58. Umbelliferae (*Hydrocotyl*) Pl. 3, Figs. 13-14.
59. Urticaceae (*Pilea*).
60. Vacciniaceae (*Vaccinium*).
61. Vitaceae (*Ampelopsis*).

F. Angiosperms (Monocotyledons)

1. Alismataceae (*Sagittaria*).
2. Araceae (*Arisaema*).
3. Commelinaceae.
4. Cyperaceae Pl. 3, Fig. 15.
5. Gramineae Pl. 3, Fig. 16.
6. Juncaceae.
7. Liliaceae.
8. Palmae.
9. Typhaceae (*Typha angustifolia*) Pl. 3, Figs. 17-18.

POLLEN ZONE AND INTERPRETATION

A pollen diagram (Fig. 3) including C^{14} dating, significant pollen types and some spores, characteristics of sediments and numbers of palynomorphs was constructed. It shows, on the basis of dominant pollen types, a clear division into 5 zones: Zone A, Zone B, Zone C, Zone D and Zone E.

Zone A (8200-7100 cm): scanty pollen zone.

Zone B (7100-5900 cm): *Quercus* is a dominant tree. The NTP types are present in quantities to 32% at the beginning of the zone and rise to a maximum of 60% in the middle, then fall to 23% at the end of the zone. It is subdivided into 2 subzones:

Subzone B1 (7100-6750 cm): *Quercus-Symplocos-Pasania-Alnus* association, Gramineae-Compositae-*Typha* subassociation.

Quercus is the predominant tree accounting for nearly 40% of the grains at first, declines rapidly to less than 2%, then rises a little. *Symplocos* shows an initial rise then decreases as *Pasania* and *Alnus* increase. In this subzone, NTP types with relative abundance mainly compose of Gramineae which rises rapidly from 18% at 7100 cm to a maximum of 46% at 7020 cm, then declines a little. A few spores from the ferns, i. e. *Dicranopteris*, *Pteris*, *Lepisorus* are present and from the bryophyte *Phaeoceros laevis*, also the pollen grains from *Typha angustifolia*, Compositae and Cyperaceae were observed. Among the spores, *Dicranopteris* disappeared at the end. Other pollen types include *Ligustrum*, *Ilex*, *Salix*, *Carpinus*, *Liquidambar*, *Ulmus/Zelkova*, *Trema* and Umbelliferae. This subzone represents a warm temperate forest, a warm and wet climate with a tendency toward a subtropical condition.

Subzone B2 (6750-5900 cm): *Quercus-Pasania-Alnus-Salix-Carpinus* association, Gramineae-Cyperaceae subassociation.

Quercus rises continuously up to 28% at 6200 cm, then falls at the end of this subzone. *Pasania* and *Alnus* are present in medium amounts, but *Pasania* rises as *Alnus* falls at the end of this subzone. *Symplocos* declines continuously to less than 2%. *Salix* and *Carpinus* increase but in the end *Carpinus* drops. *Ligustrum*, *Ilex*, *Liquidambar*, *Lagerstroemia* and Umbelliferae increase a little. *Trema* disappears as *Myrica* appears. Gramineae declines gradually. Cyperaceae rises at first, but falls in the end. *Typha angustifolia*, *Polygonum* and Compositae rise a little at the beginning of this subzone then fall. In spores, *Lepisorus* disappears and *Pteris*, *Phaeoceros laevis* fall at first, then are followed by a rise of *Selaginella* cf. *mollendorfii*. The end is marked by a rise in the number of *Dicranopteris* spores. This subzone also represents a warm temperate forest, a warm and wet climate with a tendency to warmer and drier condition.

Zone C (5900–3100 cm): *Pasania* rises rapidly and becomes a dominant tree. NTP values are low, ranging from 10% to 36%, except 3700 cm (51%) and 3300 cm (64%). It forms a closed community belonging to warm temperate forest and comprises 6 subzones:

Subzone C1 (5900–5300 cm): scanty pollen zone.

Subzone C2 (5300–5150 cm): *Pasania-Quercus-Myrica-Symplocos* association, Gramineae-Cyperaceae subassociation.

Pasania rises continuously to 60% then falls a little. *Myrica* and *Symplocos* rise at first then decline. *Quercus* and *Pinus* rise a little. *Ligustrum*, *Liquidambar*, *Carpinus* and Umbelliferae disappear. *Alnus*, *Ilex*, *Salix*, *Ulmus/Zelkova*, *Lagerstroemia* and *Polygonum* are present in small amounts. *Engelhardtia* occurs. NTP values are very low, on the average of 16%. *Phaeoceros laevis* occurs again and *Selaginella* cf. *mollendorfii* occurs in small amounts.

Subzone C3 (5150–4800 cm): scanty pollen zone.

Subzone C4 (4800–4200 cm): *Pasania-Quercus-Myrica-Symplocos-Ligustrum-Engelhardtia* association, Gramineae-Cyperaceae subassociation.

Pasania, still in relative abundance, reaches its maximum of 65% at 4450 cm then falls to 13% at the end of this subzone. *Pinus* and *Tsuga* show little peaks in the middle. The values of *Alnus*, *Myrica*, *Symplocos*, *Ilex*, *Ulmus/Zelkova* and Umbelliferae are the same as those of subzone C_2. NTP rises but is still small, on the average of 24%. Pteridophytes rise at first, fall to less than 2% in the middle then rise again at the end. The end of this subzone is marked by the decline of *Pasania* and the rise of *Myrica*, *Ligustrum* and *Polygonum*.

Subzone C5 (4200–3900 cm): scanty pollen zone.

Subzone C6 (3900–3100 cm): *Pasania-Quercus-Myrica-Symplocos-Ilex-Salix-Engelhardtia* association, Gramineae-Cyperaceae subassociation.

Pasania declines occasionally, but still remains a dominant tree. *Myrica* occurs in medium amounts, except at 3700 cm and falls rapidly at the end of this subzone. *Alnus* and Umbelliferae increase occasionally, but is still very low. *Ilex* and *Salix* rise at first, fall in the middle part and rise again at the end. The values of *Quercus*, *Engelhardtia*, *Ulmus/Zelkova* and *Symplocos* are still the same as those of Subzone C4, but *Ligustrum* declines. NTP values are still low except in 3700 cm and 3300 cm. At 3320 cm, *Pinus* shows a peak and the values of the spores (being mostly unidentified monoletes) are higher than those of the pollen.

Zone D (3100–975 cm): *Alnus*, instead of *Pasania*, becomes a dominant tree. This zone may reflect a period of poor soil, represents a warm temperate forest, with a warm and dry climate later turning to a wet condition. It is subdivided into 3 subzones:

Subzone D1 (3100–1600 cm): *Alnus-Symplocos* association, Gramineae-Cyperaceae subassociation.

This subzone is marked by the sudden rise of *Alnus*, its expansion to the average of 60%, and the decline of other pollen types. But *Symplocos*, *Ilex*, *Ulmus/Zelkova* and Compositae rise gradually. *Myrica* disappears in the upper part of this subzone. *Pasania* and *Salix* rise occasionally in the middle part. *Ligustrum* rises in the upper part, *Mallotus* and *Engelhardtia* occasionally occur. The values of Gramineae, Cyperaceae, *Typha angustifolia* and *Polygonum* are low together with a few pteridophyte species such as *Davallia*, *Lepisorus*, *Lycopodium* cf. *serratum* and *Pteris*, but Gramineae rises gradually in the upper part. *Sphagnum* appears in the middle part for the first time. *Ophioglossum vulgatum* rises in the upper part. This subzone ends with the fall of *Alnus*.

Subzone D2 (1600–1350 cm): *Alnus-Symplocos-Ligustrum-Ilex* association, Gramineae-Compositae subassociation.

Gramineae rises continuously to a maximum of 71%. *Alnus* peaks at 1400 cm. *Quercus*, *Symplocos*, *Ligustrum*, *Ilex* and Compositae decline. *Ulmus/Zelkova* increases continuously. Cyperaceae is present in small amounts as Subzone D1. At 1400 cm the amount of spores being mostly unidentified monoletes is larger than that of pollen, and *Davallia*, *Lepisorus*, *Ophioglossum vulgatum* and *Sphagnum* rise to their maxima.

Subzone D3 (1350–975 cm): *Pasania-Quercus-Alnus-Symplocos-Ilex-Salix*-Ulmaceae-*Mallotus* association, Gramineae-Cyperaceae subassociation.

This subzone begins with a rise of tree pollen. *Alnus* declines as *Quercus*, *Pasania*, *Symplocos*, *Ilex*, *Salix*, *Trema*, *Celtis*, *Ulmus/Zelkova*, *Lagerstroemia* and secondary forest species such as *Mallotus* and *Liquidambar* rise. Gramineae and Compositae decline, but Cyperaceae rises. A single grain of Onagraceae appears at 1050 cm. Spores with plenty of unidentified monoletes fall at first then rise rapidly to 153% at 1050 cm, and *Hypolepis* shows its maximum at the same time. *Davallia* declines, *Ophioglossum vulgatum* and *Sphagnum* disappear.

Zone E (975 cm–surface): *Liquidambar-Mallotus-Pinus-Ulmus/Zelkova* association, Gramineae-Cyperaceae subassociation.

