PALEOECOLOGICAL STUDY OF TAIWAN (4)

Waichiataoken profile[1]

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Abstract: In order to answer the question as to when deforestation started and when grasslands became dominant in the Puli Basin, the Waichiataoken profile II was selected as a control site for pollen analysis. After analyzing 10,873 spores, and 19,363 pollen grains belonging to 6 families and 12 genera of Gymnosperms, 94 families and 146 genera of Dicotyledons, and 13 families and 18 genera of Monocotyledons, the author came to the conclusion that the selection of this control site was unfortunate, because the Lauro-Fagaceae forest association has constantly prevailed in this area since the upper Pliocene. The past climate is recognized as having been warm temperate from the upper Pliocene through to the Recent period(?) or Pleistocene? with slight climatic fluctuation during some periods.

INTRODUCTION

Waichiataoken is located between longitudes 120°50′ to 121° East and latitudes 23°40′ to 23°50′ North in the Yuchu Basin of Nantou county, Taiwan ROC, and in the southeastern part of Puli and northeastern part of Yuchu (Fig. 1).

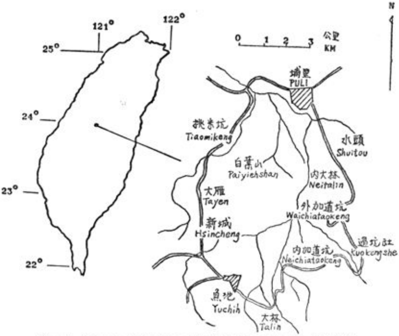

Fig. 1. Geographical map showing the sampling locality.

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The elevation at Waichiataoken is about 600–700 m. higher than that of the Puli Basin. The climatic condition is known as subtropical, with an annual rainfall of c. 2322 mm. and an annual average temperature c. 19.2°C, the coldest month being January with an average temperature of c. 14°C and the warmest month being July with an average temperature of 22.8°C. The rainfall is a little heavier and the temperature is slightly cooler than that of the Puli Basin. As the climate is moist and warm, so the vegetation in the past has been rich and a large peat deposition has been discovered here. Two profiles were drilled and Number II was assigned to us for pollen analysis. We selected this profile as a control profile in order to trace the time when deforestation began and when the grassland was formed at the Puli Basin.

MATERIALS AND METHODS

(1) Extraction of palynomorphs

The soil samples were obtained by a rotary driller to a depth of 60 m. According to the different sediments (see Table 1), 43 soil samples were chosen for pollen analysis. The extraction of fossil palynomorphs were made by using the method of Chung and Huang (1972: 119). Fossil palynomorphs from the sediments of 1 m to 36.8 m were completely mounted but sediments from 38.3 m to 60 m were only partially mounted into permanent slides. Identification of all prepared slides was done from the sediments of 1 m to 30 m, and palynomorphs extracted from sediments of 30 m to 60 m were partly identified until the count of observed grains reached to about 500 grains.

(2) Identification

For observation and identification, the Olympus photomax microscope and Zeiss Nomazuki universal microscope were used, but photographs were only taken with

Table 1. Stratigraph of Wai-chia-tao-keng profile II.

Texture / Depth(M)	Sedimentation types	Color
0.9- 1.0	Clay	Brownish yellow
1.4- 1.5		
2.4- 2.5		
2.9- 3.0		
3.4- 3.5		
3.9- 4.0	Clay	Gray
4.4- 4.5		
5.9- 6.5		
7.9- 8.0	Gray	Brown
8.4- 8.5	Clay with abundant coal	Dark gray
9.4- 9.5		
10.5-10.7		
11.0-11.1		

Texture / Depth(M)	Sedimentation types	Color
33.3-33.4	Peat	Black
33.8-33.9	Clay with abundant coal	Dark gray
36.0-36.1	Clay with small amount of sand	Gray
36.7-36.8	Clay with slate fragments	Gray
38.3-38.4	Peat	Black
38.8-38.9		
39.5-39.6	Clay	Gray
40.0-40.1	Peat	Black
41.0-41.1	Peat	Black
41.9-42.0	Clay	Gray

13.0-13.1	Clay	Gray
14.0-14.1	Clay with small slaty conglomerate	Brown
15.0-15.1	Clay	Light gray
16.0-16.1		
19.0-19.1	Sandy clay with slate fragments	Gray
20.0-20.1		
21.0-21.1	Clay	Grayish yellow
22.5-22.6	Clay with small slaty conglomerate	Brownish red
24.0-24.1	Clay	Clay
27.5-27.6	Peat	Black
29.8-30.0	Clay	Grayish white

42.8-42.9	Clay with fine slate fragments	Gray
44.0-44.1	Slate	Dark gray
45.5-45.6	Clay with abundant coal	Dark gray
48.0-48 1	Clay	Gray
50.0-50.1	Clay	Gray
50.5-50.6	Sandy clay occasionally with fine gravels	Dark gray
51.5-51.6		
53.7-53.8		
55.0-55.1		
60.0-61.0	Laterite slate	Orange

the Olympus photomax microscope. The standard references used were the same as reported in our previous work (Chung & Huang, 1972 a, b, 1973).

Due to insufficient references at hand for the spores, fern spores will be grouped into the two main categories: monolete and trilete spores. However, I am fully aware of the significance of spore distribution in our region. Fern spores are abundantly found in the old sediments, and the ecological implication of ferns in Taiwan can be utilized. A detailed study of the fern spore flora of Taiwan is in progress.

RESULTS

More than 30,235 microfossils were analysed; of the microfossils 10,873 were fern spores and 19,363 were pollen grains (see Table 2). Of the fern spores, 7,954 belong to the monolete type, and 2,919 belong to the trilete type. Of the pollen grains, 6 families, 12 genera and 511 grains of Gymnosperms, 96 families, 146 genera and 11,553 grains of Dicotyledons, 14 families, 15 genera and 3,319 grains of Monocotyledons, and 3, 980 grains of non-classified grains or 10,483 grains of tree pollen and 4,810 grains of herbaceous pollen were analysed. The families and genera found in this profile were as follow:

A. Gymnosperms.

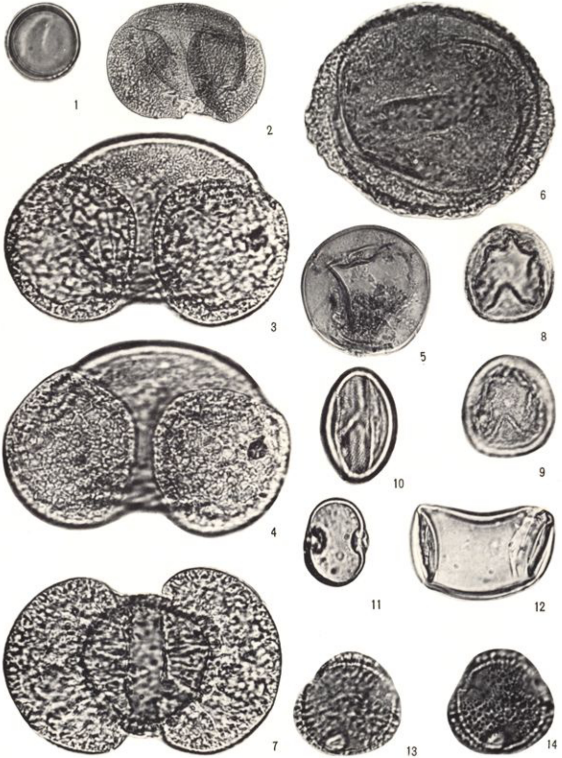
1. Cycadaceae (*Cycas*).
2. Amentotaxaceae (*Amentotaxus*).
3. Podocarpaceae (*Podocarpus*) Pl. 1, Fig. 7.
4. Pinaceae (*Abies, Keteleeria, Picea, Pinus, Pseudotsuga, Tsuga*) Pl. 1, Figs. 2–6.
5. Taxodiaceae (*Cryptomeria, Cunninghamia*) Pl. 1, Figs. 8–9.
6. Cupressaceae (*Calocedrus*) Pl. 1, Fig. 1.

