PALEOECOLOGICAL STUDY OF TAIWAN (3) —THE P'U-LI BASIN[1]

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Abstract: Pollen analysis of 19 samples from 4 locations in the P'u-li Basin, in Nantou County, ROC. was carried out during 1972-3. A total of 5,000 fossil palynomorphs were observed and identified. Based on the different pollen assemblages, the pollen diagram has been classified into zones A and B. Zone B is divided into subzones B_1, B_2 and B_3. Zone A, with samples from the surface layer of each site, was characterized by subtropical and temperate elements, such as Pinaceae, Betulaceae, Magnoliaceae, Euphorbiaceae, Rubiaceae, Cyperaceae, Convolvulaceae and Gramineae. Zone B, was found from samples in the deeper layers of the sites. Most components of subzone B_1 and B_3 were subtropical waste land elements, namely *Plantago, Carex, Cyperus, Gramineae*, and genera of Convolvulaceae. Pollen assemblages of subzone B_2 are the same as those of zone A. Indicator pollen grains for reforestation are those of *Cryptomeria, Cunninghamia*, and *Pinus*, and for crop cultivation are assemblages of *Plantago, Ipomoea, Cyperus, Carex, Gramineae* and *Chenopodium*. According to radiocarbon dating the initial deforestation of the area occured between 5,000 to 15,900 B. P. before the beginning of zone B. Evidence for cultivation are shown by the appearance of cereal pollen grains and waste land elements from subzone B_3 by at least 3,000 B. P. The evidences of pottery and lithic artifacts indicated that the Neolithic peoples of the Lunshanoid culture of southwest Taiwan and southeast China arrived to this area before 2581 B. P.

INTRODUCTION

As an intergral part of a larger study attempting to investigate the relationships between Man and his Environment along the Cho-shui and Ta-tu River valleys following paleoecological study was undertaken. The Cho-shui and Ta-tu Rivers are located at latitudes 120° 50′ to 121° East and longitudes 23° 47′ to 24° North in Nontou county, ROC. This interdisciplinary project (including the departments of Anthropology, Archaeology, Botany, Geology, Geomorphology and Zoology) was approved by the National Science Council in 1972. We were invited to join the project and be in charge of the pollen analysis by the program director, Dr. K.C. Chang, Chairman, Department of Anthropology, Yale University, New Haven, Connecticut, USA. The general purposes of the study have been to look at the relationships between man and his environment, to look at systems of cultivation and their culture-ecological relationships, to shed light on the history of plant

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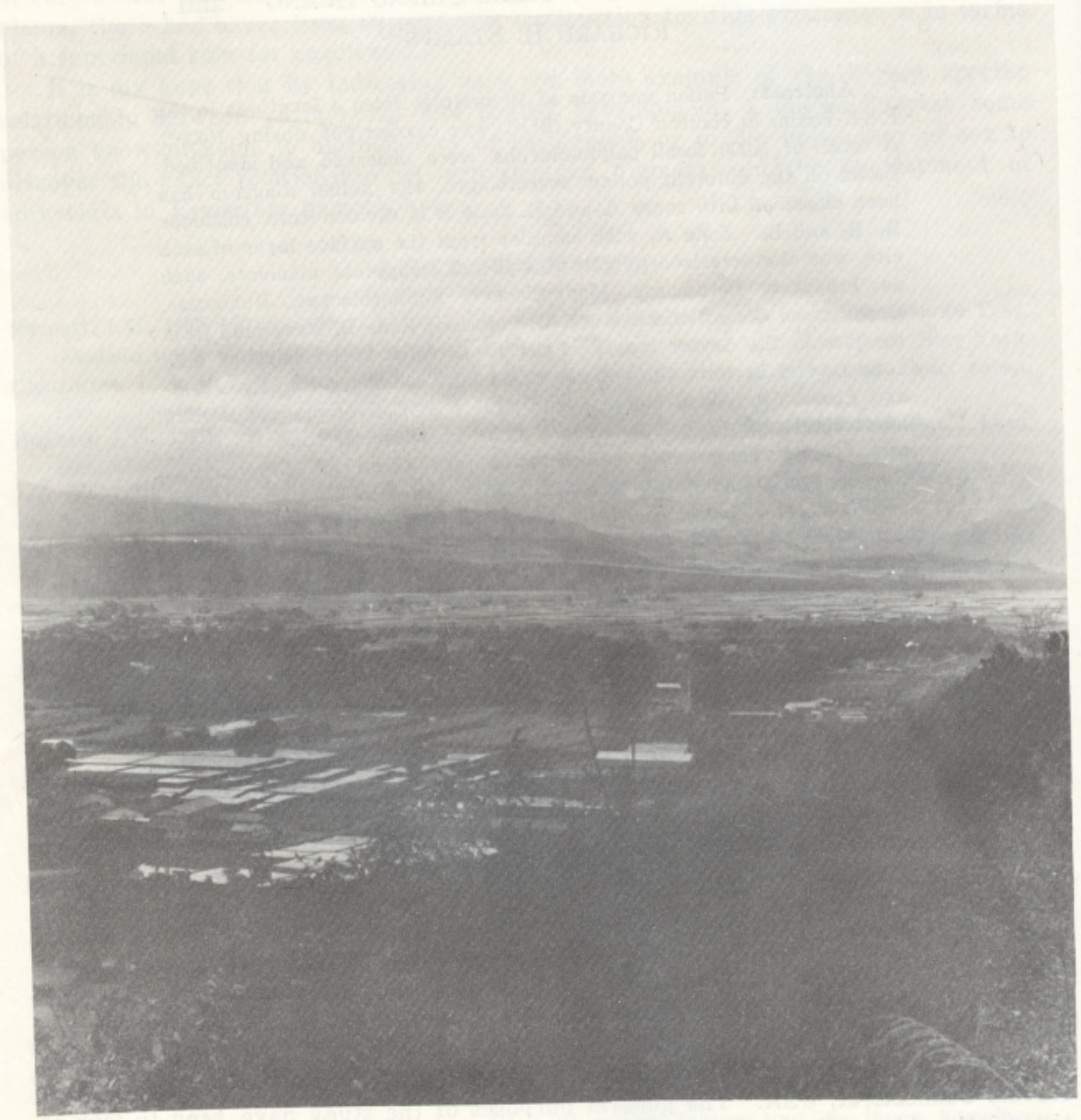

