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Significant Research on Diatom in Antarctica Lake during Last Decade

Abhijit Mazumder[1,2*], Pawan Govil1[2], Amit Kumar Ghosh[1] and Rasik Ravindra[2]

[1]Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow – 255 007, India
[2]National Centre for Antarctic and Ocean Research, Headland Sada, Goa – 403 804, India
* Corresponding Author: abhijit.mazumder.email@gmail.com

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Abstract

Study of diatom became one of the very promising fields in present science all over the world. Both biologists and geologists use this unicellular micro-organism for different purposes. Inland lakes of Antarctica region are also not exceptional in case of diatom studies. To understand the ecology and climate, the genetic complexity and even biochronology and other aspects, diatoms are used extensively over the years in Antarctica. Here we present a comprehensive overview of some prominent studies during last decade on diatom in Antarctic lake area. This will help the researcher to venture unexplored field of diatom study.

Introduction

Diatoms are microalgae consisting of a single cell with a cell wall of a siliceous skeleton enveloped by an organic case mostly composed of polysaccharides and proteins (Hecky et al., 1973; Round et al., 1990). Diatoms thrive in both freshwater and marine environments. Benthic diatom assemblages are good biological indicators of Antarctic lake ecology and environments for the few reasons. Diatoms are a very common constituent of benthic microbial mats, which are prevalent in Antarctic lakes (Fumanti et al., 1995, 1997; Vincent and James, 1996). Moreover, diatom assemblages clearly reflect environmental factors. Also, diatoms can be used as environmental indicators of the present as well as past, because their siliceous skeletons remain in lake-bottom deposits (Spaulding and McKnight, 1999). Large number of species with distinct range of habitat and tolerance to environmental conditions and the siliceous nature of the cell wall make diatoms the ideal ecological indicators with a wide range of applications both as living organisms and fossils. Jones (1996) was the first person to give a comprehensive account of diversity, distribution and ecology of diatoms from Antarctic inland waters. In the last decade the diatom study from Antarctic lake well advanced in every aspect, but unfortunately there is no documentation available to organize those studies to overview the total work done.

In order to facilitate the future research on diatom, it is important to evaluate the last decadal work in advance study on diatom. Accordingly, an attempt has been made to account of advance diatom study carried out in Antarctic lakes in last decade. To prepare a bibliography of diatom study in Antarctic lakes in last ten years as well as to highlight the major contribution of different studies are the principal objectives of this paper (Fig. 1).