B. Angiosperms (*Dicotyledons*).

1. Acanthaceae (*Justicia, Strobilanthes*) Pl. 3, Fig. 15.

2. Aceraceae (*Acer*) Pl. 1, Fig. 10.
3. Actinidiaceae (*Actinidia*).
4. Aizoaceae (*Trianthemum*).
5. Amaranthaceae (*Aeura, Gomphrena*) Pl. 3, Figs. 16–17.
6. Anacardiaceae.
7. Anonaceae (*Anona, Fissistigma*).
8. Apocynaceae (*Alyxia, Cerbera*) Pl. 1, Figs. 11–12.
9. Aquifoliaceae (*Ilex*) Pl. 1, Figs. 13–14.
10. Araliaceae (*Boerlagiodendron, Schefflera*).
11. Aristolochiaceae (*Aristolochia*).
12. Asclepiadaceae.
13. Balanophoraceae (*Balanophora*).
14. Balsaminaceae (*Impatiens*)..
15. Basellaceae (*Basella*).
16. Begoniaceae (*Begonia*).
17. Berberidaceae (*Podophyllum*).
18. Betulaceae (*Alnus, Carpinus*) Pl. 2, Figs. 1–2.
19. Boranginaceae (*Bothriospermum*).
20. Buxaceae (*Buxus*).
21. Campanulaceae (*Adenophora, Campanumoea, Codonopsis*).
22. Caprifoliaceae (*Lonicera, Viburnum*) Pl. 2, Figs. 3–4.
23. Caryophyllaceae.
24. Casuarinaceae (*Casuarina*).
25. Celastraceae (*Gymnospora*).
26. Chenopodiaceae (*Chenopodium*) Pl. 3, Fig. 18.
27. Chloranthaceae (*Chloranthus, Sarcandra*).
28. Compositae (*Artemisia, Sphaeromorphia*) Pl. 3, Figs. 19–21.
29. Connaraceae (*Rourea*).
30. Convolvulaceae (*Erycibe, Stictocardia*).
31. Cornaceae (*Helwingia*).
32. Cruciferae (*Capsella, Arabis, Brassica*(?), *Senebiera*) Pl. 3, Fig. 22.
33. Cucurbitaceae (*Melothria*) Pl. 3, Fig. 3, Figs. 23–24.
34. Daphniphyllaceae (*Dapaniphyllum*).
35. Droseraceae (*Drosera*).
36. Ebenaceae (*Diospyros*).
37. Elaeagnaceae (*Elaeagnus*) Pl. 2, Figs. 5–6.
38. Elaeocarpaceae (*Elaeocarpus, Sloanea*) Pl. 2, Figs. 7–8.
39. Ericaceae (*Rhododendron*) Pl. 2, Fig. 9.
40. Euphorbiaceae (*Antidesma, Breynia, Mallotus, Phyllanthus*) Pl. 2, Figs. 10–13.
41. Fagaceae (*Castanopsis, Pasania, Quercus*) Pl. 2, Figs. 14–18.
42. Gentianaceae (*Nymphoides*) Pl. 3. Fig. 27.
43. Geraniaceae (*Geranium*).
44. Gesneriaceae (*Rynchotechum*) Pl. 3, Figs. 25–26; 28–29.
45. Grossulariaceae (*Ribes*).
46. Guttiferae (*Hypericum*).
47. Halorrhagaceae (*Myriophyllum*).
48. Hamamelidaceae (*Liguidamber*) Pl. 2, Fig. 19.
49. Hydrocaryaceae (*Trapa*) Pl. 4, Fig. 1.

50. Juglandaceae (*Engelhardtia, Platycarya*).
51. Labiatae (*Mesona, Salvia*).
52. Lardizabalaceae (*Stauntonia*).
53. Leguminosae (*Crotalaria, Caesalpinia, Desmodium, Medicago, Smithia, Vicia*) Pl. 2, Fig. 20.
54. Lentibulariaceae (*Utricularia*).
55. Loranthaceae.
56. Lythraceae (*Lagerstroemia, Pemphis, Rotala*) Pl. 3, Fig. 1.
57. Magnoliaceae (*Michelica, Magnolia*) Pl. 3, Figs. 2–3.
58. Malpigiaceae (*Tristellateis.*).
59. Melastomataceae.
60. Meliaceae (*Melia*).
61. Menispermaceae (*Paracyclea*) Pl. 3, Figs. 4–5.
62. Moraceae (*Ficus, Humulus, Morus*) Pl. 3, Fig. 6.
63. Mysinaceae (*Maesa*)
64. Myrtaceae (*Acmea, Decaspermum, Eucalyptus, Jambosa, Syzygium*) Pl. 3, Figs. 7–8.
65. Nymphaceae (*Nupha*).
66. Oleaceae (*Fraxinus, Osmanthus*).
67. Onagraceae (*Ludwigia*) Pl. 4, Fig. 2.
68. Orobanchaceae (*Aegineta*).
69. Papaveraceae (*Corydalis*).
70. Pirolaceae (*Pirola*) Pl. 4, Fig. 3.
71. Piperaceae (*Peperonia, Piper*).
72. Polemoniaceae (*Phlox*).
73. Polygalaceae (*Polygala*).
74. Polygonaceae (*Polygonum*) Pl. 4, Figs. 4–5.
75. Proteaceae (*Helicia*) Pl. 3, Fig. 9.
76. Ranunculaceae (*Coptis*).
77. Rhamnaceae (*Rhamnus, Berchemia, Paliurus*).
78. Rosaceae.
79. Rubiaceae (*Borreria, Gardenia, Ophiorrhiza, Tricalysia*) Pl. 3, Fig. 10; Pl. 4, Figs. 6–7.
80. Rutaceae (*Citrus, Murraya, Reevesia, Severinia, Zanthoxylum*) Pl. 3, Fig. 11.
81. Salicaceae (*Salix*).
82. Sauraceae (*Houttynia*).
83. Saxifragaceae (*Astilbe, Hydrangea, Schizophragma*).
84. Schizandraceae (*Kadsura*).
85. Scrophulariaceae (*Micrargeria*).
86. Solanaceae (*Datura, Solanum*).
87. Sterculiaceae (*Kleinhovia*).
88. Symplocaceae (*Symplocos*). Pl. 3, Fig. 12.
89. Tiliaceae (*Triumfettiia*) Pl. 4, Fig. 8.
90. Trochodendraceae (*Trochodendron*).
91. Ulmaceae (*Aphananthe, Celtis, Tremna, Ulmus, Zelkova*) Pl. 3, Figs. 13–14.
92. Umbelliferae (*Caryptolepis*) Pl. 4, Figs. 9–10.
93. Urticaceae.
94. Vacciniaceae (*Vaccinium*).



Pl. 1: 1, Cupressaceae (***Calocedrus***), WK2-(9.4)-114; 2, Pinaceae (***Abies***), WK2-(10.5)-29; 3-4, Pinaceae (***Pinus***), WK2-(39.5)-154; 5, Pinaceae (***Pseudotsuga***), WK2-(9.4)-80; 6, Pinaceae (***Tsuga***), WK2-(33)-14; 7, Podocarpaceae (***Podocarpus***), WK2-(39.5)-154; 8-9, Taxodiaceae (***Cunninghamia***), WK2-(10.5)-150; 10, Aceraceae, WK2-(48)-44; 11, Apocynaceae, WK2-(38.8)-81; 12, Apocynaceae (***Alyxia***), WK2-(10.5)-137; 13-14, Aquifoliaecae (***Ilex***), WK2-(13)-38. 1, 3-4, 6-14, ×1000; 2, 5, ×400.

Table 2. Numbers and percentages of fossil palynomorphs of Wai-chia-tao-keng profile II.