Fig. 1. P'u-li Basin looking northward from the south rim.

domestication and agriculture, and to look at the modern aboriginies and compare their land use patterns with those of prehistoric peoples. As a beginning to the understanding of some of these broad problems, the P'u-li Basin was chosen for study with certain specific goals in mind. The P'u-li Basin (Fig. 1) was chosen for investigation because previous studies had been made of both its archaeology (Shih, 1953; Liu 1956) and its vegetational sequences (Liu, 1960, 1962; Tsukada, 1967). Also, because the temperature (mild winters and cool summers) and an abundant rainfall make it condusive to agriculture today, so it seemed logical that the P'u-li Basin would have been an ideal area for agriculturists in the past. The more specific goals of this study and report are:

to reconstuct the major vegetational formations in the P'u-li Basin,
to trace the vegetational history of the P'u-li Basin noting any significant changes in the successive series of plant communities,
to see when man came into the area,
to see the effects of man on past plant communities,
to see what crops man was using—(root crops or cereals or others),
to see if different vegetational communities can be related to different tool inventories as to time periods and locality.

MATERIALS AND METHODS

1. General description

The P'u-li Basin lies in the geographic center of Taiwan (Fig. 2). A monument is located north of that city on the spot where the Islands north-south dividing line crosses the east-west dividing line. Taiwan itself is an oval-shaped island that lies 110 km off the coast of southeastern China. The Taiwan Straits that divide Taiwan from the mainland are dotted with smaller islands of the Pescadores group; to the south of Taiwan we find the Philippines, and to the north the Ryukyus and Japan. Taiwan is 380 km long and 140 km wide at the widest point with an area of 35,570 square km. The island is a great fault block that runs on a north-northeast—south-southwest axis. The majority of the area is taken up by the Central Mountain Range which divides a small rift valley on the west coast. The central mountains, that consist principally of paleogen slate and limestone, contain forty peaks above 3,000 meters. The elevation of the P'u-li Basin floor ranges from 360 m to 800 m while mountain peaks that surround the basin rise to 2,400 m. The annual temperature is 19.3°C to 21°C and the precipitation is 2100–2500 mm. Thus, the P'u-li Basin lies in the subtropical zone category.

2. Sample areas

Pollen samples for this study were removed from soil samples taken during archaeological testing of the area by Stamps between September 1972 and February 1973. Samples came from four test pits located at three different archaeological sites in the P'u-li Basin and one control site from the Yu-chih Basin, Wai-chia-tao-keng profile (Fig. 2). Sites were selected because of the abundance of human remains, usually in the form of stone tools (hoes, knives and adzes) or pottery. The three sites are located on different geomorphological formations. Sites Pl 21A and C (Fig. 3) and Pl 29B are on the first terrace above the river plain. Site Pl 38TT (Fig. 4) is located on high flats above the Mei-chi River that drains into the P'u-li Basin from the high mountains to the east. The control sample (Wai-chia-tao-keng profile) is located at 23° 55′N and 120° 57′E, 7 km southwest of the town

