FOSSIL DIATOMS AND BIOSTRATIGRAPHY OF THE LOWER KAREWA FORMATION OF KASHMIR

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ABSTRACT

During the course of geological mapping of the Karewa sediments of Kashmir to assess the economic potentialities of diatomaceous earth, the author collected nearly one thousand samples from 32 measured sections. The samples were analysed for fossil diatoms.

The study has indicated that while the lower Karewa is very rich in fossil diatoms, the upper Karewa is devoid of them. It is further observed that there is a uniformity in the trend of distribution and assemblages of fossil diatoms in the lower Karewa beds. Based on these two factors, the lower Karewa is divided into two biozones, the lower — Centrales Assemblage Zone, characterized by the predominance of centric diatoms and the upper — Pennales Assemblage Zone, characterized by the predominance of pennate diatoms.

The lower age limit of the Karewa is known to be Pliocene (pre-glacial) as postulated by earlier workers but the present study indicates that it may be even Miocene.

INTRODUCTION

THE Karewa of Kashmir possess different set of extinct life ranging from invertebrate, vertebrate to plant yet none of them have been applied so far for bio-stratigraphic classification of these thick sedimentaries. This has been mainly due to following reasons: (I) the record of animal life has been too scanty for such a study, and (II) the mega plant fossils did not show such a uniform trend of distribution which could be relied upon for such studies. However, in view of this, the, author while mapping the Karewa in order to asses the economic potentialites of some of the suspected diatomaceous earth, collected about one thousand samples from 32 measured sections between Nichahom (34°23′ 25″: 74° 08′ 40″) and Kurigam (33° 35′ 45″: 75° 09′ 05″). The samples were analysed for diatom study. The study thus undertaken has shown a uniform trend of distribution of diatoms which can be successfully applied for the bio-stratigraphic classification. As such an attempt to classify the Karewa bio-stratigraphically based on diatoms has been made and consequently the controversial age problem has been discussed.

GENERAL GEOLOGY

The lower Karewa beds are extensively developed over a length of 130 km and are 10 to 16 km wide. They rest upon pre-Tertiary rocks and are about 600 metre thick. They represent mainly an argillaceous facies composed of soft, dark grey, tough clays, shales and seams of lignite. Minor pebble beds, conglomerates, sands and sandy clays are also met with. The upper Karewa, about 300 metre thick, represent mainly an arenaceous facies composed of sands, silts, sandy clays and granular clays, varve clays, boulders and erratics, moraines, conglomerates etc. Structurally the lower Karewa sequence is disturbed while the upper Karewa is horizontally bedded. They are separated from one another by well marked unconformity. According to Wadia (1941, 1948) the lower units of the lower Karewa, on fossil evidence, are pre-glacial and not of the I inter-glacial period, as De Terra (1939) has inferred cn physical evidence. De Terra while agreeing with Lydekker's two-fold classification of the Karewa into lower and upper, further subdivided the lower Karewa into five lithozones such as: 1. Basal clay zone, 2. Lower lignite zone, 3. Upper lignite zone, 4. Upper clay zone, 5. Upper sand and gravel zone.

Roy (1971) carried out geological mapping of the Karewa of Kashmir valley during 1968-1970 in collaboration with the officers of the J & K Circle, Geological Survey of India. The following table (Table 1) shows the stratigraphic succession of the Karewa of Kashmir as worked out by De Terra, Wadia, and Roy.

The rock types belonging to the lower Karewa are described briefly in the following paragraphs:

Clays: Thin and thick bedded bluish grey, dark grey, brown, light yellow, buff, almost white, sometimes with yellow limonitic materials. They form the main constituent of the lower Karewa. These clays are extremely plastic and have large capacity of water absorption. The thickness of the individual beds varies from less

TABLE 1 — STRATIGRAPHIC SUCCESSION OF THE KAREWAS

	De Terra (1939)			Wadia (1948)			Roy (1971)	
Pleistocene	u.K.	II. Interglacial	Pleistocene	u.K.	Well bedded sands and clays with boulders and erratics, varve clays	Pleistocene	u.K.	Horizontally bedded sands and silts, sandy and granular clays, boulders and erratics, also tillites, loamy materials, conglomerates and gravels
	300 m	II. Glacial		300-500 m	Basal boulder bed II. Glacial		300 m	Glacial
				UNCONFORMITY				
	l.K.	I. Interglacial		l.K.	Blue buff and blue grey shales, sands and gravel cross-bedded varve clays	Mio Pliocene	l.K.	Folded and faulted soft, dark grey, tough clays, shales and sands with seams of lignite and well bedded pebble beds
	600 m	I. Glacial	Pliocene	1550-1675 m	I. Glacial Dark, often carbonaceous, shales, sandstones with thick conglomerate beds and lignite seams		600 m	
					Pre-Glacial			
				UNCONFORMITY				
Older rocks (Triassic limestones, Panjal Volcanics, etc.)				Pre-Tertiary			Pre-Tertiary	

l.K. = Lower Karewa, u.K. = Upper Karewa than a metre to several metres and their contact with the overlying and underlying beds is fairly sharp. The clays are often carbonaceous. They are rich in fossil plants, diatoms and insects.