Palynomorphs \ Stratigraphy (M)	1	1.5	2.5	3	4	4.5	5.9	7.9	8.4	9.4	10.5	11	13	14
Spores (S) Monolete Numbers	193	254	122	78	63	39	750	103	9	7	109	223	265	17
Spores (S) Monolete %	46.6	42.4	31.5	35.5	41.3	4.1	71.3	16.8	2.3	1.2	8.3	33.5	9	14.6
Spores (S) Trilete Numbers	179	273	228	21	9	6	100	53	6	2	36	36	149	5
Spores (S) Trilete %	23.6	45.6	58.5	9.5	5.7	0.6	9.6	8.7	1.5	0.4	2.7	5.5	5	4.4
Spores (S) Subtotal	372	527	350	99	72	45	850	156	15	9	145	259	414	22
Spores (S) %	70	88	90	45	47	4.7	80.9	25.5	3.8	1.6	11	39	14	19
Pollen grains (P) Gymnosperms	3	4	0	0	6	4	0	5	13	20	28	3	66	3
Pollen grains (P) Dicotyledons	160	49	34	53	59	846	193	429	344	378	333	287	628	49
Pollen grains (P) Monocotyledons	3	10	3	53	11	47	6	26	17	141	210	12	356	13
Pollen grains (P) Non-classified grains	3	9	1	14	4	3	1	5	2	9	593	105	1,553	22
Pollen grains (P) Subtotal	169	72	38	120	80	900	200	465	376	548	1,164	407	2,603	87
Pollen grains (P) %	30	12	10	55	53	95.3	19.1	74.5	96.2	98.4	89	61	86	81
S/P ratio	2.3	7.3	9.2	0.8	0.9	0.05	4.2	0.3	0.03	0.01	0.1	0.6	0.1	0.2
Pollen grains TP Numbers	90	44	27	27	59	782	175	389	240	277	286	271	575	41
Pollen grains TP %	54.2	71.4	72.8	25.5	77.6	87.1	87.9	82.7	64.4	51.3	50.1	89.7	54.7	63.1
Pollen grains NTP Numbers	76	19	10	79	17	115	24	81	134	262	285	31	475	24
Pollen grains NTP %	45.8	28.6	27.2	74.5	22.4	12.9	12.1	17.3	35.6	48.7	49.1	10.3	45.3	36.9
Pollen grains Subtotal	166	63	37	106	76	897	199	470	374	539	571	302	1,050	65
Pollen grains TP/NTP ratio	1.1	2.3	2.7	0.3	3.4	6.8	7.2	4.8	1.7	1.1	1	8.7	1.2	1.7
Total palynomorphs	531	599	388	219	152	945	1,050	611	391	557	1,309	666	3,017	109

Palynomorphs \ Stratigraphy (M)	15	16	19	20	21	22.5	24	27.5	29.8	33.3	33.8	36	36.8	38.3	38.8
Spores (S) Monolete Numbers	118	176	6	2	126	17	1,923	278	252	24	27	97	46	33	1,149
Spores (S) Monolete %	39	38.9	33.3	100	81	30.7	86.8	44.1	66.2	16	7.9	7.2	3.4	12.6	53.2
Spores (S) Trilete Numbers	137	252	4	0	13	12	117	142	78	33	25	127	22	127	40
Spores (S) Trilete %	44	56.1	22.2	0	9	21.3	5.2	26.9	19.8	22	7.6	8.8	1.6	50.4	1.7
Spores (S) Subtotal	255	428	10	2	139	29	2,040	420	330	57	52	224	68	160	1,189
Spores (S) %	83	95	55.5	100	90	52	92	71	86	38	15.5	16	5	63	54.9
Pollen grains (P) Gymnosperms	0	1	0	0	6	0	0	3	0	33	0	28	17	37	23
Pollen grains (P) Dicotyledons	17	10	6	0	0	11	130	17	43	830	262	780	1,187	175	641
Pollen grains (P) Monocotyledons	9	6	1	0	3	9	41	54	9	538	2	278	7	306	253
Pollen grains (P) Non-classified grains	28	2	1	0	13	7	9	99	2	5	19	82	69	76	55
Pollen grains (P) Subtotal	54	19	8	0	16	27	180	173	54	1,406	283	1,168	1,280	594	972
Pollen grains (P) %	17	5	44.5	0	10	48	8	29	14	62	84.5	84	95	37	45.1
S/P ratio	4.7	22.5	1.2	0	8.6	1.07	11.3	2.4	6.1	0.04	0.18	0.18	0.05	0.82	1.2
Pollen grains TP Numbers	14	11	0	0	0	8	122	17	16	841	258	790	1,197	203	595
Pollen grains TP %	53.8	64.7	0	0	0	40	71.3	22.9	30.7	60	97.3	71.8	90.5	39.1	64.8
Pollen grains NTP Numbers	12	6	7	0	3	12	49	57	36	560	6	296	14	31.5	322
Pollen grains NTP %	46.2	35.3	100	0	100	60	28.7	77.1	69.3	40	2.7	28.2	9.5	60.9	35.2
Pollen grains Subtotal	26	17	7	0	3	20	171	74	52	140	264	1,086	1,211	518	917
Pollen grains TP/NTP ratio	1.1	1.8	0	0	0	0.6	2.6	0.2	0.4	1.5	43	2.6	85.5	0.6	1.8
Total palynomorphs	312	447	18	2	155	56	2,220	592	384	1,463	335	1,392	1,348	754	2,161

Palynomorphs \ Stratigraphy (M)	39.5	40	41	42	42.8	44	45.5	48	50	50.5	51.5	53.7	55	60	Total
Spores (S) Monolete Numbers	303	147	173	91	136	0	45	55	58	208	112	48	71	1	7,954
Spores (S) Monolete %	19.8	26.7	23.7	11.4	27.5	0	8.2	9.8	10.4	38.5	20.5	8.9	11.3	11	
Spores (S) Trilete Numbers	158	32	127	190	37	0	5	7	17	79	12	12	11	0	2,919
Spores (S) Trilete %	10.3	5.9	18.5	24.3	7.5	0	0.9	1.3	3.1	15	1.5	2.3	1.7	0	
Spores (S) Subtotal	461	179	300	281	173	0	50	62	75	287	124	60	82	1	10,873
Spores (S) %	30	32.6	44.2	35.7	34	0	9.1	11	13.5	53.5	22	11.2	13	11	
Pollen grains (P) Gymnosperms	93	14	13	5	17	0	5	2	6	2	10	23	24	0	511
Pollen grains (P) Dicotyledons	728	264	71	329	372	0	259	396	289	100	263	270	360	1	11,553
Pollen grains (P) Monocotyledons	61	56	268	38	48	0	151	29	56	16	74	68	28	2	3,319
Pollen grains (P) Non-classified grains	183	36	26	134	100	3	83	61	107	131	85	104	131	5	3,980
Pollen grains (P) Subtotal	1,065	370	378	506	437	3	498	488	458	249	432	465	543	8	19,363
Pollen grains (P) %	70	67.4	55.8	64.3	66	0	90.9	89	86.5	46.5	78	88.8	87	89	
S/P ratio	0.4	1.1	0.7	0.5	0.3	0	0.1	0.12	0.16	1.1	0.2	0.1	0.1	0.1	
Pollen grains TP Numbers	784	152	80	324	268	0	237	211	235	80	251	266	239	1	10,483
Pollen grains TP %	88.8	45.5	22.7	87.9	79.5	0	57.1	49.4	33.1	67.7	72.0	73.6	76.8	33.3	
Pollen grains NTP Numbers	98	182	272	48	69	0	178	216	116	38	96	95	73	2	4,810
Pollen grains NTP %	11.2	54.5	77.3	12.1	20.5	0	42.9	50.6	66.9	32.3	28	26.4	23.2	66.7	
Pollen grains Subtotal	882	334	352	372	33.7	0	415	427	351	118	347	361	312	3	15,293
Pollen grains TP/NTP ratio	8	0.8	0.2	6.7	38	0	1.3	0.9	2	2.1	2.6	2.8	3.2	0.5	
Total palynomorphs	1,526	549	678	787	510	3	548	550	533	536	555	524	625	9	30,236