This zone is characterized by the decrease of tree pollen and the increase of non-tree pollen. This zone represents the open community, warmer and wet climate.

All tree pollen except *Liquidambar*, *Mallotus*, *Pinus* and *Ulmus/Zelkova* declines, but *Pinus* eventually declines. Non-tree pollen mainly Gramineae, Cyperaceae, Compositae and Umbelliferae rises. *Polygonum* and *Typha angustifolia* rise in the beginning then fall. Other aquatic plants such as *Ceratopteris thalictroides*, *Myriophyllum* and Onagraceae occasionally occur in the upper part. Spores decline in middle part then rise in the upper part. *Phaeoceros laevis* appears again. *Lygodium microphyllum* shows its maximum at 580 cm. *Concentricystes* is up to its maximum within the whole boring at 180 cm.

DISCUSSION

The pollen analysis shows that the Fagaceae prevailed in Zone B and Zone C. In our present Taiwan vegetation, the association of the Fagaceae and the Lauraceae forms the dominant trees in Broad-Leaved Forest. Thus, the pollen of Lauraceae should be found where Fagaceae pollen is a major component in fossil pollen assemblage. The reason for the absence of Lauraceae pollen may be that Lauraceae pollen was destroyed by oxidation in pollen preservation or by the treatment of chemicals.

Zone B and Zone C except Subzones C1, C3 and C5 represent periods of closed communities. Occasionally open vegetation appears within these zones when Gramineae, Cyperaceae and Compositae are abundant. *Dicranopteris* grows on the sunny and dry lands, so the abundance of *Dicranopteris* in the upper part of Zone B may represent a phase of drier condition.

Zone A, Subzone C1, Subzone C3 and Subzone C5 with few pollen records being characterized by the mineral deposits, may indicate periods of open vegetation allowing violent erosion of mineral soils (Bartley, 1966).

Subzone D1, marked by high frequency of *Alnus* pollen, may reflect a period of colluvial soil. Successively *Alnus*, *Ophioglossum vulgatum*, *Sphagnum* and much of Gramineae reveal a picture of open vegetational condition and indicate a swamp environment in Subzone D2. In Subzone D3, the sharp increase of TP percentages except *Alnus* pollen and disappearances of *Ophioglossum vulgatum* and *Sphagnum* give rise to a rapid development of closed woodland in which the Fagaceae is dominant.

Zone E, began ca. 10000 years B. P. and corresponded to the Holocene, is characterized by the decrease of TP and the increase of NTP. Hicks (1971) points out that an anthropogenic effect and clearance phases are usually indicated on the pollen diagrams by an increase in NTP and a corresponding decrease in TP, together with rise in the values of Gramineae, *Plantago*, weed species and *Pteridium* spores. Turner (1964) suggests that grass pollen frequency was a rough guide to the extent of clearance. Tsukada (1966, 1967) considers that the abundance of grass pollen which is larger than 37 μ may indicate the human activity. But Huang (1974) suggests that the grass pollen which is larger than 60 μ, may belong to cereals. Thus, there is insufficient evidence from the pollen diagram to indicate whether any anthropogenic effect exists in Zone E although grass pollen frequency is high. But charcoal at 670 cm (ca. 3850 years B.P.) and wood fragments at 580 cm (ca. 3400 years B.P.) may reflect the clearance of the forest by early man. These periods can be correlated with Tahuan Age (ca. 4000-2700 years B.P.) and belong to Lungshanoid Cultural Bed (Lin, 1966, 1969).

From the data of C^{14} dating, we estimate the deposition rate of sediments. From 17000 years ago (1400 cm) to 4500 years ago (780 cm), the deposition rate is about 0.048 cm/year, and it is about 0.27 cm/year since 4500 years ago. Perhaps the soil erosion due to the clearance of the forest by early man since 4500 years ago is the reason for the big difference of deposition rate between these two periods.

Concentricystes prevailed in the past. In an earlier investigation of lake deposits (Huang, 1975), it was also reported, thus we suggest that *Concentricystes* may be an indicator of an aquatic environment. Other puzzling fossil spores are shown on Plate 4. At 3320 cm, 1400 cm and 1050 cm, the values of spores are much larger than those of pollen. Among the spores, most belong to the smooth monolete ones which are identified with difficulty. The significance of these unidentified fossils will be known if spores and pollen grains of recent plants including algae and bryophtes are well investigated.

Polygonum and *Typha angustifolia* also prevailed in past time. Their changes of amount and the occasional occurrences of other aquatic plants may reflect the unstability of lake level.

The present article is preliminary, and only a few outlines of the investigation have been mentioned. We require further data from the pollen analysis and C^{14} dating from the other seven borings in the Toushe Basin to construct a vegetational history, paleoclimatic change chart and indicate when early man came into this district. Further attention should be directed toward the modern vegetation and the pollen analysis of the subrecent soil.

ACKNOWLEGEMENT

The authors express their deepest gratitude to Dr. C. C. Lin, Professor of Geology, NTU, for field sampling and Dr. K. C. Chang, Professor of Anthropology, Yale University, for encouragement during this study. Thanks are also due to Dr. C. E. DeVol, Professor of Botany, NTU, for reading this manuscript, to Professor Y. C. Hsu, Physics Department, NTU, for providing us with the data of C^{14} dating.

LITERATURES CITED

BOULOUARD, C., & H. DELAUZE, 1972. Analyse palynolanctologique de sèdiments prelves par le bathscaphe Archimede dans la fosse du Japan. Marine Palynology, **4**(6): 462-463. *Pl. 1, Figs. 8-9.*

BARTLEY, D. D., 1966. Pollen analysis of some lake deposits near Bambrugh in Northumberland. New Phytol., **65**(2): 141-156.

CHEN, S. H., & T. C. HUANG, 1974. Spore morphology of Formosan Pteridaceae. Taiwania, **19**(2): 179-229.

CHUNG, T. F., & T. C. HUANG, 1972a. Paleoecological study of Taipei Basin (1) Taipei Botanical Garden. Taiwania, **17**(2): 118-143.

HEUSSER, C. J., 1971. Pollen and spores of Chile. The University of Arizona press. Tucson, Arizona, USA, 167pp.

HICKS, S. P., 1971. Pollen analytical evidence for the effect of prehistoric agriculture on the vegetation of North Derbyshire. New Phytol., **70**(4): 647-667.

HUANG, T. C., 1972. Pollen flora of Taiwan. NTU, Taipei, Taiwan, ROC, 297pp.

______, 1974. Pollen grains, spores and environment (in Chinese). Living organism and environments, Academia Sinica, Taipei, Taiwan, ROC, pp. 157-224.

______, 1975. Paleoecological study of Taiwan (4) Waichiataoken profile. Taiwania, **20**(1): 1-22.

KREMP, G. O. W., & T. KAWASAKI, 1972. The spores of Pteridophytes. Hirokawa Publishing Co., 389pp.

LIU, T. J., & C. W. LIU, 1956. The plant vegetation of Nantou (in Chinese), Nantou Wenhsien 3, Nantou, Taiwan, ROC, 248pp.

LIN, C. C., 1964. The geology of Nantou (in Chinese). Nantou Wenhsien 12, Nantou, Taiwan, ROC, pp. 29-45.

______, 1966. An outline of Taiwan's Quaternary geohistory, with a special discussion of the relation between natural history and cultural history in Taiwan (in Chinese with English summary). Bulletin of the Department of Archaeology and Anthropology, NTU, **28**: 7-42.

______, 1969. Holocene geology of Taiwan. Acta Geologica Taiwanica, **13**: 83-126.

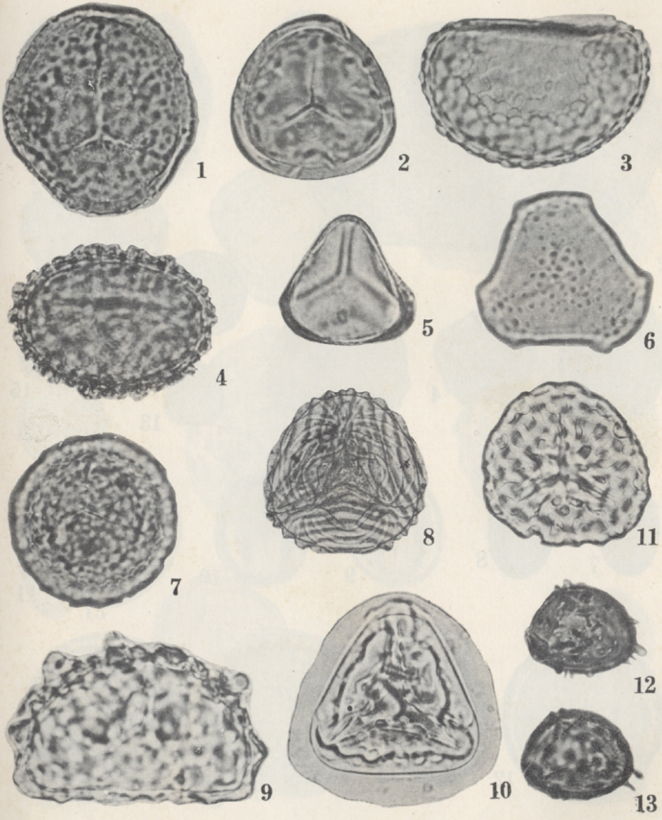
MIYOSHI, N., 1966. Spore morphology of Hepaticae in Japan. The Bulletin of the Okayama College of Science, **2**: 1-46.

