A STUDY ON THE BENTHIC DIATOMS COMMUNITIES OF MOUNTAIN STREAMS IN CENTRAL TAIWAN

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INTRODUCTION

The communities of benthic diatoms have generally received less attention when compared with the communities of planktonic forms. Lackey (1964) and Patrick (1966) have discussed some aspects about the ecological problems of benthic diatoms. Both of them showed that the type of water mass, depth, rate of current, turbidity, aeration, water quality, temperature, light intensity, and substrate texture greatly affect the pattern of the community of benthic diatoms. To the writer's knowledge, there is no report on the benthic diatoms communities in central Taiwan (Fig. 1). Based on the results of this collection, the writer is trying to describe some characteristics of the benthic diatoms communities of mountain streams in central Taiwan.

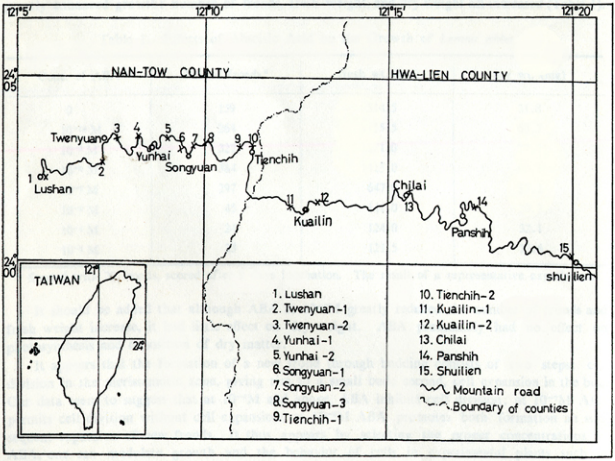

Fig. 1. Map showing sampling stations.

The mountain streams in central Taiwan mostly flow through dense forests and the surrounding atmosphere is foggy. The currents in them are usually small and fast flowing. Small

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waterfalls are frequently seen. The water in all season is clear and cool. At high altitudes, the pH values of them are usually slightly acidic.

In the rapid flowing mountain streams belonging to the genera *Cocconeis*, *Achnanthes*, *Gomphonema*, *Cymbella*, *Epithemia*, and *Denticula* are found. These produce a mass of mucilage which serves to attach them to rocks and sticks. They usually form thick dark brown layers on the bottom stones where as planktonic algae are almost absent in these water. In habitats with very dim light, a few species of diatoms, e. g., *Melosira roeseana* var. *epidendron* and *Stauroneis phoenicenteron* var. *brunii* grow well and these are seldom found in sunny habitats. *M. roeseana* var. *epidendron*, *Rhopalodia gibba*, *Epithemia zebra*, *E. sorex*, and *Hantzschia amphioxys* var. *capitata* are found on the damp stones or mosses moistened by the spray, and these have been previously reported as subaerial species (Skvortzow, 1938a; Patrick, 1966). In waters of low pH values, species of *Eunotia bigibba*, *E. diodon*, *E. praerupta*, *Frustulia vulgaris*, *Pinnularia dactylus*, and *P. abaujensis* var. *subundulata* are found, and these have been frequently reported from acidic water (Patrick, 1966; Kobayasi and Haragushi, 1969; Yamagishi and Kobayasi, 1971).

The mountain streams with low temperature, high oxygen content, and low in dissolved nutrients are typically oligotrophic. The structures of the diatom communities in oligotrophic streams like those in dystrophic streams, are characterized by relatively few species while the population of some species is fairly large, that is, the species diversity indexes are low, and are quite different from those in unpolluted eutrophic fresh water and brackish water.

The writer proposes one simple method to determine the figure of the structure of the diatom community in such oligotrophic environments. Only four intervals are selected, the individuals of each interval are as follows: 1-10(+), 10-100(++), 100-1000(+++), 1000-10000(+++). Although this method is rougher than that used by Hohn & Hellerman (1963) and Patrick (1964, 1966), the results are usually similar. Fig. 2 and 3 are two examples of this method.

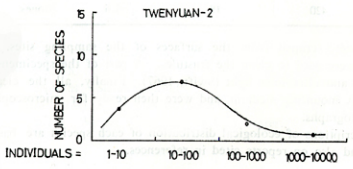


Fig. 2. Structure of the diatom community from Twenyuan-2.

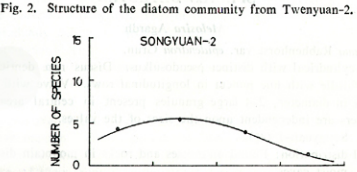


Fig. 3. Structure of the diatom community from Songyuan-2.

COLLECTION OF MATERIALS

This investigation was made in the spring of 1974. Fifteen stations were selected. The features of each stations are as follows:

Station	Altitude (m)	Day temperature (°C)	pH value	Sampling sites (on the surfaces of)
Lushan	1440	13	6.4	Rotted branches and stones
Twenyuan-1	1750	10	6.4	Stones
Twenyuan-2	1950	8	6.0	Stones and *Sphagnum* mosses
Yunhai-1	2300	5	6.0	Stones
Yunhai-2	2400	3	6.2	Wall of a small reservior
Songyuan-1	2250	3	6.8	Stones
Songyuan-2	2540	2	5.4	Stones
Songyuan-3	2750	2	5.6	Stones (beneath a waterfall)
Tienchih-1	2850	0	5.6	Stones and *Sphagnum* mosses
Tienchih-2	2630	6	5.8	Rotted leaves and *Sphagnum* mosses
Kuailin-1	2340	10	6.4	Stones (beneath a waterfall)
Kuailin-2	2020	12	6.2	Stones (beneath a waterfall)
Chilai	1100	16	6.6	Stones (beneath a waterfall)
Panshih	700	16	6.4	Stones and sediments (beneath a waterfall)
Shuilien	420	18	6.6	Stones

The diatoms were scraped from the surfaces of the sampling sites. Sulfuric acid and potassium nitrate were used to clean the frustules. A part of the specimens were treated with hydrogen peroxide and ultraviolet light (Swift, 1967). Finally, all the cleaned frustules were mounted in Pleurax mounting medium, and were then ready for microscopic examination and the taking of photographs.