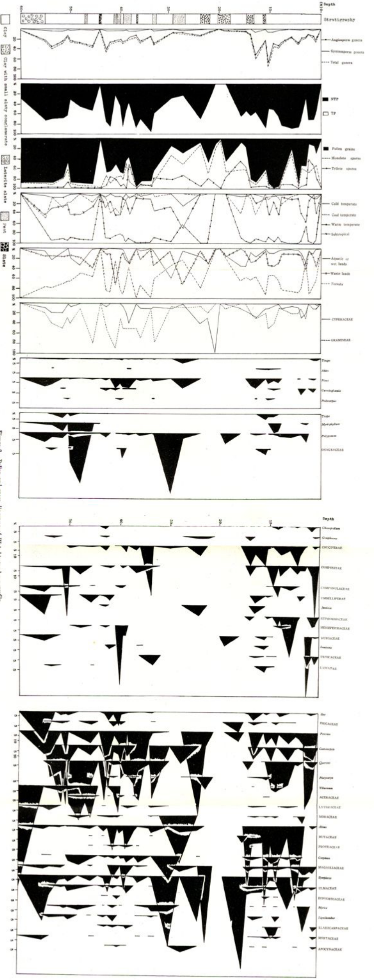
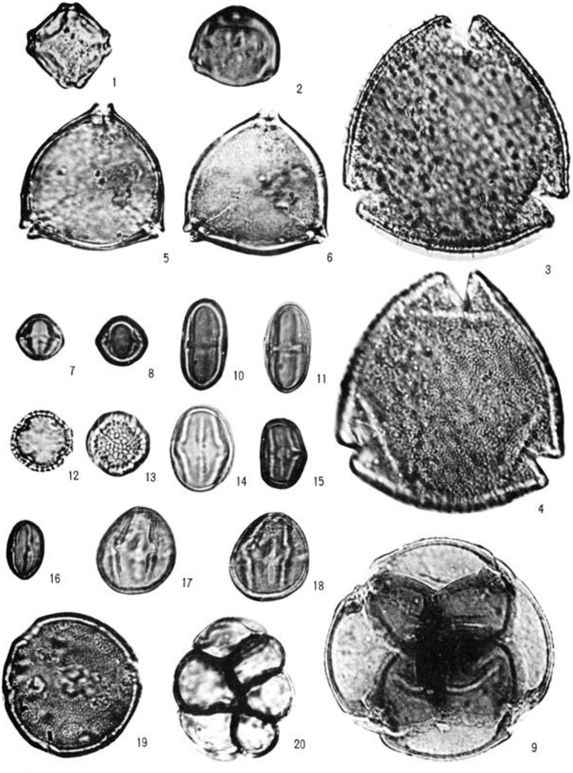
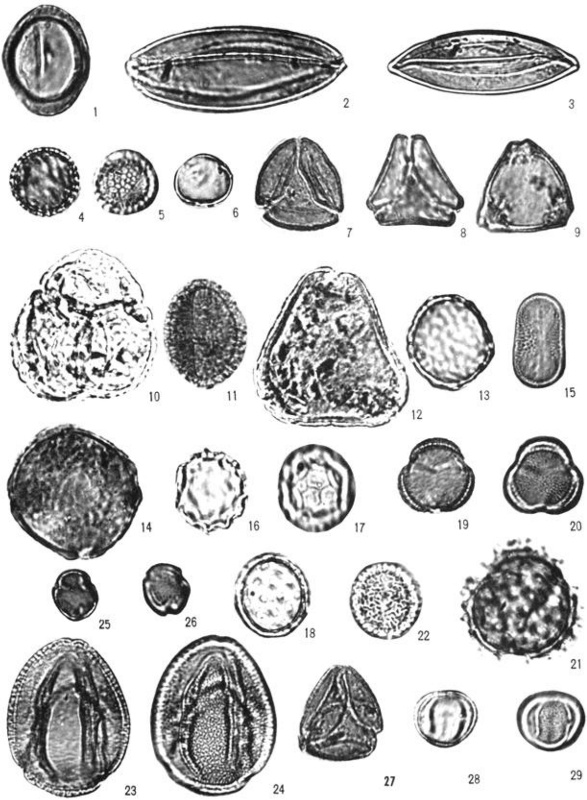


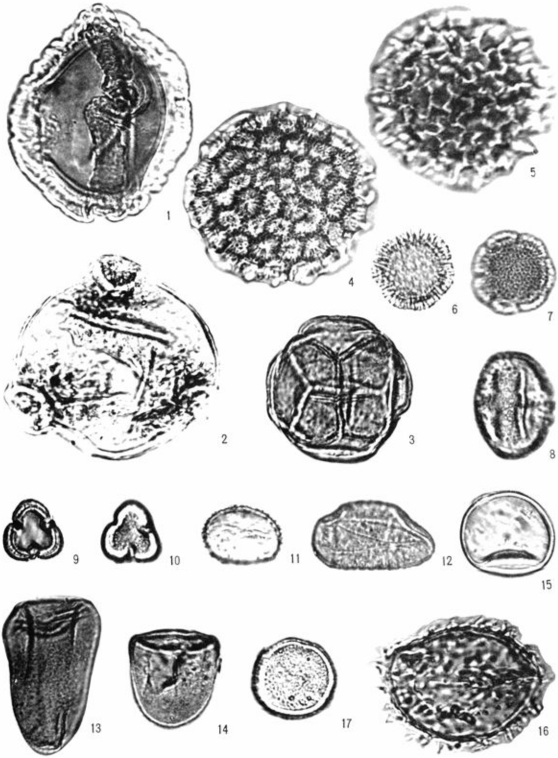
Figure 2. Pollen and spore diagrams of Wai-chia-tao-keng profile.



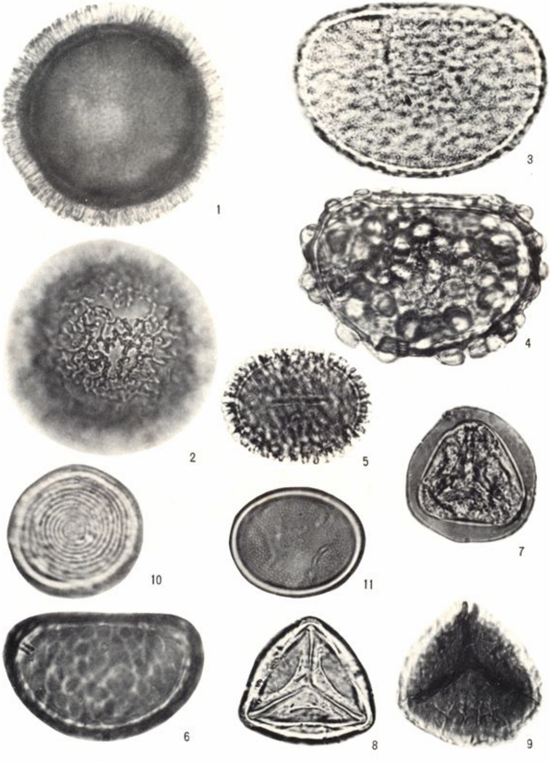
Pl. 2: 1, Betulaceae (*Alnus*), WK2-(39.5)-43; 2, Betulaceae (*Carpinus*), WK2-(39.5)-127; 3-4, Caprifoliaceae (*Lonicera*), WK2-(36)-81; 5-6, Elaeagnaceae (*Elaeagnus*), WK2-(48)-17; 7-8, Elaeocarpaceae (*Elaeocarpus*), WK2-(33)-80; 9, Ericaceae (*Rhododendron*), WK2-(13)-63; 10-11, Euphorbiaceae (*Antidesma*), WK2-(10.5)-103; 12-13, Euphorbiaceae (*Phyllanthus*), WK2-(40)-47; 14, Fagaceae (*Cyclobalanopsis*), WK2-(19)-3; 15-16, Fagaceae (*Pasania*), WK2-(33)-48. WK2-(13)-25; 17-18, Fagaceae (*Quercus*), WK2-(36)-19; 19, Hamamelidaceae (*Liquidambar*), WK2-(10.5)-30; 20, Leguminosae, WK2-(1)-24. 1-20. ×1000.



