PALEOECOLOGICAL STUDY OF TAIPEI BASIN

(1) Taipei Botanical Garden[1]

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Abstract: The samples for this palynological study were taken from a sedimentary deposit in the central part of the Taipei Basin, namely the Taipei Botanical Garden. Soil was sampled to a depth of 44.8 m. and covered all ranges of the Sungshan Gravel Deposit. According to the different sediments, 16 samples were chosen for study. The soil composition was analysed by the methods of Bouyoucus (1936) and Day (1950, 1953). Pollen grains were extracted by chemical deflocculation by a modified Nakamura's method (1967), then permanent slides were prepared and sealed with paraffin. Based on the examination of all the permanent slides, a hypothesis was formulated for the successive series of plant communities of the Taipei Basin based on the Sungshan Deposit from about 380,000 to 4,500 years B. P. as follow:

Palmae, Cycadaceae, Cyperaceae of Tropical sunny wet lands elements (43.5 m.)→Fagaceae, Moraceae, Theacae, Elaeocarpaceae of Subtropical with increasing cool temperate forest elements (36.5-31.9 m.)→Aceraceae, Fagaceae, Theaceae, Aquifoliaceae, Betulaceae and Elaeocarpaceae of Warm temperate forest (23.6-19.3 m.)→Betulaceae, Cyperaceae of Subtropical forest elements (16.6 m.)→Aquifoliaceae, Pinaeae, Juglandaceae and Trochodendraceae of Warm temperate forest (15.7-13.6 m.)→Fagaceae, Betulaceae, Myricaeae, Pinaceae of Subtropical forest (11.5-9.3 m.)→Myricaceae, Elaeocarpaceae, Pinaceae, Betulaceae, Fagaceae of Subtropical forest elements (7.2-1 m.)

1. INTRODUCTION

The paleoecological study of Taipei Basin has been carried out by the authors from 1969 to the present time. This paper will report the pollen analysis of Sungshan Deposit located at the Taipei Botanical Garden which is the center of the basin. Taipei Basin is in the Northern part of Taiwan, ROC. It is located at latitude 121°31′ East and longitude 25°North (Fig. 1), which is triangular in shape, the terminal point is toward the northwest where the Tanshui river empties into the sea, the base of this triangular area is formed by lines running northeast. Both the Keelung and Hsintien rivers pass through the center of this basin. According to Dr. Lin (1954, 1957, 1963, 1966, 1968), the Sungshan Deposit was that part of the Taipei Basin which was formed during the Tungling orogenic cycle in the late Pleistocene. The lower part of the basin belongs to the Toukoshan, Tananwan and Tienzuhu formations whose soil components are gravels and laterizated soil. The Sungshan Deposit is located between the upper part of the Tienzuhu formation and the lower part of Taipei peat formation which was formed from about 4,500 to

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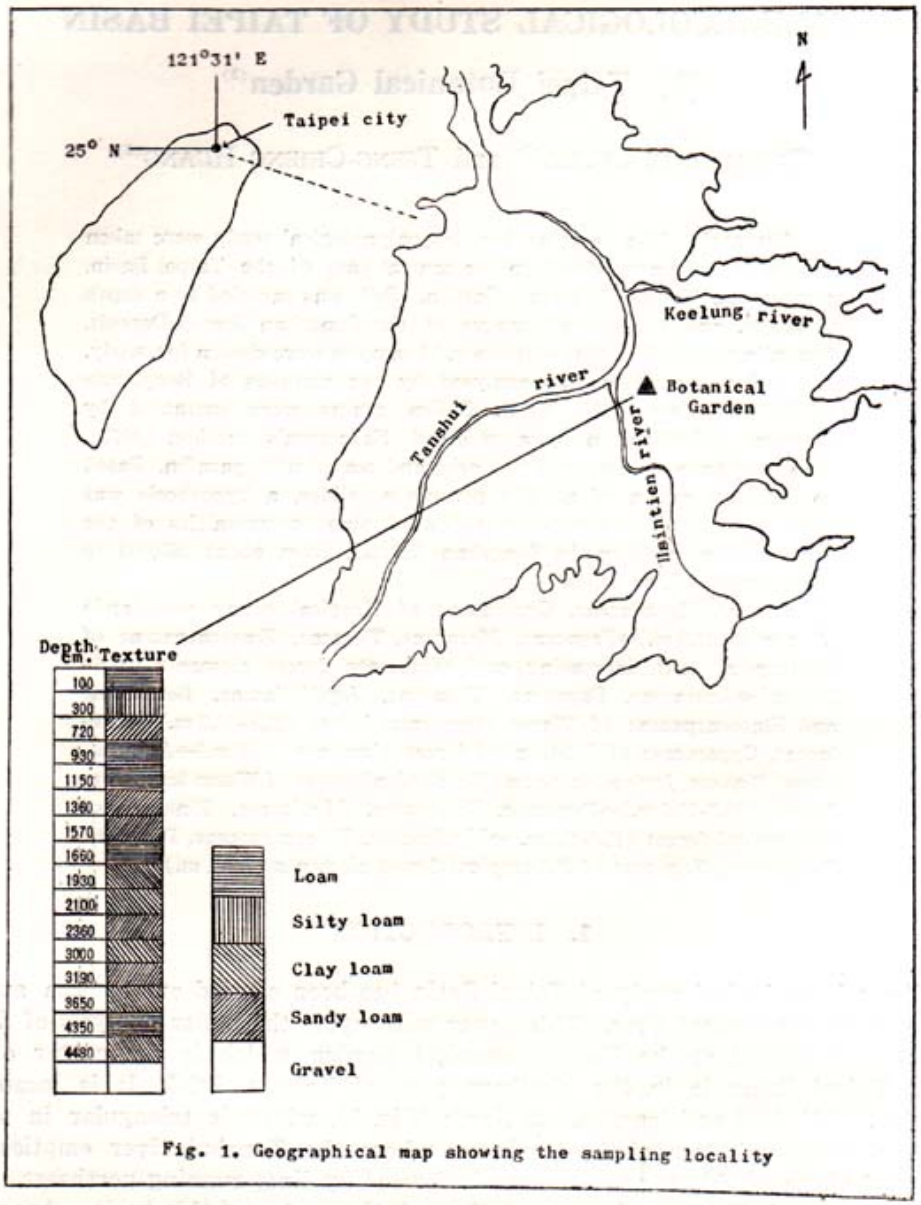


Fig. 1. Geographical map showing the sampling locality

380,000 years B. P. according to C^{14} dating. The geohistorical time scale for Taipei Basin is listed in Table 1.

Pollen analysis has been done by Masamune and Kohayakawa (1942), Masamune & Nakamura (1940), Ling (1964) and Tsukada (1966, 1967) in Taiwan. Only the last author attempted to correlate his results with the late pleistocene climatic sequence. This work is also intended to trace the vegetational history and to interprete the climatic sequence of late Pleistocence of Taipei Basin in terms of plant community sucession from fossil pollen grains.

Table 1. Taiwan Quaternary geohistorical time scale (Lin, 1966)

Taipei Basin	Epoch		Absolute Age (B. P.)	Eustatic Movement
Peipin formation	HOLOCENE		1,200	Regression Transgression
Taipei peat formation			4,500	Regression Transgression Regression Transgression
Sungshan formation			10,000	Regression Transgression Regression Transgression Regression Transgression
	PLEISTOCENE	Late	50,000	Regression Transgression Regression Transgression
Tienzuhu formation			380,000	Regression
		Middle		Transgression
Tananwan formation			550,000	Regression
Toukoshan formation		Early	2,000,000	Transgression

2. MATERIALS AND METHODS

1. Soil samples from a depth of 44.8 m. were taken by rotary drill in the Taipei Botanical Garden. Based on different sediments due to the eustatic movement, 16 samples were chosen for analysis.

2. Soil analysis: Soil components were analysed by the methods of Bouyoucus (1936), and Day (1950, 1953). The components and textures are listed in Table 2.

3. Pollen analysis: Soil samples were treated with 3–5 cc of 15% of KOH, stirred and boiled for 5 min. After cooling they were centrifuged at 3,000 rpm for 5 min. and the supernant was decanted. The remainder was washed with distilled water three times, 3–5 cc of $ZNCL_2$ solution (with specific gravity of 1.8–2.0) was added, then the supernant was collected. The supernant was washed with distilled water three times, and 4 cc of 50% glycerine was added. Either single or group mounts of pollen were prepared in glycerine jelly and sealed with paraffin.

4. Observation and identification: Olympus and Nikon binomal microscopes were used for the observation of the prepared slides and photomicrographs were taken by Olympus Photomax microscope. The identification of the palynomorphs in this study is based on the works of Erdtman (1952, 1954, 1957), Harris (1955), Huang (1966–1968, 1970, 1972), Huang and Chen (1969), Huang and Chung (1971), Huang and Wong (1968), Ueno (1960, 1962) and Wodehouse (1932–1933, 1935), but palynomorphic description mainly follows that of Huang's recent publication (1972).

5. Results: More than 4,000 microfossils were analysed; about 50% of the records were fern spores and the other 50% were pollen grains. 12 families of the pteridophyta and 54 families gymnosperms and angiosperms were identified. The

Table 2. Soil components and texture of various sediments

Characters / Depth (cm)	Texture	Color	Sand (%)	Silt (%)	Clay (%)
100	Loam	Yellow	5	50	45
300	Silty clay	Yellow with white spots	2	42	56
720	Sandy loam	Brown	10	60	30
930	Loam	Brown	8	48	44
1,150	Loam	Light green	4	50	46
1,360	Sandy loam	Yellow	10	65	25
1,570	Sandy loam	Greyish-green	10	70	20
1,660	Loam	Greyish-brown	14	50	36
1,930	Clay loam	Grey	0	36	64
2,100	Clay loam	Greyish-brown	44	28	28
2,360	Sandy loam	Light green	8	52	40
3,000	Clay loam	Greyish-brown	37.5	34.5	28
3,190	Sandy loam	Greyish-brown	10	65	25
3,650	Clay loam	Greyish-brown	40	31	29
4,350	Loam	Brown	12	40	48
4,480	Clay loam	Greyish-brown	35	35	30

result is shown in Table 3 and Pollen Diagram No. 1.