TSCHUDY, R. H., & R. A. SCOTT, 1969. Aspects of Palynology. John Wiley & Sons Inc., *Pl. 8, Figs. 12-13.*

TSUKADA, M., 1966. Late Pleistocene vegetation and climate in Taiwan (Formosa). The Proceeding of the National Academy of Sciences, **55**(3): 543-548.

______, 1967. Vegetation in subtropical Formosa during the Pleistocene glaciations and the Holocene. Palaeogeography, Palaeoclimatology, Palaeoecology, **3**: 49-64.

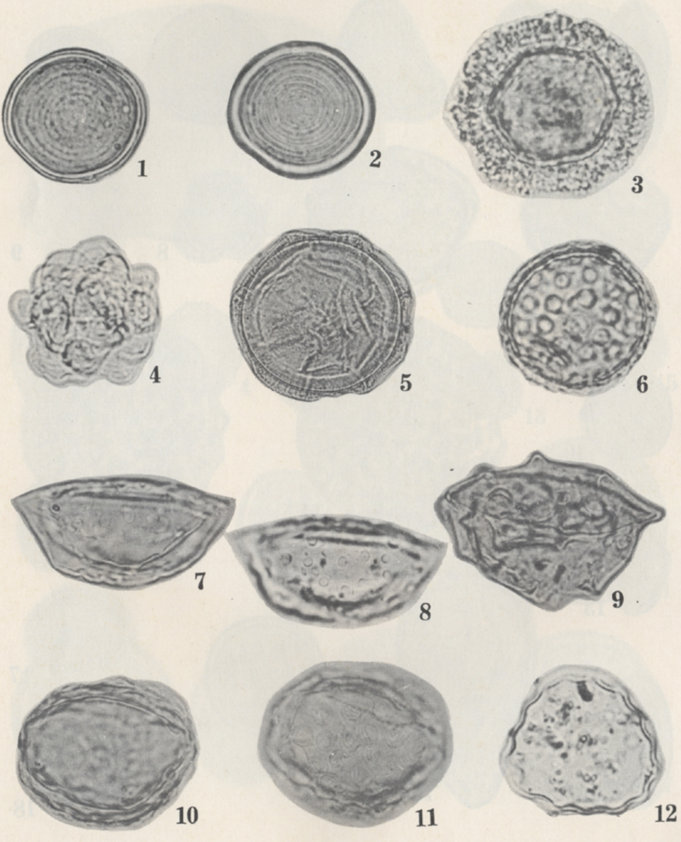
TURNER, J., 1964. The Anthropogenic factor in vegetational history (1) Tregaron and Whixall Mosses. New Phytol., **63**: 73-90.



Pl. 1. 1. *Phaeoceros laevis* TS-580-613; 2. *Sphagnum* TS-1400-608-2; 3. Davalliaceae (*Davallia*) TS-70-605; 4. Dennstaedtiaceae (*Hypolepis*) TS-1050-609; 5. Gleicheniaceae (*Dicranopteris*) TS-180-603; 6. Lycopodiaceae (*Lycopodium* cf. *serratum*) TS-2970-611; 7. Ophioglossaceae (*Ophioglossum vulgatum*) TS-1400-607; 8. Parkeriaceae (*Ceratopteris thalictroides*) TS-180-PL; 9. Polypodiaceae (*Lepisorus*) TS-780-800 R; 10. Pteridaceae (*Pteris*) TS-1400-601; 11. Schizaeaceae (*Lygodium microphyllum*) TS-580-602; 12-13. Selaginellaceae (*Selaginella* cf. *mollendorfii*) TS-4600-612. 1-7, 9-10, 12-13, ×1000; 8, ×250; 11, ×500.

Pl. 2. 1. Pinaceae (*Pinus*) TS-3700-1; 2. Pinaceae (*Tsuga*) TS-1200-6-1; 3. Aquifoliaceae (*Ilex*) TS-1050-51-1; 4. Betulaceae (*Alnus*) TS-1600-34; 5. Betulaceae (*Carpinus*) TS-780-56; 6. Euphorbiaceae (*Mallotus*) TS-180-64; 7-8. Fagaceae (*Pasania*) TS-1050-27-2; 9-10. Fagaceae (*Quercus*) TS-2970-26; 11-12. Hamamelidaceae (*Liquidambar*) TS-1200-33; 13. Juglandaceae (*Engelhardtia*) TS-3200-A; 14. Lythraceae (*Lagerstroemia*) TS-1050-49; 15. Myricaceae (*Myrica*) TS-4200-30; 16-17. Oleaceae (*Ligustrum*) TS-1770-126. 1, 3-17, ×1000; 2, ×500.

Pl. 3. 1-2. Salicaceae (*Salix*) TS-1050-100-1; 3. Symplocaceae (*Symplocos*) TS-2400-50; 4. Ulmaceae (*Celtis*) TS-1050-69-1; 5. Ulmaceae (*Trema*) TS-1600-54; 6. Ulmaceae (*Ulmus*) TS-1600-31; 7. Ulmaceae (*Zelkova*) TS-2200-66; 8. Compositae (*Artemisia*) TS-2200-29; 9. Compositae TS-70-32-1; 10. Haloragaceae (*Myriophyllum*) TS-70-37; 11-12. Polygonaceae (*Polygonum*) TS-2400-65-1; 13. Umbelliferae (*Hydrocotyl*) TS-2970-128; 14. Umbelliferae TS-1600-44-2; 15. Cyperaceae TS-1200-302-2; 16. Gramineae TS-1400-301-3; 17-18. Typhaceae (*Typha angustifolia*) TS-2050-308. 1-18, ×1000.



Pl. 4. 1-2. *Concentricystes* TS-2050-1004-3; 3-12. Unknown palynomorphs; 3. TS-70-1005; 4. TS-70-1006; 5. TS-180-1007; 6. TS-400-AR; 7-8. TS-1600-1008; 9. TS-2200-1003; 10-11. TS-2400-1001; 12. TS-5300-AL. 1-4, 6-12, ×1000; 5, ×500.

PALEOECOLOGICAL STUDY OF TAIWAN (5)—TOUSHE BASIN[1]

SHU-YUE HUANG[2] and TSENG-CHIENG HUANG[3]

Abstract: In order to investigate the vegetational history, paleoclimatic changes and the activity of early man in Central Taiwan, the Toushe Basin was selected as a site for palynological study.

From the sediments extending down to 82 m and through 31 m of thick peat, 40 samples were taken for this study. The palynomorphs were extracted by chemical deflocculation, then permanent slides were prepared by sealing with paraffin. Based on the examination of the permanent slides, a hypothesis for the vegetational history and past climate is proposed as follows:

A warm temperate period has prevailed in this area ever since the formation of the lake. Except for scanty pollen zones such as Zone A (8200-7100 cm), Subzone C1 (5900-5300 cm), Subzone C3 (5150-4800 cm) and Subzone C5 (4200-3900 cm), successive series of plant communities have been found as follows: starting at a depth of 71 m, we find that Subzone B1 (7100-6750 cm), has a *Quercus-Symplocos-Pasania-Alnus* association, Gramineae-Compositae-*Typha* subassociation; Subzone B2 (6750-5900 cm), *Quercus-Pasania-Alnus-Salix-Carpinus* association, Gramineae-Cyperaceae subassociation; Subzone C2 (5300-5150 cm), *Pasania-Quercus-Myrica-Symplocos* association, Gramineae-Cyperaceae subassociation; Subzone C4 (4800-4200 cm), *Pasania-Quercus-Myrica-Symplocos-Ligustrum-Engelhardtia* association, Gramineae-Cyperaceae subassociation; Subzone C6 (3900-3100 cm), *Pasania-Quercus-Myrica-Symplocos-Ilex-Salix-Engelhardtia* association, Gramineae-Cyperaceae subassociation; Subzone D1 (3100-1600 cm), *Alnus-Symplocos* association, Gramineae-Cyperaceae subassociation; Subzone D2 (1600-1350 cm), *Alnus-Symplocos-Ligustrum-Ilex* association, Gramineae-Compositae subassociation; Subzone D3 (1350-975 cm), *Pasania-Quercus-Alnus-Symplocos-Ilex-Salix*-Ulmaceae-*Mallotus* association, Gramineae-Cyperaceae subassociation; and Zone E (975 cm-surface), *Liquidambar-Mallotus-Pinus-Ulmus/Zelkova* association, Gramineae-Cyperaceae subassociation.

From the evidences of charcoal at 670 cm (ca. 3850 years B.P.), and wood fragments with burning traces at 580 cm (ca. 3400 years B.P.) and a steep rise in deposition rate of sediments since 4500 years ago, we suggest that early man may have come into this district to clear the forest as early as 4500 years ago.

INTRODUCTION

Toushe Basin, situated in Yuchih Hsiang of Nantou County, Taiwan, ROC, at longitude 120°53′ East and latitude 23°49′ North (Fig. 1), has been a lake since the Pleistocene, and now is a basin belonging to the Puli Basin Group. The Basin, 0.1 square kilometers in area and about 650 m above sea level, is surrounded by mountains which are higher than 1000 m (Fig. 2) (Lin, 1964).