Pl. 3: 1, Lythraceae (***Lagerstroemia***), WK2-(33)-13; 2-3, Magnoliaceae, WK2-(13)-56, WK2-(38.8)-26; 4-5, Menispermaceae, WK2-(39.5)-64; 6, Moraceae, WK2-(48)-34; 7, Myrtaceae (***Jambosa***), WK2-(10.5)-63; 8, Myrtaceae (***Eucalyptus***), WK2-(13)-52; 9, Proteaceae (***Helicia***), WK2-(38.3)-53; 10, Rubiaceae (Gar***denia***), WK2-(40)-71; 11, Rutaceae (***Zanthoxylum***), WK2-(10.5)-104; 12, Symplocaceae (***Symplocos***), WK2-(38.3)-64; 13, Ulmaceae (***Ulmus***) WK2-(48)-80; 14, Ulmaceae (Zelkova), WK2-(38.3)-32; 15, Acanthaceae (***Justicia***), WK2-(24)-4; 16-17, Amaranthaceae (***Gomphrena***), WK2-(1)-31; 18, Chenopodiaceae (***Chenopodium***), WK2-(1)-59; 19-20, Compositae (***Artemisia***), WK2-(10.5)-82; 21, Compositae, WK2-(33)-35; 22, Cruciferae (***Wasabia***), WK2-(38.8)-29; 23-24, Cucurbitaceae (***Melothria***), WK2-(33)-35; 25-26, Gesneriaceae, WK2-(36)-4; 27, Gentianaceae (***Nymphoides***), WK2-(9.4)-63; 28-29, Gesneriaceae (***Rynchotechum***), WK2-(10.5)-88. 1-29, ×1000.



Pl. 4: 1, Hydrocaryaceae (*Trapa*), WK2-(10.5)-52; 2, Onagraceae, WK2-(39.5)-43; 3, Pirolaceae, WK2-(36)-46; 4-5, Polygonaceae (*Polygonum*), WK2-(55)-47, WK2-(36)-51; 6-7, Rubiaceae (*Borreria*), WK2-(10.5)-143; 8, Tiliaceae (*Triumfetta*), WK2-(10.5)-86; 9-10, Umbelliferae, WK2-(45.5)-46; 11, Araceae (*Arisaema*), WK2-(24)-25; 12, Commelinaceae, WK2-(2.5)-8; 13-14, Cyperaceae, WK2-(33)-19, WK2-(36)-25; 15, Graminae, WK2-(4.5)-53; 16, Palmae (*Arenga*?), WK2-(36)-51; 17, Typhaceae (*Typha*), WK2-(45.5)-31. 1-17. ×1000.



Pl. 5: 1-2, 7-9, trilete spores; 3-6, monolete spores; 10-11, concentricyste. 1-2, Marsileaceae (***Regnellidium***). WK2-(42.8)-40; 3, Polypodiaceae, WK2-(13)-31; 4, Polypodiaceae (***Pyrrosia***), WK2-(36.8)-26; 5, Pteridaceae (***Hypolepis***), WK2-(42.8)-28; 6, Davalliaceae (***Davallia***), WK2-(1.5)-5; 7, Pteridaceae (***Pteris***), WK2-(36)-4; 8, ***Azonotrilete***, WK2-(1)-22, 9, Megaspore, WK2-(38.8)-109; 10-11, concentricyste, WK2-(21)-2, WK2-(33)-68, 1-8, ×1000; 9×20.

95. Valerianaceae (*Patrinia*).
96. Verbenaceae (*Vitex*).

C. Angiosperms (*Monocotyledons*).

1. Alismataceae (*Sagittaria*).
2. Amaryllidaceae (*Curculigo*).
3. Araceae (*Arisaema*) Pl. 4, Fig. 11.
4. Commelinaceae (*Commelina, Floscopa*) Pl. 4, Fig. 12.
5. Cyperaceae Pl. 4, Figs. 13-14.
6. Dioscoreaceae (*Dioscorea*).
7. Eriocaulaceae (*Eriocaulon*).
8. Graminae Pl. 4, Fig. 15.
9. Hydrocharitaceae (*Blyxa*).
10. Juncaceae (*Juncus*).
11. Liliaceae (*Lilium, Paris*).
12. Palmae (*Arenga?, Phoenix?*) Pl. 4, Fig. 16.
13. Potamogetonaceae (*Potamogeton*).
14. Typhaceae (*Typha*) Pl. 4, Fig. 17.

DISCUSSION

1. General information

From the pollen and spore diagrams (Fig. 2), we can deduce the two following general points.

A. Number of palynomorphs (see Table 2).

The richness of fossil palynomorphs found in the different stratigraphic layers can be classified into five classes according to the numbers of grains.

Class 1. Very rare: when less than 100 grains were extracted from a sample, there are five sedimentary layers of this type: 19 m, 20 m. 22.5 m, 44 m, and 60 m depths.

Class 2. Rare: when between 101 to 500 grains were extracted, there are eleven such sedimentary layers: 2.5 m, 3 m, 4 m, 8.4 m, 13 m, 14 m, 15 m, 16 m, 21 m, 29.8 m, and 33.8 m depths.

Class 3. Infrequent: when between 501 to 1,000 grains were extracted, there are eleven such sedimentary layers: 1m, 1.5 m, 4.5 m, 7.9 m, 9.4 m, 11 m, 27.5 m, 45.5 m 50.5 m, 51.5 m, and 53.7 m depths.

Class 4. Abundant: when between 1,001 to 1,500 grains were extracted, there are 13 such sedimentary layers of 5.9 m, 10.5 m, 33.3 m, 36 m, 36.8 m, 38.8 m, 40 m, 41 m, 42 m. 42.8 m, 48 m, 50 m, and 55 m depths.

Class 5. Very abundant: when more than 1,501 grains were extracted, there are four such sedimentary layers: 13 m, 24 m, 38.8 m, and 39.5 m depths.

The texture of the sedimentary deposition decides the number of palynomorphs in each different stratigraphic layer. Sandy clay mixed with slate or laterite slate produced less fossil palynomorphs while clay or peat produced abundant palynomorphs.

The density of floral composition may be estimated from the above data.

Spores were extracted more abundantly than pollen grains in the stratigraphic layers of 1 m, 1.5 m, 2.5 m, 5.9 m, 10.5 m, 16 m, 19 m, 21 m, 22.5 m, 24 m, 27.5 m, 29.8 m, 38.8 m, and 50.5 m depths.

Dicotyledonous pollen grains generally appeared more abundantly than the monocotyledonous ones, except in the stratigraphic layers at a depth of 27.5 m, 38.3 m, and 41 m.

Tree pollen grains were usually found in larger amounts than non-tree pollen grains except in stratigraphic layers of 21 m, 22.5 m, 27 m, 29.8 m, 38.3 m, 40 m, 41 m, and 48 m.

B. Number of palynomorphic genera (see Table 3, Fig. 2).

The number of palynomorphic genera can be classified into the following five classes.

Class 1. Very rare: when less than 5 palynomorphic genera were identified, there were five sedimentary layers with such genera: 16 m, 19 m, 20 **m**, 21 m, and 60 m depths.

Class 2. Rare: when between 6 to 15 genera were identified, there were eight such sedimentary layers: 2.5 m, 14 m, 15 m, 24 m, 27.5 m, 29.8 m, 33.8 m, and 50.5 m depths.

Class 3. Infrequent: when between 16 to 30 genera were identified, there were twenty such sedimentary layers: 1 m, 1.5 m, 3 m, 4 m, 4.5 m, 5.9 m 7.9 m, 11 m, 36 m, 36.8 m, 38.5 m, 38.8 m, 39.5 m, 40 m, 41 m, 42 m, 48 m, 50 m, 51.5 m, and 55 m depths.

Class 4. Abundant: when between 31 to 50 genera were identified, there were eight such sedimentary layers: 8.4 m, 9.4 m, 10.5 m, 13 m, 33.3 m, 42.8 m, 45.5 m, and 53.7 m.

Class 5. Very abundant: when more than 51 genera were identified, there were two such sedimentary layers: 10.5 m, and 13 m depths.

The degree of floral heterogeneity can be estimated from the above data.

2. Special information

This discussion particularly applies to our present knowledge of plant distribution and of indicator plant(s), and concerns climatic, edaphic and pedaphic conditions in Taiwan in order to enable us to deduce the past vegetational types, its successional history, and its ecological conditions.