The brief descriptions of ecological distribution of each species are based on the writer's own collections and also on reports cited in references.

SPECIES DETECTED

Melosira Agardh

1. *Melosira roeseana* Rabhenhorst var. *epidendron* Grun. —Pl. 1, Fig. 1.

Frustules cylindrical with distinct pseudosulkus. Discus rim denticulate. Sulkus and neck broad. Girdle with fine puncta in longitudinal rows. Valve with radiating rows of beads, 10-35 μ in diameter; 2-4 large granules present in central area in my specimens and the numbers are independent upon the sizes of the valves.

Locality: Songyuan-1 (卄).

Ecological distribution: Found on mosses and rocks in mountain districts, sometimes in moist caves.

Diatoma Bory

2. *Diatoma hiemale* (Roth) Heib. var. *hiemale*. —Pl. 1, Fig. 2.

Frustules in straight filaments. Intercalary bands present. Valve linear lanceolate; 8–14 μ in breadth, 25–50 μ in length. Pseudoraphe usually indistinct, linear. Striae, fine. Costae usually above 6.

Locality: Songyuan-3 (卄).

Ecological distribution: Prefers flowing cool fresh water. Not frequently seen in Taiwan.

3. *Diatoma hiemale* (Roth) Heib. var. *mesodon* (Ehr.) Grun. —Pl. 1, Fig. 3.

Frustules usually in zigzag filaments, sometimes occurs singly. Intercalary bands present. Valve elliptical to lanceolate; 11–14 μ in breadth, 8–25 μ in length. Pseudoraphe narrow, linear, usually indistinct. Striae, fairly fine. Costae, usually below 5. Differs from the nominate variety in the shape of filaments, fewer costae, and straight narrow pseudoraphe.

Localities: Lushan (卅), Twenyuan-1 (卄), Twenyuan-2 (卄), Yunhai (+), Songyuan-2 (卅), Songyuan-3 (卅), Tienchih-1 (卄), Tienchih-2 (卅), Kuailin-1 (卅), Chilai (+), Panshih (卄).

Ecological distribution: Widely distributed in fresh water.

Fragilaria Lyngb.

4. *Fragilaria vaucheriae* (Kütz.) Peters. —Pl. 2, Fig. 5.

Frustules in chains, occasionally singly. Valve linear with rounded or rostrate ends; 6–10 μ in length, 4 μ in breadth. Central area on one side of the valve usually slightly swollen. Because of the similarities of the excentric central area and the manner of the frustule growth, sometimes it is hard to distinguish the large individuals of this taxon from *Synedra dorsiventralis*.

Locality: Songyuan-3 (卄).

Ecological distribution: Seems to prefer cool fresh water.

Synedra Ehr.

5. *Synedra acus* Kütz. —Pl. 1, Fig. 10.

Frustules occur singly. Valve linear lanceolate with narrowed rounded ends; 32–250 μ in length, 3–10 μ in breadth. Central area nearly square and usually reaching the margins. Pseudoraphe narrow, straight. Striae parallel.

Localities: Kuailin-2 (卄), Lushan (卅), Twenyuan-1 (卅), Chilai (+), Panshih (卄).

Ecological distribution: Widely distributed in fresh water.

Eunotia Ehr.

6. *Eunotia bigibba* Kg. —Pl. 1, Fig. 6.

Valve with concave ventral margin, distinctly twice undulated dorsal margin, and truncate-rostrate ends; 33 μ in length, 11 μ in breadth. Striae indistinctly punctate, parallel at the center, gradually radiate towards the ends.

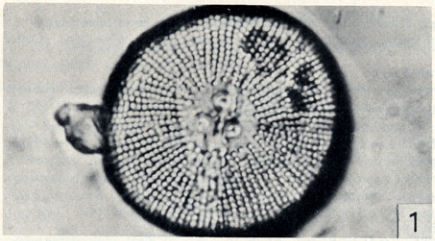
Locality: Songyuan-1 (+).

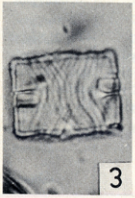
Ecological distribution: In acidic cool mountain water. usually found epiphytic on Sphagnum mosses.

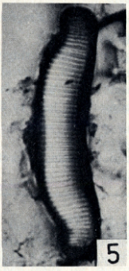
7. *Eunotia diodon* Ehr. —Pl. 1, Fig. 7.

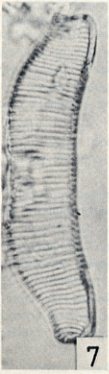
Valve with concave ventral margin and twice undulated dorsal margin; 25–70 μ in length, 10–15 μ in breadth. Ends rounded, sometimes slightly truncate. Differs from *E. arcus* var. *bidens* in less length to breadth ratio and much narrower ends than the central part of the valve. Differs from *E. major* var. *bidens* in much narrower ends than the central part of the valve. Striae indistinctly punctate, parallel at the center, gradually radiate towards the ends.

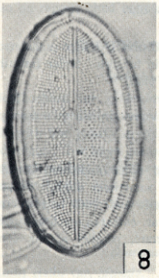
Locality: Songyuan-1 (卄).











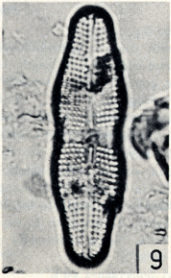


Plate 1

Ecological distribution: In acidic cool mountain water, usually found epiphytic on Sphagnum mosses.

8. *Eunotia epithemioides* Hust. —Pl. 1, Fig. 4.
Valve linear, slightly arcuate, and slightly narrowed toward the ends; 40–50 μ in length, 8–12 μ in breadth. Ends rounded, somewhat rostrate. Striae variable, not equidistant from each other, usually 1–3 striae forming a distinct band, parallel, and punctate. This taxon is characterized by the shape of valves and the pattern of striation.
Locality: Twenyuan-2 (+).
Ecological distribution: Reported as a fresh water species from tropical Africa and Asia. Only collected once in Taiwan.