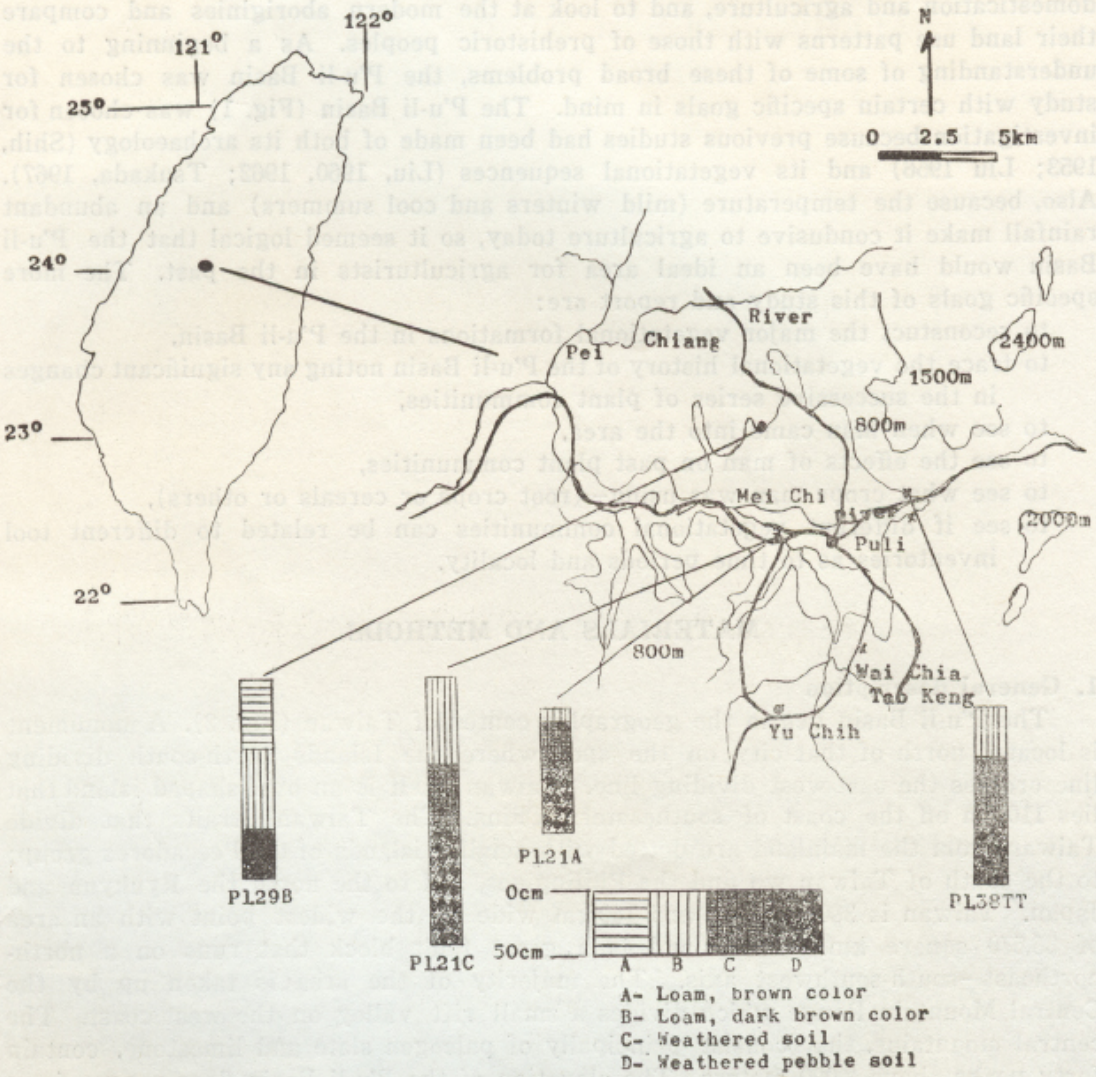

Fig. 2. Map showing sites located and stratigraphy

of P'u-li. Sites were chosen so as to have different landforms, elevations, and degrees of slope represented for comparative purposes.

After sites that produced human artifacts had been located, test pits were dug using standard archaeological methods. Soil samples were then taken from each distinct level. At least one sample in each column was also taken form the sterile (free from human disturbance of artifacts) soil below the human occupation. Some of the sites had only one cultural level (Ex. PL 29B, Fig. 5) so the pollen column only had three samples, i.e. sterile below the human occupation (representing the natural state), the cultural level, and the near surface level. Other sites, for example, PL 21 C had five levels that went to a depth of below two meters (Fig. 6). After each test pit had been excavated and the levels designated, samples were taken. Samples for each level were extracted with a clean trowel from the side wall of the test pit and placed in plastic bags for transport to the laboratory. Sampling was done from the bottom to the top.

Fig. 3. Pl 21, on the Ai-lan Terrace.

Fig. 4. Pl 38TT, on a high flat, east of P'u-li.

Fig. 5. Pl 29B, a single occupation.

Fig. 6. Pl 21C, test pit over 3 meters deep with five levels.

Several charcoal samples were found among the cultural layers at the three archaeological sites and two samples were found from the control site. These were submitted to professor Yuin-Chi Hsu, Department of Physics, N. T. U. and determined to date from 2381 B. P. to the present at the archaeological sites and over 25,000 B. P. at the control site.

3. Sites and stratigraphy

1. Shui-wa-k'u (Fig. 5, Table 1)

This site is located on the first terrace above the River Mei-chi at the junction with the stream from Hsiao-pu-she. The site is 4 km north of P'u-li at an elevation of 430 m above sea level. The sample was taken to a depth of 170 cm and three layers of samples were selected for pollen analysis.

Table 1. Shui-wa-k'u site

Sample Numbers	Depth (cm)	Description of Soil	Dating by C^{14}
Pl 29B I	47–63	Sandy loam, yellowish-brown in color.	
Pl 29B II	100–110	Laterite soil with fine gravel, dark brown in color.	2381±71
Pl 29B III	160–170	Laterite soil with gravel up to 2 cm diameter, reddish-brown in color.	

2. Ta-ma-lin (Fig. 6, Table 2)

This site is located 2.5 km west of P'u-li town on the Ai-lan terrace above the Mei-chi River. It lies 450 m above sea level. There were two site columns sampled in this area, i. e. Pl 21A, and Pl 21C. Three samples from Pl 21A, and 9 samples from Pl 21C were selected for palynological study.

