 5.80 – 6.45 grey clay with many organic remains
- 6.45 – 7.65 grey clay with organic remains
- 7.45 – 7.51 and 7.65 – 7.73 no recovery
- 7.73 – 8.45 clayey peat
- 8.45 – 9.31 blue-grey sandy clay
- 9.31 end of the boring.

3.2.2 *Danau Tempe*

The Danau Tempe coring site was situated in the eastern part of the lake, c. 1.5 km from the border, opposite the dessa of Empagae. At that place the lake was about 3.40 m deep. From between 3.60 m and 8.61 m below the water surface grey to blue-grey clay was sampled. At some levels the sediment was very soft and could not be collected.

3.2.3 *Danau Buaja*

North of Danau Tempe, Danau Buaja (Crocodile Lake) is situated. At the southeast side of this lake a coring was carried out. Here the water was c. 2 m deep. The following lithology was recorded in m below the water surface:

- 2.10 – 2.20 sandy clay, too soft to collect
- 2.20 – 2.40 blue-grey clay
- 2.40 – 2.57 dark blue-grey sandy clay
- 2.57 – 2.62 clayey sand
- 2.62 – 2.85 grey sand
- 2.85 – 3.11 sandy clay
- 3.11 – 5.80 blue-grey clay
- 4.25 – 4.35 no recovery
- 5.80 end of the boring.

3.3 *Preparation of samples*

From the centre of the core segments samples of about 1–2 cm³ were taken. Gravity separation with bromoform alcohol (s.g. 2.0) was used to remove most of the mineral particles. The last mineral remains were dissolved by boiling the sample in a 30% HF solution during about 3 minutes. After acetolysis the sample residues were stained with safranin and mounted in silicone oil (AK 2000).

3.4 *The identification of pollen and spores*

The pollen grains and spores found in the sediments were primarily identified by comparison with modern pollen and spores, present in the reference collection of the Biologisch-Archaeologisch Instituut.

The use of the pollen collection is facilitated by the presence of a perforated key card file and of photographic documentation. Illustrations by various authors were also consulted to solve identification problems mainly due to the fact that the pollen reference collection is still far from complete. Various subfossil pollen types remained unidentified. If they occurred more than three times in a sediment core, they are included in the pollen diagram, indicated with a code. Of the unknown types included in the pollen diagrams photographs are presented in Plates 1–4, except Su type 2 and Su type 7 of which no photographs are available.

The identification often had to remain confined to the type, which may imply that it includes other genera besides the one it is named after. For example, *Eugenia*-type may include other genera of the Myrtaceae as well. The same is true for the fern spore types.

4 THE PRESENTATION OF THE RESULTS

The pollen frequencies of the different taxa are expressed as percentages of the total number of identified pollen grains (pollen sum) examined in the sample concerned. For practical reasons the unidentified grains are excluded from this sum. To include them would cause difficulties in determining the ratio between arboreal and non-arboreal pollen. The pollen frequencies of the unknown types as well as the fern spore frequencies are based on the above-mentioned pollen sum.

The curve of indeterminata represents the pollen grains that could not be identified because of corrosion or other damage. Their percentages can be considered as an indication of the preservation of the pollen in the samples concerned.

The main diagram shows the ratio between the arboreal pollen types (AP) and the non-arboreal types (NAP). Dominant taxa may be shown in this diagram too. To the left side of the diagram, the curves of the separate tree pollen types are presented, to the right side those of the non-arboreal pollen types. In the section at the extreme right of each diagram the ratios between arboreal pollen, non-arboreal pollen and spores is presented on the base of taking their total number as equal to 100%.