9. *Eunotia praerupta* Ehr. —Pl. 1, Fig. 5.
Valve with concave ventral margin, convex dorsal margin, and truncate-rostrate ends; 30–45 μ in length, 7–9 μ in breadth. Striae indistinctly punctate, parallel.
Locality: Songyuan-1 (+).
Ecological distribution: Alpine species. Found in acidic mountain water.

Cocconeis Ehr.

10. *Cocconeis placentula* Ehr. var. *euglypta* (Ehr.) Cl. —Pl. 2, Fig. 4.
Valve elliptical with coarser dashes than the nominate variety and the dashes are longer than those of var. lineata; 12–18 μ in length, 9–11 μ in breadth. 2–4 longitudinal hyaline ribs on each side of the pseudoraphe valve. Raphe valve with marginal and submarginal hyaline area. The average length to breadth ratio of my present specimens is not greater than that of var. *lineata*.
Localities: Songyuan-3 (+), Yunhai-2 (+), Chilai (+), Panshih (+).
Ecological distribution: Found mostly in fresh water as a benthic form.

11. *Cocconeis placentula* Ehr. var. *lineata* (Ehr.) V. H. —Pl. 1, Fig. 8.
Valve elliptical; 25–50 μ in length, 15–25 μ in breadth. Differs from the nominate variety in the fewer longitudinal hyaline ribs on the pseudoraphe valve. Raphe valve with marginal and submarginal hyaline area.
Localities: Lushan (+), Twenyuan-2 (+).
Ecological distribution: Widely distributed in fresh water as a benthic form.

Achnanthes Bory

12. *Achnanthes coarctata* (Bréb. in W. Sm.) Grun. —Pl. 1, Fig. 9.
Valve with constricted center and protracted obtusely rounded ends; 33 μ in length, 10 μ in breadth. Raphe valve with a stauroid area and distinctly punctate radiate striae. Distal raphe ends curve in the same direction. Differs from *A. inflata* in the constrictive pattern of the valve.
Locality: Songyuan-1 (+).
Ecological distribution: Aerophilic or rheophilic form in fresh water.

13. *Achnanthes inflata* (Kütz.) Grun. var. *elata* (Leud.-Fortm.) Hust. —Pl. 2, Fig. 1.
Frustules occur in short chains. Valve biconstricted with obtuse rounded ends; 40 μ

Plate 1. Fig. 1. *Melosira roeszana* Rabhenhorst var. *epidendron* Grun. 2. *Diatoma hiemale* (Roth) Heib. var. *hiemale*. 3. *Diatoma hiemale* (Roth) Heib. var. *mesodon* (Ehr.) Grun. 4. *Eunotia epithemioides* Hust. 5. *Eunotia praerupta* Ehr. 6. *Eunotia bigibba* Kg. 7. *Eunotia diodon* Ehr. 8. *Cocconeis placentula* Ehr. var. *lineata* (Ehr.) V. H. 9. *Achnanthes coarctata* (Bréb. in W. Sm.) Grun. 10. *Synedra acus* Kütz.

in length, 11 μ in breadth. Raphe valve with a stauroid central area and distinctly punctate radiate striae. Differs from the nominate variety in less gibbous center.

Locality: Twenyuan-1 (+).

Ecological distribution: Found in fresh and slightly brackish water, grows luxuriantly in quiescent water.

14. *Achnanthes lanceolata* (Bréb.) Grun. —Pl. 2, Fig. 7, 11.

Valve elliptical-lanceolate, elliptical in smaller cells, with obtusely rounded ends; 18–25 μ in length, 6–8 μ in breadth. Raphe valve with linear lanceolate axial area and rectangular central area. Central striae few (0–3), short. Pseudoraphe valve eccentrically with distinct horseshoe-shaped clear space.

Localities: Lushan (卄), Songyuan-1 (+), Songyuan-2 (卅), Tienchih (卅).

Ecological distribution: Widely distributed in fresh water. Although it is usually regarded as a rheophilic and alkaliphilic form, I once found a dense population in slightly acidic quiescent water.

15. *Achnanthes linearis* (W. Sm.) Grun. —Pl. 2, Fig. 2.

Frustules arcuate in girdle view. Valve linear with obtusely rounded ends; 10–25 μ in length, 3–4 μ in breadth. Striae slightly radiate, fairly fine, however, one or two central striae are more distinct than the others. Stauroid central area on raphe valve is not seen in my specimens.

Localities: Lushan (卄), Twenyuan-2 (卅), Yunhai (卅), Songyuan-2 (卅), Tienchih-2 (卄), Kuailin-1 (卅), Kuailin-2 (卅), Chilai (卅).

Ecological distribution: Widely distributed in fresh water. Reimer stated that it is halophobe, however, it was recently found in brackish water.

16. *Achnanthes minutissima* Kütz. var. *macrocephala* Hust. —Pl. 2, Fig. 3.

Valve lanceolate with broadly capitate ends; 10–16 μ in length, 3–5 μ in breadth. Raphe valve with irregular central area, 1–3 short central striae present on the margins. Striae fairly fine, radiate. Differs from the relative taxon *A. microcephala* in the more radiate striation. According to Hustedt's figures, this variety differs from the nominate variety in the more broadly capitate ends.

Localities: Lushan (卄), Songyuan-2 (卄).

Ecological distribution: Found in fresh water.

Amphipleura Kütz.

17. *Amphipleura pellucida* Kütz. —Pl. 2, Fig. 6.

Frustules occur singly. Valve linear-lanceolate with attenuate rounded ends; 60–80 μ in length, 8–9 μ in breadth, shorter than patrick's description (80–140 μ in length). Raphe with branches at the ends. Striae, longitudinal and transversal, finely punctate.

