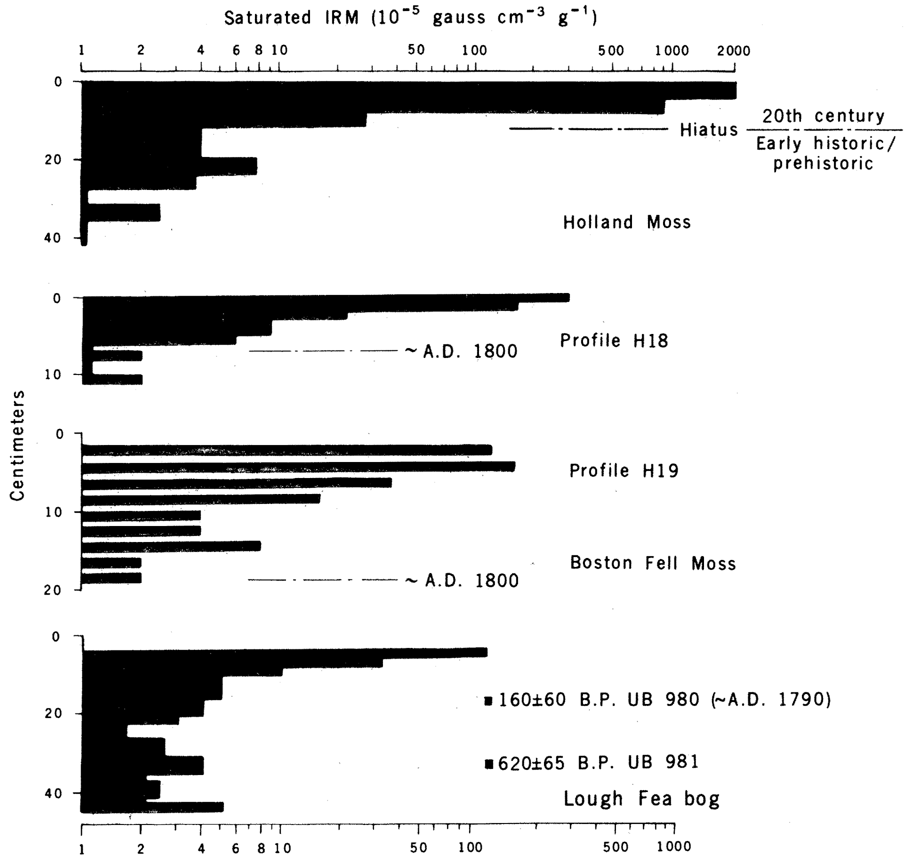

Fig. 1. Variations in saturated isothermal remanent magnetization (*IRM*) with depth in near-surface profiles from three ombrotrophic peat bogs in the United Kingdom. All samples were measured after saturation in an applied field of 10^4 oersteds.

at 15 to 20 cm. The radiocarbon date of 160 ± 60 years before present (B.P.) is for peat between 16 and 18 cm. The increase in IRM values clearly postdates these levels, indicating a period during and after the Industrial Revolution for the increase in magnetic content of the peat.

At Bolton Fell Moss, pollen analysis of both profiles also shows land-use changes characteristic of the late 18th and early 19th century in northwest England, including the virtual end of hemp cultivation (*6*) and the afforestation of local parkland with pines and exotic conifers. In profile H18 from a large hummock, the changes take place at 6 to 7 cm, just below the increase in IRM. In profile H19 from an adjacent, deep, infilled pool, the change occurs as low as 18 cm, 10 cm below the first major increase in IRM. A lower level in the profile, radiocarbon-dated to 505 ± 35 years B.P., lies 22 cm below this. In both profiles, the results are consistent with a 19th-century increase in magnetism and point to a recent anthropogenic source for the bulk of the magnetic particles present in the peat.

Holland Moss is a rather special case in that the surface of the bog has been trimmed down to the present level by an unknown amount of peat cutting for horticultural use in the present century. There is thus a hiatus at the top with very recent highly magnetic material overlying very weakly magnetic peat of prehistoric or early historic age. As with the two previous sites, however, the more magnetic peat is seen to be a very recent phenomenon resulting from human activities.

