

ROCK ALGAE OF BATKHELA DISTRICT MALAKAND, PAKISTAN

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Abstract

The present study describes a total of 63 lithophytic algal species belonging to Cyanophyta (11 genera, 30 species), Chlorophyta (3 genera, 7 species) and Bacillariophyta (16 genera, 26 species) from rocks of Batkhela, District Malakand. The collected specimens were identified and described. This is the first ever report on rock algae from this area.

Introduction

Worldwide, algae are significant for producing half of photosynthetic organic materials that provide bases for food webs of variety of the animals (Valeem & Shameel, 2009). Algae play a significant role in the settlement of environment for human beings (Akhtar & Rehman, 2009). The present study described algae from rocks of Batkhela, District Malakand. Some previous workers also reported algae from rocks (Anjum *et al.*, 1985; Anjum & Faridi, 1985; Hussain *et al.*, 2003; Naz *et al.*, 2004; Zarina *et al.*, 2009; Ali *et al.*, 2010). Recently Hussain *et al.*, (2009, 2010) reported some algae from soil of KPK, Pakistan. The review of literature suggested that no work has been done exclusively on lithophytic algae in this area. This study is the first ever report on rock algae from District Malakand, Pakistan.

Materials and Methods

Batkhela District Malakand is located at coordinates of 34°35'N 71°57'E/ 34.583°N 71.95°E in the Khyber Pukhtunkhwa, Pakistan. Algal samples were collected from the different rocks located at Nasir Khan Dub, Yakh Dand, Zwarande Obra, Amandara head works, and Gumbat with the help of tooth brush and knife from rock surfaces near water bodies. The collected samples were taken in polythene bags with little quantity of water and was mixed thoroughly till it got homogenised. The materials were then transferred to bottle for preservation in 4% formalin solution (Anon., 1985; Mason, 1967).

Identification: The specimens were then identified with the help of available literature (Smith, 1950; Prescott, 1961; Tiffany & Britton, 1971; Desikachary, 1959) using BH-2 Olympus (Japan) microscope.

Results and Discussion

Algae are reported from variety of fresh water marine and marine habitats. However they also occur in wide variety of terrestrial environments where they form conspicuous growth. These include rocks, urban walls, metals, tree barks, leaves and animal hairs (Nakano, 1997; Lopez-Bautista *et al.*, 2007; Silva *et al.*, 2010). Such algae may not complete their reproductive stages without water (Lewis & McCourt, 2004). The present attempt to explore algal flora from rocks of Batkhela District Malakand indicated a total of 63 lithophytic species

(Table 1). These belonged to Cyanophyta (11 genera, 30 species), Chlorophyta (3 genera, 7 species) and Bacillariophyta (16 genera, 26 species) were identified and described. *Oscillatoria* (11 species), *Lyngbya* (6 species), *Chroococcus* (3 species), *Aphanocapsa*, *Gloecapsa* (2 species each), *Chlorogloea*, *Microcystis*, *Microcoleus*, *Neidium*, *Phormidium* and *Spirolina*, (Each with one species) were the blue green algae. *Closterium* (3 species), *Ulothrix* (2 species) and *Cosmerium* (one species) were belonged to Chlorophyta. While *Fragilaria*, *Navicula* (4 species each), *Cymbella*, *Epithemia*, *Gomphonema*, *Nitzschia* (2 species each), *Amphipleura*, *Amphora*, *Arthrospira*, *Colonies*, *Diatoma*, *Frustule*, *Meridion*, *Pinnularia*, *Rhapalodea* and *Syenedra* (each with one species) belonged to the Bacillariophyta.

Aphanocapsa (Nag): Cells spherical or nearly so, many loosely arranged without an order, forming a formless gelatinous mass.

Aphanocapsa biformis A. Braun

Cells 4-7 μ diameter, spherical, loosely arranged 2-4 together in a common mucilaginous envelope (Fig. 1).

Aphanocapsa endophytica G. M. Smith

Endophytic in the colonial mucilage of *microcystis*. cells solitary or arrange in small clumps, cell contents homogenous, pale to bright blue green, 2 μ in diameter (Fig. 2).

Arthrospira massartii (Kuffareth)

Trichomes loosely coiled, cells 5-6 μ broad, 2-4 μ long end cells rounded conical, cross-walls not granulated (Fig. 3).

Chlorogloea fritschii (Mitra)

Cells arranged in vertical and horizontal rows, rounded or angular usually 6-8 μ diameter, single or in groups of 2 or more cells separating for propagation (Fig. 4).

Chroococcus (Nag)

Cells spherical or sub spherical, hemispherical, after division in small groups of 2-4 individuals, sometimes 8-16, rarely single, in gelatinous or mucous matrix.

Cyanophyceae

Key to genera

1. Cell unicellular or colonial 2
1. Cell united to form trichome 6
2. Cells arrange radially in mucilage *Chlorogloea*
2. Cell spherical arrange irregularly in mucilage 3
3. Cells closely packed in colony *Microcystis*
3. Cells loosely arranged in colony 4
4. Colored mucilage, 2-8 cells *Gleocapsa*
4. Colorless mucilage, spherical cells 5
5. Small spherical cells, many in mucilage *Aphanocapsa*
5. Large spherical cells, 2-4 in mucilage *Chroococcus*
6. Trichome without sheath 7
6. Trichome with sheath 9
7. Trichome coiled/spiriled, septa not visible *Spirulina*
7. Trichome not coiled, septa visible 8
8. Trichome strait, cell wider than length, many septa *Oscillatoria*
8. Trichome isopolar, cells cylindrical, 4-8 septa *Arthrospira*
9. Trichome not in bundle in mucilage *Lyngbya*
9. Trichome many, arrange in cluster in mucilage 10
10. Trichomes entangled in mucilage, constricted at cross wall *Phormidium*
10. Trichome many in mucilage, not constricted at cross wall *Microcoleus*

Key to species

1. Cells 4-7 μ in diameter *A. biformis*
1. Cells 2 μ in diameter *A. endophytica*

Key to species

1. Sheath thin hardly visible *C. minor*
1. Sheath thick, distinct 2
2. Cell diameter, 4-8 μ with sheath *C. varius*
2. Cell diameter, 8-14 μ with sheath *C. limneticus*

***Chroococcus limneticus* (Lemm.)**

Cells spherical or sub spherical after division, 4-32, free floating, mostly in a tabular gelatinous layer, without sheath cells 6-12 μ diameter (Fig. 5).