Locality: Twenyuan-2 (卄).

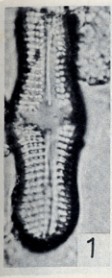
Ecological distribution: Infrequently seen in Taiwan. Found in hard water elsewhere.

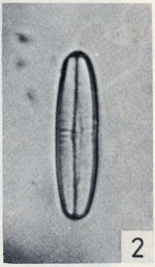
Frustulia Rabh.

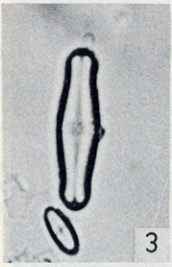
18. *Frustulia vulgaris* (Thwaites) De Toni —Pl. 2, Fig. 8.

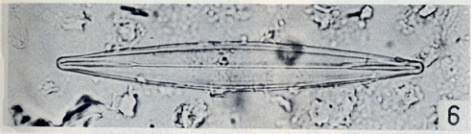
Valve lanceolate with subrostrate rounded ends; 40–48 μ in length, 9–10 μ in breadth.

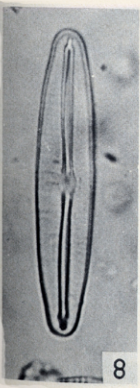
Plate 2. Fig. 1. *Achnanthes inflata* (Kütz.) Grun. var. *elata* (Leud.-Fortm.) Hust. 2. *Achnanthes linearis* (W. Sm.) Grun. 3. *Achnanthes minutissima* Kütz. var. *macrocephala* Hust. 4. *Cocconeis placentula* Ehr. var. *euglypta* (Enr.) Cl. 5. *Fragilaria vaucheriae* (Kütz.) Peters. 6. *Amphipleura pellucida* Kütz. 7. *Achnanthes lanceolata* (Bréb.) Grun. 8. *Frustulia vulgaris* (Thwaites) De Toni 9. *Neidium affine* (Ehr.) Pfitz. 10. *Stauroneis anceps* Ehr. 11. *Achnanthes lanceolata* (Bréb.) Grun.

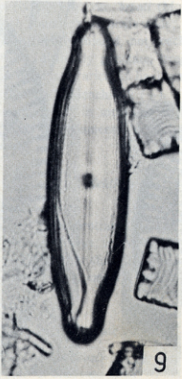


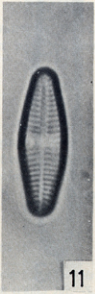












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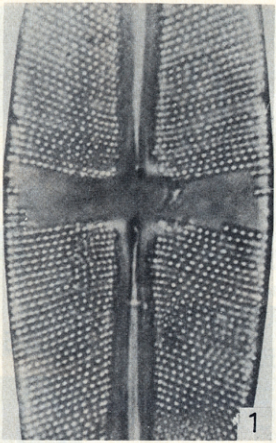
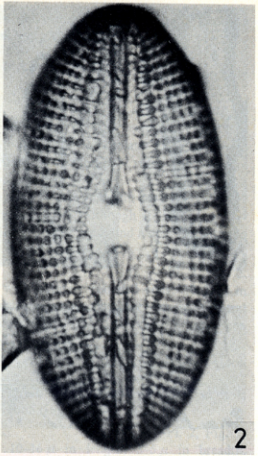
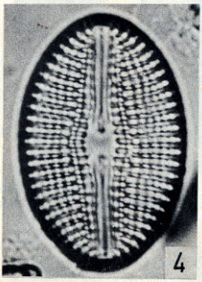






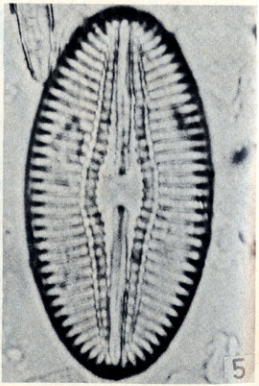


Plate 3

Siliceous ribs distinct. Terminal nodules pencil point shaped. Striae fairly fine, longitudinal and transversal.

Localities: Songyuan-2 (卅), Tienchih-2 (卅).

Ecological distribution: Usually reported in water of low mineral content which is circumneutral, only seen in slightly acidic water in Taiwan until now.

Stauroneis Ehr.

19. *Stauroneis acuta* W. Sm. —Pl. 3, Fig. 3.

Frustules joined into short chains. Valve rhombo-lanceolate with a slightly median inflation and rounded ends; 50 μ in length, 7 μ in breadth. Axial area linear, broad. Stauros dilated, broad. Striae radiate throughout the valve, distinctly punctate. Pseudosepta present, distinct. My specimens are smaller than those previously described (15–40 × 80–170 μ).

Locality: Songyuan-1 (+).

Ecological distribution: Insufficently known in Taiwan. Alkaliphilous, oligohalob, elsewhere.

20. *Stauroneis anceps* Ehr. —Pl. 2, Fig. 10.

Valve lanceolate with capitate ends; 21–45 μ in length, 5–10 μ in breadth. Stauros slightly dilated. Striae radiate, finely punctate. This quite variable taxon has been studied by Hostetter and Hoshaw (1972), they showed that when cells longer than 26 μ typically had capitate ends; as the cells became shorter, there was a gradual decrease in this capitate configuration with the smallest cells being oval in outline.

Localities: Twenyuan-1 (+), Twenyuan-2 (卅), Songyuan-2 (+), Tienchin-1 (+), Tienchih-2 (卅), Panshih (+).

Ecological distribution: Widely distributed in fresh water.

21. *Stauroneis phoenicenteron* (Nitz.) Ehr. var. *brunii* (M. Perag. & Hérib.) Voigt —Pl. 3, Fig. 1.

Valve lanceolate with rounded, attenuate ends; 110–138 μ in length, 30–31 μ in breadth. Axial area broad. Stauros slightly dilated, not reaching the margins of the valve. Striae radiate throuhout the valve, distinctly punctate, irregularly shortened at the center of the valve. Differs from the nominate variety in having short striae on the margins of the stauros.