Figure 1

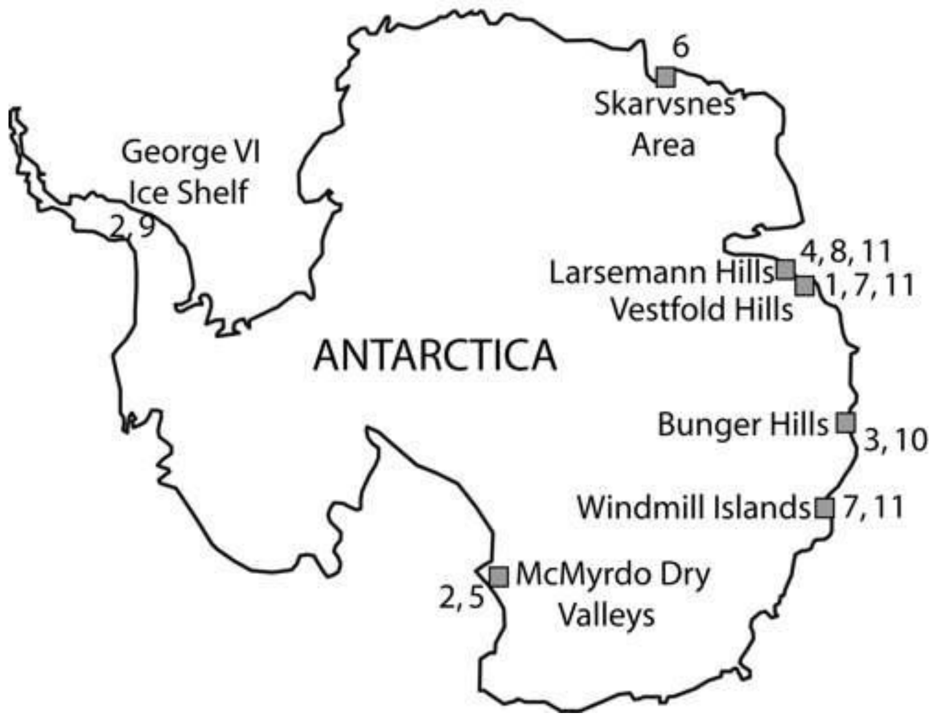

Figure 1: Location map showing significant diatom studies in Antarctic lakes in last decade [1. Coolen et al., 2004; 2. Esposito et al., 2006, 2008; 2006, 2008; 3. Gibson et al., 2006; 4. Hodgson et al., 2005; 5. McKay et al., 2008; 6. Ohtsuka et al., 2006; 7. Roberts et al., 2001a,b, 2004; 8. Sabbe et al., 2004; 9. Smith et al., 2006; 10. Verkulich et al., 2002; 11. Verleyen et al., 2003, 2004]

Genetic Studies of Diatom

Raymonda and Knight (2003) showed that two of the Ice Active Substances (IAS), extracellular macromolecules associated with Antarctic sea ice diatoms have a strong ability to inhibit the recrystallization of ice, possibly signifying a cryoprotectant function. To test this possibility, two species of marine diatom (*Fragilariopsis* sp., Antarctic and *Nitzschia frustulum*, temperate) were subjected to a single freeze–thaw cycle (approximately 20 h at -4 to -5º C) in the presence or absence of IAS. Viability, based on a double staining technique and etching of single crystal ice hemispheres grown from dilute IAS solutions suggest that the IASs acts as a cryoprotectant, probably through some ice-binding mechanism. Coolen et al. (2004) studied reserved ribosomal DNA of planktonic phototrophic algae recovered from Holocene anoxic sediments of Ace Lake, and they identified the ancient community members based on comparative sequence analysis. Using the novel paleo-ecological approach of combining data from lipid biomarkers and preserved DNA, they showed that the post-glacial development of Ace Lake from freshwater basin to marine inlet and the present-day lacustrine saline system caused major qualitative and quantitative changes in the biodiversity of the planktonic populations over time.

Paleoclimatic (and Ecological) Studies

Roberts et al. (2001 a) presented the limnology and sedimentary diatom flora of fourteen lakes and ponds (both saline and freshwater) from the Windmill Islands, East Antarctica. In their observation, the Windmill Island lake diatom flora represented an intermediate floral assemblage between that of the freshwater lakes of the Larsemann Hills and the saline lakes of Vestfold Hills, East Antarctica. They provided the reason of lakewater salinity/phosphate gradient which can explain this variation. Roberts et al. (2001 b) derived a high-resolution record of evaporation for the last 6.5 kyr from the diatom-salinity signal preserved in a sediment core taken from Ace Lake, Vestfold Hills. These data were highly correlatable with the seasonal oxygen isotope signal preserved in an ice core from Law Dome, which implied not only to provide a climate record for the past similar to 6.5 kyr of coastal East Antarctica but also to give a confirmation of the utility of reconstructions using these methods. Verkulich et al. (2002) studied the lithology, radiocarbon chronology, granulometry, geochemistry and distribution of diatoms in three sediment cores from fresh-water Figurnoye Lake in the southern Bunger Hills, East Antarctica and hence, detected several periods of warming and cooling climate within Holocene. Verleyen et al. (2003) inter-calibrated diatoms and water chemistry data from five different East Antarctic oases, namely the Larsemann Hills, the Boelingen Islands, the Vestfold Hills, the Rauer Islands and the Windmill Islands. On the basis of these data they concluded that salinity is the most important environmental variable explaining the variance in the diatom flora in East Antarctic lakes. Roberts et al. (2004) used an expanded diatom salinity weighted averaging (WA) regression and calibration model to reconstruct the paleosalinity of closed saline Beall Lake from the Windmill Islands. This improved model was used to infer a synchronous mid-Holocene optimum occurred across coastal East Antarctica. Sabbe et al. (2004) analyzed the morphological taxonomy of 26 diatom morphospecies (*viz. Pinnularia microstauron* var. *microstauron*, *P. boreali*, *Amphora veneta* etc.) and 33 cyanobacterial morphotypes from different lakes and ponds in the Larsemann Hills and Boelingen Islands, East Antarctica. Though no relationship was found between the distribution of these cyanobacterial morphotypes and conductivity, variation in diatom species composition was strongly related to both lake depth and conductivity. They also noted that the relationships between diatom species composition and conductivity, and diatom species composition and depth, were statistically significant. They summerized that the transfer functions based on these data can be used in paleolimnological reconstruction to infer changes in the precipitation-evaporation balance in continental Antarctic lakes. Verleyen et al. (2004) reconstructed the Late Quaternary climate history of the Larsemann Hills depending upon the siliceous microfossils (diatoms, chrysophytes and silicoflagellates) in sediment cores collected from three different lakes. Different episodes of warmer-wetter and dry-cold climatic conditions prevailed in this region. These data were consistent with ice-core records from Antarctica and supported the hypothesis that lacustrine and marine sediments on land could be used to evaluate the effect of long-term climate change on the terrestrial environment. Hodgson et al. (2005) presented multi-proxy data, including geochronology, diatoms, pigments and carbonate stable isotopes to show the ice-free condition for last 40kya in the Larsemann Hills region. They also stated that the warmer and wetter condition of earlier recorded period was gradually changed into arid and saline present. Gibson et al. (2006) studied the biogeography of Antarctic lacustrine diatom from Bunger Hills with the identification of 39 diatom species (under the genera *Achnanthes*, *Amphora*, *Craspedostauros*, *Craticula*, *Diadesmis*, *Fragilaria*, *Fragilariopsis*, *Luticola*, *Navicula*, *Nitzschia*, *Pinnularia*, *Psammothidium* and *Stauroneis*). They showed that the distribution and relative abundance of all diatoms are strongly influenced by the salinity along with some other factors, such as characteristics of lakes in the immediate area of the studies lake.