(1) This paper is based partly on a M.S. thesis of the first author to the Research Institute of Botany, NTU. The research grant was supported by the National Science Council, ROC during 1974-5.

(2) 黃淑玉, Research Assistant. Botany Department, NTU.

(3) 黃增泉, Professor, Botany Department, NTU.

Much rice is grown in this basin. Floating plants as *Lemna* spp. are abundant in the rice fields, and some marsh plants such as *Commelina* spp., *Hydrocotyl* sp., *Juncus wallichitinus*, *Monochoria vaginalis*, *Najas graminea*, *Polygonum sieboldii*, *Potamogeton* spp., *Ranunculus cantoniensis*, *Roripa* sp., *Sagittaria sagitifolia*, *Typha angustifolia*, and other plants belonging to the Onagraceae and Compositae growing along the paths between the rice fields. Secondary forests and plantation forests are on the surrounding mountains (Liu & Liu, 1956).

Under the Cho-shui and Ta-tu river valley project in Environmental and Anthropological Research supported by National Science Council, many cores at Toushe, Sun-Moon-Lake and Waichiataoken were drilled for pollen analysis.

Tertiary slates lay under the sediments of this ancient lake unconformably. Eight borings

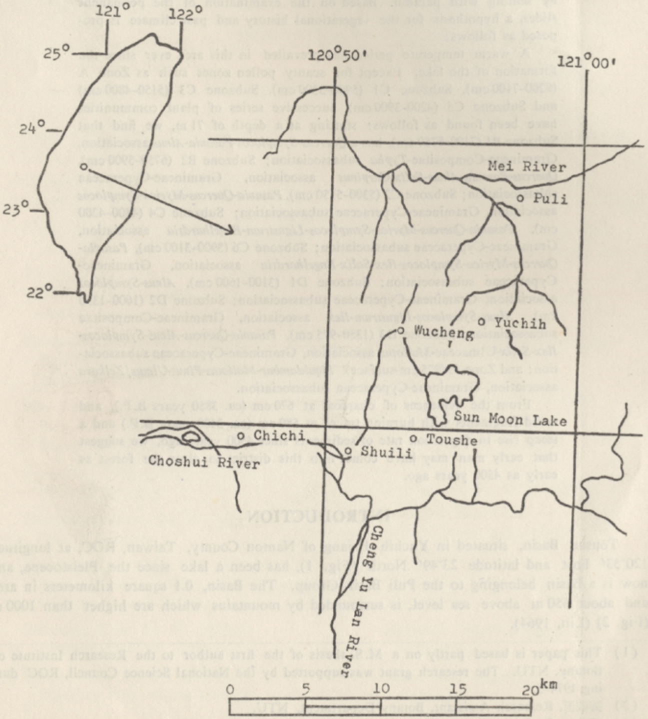


Fig. 1. Geographical map showing the location of sampling site.

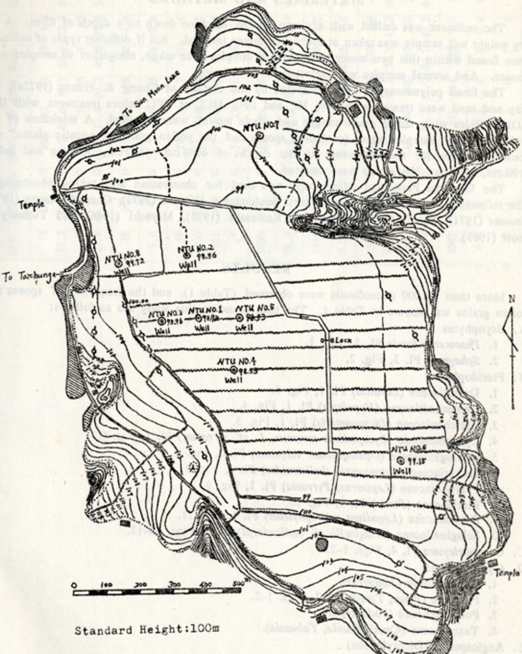


Fig. 2. Geological map of the Toushe Basin (C.C. Lin).

were made down to the slate zone in Toushe Basin (Fig. 2), but the sediments of NTU No. 1 were taken for pollen analysis in order to trace the vegetational history and the paleoclimatic change. With the use of C^{14} dating and the macrofossils found within the sediments, it is hoped that it will be possible to suggest when early man began to live in this district.

MATERIALS AND METHODS

The sediment was drilled with a piston boring machine down to a depth of 82 m. A 2 g dry weight soil sample was taken at every two meter interval. But if different types of sediment were found within this two meter zone, further samples were taken, altogether 40 samples were chosen. And several samples were selected for C^{14} dating.

The fossil palynomorphs were extracted by the method of Chung & Huang (1972a), but clay and sand were treated with 47% HF and 10% HCL at 70°C before treatment with 10% KOH. Slides with single grain mount and whole mount were prepared. A minimum of 500 grains per each sampled zone (excluding spores and the pollen grains of aquatic plants) was counted, except for the sediments at the depths of 4080 cm, 4850 cm, 5600 cm and below 7100 cm, less than 100 grains were counted.

The Olympus Photomax Microscope was used for observation and taking photographs. The references used for identification are: Boulouard & Delauze (1972), Chen & Huang (1974), Heusser (1971), Huang (1972), Kremp & Kawasaki (1972), Miyoshi (1966) and Tschudy & Scott (1969).

RESULTS

More than 40,000 microfossils were observed (Table 1), and the frequency of spores and pollen grains was shown in Table 1. The taxa found in this study are as follows:

A. Bryophytes
1. *Phaeoceros laevis* Pl. 3, Fig. 1.
2. *Sphagnum* Pl. 3, Fig. 2.

B. Pteridophytes
1. Davalliaceae (*Davallia*) Pl. 1, Fig. 3.
2. Dennstaedtiaceae (*Hypolepis*) Pl. 1, Fig. 4.
3. Gleicheniaceae (*Dicranopteris*) Pl. 1, Fig. 5.
4. Lycopodiaceae (*Lycopodium cernuum, L.* cf. *serratum*) Pl. 1, Fig. 6.
5. Ophioglossaceae (*Ophioglossum vulgatum*) Pl. 1, Fig. 7.
6. Parkeriaceae (*Ceratopteris thalictroides*) Pl. 1, Fig. 8.
7. Polypodiaceae (*Lepisorus, Pyrrosia*) Pl. 1, Fig. 9.
8. Pteridaceae (*Pteris*) Pl. 1, Fig. 10.
9. Schizaeaceae (*Lygodium microphyllum*) Pl. 1, Fig. 11.
10. Selaginellaceae (*Selaginella* cf. *mollendorfii*) Pl. 1, Figs. 12–13.

C. *Concentricystes* Pl. 4, Figs. 1–2.

D. Gymnosperms
1. Cupressaceae (*Juniperus*).
2. Pinaceae (*Pinus, Tsuga*) Pl. 2, Figs. 1–2.
3. Podocarpaceae (*Podocarpus*).
4. Taxodiaceae (*Cunninghamia, Taiwania*).

E. Angiosperms (Dicotyledons)
1. Acanthaceae (*Justicia*).
2. Aceraceae (*Acer*).
3. Actinidiaceae (*Actinidia*).
4. Aizoaceae.
5. Anacardiaceae (*Pistacia, Rhus*).
6. Annonaceae (*Fissistigma*).
7. Apocynaceae (*Alyxia, Rauwolfia*).
8. Aquifoliaceae (*Ilex*) Pl. 2, Fig. 3.

Table 1. Numbers and percentages of fossil palynomorphs appearing in the sediments of Toushe Basin Profile.