Localities: Songyuan-2 (+), Tienchih-2 (+).

Ecological distribution: Found in mountain streams, small quiescent water, or caves. Prefers shady environments, sometimes forms a dark-brown layer on the sediments.

Neidium Pfitz.

22. *Neidium affine* (Ehr.) Pfitz. —Pl. 2, Fig. 9.

Valve linear-lanceolate with protracted round ends; 50–95 μ in length, 12–20 μ in breadth. Central area slightly obligue, transversally broad. Proximal ends of raphes curving in opposite directions, however, this characteristic is not obvious in my specimens. Striae obliquely spaced. Differs from var. *amphirhynchus* and var. *ceylonicum* mainly in the sizes of the valves.

Locality: Songyuan-2 (+).

Ecological distribution: In fresh water. Only found in mountain streams in Taiwan.

Plate 3. Fig. 1. *Stauroneis phoenicenteron* (Nitz.) Ehr. var. *brunii* (M. Perag. & Hérib.) Voigt 2. *Diploneis ostracodarum* (Pant.) Jur. 3. *Stauroneis acuta* W. Sm. 4. *Diploneis ostracodarum* (Pant.) Jur. 5. *Diploneis smithii* (Bréb. ex W. Sm.) Cl. var. *dilatata* (M. Perag.) Boyer

Diploneis Ehr.

23. *Diploneis ostracodarum* (Pant.) Jur. —Pl. 3, Fig. 2, 4.
Valve elliptical; 25-47 μ in length, 21-25 μ in breadth. Central area elliptical. Longitudinal canals crossed by transverse costae of similar number of marginal costae. One row of large, coarse alveoli present between the marginal costae. The siliceous ribs slightly wider at the median ends.
Locality: Songyuan-2 (卄).
Ecological distribution: Found in mountain streams.

24. *Diploneis smithii* (Brèb. ex W. Sm.) Cl. var. *dilatata* (M. Perag.) Boyer —Pl. 3, Fig. 5.
Valve elliptical or broadly elliptical; 25-65 μ in length, 15-25 μ in breadth. Longitudinal canals narrower than the nominate variety. Central area and its extensions forming a somewhat broadly lanceolate space. Longitudinal canals crossed by transverse costae of similar number of marginal costae. Double rows of alveoli present between the marginal costae.
Localities: Twenyuan-2 (卄), Songyuan-1 (+).
Ecological distribution: Found in mountain streams.

Navicula Bory

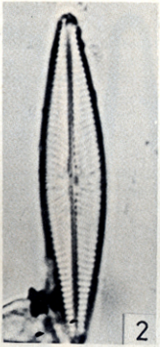
25. *Navicula bocillum* Ehr. —Pl. 4, Fig. 7, 8. and Pl. 5, Fig. 5.
Valve linear with rounded ends; 50-84 μ in length, 10-12 μ in breadth. Central area elliptical, distinct. Terminal areas variable in extension to sides of the valve. Striae radiate, slightly curved.
Locality: Panshih (+).
Ecological distribution: Fresh to slightly brackish water.

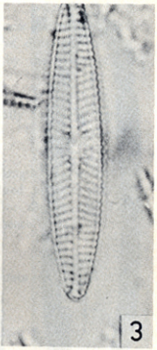
26. *Navicula exigua* Greg. ex Grun. var. *capitata* Patr. —Pl. 4, Fig. 9.
Valve linear-elliptical with rostrate-capitate ends, 20-25 μ in length, 7-8 μ in breadth. striae radiate, irregularly shortened at the center of the valve.
Locality: Tienchih-2 (+).
Ecological distribution: Found in fresh water. According to Patrick, this taxon seems to prefer water of less than 100 p. p. m. hardness ($CaCO_3$).

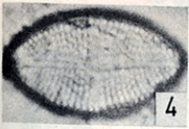
27. *Navicula inflexa* (Greg.) Ralfs —Pl. 4, Fig. 5, 6.
Valve lanceolate with acute, rounded ends; 23-30 μ in length, 6-8 μ in breadth. A dark band present near each end. Axial area narrow, distinct. Striae radiate, but parallel at the ends; irregularly shortened at the center of the valve.
Locality: Songyuan-2 (卅).
Ecological distribution: Previously reported as a brackish water form.

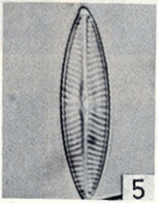
28. *Navicula mutica* Kütz. var. *tropica* Hust. —Pl. 4, Fig. 10.
Valve lanceolate to elliptical-lanceolate with rounded ends; 23-28 μ in length, 8 μ in breadth. Axial area narrow. A distinct stigma present on one side of the transverse central area. Striae radiae, distinctly punctate, much shortened at the center of the valve. Differs from the nominate variety in the stigmatic form of the isolated punctum.
Locality: Songyuan-1 (卅).
Ecological distribution: Found in fresh circumneutral water.

Plate 4. Fig. 1. *Navicula pseudodemerarae* Hust. 2. *Navicula radiosa* Kütz. 3. *Navicula tripunctata* (O. F. Müll.) Bory var. *shizonemoides* (V. H.) Patr. 4. *Navicula mutica* Kütz. f. *cohnii* (Hilse) Grun. 5. *Navicula inflexa* (Greg.) Ralfs 6. *Navicula inflexa* (Greg.) Ralfs 7. *Navicula bacillum* Ehr. 8. *Navicula bacillum* Ehr. 9. *Navicula exigua* Greg. ex Grun. var. *capitata* Patr, 10. *Navicula mutica* Kütz. var. *tropica* Hust.