Shales: Buff, grey, brown and dark shales constitute the second major rock type of the lower Karewa. Their thickness varies from a fraction of a metre to ten metres. They are normally rich in fossil plants, diatoms, insects and occassionally fishes.

Sandy clays: Black and ash-grey, brown and yellow coloured sandy clays with varying proportions of sand and clay form another constituent of the lower Karewa. They are several metres thick but beds less than a metre thick are not infrequent. They are very poor in fossil plants and diatoms.

Lignites: Generally two lignite horizons but sometimes more, each not exceeding five metres thick, have been noticed almost everywhere in the lower Karewa sequence. They have been noticed in the Upper Ningle valley, Sochalpathri, Niehahom, Sonyan-Saidnar, Kulgam-Kurigam, Shaliganga valley, Nagbal-Sitarsiran, Laredura, Wanim nala etc. They have yielded rich miofloral assemblages, the study of which is under progress. Middlemiss (1932) reported rich deposits of lignite in the lower Karewa of the Kashmir valley.

Besides the above, sporadic occurrences of pebble beds, conglomerates and sands have also been noticed in the lower Karewa.

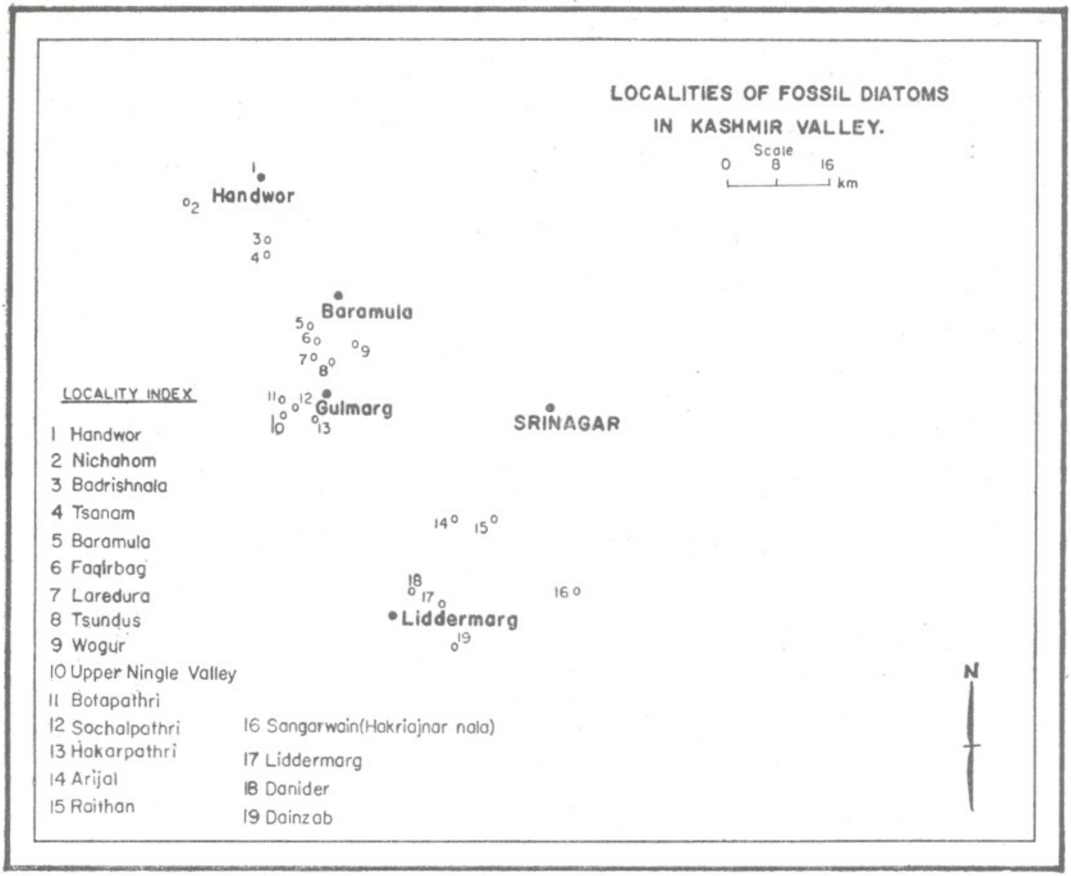
BIO-STRATIGRAPHY

No bio-stratigraphic classification of the Karewa in general and the lower Karewa in particular has been made so far though the general vegetational difference between the lower and upper Karewa was observed by Wodehouse (1935). His palynological studies led him to the conclusion that during the lower Karewa there were grassy plains which might have been absent during the upper Karewa. Later, Nair (1960) in his analysis of the pollens from the Karewa of Kashmir suggested a vegetational succession in the lower Karewa. He observed that during the early stages of lower Karewa, there was possibly an aquatic vegetation dominated by *Typha*. This was gradually replaced by a forest vegetation dominated by *Alnus*. This climax forest underwent destruction and there was open land occupied by *Plantago*, Chenopods, etc. The recent pollen analytical study of the Karewa by Vishnu-Mittre *et al.* (1962) has brought out a prominent Oak phase in the lowermost strata of the lower Karewa (litho zone 1 of De Terra). This Oak phase is replaced by the open Pine-mixed woods which are preceded and followed by a phase each devoid of vegetation. These two phases are referred to as the Lower Transition Zone (I glacial sequence in the lower Karewa according to them) and the Upper Transition Zone, respectively. The Lower Transition Zone corresponds to the top of litho zone I and entire litho zone II while the Upper Transition Zone corresponds to the base of litho zone IV. The Upper Transition Zone is succeded by a brief phase of Oak-mixed woods followed by a phase of Picea-Oak woods which are replaced towards the top of the profile by the Juglan-elm phase.

No attempt has so far been made to classify the Karewa on fossil diatoms. However, an account of the previous work on fossil diatom may be given here: Conger (in De Terra, 1939) reported a number of fossil diatoms from the Karewa for the first time. Thereafter, Iyengar and Subramanyan (1943) described some diatoms from them. Subsequently, Rao and Awasthi (1962) recorded and described some centric diatoms from the Karewa rocks exposed at Laredura, Kashmir. Recently Roy (1970) recorded 72 species of diatoms belonging to 29 genera from the lower Karewa of the Kashmir valley. The accompanying (Text-fig. 1) shows the distribution of fossil diatoms in the Kashmir valley.