3. RESULTS (PALYNOMORPHS OF THE FAMILIES)

A. PTERIDOPHYTA: Fern spores are abundant in every sediment but with limited references at hand, the identification is rather difficult at the present time. The following publications: DeVol (1966), Erdtman (1952, 1954, 1957), Harris (1955), Kremp (1965), and Pokrovskaya (1950) are referred to for identification. The present distribution of ferns in Taiwan is widely distributed among the various types of forest communities.

1. ASPIDIACEAE

Grains monolete; bilateral symmetry; lateral view kidney shape, polar view elliptic; 50×37μ; aperture 15–20×2–4μ; exine psilate, 1–1.5μ thick.

2. DAVALLIACEAE Pl. 1: 9–14

Grains monolete; bilateral symmetry; lateral view kidney shape, polar view elliptic; 18–35×13–17μ; exine with verrucate processes, 1–1.5μ thick.

3. DIPTERIDACEAE

Grains monolete; bilateral symmetry; lateral view kidney shape, polar view elliptic; 30–45×17–30μ; aperture 12×2μ; exine psilate, 1–1.5μ thick.

4. POLYPODIACEAE (sensu stricta) Pl. 2: 4–11

Grains monolete; bilateral symmetry; lateral view kidney shape, polar view elliptic; 25–62×20–44μ; exine psilate or with verrucate or gemmate processes, 1.5–2μ thick.

5. ADIANTACEAE

Grains trilete; polar view triangular shape; 50–59μ wide for the longest diameter in polar view; exine psilate, 1.5μ thick.

6. ANGIOPTERIDACEAE Pl. 1: 1–2

Table 3. Numbers of pollen and spore appearing in the sediments

Contents / Depth (cm)	Classified grains				Non-classified grains		Spore/ Pollen	Total	Identified grains								Non-identified grains					
	Spores		Pollen						Total		Gymno-sperm		Dicot.		Mono-cot.		Total		Dicot.		Mono-cot	
	Number	%	Number	%	Number	%	Ratio		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
100	77	68.1	33	28.4	4	3.5	2.30	114	23	70	5	15	13	45	5	15	10	30	5	15	5	15
720	209	61	136	39	0	0	1.50	345	99	72.7	8	6	77	56.2	14	10.5	37	27.3	35	26.8	2	0.5
930	247	31	525	68	6	1	0.47	788	403	77	12	2.3	306	58.7	85	16	122	23	75	14	47	9
1,150	352	48	377	51.4	4	0.6	0.90	723	293	77.7	23	6.1	194	51.6	76	20	84	22.3	74	19.6	10	2.7
1,360	72	38	144	60.6	3	1.4	0.63	189	88	77.2	3	2.6	64	56	21	18.6	26	22.8	19	16.6	7	6.2
1,570	217	80	52	20.0	0	0	4.00	269	37	74	6	12	11	22	20	40	15	26	2	4	13	25
1,660	77	41.2	106	56.6	4	2.2	0.72	187	81	71	13	7.2	47	44	21	19.8	25	29	15	14.2	10	9.8
1,930	155	52.9	137	46.7	1	0.4	1.12	293	94	67	10	7.7	15	38.3	29	21	43	33	20	15.3	23	16.7
2,100	26	21.9	89	74.8	4	3.3	0.29	119	54	59.7	3	3.4	43	47.3	8	9	35	40.3	20	23.3	15	17
2,360	112	58.5	74	38.7	5	2.8	1.50	191	56	75	6	8	32	43	18	24	38	25	5	6.8	13	18.2
3,190	109	55.4	81	41.3	5	3.3	1.40	195	65	79.9	5	6.2	42	51.2	18	22.5	16	20.1	14	17.5	2	2.5
3,650	10	21.3	37	78.7	0	0	0.27	47	24	64.9	6	16.2	3	8.1	15	40.6	13	35.1	8	22	5	13
4,350	193	45	223	51.7	12	2.3	0.87	428	201	94	6	2.7	24	10.8	171	80.5	13	6	0	0	13	6

Grains trilete; subspheroidal to spheroidal; 20–30μ wide; exine with scabrate processes, 1–1.5μ thick.

7. CYATHEACEAE Pl. 1: 3–8

Grains trilete; polar view angular or concave-angular; 31–50μ wide in its longest diameter in polar view; exine psilate or striate, 2μ thick.

8. GLEICHENIACEAE Pl. 1: 15–16

Grains trilete; polar view triangular shape; 25–30μ wide; exine psilate, 1–1.5μ thick at angule and 2.5–3μ thick at sides.

9. HYMENOPHYLLACEAE Pl. 2: 1–3

Grains trilete; polar view subangular; 31–43 μ wide for the longest diameter in polar view; exine with scabrate or finely echinate processes, 2μ thick.

10. MARATTIACEAE Pl. 1: 17–18

Grains trilete; subspheroidal; 20–30μ wide; exine with echinate or scabrate, processes, 1–1.5μ thick.

11. PTERIDACEAE Pl. 2: 12–18 & Pl. 3: 1–2

Grains trilete; polar view triangular shape; 35–50μ wide in polar view; exine with scabrate or verrucate processes on distal face, with smooth equatorial ridge, 1.5–2μ thick.

12. SELAGINELLACEAE Pl. 3: 3–6

Grains trilete; subspheroidal or spheroidal; 30–43μ wide; exine with gemmate or echinate and baculate processes, 1.5–2.5μ thick.

B. GYMNOSPERMAE

The saccate grains of the gymnosperms are difficult to distingush at the intraspecific level. Size has frequently been used by palynologists, although it is not an accurate method for identification.

1. CYCADACEAE (*Cycas*) Pl. 3: 7–8

Grains 1-colpate; 20–25×15–20μ; furrow rounded at both ends; exine psilate, 1μ thick; sexine granulate. The pollen morphology of this family is very similar to that of the Ginkgoaceae, and some genera of Magnoliaceae and Palmae.

Present distribution: This is distributed in tropical forests at altitudes below 500 m. high.

2. GINKGOACEAE (*Ginkgo*) Pl. 3: 9

The grains of *Ginkgo* are similar to those of *Cycas*, but are much more smaller than the *Cycas* grains.

Present distribution: This relic species is only cultivated at Chitou, N. T. U. Experimental Forest Station at altitudes of about 1,000 m. high.

3. PINACEAE Pl. 3: 10–17 & Pl. 4: 1–5

Grains saccate; 50–150×40–70μ; sac rounded, reticulate; exine of cap 2–3μ thick; sexine irregularly reticulate or granulate (*Pinus*, *Abies* or *Picea*).

Grains inaperturate or ring-saccate; 70–80μ wide; exine psilate or with echinate processes, 2–4μ thick (*Tsuga*, *Pseudotsuga*?).

Present distribution: These are distributed from subtropical to frigid climate zones at altitude from 800–3700 m. high. It is found in the mixed forest of hardwoods and conifers or in pure coniferous stands.

4. PODOCARPACEAE (*Podocarpus*) Pl. 4: 6–9

The grains are very similar to those of *Pinus*, but they can be distingushed by the size and attachment of the sacs to the body and the thickness of cap.

Present distribution: This is distributed in subtropical hardwood forests at altitudes of 500–1000 m. high.

5. TAXODIACEAE Pl. 4: 10–12

Grains inaperturate or 1-colpate; exine with scabrate processes, 1μ thick; sexine granulate, neck present; 35–45μ wide for *Cunninghamia* and 28×16μ for *Cryptomeria*.

Present distribution: This is distributed in temperate, mixed forest of hardwoods and conifers at altitudes from 1800–3200 m. high.

C. DICOTYLEDONS

1. ACERACEAE (*Acer*) Pl. 5: 1–2

Grains 3-colporate; prolate; 20–25×16–18μ; exine 1–1.5μ thick; tectum with scabrate processes; sexine striate.

Present distribution: This is distributed in temperate mixed forests at altitudes of 1000–1800 m. high.

2. ACTINIDACEAE (*Actinidia*)

Grains 3-colporate; prolate; 18–20×9–12μ; ora transversally parallel; exine psilate, 1μ thick; exine granulate.

Present distribution: This is distributed in warm temperate mixed forests at altitudes 1800 m. high.

3. AMARANTHACEAE (*Celosia*)

Grains pantoporate; subspheroidal; 30–34μ wide; pores crustate; exine 1.5–2μ thick; sexine granulate.

Present distribution: This is distributed in tropical waste lands at altitudes below 500 m. high.

4. ANACARDIACEAE (*Pisticia, Rhus*) Pl. 5: 3–4

Grains 5–6-porate; subspheroidal; 25×23μ; pores non-crassimarginate; exine 1μ thick; tectum with scabrate processes; sexine granulate. (The pollen morpholgy of *Pisticia* is similar to the genus of *Plantago*).

Grains 3-colporate; prolate; 32×23μ; exine 1.5μ thick; tectum with scabrate processes; sexine striato-reticulate, with OL-pattern. (*Rhus*).

Present distribution: This is distributed in tropical to subtropical forests at altitudes below 800 m. high.

5. AQUIFOLIACEAE (*Ilex*) Pl. 5: 5–7

Grains 3-colporate; prolate; 22–27×17–20μ; exine 1–2μ thick; tectum with gemmate or clavate processes; sexine large granulate.

Present distribution: This is distributed in the subtropical to temperate mixed forests at altitudes from 500–1800 m. high.

6. ARALIACEAE (*Schefflera*) Pl. 5: 8–9

Grains 3-colporate; prolate; 22×18μ; colpi non-crassimarginate; ora H-shaped; exine 1.5 μ thick; tectum with scabrate processes; sexine reticulate, with OL-pattern.

Present distribution: This distributed in subtropical forests at altitudes from 500–1500 m. high.

7. ASCLEPIADACEAE (*Wattakaka*) Pl. 5: 10

Grains polyad; 200×100μ; exine 1μ thick; tectum psilate; sexine granulate.