In summary, the evidence outlined here appears to be conclusively in support of the suggestion of Doyle *et al.* (*1*) that the dominant sources of magnetic particles in the atmosphere at present are industrial and urban. Magnetic measurements in recent peat profiles show that, at the sites studied, the influx of these minerals has increased by two to three orders of magnitude since the beginning of the Industrial Revolution and the first widespread use of fossil fuel for industrial and domestic purposes. Ongoing studies, designed to characterize more fully the magnetic particles responsible for both the recent maximum and the smaller pre–Industrial Revolution peaks in IRM and to date the magnetic variations recorded by ^{14}C and ^{210}Pb analysis, should increase our knowledge of the nature of the long-term influx of magnetic material and the precise age and origins of the variations recorded. Results to date show that rapid, nondestructive magnetic measurements of ombrotrophic peat provide a means both of estimating spatial and temporal variations in post–Industrial Revolution particulate atmospheric fallout and of characterizing and differentiating pre–19th century fallout.

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11 October 1977

Aluminum in Seawater: Control by Biological Activity

Abstract. *The distribution and concentration of dissolved aluminum in a vertical hydrographic profile in the Mediterranean Sea near Corsica are controlled by biological activity. The concentrations of dissolved silica and aluminum covary in the profile and exhibit minima coincident with the seasonal thermocline, a nitrate minimum, and an oxygen maximum. These observations support the hypothesis that the silicon and aluminum cycles in the oceans are linked through the activity of diatoms.*

The factors that control the concentration and distribution of dissolved aluminum in seawater are poorly known. Sillén (*1*), in his model of the controls of the chemical composition of seawater, proposed that aluminum is regulated by thermodynamic equilibria between seawater and various aluminosilicate minerals found in marine sediments. Various authors (*2*) have discussed, extended,

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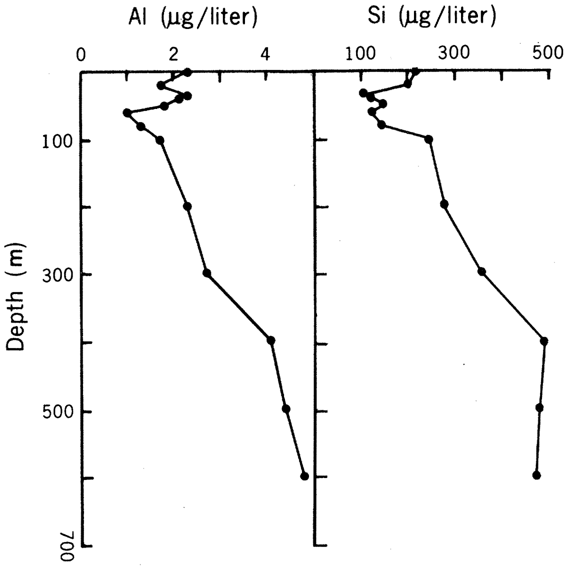

Fig. 1 (left). Vertical profiles of dissolved Al and Si in the Mediterranean Sea west of Calvi, Corsica.

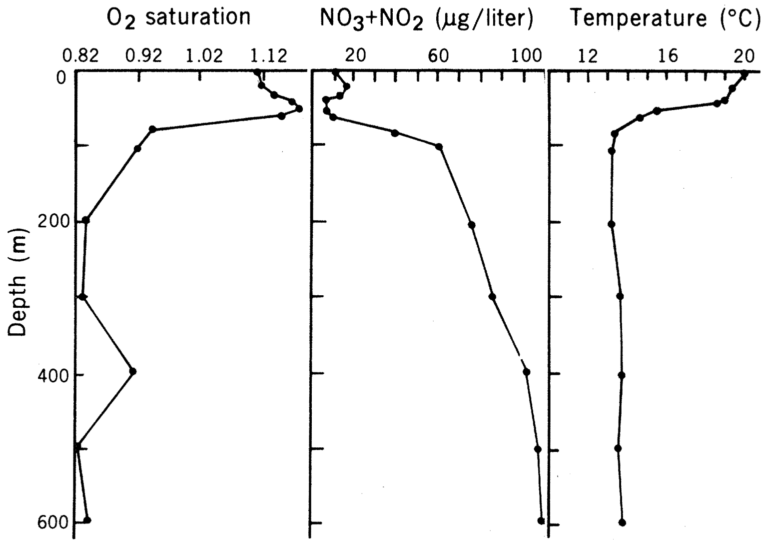

Fig. 2 (right). Vertical profiles of oxygen saturation, nitrate, and temperature in the Mediterranean Sea west of Calvi, Corsica.

and modified Sillén's thermodynamic approach or have developed models of seawater composition emphasizing kinetic factors (*3*). Recently, Stoffyn (*4*) and van Bennekom and van der Gaast (*5*) proposed that the geochemical cycles of Si and Al in seawater are coupled (*6*). Stoffyn argued that Al is incorporated into the siliceous frustules of living diatoms and subsequently released by dissolution of the frustules after the death of the organisms. Van Bennekom and van der Gaast suggested that Al in diatom frustules may be present in very fine grained clay minerals ("smectite") of authigenic origin.