Before summarizing the results of the present study a general account of the importance of diatoms in bio-stratigraphic zonation is necessary here. Diatoms occur in the Mesozoic, Tertiary and Quaternary deposits throughout the world but their maximum development is noticed in the Tertiary and Quaternary sediments. There is no satisfactory evidence of their occurrence in the Palaeozoic. Most of the extinct genera belong to the centrales and many genera represented by numerous species in the past have now only a few living ones. A thorough study of the literature in this sphere seems to support the view that the centrales are older than the pennales.

The great beauties that the diatoms possess due to the remarkable sculpturing



TEXT-FIG. 1

of their silicified cell-walls have attracted the microscopists for a very long period. Too much stress has so long been laid down on points of minute details with complete disregard to the stratigraphic and other geologic importance and as a result countless species have been created. But the Russian scientists have made significant advances in this subject and have successfully used the diatoms in the stratigraphic subdivisions and local and regional correlations of various formations, particularly the Palaeogene and Neogene formations of U.S.S.R. and other European countries. Similar attempts have also been made by a few workers in many other countries. While dealing with the lowest known Tertiary diatoms in California Hanna (1927a) opines "...... it will be possible to correlate the important shale-depositing epochs of the California Miocene, one with other; to be of greatest value such correlation should depend upon common 'marker species' of fossils, and it is believed that these exist in the diatoms, radiolarians, and silicoflagellates. Not only it is believed that local correlation will be possible, but because of the extremely great geographic range of these organisms, they should be a valuable aid in the world-wide age determinations of formations". The veteran Japanese scientist Ichikawa (1967) also felt that the assemblages of diatoms, peculiar to a deposit, may be used in correlating the strata of a given age in different places or even in different countries.

The studies of Zhuze, Shliapina, Gaponov, Proteskii, Krishtofovish and several other Russian workers have demonstrated beyond doubt that the diatom assemblages of Palaeocene, Eocene, Oligocene, Miocene and Pliocene ages differ markedly from each other. They have also brought out distinct assemblages for lower, middle and upper Miocene and Pliocene sediments. Zhuze (in Krishtofovish, 1949) and Shliapina (in Krishtofovish, 1949) carried out researches independently and correlated, on the basis of fossil diatoms, the Lower Miocene strata of North Caucasus with Tamansk and Kerchensk. Similarly, Shliapina (in Krishtofovish, 1949) correlated the Middle Miocene of Kargans with that of Konks. The Upper Miocene (Lower Sarmatian in particular) of Kamanets-Podolsk has been correlated with that of Dnepropetrovsk by Gaponov (in Krishtofovish, 1949).