Palynomorphs	Depth (cm)	70	180	400	580	780	1050	1200	1400	1600	1770	2050	2200	2400	2600	2800	2970	3100	3200	3300	3320	3400	3700	3850	4080	4200	4450	4500	4600	4850	5240	5300	5600	5950	6200	6500	6700	6880	7020	7100	7700	Total
Spores (S)	Monolete Numbers	134	368	68	273	469	697	209	1090	70	70	61	14	112	80	51	9	22	22	26	1166	101	23	27	10	173	3	35	67	12	13	35	0	66	43	63	13	143	20	18	0	5876
	Monolete %	68.7	81.2	73.1	65.9	89.3	90.1	95.0	90.8	85.4	95.9	79.2	77.8	91.1	94.1	89.5	90.0	41.5	84.6	70.3	99.6	92.7	65.7	81.8	66.7	89.6	21.4	83.3	77.0	85.7	72.2	51.5	0	30.7	89.6	79.7	59.1	72.2	69.0	90.0	0	
	Trilete Numbers	61	85	25	141	56	77	11	110	12	3	16	4	11	5	6	1	31	4	11	5	8	12	6	5	20	11	7	20	2	5	33	0	149	5	16	9	55	9	2	0	1049
	Trilete %	31.3	18.8	26.9	34.1	10.7	9.8	5.0	1.2	14.6	4.1	20.8	22.2	8.9	5.9	10.5	10.0	58.5	15.4	29.7	0.4	7.3	34.3	18.2	33.3	10.4	78.6	16.7	23.0	14.3	27.8	48.5	0	69.3	10.4	20.3	40.9	27.8	31.0	10.0	0	
	Subtotal	195	453	93	414	525	774	220	1200	82	73	77	18	123	85	57	10	53	26	37	1171	109	35	33	15	193	14	42	87	14	18	68	0	215	48	79	22	198	29	20	0	6925
	%	26.8	23.9	7.6	31.9	32.1	60.4	13.9	58.8	6.9	6.5	4.7	2.1	7.4	5.0	5.5	1.2	5.2	2.2	4.3	55.0	9.7	5.4	5.2	30.0	23.4	21.0	6.3	10.9	53.8	1.6	7.9	0	25.2	4.6	9.5	2.8	19.9	3.5	3.3	0	
Pollen Grains (P)	Gymnosperms	14	37	21	38	77	8	27	5	3	6	6	3	6	5	2	17	15	32	8	60	19	20	8	1	24	9	34	22	0	45	25	0	19	2	7	11	1	11	3	0	651
	Dicotyledons	130	334	175	159	386	346	581	282	595	726	1371	693	1308	1439	874	452	508	562	272	606	851	265	489	10	384	558	394	422	0	906	578	0	463	716	446	313	388	449	427	0	19858
	Monocotyledons	359	1042	898	658	591	134	679	518	445	269	171	124	199	157	82	293	360	551	492	258	98	299	76	8	143	62	156	239	2	131	144	0	125	254	231	414	379	295	140	0	11476
	Unidentified	31	28	42	30	55	19	80	36	62	56	28	21	30	28	13	43	75	19	50	36	48	33	25	16	80	24	36	31	10	14	42	0	31	33	66	26	29	38	20	0	1384
	Subtotal	534	1441	1136	885	1109	507	1367	841	1105	1057	1576	841	1543	1629	971	805	958	1164	822	960	1016	617	598	35	631	653	620	714	12	1096	789	0	638	1005	750	764	797	793	590	0	33369
	%	73.2	76.1	92.4	68.1	67.9	39.6	86.1	41.2	93.1	93.5	95.3	97.9	92.6	95.0	94.5	98.8	94.8	97.8	95.7	45.0	0.3	94.6	94.8	70.0	76.6	79.0	93.7	89.1	46.1	98.4	92.1	0	74.8	95.4	90.5	97.2	80.1	96.5	96.7	0	
Subtotal of spores and pollen grains		729	1894	1229	1299	1634	1281	1587	2041	1187	1130	1653	859	1666	1714	1028	815	1011	1190	859	2131	1125	652	631	50	824	667	662	801	26	1114	857	0	853	1053	829	786	797	822	610	0	40294
S/P ratio		0.4	0.3	0.1	0.5	0.5	1.5	0.2	1.4	0.1	0.1	0.1	0.01	0.1	0.1	0.1	0.01	0.1	0.02	0.1	1.2	0.1	0.1	0.1	0.4	0.3	0.02	0.1	0.1	1.2	0.02	0.1	0	0.3	0.1	0.1	0.03	0.3	0.04	0.03	0	
Pollen Grains (P)	TP Numbers	84	296	152	155	412	336	576	267	503	668	1264	660	1251	1345	873	446	491	552	247	629	860	269	493	10	357	556	416	429	0	940	573	0	458	674	436	479	376	402	397	0	19332
	TP %	15.7	20.5	13.4	17.5	37.2	66.2	42.2	31.7	45.5	62.3	80.2	78.5	81.1	82.6	89.9	55.3	51.3	47.4	30.1	65.6	84.6	43.6	82.4	28.6	56.4	85.2	67.1	60.1	0	85.8	72.6	0	71.8	68.1	58.2	36.5	47.2	50.7	67.3	0	
	NTP Numbers	419	1117	942	700	642	152	711	538	540	333	284	160	262	256	85	316	392	593	525	295	108	315	80	9	194	73	168	254	2	142	174	0	149	298	248	259	392	353	173	0	12653
	NTP %	78.5	77.5	83.0	79.1	57.9	30.0	51.9	64.0	48.9	31.5	18.0	19.0	16.9	15.7	8.7	39.4	40.9	51.0	63.8	30.7	10.6	51.1	13.4	25.7	30.9	11.2	27.1	35.6	100	12.9	22.1	0	23.4	28.7	33.0	60.1	49.2	44.5	29.3	0	
	Subtotal	503	1413	1094	855	1054	488	1287	805	1043	1001	1548	820	1513	1601	958	762	883	1145	772	924	968	584	573	19	551	629	584	683	2	1082	747	0	607	972	684	738	768	755	570	0	31985
	TP/NTP ratio	0.2	0.3	0.2	0.2	0.6	2.2	0.8	0.5	0.9	2.0	4.5	4.1	4.8	5.3	10.3	1.4	1.3	0.9	0.5	2.1	8.0	0.9	6.2	1.1	1.8	7.6	2.5	1.7	0	6.6	3.3	0	3.1	2.3	1.8	1.8	0.9	1.1	2.3	0	
Concentricystes		0	45	2	5	9	0	0	6	1	0	14	11	23	15	8	5	0	7	0	9	5	0	0	2	2	1	1	0	0	0	3	0	0	7	0	1	1	0	0	0	183
Total palynomorphs		729	1939	1231	1304	1643	1281	1587	2047	1188	1130	1667	870	1689	1729	1036	820	1011	1197	859	2140	1130	652	631	52	826	668	663	801	26	1114	860	0	853	1060	829	787	996	822	610	0	40477

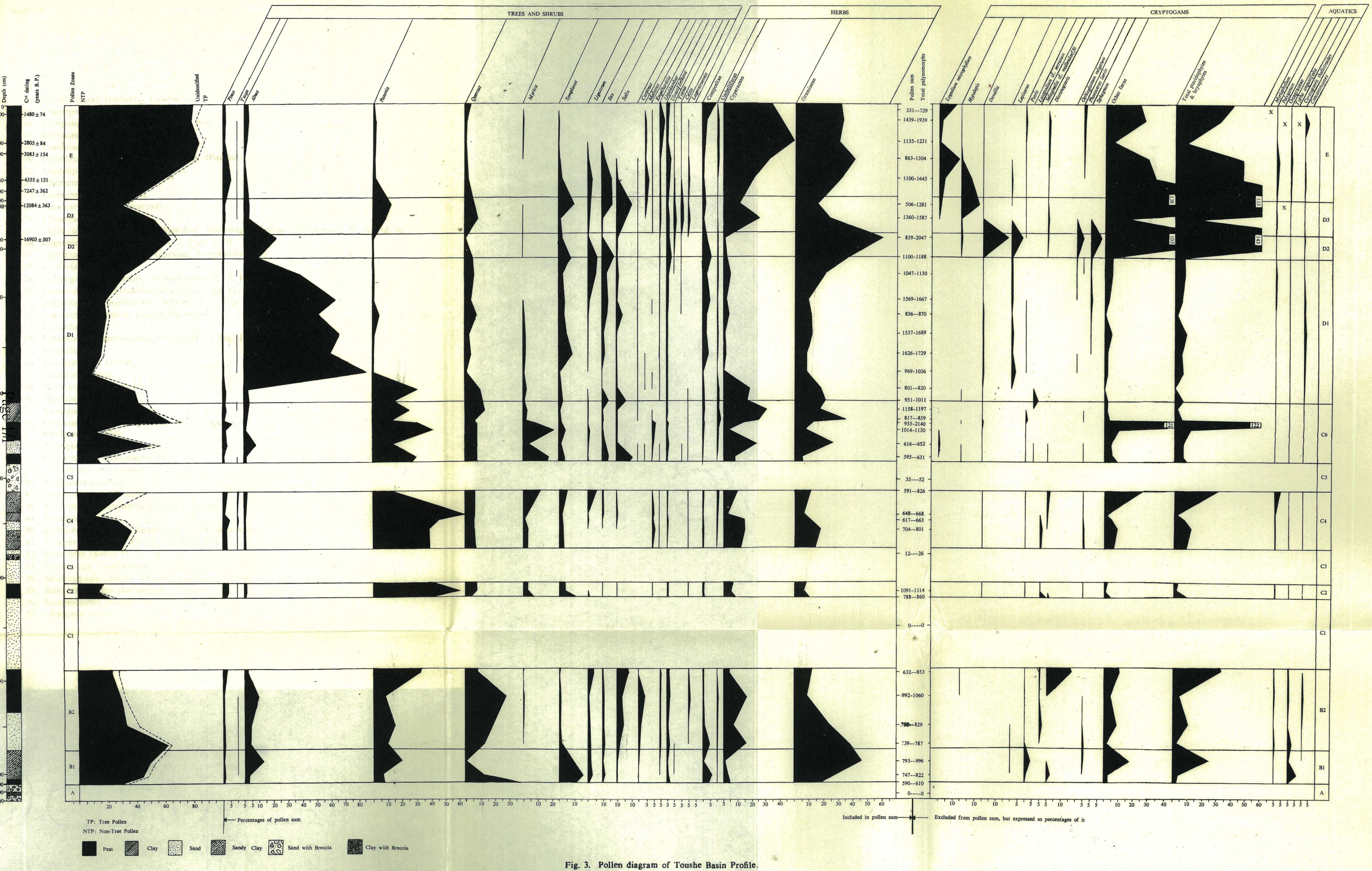


Fig. 3. Pollen diagram of Toushe Basin Profile.