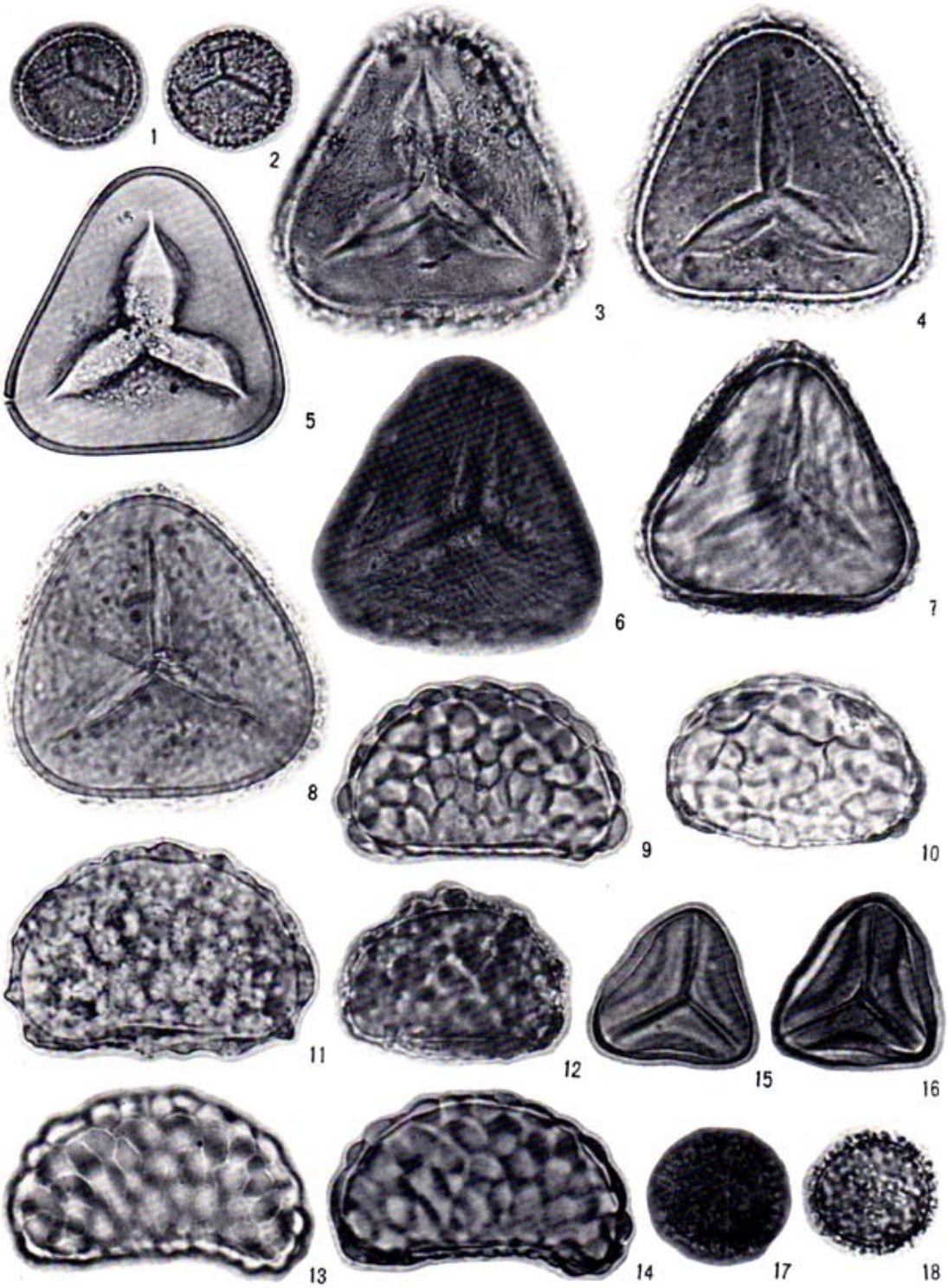
Present distribution: This distributed in subtropical forests at altitudes below 1,000 m. high.

8. BEGONIACEAE (*Begonia*)

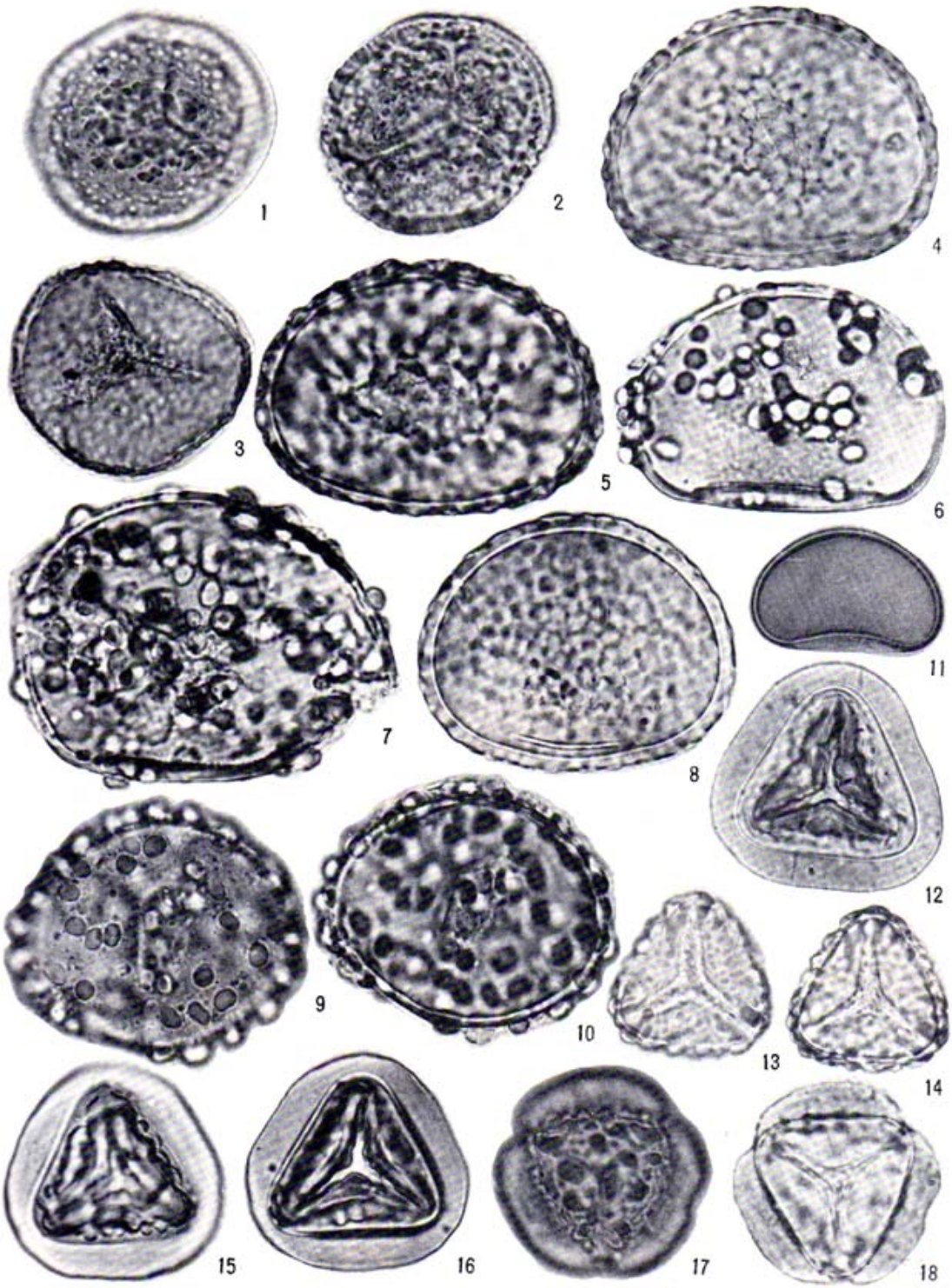
Grains 3-colporate; prolate; 17–23×11–14μ; exine 1–1.5μ thick; tectum psilate or with scabrate processes?; sexine reticulate.

Present distribution: This is distributed in subtropical forests at altitudes 500–1500 m. high.

9. BETULACEAE (*Alnus, Carpinus*) Pl. 5: 11–15



Pl. 1. 1-2, Angiopteridaceae (*Angiopteris*) TB-3150-598; 3, Cyatheaceae (*Cyathea*) TB-2200-462; 4, Cyatheaceae (*Cyathea*) TB-2200-461; 5, Cyatheaceae (*Cyathea*) TB-3150-562; 6-7, Cyatheaceae (*Cyathea*) TB-2200-442; 8, Cyatheaceae (*Cyathea*) TB-2200-400; 9, Davalliaceae (*Davallia*) TB-720-463; 10, Davalliaceae (*Davallia*) TB-1950-142; 11, Davalliaceae (*Davallia*) TB-3150-321; 12, Davalliaceae (*Davallia*) TB-1950-134; 13-14, Davalliaceae (*Davallia*) TB-3150-404; 15-16, Gleicheniaceae (*Gleichenia*) TB-3150-592, 666; 17-18, Marattiaceae (*Marattia*) TB-2200-11. 1-18, × 1000.



Pl. 2. 1-2, Hymenophyllaceae TB-4250-524; 3, Hymenophyllaceae TB-3150-712; 4-11, Polypodiaceae TB-3150-524, 325, 483, 408, 521, 437, 320; 12, Pteridaceae (*Pteris*) TB-2200-472; 13-14, Pteridaceae (*Pteris*) TB-2200-374; 15-16, Pteridaceae (*Pteris*) TB-3150-635; 17-18, Pteridaceae (*Pteris*) TB-2200-490. 1-18, × 1000.

Grains 3–6–porate; 20–24μ wide; aperture aspidate, vestibulum type and with acroid streak between the pores in genus of *Alnus;* and aperture drop type; exine psilate, 1μ thick for *Carpinus.*

Present distribution: These are distributed in subtropical to warm temperate mixed forests at altitudes 1000–1800 m. high.

10. CAMPANULACEAE (*Campanumoea*)

Grains 3–porate; 33μ wide; amb circular; tectum with echinate processes, echini loosely distributed; sexine granulate. Identification for this genus is based on the characters of exine and sexine pattern.