***Chroococcus minor* (Kutz)**

Thallus slimy- gelatinous, cells spherical, 3-4 μ in diam., singly or in pairs, sheath colorless, very thin (Fig. 6).

***Chroococcus varius* A. Br.**

Thallus gelatinous, dirty olive green or brownish; cells globular single or 2-4 to gather, irregularly arranged without sheath 2-4 μ , with sheath 4-8 μ (Fig. 7).

***Gleocapsa* Kutzing**

Cells spherical, 2-8 in colonies, seldom many, with a number of concentric special envelopes, colonies single or many forming an expanded mass, individual sheaths

lamellated or unlamellated, cells in large colonies usually with secondary colonies.

***Gleocapsa calcarea* Tilden**

Cell with or without individual sheath, 6-9 μ in diameter, blue-green, sheath colorless often thin, colonies 25-50 μ in diameter, with 4-16 cells (Fig. 8).

***Gleocapsa magma* (Berb) Kutz**

Colonies spherical or irregularly arranged, 30-60 μ in diameter, cells spherical or angular, 3-7 μ in diameter, blue-green, mostly with a thin, 0.5-1.5 μ broad, colored individual sheath (Fig. 9).

***Lyngbya* Ag.**

Trichomes single or free in a thin or very massive thick, firm sheath, sheath mostly colorless, seldom colored yellow to brown or red, filaments sometimes coiled or attached, mostly without such attachments.

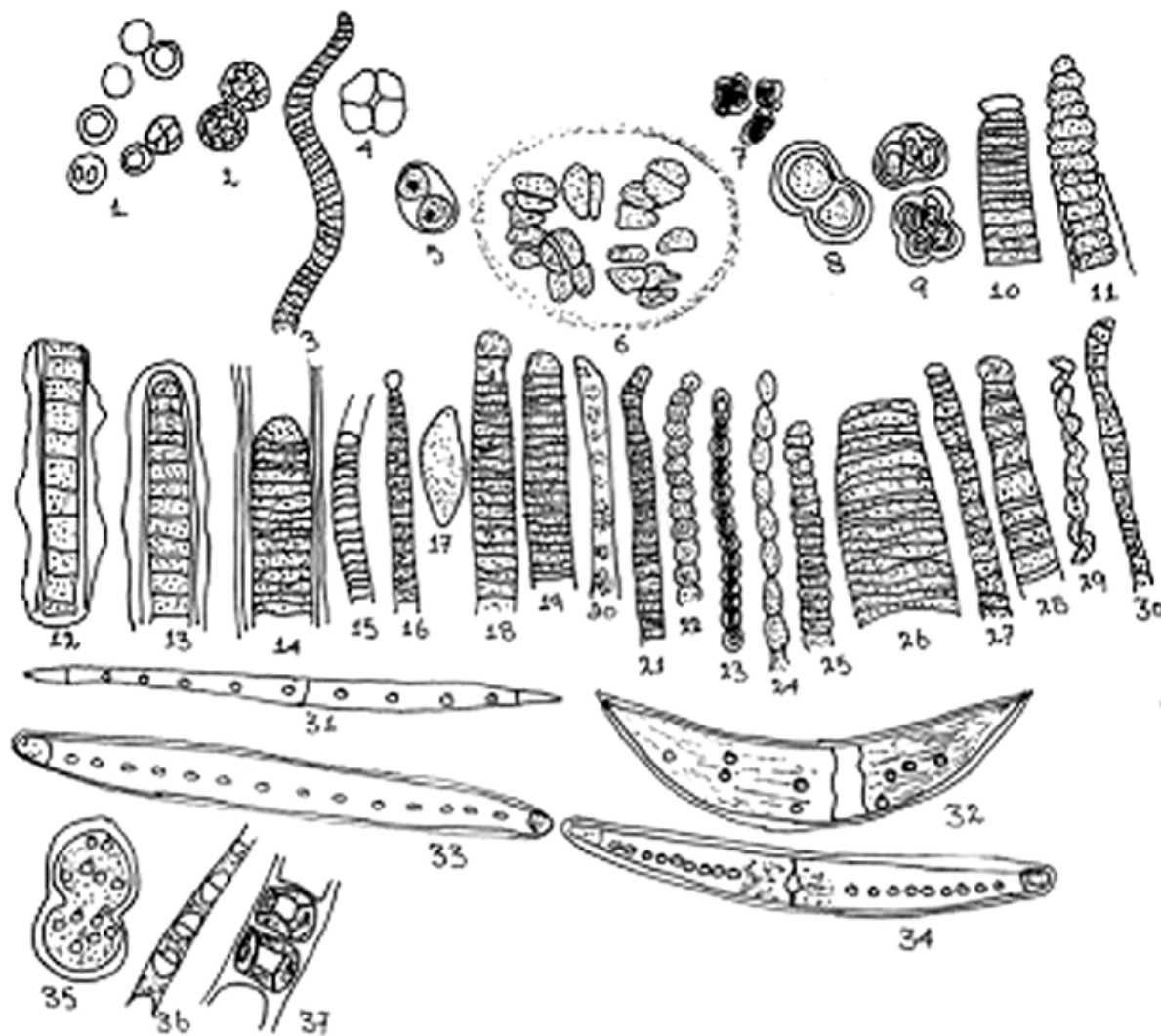


Plate 1.