Smith et al. (2006) analyzed the water column and sediments from two epishelf lakes of George VI Ice Shelf for multidisciplinary studies, including diatoms, stable isotopes, geochemistry and grain-size analysis. The collective data was used to develop a conceptual model for determining past ice shelf configuration in epishelf lakes. They concluded that the change of ice shelf in this region would leave a clear signature in the lake sediment record. Previously it was inferred that the warming around 3 Ma caused a collapse of the ice sheet, exposing the Antarctic interior to inland seas on the basis of the presence of rare Pliocene marine diatoms in the Sirius Group tillites of the Transantarctic Mountains. McKay et al. (2008) documented an alternative source for the Sirius Group diatoms (specially *Thalassiosira* cf. *torokina*) through atmospheric transport onto the surface of the East Antarctic Ice Sheet to be carried downslope by katabatic winds flowing over the Allan Hills, one of many nunataks that border the East Antarctic Ice Sheet. They suggested the mechanism of melting of wind-blown snow during summer and thereafter transportation and concentration of these diatoms into "diatom-rich" layers, along with the extreme sparseness and sporadic occurrence of diatoms previously documented in the Sirius Group, justifies a more likely scenario in which diatoms from the atmosphere contaminated tillites that had been deposited beneath wet-based glaciers in much older and warmer times. Hence, they postulated Pliocene marine diatoms may have been injected into the troposphere by meteorite impact, or picked up from exposed land around the Ross Embayment following the disappearance of the Ross Ice Shelf in Pliocene times. Esposito et al. (2008) reported nine diatom taxa from the inland streams and lakes of the McMurdo Dry Valleys and James Ross Island, Antarctica, among which four are new species. They also observed that the diatom of the region is characterized by species assemblages favored under harsh conditions, where naviculoid taxa thrives prominantly than other several major diatom groups. Mazumder et al. (communicated) reported 13 species of diatom (few