Present distribution: This is distributed in subtropical hardwood forests at altitudes 500–1500 m. high.

11. CARYOPHYLLACEAE (*Silene*)

Grains pantoporate; spheroidal; 50–54μ wide; pores crustate; exine 2μ thick; tectum with scabrate processes; sexine granulate.

Present distribution: This is distributed widely from subtropical forests to temperate forests at altitudes below 1500 m. high.

12. CHENOPODIACEAE (*Chenopodium*) Pl. 5: 16–21

Grains pantoporate; spheroidal; 20–25μ wide; pores 1–2μ wide; exine 1.5μ thick; tectum with scabrate processes; sexine granulate.

Present distribution: This is distributed in the tropical to subtropical waste lands at altitudes below 500 m. high.

13. CHLORANTHACEAE (*Chloranthus*)

Grains 6–colpate; 25μ wide; exine 2–3μ thick; tectum with scabrate processes; sexine reticulate. Pollen grains of this genus is similar to that of *Galium* of Rubiaceae.

Present distribution: This is distributed in subtropical forests at altitudes below 800 m. high.

14. COMPOSITAE Pl. 5: 22–23

Grains 3–colpate or 3–colporate; prolate; 18–25×14–20μ; amb circular; exine thinning toward the aperture, 2.5μ thick in intercolpate area; tectum with scabrate processes in *Artemsia*, echinate processes in other genera of Compositate.

Present distribution: This is distributed widely from tropical rain forests to cold temperate grasslands at altitudes from 500 m. to 2000 m.

15. CONVOLVULACEAE (*Stictocardia*) Pl. 5: 24–25

Grains inaperturate or pantoporate; spheroidal; 50–57μ wide; exine 2.5μ thick; tectum with clavate or baculate processes; sexine large granulate. Such pollen grains were identified by Saad and Sani (1967) as a taxon of Euphorbiaceae, but none of the Formosan genera of Euphorbiaceae have the above characters.

Present distribution: This is distributed in tropical waste lands at altitudes below 300 m. high.

16. CRUCIFERAE (*Wasabia*) Pl. 5: 26–27

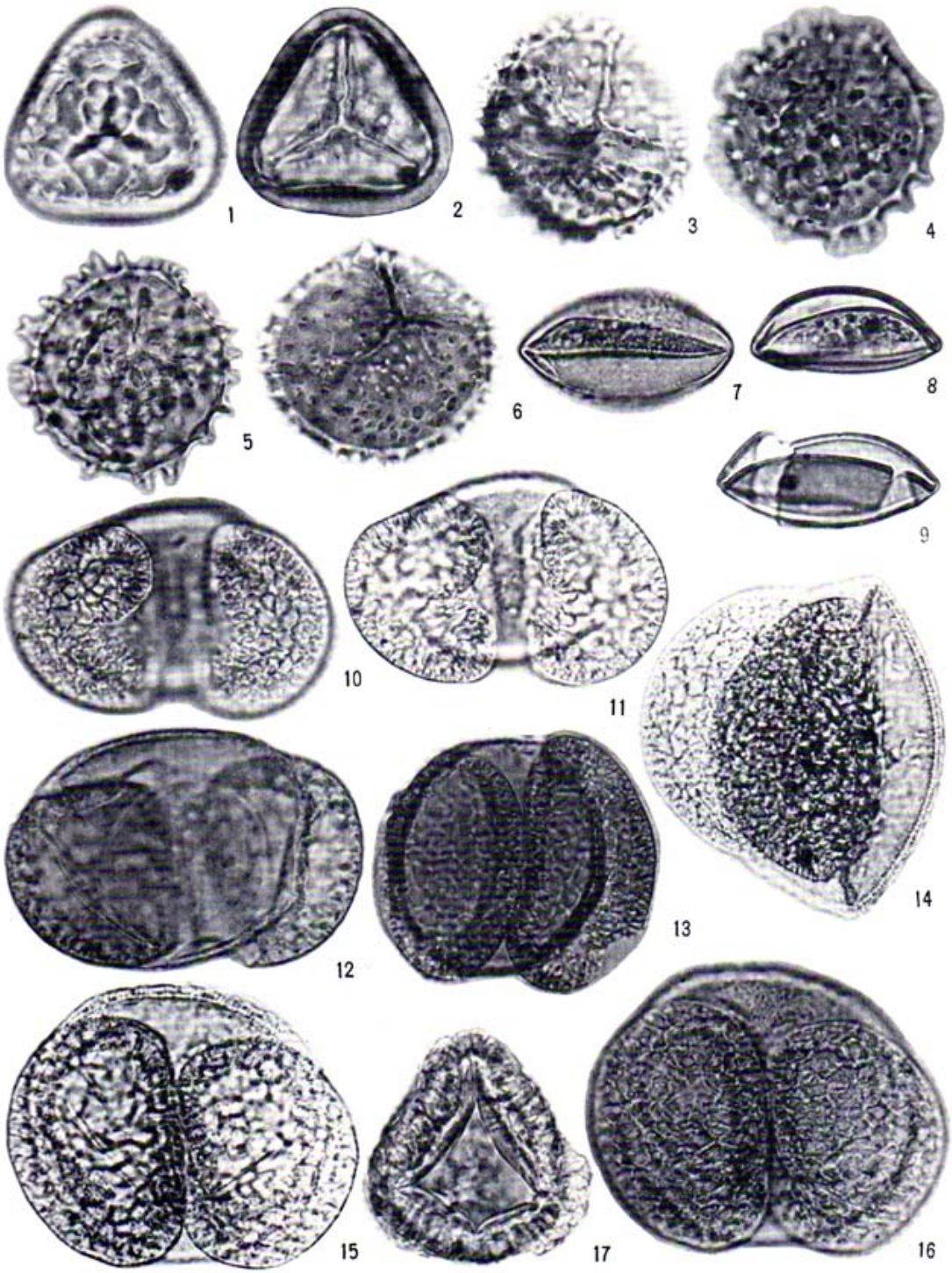
Grains 3–colpate; prolate-spheroidal; 16×15μ; exine 1μ thick; tectum with scabrate or verrucate processes; sexine reticulate, with OL-pattern.

Present distribution: This is distributed in cultivated lands.

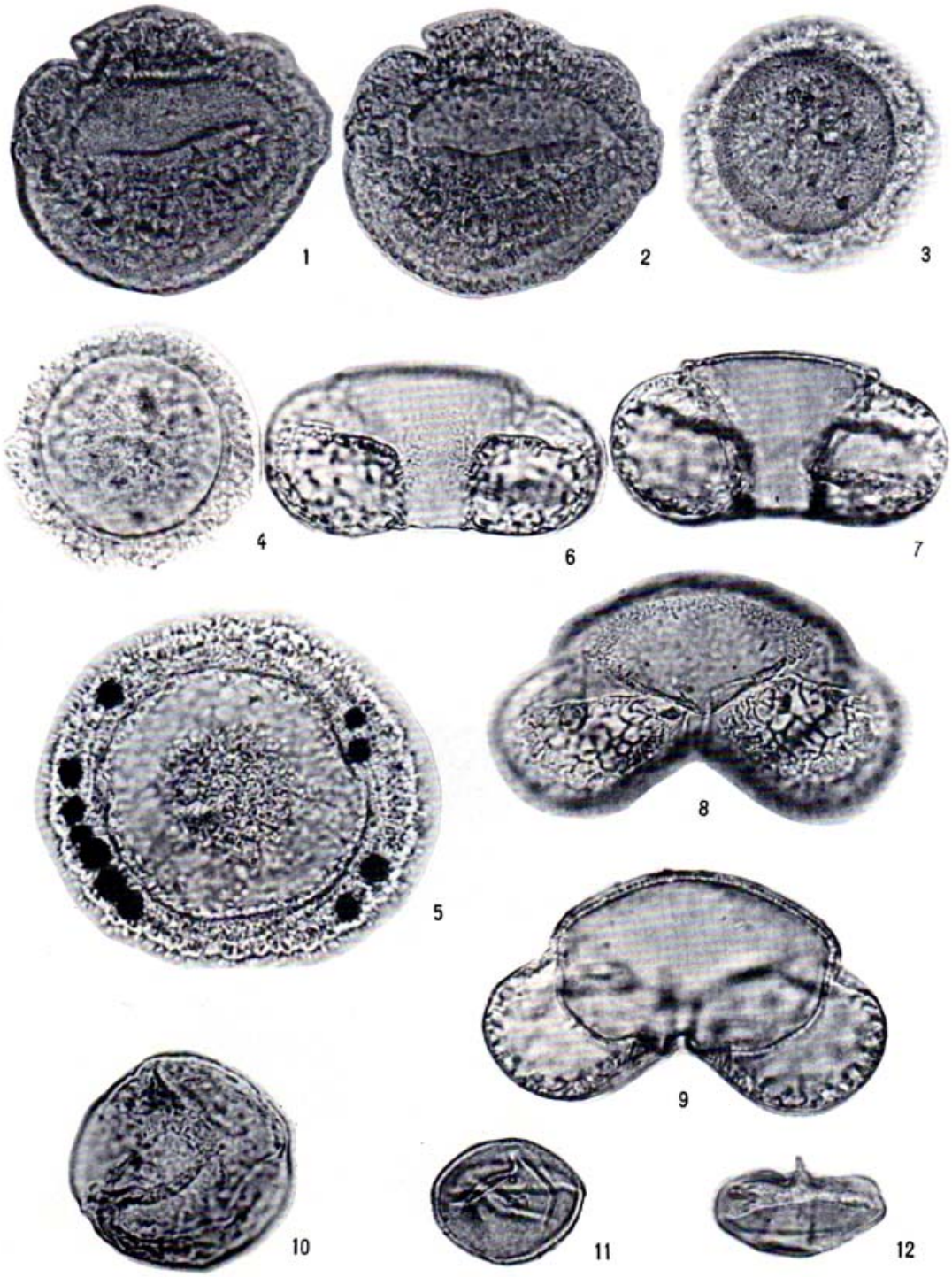
17. EBENACEAE (*Diospyros*)

Grains 3–colporate; prolate; 20–23×14–16μ; ora transversally parallel; exine 1–1.5μ thick; tectum psilate; sexine granulate.