Fig. No.	Species name	Fig. No.	Species name
Cyanophyceae			
1.	<i>Aphanocapsa biformis</i> A. Braun X 1000	20.	<i>Oscillatoria irrigua</i> (Kütz.) Gomont X720
2.	<i>Aphanocapsa endophytica</i> G. M. Smith X1000	21.	<i>Oscillatoria limosa</i> Ag. ex Gomont X720
3.	<i>Arthrospira massartii</i> Kuffareth X720	22.	<i>Oscillatoria okeni</i> Ag. ex Gomont X720
4.	<i>Chlorogloea fritschii</i> Mitra X1000	23.	<i>Oscillatoria pseudogeminata</i> G. Schmid X720
5.	<i>Chroococcus limneticus</i> Lemm. X1000	24.	<i>Oscillatoria princeps</i> Vaucher ex Gomont X720
6.	<i>Chroococcus minor</i> Kütz. X1000	25.	<i>Oscillatoria raoi</i> De Toni, J. X720
7.	<i>Chroococcus varius</i> A. Br. X1000	26.	<i>Oscillatoria subbrevis</i> Schmidle X720
8.	<i>Gloeocapsa calcarea</i> Tilden X1000	27.	<i>Oscillatoria tenuis</i> Ag. ex Gomont X720
9.	<i>Gloeocapsa magma</i> (Berb) Kütz X1000	28.	<i>Oscillatoria willei</i> Gardner em. Drouet X720
10.	<i>Lyngbya polysiphoniae</i> Frey X720	29.	<i>Phormidium tenue</i> (Menegh.) Gomont X720
11.	<i>Lyngbya major</i> Menegh, ex Gomont X720	30.	<i>Spirulina major</i> Kütz. Ex Gomont X720
12.	<i>Lyngbya arboricola</i> Bruhl et Biswas X720	Chlorophyceae	
13.	<i>Lyngbya aestuarii</i> Liebm. Ex Gomont X720	31.	<i>Closterium acerosum</i> (Sehrank) Ehrenberg X1600
14.	<i>Lyngbya corticicola</i> Bruhl et Biswas X720	32.	<i>Closterium acutum</i> (Lyngbye) Brebisson X1600
15.	<i>Lyngbya calcifera</i> Bruhl et Biswas X720	33.	<i>Closterium didymotocum</i> Ralfs X1600
16.	<i>Microcoleus vaginatus</i> (Vaucher) Gomont X720	34.	<i>Closterium ehrenbergii</i> Meneghin X1600
17.	<i>Microcystis marginata</i> (Menegh.) Kütz X 100	35.	<i>Cosmarium cucumis</i> (Corda) Ralfs X1600
18.	<i>Oscillatoria chlorina</i> Kütz. ex. Gomont X720	36.	<i>Ulothrix tenuissima</i> Kuetzing X720
19.	<i>Oscillatoria formosa</i> Bory ex Gomont X720	37.	<i>Ulothrix variabilis</i> Kuetzing X720

Key to species

1. Colonies 25-50 μ in diameter, with 4-16 cells *G. calcarea*
 1. Colonies 30-60 μ in diameter, with 4-8 cells *G. magna*

Key to species

1. Cells $\frac{1}{2}$ - $\frac{1}{3}$ as long as broad 2
 1. Cells otherwise 3
 2. Filaments flexuous, 12-26 μ broad *L. corticicola*
 2. Filaments short, 2 μ broad *L. polysiphoniae*
 3. Trichomes constricted 4
 3. Trichomes not constricted 5
 4. Septa not granulated *L. arboricola*
 4. Septa granulated with calcium carbonate *L. calcifera*
 5. Cells 11-16 μ broad *L. major*
 5. Cells 8-24 μ broad *L. aestuarii*

***Lyngbya aestuarii* Liebm. Ex Gomont**

Filaments single or forming a brown or dull blue-green thallus, nearly straight or coiled, sheath yellow brown, lamellated, cells 8-24 μ broad, 2.7-5.6 μ long, not constricted at the cross walls, cross walls often granulated (Fig. 10).

***Lyngbya arboricola* Bruhl et Biswas**

Filaments nearly straight, 18-22 μ broad, sheath reddish brown, firm, 1.5-2 μ thick, homogeneous, trichome distinctly constricted, septa not granulated, cells 5-6 μ long, contents blue green (Fig. 11).

***Lyngbya calcifera* Bruhi et Biswas**

Filament 1-2 mm in diameter, filaments are incrustated by calcium carbonate, cells about 4 μ in diameter, 6-10 μ long (Fig. 12).

***Lyngbya corticicola* Bruhi et Biswas**

Filaments fragile, moderately flexuous, 12-26 μ thick, sheath at first hyaline, but later becoming brown, 2 μ thick, trichome slightly constricted at the joints, cells about $\frac{1}{2}$ to $\frac{1}{3}$ as long as broad, apex rotund, contents green and granular (Fig. 13).

***Lyngbya major* Menegh, ex Gomont**

Filaments long, straight, sheath thick, colorless, lamellated, cells 11-16 μ broad, $\frac{1}{4}$ to $\frac{1}{8}$ as long as broad, cell rounded with slightly thickened membrane (Fig. 14).

***Lyngbya polysiphoniae* Fremy**

Filaments straight or curved, single or in bundle, up to 200 μ long, sheath very thin, cells $\frac{1}{2}$ to $\frac{1}{3}$ as long as broad, cross walls visible, end cells convex not capitate (Fig. 15).

***Microcoleus vaginatus* (Vaucher) Gomont**

Cells 3.5-7 μ broad, sub quadrate or 1/2-2 times as long as broad, 3-7 μ long. Often granulated at the cross-walls, but not constricted, blue green or green; end cells capitate, with flat conical calyptra (Fig. 16).

***Microcystis marginata* (Menegh.) Kutz**

Colony round, irregular flattened, simple, mucilage distinct, single colony ellipsoid to ovoid, 140-150 μ in length and 60-95 μ in width; cells 3-6 μ in diameter (Fig. 17).

***Oscillatoria* Vaucher**

Trichome single or forming a flat or spongy free-swimming thallus, sheath absent, motile, mostly by creeping movement, ends of trichome distinctly marked, pointed, bent like sickle or coiled more or less like a screw.

***Oscillatoria chlorina* Kutz. ex. Gomont**

Trichome straight or curved, not constricted at the cross walls, 3.4-4 μ broad, Cells sometime longer than broad, cross walls not granulated, calyptra absent (Fig. 18).

***Oscillatoria formosa* Bory ex Gomont**

Trichome straight, slightly constricted at the cross walls, 4-6 μ wide, attenuated at the ends and bent, $\frac{1}{2}$ as long as broad, 2.5-5 μ long, calyptra absent, not capitate (Fig. 19).