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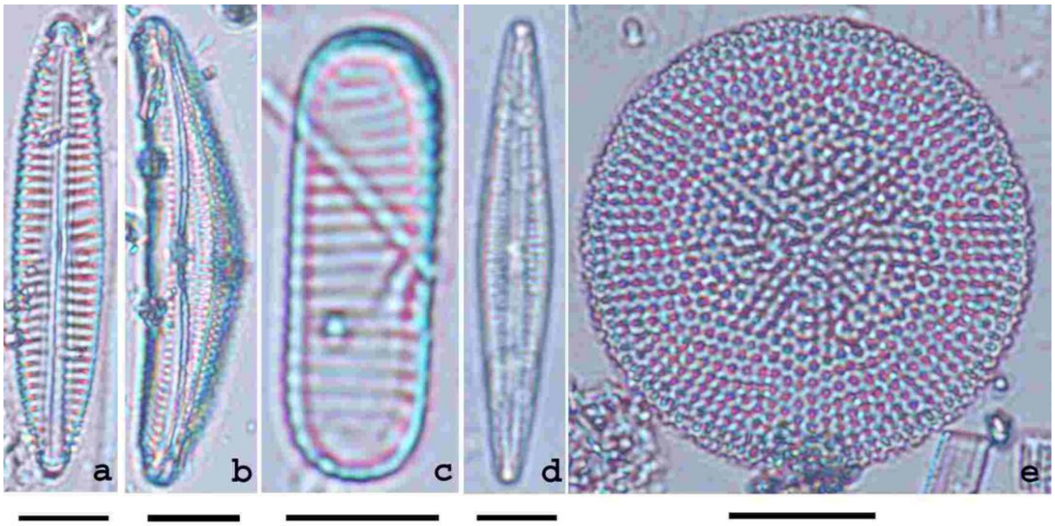
important genera shown in Fig. 2) from an inland lake in Vestfold Hills and on the base of the population of diatom along with the present of salt crystal it was postulated that the lake was detached from regular intervention of sea at ~5000 years BP.



<u>Figure 2:</u> Few representative genera of diatom reported from Antarctic Lake sediment studies.
a. *Achnanthes* sp. [Scale bar = 5 µm]
b. *Amphora* sp. [Scale bar = 5 µm]
c. *Fragilariopsis* sp. [Scale bar = 3 µm]
d. *Navicula* sp. [Scale bar = 5 µm]
e. *Thalassiosira* sp. [Scale bar = 5 µm]

Biochronology and Other Studies

Regoli et al. (2004) investigated the role of endosymbiotic diatoms as pro-oxidant stressors in porifera in the Antarctic sponge *Haliclona dancoi* in which the presence of diatoms is influenced by marked seasonal variations during the austral summer. They found that both chlorophaeopigments and frustules were absent in sponge tissues sampled in early November at the beginning of the summer and increased from the mid of December with slightly shifted temporal trends. The concluded that the efficiency of antioxidant defenses in the sponge showed a marked response to symbionts with clearly enhanced values corresponding to the peak of diatoms. Ohtsuka et al. (2006) studied diatoms from benthic microbial mats in 13 freshwater lakes from Skarvsnes area, East Antarctica in terms of their taxonomy and relationship to environmental factors. Depending on the redundancy analysis which revealed the electric conductivity as the main environmental gradient for diatoms, they concluded that *Diadesmis* sp. and *Psammothidium metakryophilum* are halophobes, whereas *Amphora* sp. is a halophile. Esposito et al. (2006) analyzed diatom samples from glacial meltwater streams in the McMurdo Dry Valleys to understand biotic responses to an Antarctic cooling trend. They concluded that cooling favoured the Antarctic species, and lowers diatom species diversity in this region. Edlund and Spaulding (2006) examined two diatom species *Muelleria peraustralis* and *Scoliopleura peisonis* and found undergoing uniparental auxosporulation to regain maximum valve size. Galster et al. (2010) discussed some theoretical aspects of quantitative biochronology and to compare the constrained optimization with the deterministic method called Unitary Associations, a graph theoretical model, and they illustrate the fact that the UAM is an extremely powerful and unique theory allowing an in-depth analysis of the internal conflicting inter-taxon stratigraphic relationships, inherent to any complex biostratigraphical database.

Conclusion

This paper portrayed a brief representation of the major study regarding diatom in last decadal period. The paleoclimatic study depending on the diatom ecology was mostly worked area of study. Still there are many lakes of Antarctic region remained untouched till date in case paleoclimatic studies. Genetic studies also got privileged among the last decadal promising works regarding diatom. Unlike other fields of study; geochemical or geophysical, even other biological aspects, diatom remained less studied subject from Antarctic lakes.

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