Present distribution: This is distributed in tropical to subtropical forests at altitudes below 500 m. high.



Pl. 3. 1-2, Pteridaceae (*Pteris*) TB-3150-549; 3, Selaginellaceae (*Selaginella*) TB-1300-117; 4-5, Selaginellaceae (*Selaginella*) TB-720-5; 6, Selaginellaceae (*Selaginella*) TB-950-214; 7, Cycadaceae (*Cycas*) TB-4250-142; 8, Cycadaceae (*Cycas*) TB-3150-58; 9, Ginkgoaceae (*Ginkgo*) TB-2200-55; 10-11, Pinaceae (*Pinus*) TB-3150-1; 12, Pinaceae (*Pinus*) TB-4450-1, 13. Pinaceae (*Pinus*) TB-700-3; 14, Pinaceae (*Pinus*) TB-720-2; 15-16, Pinaceae (*Pinus*) TB-950-3; 17, Pinaceae (*Tsuga*) TB-3150-716. 1-16, × 1000.



Pl. 4. 1-2, Pinaceae (*Tsuga*) TB-1950-4; 3-4, Pinaceae (*Tsuga*) TB-1550-3; 5, Pinaceae (*Tsuga*) TB-1150-12; 6-7, Podocarpaceae (*Podocarpus*) TB-1300-2; 8-9, Podocarpaceae (*Podocarpus*) TB-1150-1; 10, Taxodiaceae (*Cunninghamia*) TB-720-4; 11, Taxodiaceae (*Cryptomeria*) TB-3150-109; 12, Taxodiaceae (*Cryptomeria*) TB-4250-1. 12, × 1000.

18. ELAEOCARPACEAE (*Elaeocarpus*) Pl. 6: 1–3

Grains 3-colporate; prolate; 11–15×8–10μ; amb circular-lobate; exine psilate, 1μ thick; sexine indistinctly granulate.

Present distribution: This is distributed in subtropical to temperate hardwood forests at altitudes below 1800 m. high.

19. ERICACEAE (*Rhododendron*) or PYROLACEAE (*Moneses*) Pl. 7: 6–8

Grains tetrad; 3-colporate; 24–35μ wide; exine psilate, 1.5μ thick; sexine granulate.

Present distribution: This is distributed in subtropical to temperate mixed forests at altitudes 1500–3500 m. high.

20. EUPHORBIACEAE (*Homalanthus*)

Grains 3-colporate; prolate; 31–50×20–29μ; ora transversally elliptic; exine 1.5–2μ thick; tectum with scabrate processes; sexine reticulate, with OL-pattern.

Present distribution: This is distributed in tropical rain forests at altitudes below 500 m. high.

21. FAGACEAE (*Castanopsis, Lithocarpus, Pasania*) Pl. 6: 4–9

Grains 3-colporate; prolate; 11–18×8–11μ; ora transversally elliptic; exine granulate.

Present distribution: These are distributed in temperate hardwood forests at altitudes 500–1800 m. high.

22. GESNERIACEAE

Pollen morphology of this family is very similar to the family of Fagaceae, but the colpi of the former is neither crassimarginate nor crustate.

Present distribution: This is distributed in subtropical forests at altitudes below 1000 m. high.

23. HAMAMELIDACEAE (*Liquidambar*) Pl. 6: 12–15

Grains pantoporate; spheroidal; 30–42 μ wide; pores crustate or with granules on its membrance; exine 1.5–2μ thick; tectum with scabrate processes; sexine reticulate, with OL-pattern.

Present distribution: This is distributed in subtropical hardwood forests at altitudes 500–1000 m. high.

24. JUGLANDACEAE Pl. 6: 16–17

Grains 3-porate; 13–23 μ wide; pores 1.5–2μ wide; exine psilate, less than 1μ thick; aperture atrium type; 13–17μ wide for *Engelhardtia;* and aperture drop type, with pseudo-colpate between the pores in *Platycarya*.

Present distribution: This is distributed in hardwood or mixed forests of hardwoods and conifers at altitudes 500–3000 m. high.

25. LYTHRACEAE (*Lagerstroemia*) Pl. 6: 18–21

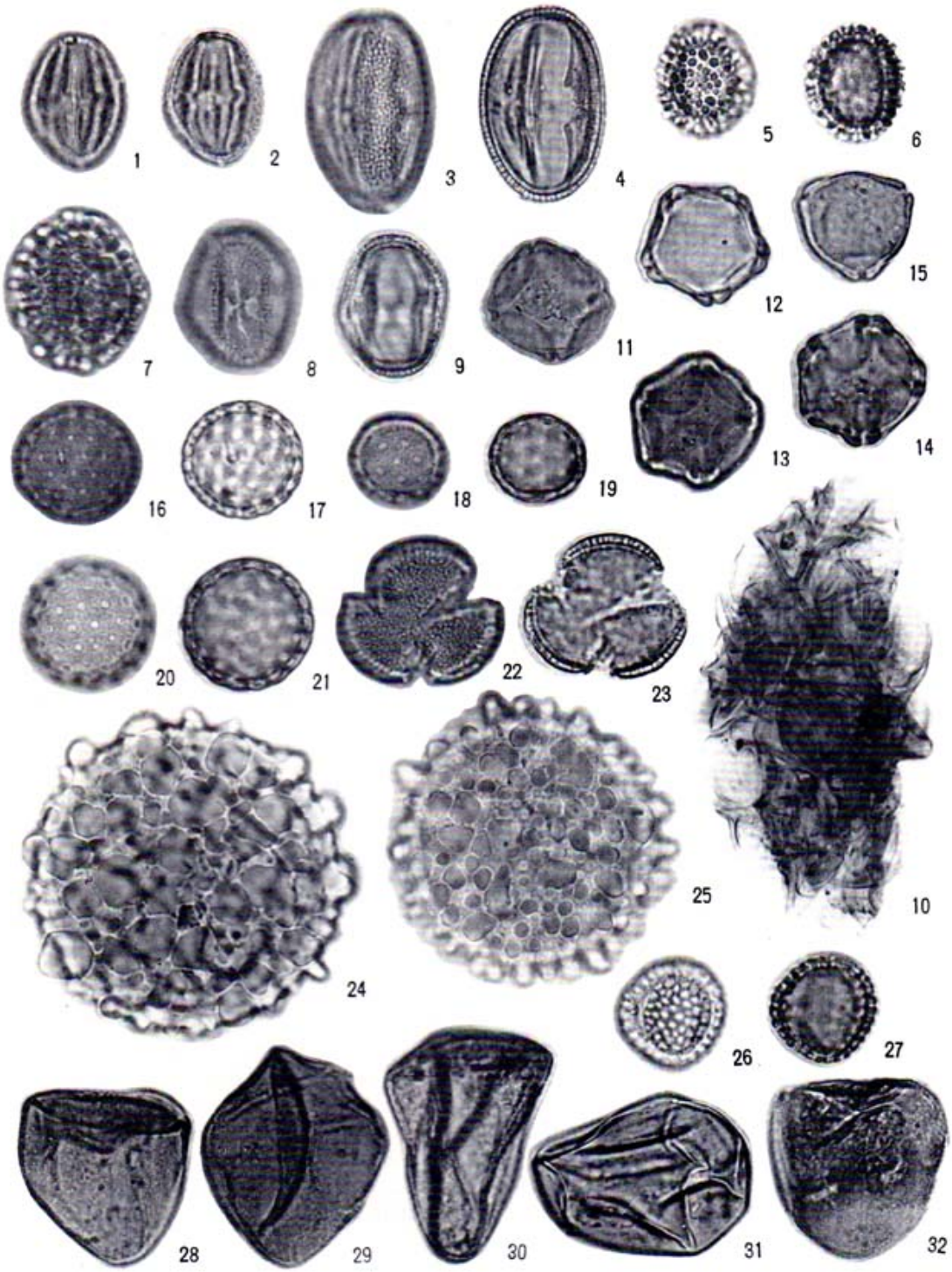
Grains 3-colporate; prolate; 28–34×23–30μ; amb inter-semi-angular; ora circular, 1.5–2μ wide; exine psilate, 2μ thick; sexine granulate.

Present distribution: This is distributed in subtropical forests at altitudes lower than 500 m. high.