An attempt is made to order the arboreal pollen types according to their ecological demands. Only a general division is made, mainly based on data from botanical publications. The following habitats are distin-

guished: mangrove, back-mangrove, lowland and swamp forest, with a special place for riversides, upland forest and a group of indifferent taxa. The mangrove group is most clearly defined, and the number of taxa is limited including Rhizophoraceae and Sonneratiaceae. The back-mangrove group consists of taxa, such as the palms *Ceratolobus*, *Calamus* and *Arenga*, *Pandanus* and *Melaleuca*, which are salt tolerant and therefore can grow under brackish conditions (Schimper 1891). The lowland and swamp forest taxa require freshwater conditions and therefore usually grow more inland or at higher elevations within the lowland coastal area. *Elaeocarpus*, *Meliaceae*, *Melastoma* and *Bredia*, *Shorea/Hopea* and *Castanopsis/Lithocarpus* are taxa belonging to this group. *Pandanus*, *Macaranga* and *Mallotus* can be very common especially along riversides. The upland forest vegetation is represented by taxa, such as *Podocarpus*, *Pinus*, *Piperaceae* and *Celtis*. The group of indifferent taxa comprises amongst others *Urticaceae/Moraceae*, *Pycnarrhena* and *Schleichera*.

It should be remarked that most taxa, except for the mangrove species, are not restricted to the group they are placed in. Therefore, this division in ecological groups should only be considered as indicative.

In the diagrams, pollen assemblage zones are distinguished. Each zone covers a section of the pollen diagram which is characterized by its pollen-floristic composition. Each of the three diagrams has its own local pollen assemblage zones.

5 THE POLLEN DIAGRAMS (in the fold at the back of this volume)

5.1 Rawa Lampulung (Fig. 2)

In the pollen diagram of Rawa Lampulung the following pollen assemblage zones are distinguished:

Zone RL 1, spectra 1-5, shows a good representation of back-mangrove and lowland and swamp-forest taxa, especially *Palmae* and *Pandanus*. The percentages of fern spores are very high, especially those of *Stenochlaena*, a fern of the swamp forest which can grow in the zone immediately behind the mangrove as long as fresh water comes in regularly.

Zone RL 2, spectra 6-21, shows mangrove taxa, i.e. *Rhizophoraceae*, in a dominant role. The curves of some taxa, such as *Ficus*, *Maesa*-type and *Sonneratia* species, show a positive correlation to those of the *Rhizophoraceae*, suggesting that these taxa formed part of the mangrove vegetation. However, most species of the genus *Maesa* are forest trees which means that presumably the taxon represented in the diagram is not *Maesa* itself, but another one with a pollen grain like that of *Maesa*. Other pollen types and spores show very low values.