Table 2. Ta-ma-lin site

Sample Numbers	Depth (cm)	Description of Soil	Dating By C^{14}
Pl 21A I	10–20	Loam with pieces of root fragments, brown in color.	
Pl 21A II	50–60	Loam with pieces of root fragments, brown in color.	
Pl 21A III	100–110	Laterite pebble soil with gravel up to 2 cm diameter, reddish-brown in color.	1783±53
Pl 21C I	5–15	Loam with root fragments, brown in color	
Pl 21C II	50–60	Loam, brown in color	
Pl 21C III	65–70	Loam, dark brown in color	
Pl 21C IV	105–110	Loam, brown in color	
Pl 21C V	130–140	Laterite soil, reddish-brown	1846±55
Pl 21C VI	175–180	Loam, brown in color	2104±63
Pl 21C VII	185–190	Loam, dark brown in color	
Pl 21C VIII	210–215	Laterite soil with gravel up to 1 cm diameter, brown in color.	
Pl 21C IX	235–240	Laterite pebble soil, with gravel up to 2 cm diameter, reddish-yellow in color	

3. Shih-tzu-tou (Table 3)

This site is located on a hill side flat on the north bank of the Mei-chi River about 730 meters above sea level, 7 km east from the town of P'u-li. The column was taken at a depth of 160 cm, and 4 samples were selected for analysis.

Table 3. Shih-tzu-tou site

Sample Numbers	Depth (cm)	Description of Soil	Dating By C^{14}
Pl 38TT I	10–20	Loam with pieces of root fragments, brown in color	
Pl 38TT II	40–50	Loam with root fragments, dark brown in color	
Pl 38TT III	100–110	Laterite soil with gravel up to 1 cm diameter, brown in color	
Pl 38TT IV	150–155	Laterite pebble soil with gravel up to 2 cm diameter, reddish-yellow in color	

4. Extraction of palynomorphs

The extraction of fossil palynomorphs were made by using the method of Chung and Huang (1972), including the treatment of 10% KOH for the dissolution of humic materials. Heavy solution of $ZNCL_2$ for flotation (S. G. 1.8–2.2) and also 10% of HCL, 52% of FH were used for maceration of the laterite pebble samples, which were collected from the bottom of each site.

A minimum of 500 grains of palynomorphs were counted for each sample; over 1,000 grains were observed when 2 g of treated sample was completely mounted. For laterite pebble sample, few fossil palynomorphs were extracted even in 2 g samples, so that more than 2 g of samples and various chemical treatment were necessary to extract enough fossil palynomorphs for this study.

5. Identification

For observation and identification, the Olympus Photomax microscope and the standard references as Erdtman (1954), Faegri *et al* (1964), Huang (1972), Ikuse (1956) and Wodehouse (1959) were used.

RESULTS

About 7,000 of microfossils have been extracted and identified from the 19 samples at the three sites. More than 5,000 of them were pollen grains and fern spores and about 2,000 fungi spores. Due to insufficient references at hand for the fungi spores, they will not be reported in this paper. The palynomorphs of 3 families of gymnosperms, 25 families of dicotyledons, 3 families of monocotyledons and 7 families of pteridophyte were indentified (see Table 4, Plate 1–2 and Fig. 7).

DISCUSSION

1. Past vegetation

The pollen diagram (Fig. 7) was constructed by using a sum of total fossil pollen grains. From the pollen diagram, non-tree-pollen (NTP), was observed to be generally abundant in all assemblages. Two pollen zones, i.e. zone A and zone