A. Habitats (see Table 4, Fig. 2)

Three types of habitats are recognized: (1) aquatic, moist grasslands. (2) waste grasslands including cultivated lands and (3) forest sites. Palynomorphs appearing within forests included vines, climbers, woody trees and herbaceous undergrowth on forest floors and also epiphytes. The stratigraphic layers were identified on the basis of the abundance of different types of habitats based on the palynomorphs appearing as indicated below: (a) Forest site elements absolutely dominant when grains occurred in the forest sites occupying more than 90% of the total number of pollen grains, there were five such sedimentary layers at: 2.5 m, 11 m, 33.8 m, 36.8 m, and 39.5 m depths; (b) Forest sites elements abundant but with elements of aquatic moist grassland and waste grassland occupying more than 10% of the total number of pollen grains, there were eight such sedimentary layers at: 1.5 m, 9.4 m, 13 m, 38.8 m, 48 m, 50 m, 51.5 m, and 53.7 m depths; (c) Forest site elements abundant, but waste grassland elements occupying over 10% of the total number of pollen grains and aquatic or moist grassland elements less than 10%, there were 19 such sedimentary layers at: 1 m, 1.5 m, 4 m, 4.5 m, 5.9 m 7.9 m, 8.4 m,

Table 3. Number of Palynomorphic genera or taxa

Stratigraphy (M) / Numbers	1	1.5	2.5	3	4	4.5	5.9	7.9	8.4	9.4	10.5	11	13	14	15	16	19	20	21	22.5
Gymnosperms	2	3	0	0	2	2	0	3	3	6	6	0	7	0	1	1	0	0	0	0
Dicotyledons	22	12	6	15	15	23	15	23	33	27	64	19	50	10	4	3	3	0	0	4
Monocotyledons	2	3	3	2	4	5	2	3	2	2	5	4	3	2	1	1	1	0	1	3
Total	26	18	9	17	21	30	17	29	38	35	75	23	60	12	6	5	4	0	1	7

Stratigraphy (M) / Numbers	24	27.5	29.8	33.3	33.8	36	36.8	38.3	38.8	39.1	40	41	42	42.8	44	45.5	48	50	50.5	51.5	53.7	55	60
Gymnosperms	1	3	0	4	0	2	4	4	2	3	3	3	3	3	0	2	1	3	2	4	4	2	0
Dicotyledons	10	6	6	26	11	23	12	16	21	24	20	21	26	39	0	31	25	22	10	23	34	21	1
Monocotyledons	4	1	2	3	2	3	1	2	2	2	1	3	1	5	0	4	3	2	2	2	2	2	1
Total	15	10	8	33	13	28	17	22	25	29	24	27	30	47	0	37	29	27	13	29	40	25	2

Table 4. Palynomorphs and habitats

Stratigraphy (M) / Habitats		1	1.5	2.5	3	4	4.5	5.9	7.9	8.4	9.4	10.5	11	13	14	15	16	19	20	21	22.5
Aquatic	Numbers	0 (1)	1 (4)	1 (3)	1	0	1	0	0 (4)	16 (4)	41 (1)	10 (3)	4	2	0	0	0	0	0	0 (3)	2
	%	0	1.5	2.7	0.9	0	1.2	0	0	4.2	7.6	1.7	1.3	0.1	0	0	0	0	0	0	10
Moist Grassland	Numbers	1	6	1	30	7	13	2	17	5	18	45	2	188	6	9	6	1	0	3	4
	%	0.6	9.5	2.7	28.3	9.2	1.5	1	3.6	1.3	3.3	7.8	0.6	17.7	9.1	34.6	35.2	14.2	0	1	20
Waste Grassland	Numbers	62	9	1	46	9	92	22	52	109	189	203	17	270	17	2	0	1	0	0	3
	%	37.3	14.2	2.7	43.4	11.8	10.2	11.0	11.1	29.1	35.1	33.7	5.6	25.6	26.1	7.6	0	14.2	0	0	15
Cultivated Area	Numbers	2	1	0	0	0	1	0	0	0	6	1	0	0	1	0	0	4	0	0	3
	%	1.2	1.5	0	0	0	0.1	0	0	0	1.1	0.1	0	0	1.5	0	0	57.1	0	0	15
Forest Site	Numbers	101	46	34	29	60	790	175	391	244	285	312	279	590	41	15	11	1	0	0	8
	%	60.8	73.0	91.8	27.2	78.9	88.1	87.8	83.1	65.2	52.8	54.6	92.3	56.1	63.7	57.6	64.7	14.2	0	0	40
Total (Numbers)		166	63	37	106	76	897	199	470	374	539	571	302	1,050	65	26	17	7	0	3	20

Stratigraphy (M) / Habitats		24	27.5	29.8	33.3	33.8	36	36.8	38.3	38.8	39.5	40	41	42	42.8	44	45.5	48	50	50.5	51.5	53.7	55	60
Aquatic	Numbers	2 (9)	0 (1)	0 (1)	1 (42)	0	0	0	0 (1)	0 (38)	13	1	0 (1)	0	1	0	4	141	54	0	13	5	1	0 (1)
	%	1.1	0	0	0.1	0	0	0	0	0	1.5	0.2	0	0	0.2	0	0.9	33.0	15.3	0	3.7	14.7	0.3	0
Moist Grassland	Numbers	23	3	31	58	1	50	0	150	94	5	1	3	1	8	0	4	1	12	1	26	30	17	0
	%	13.4	4.05	59.3	4.2	0.3	4.6	0	28.9	10.2	0.5	0.2	0.8	0.2	1.8	0	0.9	0.2	3.4	0.8	7.4	8.7	5.4	0
Waste Grassland	Numbers	9	54	3	500	4	240	14	165	188	63	61	266	42	53	0	168	69	49	37	57	52	50	0
	%	5.2	72.9	5.7	35.6	1.5	22.1	1.1	31.9	20.5	7.1	18.2	75.1	11.2	11.8	0	40.4	16.1	13.9	31.3	16.4	15.2	16.0	0
Cultivated Area	Numbers	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	3	0	0
	%	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0.8	0	0
Forest Site	Numbers	136	17	18	845	259	796	1,197	203	635	801	271	83	328	374	0	241	216	236	80	251	27.1	244	1
	%	79.5	22.9	34.6	60.1	98.1	73.2	98.8	39.1	69.2	90.8	81.1	23.5	88.1	85.5	0	58.1	50.6	67.2	67.7	72.3	79.4	78.2	100
Total (Numbers)		171	74	52	1,404	264	1,086	1,211	518	917	882	334	352	372	437	0	415	427	351	118	347	341	312	1

( ) Number of concentricyste spore which indicate lake or marine condition, observed, are not included in the percentage count.

Table 5. Palynomorphs and climate

Climate \ Stratigraphy (M)		1	1.5	2.5	3	4	4.5	5.9	7.9	8.4	9.4	10.5	11	13	14	15	16	.. 19	20	21	22.5
Cold temperate	Numbers	2	1	0	0	0	0	0	1	1	2	4	3	0	0	0	0	0	0	0	0
	%	2.2	2.2	0	0	0	0	0	0.3	0.4	0.7	1.3	1.1	0	0	0	0	0	0	0	0
Cool temperate	Numbers	1	1	0	0	0	2	2	20	6	0	9	1	62	1	0	1	0	0	0	0
	%	1.1	2.2	0	0	0	0.2	1.1	5.0	2.4	0	3.1	0.3	10.7	2.4	0	9.9	0	0	0	0
Warm temperate	Numbers	78	42	26	17	54	767	170	364	199	260	237	261	487	40	13	9	0	0	0	8
	%	86.6	95.4	92.9	62.9	91.5	98.1	97.1	93.6	83.0	93.0	83.0	96.3	84.6	97.5	92.7	81.8	0	0	0	100
Subtropical	Numbers	9	0	1	10	5	1.3	3	4	34	16	36	6	26	0	1	1	0	0	0	0
	%	10	0	3.7	37.3	8.4	1.6	2.2	1.2	14.1	5.7	12.5	2.2	4.5	0	7.1	9.9	0	0	0	0
Total (Numbers)		90	44	27	27	59	782	175	389	240	278	286	271	575	41	14	11	0	0	0	8