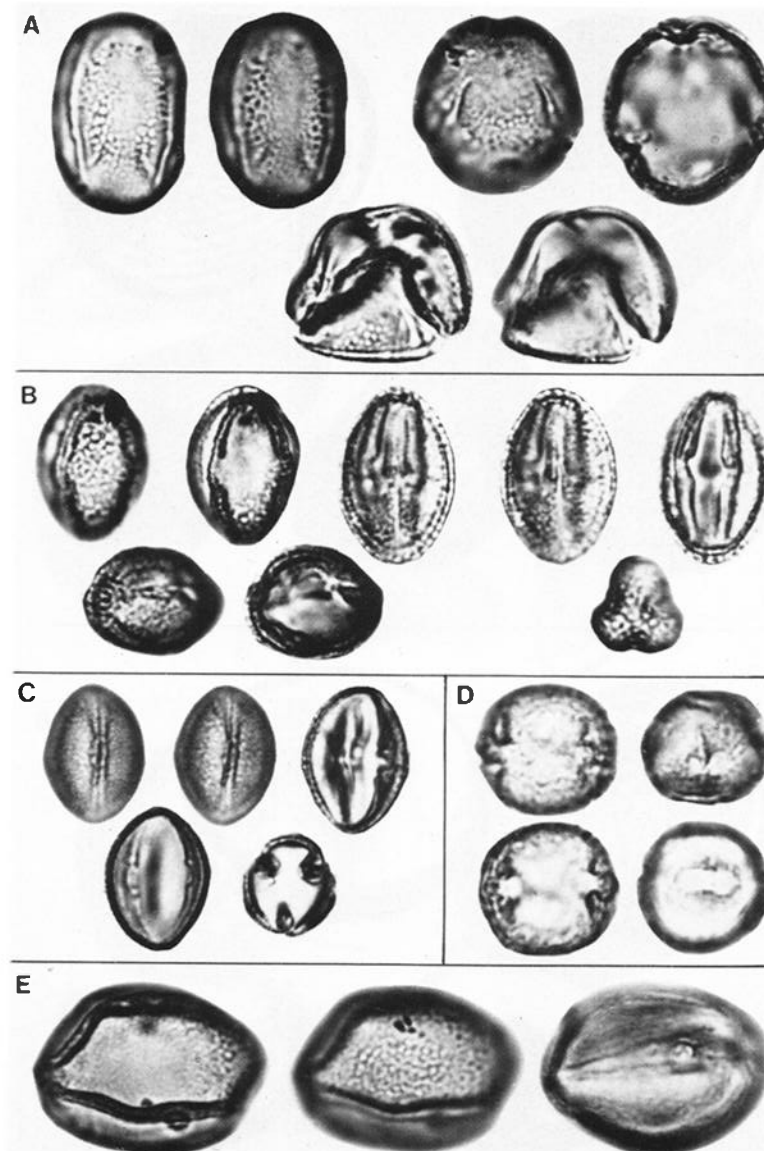


Plate 1. Unidentified pollen types. A: type Su-1; B: type Su-3; C: type Su-5; D: type Su-6; E: type Su-4. Magnification: 1250x

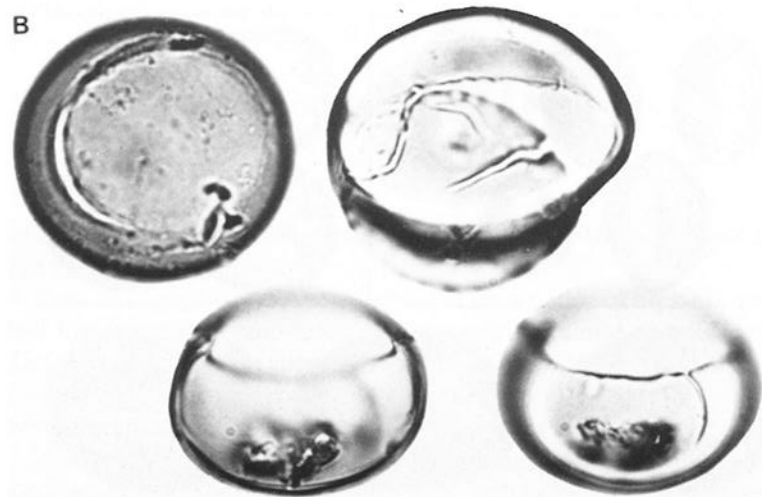


Plate 2. Unidentified spore types. A: type Su-9; B: type Su-11. Magnification: 1250×