On the basis of fossil diatoms Hanna (1927b) correlated the Moreno shale of Cal - fornia (Upper Cretaceous) with that of the Upper Cretaceous sediments of the Simbirsk area of U.S.S.R. and remarks 'A similar assemblage with some identical species occurs in northern Russia at Archangelsk Kurojedowo in Simbirsk'. In one of his subsequent papers Hanna (1934) described some additional forms of diatoms from the Cretaceous of California and observes 'Some of these are of much interest because they further confirm the closeness of these beds in age to those of the Simbirsk area of Central Russia'. Hanna (in Hertlein, 1933) assigned a Upper Miocene age for the Tertiary shale of Turtle Bay, Lower California, and observes 'it is believed that a sufficient number of diagnostic forms was found to definitely place the sample in the Upper Miocene'. In this connection he further opines 'Relationship with the deposit on Maria Madre Island is evident and the diatomites of comparable age are widespread in California'.

Colom (1952) made an exhaustive study of the Aquitanian-Burdigalian diatom deposits of the North Betic Strait, Spain and found their wide distribution in the eastern provinces of the Peninsula (Alicante, Southern Valencia). He also found relationship between the Spanish deposits and the Burdigalian deposits of the Balearics and observed the continuation of the Balearic sediments and those of the same age and composition at St. Laurent-La-Vernide (Gard, France) containing identical associations of benthonic diatoms.

Ichikawa (1950) recognized the stratigraphic significance of the Tertiary Diatomaceae of Japan and correlated the diatom bearing late Miocene or early Pilocene mudstones of Iizuka, Tsukada, Wakura, Yamatoda, Awara, Hijirikawa and Mitsukoji in the Nato Peninsula and the vicinity of Kanazawa city.

The author made an extensive study of the fossil diatoms from the Karewa and found that the lower Karewa is very rich in fossil diatoms while the upper Karewa is devoid of them. The uniform distribution of these fossils and their greatly differing assemblages in the lower Karewa have been utilized as tools in classifying them into two bio-zones; the lower — Centrales Assemblage Zone, characterized by the predominance of centric diatoms and the upper — Pennales Assemblage Zone, characterized by the predominance of pennate diatoms.

Centrales Assemblage Zone: This zone is characterized by the centric forms like *Cyclotella*, *Melosira*, *Coscinodiscus*, and *Stephanodiscus*. A few pennate forms like *Amphora*, *Caloneis*, *Cymbells*, *Eunotia*, *Epithemia*, *Fragilaria*, *Gomphonema*, *Hantzschia* and *Synedra*, are also present. The percentage of centric diatoms in this zone varies from 90 to 98. This zone is equivalent to lithozone I of De Terra and is represented by dark grey, bluish grey, brown, light yellow buff clays and shales with very little interbedded sands. This zone is present in the, Upper Ningle valley, Botapathri, Sochalpathri, Tsundus, Baramula, Sangarwain Sukhnag valley, Liddermarg and Tsanam.

Pennales Assemblage Zone: This zone is characterized by the predominance of pennate diatoms. The assemblage includes: *Navicula*, *Achnanthes*, *Tetracyclus*, *Cocconeis*, *Synedra*, *Fragilaria*, *Surirella*, *Nitzschia*, *Gomphonema*, *Rhopalodia*, *Mastogloia*, *Pinnularia*, *Cymbella*, *Caloneis*, *Rhaphoneis*, *Hantzschia*, *Tabellaria*, *Diploneis*, *Licmophora*, *Peronia*, *Rhoicosphenia*, *Frustulia*, *Stauroneis*, *Amphipleura*, *Epithemia*, *Campylodiscus*, *Pleurosigma*. The presence of centric forms in this zone is very insignificant and includes *Cyclotella*, *Melosira*, *Coscinodiscus* and *Stephanodiscus*. The pennales in this zone constitute more than 90% of the total diatoms. Lithologically, this zone is characterized by laminated blue-grey and light grey clays, shales; generally two, often more horizons of lignite, silts and some sands and sandy clays. This zone corresponds to the lithozones II to IV of De Terra and is exposed in the Upper Ningle valley, Botapathri, Sochalpathri, Hakarpathri, Baramula, Handawar, Faqirbagh, Wogur, Badrish valley, Shaliganga valley etc.

The proposed bio-stratigraphy is tabulated below:

AGE OF THE LOWER KAREWA

As regards the age of lower Karewa there are, at present, two views --- (I) they are Pleistocene (De Terra, 1939; Pilgrim, 1944) and (II) they extend down to Pliocene (Lydekker, 1878 and 1883; Middlemiss, 1923; Wadia, 1948). The protagonists of the first school of thought led by De Terra were guided by the fact that the lower Karewa sediments belong to the I interglacial. The second school does not believe in the presence of basal glacial deposits. The principal basis for dating the Karewa were the vertebrate fossil remains from the 'bone bed' of Sombur which yielded *Elephas hysudricus* and *Palaeoloxodon anticuus* (*namadicus*) suggestive of a Lower Pleistocene age (Tripathi & Chandra, 1962). Roy (1971) has recently grouped the Sombur bone bed and the Karewa sequence exposed at Hatwar, Gogjipathri etc. with upper Karewa and opines that the Lower Pleistocene age indicated by the fossil vertebrate remains of these beds is valid for upper, Karewa only and thus can not be generalised for the entire Karewa Group.