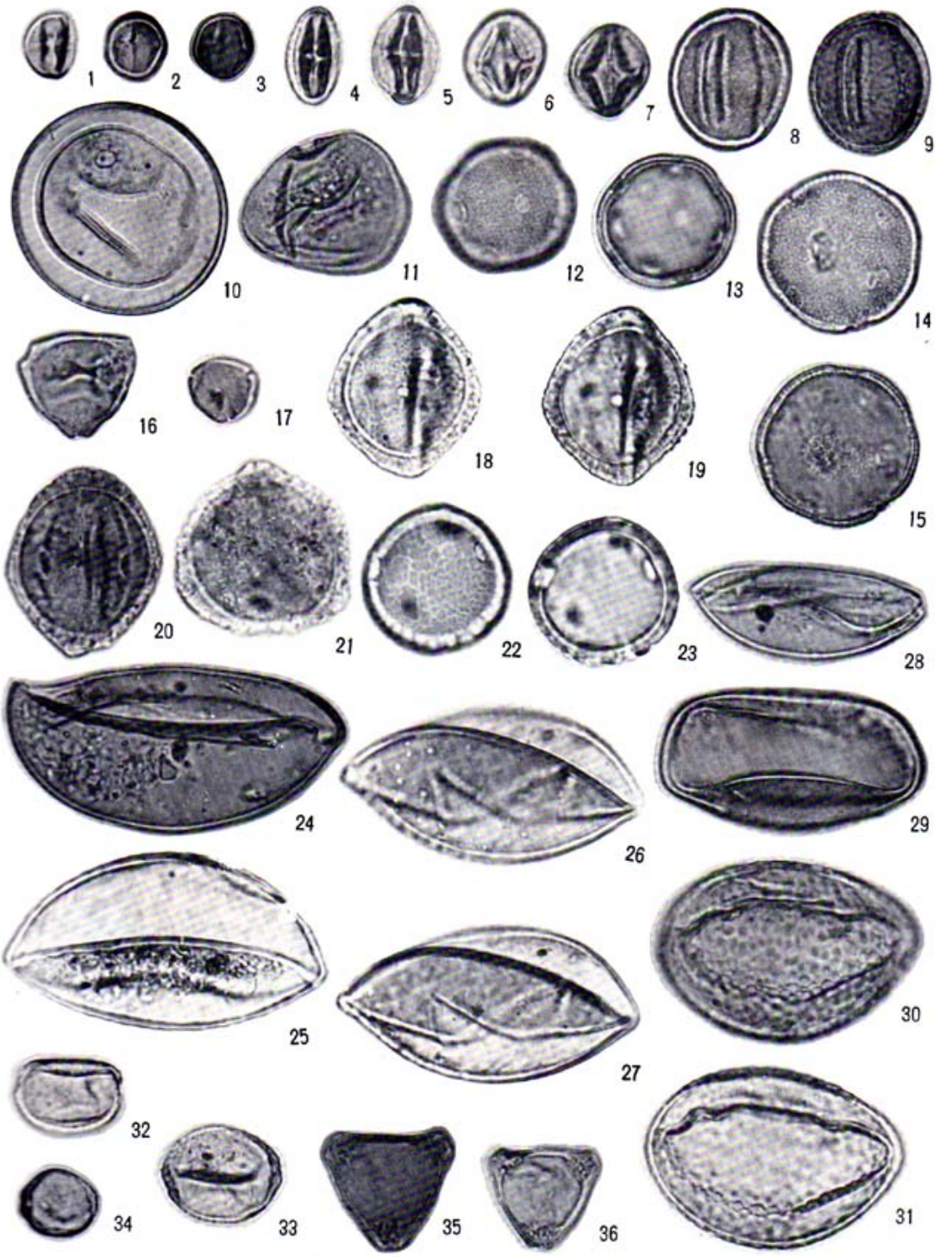
26. MAGNOLIACEAE Pl. 6: 24–31

Grains 1-colpate; elliptic or boat-shaped; exine 1–2μ thick; tectum with scabrate processes; sexine granulate; 18–45×15–25μ for *Michelia;* 52–60×24–37μ for *Magnolia* or sexine with verrucate processes; 35–47×23–28μ; colpus boat-shaped for *Liriodendron.*

Present distribution: These are distributed in subtropical to temperate hardwood or mixed forests of hardwoods and conifers, at altitudes 500–2500 m. high.



Pl. 5. 1-2, Aceraceae (*Acer*) TB-1550-189; 3-4, Anacardiaceae (*Rhus*) TB-1950-37; 5-6, Aquifoliaceae (*Ilex*) TB-1150-10; 7, Aquifoliaceae (*Ilex*) TB-1950-53; 8-9, Araliaceae (*Schefflera*) TB-700-234; 10, Asclepiadaceae (*Wattakaka*) TB-950-191; 11, Betulaceae (*Alnus*) TB-700-295; 12, Betulaceae (*Alnus*) TB-700-309; 13-14, Betulaceae (*Alnus*) TB-3150-140; 15, Betulaceae (*Carpinus*) TB-720-199; 16-17, Chenopodiaceae (*Chenopodium*) TB-720-237; 18-19, Chenopodiaceae (*Chenopodium*) TB-3150-144; 20-21, Chenopodiaceae (*Chenopodium*) TB-720-238; 22-23, Compositae (*Artemisia*) TB-700-143; 24-25, Convolvulaceae (*Stictocardia*) TB-4250-55, 49; 26-27, Cruciferae (*Wasabia*) TB-100-1; 28-30, Cyperaceae (*Cyperus*) TB-720-43, 182, 180; 31, Cyperaceae (*Cyperus*) TB-3150-39; 32, Cyperaceae (*Carex*) TB-3150-28. 1-9, 11-32, ×1000; 10, ×400.



Pl. 6. 1, Elaeocarpaceae (*Elaeocarpus*) TB-1550-382; 2-3, Elaeocarpaceae (*Elaeocarpus*) TB-2200-92; 4, Fagaceae (*Castanopsis*) TB-1550-252; 5, Fagaceae (*Castanopsis*) TB-2300-98; 6-7, Fagaceae (*Lithocarpus*) TB-2350-35; 8-9, Fagaceae (*Quercus*) TB-2200-68; 10, Gramineae TB-2200-13; 11, Gramineae TB-3150-123; 12-13, Hamamelidaceae (*Liquidamber*) TB-700-325; 14-15, Hamamelidaceae (*Liquidamber*) TB-2200-151; 16, Juglandaceae (*Platycarya*) TB-700-125; 17, Juglandaceae (*Engelhardtia*) TB-1150-39; 18-19, Lythraceae (*Lagerstroemia*) TB-1360-107; 20-21, Lythraceae (*Lagerstroemia*) TB-3150-272, 277; 22-23, Malpighiaceae (*Hiptage*) TB-1150-50; 24, Magnoliaceae (*Magnolia*) TB-700-23; 25, Magnoliaceae (*Magnolia*) TB-950-14; 26-27, Magnoliaceae (*Magnolia*) TB-1300-10; 28, Magnoliacea (*Michelia*) TB-3150-32; 29, Magnoliaceae (*Michelia*) TB-3150-60; 30-31, Magnolianceae (*Liriodendron*) TB-1150-18; 32, Moraceae (*Humulus*) TB-1150-40; 33, Moraceae (*Broussonetia*) TB-720-197; 34, Moraceae (*Broussonetia*) TB-1550-119; 35, Myricaceae (*Myrica*) TB-700-100; 36, Myricaceae (*Myrica*) TB-720-200. 1-36, × 1000.

But the genus *Liriodendron* is absent from the present Taiwan flora, it is now distributed only in Mainland China and North America.

27. MALPIGHIACEAE (*Hiptage*) Pl. 6: 22–23

Grains 5-porate; spheroidal; 23μ wide; exine 2–2.5μ thick; tectum with scabrate processes; sexine hetero-reticulate, with OL-pattern.

Present distribution: This is distributed in subtropical forests at altitudes from 500–1000 m. high.

28. MORACEAE Pl. 6: 32–34

Grains 2–4-porate; subspheroidal; 11–17μ wide; pores 2μ wide; exine psilate, 1μ thick; sexine granulate, 3–4-porate and 11–17μ wide for *Morus;* 2-porate and 14–15μ wide for *Cudramia* or *Malaisia.*

Present distribution: These are distributed in subtropical forests at altitudes below 500 m. high.

29. MYRICACEAE (*Myrica*) Pl. 6: 35–36

Grains 3-porate; 17–21μ wide; amb angular; aperture atrium type; exine psilate, 1μ thick; sexine granulate.

Present distribution: This is distributed in tropical forests at altitudes below 500 m. high.

30. MYRSINACEAE (*Maesa*)

Grains 3-colporate; prolate; 16–22×15–18μ; amb circular-lobate; ora transversally parallel; exine 1μ thick; tectum with scabrate processes; sexine reticulate. Pollen morphology of this genus is similar to that of *Salix.*

Present distribution: This is distributed in hardwood forests at altitudes below 1000 m. high.

31. OLEACEAE (*Fraxinus*) Pl. 7: 1–2

Grains 3-colporate; prolate; 17×14μ; amb circular; exine 1.5μ thick; tectum with scabrate processes; sexine reticulate, with OL-pattern.

Present distribution: This is distributed in tropical forests at altitudes below 500 m. high.

32. OPILIACEAE (*Champeria*)

Grains 3-colporate; prolate; 13–17×7–10μ; ora indistinct; exine psilate, 1μ thick; sexine granulate.

Present distribution: This is distributed in tropical forests at altitudes below 500 m. high.

33. PASSIFLORACEAE (*Modecca*)

Grains pantoporate; spheroidal; 35μ wide; pores more than 12, 1.5μ wide; exine psilate, 2μ thick; sexine granulate. Pollen grains of *Modecca* is very similar to those of *Chenopodium*, but the former are much larger than the later.

Present distribution: This is distributed in tropical forests, in the southern part of Formosa at altitudes below 500 m. high.