9. Araliaceae (*Schefflera*).
10. Balsaminaceae (*Impatiens*).
11. Betulaceae (*Alnus, Carpinus*) Pl. 2, Figs. 4–5.
12. Campanulaceae (*Campanumoea*).
13. Capparidaceae (*Gynandropsis*).
14. Caprifoliaceae (*Lonicera, Viburnum*).
15. Chenopodiaceae (*Chenopodium*).
16. Compositae (*Artemisia*). Pl. 3, Figs. 8–9.
17. Cornaceae (*Helwingia*).
18. Crassulaceae (*Sedum*).
19. Cruciferae (*Arabis, Brassica, Capsella, Wasabia*).
20. Daphniphyllaceae (*Daphniphyllum*).
21. Ebenaceae (*Diospyros*).
22. Elaeagnaceae (*Elaeagnus*).
23. Elaeocarpaceae (*Elaeocarpus*).
24. Ericaceae (*Rhododendron*).
25. Euphorbiaceae (*Euphorbia, Glochidion, Macaranga, Mallotus, Phyllanthus*) Pl. 2, Fig. 6.
26. Fagaceae (*Pasania, Quercus*) Pl. 2, Figs. 7–10.
27. Gentianaceae (*Crawfurdia, Gentiana, Nymphoides*).
28. Gesneriaceae.
29. Haloragaceae (*Haloragis, Myriophyllum*) Pl. 3, Fig. 10.
30. Hamamelidaceae (*Liquidambar*) Pl. 2, Figs. 11–12.
31. Juglandaceae (*Engelhardtia, Juglans*) Pl. 2, Fig. 13.
32. Leguminosae (*Acacia, Cassia, Phaseolus*).
33. Loranthaceae.
34. Lythraceae (*Lagerstroemia, Rotala*) Pl. 2, Fig. 14.
35. Magnoliaceae.
36. Malpighiaceae (*Hiptage*).
37. Melastomataceae.
38. Myricaceae (*Myrica*) Pl. 2, Fig. 15.
39. Myrtaceae.
40. Nymphaeaceae (*Nuphar*).
41. Oleaceae (*Fraxinus, Ligustrum*) Pl. 2, Figs. 16–17.
42. Pirolaceae (*Pirola*).
43. Pittosporaceae (*Pittosporum*).
44. Polygonaceae (*Polygonum*) Pl. 3, Figs. 11–12.
45. Primulaceae (*Lysimachia*).
46. Proteaceae (*Helicia*).
47. Ranunculaceae (*Clematis*).
48. Rhamnaceae (*Berchemia, Paliurus, Rhamnus*).
49. Rosaceae (*Prunus*).
50. Rubiaceae (*Gardenia, Randia, Rubia, Thysanospermum*).
51. Rutaceae (*Clausena, Evodia, Zanthoxylum*).
52. Salicaceae (*Salix*) Pl. 3, Figs. 1–2.
53. Saururaceae (*Houttuynia*).
54. Saxifragaceae (*Astilbe, Deutzia, Hydrangea, Parnassia, Schizophragma*).
55. Scrophulariaceae (*Micrargeria, Torenia*).
56. Symplocaceae (*Symplocos*) Pl. 3, Fig. 3.
57. Ulmaceae (*Celtis, Trema, Ulmus, Zelkova*) Pl. 3, Figs. 4–7.

58. Umbelliferae (*Hydrocotyl*) Pl. 3, Figs. 13-14.
59. Urticaceae (*Pilea*).
60. Vacciniaceae (*Vaccinium*).
61. Vitaceae (*Ampelopsis*).

F. Angiosperms (Monocotyledons)
1. Alismataceae (*Sagittaria*).
2. Araceae (*Arisaema*).
3. Commelinaceae.
4. Cyperaceae Pl. 3, Fig. 15.
5. Gramineae Pl. 3, Fig. 16.
6. Juncaceae.
7. Liliaceae.
8. Palmae.
9. Typhaceae (*Typha angustifolia*) Pl. 3, Figs. 17-18.

POLLEN ZONE AND INTERPRETATION

A pollen diagram (Fig. 3) including C^{14} dating, significant pollen types and some spores, characteristics of sediments and numbers of palynomorphs was constructed. It shows, on the basis of dominant pollen types, a clear division into 5 zones: Zone A, Zone B, Zone C, Zone D and Zone E.

Zone A (8200-7100 cm): scanty pollen zone.

Zone B (7100-5900 cm): *Quercus* is a dominant tree. The NTP types are present in quantities to 32% at the beginning of the zone and rise to a maximum of 60% in the middle, then fall to 23% at the end of the zone. It is subdivided into 2 subzones:

Subzone B1 (7100-6750 cm): *Quercus-Symplocos-Pasania-Alnus* association, Gramineae-Compositae-*Typha* subassociation.

Quercus is the predominant tree accounting for nearly 40% of the grains at first, declines rapidly to less than 2%, then rises a little. *Symplocos* shows an initial rise then decreases as *Pasania* and *Alnus* increase. In this subzone, NTP types with relative abundance mainly compose of Gramineae which rises rapidly from 18% at 7100 cm to a maximum of 46% at 7020 cm, then declines a little. A few spores from the ferns, i. e. *Dicranopteris*, *Pteris*, *Lepisorus* are present and from the bryophyte *Phaeoceros laevis*, also the pollen grains from *Typha angustifolia*, Compositae and Cyperaceae were observed. Among the spores, *Dicranopteris* disappeared at the end. Other pollen types include *Ligustrum*, *Ilex*, *Salix*, *Carpinus*, *Liquidambar*, *Ulmus/Zelkova*, *Trema* and Umbelliferae. This subzone represents a warm temperate forest, a warm and wet climate with a tendency toward a subtropical condition.

Subzone B2 (6750-5900 cm): *Quercus-Pasania-Alnus-Salix-Carpinus* association, Gramineae-Cyperaceae subassociation.

Quercus rises continuously up to 28% at 6200 cm, then falls at the end of this subzone. *Pasania* and *Alnus* are present in medium amounts, but *Pasania* rises as *Alnus* falls at the end of this subzone. *Symplocos* declines continuously to less than 2%. *Salix* and *Carpinus* increase but in the end *Carpinus* drops. *Ligustrum*, *Ilex*, *Liquidambar*, *Lagerstroemia* and Umbelliferae increase a little. *Trema* disappears as *Myrica* appears. Gramineae declines gradually. Cyperaceae rises at first, but falls in the end. *Typha angustifolia*, *Polygonum* and Compositae rise a little at the beginning of this subzone then fall. In spores, *Lepisorus* disappears and *Pteris*, *Phaeoceros laevis* fall at first, then are followed by a rise of *Selaginella* cf. *mollendorfii*. The end is marked by a rise in the number of *Dicranopteris* spores. This subzone also represents a warm temperate forest, a warm and wet climate with a tendency to warmer and drier condition.

Zone C (5900–3100 cm): *Pasania* rises rapidly and becomes a dominant tree. NTP values are low, ranging from 10% to 36%, except 3700 cm (51%) and 3300 cm (64%). It forms a closed community belonging to warm temperate forest and comprises 6 subzones:

Subzone C1 (5900–5300 cm): scanty pollen zone.

Subzone C2 (5300–5150 cm): *Pasania-Quercus-Myrica-Symplocos* association, Gramineae-Cyperaceae subassociation.

Pasania rises continuously to 60% then falls a little. *Myrica* and *Symplocos* rise at first then decline. *Quercus* and *Pinus* rise a little. *Ligustrum, Liquidambar, Carpinus* and Umbelliferae disappear. *Alnus, Ilex, Salix, Ulmus/Zelkova, Lagerstroemia* and *Polygonum* are present in small amounts. *Engelhardtia* occurs. NTP values are very low, on the average of 16%. *Phaeoceros laevis* occurs again and *Selaginella* cf. *mollendorfii* occurs in small amounts.

Subzone C3 (5150–4800 cm): scanty pollen zone.

Subzone C4 (4800–4200 cm): *Pasania-Quercus-Myrica-Symplocos-Ligustrum-Engelhardtia* association, Gramineae-Cyperaceae subassociation.

Pasania, still in relative abundance, reaches its maximum of 65% at 4450 cm then falls to 13% at the end of this subzone. *Pinus* and *Tsuga* show little peaks in the middle. The values of *Alnus, Myrica, Symplocos, Ilex, Ulmus/Zelkova* and Umbelliferae are the same as those of subzone C_2. NTP rises but is still small, on the average of 24%. Pteridophytes rise at first, fall to less than 2% in the middle then rise again at the end. The end of this subzone is marked by the decline of *Pasania* and the rise of *Myrica, Ligustrum* and *Polygonum*.

Subzone C5 (4200–3900 cm): scanty pollen zone.

Subzone C6 (3900–3100 cm): *Pasania-Quercus-Myrica-Symplocos-Ilex-Salix-Engelhardtia* association, Gramineae-Cyperaceae subassociation.