***Oscillatoria irrigua* (Kutz) Gomont**

Thallus blackish blue-green, trichome straight, 6-11 μ broad, apex slightly attenuated, Cells quadrate, 4-11 μ long, septa not granulated, apical cell convex with an evident thickened wall (Fig. 20).

Key to species

1. Cells $\frac{1}{2}$ as long as broad 2
1. Cells otherwise 3
2. Cells 6-11 μ broad *O. irrigua*
2. Cells 5.5-9 μ broad *O. okeni*
3. Trichomes constricted at the cross walls 4
3. Trichomes not constricted at cross walls 5
4. End cells hemispherical *O. tenuis*
4. End cells nearly obtuse *O. Formosa*
5. Cell walls frequently granulated *O. limosa*
5. Cell walls not granulated 6
6. Trichomes straight 7
6. Trichomes bent\ coiled 8
7. Trichomes, 1.3-2.2 μ broad *O. pseudogeminata*
7. Trichomes bent, 2.4-3.6 μ broad *O. willei*
8. Trichome attenuated at the apex, 16-60 μ broad *O. princeps*
8. Trichome not attenuated at the apex, less than 16 μ broad 9
9. Cell length less than 2 μ long *O. subbrevis*
9. Cell length more than 2 μ long 10
10. Trichome, 3-4 μ broad *O. chlorina*
10. Trichome, 3-4 μ broad *O. raoi*

***Oscillatoria limosa* Ag. ex Gomont**

Trichomes more or less straight, not constricted at the cross walls, commonly 13-16 μ broad, cells 2-5 μ long, cross walls frequently granulated, end cell flatly round (Fig. 21).

***Oscillatoria okeni* Ag. ex Gomont**

Trichome straight, fragile, distinctly constricted at the cross walls, 5.5-9 μ broad, at the ends gradually attenuated, cells $\frac{1}{3}$ as long as broad, 2.7-4.5 μ long, end cells obtuse, not capitate, without calyptra (Fig. 22).

***Oscillatoria princeps* Vaucher ex Gomont**

Trichomes blue-green, mostly straight, not constricted at the cross walls, 16-60 μ broad, slightly attenuated at the apices and bent, cells 3.5-7 μ long, end cells flatly rounded with slightly thickened membrane (Fig. 23).

***Oscillatoria pseudogeminata* G. Schmid**

Trichomes coiled, pale blue-green, ends not attenuated, 1.3-2.2 μ broad, cells as long as broad, not constricted at the cross walls, cross walls thick, not granulated, end cell rounded, calyptra absent (Fig. 24).

***Oscillatoria raoi* De Toni, J.**

Trichome straight, usually of uniform thickness, without constrictions at the joints, 5.2-6 μ broad, and cells 2.5-6 μ long, end cells rounded, not capitate, without any calyptra (Fig. 25).

***Oscillatoria subbrevis* Schmidle**

Trichomes single, 5-6 μ broad, nearly straight, not attenuated at the apices, cells 1-2 μ long, not granulated at the side walls, end cells round, calyptra absent (Fig. 26).

***Oscillatoria tenuis* Ag. ex Gomont**

Trichome straight, fragile, slightly constricted at the cross walls, 4-10 μ broad, not attenuated at the apices, not capitate, 2.6-5 μ long, end cells hemispherical with thickened outer membrane (Fig. 27).

***Oscillatoria willei* Gardner em. Drouet**

Trichome bent at the ends or screw like, broad unconstricted at the cross walls, ends not attenuated, not capitate, 2.4-3.6 μ broad, and end cell rounded without thickened membrane (Fig. 28).

***Phormidium tenue* (Menegh.) Gomont**

Thallus pale blue-green, thin, membranous, expanded; trichome straight or slightly bent, densely entangled, slightly constricted at the cross-walls, attenuated at the ends, 1-2 μ broad, pale blue-green; cells up to 3 times longer than broad, 2.5-5 μ long, calyptra absent (Fig. 29).

***Spirulina major* Kutz. Ex Gomont**

Cells 1.2-1.7 μ broad, regularly spirally coiled, blue green, spirals 2.5-4 μ broad and 2.7-5 μ distant (Fig. 30).

Chlorophyta**Key to genera**

- 1. Unicellular 2
- 1. Multicellular filamentous *Ulothrix*
- 2. Cells without median constriction *Closterium*
- 2. Cells with deeply median constriction *Cosmarium*

Closterium Nitzsch

Cells elongated, usually markedly alternate, rarely straight, strongly arcuate or lunate, without median constriction, poles obtuse, truncate, rostrate, attenuate, cells wall smooth, costate or striate, colorless or yellow to brown in color.

***Closterium acerosum* (Sehrank) Ehrenberg**

Cells 19-53 × 228-530 μ, 8-16 times longer than wide, almost straight, narrowly fusiform, pyrenoids 7-12 in a median series (Fig. 31).

***Closterium acutum* (Lyngbye) Brebisson**

Cells 3.7-11 × 60-180 μ, slightly curved, gradually attenuated to acute apices, cell wall smooth, colourless, chromatophores without ridges, pyrenoids 4-5 in a median series (Fig. 32).

***Closterium didymotocum* Ralfs**

Cells 24-56 × 295-672 μ, slightly curved, median portion with sub-parallel sides, gradually and slightly

attenuated to the broad rounded apices, chromatophores with 5-10 large pyrenoids (Fig. 33).

***Closterium ehrenbergii* Meneghini**

Cells 60-145 × 285-720 μ, apices 12-18 μ wide, stout, 5 times longer than wide, pyrenoids numerous, cell wall smooth (Fig. 34).

***Cosmarium cucumis* (Corda) Ralfs**

Cells 34-56 × 59-102 μ and 19-38 μ thick, longer than wide, deeply constricted, sinus linear, the apex rounded, semi-cells semi-elliptic, the apex rounded or slightly truncate., cell wall smooth, chromatophores 6-9 in each semi-cell, pyrenoids several in each chromatophore (Fig. 35).

Ulothrix Kutzing

Simple unbranched filaments of cylindrical cells, often showing basal differentiation and arising from a special hold fast cell; chloroplast a parietal band which extends 2/3 to 3/4 of the way around the cell and sometime extending the entire length of the cell.