34. POLYGALACEAE (*Salomonia*)

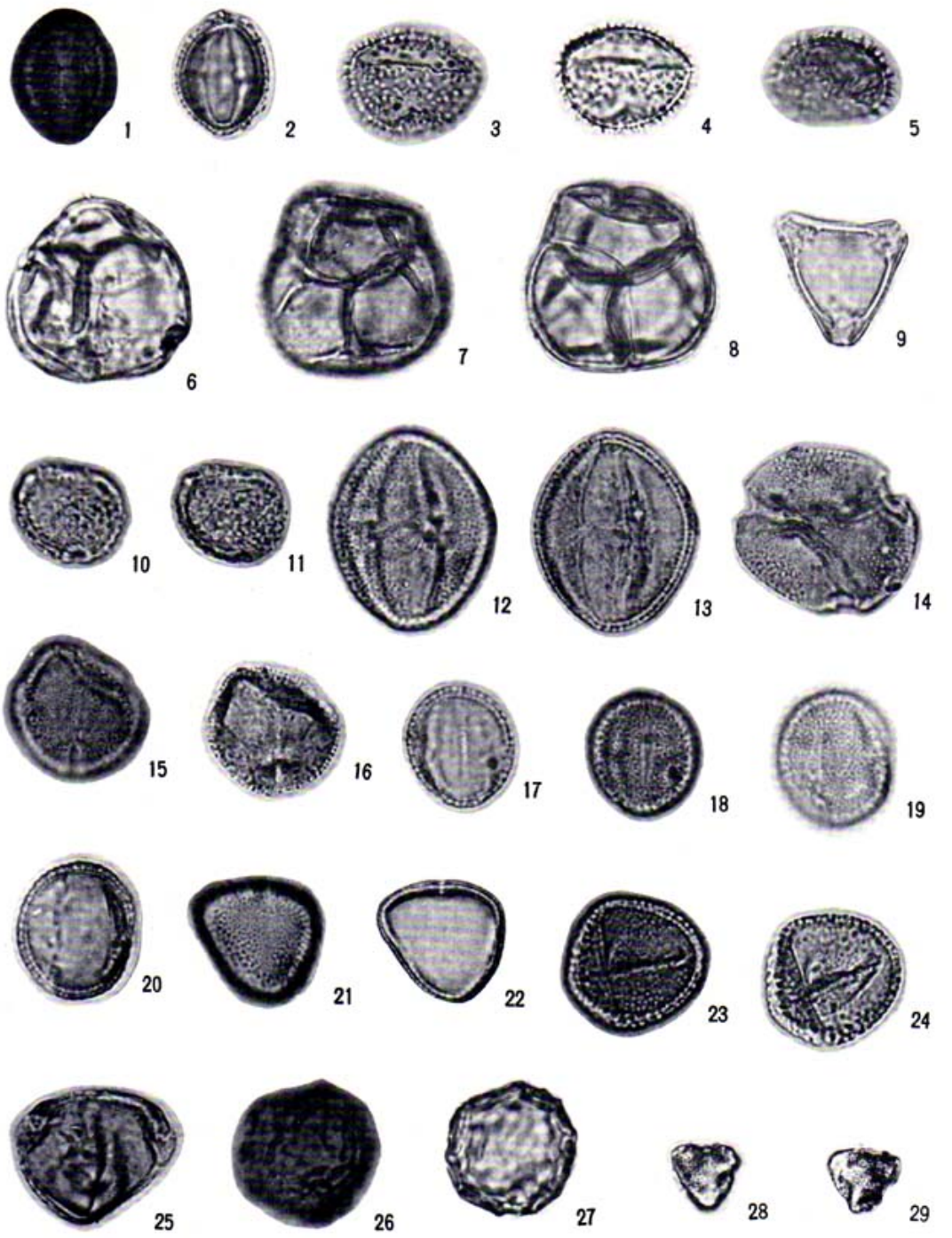
Grains pantocolporate; 40–45μ wide; exine psilate, 1.5μ thick; sexine granulate.

Present distribution: This is distributed in subtropical to tropical forests at altitudes below 800 m. high.

35. POLYGONACEAE (*Polygonum*)

Grains pantoporate or 3-colporate; prolate or spheroidal; 50μ wide or 32–35×23–27μ in 3-colporate grains; exine 2–3μ thick; tectum with scabrate processes; sexine reticulate.

Present distribution: This is distributed in temperate to tropical forests at



Pl. 7. 1-2, Oleaceae (*Fraxinus*) TB-700-148; 3-4, Pandanaceae (*Pandanus*) TB-1150-13; 5, Pandanaceae (*Pandanus*) TB-1950-5; 6-5; 6-8, Pirolaceae (*Moneses*) TB-700-2, 1; 9, Proteaceae (*Helicia*) TB-720-209; 10-11, Rubiaceae (*Randia*) TB-1550-121; 12-13, Rubiaceae (*Tarenna*) TB-950-73; 14, Rubiaceae (*Tarenna*) TB-1550-442; 15-16, Salicaceae (*Salix*) TB-720-347; 17-18, Salicaceae (*Salix*) TB-1950-40; 19-20, Trochodendraceae (*Trochodendron*) TB-700-159; 21-24, Typhaceae (*Typha*) TB-3150-108, 69; 25, Ulmaceae (*Trema*) TB-700-114; 26-27, Ulmaceae (*Ulmus*) TB-720-6; 28-29, Umbelliferae (*Foeniculum*) TB-1550-312. 1-29, × 1000.

altitudes below 1800 m. high.

36. PROTEACEAE (*Helicia*) Pl. 7: 9

Grains 3-porate; 17–23μ wide; pores 1.5–2μ wide; amb angular; aperture club type; exine 1μ thick; tectum psilate; sexine granulate.

Present distribution: This is distributed in the subtropical to hardwood forests at altitudes below 1500 m. high.

37. PRIMULACEAE (*Androsace*)

Grains 3-colporate; subspheroidal; 11–12×11μ; amb circular; exine psilate, 1μ thick; sexine indistinct pattern. It is difficult to distingush this from Elaeocarpaceae, the aperture of the former being distinct but the later indistinct.

Present distribution: This is distributed in subtropical forests at altitudes below 500 m. high.

38. RHAMNACEAE (*Rhamnus*)

Grains 3-colporate; oblate; 17×23μ; ora transversally parallel; exine psilate, 1.5μ thick; sexine granulate.

Present distribution: This is distributed in open tropical forests.

39. RUBIACEAE (*Randia, Tarenna*) Pl. 7: 10–14

Grains 3-colporate; prolate; 18–19×12–14μ; amb circular; exine 1μ thick; tectum with scabrate processes; sexine reticulate.

Present distribution: This is distributed in tropical forests at altitudes below 500 m. high.

40. SALICACE (*Salix*) Pl. 7: 15–18

Grains 3-colporate; prolate; 15–18×12–14μ; amb circular-lobate; exine 1μ thick; tectum with scabrate processes; sexine reticulate, with OL-pattern.

Present distribution: This is distributed from subtropical to temperate forests at altitudes below 2500 m. high,

41. SAPINDACEAE (*Dodonea*)

Grains 3-colporate; prolate; 34×20μ; exine psilate, 1μ thick; sexine granulate.

Present distribution: This is distributed in subtropical forests at altitudes below 1000 m. high.

42. SCROPHULARIACEAE (*Mazus, Scrophularia*)

Grains 3-colporate; prolate; 16–19×9–14μ; ora transversally elliptic; exine 1μ thick; tectum with scabrate processes; sexine reticulate, or grains 3-colpate and 15–20×12–14μ for *Scrophularia*.

Present distribution: These are distributed in sunny places at altitudes below 100 m. high.

43. SIMARUBACEAE (*Brucea*)

Grains 3-colporate; prolate; 27×20μ; ora circular; exine thicken at poles, 2μ thick; sexine reticulate, with OL-pattern.

Present distribution: This is distributed in subtropical forests at altitudes below 1000 m. high.

44. SOLANACEAE (*Solanum*)

Grains 3-colporate; prolate to prolate-spheroidal; 20–25×18–20μ; ora transversally elliptic; exine psilate, 1.5μ thick; sexine granulate.

Present distribution: This is distributed in subtropical waste lands at altitudes below 1000 m. high.

45. THEACEAE

Grains 3-colporate; prolate; 15–22×11–17μ; ora transversally parallel; exine 1–1.5μ thick; sexine granulate; 22×17μ for *Adinandra* and 15×11μ for *Eurya*.

Present distribution: These are distributed in subtropical to temperate forests at altitudes below 1600 m. high.

46. TROCHODENDRACEAE (*Trochodendron*) Pl. 7: 19–20

Grains 3-colpate; prolate; 21–30×19–25μ; exine 1.5μ thick; tectum with scabrate processes; sexine reticulate, with OL-pattern.

Present distribution: This is distributed in temperate hardwood forests at altitudes below 2000 m. high.

47. ULMACEAE Pl. 7: 25–27

Grains 3–5-porate; aperture common type, pores 1.5–2μ wide; exine 1μ thick; tectum with scabrate processes or psilate; sexine granulate or striate. *Aphanthe* and *Trema:* 3-porate, 24–28μ wide; *Celtis:* 3–4-porate, 21–23μ wide; and *Ulmus:* 4–5-porate, sexine striate.

Present distribution: These are distributed in temperate to tropical forests at altitudes between 500–1500 m. high.

48. UMBELLIFERAE (*Foeniculum*) Pl. 7: 28–29

Grains 3-colporate; perprolate; 29–33×10–20μ; amb inter-semi-angular; exine 2μ thick, especially in intercolpate area; tectum with scabrate processes; sexine reticulate, with OL-pattern.

Present distribution: This is distributed in subtropical waste lands at altitudes below 800 m. high.

49. VERBENACEAE (*Premna*)

Grains 3-colpate; prolate; 24–26×12–18μ; exine psilate, 1.5μ thick; sexine granulate.

Present distribution: This is distributed in subtropical forests at altitudes below 800 m. high.

D. MONOCOTYLEDONS

1. CYPERACEAE (*Cyperus, Carex*) Pl. 5: 28–32

Grains 1-colpate or 1–4-aperturate; ovoidal or apple-like in lateral view, elliptic or ellipsoidal in polar view; 25–40×18–30μ; colpus irregularly broken at distal end and indistinct in lateraal view; exine 1μ thick; tectum with scabrate processes or psilate; sexine granulate.

Present distribution: It is distributed in temperate to tropical grass lands.