Climate \ Stratigraphy (M)		24	27.5	29.8	33.3	33.8	36	36.8	38.3	38.8	39.5	40	41	42	42.8	44	45.5	48	50	50.5	51.5	53.7	55	60
Cold temperate	Numbers	0	1	0	1	0	6	1	4	0	17	2	1	1	4	0	2	0	1	0	4	4	3	0
	%	0	5.8	0	0.1	0	0.7	0.1	1.9	0	2.2	1.3	1.2	0.3	1.4	0	0.8	0	0.4	0	1.6	1.6	0.8	0
Cool temperate	Numbers	1	0	0	10	1	2	13	3	16	54	24	6	31	7	0	10	2	10	3	17	3	75	0
	%	0.4	0	0	1.2	0.3	0.2	1.1	1.4	2.6	7.0	15.7	7.5	9.5	2.6	0	4.0	0.4	4.3	3.7	6.8	1.1	22.1	0
Warm temperate	Numbers	121	7	15	752	250	764	1.170	169	559	680	107	61	281	236	0	219	185	196	73	213	240	214	1
	%	99.1	41.1	93.7	89.4	96.4	96.8	97.6	83.2	93.9	88.6	71.5	76.2	86.4	84.6	0	89.6	88.1	83.4	91.2	85.2	90.2	63.4	100
Subtropical	Numbers	0	9	1	78	7	17	13	27	20	16	19	12	11	20	0	16	23	28	4	16	19	47	0
	%	0	52.9	6.2	8.3	2.6	2.1	1.1	13.3	3.3	2.1	12.4	15	3.3	7.4	0	6.4	10.9	11.8	5	6.4	7.1	13.8	0
Total (Numbers)		122	17	16	841	258	789	1.197	203	596	767	152	80	324	267	0	247	210	235	80	250	266	339	1

9.4 m, 10.5 m, 14 m, 33.3 m, 36 m, 40 m, 42 m, 42.8 m, 45.5 m, 50.5 m, 51.5 m, and 55 m depths; (d) Forest site elements abundant, but aquatic and moist grassland elements occupying over 10% of the total number of pollen grains and waste grassland element less than 10%, there were three such sedimentary layers: at: 15 m, 16 m, and 24 m depths; (e) Aquatic or moist grassland elements most abundant, up to 59.3% of the total number of pollen grains, there was only one such sedimentary layer which was at 29.8 m depth but 29 layers contained pollen from aquatic plants and concentricyst spores from lake plants. In the following 14 layers no aquatic palynomorphs were observed; 4 m, 5.9 m, 14 m, 15 m, 16 m, 19 m, 20 m, 22.5 m, 33.8 m, 36 m, 36.8 m, 42 m, 44 m and 50 m; (f) Waste grassland element most abundant, there were four such sedimentary layers at: 3 m, 19 m, 27.5 m, and 41 m depths; (g) Waste grassland elements, and aquatic or moist grassland elements more abundant than forest site elements, there were only two such sediemntary layers at: 3 m, and 19, depths.

The above data, shows that the forest sites elements were abundant through most of the geological times, next comes the waste grassland elements and the last the aquatic or moist grassland elements. Therefore, the habitat in this area has nearly always been occupied by forests, surrounding a shallow lake and never by marine elements such as were observed in the Neihu profile (Chung & Huang, 1972b).

B. Vegetation types (see Fig. 2).

The past vegetation types were mainly identified on the basis of dominant tree pollen grains, but dominant herbaceous pollen grains are also listed as a supplementary evidence to indicate the climatic, and habitat conditions.

The forest types were represented by an ecological unit such as an association of trees and a subassociation for grassland. The vegetation types for each stratigraphic layer were analysed as follows:

1 m depth.

Pasania/Castanopsis association.

Compositae/Urticaceae subassociation.

1.5 m depth.

Pasania/Theaceae association and no herbaceous plant was dominant.

2.5 m depth.

Pasania association with no herbaceous plants dominant.

3 m depth.

Alnus/Myrica association.

Grass/Cyperaceae-*Polygonum* subassociation.

4 m depth.

Alnus/Symplocos association.

Cyperaceae subassociation.

4.5 m depth.

Alnus/Symplocos association.

Grass/Cyperaceae-Cruciferae-Compositae subassociation.

5.9 m depth.

Symplocos/Quercus (*Pasania-Castanopsis-Alnus*) association.

Euphorbiaceae/Grass subassociation.

7.9 m depth.

Alnus/Quercus (*Symplocos-Hydrangea*) association.

Compositae/Cyperaceae-Grass subassociation.

8.4 m depth.

Alnus/Quercus (*Pasania*-Elaeocarpaceae-*Carpinus*-Rhamnaceae-*Liquidamber*-*Pinus*) association.

Campaunlaceae-Grass/Euphorbiaceae subassociation.

9.4 m depth.

Quercus/Alnus-Elaeocarpaceae (*Castanopsis*-*Carpinus*-*Pinus*-*Symplocos*-*Pasania*) association.

Grass/Compositae (Cyperaceae-*Myriophyllum*) subassociation.

10.5 m depth.

Alnus/Symplocos (*Pinus*-*Pasania*-*Caprinus*-*Liquidamber*) association.

Grass/Cyperaceae (Cruciferae) subassociation.

11 m depth.

Quercus/Alnus-*Symplocos* association.

Cruciferae/Grass subassociation.

13 m depth.

Pasania/Alnus-*Symplocos*-*Castanopsis*-*Pinus* (*Ilex*-Ericaceae-*Liquidamber*-*Carpinus*-Magnoliaceae) association.

Cyperaceae-Grass/*Justicia*-Cruciferae-Umbelliferae subassociation.

14 m depth.

Alnus/Symplocos association with no herbaceous plants dominant.

15–16 m depth.

Symplocos association.

Cyperaceae subassociation.

22.5 m depth.

Magnoliaceae were abundant, but few grains were extracted, and no dominant community can be suggested.

24 m edpth.

Pasania/Symplocos association and no herbaceous plant was dominant.

27.5 m depth.

Moraceae association and Grassland subassociation.

29.8 m depth.

Symplocos/Polygonum association.

33.3 m depth.

Castanopsis/Quercus (*Alnus*-*Myrica*-*Pinus*-*Pasania*-*Symplocos*) association.

Grass/Cyperaceae-Compositae subassociation.

36 m depth.

Pasania/Quercus (*Symplocos*-*Carpinus*-*Tsuga*) association.

Grass/Cyperaceae subassociation.

38 m depth.

Pasania/Quercus-*Alnus* (Magnoliaceae-*Pinus*-*Ilex*-*Alnus*) association.

Grass/Cyperaceae subassociation.

38.8 m depth.

Pasania/Magnoliaceae-*Quercus* (*Alnus*-*Ilex*-*Pinus*-*Ulmaceae*) association.

Grass/Cyperaceae (Menispermaceae) subassociation.

39.5 m depth.

Pasania/Castanopsis-*Pinus* (*Tsuga*-*Alnus*-*Ilex*-Ericaceae-*Quercus*-*Carpinus*) association.

Grass/Onagraceae-Menispermaceae subassociation.

40 m depth.

Viburnum/Ilex-Pasania (*Castanopsis*) association.

Menispermaceae/Grass subassociation.

41 m depth.

Alnus/Magnoliaceae association.

Grass subassociation.

42 m depth.

Castanopsis/Pasania (*Symplocos-Ilex*) association.

Grass subassociation.

42.8 m depth.

Quercus/Pasania (*Castanopsis-Alnus-Tsuga-Pinus-Cunninghamia*) association.

Grassland subassociation.

45.5 m depth.

Viburnum/Quercus (*Pasania-Castanopsis-Symplocos-Tsuga-Pinus*) association.

Grassland subassociation.

48 m depth.

Quercus/Carpinus (*Pasania-Pinus*) association.

Myriophyllum/Grass-Cruciferae-Compositae) subassociation.

50 m depth.

Quercus/Castanopsis (*Symplocos-Carpinus-Liquidamber*-Ulmaceae) association.

Myriophyllum/Grass subassociation.

50.5 m depth.