From the study of the fossil diatoms of the lower Karewa of Kashmir it is evident that they may be used as valid stratigraphic markers which is in accordance with the usage by a number of Russian workers on their works on the various formations of U.S.S.R. and other European countries. The great abundance (90 to 98%) of the centric forms in the lowest unit of the lower Karewa (lithozone I of De Terra) as compared to the diminished frequency (sometimes as low as 2%) in the rest of the lower Karewa beds (lithozones II to IV of De Terra) is a significant fact. Equally significant is the reverse trend shown by the pennate forms which have very low representation in lithozone I and very high percentage (90 and above) in lithozones II to IV. This sudden decline of the centric forms and the appearance of pennate forms in time implies that certain typical assemblage of diatoms reigned over others during the course of geological time.

Fritsch (1956) regards that the oldest and the most evolved diatoms are the centrales and are represented by forms like *Cyclotella*, *Coscinodiscus*, *Melosira*, *Stephanodiscus* and *Stephanopyxis* etc. Pia (in Fritsch, 1956) concludes that at the period of maximum development of diatoms in the Miocene centric forms preponderate. Hanna (1927a) found mainly centric diatoms with a few pennate forms from the Miocene strata of California. He further (Hanna, 1929) noted abundant pennate diatoms from the Pliocene beds and only centric diatoms from Cretaceous deposits of California (Hanna, 1927b). Okuno (1952) recorded only centric diatoms from the Miocene diatomite deposits of Kumaki, Tsuzureko, Yonaizawa, and Kitaura in Japan. Krishtofovish (1949) in his monumental work 'Diatom analysis' writes that the centrales dominated in the pre-Tertiary and Tertiary times, giving away to pennales through evolution. He further writes that large number of species of the pennate diatoms have evolved in Pliocene. He also noted that *Navicula* first appears in the Lower Sarmatian and is typical of Sarmatian. He cited the following assemblage to be typical of Sarmatian: *Achnanthes*, *Amphora*, *Campylodiscus*, *Coscinodiscus*, *Mastogloia*, *Navicula*, *Rhopalodia*,

TABLE 2 — BIO-STRATIGRAPHY OF LOWER KAREWA FORMATION

LITHOZONES (modified after De Terra)	PROPOSED BIO-ZONES	CHARACTERISTIC FOSSIL DIATOMS
Upper clay zone (140 m) Upper lignite zone (205 m) Lower lignite zone (135 m)	Pennales Assemblage Zone	*Navicula*, *Achnanthes*, *Tetracyclus*, *Cocconeis*, *Surirella*, *Rhopalodia*, *Mastogloia*, *Pinnularia*, *Rhaphoneis*, *Tabellaria*, *Gomphonema*, *Diploneis*, *Licmophora*, *Peronia*, *Rhoicosphenia*, *Frustulia*, *Stauroneis*, *Amphipleura*, *Campylodiscus*, *Pleurosigma*, etc.
Basal clay zone (180 m)	Centrales Assemblage Zone	*Cyclotella*, *Melosira*, *Stephanodiscus* and *Coscinodiscus*

Surirella, and *Synedra*. Proteskii (in Krshtofovish, 1949) while dealing with the fresh water Pliocene and later flora in the diatomites of Georgia (Kisatib deposit) and Armenia (Nurnus and Arzin deposits) in Caucasus opines that all presently known genera of pennales such as *Navicula*, *Amphora*, *Rhopalodia*, *Achnanthes*, *Mastogloia* etc. appeared in the Mio-Pliocene. He further opines that in Neogene pennales dominate over centrales which flourished and dominated in Lower Tertiary. He continued to remark that all the known genera of centrales appeared before Neogene and most of them died in Neogene. Conger (in De Terra, 1939) reported rich diatomaceous flora, dominated by pennales, from the Tatrot beds (Astian) of Naushahra, Salt Range.

A critical study of the lower Karewa flora shows that the typical Lower Sarmatian genus *Navicula* is completely absent in the proposed bio-zone I. It shows its first appearance in the lower part of bio-zone II (lithozone II of De Terra). Here the assemblage is: *Achnanthes*, *Amphora*, *Coscinodiscus*, *Mastogloia*, *Navicula*, *Rhopalodia*, *Synedra* and *Campylodiscus*. In the proposed bio-zone II also appears for the first time the other pennate forms like *Peronia*, *Pinnularia*, *Tetracyclus*, *Tabellaria*, *Licmophora*, *Rhoicosphenia*, *Frustulia*, *Stauroneis*, *Amphipleura*, *Pleurosigma*, *Nitzschia*, etc. All the above evidences suggest a Mio-Pliocene age to the lower Karewa.