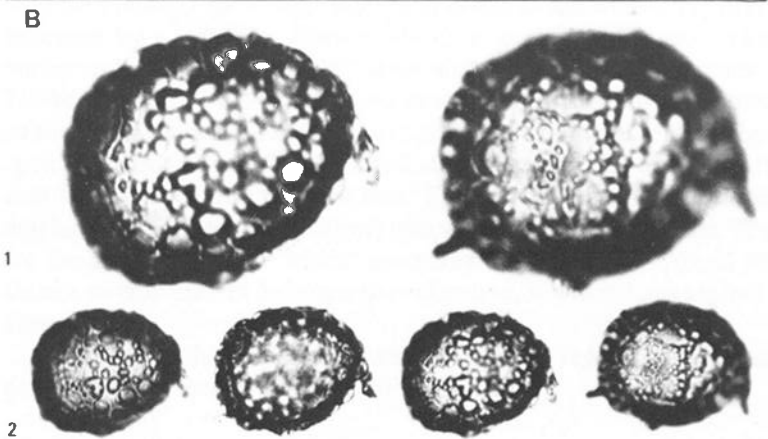
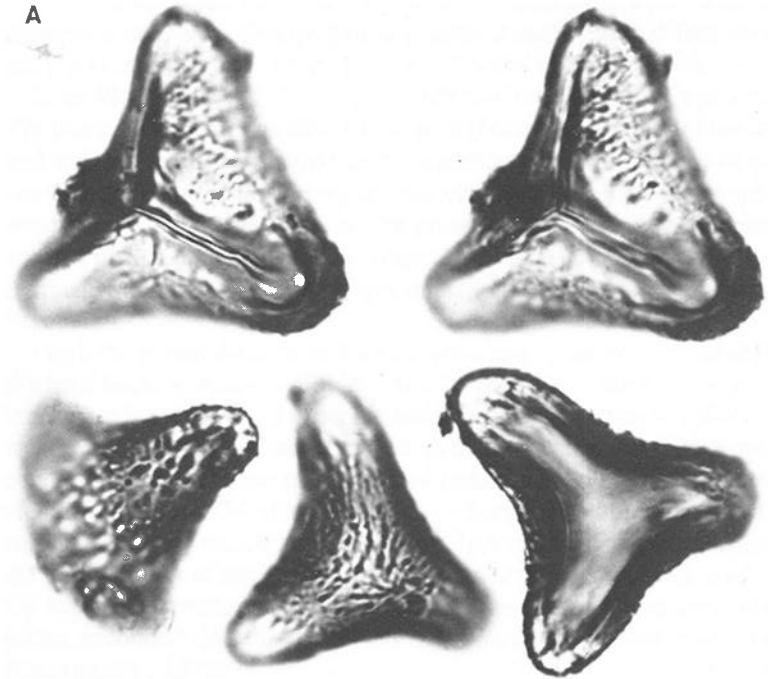


Plate 3. Unidentified spore types. A: type Su-8; B1 and B2: type Su-12. Magnification: A and B1: 1250×; B2: 500×

Zone RL 3, spectra 22-24, shows very low values for tree pollen and the mangrove taxa have disappeared altogether. Gramineae and fern spores are most common, indicating a regularly flooded open vegetation.

Zone RL 4, spectra 25-37, is dominated by Gramineae and Cyperaceae. The number of arboreal pollen is low, mainly consisting of taxa of lowland and upland forest. Compared to the previous zone, the values of fern spores have decreased. The occurrence of *Nelumbo* pollen in the uppermost part of this zone points to the presence of open water. *Pandanus* species presumably grew at the edge of it. Pollen of Su type 1 occurs frequently in this zone, suggesting that it represents a taxon of open marsh vegetation.

From the pollen diagram of Rawa Lampulung it can be concluded that the area became inundated by the sea. In zone RL 1 fresh- or possibly brackish-water conditions are indicated. The predominance of Rhizophoraceae in zone RL 2 makes it clear that they changed into salt-water conditions. Although the mangroves of Indonesia and adjacent countries are known as the most diverse in species (Soegarto & Polunin 1982) this variety is not very well expressed in the pollen spectra. Partly this is due to the impossibility of identifying pollen grains to the species level, partly to the over-representation of the Rhizophoraceae. These plants are prolific pollen producers and the grains are well distributed by water and wind (Caratini et al. 1973).

In the lithology, the change from fresh-water to salt-water conditions is indicated by a transition from sandy clay to clay with many organic remains. According to the ^{14}C determination this change is dated at 7100 ± 70 BP (GrN-10514). It seems that the influence of the sea came to an end rather suddenly. The mangrove disappeared and was replaced by an open vegetation in which grasses and sedges, and initially to some extent also ferns, played an important role. The area must have been flooded regularly, or was part of a (shallow) lake with slowly moving water. These are the conditions under which, according to Paijmans (1976), in New Guinea swamp grasses dominate the vegetation, in which ferns are mostly absent.

According to the ^{14}C determination mangrove vegetation had disappeared from the area by 2610 ± 50 BP (GrN-12540).