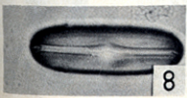


Plate 4

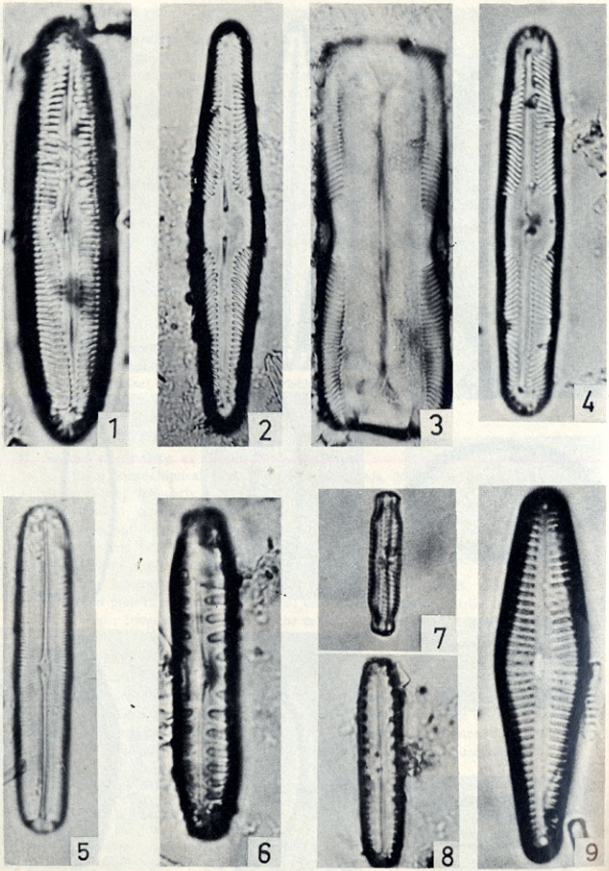


Plate 5

29. *Navicula mutica* Kütz f. *cohnii* (Hilse) Grun. —Pl. 4, Fig. 4.
Valve elliptical: 19-21 μ in length, 10-11 μ in breadth. Transverse central area not reaching the margins of the valve. Striae radiate throughout the valve, distinctly punctate, irrgularly much shortened at the center of the valve. Characterized by the shape of the valve, punctated striation, and transverse central area.
Locality: Songyuan-1 (卅).
Ecological distribution: Widely distributed in fresh water, especially in slightly shady and subaerial environments.

30. *Navicula pseudodemerarae* Hust. —Pl. 4, Fig. 1.
Valve elliptical-lanceolate with attenuate, subacute ends; 57 μ in length, 17 μ in breadth. Axial area wide. Central area widely transverse with a distinct isolated punctum near the central nodule. Striae radiate, distinctly punctate, much shortened or disappeared at the center of the valve. Differs from *N. kotschyi* var. *rupestris* in the absence of irrgular longitudinal blank undulating bands.
Locality: Songyuan-1 (+).
Ecological distribution: Fresh water. Found on mosses on mountain rocks, it seems to prefer a damp aerial condition.

31. *Navicula radiosa* Kütz. —Pl. 4, Fig. 2.
Valve linear-lanceolate with acute, rounded ends; 40-50 μ in length, 7-9 μ in breadth. Axial area narrow, distinct. Axial area and central nodule often appearing more heavily silicified than the rest of the valve. Striae radiate, but parallel at the ends; irregularly shortened at the center of the valve.
Locality: Panshih (卅).
Ecological distribution: Widely distributed in fresh water, but only found at one station in this collection, perhaps, owing to the altitude.

32. *Navicula tripunctata* (O. F. Müll.) Bory var. *shizonemoides* (V. H.) Patr. —Pl. 4, Fig. 3.
Valve linear with gradually narrowed rounded ends; 32-41 μ in length, 6-9 μ in breadth. Axial area narrow, distinct. Differs from the nominate variety in smaller central area. Striae radiate, but parallel at the ends.
Locality: Twenyuan-2 (卅).
Ecological distribution: Widely distributed in fresh water, but only found at one station in this collection, perhaps owing to the altitude.

Pinnularia Ehr.

33. *Pinnularia abaujensis* (Pant.) Ross var. *subundulata* (A. Mayer ex Hust.) Patr. —Pl. 5, Fig. 4.
Valve linear with slightly undulate sides and broadly rounded to rostrate ends; 50-60 μ in length, 7-9 μ in breadth. Transverse fascia distinct. Costae strongly divergent at the center of the valve and strongly convergent towards the ends. Differs from *P. hedini* in the shape of the valve.
Locality: Panshih (卄).
Ecological distribution: Found in streams, lakes, and bogs. Prefers cool, slightly acidic water of low mineral content.

Plate 5. Fig. 1. *Pinnularia dactylus* Ehr. 2. *Pinnularia hedini* Hust. 3. *Pinnularia hedini* Hust. 4. Pinnularia abaujensis (Pant.) Ross var. subundulata (A. Mayer ex Hust.) Patr. 5. *Navicula bacillum* Ehr. 6. *Pinnularia borealis* Ehr. var. *rectangularis* Carlson 7. *Pinnularia undulata* Greg. 8. *Pinnularia borealis* Ehr. var. *rectangularis* Carlson 9. *Gomphonema subclavatum* Grun.

34. *Pinnularia borealis* Ehr. var. *rectangularis* Carlson —Pl. 5, Fig. 6, 8.
Valve linear with broadly rounded ends; 35–38 μ in length, 7 μ in breadth. Median ends of the raphe turned to one side. Costae widely spaced, parallel, and shortened in the central area. The widthes of axial areas of my specimens were not always one half the breadth of the valves as described by Patrick (1966). The figure illustrated by Kobayasi & Haraguchi also had a less broad axial area.
Locality: Songyuan-1 (+).
Ecological distribution: Found in mountain streams, also in springs, pools and irrigation ponds.

35. *Pinnularia dactylus* Ehr. —Pl. 5, Fig. 1.
Valve broadly linear, slightly narrowed toward the ends; 55–105 μ in length, 13–16 μ in breadth. Central area rounded, slightly asymmetrical. Raphe, not complex. Costae slightly radiate at the center of the valve and convergent toward the ends. The specimens in this collection smaller than those have been described (150–340 μ in length, 30–50 μ in length, 30–50 μ in breadth.
Localities: Songyuan-2 (+), Kuailin-2 (+).
Ecological distribution: Found in acidic running water, swamps and ponds.