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EXPLANATION OF PLATES

PLATE 1

1. *Cyclotella comta* (Ehrenberg) Kutzing. × 1200.
2. *Cyclotella* sp. × 530.
3. *Cyclotella comensis* Grünow. × 1200.
4. *C. transilvanica* Pantocsek. × 530.
5. *C. meneghiniana* Kützing. × 530.
6. *C. comta* (Ehrenberg) Kützing. × 530.

7a and 7b. *Melosira granulata* (Ehrenberg) Ralfs. × 530. Girdle view.

8a and 8b. *M. ambigua* (Grünow) O. Müller var. *laredura* Rao & Awasthi. × 530. Valve and Girdle view respectively.

9. *Cyclotella* sp. II. × 530.
10. *Coscinodiscus marginatus* Ehrenberg. × 1200.
11. *Cyclotella* sp. III. × 530.
12. *Melosira* sp. × 530.
13. *Coscinodiscus morenoensis* Hanna. × 530.

PLATE 2

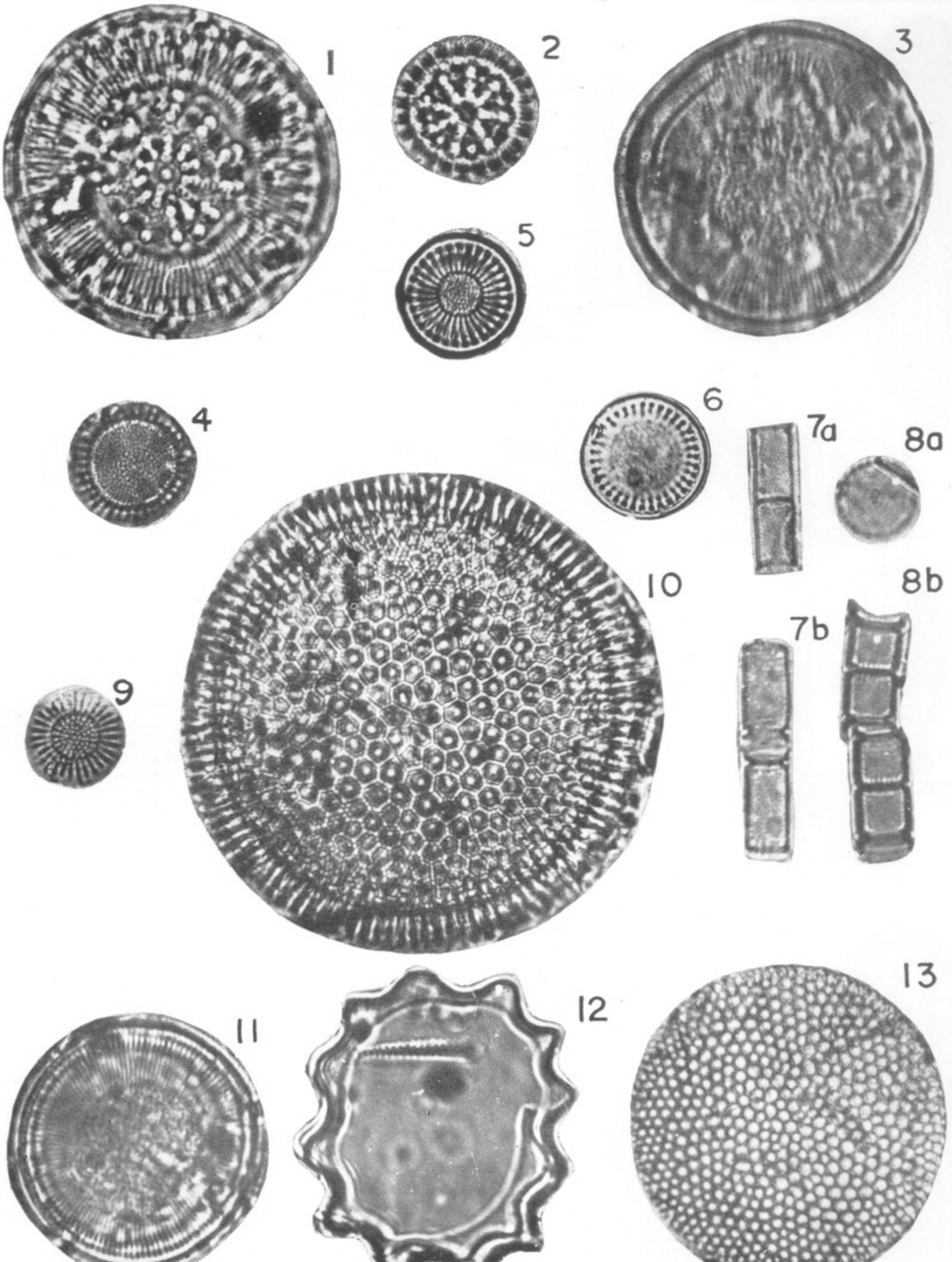
14. *Navicula americana* Ehrenberg. × 530.
15. *Achnanthes* sp.