5.2 Danau Tempe (Fig. 3)

In the pollen diagram of Danau Tempe the following pollen assemblage zones are distinguished:

Zone DT 1, spectra 1-7, reflects a rich lowland and swamp forest vegetation with very high pollen values for trees and a great variety of ferns. Mangrove species are present in low percentages suggesting that the

mangrove vegetation zone was not far away. The presence of many salt tolerant taxa points in the same direction.

Zone DT 2, spectra 8-24, shows a completely different picture. Arboreal pollen values are strongly reduced, whereas pollen of Gramineae and Cyperaceae is most abundant. The presence of pollen types like *Potamogeton*, *Polygonum*, *Epilobium* and *Telanthera* indicates very wet conditions. Generally, the fern spore values are low in this zone.

The pollen diagram of Danau Tempe seems to reflect a transition from a more or less brackish lowland or swamp forest vegetation, to a more open vegetation mainly consisting of grasses and sedges, under fresh-water conditions.

In the sediment water lenses were present between 7.00 and 7.40 m. The sampler remained empty. One must consider the possibility of a hiatus in the sedimentation.

According to a ^{14}C determination the base of the diagram dates to 4410 ± 100 BP (GrN-10515).

5.3 Danau Buaja (Fig. 4)

In the pollen diagram of Danau Buaja the following pollen assemblage zones are distinguished:

Zone DB 1, spectra 1-5, is dominated by Gramineae and Cyperaceae. The numbers of arboreal pollen are very low. Spores are also poorly represented. The presence of pollen types such as *Epilobium*, *Ipomoea*, *Polygonum* and *Telanthera* points to wet conditions.

In zone DB 2, spectra 6-12, the percentages of arboreal pollen have increased markedly. Palmae are especially well represented. The values of Gramineae and Cyperaceae decreased, whereas those of the fern spores became high.

The pollen diagram of Danau Buaja shows a vegetation development which is more or less the opposite of the one reflected in the Danau Tempe diagram. The latter shows a change from a lowland forest to a vegetation dominated by grasses and sedges, whereas at Danau Buaja an open Gramineae-Cyperaceae vegetation changed into a lowland forest with a considerable amount of salt-tolerant taxa.

Unfortunately, the sediment of the Danau Buaja core was not suitable for radiocarbon dating.

6 DISCUSSION

Information about the present vegetation and the potential natural vegetation of Southwest Sulawesi is not available. As far as mangrove vegeta-

tions are concerned, information from other parts of Indonesia can be used, because within the region of Malesia mangrove vegetations are relatively uniform. However, when back-mangrove and lowland vegetations are concerned one cannot rely on information from other islands. This lack of information about the vegetation of Sulawesi requires a cautious approach when attempting to present an ecological interpretation of the pollen diagrams of Rawa Lampulung, Danau Tempe and Danau Buaja.

Despite these limitations, the Rawa Lampulung pollen diagram provides clear evidence that at least part of the Cenrana alluvial plain, east of Singkang, was covered by mangrove vegetations during part of the Holocene. This means that the area was inundated by the sea. According to the ^{14}C determinations this lasted from 7100 ± 70 BP (GrN-10514) to 2610 ± 50 BP (GrN-12540). During this period Rawa Lampulung was situated in the tidal zone.

The diagram of Danau Tempe does not reflect a mangrove vegetation. According to the ^{14}C determinations, the base of the Danau Tempe diagram (4410 ± 100 BP) is contemporaneous to the upper part of the *Rhizophora* zone in the Rawa Lampulung diagram. However, it reflects a predominantly fresh-water vegetation and not a mangrove. Therefore it can be concluded that the sea did not reach the Danau Tempe area at that time. Possibly the molasse ridge east of Danau Tempe is responsible for this.

Although Danau Tempe and Danau Buaja are situated in the same depression, at a rather short distance from each other, the diagrams of both sides do not reflect a similar but rather a contrasting vegetation development. It is known that in lowland areas the vegetation can show differences at very short distances in connection with factors like soil, water (fresh or brackish), running or stagnant water, and elevation (Paijmans 1976). In this way the different vegetation developments reflected in the diagrams of Danau Tempe and Danau Buaja can be explained.