Key to species

- 1. Pyrenoids, 5-12 2
- 1. Pyrenoids, numerous *C. ehrenbergii*
- 2. Cells straight, tapering at the apices *C. acerosumi*
- 2. Cells slightly curved 3
- 3. Cells 24-56 μ broad, rounded apices *C. didymotocum*
- 3. Cells 3.7-11 μ broad, acute apices *C. acutum*

Key to species

- 1. Chloroplast broad with two or more pyrenoids *Ulothrix tenuissima*
- 1. Chloroplast folded with one pyrenoid *Ulothrix variabilis*

***Ulothrix tenuissima* Kuetzing**

Filaments long, composed of cylindrical cells shorter than wide, 16-20 μm in diameter, thin walled and not constricted at the cross wall, chloroplast, broad encircling 2/3 of the circumference of the cell with 2 or more pyrenoids (Fig. 36).

***Ulothrix variabilis* Kuetzing**

Long, slender, entangled filaments, forming cottony masses. Cells cylindrical, without constriction of the cross-walls, chloroplast a folded parietal plate, 1/2 to 2/3 the length of the cell, with one pyrenoid. Cells 4.5-6 μ in diameter and up to 15 μ long, forming bright green slimy masses (Fig. 37).

Bacillariophyta**Key to genera**

- | | |
|---|--------------------|
| 1. Valves with transverse ornamentation | 2 |
| 1. Otherwise | 8 |
| 2. Valves transversely asymmetrical | 3 |
| 2. Valves transversely symmetrical | 4 |
| 3. Valves jointed into fan shaped or spiral colony | <i>Meridion</i> |
| 3. Valves not jointed | <i>Gomophonema</i> |
| 4. Girdle view asymmetrical not wedge shaped | <i>Cocconeis</i> |
| 4. Girdle view otherwise | 5 |
| 5. Girdle view rectangular, colony absent | <i>Diatoma</i> |
| 5. Colony formation frequent | 6 |
| 6. Cells with in gelatinous matrix | <i>Frustulia</i> |
| 6. Cells not in gelatinous matrix | 7 |
| 7. Cells linear to fusiform | <i>Fragilaria</i> |
| 7. Cells narrow and greatly elongated | <i>Synedra</i> |
| 8. Central or polar nodule elongated | <i>Amphipleura</i> |
| 8. Central or polar nodule not elongated | 9 |
| 9. Longitudinal lines or smooth area crossing striae | 10 |
| 9. Longitudinal lines or smooth area crossing striae absent | 11 |
| 10. Valves with transverse rows of punctae | <i>Neidium</i> |
| 10. Otherwise | 12 |
| 11. Valves with transverse costae | <i>Pinnularia</i> |
| 11. Valves with transverse striae or punctae | <i>Navicula</i> |
| 12. Raphe with marginal keel | <i>Nitzschia</i> |
| 12. Raphe without marginal keel | 13 |
| 13. Raphe without marginal keel, Valves with transverse costae | 14 |
| 13. Raphe without marginal keel, Valves without transverse costae | 15 |
| 14. Girdle view rectangular | <i>Epithemia</i> |
| 14. Girdle view medianly inflated | <i>Rhopalodia</i> |
| 15. Cells with parallel sides in girdle view | <i>Cymbella</i> |
| 15. Cells broadly elliptic in girdle view | <i>Amphora</i> |

***Amphipleura pellucida* Kuetzing**

Cells 7-9×80-140 μ, fusiform with sharply rounded ends, valves with very fine striations, 30-70 in 10 μ, terminal forks 18-20 μ long (Fig. 38).

***Amphora normani* Rabenhorst**

Cells in girdle view long-elliptic with broadly rounded ends, 10-14×16-40 μ; intercalary bands numerous, about 12 in 10 μ on the dorsal side, finely cross-lined; valves lunate, axial area narrow, central area absent; central nodule large, transverse striations somewhat radial, 16-18 in 10 μ (Fig. 39).

***Caloneis bacillum* (Grunow) Mereschkowsky**

Cells 4-9× 15-45 μ, valves linear to lanceolate, with straight or slightly convex sides and broadly rounded ends; transverse striations 22-28 in 10 μ, raphe straight (Fig. 40).

***Cymbella* C.A. Agardh**

Cells solitary and free-floating or attached, with parallel walls in girdle view and smooth girdles, without intercalary bands, valves asymmetric, lunate or nearly elliptic or naviculoid, dorsally convex and ventrally concave, raphe curved with well-defined nodules.

Key to species

- | | |
|--|--------------------------|
| 1. Valves asymmetric, striations 12-14 in 10 μ | <i>C. naviculiformis</i> |
| 1. Valves lanceolate, striations 12-16 in 10 μ | <i>C. amphicephala</i> |