16-18. *Fragilaria construens* (Ehrenberg) Grünow. × 530.

19. *F. pinnata* Ehrenberg var. *lancettula* (Schumann) Hustedt. × 1200.
20. *Rhopalodia gibba* (Kutzing) O. Muller. × 530.
21. *Rhopalodia* sp. × 530.
22. *Meridion* sp. × 1200.
23. *Synedra* sp. × 1200.
24. *Diploneis ovalis* (Hilse) Cleve. × 1200.
25. *Tabellaria flocculosa* (Roth) Kützing. × 530.
26. *T. fenestrata* (Lyngbye) Kützing. × 530.
27. *Amphora* sp. × 1200.
28. *Tetracyclus emerginatus* (Ehrenberg) W. Smith. × 530.
29. *Cocconeis placentula* Ehrenberg. × 530.
30. *C. disculus* (Schumann) Cleve. × 530.
31. *Surirella* sp. × 1200.

PLATE 3

32. *Cymbella aspera* (Ehrenberg) Cleve. × 1200.
33. *Gomphonema accuminatum* Ehrenberg. × 530.
34. *G. clevi* Fricke. × 530.
35. *Stauroneis phoenicenteron* Ehrenberg. × 530.
36. *Denticula* sp. × 1200.
37. *Pinnularia gibba Ehrenberg.* × 530.
38. *Navicula elongata* Poretzky. × 530.
39. *Epithemia sorex* Kützing. × 530.
40. *Cymbella cistula* (Hemprich) Kirchner. × 530.
41. *Eunotia valida* Hustedt. × 530.
42. *E. pectinalis* Rabenhorst var *undulata* Ralfs. × 530.
43. *E. robusta* Ralfs. × 530.
44. *Synedra crystallina* (Agardh) Kützing. × 1200.
45. *Rhoicosphenia curvata* (Kützing) Grünow. × 530.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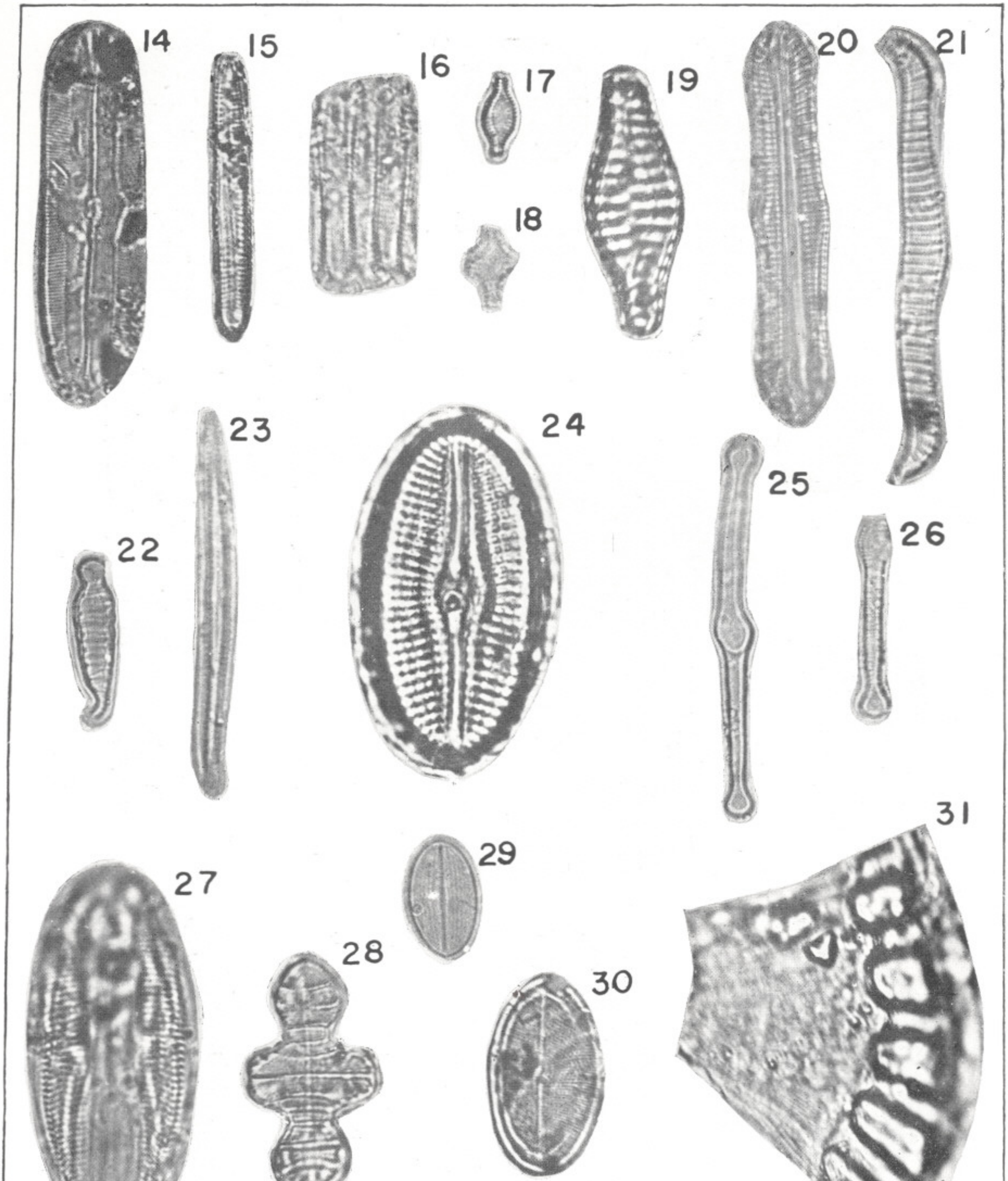
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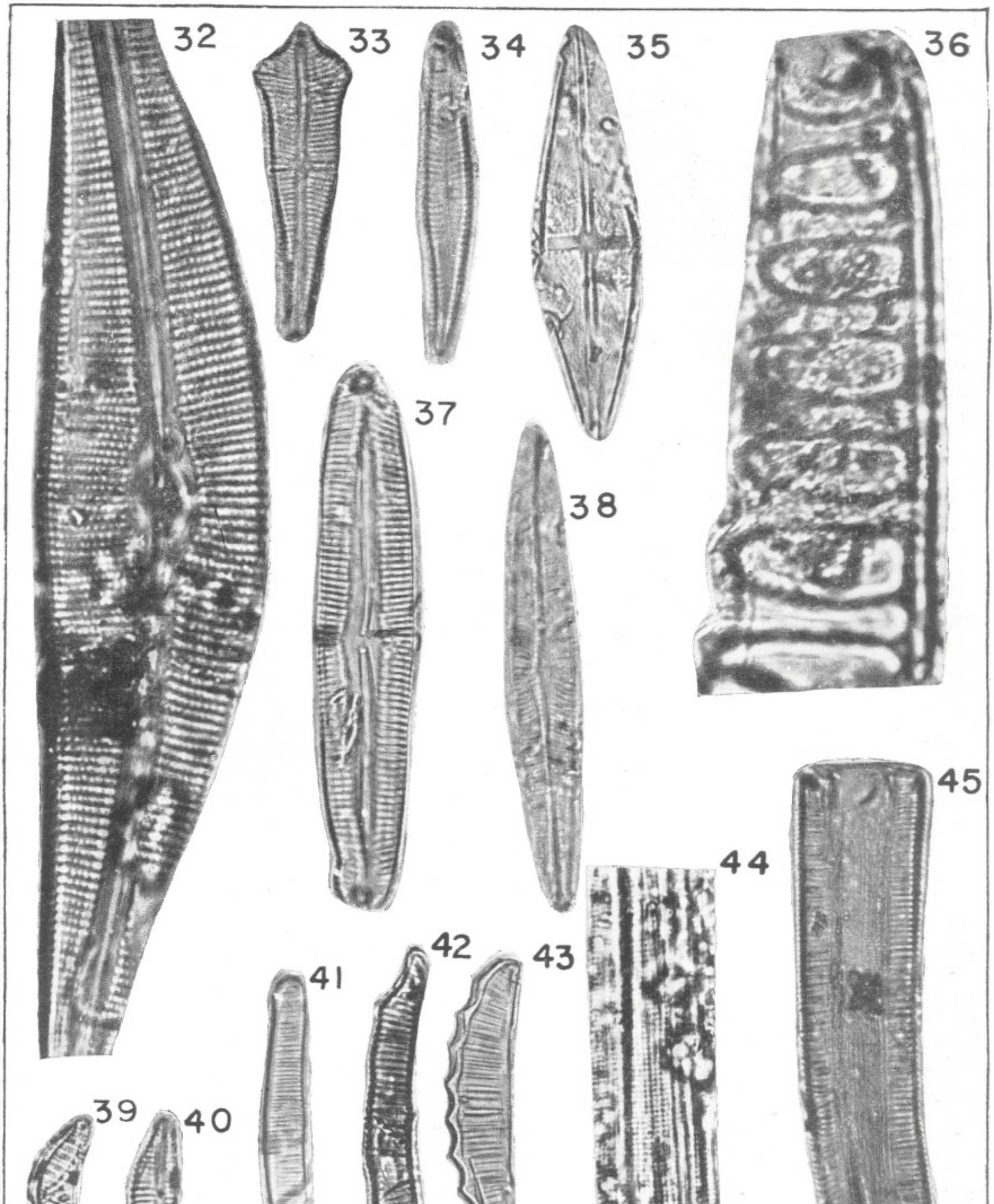
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