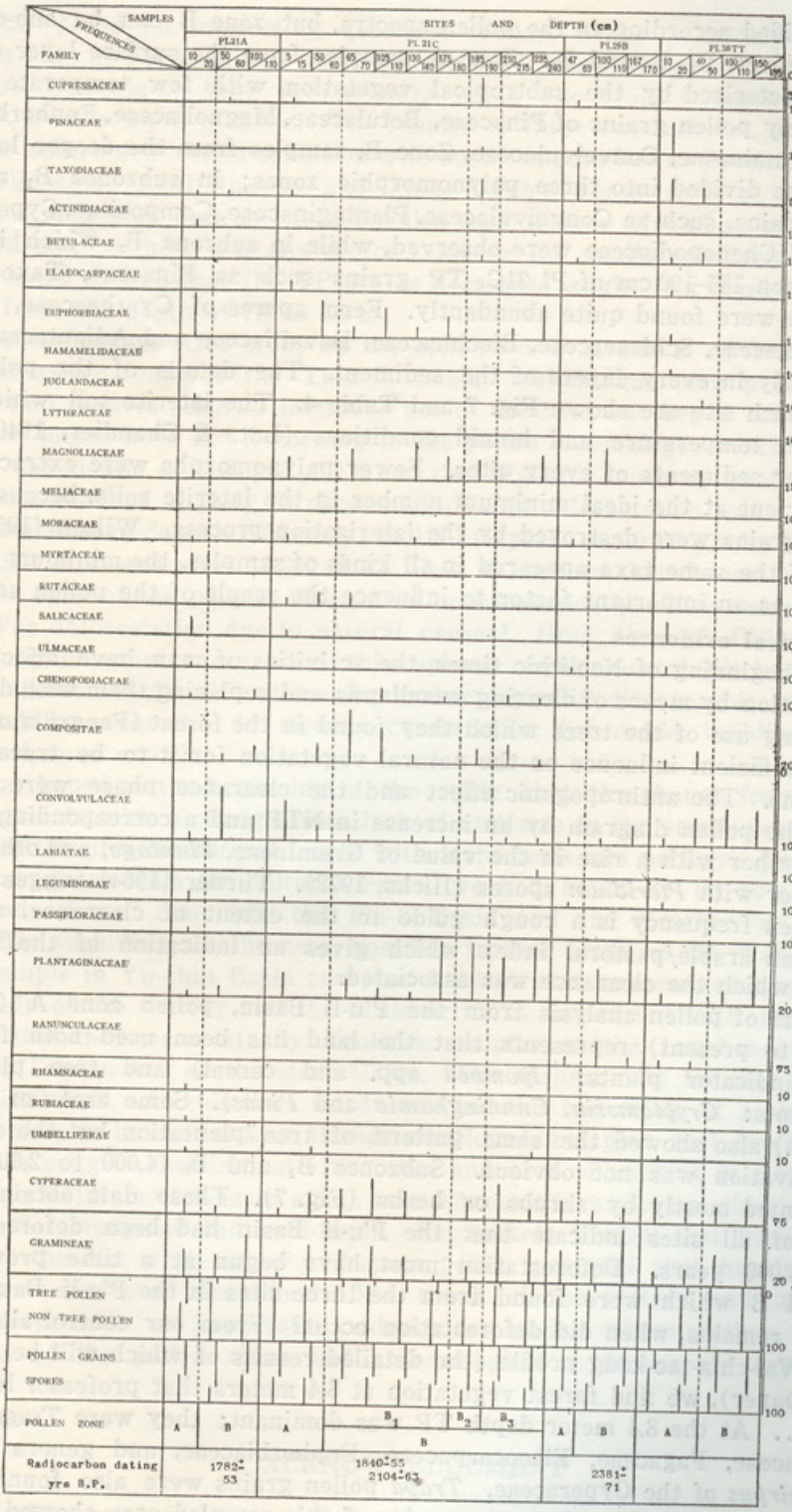

Fig. 7. Pollen diagram of 19 samples from 3 sites of P'u-li Basin, central Taiwan. Percentage of pollen and spore based on the total palynomorphs and percentage of TP and NTP based on the sum of (TP+NTP)

B can be classified according to the pollen spectra, but zone B can be sub-divided into three subzones, B_1, B_2 and B_3. Zone A, samples from the surface layer of each site were characterized by the subtropical vegetation with few temperate forest elements, namely pollen grains of Pinaceae, Betulaceae, Magnoliaceae, Euphorbiaceae, Rubiaceae, Leguminosae, Convolvulaceae. Zone B, samples from the deeper layer of each site can be divided into three palynomorphic zones; in subzones B_1 and B_3, mostly NTP grains, such as Convolvulaceae, Plantaginaceae, Compositae, Cyperaceae, Gramineae and Chenopodiaceae were observed, while in subzone B_2 which is at a depth of between 185–190 cm of Pl 21C, TP grains such as Pinaceae, Taxodiaceae and Betulaceae were found quite abundantly. Fern spores of Cyatheaceae, Pteridaceae, Gleicheniaceae, Schizaeaceae, Blechnaceae, Davalliaceae and Adiantaceae were found abundantly in every layers of the sediment. The details of the pollen assemblages of each site are shown Fig. 7 and Table 4. The laterite soil which was caused by high temperature and humid conditions (Lutz & Chandler, 1949), was found in deeper sediments of every sites. Fewer palynomorphs were extracted and were not sufficient at the ideal minimum number in the laterite soils, because most of the pollen grains were destroyed by the laterization process. Wilson (1959) considered that if the same taxa appeared in all kinds of samples, the minimum number would not act as an important factor to influence the result of the pollen analysis.

2. Archaeological evidences

Since the beginning of Neolithic times, the activities of man have affected the natural vegetation by means of clearing woodlands and replacing them with domestic crops or making use of the trees which they found in the forest (Faegri *et al*, 1964). Man exerted sufficient influence on the natural vegetation for it to be traceable in pollen diagrams. The anthropogenic effect and the clearance phase were usually indicated on the pollen diagram by an increase in NTP and a corresponding decrease in TP together with a rise in the value of Gramineae, *Plantago*, and other weed species together with *Pteridium* spores (Hicks, 1972). Turner (1964) suggested that the grass pollen frequency is a rough guide to the extent of clearance, and she also deduced an arable/pastoral index which gives an indication of the type of activity with which the clearance was associated.

The results of pollen analysis from the P'u-li Basin, pollen zone A (approximately 1,500 to present) represents that the land has been used both for crop cultivation (indicator plants: *Ipomoea* spp. and cereal) and tree plantation (indicator plants: *Cryptomeria*, *Cunninghamia* and *Pinus*). Some areas of subzone B_2 (3,000 B. P.) also showed the same pattern of tree plantation but the evidence of crop cultivation was not obvious. Subzones B_1 and B_3 (4,000 to 2,000 B. P.) were represented mostly by shrubs or herbs (Fig. 7). These data obtained from all profiles of all sites indicate that the P'u-li Basin had been deforested for more than 4,000 years. Deforestation must have begun at a time previous to zones A and B which were found from the three sites in the P'u-li Basin. The question still remains, when did deforestation occur? From our control site at Yu-chih Basin, Wai-chia-tao-keng profile (the detailed results of which will be reported in the next paper), we find forest vegetation at 8.4 meters that professor Hsu dates to 25,000 B. P.. At the 8.4 meter depth TP was dominant; they were *Tsuga*, *Abies*, *Picea*, Betulaceae, Fagaceae, Elaeocarpaceae, Euphorbiaceae, and genera *Cyperus*, *Carex* and *Scirpus* of the Cyperaceae. *Trapa* pollen grains were also found abundantly in this sediment. The plant community of this sampled area showed a warm to cool climate condition, but the presence of *Trapa* pollen grains (cf. *Trapa*

natans L.) posed an interesting question. Today, *Trapa* is widely cultivated in southern part of Formosa and its fruits are used as a delicacy. Two other samples from the Wai-chia-tao-keng profile were taken one from a depth of 7.9 m and anothers from a depth of 5.9 m. The results of these two samples showed a temperate to subtropical forest condition with such components, as Betulaceae, Fagaceae, Hamamelidaceae, Aquifoliaceae and *Pinus*. From these samples there was no significant indication that the forest pollen assemblages (found at 8.4 m) had been destroyed or that there was any direct evidence for man's cultivation of this land. It was noted though that the TP grains decreased slightly in number towards the surface from the depth of 7.9 to 5.9 m.