Pasania declines occasionally, but still remains a dominant tree. *Myrica* occurs in medium amounts, except at 3700 cm and falls rapidly at the end of this subzone. *Alnus* and Umbelliferae increase occasionally, but is still very low. *Ilex* and *Salix* rise at first, fall in the middle part and rise again at the end. The values of *Quercus, Engelhardtia, Ulmus/Zelkova* and *Symplocos* are still the same as those of Subzone C4, but *Ligustrum* declines. NTP values are still low except in 3700 cm and 3300 cm. At 3320 cm, *Pinus* shows a peak and the values of the spores (being mostly unidentified monoletes) are higher than those of the pollen.

Zone D (3100–975 cm): *Alnus*, instead of *Pasania*, becomes a dominant tree. This zone may reflect a period of poor soil, represents a warm temperate forest, with a warm and dry climate later turning to a wet condition. It is subdivided into 3 subzones:

Subzone D1 (3100–1600 cm): *Alnus-Symplocos* association, Gramineae-Cyperaceae subassociation.

This subzone is marked by the sudden rise of *Alnus*, its expansion to the average of 60%, and the decline of other pollen types. But *Symplocos, Ilex, Ulmus/Zelkova* and Compositae rise gradually. *Myrica* disappears in the upper part of this subzone. *Pasania* and *Salix* rise occasionally in the middle part. *Ligustrum* rises in the upper part, *Mallotus* and *Engelhardtia* occasionally occur. The values of Gramineae, Cyperaceae, *Typha angustifolia* and *Polygonum* are low together with a few pteridophyte species such as *Davallia, Lepisorus, Lycopodium* cf. *serratum* and *Pteris*, but Gramineae rises gradually in the upper part. *Sphagnum* appears in the middle part for the first time. *Ophioglossum vulgatum* rises in the upper part. This subzone ends with the fall of *Alnus*.

Subzone D2 (1600–1350 cm): *Alnus-Symplocos-Ligustrum-Ilex* association, Gramineae-Compositae subassociation.

Gramineae rises continuously to a maximum of 71%. *Alnus* peaks at 1400 cm. *Quercus*, *Symplocos*, *Ligustrum*, *Ilex* and Compositae decline. *Ulmus/Zelkova* increases continuously. Cyperaceae is present in small amounts as Subzone D1. At 1400 cm the amount of spores being mostly unidentified monoletes is larger than that of pollen, and *Davallia*, *Lepisorus*, *Ophioglossum vulgatum* and *Sphagnum* rise to their maxima.

Subzone D3 (1350–975 cm): *Pasania-Quercus-Alnus-Symplocos-Ilex-Salix*-Ulmaceae-*Mallotus* association, Gramineae-Cyperaceae subassociation.

This subzone begins with a rise of tree pollen. *Alnus* declines as *Quercus*, *Pasania*, *Symplocos*, *Ilex*, *Salix*, *Trema*, *Celtis*, *Ulmus/Zelkova*, *Lagerstroemia* and secondary forest species such as *Mallotus* and *Liquidambar* rise. Gramineae and Compositae decline, but Cyperaceae rises. A single grain of Onagraceae appears at 1050 cm. Spores with plenty of unidentified monoletes fall at first then rise rapidly to 153% at 1050 cm, and *Hypolepis* shows its maximum at the same time. *Davallia* declines, *Ophioglossum vulgatum* and *Sphagnum* disappear.

Zone E (975 cm–surface): *Liquidambar-Mallotus-Pinus-Ulmus/Zelkova* association, Gramineae-Cyperaceae subassociation.

This zone is characterized by the decrease of tree pollen and the increase of non-tree pollen. This zone represents the open community, warmer and wet climate.

All tree pollen except *Liquidambar*, *Mallotus*, *Pinus* and *Ulmus/Zelkova* declines, but *Pinus* eventually declines. Non-tree pollen mainly Gramineae, Cyperaceae, Compositae and Umbelliferae rises. *Polygonum* and *Typha angustifolia* rise in the beginning then fall. Other aquatic plants such as *Ceratopteris thalictroides*, *Myriophyllum* and Onagraceae occasionally occur in the upper part. Spores decline in middle part then rise in the upper part. *Phaeoceros laevis* appears again. *Lygodium microphyllum* shows its maximum at 580 cm. *Concentricystes* is up to its maximum within the whole boring at 180 cm.

DISCUSSION

The pollen analysis shows that the Fagaceae prevailed in Zone B and Zone C. In our present Taiwan vegetation, the association of the Fagaceae and the Lauraceae forms the dominant trees in Broad-Leaved Forest. Thus, the pollen of Lauraceae should be found where Fagaceae pollen is a major component in fossil pollen assemblage. The reason for the absence of Lauraceae pollen may be that Lauraceae pollen was destroyed by oxidation in pollen preservation or by the treatment of chemicals.

Zone B and Zone C except Subzones C1, C3 and C5 represent periods of closed communities. Occasionally open vegetation appears within these zones when Gramineae, Cyperaceae and Compositae are abundant. *Dicranopteris* grows on the sunny and dry lands, so the abundance of *Dicranopteris* in the upper part of Zone B may represent a phase of drier condition.

Zone A, Subzone C1, Subzone C3 and Subzone C5 with few pollen records being characterized by the mineral deposits, may indicate periods of open vegetation allowing violent erosion of mineral soils (Bartley, 1966).

Subzone D1, marked by high frequency of *Alnus* pollen, may reflect a period of colluvial soil. Successively *Alnus*, *Ophioglossum vulgatum*, *Sphagnum* and much of Gramineae reveal a picture of open vegetational condition and indicate a swamp environment in Subzone D2. In Subzone D3, the sharp increase of TP percentages except *Alnus* pollen and disappearances of *Ophioglossum vulgatum* and *Sphagnum* give rise to a rapid development of closed woodland in which the Fagaceae is dominant.

Zone E, began ca. 10000 years B. P. and corresponded to the Holocene, is characterized by the decrease of TP and the increase of NTP. Hicks (1971) points out that an anthropogenic effect and clearance phases are usually indicated on the pollen diagrams by an increase in NTP and a corresponding decrease in TP, together with rise in the values of Gramineae, *Plantago*, weed species and *Pteridium* spores. Turner (1964) suggests that grass pollen frequency was a rough guide to the extent of clearance. Tsukada (1966, 1967) considers that the abundance of grass pollen which is larger than 37 μ may indicate the human activity. But Huang (1974) suggests that the grass pollen which is larger than 60 μ, may belong to cereals. Thus, there is insufficient evidence from the pollen diagram to indicate whether any anthropogenic effect exists in Zone E although grass pollen frequency is high. But charcoal at 670 cm (ca. 3850 years B. P.) and wood fragments at 580 cm (ca. 3400 years B. P.) may reflect the clearance of the forest by early man. These periods can be correlated with Tahuan Age (ca. 4000-2700 years B. P.) and belong to Lungshanoid Cultural Bed (Lin, 1966, 1969).

From the data of C^{14} dating, we estimate the deposition rate of sediments. From 17000 years ago (1400 cm) to 4500 years ago (780 cm), the deposition rate is about 0.048 cm/year, and it is about 0.27 cm/year since 4500 years ago. Perhaps the soil erosion due to the clearance of the forest by early man since 4500 years ago is the reason for the big difference of deposition rate between these two periods.

Concentricystes prevailed in the past. In an earlier investigation of lake deposits (Huang, 1975), it was also reported, thus we suggest that *Concentricystes* may be an indicator of an aquatic environment. Other puzzling fossil spores are shown on Plate 4. At 3320 cm, 1400 cm and 1050 cm, the values of spores are much larger than those of pollen. Among the spores, most belong to the smooth monolete ones which are identified with difficulty. The significance of these unidentified fossils will be known if spores and pollen grains of recent plants including algae and bryophtes are well investigated.

Polygonum and *Typha angustifolia* also prevailed in past time. Their changes of amount and the occasional occurrences of other aquatic plants may reflect the unstability of lake level.

The present article is preliminary, and only a few outlines of the investigation have been mentioned. We require further data from the pollen analysis and C^{14} dating from the other seven borings in the Toushe Basin to construct a vegetational history, paleoclimatic change chart and indicate when early man came into this district. Further attention should be directed toward the modern vegetation and the pollen analysis of the subrecent soil.

ACKNOWLEGEMENT

The authors express their deepest gratitude to Dr. C. C. Lin, Professor of Geology, NTU, for field sampling and Dr. K. C. Chang, Professor of Anthropology, Yale University, for encouragement during this study. Thanks are also due to Dr. C. E. DeVol, Professor of Botany, NTU, for reading this manuscript, to Professor Y. C. Hsu, Physics Department, NTU, for providing us with the data of C^{14} dating.

LITERATURES CITED

BOULOUARD, C., & H. DELAUZE, 1972. Analyse palynolanctologique de sèdiments prelves par le bathscaphe Archimede dans la fosse du Japan. Marine Palynology, **4**(6): 462-463. *Pl. 1, Figs. 8-9.*

BARTLEY, D. D., 1966. Pollen analysis of some lake deposits near Bambrugh in Northumberland. New Phytol., **65**(2): 141-156.

CHEN, S. H., & T. C. HUANG, 1974. Spore morphology of Formosan Pteridaceae. Taiwania, **19**(2): 179-229.

CHUNG, T. F., & T. C. HUANG, 1972a. Paleoecological study of Taipei Basin (1) Taipei Botanical Garden. Taiwania, **17**(2): 118-143.