Castanopsis/Pasania association.

Compositae/Grass subassociation.

51.5 m depth.

Quercus/Castanopsis (*Viburnum-Symplocos-Ilex-Tsuga*) association.

Grass/Cyperaceae subassociation.

53.7 m depth.

Castanopsis/Pasania-Symplocos (*Quercus-Tsuga-Picea*) association.

Grass/Cyperaceae subassociation.

55 m depth.

Symplocos/Ilex (*Pasania*-Meliaceae-*Tsuga*) association.

Grass/Cyperaceae-Umbelliferae-Compositae) subassociation.

Some cold temperate elements were found in small amounts in many warm temperate stratigraphic layers, these palynomorphs, perhaps, can be treated as allopatric palynomorphs and exclude the existence at the area, for instance, pollen grains of *Tsuga* were found in the sediments of 1 m, 1.5 m, 7.9 m, 27.5 m. 33.3 m, 36.8 m 38.3 m, 40 m, 41 m, 42 m, 45.5 m, and 50 m, and *Abies* were found in the sediments of 8.4 m, 38.3 m, and 55 m.

Dominant tree species varied slightly in the different stratigraphic layers, but all compositions belonged to the warm temperate elements of Lauro-Fagaceae association, except that the subtropical element of Moraceae was dominant only at the depth of 27.5 m. The above data also suggested that the forest type of vegetation constantly prevailed from the past to the present, and no evidence of deforestation has occurred here. Unfortunately this result tells us that our selection of this profile as a control site to investigate the initial time of grassland formation of Puli Basin was a mistake.

C. Climatic condition (see Table 5, Fig. 2).

In the presentation of past climatic conditions, most palynologists only utilize the knowledge of the dominant indicator tree pollen grains and their climatic factors, but in this paper, the past climatic conditions are analysed on the basis of the percentage of whole palynomorphs which can be grouped into particular climatic conditions, and the suggestion of the possible past climate in this area is as follows:

(a) Warm temperate pollen elements were absolutely dominant, when this element appeared as more than 90% of the total pollen grains, there are nineteen such sedimentary layers: 1.5 m, 2.5 m, 4 m, 4.5 m, 5.9 m, 9.4 m, 11 m, 14 m, 15 m, 22.5 m 24 m, 29.8 m, 33.3 m, 33.8 m, 36 m, 36.8 m, 39.5 m, 50.5 m, and 53.7 m depths.

(b) Warm temperate pollen elements were abundant but cool temperate elements occupied over 10%, there are three such sedimentary layers: 13 m, 40 m, and 55 m depths.

(c) Warm temperate pollen elements were abundant, but subtropical element occupied over 10%, there are eight such sedimentary layers: 1 m, 3 m, 8.4 m, 10.5 m, 38.3 m, 41 m, 50 m, and 55 m depths.

(d) Warm temperate pollen elements were abundant, but subtropical element equalled the number of cool to cold elements, there were two such sedimentary layers: 16 m and 36.8 m depths.

(e) Subtropical pollen element were abundant, there was only one such sedimentary layer: 27.5 m depth.

According to the above data, warm temperate climate has been prevailing in the Waichiataoken area, except there was a subtropical climate at the depth of 27.5 m. In some of the other stratigraphic layers, the climatic conditions were also mainly warm temperate but tended to be cool at the depths of 13 m, 40 m and 42 m, or tended to be hot at the depths 8 m, 6 m, 3 m, 8.4 m, 10.5 m, 38.3 m, 41 m, 48 m and 50 m. The dominant climate at depths of 40 m and 55 m was warm temperate but there also appeared a large amount of cool temperate and subtropical elements, which might suggest that the vegetation at these two periods was complex.

CONCLUSION

1. The past climax plant community here was identified as having been a Lauro-Fagaceae association since the upper Pliocene to Pleistocine? or Recent? except that at the depth of 27.8 m grassland was dominant.

2. A warm temperate climate has been prevailing in this area except that there were climatic fluctuations toward cool or hot during some periods.

3. Aquatic pollen and concentricyste spores were found in more than 2/3 of the total layers studied. Perhaps, the habitat of this area was a lake surrounded by hard-wood forests in the past geologic times.

4. Since there was no evidence for deforestation or grassland formation found in the Waichiataoken profile II during the Recent? period, the selection of this control site was not appropriate for realizing the main objective of this investigation.

5. Based on the combination of climatic data and vegetation types deducted from the dominant forest types and floral composition which were used to indicate the particular climatic condition, three pollen zones were recognized. They were: A zone from depths 0 to 19 m which was again subdivided into four subzones,

namely subzone A1, at the depths of 0 to 4.5 m where the dominant vegetation type was *Pasania-Alnus/Symplocos-Castanopsis-Myrica* association and the climate was warm temperate with a tendency toward hot; subzone A2, at the depths of 4.5 m to 7.9 m where the dominant vegetation types was *Alnus-Symplocos/Quercus* association and the climate was warm temperate; subzone A3, at the depths of 7.9 m to 11 m where the dominant vegetation type was *Alnus-Quercus/Symplocos* association and the climate was warm temperate with a tendency toward hot, and subzone A4, at the depths of 11 m to 19 m, where the dominant vegetation type was *Pasania-Alnus-Symplocos/Castanopsis* association and the climate was warm temperate with a tendency toward cool; B zone from depths of 21 m to 44 m which was again subdivided into four subzones, namely subzone B1, at the depths of 21 m to 26 m where the dominant vegetation type was Grassland or *Pasania/Symplocos* association and the climate was warm temperate with a slightly hot condition, subzone B2, at the depths of 26 m to 29 m where the dominant vegetation type was Grassland association and the climate was subtropical with a tendency toward warm temperate; subzone B3, at the depths of 29 m to 37 m where the dominant vegetation type was *Pasania-Castanopsis/Quercus-Alnus-Myrica-Symplocos* association, and the climate was warm temperate, and subzone B4, at the depths of 37 m to 44 m where the dominant vegetation type was *Pasania-Quercus-Castanopsis*/Magnoliaceae-*Alnus*-

Table 6. Pollen zones, past climate and past vegetation type of Waichiataoken profile II. since upper Pliocene

Stratigraphy (m)	Vegetation (Association)	Climatic condition	Pollen Zones	
4.5	*Pasania-Alnus/Symplocos-Castanopsis-Myrica*	toward hot	A_1	A
7.9	*Alnus-Symplocos/Quercns*	toward warm	A_2	
11.0	*Alnus-Quercus/Symplocos*	toward hot	A_3	
19.0	*Pasania-Alnus-Symplocos/Castanopsis*	toward cool	A_4	
26.0	Grassland and *Pasania/Symplocos*	toward warm	B_1	B
27.5	Grassland	toward hot	B_2	
37.0	*Pasania Castanopsis/Quercus-Alnus-Myrica-Symplacos*	toward warm	B_3	
44.0	*Pasania-Quercns-Castauopsis/Alnus-Ilex*	warm with wide fluctuation toward cool and hot	B_4	
50.5	*Quercus/Carpinus-Pasania-Castanopsis*	toward hot	C_1	C
53.8	*Quercus-Castanopsis/Pasania-Ilex-Symplocos*	toward warm	C_2	
60.0	*Symplocos/Ilex*	warm with wide fluctuation toward cool and hot	C_3	

Ilex association, and the climate was warm temperate with a wide variation between cool and hot climatic fluctuations; C zone from depths 44 m to 60 m which was again subdivided into three subzones, namely subzone C_1, at the depths of 44 m to 50.5 m where the dominant vegetation type was *Quercus/Carpinus-Pasania-Castanopsis* association, and the climate was warm temperate with a tendency toward hot; subzone C2, at the depths of 50.5 m to 53.8 m where the dominant vegetation type was *Quercus-Castanopsis-Pasania-Ilex-Symplocos* association, and the climate was warm temperate; and subzone C3, at the depths of 53.8 m to 60 m where the dominant vegetation type was *Symplocos/Ilex* association and the climate was warm temperate with a considerable variation of cool and hot climatic fluctuations.

The above statements regarding past successive series of plant communities and their climatic fluctuation for this area can be seen in Table 6.

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