After the comparative study of the pollen zones A and B of P'u-li Basin and the pollen assem blagesof the Yu-chih Basin, Wai-chia-tao-keng profile it can be deduced that deforestation of intensive use of the land was begun some time before the age of pollen zone B. According to the pollen assemblages which were obtained from the depth of 7.9 and 5.9 m of the Wai-chia-tao-keng profile the woody components declined slightly in these periods and deforestation was calculated (by the accumulation of deposit 0.06 cm/yr to 0.05 cm/yr or *ca.* 16–20 yrs/cm) to be at least before 5,000 B. P. and after 15,900 B. P. Thus it appears that deforestation occurred before the time of the peoples discovered archaeologically. This raises more questions. Was deforestation due to natural causes? fire? disease? Did people living permanently in other areas clear this upland environmental nitch as part of a yearly collection cycle without leaving archaeologically discoverable remains? Was there sampling error due to modern construction (of roads, buildings and farm lands) or human error?

It was hoped at the beginning of the study that the change from TP to NTP would correlate with a change from lack of artifacts in the sterile level below the archaeological sites to cultural levels with stone tools and pottery. Because we had radiocarbon dates from the cultural levels, we had hoped to be able to date the first introduction of man into the P'u-li Basin and the clearing of the primary forests. But such was not the case, possibly further study of the Wai-chia-tao-keng control sample in Yu-chih Basin can shed light on this unanswered question.

A study of the pottery and the lithic artifacts associated with zones A and B indicated that they were left by Neolithic peoples of the Lunshanoid Culture of southwest Taiwan and southeastern China. The earliest date for man in the P'u-li Basin is 2381 B. P. At this time we do not find the beginning of a developmental sequence of tools but instead an already developed, complex tool inventory. Some of the tools suggest farming activities; hoe and axes of varying in size from large ones 24.2 cm×11.5 cm×3.4 cm to small ones 9.3 cm×4.5 cm×1.4 cm, chisels and adzes, and knives—rectangular and semi-lunar. Net sinkers suggest that fishing also contributed to the diet while arrow and spear points indicated that hunting was also an important source of their food. The result of the pottery and lithic artifacts study also provide an important evidence for pollen interpretation. A possible correlation of the pollen zones and archaeological evidences are summarized in Figure 8.

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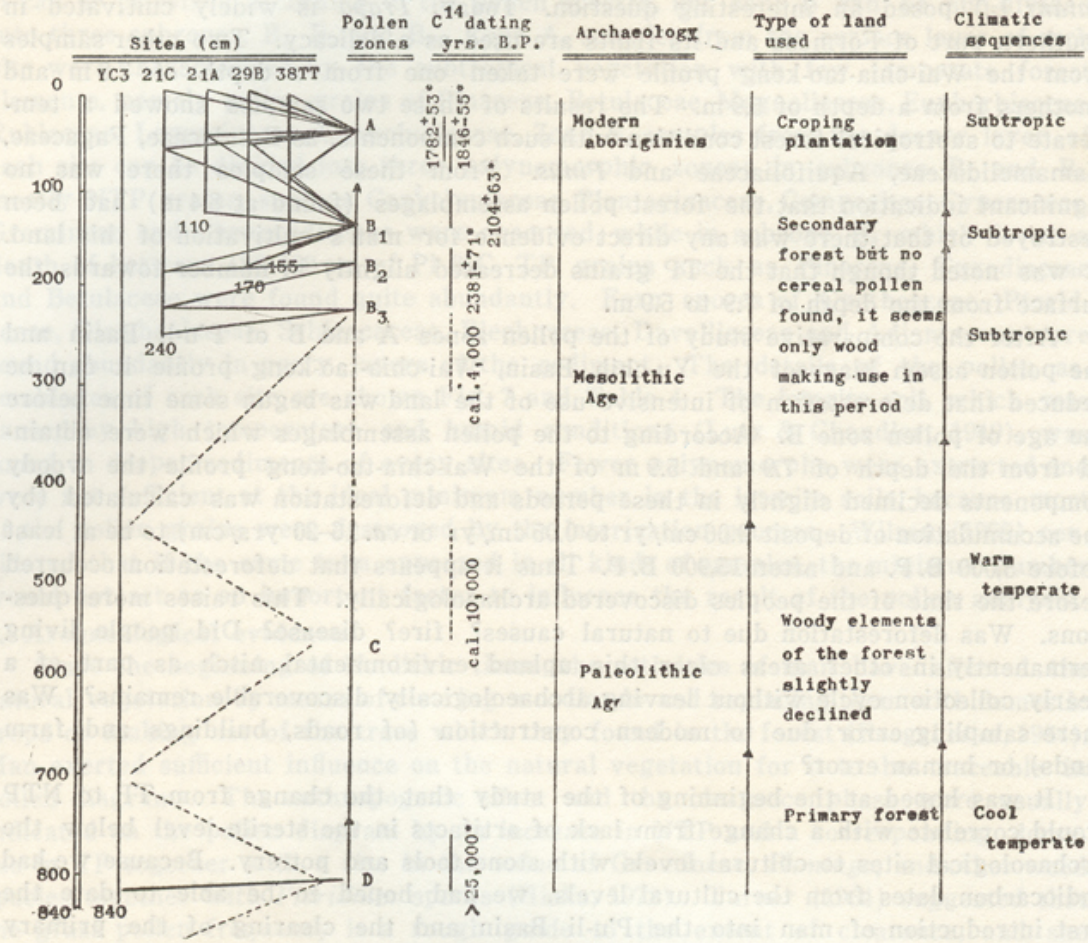