36. *Pinnularia hedini* Hust. —Pl. 5, Fig. 2, 3.
Valve linear-lanceolate, gradually narrowed toward the ends, ends rounded; 40–100 μ in length, 11–15 μ in breadth. Transverse fascia distinct. Costae strongly divergent at the center of the valve and strongly convergent towards the ends.
Locality: Twenyuan-2 (卄).
Ecological distribution: Found in mountain streams. Rarely reported elsewhere.

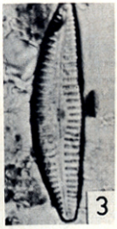
37. *Pinnularia undulata* Greg. —Pl. 5, Fig. 7.
Valve linear with capitate ends; 20 μ in length, 5 μ in breadth. Margins slightly triundulate. Smaller than the related taxons, such as *P. mesolepta* and *P. nodosa*.
Locality: Songyuan-1 (+).
Ecological distribution: Found in small mountain streams and ponds, but infrequently seen.

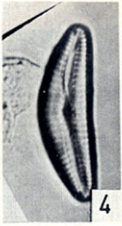
Gomphonema Agardh

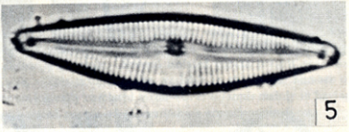
38. *Gomphonema gracile* Ehr. —Pl. 6, Fig. 1.
Valve lanceolate with attenuate ends; 58 μ in length, 9 μ in breadth. Striae slightly radiate; the midmost one of one side shorter than the others and furnished with an isolated punctum; the opposite side with a quite shortened striae.
Locality: Songyuan-2 (+).
Ecological distribution: Found in fresh water. Epiphytic form.

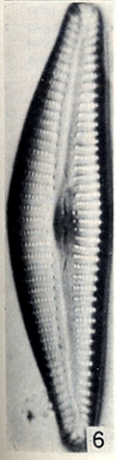
39. *Gomphonema subclavatum* Grun. —Pl. 5, Fig. 9.
Valve lanceolate with broadly rounded ends; one end broader than the other; 38–42 μ in length, 9–11 μ in breadth. Axial area broad. Striae slightly radiate, the midmost one of both sides shorter than the others. An isolated punctum present near the central nodule. Gelatin pore distinct.
Locality: Songyuan-2 (卅).
Ecological distribution: Found in fresh water. Epiphytic form.

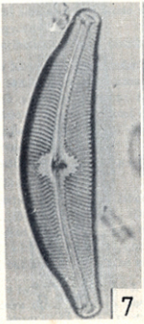
Plate 6. Fig. 1. *Gomphonema gracile* Ehr. 2. *Cymbella ventricosa* Kütz. var. *semicircularis* (Lagerst.) Cl. 3. *Cymbella alpina* Grun. 4. *Cymbella cistula* (Hemprich) Grun. 5. *Cymbella* sp. 6. *Cymbella cistula* (Hemprich) Grun. 7, 8, 9. *Cymbella tumida* (Bréb.) V. H.

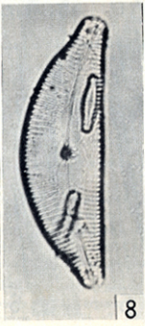












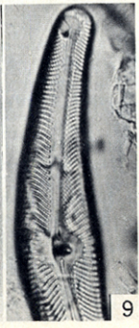
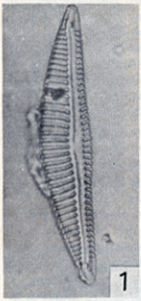
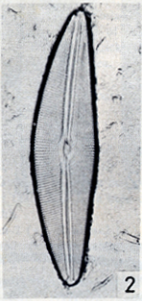


Plate 6





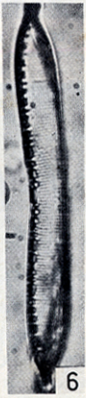


Plate 7

Cymbella Agardh

40. *Cymbella aspera* (Ehr.) Cl. —Pl. 7, Fig. 2.

Valve asymmetricly lanceolate with rounded ends, dorsally convex and ventrally straight with a slightly median inflation; 120–150 μ in length, 42–50 μ in breadth. Axial area broad, slightly curved. Central area asymmetric, wider than the axial area, without any isolated puncta. Striae radiate, distinctly punctate. Differs from *C. lanceolata* in the shape of the valve.

Localities: Lushan (卄), Twenyuan-1 (卄), Twenyuan-2 (+), Songyuan-1 (卄).

Ecological distribution: Widely distributed in fresh water.

41. *Cymbella alpina* Grun. —Pl. 6, Fig. 3.

Valve asymmetricly lanceolate with rounded-truncate ends; 36 μ in length, 8 μ in breadth. Central area wider than axial area. Differs from *C. subalpina* in having narrower axial area, but I think it's not a critical characteristic, since the widthes of axial areas of different individuals or even the same cell were variable in my specimens.

Locality: Songyuan-1 (+).

Ecological distribution: Found in fresh water, perhaps prefers high altitude or cool water.

42. *Cymbella cistula* (Hemprich) Grun. —Pl. 6, Fig. 4, 6.

Valve asymmetricly lanceolate to semielliptic with rounded ends; 30–80 μ in length, 8–12 μ in breadth. Ventral margin slightly concave and with a median inflation (in larger cells). Striae slightly radiate, distinctly punctate. Several isolated puncta present near the central nodule on the ventral side. This taxon is quite variable in shape and number of isolated puncta. Differs from the ecologically corelated taxon—*C. crusiformis* mainly in having strongly deflected raphe and the isolated puncta of *C. crusiformis* are stigmatic form.

Localities: Kuaylin-1 (卄), Shuilein (卅).