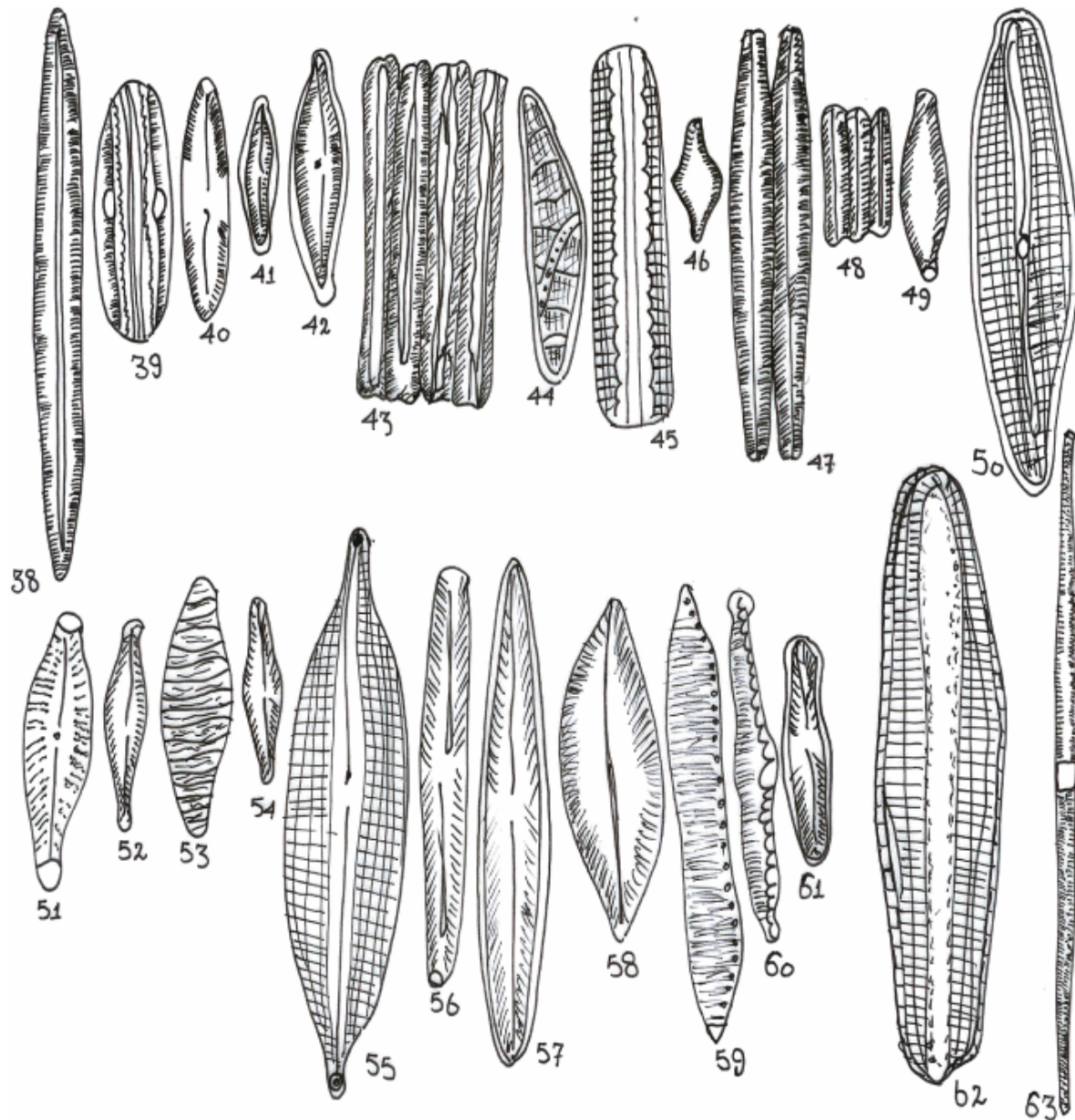


Plate 2.

Fig. No.	Species name	Fig. No.	Species name
	Bacillariophyceae		
38.	<i>Amphipleura pellucida</i> Kuetzing X1600	51.	<i>Gomphonema angustatum</i> (Kuetzing) Grunow X1600
39.	<i>Amphora normani</i> Rabenhorst X1600	52.	<i>Gomphonema sphaerophorum</i> Ehrenberg X1600
40.	<i>Caloneis bacillum</i> (Grunow) Mereschkowsky X1600	53.	<i>Meridion circulare</i> (Greville) C.A. Agardh X1600
41.	<i>Cymbella amphicephala</i> Naigeli X1600	54.	<i>Navicula cryptocephala</i> Kuetzing X1600
42.	<i>Cymbella naviculiformis</i> Auerswald X1600	55.	<i>Navicula cuspidata</i> Kuetzing X1600
43.	<i>Diatoma anceps</i> (Ehrenberg) Kirchner X1600	56.	<i>Navicula oblonga</i> Kuetzing X1600
44.	<i>Epithemia argus</i> (Ehrenberg) Kuetzing X1600	57.	<i>Navicula radiosa</i> Kuetzing X1600
45.	<i>Epithemia zebra</i> (Ehrenberg) Kuetzing X1600	58.	<i>Neidium iridis</i> (Ehrenb.) Cleve X1600
46.	<i>Fragilaria construens</i> (Ehrenberg) Grunow X1600	59.	<i>Nitzschia commutata</i> Grunow X1600.
47.	<i>Fragilaria crotonensis</i> Kitton X1600	60.	<i>Nitzschia sigmides</i> (Nitzsch) Wm. Smith. X1600
48.	<i>Fragilaria pinnata</i> Ehrenberg X1600	61.	<i>Pinnularia globiceps</i> Gregory X1600
49.	<i>Fragilaria virescens</i> Ralfs X1600	62.	<i>Rhopalodia gibba</i> (Kuetzing) Mueller X1600

50. *Frustulia vulgaris* (Thwaites) De Toni63. *Synedra acus* KuetzinX16

Table 1. Occurrence of rock algae in different localities of Batkhela, District Malakand.