HEUSSER, C. J., 1971. Pollen and spores of Chile. The University of Arizona press. Tucson, Arizona, USA, 167pp.

HICKS, S. P., 1971. Pollen analytical evidence for the effect of prehistoric agriculture on the vegetation of North Derbyshire. New Phytol., **70**(4): 647-667.

HUANG, T. C., 1972. Pollen flora of Taiwan. NTU, Taipei, Taiwan, ROC, 297pp.

______, 1974. Pollen grains, spores and environment (in Chinese). Living organism and environments, Academia Sinica, Taipei, Taiwan, ROC, pp. 157-224.

______, 1975. Paleoecological study of Taiwan (4) Waichiataoken profile. Taiwania, **20**(1): 1-22.

KREMP, G. O. W., & T. KAWASAKI, 1972. The spores of Pteridophytes. Hirokawa Publishing Co., 389pp.

LIU, T. J., & C. W. LIU, 1956. The plant vegetation of Nantou (in Chinese), Nantou Wenhsien 3, Nantou, Taiwan, ROC, 248pp.

LIN, C. C., 1964. The geology of Nantou (in Chinese). Nantou Wenhsien 12, Nantou, Taiwan, ROC, pp. 29-45.

______, 1966. An outline of Taiwan's Quaternary geohistory, with a special discussion of the relation between natural history and cultural history in Taiwan (in Chinese with English summary). Bulletin of the Department of Archaeology and Anthropology, NTU, **28**: 7-42.

______, 1969. Holocene geology of Taiwan. Acta Geologica Taiwanica, **13**: 83-126.

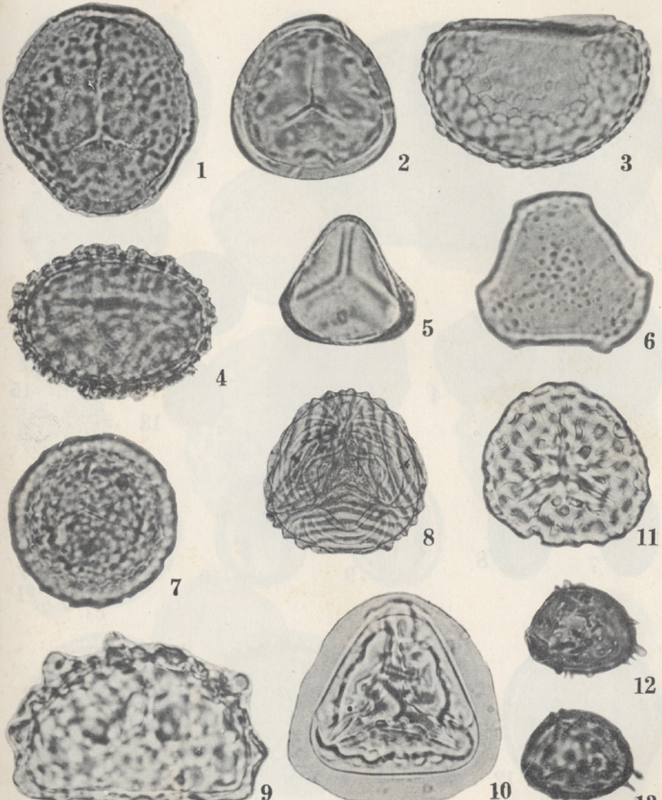
MIYOSHI, N., 1966. Spore morphology of Hepaticae in Japan. The Bulletin of the Okayama College of Science, **2**: 1-46.

TSCHUDY, R. H., & R. A. SCOTT, 1969. Aspects of Palynology. John Wiley & Sons Inc., *Pl. 8, Figs. 12-13.*

TSUKADA, M., 1966. Late Pleistocene vegetation and climate in Taiwan (Formosa). The Proceeding of the National Academy of Sciences, **55**(3): 543-548.

______, 1967. Vegetation in subtropical Formosa during the Pleistocene glaciations and the Holocene. Palaeogeography, Palaeoclimatology, Palaeoecology, **3**: 49-64.

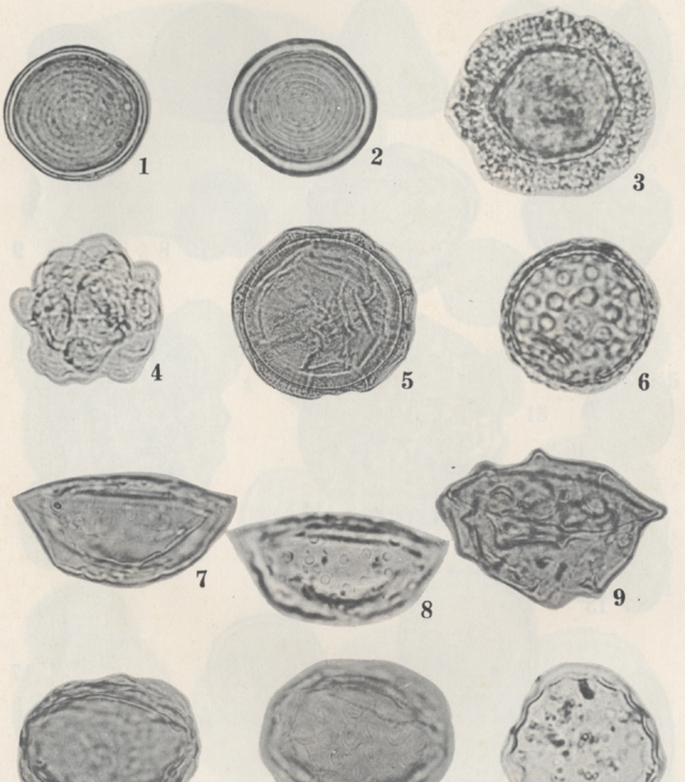
TURNER, J., 1964. The Anthropogenic factor in vegetational history (1) Tregaron and Whixall Mosses. New Phytol., **63**: 73-90.



Pl. 1. 1. *Phaeoceros laevis* TS-580-613; 2. *Sphagnum* TS-1400-608-2; 3. Davalliaceae (*Davallia*) TS-70-605; 4. Dennstaedtiaceae (*Hypolepis*) TS-1050-609; 5. Gleicheniaceae (*Dicranopteris*) TS-180-603; 6. Lycopodiaceae (*Lycopodium* cf. *serratum*) TS-2970-611; 7. Ophioglossaceae (*Ophioglossum vulgatum*) TS-1400-607; 8. Parkeriaceae (*Ceratopteris thalictroides*) TS-180-PL; 9. Polypodiaceae (*Lepisorus*) TS-780-800 R; 10. Pteridaceae (*Pteris*) TS-1400-601; 11. Schizaeaceae (*Lygodium microphyllum*) TS-580-602; 12-13. Selaginellaceae (*Selaginella* cf. *mollendorfii*) TS-4600-612. 1-7, 9-10, 12-13, ×1000; 8, ×250; 11, ×500.

Pl. 2. 1. Pinaceae (*Pinus*) TS-3700-1; 2. Pinaceae (*Tsuga*) TS-1200-6-1; 3. Aquifoliaceae (*Ilex*) TS-1050-51-1; 4. Betulaceae (*Alnus*) TS-1600-34; 5. Betulaceae (*Carpinus*) TS-780-56; 6. Euphorbiaceae (*Mallotus*) TS-180-64; 7-8. Fagaceae (*Pasania*) TS-1050-27-2; 9-10. Fagaceae (*Quercus*) TS-2970-26; 11-12. Hamamelidaceae (*Liquidan.bar*) TS-1200-33; 13. Juglandaceae (*Engelhardtia*) TS-3200-A; 14. Lythraceae (*Lagerstroemia*) TS-1050-49; 15. Myricaceae (*Myrica*) TS-4200-30; 16-17. Oleaceae (*Ligustrum*) TS-1770-126. 1, 3-17, ×1000; 2, ×500.

Pl. 3. 1-2. Salicaceae (*Salix*) TS-1050-100-1; 3. Symplocaceae (*Symplocos*) TS-2400-50; 4. Ulmaceae (*Celtis*) TS-1050-69-1; 5. Ulmaceae (*Trema*) TS-1600-54; 6. Ulmaceae (*Ulmus*) TS-1600-31; 7. Ulmaceae (*Zelkova*) TS-2200-66; 8. Compositae (*Artemisia*) TS-2200-29; 9. Compositae TS-70-32-1; 10. Haloragaceae (*Myriophyllum*) TS-70-37; 11-12. Polygonaceae (*Polygonum*) TS-2400-65-1; 13. Umbelliferae (*Hydrocotyl*) TS-2970-128; 14. Umbelliferae TS-1600-44-2; 15. Cyperaceae TS-1200-302-2; 16. Gramineae TS-1400-301-3; 17-18. Typhaceae (*Typha angustifolia*) TS-2050-308. 1-18, ×1000.



Pl. 4. 1-2. *Concentricystes* TS-2050-1004-3; 3-12. Unknown palynomorphs; 3. TS-70-1005; 4. TS-70-1006; 5. TS-180-1007; 6. TS-400-AR; 7-8. TS-1600-1008; 9. TS-2200-1003; 10-11. TS-2400-1001; 12. TS-5300-AL. 1-4, 6-12, ×1000; 5, ×500.