Fig. 8. A possible correlation of pollen zones and archaeological evidence
* by radiocarbon dating

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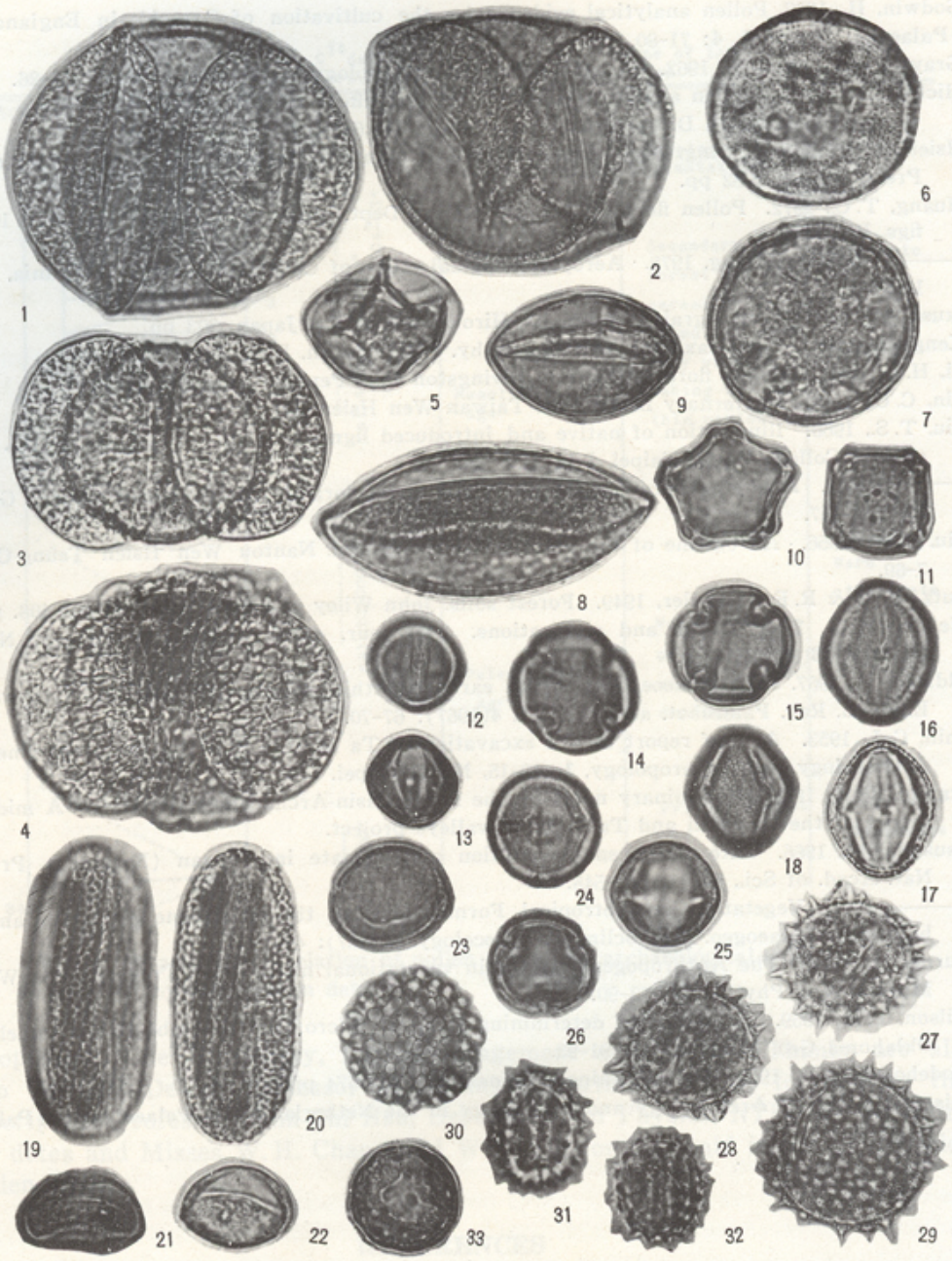
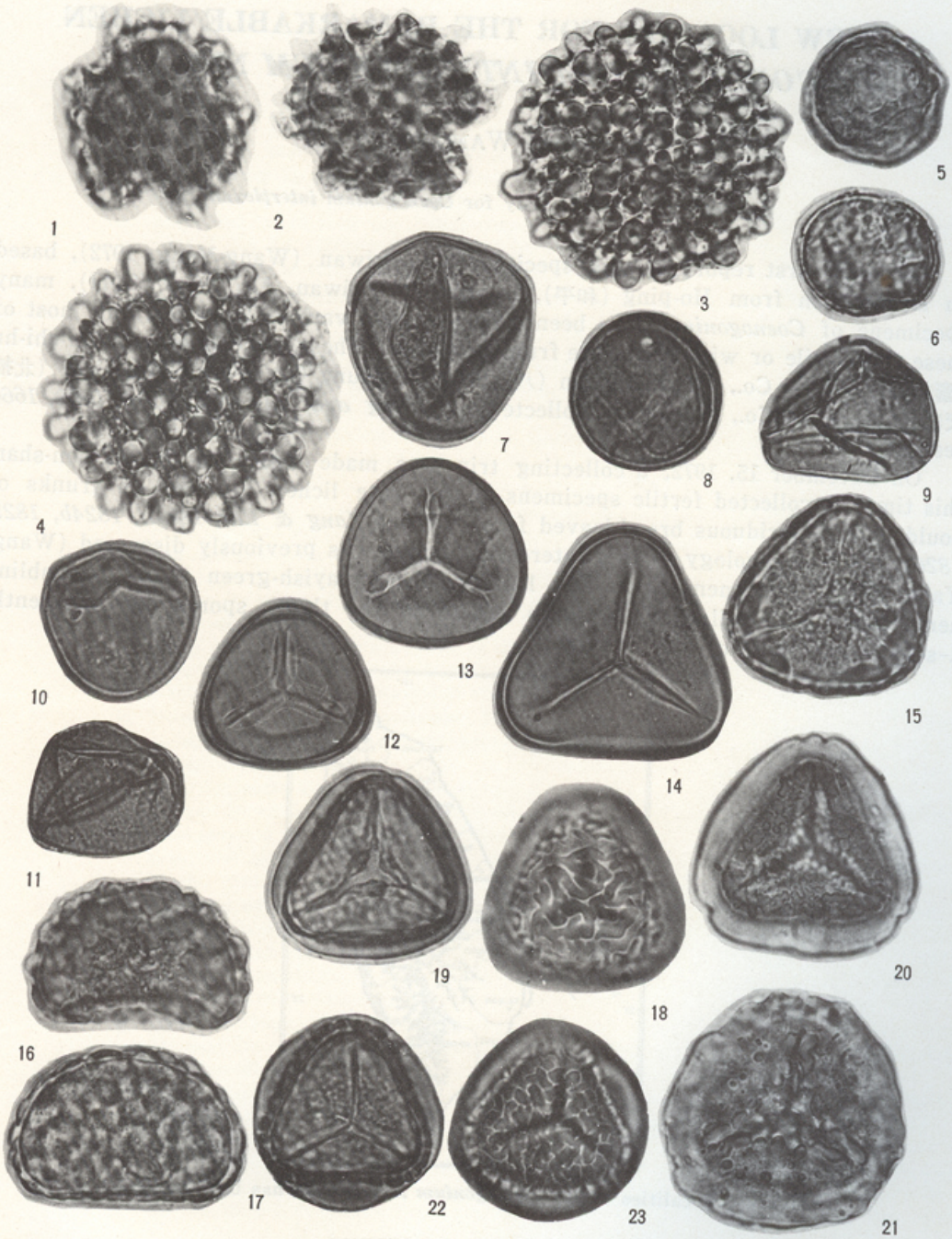