S. No.	Species name	Localities				
		Nasir Khan dub	Amandara Head works	Yakh dand	Zwarande oba	Gumbat
Cynophyceae						
1.	<i>Aphanocapsa bififormis</i> A. Braun	+	+	+	+	+
2.	<i>Aphanocapsa endophytica</i> G. M. Smith	+	-	-	-	-
3.	<i>Arthrospira massartii</i> Kuffareth	+	+	+	+	+
4.	<i>Chlorogloea fritschii</i> Mitra	-	-	+	+	-
5.	<i>Chroococcus limneticus</i> Lemm.	+	-	+	-	+
6.	<i>Chroococcus minor</i> Kutz.	+	+	+	+	+
7.	<i>Chroococcus varius</i> A. Br.	+	+	+	+	+
8.	<i>Gloeocapsa calcarea</i> Tilden	+	-	+	-	+
9.	<i>Gloeocapsa magma</i> (Berb) Kutz	-	-	+	-	-
10.	<i>Lyngbya polysiphoniae</i> Frey	+	+	+	+	+
11.	<i>Lyngbya major</i> Menegh, ex Gomont	+	+	+	+	+
12.	<i>Lyngbya arboricola</i> Bruhl et Biswas	+	+	-	-	+
13.	<i>Lyngbya aestuarii</i> Liebm. Ex Gomont	+	+	+	+	+
14.	<i>Lyngbya corticola</i> Bruhl et Biswas	+	+	+	+	+
15.	<i>Lyngbya calcifera</i> Bruhl et Biswas	+	+	+	+	+
16.	<i>Microcoleus vaginatus</i> (Vaucher) Gomont	+	-	+	-	-
17.	<i>Microcystis marginata</i> (Menegh.) Kutz	+	+	+	+	+
18.	<i>Oscillatoria chlorina</i> Kutz. ex. Gomont	+	+	+	+	+
19.	<i>Oscillatoria formosa</i> Bory ex Gomont	+	+	+	+	+
20.	<i>Oscillatoria irrigua</i> (Kutz) Gomont	-	-	+	+	+
21.	<i>Oscillatoria limosa</i> Ag. ex Gomont	+	+	+	+	+
22.	<i>Oscillatoria okeni</i> Ag. ex Gomont	-	-	+	+	+
23.	<i>Oscillatoria pseudogeminata</i> G. Schmid	+	+	+	+	+
24.	<i>Oscillatoria princeps</i> Vaucher ex Gomont	+	+	+	+	+
25.	<i>Oscillatoria raoi</i> De Toni	-	+	+	-	+
26.	<i>Oscillatoria subbrevis</i> Schmid	+	+	+	+	+
27.	<i>Oscillatoria tenuis</i> Ag. ex Gomont	+	+	+	+	+
28.	<i>Oscillatoria willei</i> Gardner em. Drouet	+	+	-	-	+
29.	<i>Phormidium tenue</i> (Menegh.) Gomont	+	+	+	+	+
30.	<i>Spirulina major</i> Kutz. Ex Gomont	+	+	-	-	-
Chlorophyceae						
31.	<i>Closterium acerosum</i> (Sehrank) Ehrenberg	+	+	+	+	+
32.	<i>Closterium acutum</i> (Lyngbye) Brebisson	-	-	+	+	+
33.	<i>Closterium didymotocum</i> Ralfs	+	+	+	+	+
34.	<i>Closterium ehrenbergii</i> Meneghin	+	+	-	-	-
35.	<i>Cosmarium cucumis</i> (Corda) Ralfs	+	+	-	+	+
36.	<i>Ulothrix tenuissima</i> Kuetzing	+	+	+	+	+
37.	<i>Ulothrix variabilis</i> Kuetzing	+	+	+	+	+
Bacillariophyceae						
38.	<i>Amphipleura pellucida</i> Kuetzing	+	+	+	+	+
39.	<i>Amphora normani</i> Rabenhorst	-	-	+	+	+
40.	<i>Caloneis bacillu</i> (Grunow) Mereschkowsky	-	-	+	+	+
41.	<i>Cymbella amphicephala</i> Naigeli	+	+	+	+	+
42.	<i>Cymbella naviculiformis</i> Auerswald	+	+	-	-	+
43.	<i>Diatoma anceps</i> (Ehrenberg) Kirchner	+	+	+	+	+
44.	<i>Epithemia argus</i> (Ehrenberg) Kuetzing	-	-	+	+	-
45.	<i>Epithemia zebra</i> (Ehrenberg) Kuetzing	+	+	+	+	+
46.	<i>Fragilaria construens</i> (Ehrenberg) Grunow	+	+	+	+	+
47.	<i>Fragilaria crotonensis</i> Kitton	+	+	+	+	+
48.	<i>Fragilaria pinnata</i> Ehrenberg	-	-	+	+	-
49.	<i>Fragilaria virescens</i> Ralfs	+	+	+	+	+
50.	<i>Frustulia vulgaris</i> (Thwaites) De Toni	+	+	+	+	+
51.	<i>Gomphonema angustatum</i> (Kuetzing) Grunow	+	+	-	-	+
52.	<i>Gomphonema sphaerophorum</i> Ehrenberg	+	+	-	-	+
53.	<i>Meridion circulare</i> (Greville) C.A. Agardh	+	+	-	-	+
54.	<i>Navicula cryptocephala</i> Kuetzing	+	+	+	+	+
55.	<i>Navicula cuspidata</i> Kuetzing	+	+	+	+	+
56.	<i>Navicula oblonga</i> Kuetzing	+	+	+	+	+
57.	<i>Navicula radiosa</i> Kuetzing	-	-	+	+	+
58.	<i>Neidium iridis</i> (Ehrenb.) Cleve	+	+	-	-	+
59.	<i>Nitzschia commutata</i> Grunow	-	-	+	+	-
60.	<i>Nitzschia sigmides</i> (Nitzsch) Wm. Smith.	+	+	-	-	+
61.	<i>Pinnularia globiceps</i> Gregory	+	+	+	+	+

62. <i>Rhopalodia gibba</i> (Kuetzing) Mueller	-	-	+	+	-
63. <i>Synedra acus</i> KuetzingX1600	+	+	+	+	+

***Cymbella naviculiformis* Auerswald**

Cells 9-16 × 30-50 μ, valves asymmetric, raphe slightly curved and excentric, transverse striations radiate 12-14 in 10 μ (Fig. 41).

***Cymbella amphicephala* Naigeli**

Cells 9-16 × 30-50 μ, valves lanceolate, with convex sides and evident constrictions, raphe straight, slightly excentric, transverse striations radiate (Fig. 42).

***Diatoma anceps* (Ehrenberg) Kirchner**

Cells 4-8 × 15-100 μ, united into closed chains, with few or no intercalary bands, valves linear, capitate at poles, striations transverse (Fig. 43).

Epithemia Brebisson

Cells solitary, rectangular in girdle view, smooth girdles, intercalary bands, valves slightly to strongly curved, dorsally convex, ventrally straight to concave with broadly rounded to capitate and sometimes recurved poles.

Key to species

1. Valves with constricted end, cells 6-15 μ broad *E. argus*
 1. Valves not constricted, cells 7-14 μ broad *E. zebra*

***Epithemia argus* (Ehrenberg) Kutezing**

Cells 6-15 × 30-130 μ, valves ventrally straight to slightly concave, dorsally quite convex, with curved, broadly rounded ends (Fig. 44).

***Epithemia zebra* (Ehrenberg) Kutezing**

Cells 7-14 × 30-150 μ, valves lanceolate, gently curved with nearly parallel sides, gradually attenuated to rounded poles (Fig. 45).