Another correlation is possible. Zone DB 1 could be correlated with zone RL 1, and zone DB 2 with the lower part of zone RL 2. Such a correlation implies that in Danau Buaja the sediments representing the last 6000 or 7000 years are missing. Either they have not been formed or they have been removed. There are no indications for either one or the other explanation.

The presence of a *Rhizophora* vegetation in the Rawa Lampulung area proves that at the corresponding time the sea-level was higher than at present. Presumably it was at about 5 m which is the elevation of the coring site above present sea-level. This difference has been caused by a sea-level rise, the height of which may be influenced by tectonic movements. At present the Sulawesi area is still tectonically active, but little is

known about the tectonic movements of the island in Holocene times.

The Sunda Shelf was a tectonically stable area in Holocene times and real sea-level changes are shown for Peninsular Malaysia and for the Tin Islands east of Sumatra (Tjia et al. 1984). The curves of these changes show that roughly between 4000 and 5000 years ago the sea-level was 2.5 or 3 m higher than at present. After 4000 BP it never reached that high again.

In Papua New Guinea sea-level changes over the last 250,000 years are studied. These studies show a general sea-level rise over the last 10,000 years but the information is not very detailed (Chappell & Thom 1977). New Guinea is situated at the Sahul Shelf, which, like the Sunda Shelf, is considered to have been tectonically stable during Holocene times. According to Chappell & Thom (1977:282) a maximum sea-level of about one or two metres above present between 6000 and 4000 BP is likely for northern Australia.

The situation at the margins of the shelves is less stable. Sulawesi is situated in the area between the Sunda and Sahul Shelves and therefore data from other areas must be used with caution. Statements about relative Holocene sea-levels must be established for each region of interest.

To conclude this section, it can be said that between about 7100 and 2600 BP there was a mangrove vegetation present in the Rawa Lampulung area indicating a relative sea-level of about 5 m above present. It cannot be proved to what extent this sea-level rise was influenced by tectonic movements. In the Danau Tempe area no mangrove vegetation is demonstrated for the period since 4400 BP.

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7

Grass pollen and the origins of rice agriculture in North Sumatra

ABSTRACT

A light microscope comparison of Sumatran grass pollen grain sizes, including those of numerous rice strains, with the pollen content of surface samples from various ecological situations and subfossil grass pollen in cores from Pea Sim-sim (c. 18,500 B.P. – present) and Tao Sippinggan (c. 12,000 B.P. – present) was made to provide data on the origins of rice agriculture in highland North Sumatra. Pollen within the size range of rice was present at Pea Sim-Sim from c. 18,000 – 17,900 B.P., at c. 17,700 B.P., c. 10,700 B.P., c. 9,750 B.P. and c. 2,600 B.P. and at Tao Sippinggan at c. 2,200 B.P. and continuously from c. 1700 B.P. to the present. Early cultivation cannot be substantiated but an SEM study of surface patterning may confirm if this pollen is from rice (wild or cultivated) or other grasses. *Oryza sativa* L. is unlikely to be distinguishable palynologically. However, the presence of *Oryza*-type pollen and appropriate leaf cuticles, phytoliths and spores of fungal pathogens in sediments may contribute, in combination, further circumstantial evidence for cultivation. Proof of cultivation must rest with discovery of identifiable macrofossil remains as rice field weeds of indicator value do not occur.

1 INTRODUCTION

The question of where and when rice agriculture began and of whether the crop was first grown under dry or wet land conditions is a subject of interest and debate (cf Sauer, 1952; Solheim, 1971; Whyte, 1972, 1974; Chang, 1976; Gorman, 1977; Higham, 1977, 1979; Higham and Kijngam, 1979; Ho, 1977). In an attempt to go beyond the tracing of forest clearance phases, a pollen morphological study was made of wild and