Pl. 1: 1-4, Pinaceae (*Pinus*), 21A-(10-20)-7,21C-(5-15)-2, 38TT-(10-20)-5, 1; 5, Taxodiaceae (*Cryptomeria*), 38TT-(10-20)-30; 6-7, Hamamelidaceae (*Liquidambar*), 38TT-(10-20)-81; 8-9, Magnoliaceae (*Michelia*), 21C-(5-15)-103, 105; 10-11, Betulaceae (*Alnus*), 21A-(10-20)-252, 260; 12-13, Rubiaceae (*Uncaria*), 21A-(10-20)-514; 14-15, Actinidaceae (*Saurauja*,) 21A-(10-20)-515; 16-17, Salicaceae (*Salix*), 21A-(10-20)-327, 330; 19-20, Passifloraceae (*Passiflora*), 21A-(10-20)-273; 21-22, Moraceae (*Artocarpus*), 21A-(10-20)-55, 63; 23, Ulmaceae (*Trema*), 21A-(10-20)-225; 24-26, Euphorbiaceae (*Mallotus, Macaranga*), 21A-(10-20)-455, 438, 458; 27-29, Convolvulaceae (*Ipomoea*), 21A-(10-20)-269, 216-(5-15)-16; 30, Convolvulaceae (*Stictocardia*), 21A-(10-20)-14; 31-32, Compositae (*Erigeron*), 21A-(10-20)-374, 408; 33, Chenopodiaceae (*Chenopodium*), 21A-(10-20)-232. 1-26, 31-33, ×1000, 27-30, ×400.



Pl. 2: 1-2. Compositae (*Chrysanthemum*), 21C-(185-190)-50; 3-4, Convolvulaceae (*Stictocardia*), 21C-(5-15)-72, 85; 5-6, Plantaginaceae (*Plantago*), 29B-(47-63)-102, 38TT-(10-20)-9; 7-8, Gramineae, 21A-(10-20)-213, 29B-(47-63)-76; 9-11, Cyperaceae (*Carex*), 38TT-(10-20)-158, 101, 21A-(10-20)-89; 12-13, Adiantaceae (*Adiantum*), 21C-(5-15)-254, 261; 14-15, Cyatheaceae (*Cyathea*), 21A-(10-20)-904, 21C-(5-15)-263; 16-17, Davalliaceae (*Davallia*), 21C-(5-15)-272, 24C-(50-60)-150; 18-23, Pteridaceae (*Pteris*), 21C-(5-15)-256, 255, 21A-(10-20)-900, 903. 12-13, × 400, 1-11, 14-23, × 1000.