Fragilaria Lyngbye

Cells rectangular in girdle view, with one or two intercalary band without septa and costae. Valves linear to

fusiform, bilaterally symmetric attenuated with pole, sometime capitated. Ransverse striae usually fine. Pseudo raphe narrow, chromatophores numerous.

***Fragilaria construens* (Ehrenberg) Grunow**

Cells 5-12 × 7-25 μ, united into compact chains, cruciform with lace-like pseudoraphe, striation transverse (Fig. 46).

***Fragilaria crotonensis* Kitton**

Cells 1-3 × 40-150 μ, united medianly into ribbon-like bands, ends often touching, valves narrowly linear, transverse striations, fine, about 15-18 in 10 μ (Fig. 47).

Key to species

1. Cells united in the middle portion only *F. crotonensis*
 1. Cells united through entire length 2
 2. Radial striations 14-17 in 10 μ *F. construens*
 2. Transverse striations 3
 3. Striations 10-12 in 10 μ *F. pinnata*
 3. Striations 12-19 in 10 μ *F. virescens*

***Fragilaria pinnata* Ehrenerg**

Cells 2-6 × 3-30 μ, united into flat chains, valves broadly to narrowly elliptical, evident linear pseudoraphe, rib-like transverse striation (Fig. 48).

***Fragilaria virescens* Ralfs**

Cells 5-10 × 12-120 μ, united into long chains, with straight to slightly convex sides, rounded poles and very narrow pseudoraphe, transverse striations moderately fine (Fig. 49).

***Frustulia vulgaris* (Thwaites) De Toni**

Cells 10-13 × 40-80 μ, unbranched tube, with elliptic valves having obtuse to rostrate extremities; striae somewhat radiant, about 24 in 10 μ (Fig. 50).

Gomphonema C. A. agarth

Cells usually solitary, free floating, Transversely asymmetric in both girdles and valves view, Cuneat in girdle view, with one pole capitated or broader than the other; strait raphe and conspicuous central and polaranodes; stration strictly transverse or somewhat radial; Chromatophore single.

Key to species

1. Valves elliptic clavate, cells 7-10 × 30-47 μ *Gomphonema sphaerophorum*
 1. Valves slender lanceolate, cells 5-9 × 12-45 μ *Gomphonema angustatum*

***Gomphonema angustatum* (Kuetzing) Grunow**

Cells 5-9 × 12-45 μ, valves slender, clavate-lanceolate, nearly symmetric, with slightly constricted and abruptly rounded poles, axial area narrow (Fig. 51).

***Gomphonema sphaerophorum* Ehrenberg**

Cells 7-10 × 30-47 μ, valves elliptic clavate, sharply narrowing towards a rounded and slightly apitate basal pole and with a much wider knob-like apical pole (Fig. 52).

***Meridion circulare* (Greville) C.A. Agardh**

Cells 4-8 × 12-80 μ, wedge-shaped, costae 3-5 in 10 μ and finely punctuate striations (Fig. 53).

***Navicula* Bory**

Cells generally solitary and free floating, sometimes aggregated into irregularly radiating clusters, rectangular in girdle view, with smooth girdle without intercalary bands, valves elongate usually attenuated toward capitate.

Key to species

1. Striations transverse 2
 1. Striations longitudinal, valve with rhombo-lanceolate ends *N. cuspidata*
 2. Ends broadly rounded *N. oblonga*
 2. Ends capitate or pointed 3
 3. Ends pointed, striations 10-12 in 10 μ *N. radiosa*
 3. Ends slightly capitate, striations 16-18 in 10 μ *N. cryptocephala*

***Navicula cryptocephala* Kuetzing**

Cells 5-7 × 40-120 μ, valves lanceolate with slender, somewhat capitate ends, central area elongated, striations medianly radial and polarly convergent, 16-18 in 10 μ (Fig. 54).

***Navicula cuspidata* Kuetzing**

Cells 17-37 × 50-170 μ, valves rhombo-lanceolate, tapering sharply to rounded ends, transverse striations, evidently punctate, longitudinal striations about 24 in 10 μ and parallel to axial area (Fig. 55).

***Navicula oblonga* Kuetzing**

Cells 13-24 × 70-220 μ, valves linear-lanceolate with broadly rounded ends, transverse striations in polar and sub-polar area, central area large (Fig. 56).

***Navicula radiosa* Kuetzing**

Cells 10-19 × 35-60 μ, valves lanceolate, gradually tapering to more or less pointed ends, transverse striations, 10-12 in 10 μ (Fig. 57).

***Neidium iridis* (Ehrenb.) Cleve**

Cells usually solitary, free floating, rectangular in girdle view and without girdle bands. Valve view linear with rounded or oval central area; raphe straight, usually bifurcated at poles, transverse rows of punctae crossed near the valves margins by narrow longitudinal clear spaces; two incised chromatophore (Fig. 58).

***Nitzschia* Hassall**

Cells generally solitary and free floating, sometime band like, elongate, rhombic or rectangular in transverse section, valves longitudinally asymmetric very variable in shape.

Key to species

1. Cells 7-12 μ broad, valves linear *N. commutata*
 1. Cells 5-8 μ broad, valves lanceolate *N. sigmidis*

***Nitzschia commutata* Grunow.**

Cells 7-12 × 50-80 μ, in girdle view broadly linear, with rounded poles, valves linear with concave sides and cuneate, ends acute (Fig. 59).

***Nitzschia sigmidis* (Nitzsch) Wm. Smith.**

Cells 5-8 × 20-50 μ, angular in girdle view, valves lanceolate with undulate margins, striations about 18 in 10 μ (Fig. 60).

***Pinnularia globiceps* Gregory**

Cells 8-10 × 30-40 μ, valves elliptic, with convex sides and broadly capitate poles, striations transverse (Fig. 61).

***Rhopalodia gibba* (Kuetzing) Mueller**

Cells broadly linear with median inflation and broadly rounded poles, 18-30 × 35-300 μ; valves very broadly lunate, with almost straight ventral sites and recurved acute poles. Costae 6-8 in 10 μ (Fig. 62).

***Synedra acus* Kuetzing**

Cells 5-6 × 100-300 μ, solitary, valves linear to lanceolate, needle-like towards the poles, transverse striations 12-14 in 10 μ; pseudoraphe narrow, linear with central area rectangular (Fig. 63).

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