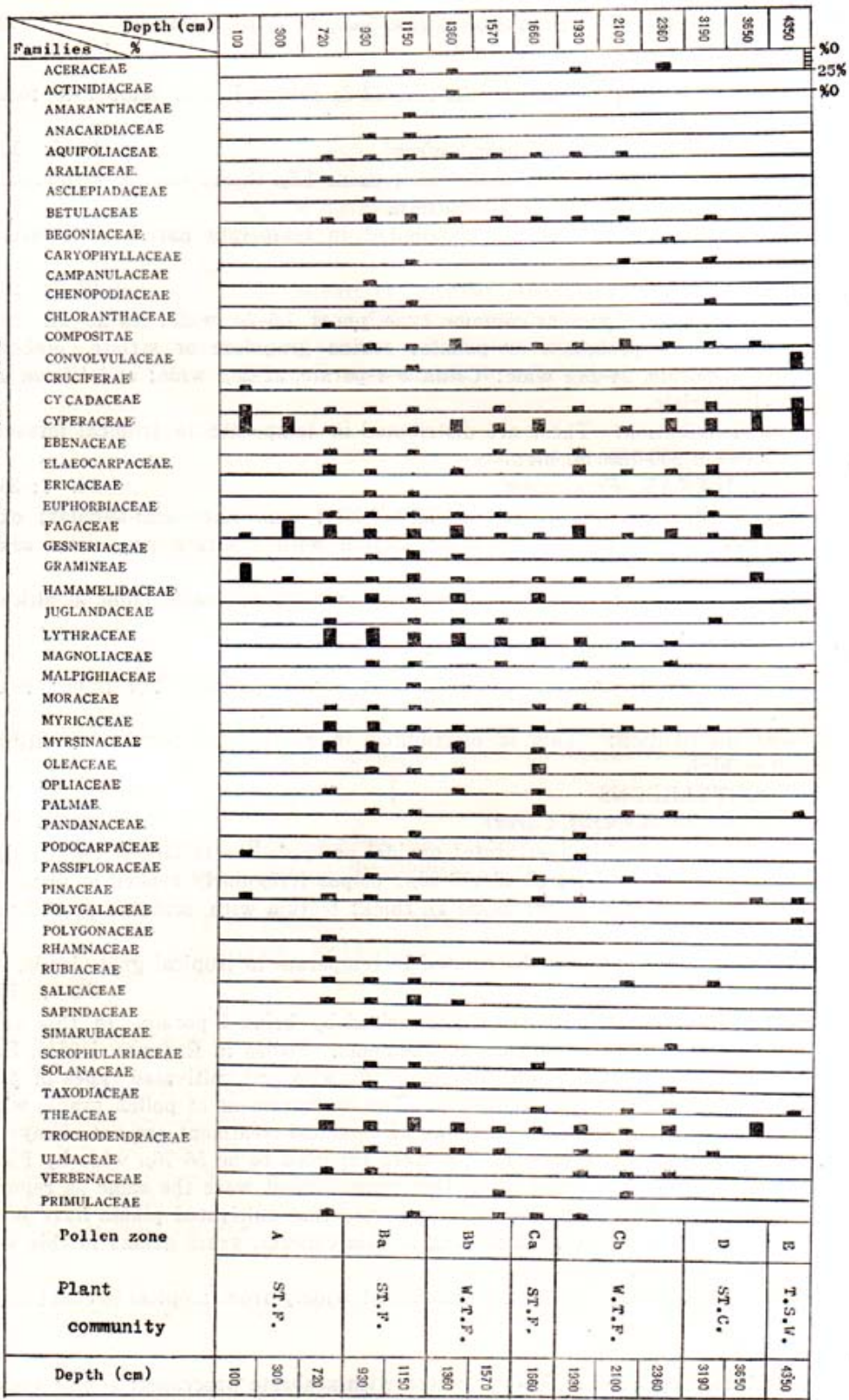
2. GRAMINEAE Pl. 6: 10–11

Pollen grains of Gramineae are characterized by being 1-porate. In this study they were found abundantly in various sediments. Firbas in Erdtman (1954), Erdtman (1954) and Wodehouse (1935) classified the wild and cultivated types of grass pollen grains by means of size frequency. The measurement of pollen grains which have been prepared by different methods of chemical treatment are not always the same. For example the grains of Zea were reported to be 56–76μ wide by Firbas but to be 90–100μ wide by Wodehouse. Our measurement were the same as reported by Wodehouse. It has been generally reported that cultivated plants have larger pollen grains than wild ones. According to this concept, grass grains in this work belong to wild grasses.

Present distribution: These are distributed widely from tropical to cold temperate grasslands.

3. PALMAE

Grains 1-colpate; 32–43×18–28μ; tectum with scabrate processes; sexine reticulate, e.g. *Calamus* (similar to some genera of Magnoliaceae.), and grains 22×18μ,



Pollen diagram of all taxa appearing in various sediments (1)

T.S.W. (Tropical sunny wet lands elements)

ST.C. (Subtropical with increase cool temperate forest)

W.T.F. (Warm temperate forest)

ST.F. (Subtropical forest)

tecum with echinate processes, eg. *Arenga* (similar to some genera of Araceae or smilaceae).

Present distribution: This is distributed in tropical forests.

4. Pandanaceae (*Pandanus*) Pl. 7: 3–5

Grains 1-colpate; prolate; 20×18μ; exine 1μ thick; tectum with echinate processes. The grains of *Pandanus* are similar to those of Palmae, but much smaller in size and also the echini are more sharp in shape than those of the Palmae.

Present distribution: This is distributed in tropical coastal areas at altitudes below 300 m. high.

5. Typhaceae (*Typha*) Pl. 7: 21-24

Grains 1-porate; subspheroidal; 22–25×17–20μ; exine 1.5μ thick; tectum with scabrate processes; sexine reticulate, with OL-pattern.

Present distribution; This is distributed in tropical areas and grows near water at altitudes below 300 m. high.

4. DISCUSSION

1. Present plant communities

It is generally accepted by palynologists and paleoecologists that a knowledge of present flora is a key to interpretation of past climatic sequences. The composition of Taiwan flora has been reported by Hsieh and Yang (1969) and Masamune (1936, 1954) and even though the flora is still incompletely known, yet Keng (1956), Li (1963), C. Liu (1966, 1968) and T. S. Liu (1960, 1962) have pointed out that the flora of Taiwan consists of 72.5% of endemic species, of which 35% of the families belong to tropical elements and 30% of the families belong to temperate forest vegetation, it seems that these plants are closer to the tropical than to temperate vegetation. As a whole, the vegetation of this area is a subtropical forest. According to various edaphic and temperture conditions, there are 7 vegetational zones recognized in Taiwan which are as follow:

1. Mangroove vegetation (Tropical brackish vegetation): Rhizophoraceae, Combretaceae, some species of Verbenaceae are the best representatives.

2. Coastal vegetation: *Pandanus, Ipomoea* and *Vitex* frequently grow in this zone.

3. Subtropical rainfall vegetation: This zone includes plants growing from sea level to an altitude of 500 m. and has very heavy precipitation. Moraceae, Euphorbiaceae, Magnoliaceae are usually present.

4. Warm temperate broad leaf evergreen vegetation and hardwood forests: This zone ranges from 500–2000 m., Fagaceae, Elaeocarpaceae, *Helicia, Ficus, Pinus, Juglans, Ulmus, Alnus, Acer, Calocedrus* and *Podocarpus* are some of the major members found in this area.

5. Cool temperate of coniferous and hardwood mixed forests: This area extends from 2000–3000 m. above sea level, the indicator plants are *Cryptomeria, Cunninghamia, Pseudotsuga, Taiwania, Alnus* and *Eurya*.

6. Cold temperate coniferous forests: This zone extends from 3000–3600 m. above sea level. The major plants are *Abies, Picea, Tsuga, Juniperus, Rhododendron* and *Ribes*.

7. Tundra vegation: This area is mostly above 3600 m., *Veronica, Anaphalis, Cerastium, Artemisia, Cardamine, Arabis, Hypericum, Gentiana* are representive genera.

In the northern part of Taiwan including Taipei, Hsinchu, Toayuan and Miaoli counties, T. S. Liu (1960) reported that the annual average temperture is 22.5°C and the relative humidity ranges from 1500 to 2500 mm. and under these conditions subtropical vegetation grows very well.

2. Past plant communities

Pollen assemblage appearing in various sediments makes it possible to use the pollen as indicators of different plant communities. A very small amount of pollen and spores appear below a depth of 44.8 m., thus it is difficult to deduce the type of the plant community at that time. Pollen grains of Compositae, Palmae, Cyperaceae, Cycadacea, Convolvulaceae and species of Taxodiaceae are commonly found at a depth of 43.5 m., but Cyperaceae seems to be the major elements in this period. Thus we suggest that this was a period of the tropical sunny wet lands (pollen zone E). Grains of Cyperaceae, Fagaceae, Gramineae, Moraceae and Pinaceae appeared in strata of 36.5 m. deep and grains of Cyperaceae, Theaceae, Elaeocarpaceae and Cycadaceae were found in the layer at 31.9 m., these show a subtropical forest period with an increasing cool temperate forest (pollen zone D). The pollen composition at 30 m. depth is the same as that of 44.8 m. depth, except that monocotyledonous pollen grains are the major ones while grains of dicotyledons and gymnosperms are seldom seen. Aceraceae, Cyperaceae, Fagaceae, Theaceae are dominant components at 23.6 m. depth and grains of Aquifoliaceae, Betulaceae Compositae and Elaeocarpaceae are major pollen components at 21 m. depth. The pollen assemblage at 19.3 m. depth is quite similar to that of 21 m. depth, these three pollen zones belong to warm temperate forests period (pollen zone Cb). Various pollen components, such as Compositae, Cyperaceae, Pinaceae, Betulaceae and Aquifoliaceae are found at 16.6 m. depth which show a complicated subtropical forest community (pollen zone Ca). Grains of Aquifoliaceae, Pinaceae, Juglandaceae and Trochodendraceae are found at 15.7 m. depth, which is similar to a warm temperate forest community. 13.6 m. depth, pollen grains appeared to be the same to those at 15.7 m. depth but Pinaceae pollen grains decreased (Pollen zone Bb). Both in 11.5 m. and 9.3 m. depths, there are abundant fern spores and grains of Fagaceae, Betulaceae, Myricaceae and Pinaceae, probably this community belongs to subtropical forest (pollen zone Ba). The major pollen assemblage of 7.2 m. depth were those of Myricaceae, Elaeocarpaceae, Pinaceae all of which belong to subtropical forest period. At 3 m. depth and in recent sediments, the assemblage of pollen grains are those of Betulaceae, Cyperaceae, Fagaceae (Pollen zone A). In all sediments mentioned above, the fern spores are quite abundant.

Pollen grains of *Cunninghamia* (*C. lanceolata*) and *Tsuga* appeared at a depth of 43.5 m., 31.9 m., 15.7 m. and 7.2 m., but we cannot say for sure that the pollen grains of *Cunninghamia* came from trees growing in Taipei Basin, for these trees grew on Mainland China and may have been carried to this area. Today, *Tsuga* or *Cunninghamia konishii*, grow along the upper courses of the Hsintien river, but they never appear in the Taipei Basin area at altitudes below 1000 m., therefore they may have been transported by the Hsintien river to the Taipei Basin. It is difficult to determine by a single core study whether these two indicator plants actually grew in the Taipei Basin or not. The ratio and number of spores and pollen grains observed in this study are listed in Table 3. and Pollen Diagram No. 1.

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