Ecological distribution: Widely distributed in fresh water.

43. *Cymbella turgida* (Greg.) Cl. —Pl. 7, Fig. 1.

Valve semielliptic with rounded or slightly protracted ends; 20–25 μ in length, 5–6 μ in breadth. Ventral side narrow. Striae slightly radiate.

Locality: Songyuan-2 (卅).

Ecological distribution: Widely distributed in fresh and brackish water.

44. *Cymbella ventricosa* Kütz. var. *semicircularis* (Lagerst.) Cl. —Pl. 6, Fig. 2.

Valve almost semicircular with strongly convex dorsal margin and protracted ends, ventral margin with a median inflation; 16–20 μ in length, 6–7 μ in breadth. Ventral side narrow. Raphe almost straight, terminal ends curved in the same direction. Striae nearly parallel, slightly radiate at the ends of dorsal side.

Locality: Yunhai-2 (卅).

Ecological distribution: Prefers cool fresh water, infrequently seen in Taiwan.

45. *Cymbella tumida* (Brēb.) V. H. —Pl. 6, Fig. 7, 8, 9.

Valve asymmetricly elliptical to lanceolate with protracted subcapitate rounded ends; 50–95 μ in length, 15–18 μ in breadth. Dorsal margin convex; ventral margin concave and with a slightly median inflation in larger cells, almost straight in smaller cells. Central area tranversely broad, with an isolated punctum near the central nodule. Striae distinctly punctate; radiate, but convergent at the ends. I think var. *gracilis* should be treated with

Plate 7. Fig. 1. *Cymbella turgida* (Greg.) Cl. 2. *Cymbella aspera* (Ehr.) Cl. 3. *Epithemia sorex* Kütz. 4. *Epithemia zebra* (Ehr.) Kütz. 5. *Surirella striatula* Turpin var. *gautieri* Hérib. et Brun. 6. *Hantzschia amphioxys* (Ehr.) Grun. var. *capitata* O. F. Müll. 7. *Rhopalodia gibba* (Kütz.) Müll. 8. *Denticula thermalis* Kütz.

the nominate variety as a same taxon, but the larger ones in a population, since they showed a strong positive corelation in my collections. An abnormal one was collected, three isolated puncta were present near the central nodule and the striae near the central area were quite fewer than those on the normal cells.

Localities: Twenyuan-1 (+), Panshih (卄), Shuilien (卅).

Ecological distribution: Widely distributed in fresh water. Sometimes forms a yellow-brown mucilaginous mass.

46. *Cymbella* sp. —Pl. 6, Fig. 5.

Valve slightly asymmetrically lanceolate with rounded ends: 37-42 μ in length, 8-10 μ in breadth. Axial area broad. Striae almost parallel, shortened or lacked at the central part of the dorsal side. Median ends of raphe slightly curved to the ventral side. Terminal and central nodules distinct.

Locality: Panshih (卄).

Ecological distribution: Rarely found in Taiwan.

Epithemia Bréb.

47. *Epithemia sorex* Kütz. —Pl. 7, Fig. 3.

Valve strongly arcuate with capitate ends; 35-45 μ in length, 11-15 μ in breadth. Central nodule nearly reaching the dorsal margin. Costae radiate with 2-3 rows of punctate striae between each two costae.

Localities: Twenyuan-1 (卅), Twenyuan-2(+).

Ecological distribution: In fresh and brackish water. Subaerial or benthic (epilithic, epiphytic) form.

48. *Epithemia zebra* (Ehr.) Kütz. —Pl. 7, Fig. 4.

Valve lanceolate, gently curved with gradually attenuated to rounded ends; 33 μ in length, 7 μ in breadth. Central nodule nearly reaching the middle part of the valve. Costae slightly radiate with 4-8 rows of punctate striae between each two costae.

Locality: Twenyuan-1 (+).

Ecological distribution: In fresh water. Subaerial or benthic (epilithic, epiphytic) form.

Rhopalodia O. F. Müll.

49. *Rhopalodia gibba* (Kütz.) O. F. Müll. —Pl. 7, Fig. 7.

Valve lunate with almost straight ventral side and recurved acute ends; 60-90 μ in length, 20-30 μ in breadth. Frustules broadly linear with median inflation in girdle view. Costae alternating with 2-3 rows of striae.

Localities: Twenyuan-1 (卅), Twenyuan-2 (卄).

Ecological distribution: Often found in rivers and lakes.

Hantzschia Grun.

50. *Hantzschia amphioxys* (Ehr.) Grun. var. *capitata* O. F. Müll. —Pl. 7, Fig. 6.

Valve with capitate ends; 40-138 μ in length, 7-13 μ in breadth. Keel puncta and striae distinct. Differs from var. *pumilla* in having capitate ends.

Localities: Twenyuan-2 (+), Songyuan-1 (卄), Songyuan-2 (+), Tienchih-2 (+).

Ecological distribution: Widely distributed in fresh water.

Denticula Kütz.

51. *Denticula thermalis* Kütz. —Pl. 7, Fig. 8.

Frustules rectangular in girdle view. Valve lanceolate with attenuate ends; 18-22 μ in

length, 4-6 μ in breadth. Raphe with small central and polar nodules within the marginal keel. A series of transversely parallel septa present.

Locality: Yunhai-2 (▦).

Ecological distribution: Rarely seen in Taiwan. Prefers cool mountain water.

Surirella Turpin

52. *Surirella striatula* Turpin var. *gautieri* Hérib. et Brun. —Pl. 7, Fig. 5.

Valve ovate with one more attenuate ens; 95 μ in length, 36 μ in breadth. Alae and costae distinct.

Locality: Kuailin-2 (+).

Ecological distribution: Found in fresh water as a benthic form.

ACKNOWLEDGEMENTS

I should like to express my sincere thanks to Dr. Eugene Y. F. Shen, Dr. Charles E. DeVol and Dr. Y. M. Chiang for their encouragements and reading the manuscript.

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