To assess the possible link between the geochemical cycles of Si and Al, we decided to investigate the concentration profile of dissolved Al, as well as physical and nutrient properties, in seawater in a region where the primary productivity is restricted to a well-defined water layer. To investigate seasonal and annual variations in physical, chemical, and biological properties of a portion of the Mediterranean Sea, a standard oceanographic station located 12 nautical miles (22 km) west of Calvi, Corsica, has been occupied by the Stareso Marine Laboratory research vessel *Recteur Debuission* at irregular intervals since 1974. The ocean depth is 2000 m. Water samples for Al and nutrient analysis were collected there from various depths (Fig. 1) during September 1976. Oxygen was determined by the conventional Winkler titration method and temperature by reversing thermometers.

All the samples for Al and nutrient analyses were filtered through 0.45-μm Millipore filters immediately after collection. The samples were analyzed for nitrate and silica shortly after filtration. The filtered samples for Al determinations were kept at 4°C in polyethylene bottles for later analysis. To prevent further biological activity, one or two drops of chloroform was added to each sample destined for Al analysis. The samples were analyzed for Al 2 weeks after collection by a fluorometric method, using lumogallion as the chelating agent (*7*). Analysis of Al by this method has a precision and accuracy of ± 0.1 μg liter. A duplicate series of samples for Al were frozen after filtration. The samples were analyzed by the same method about 3 months after collection (*8*) and the same results were obtained. The results of the analysis are shown in Fig. 1.

The vertical profile of Al (Fig. 1) shows a definite variation of the concentration of dissolved Al with depth. A minimum Al concentration of about 1 μg/liter occurs between 40 and 80 m in depth, coincident with the thermocline (Fig. 2), whereas a maximum of about 5 μg/liter occurs at 600 m. These results are contrary to the observations of previous investigators (*9*), who concluded that the concentration of dissolved Al in the oceans is independent of depth.

The vertical distribution of oxygen, nitrate, and silica (Figs. 1 and 2) shows the presence of a zone of intense biological activity between 40 and 70 m in depth. In this zone there are a maximum in the O_2 content and minima in the silica and nitrate concentrations of the water (Fig. 2). The minimum in the Al profile occurs within this zone of high biological activity. The similarity between the silica and Al profiles is striking. Figure 3 is a plot of the Al concentration against the silica concentration observed for each sample of the vertical profile. A linear regression

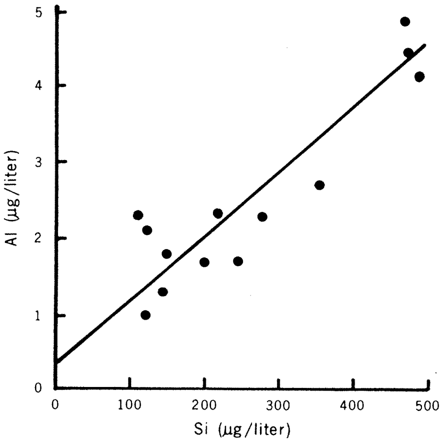

Fig. 3 (left). Covariation of dissolved Al and Si for the vertical profiles of these constituents shown in Fig. 1.

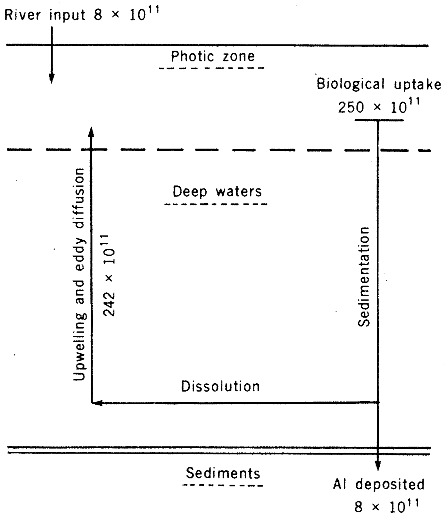

Fig. 4 (right). Tentative cycle of Al in the oceans. Biological uptake of Al is calculated as 0.1 percent of silica uptake as biogenic opal (*3*, *10*). Fluxes are in units of grams per year.

fit to the observed data is also shown. The regression yields a correlation coefficient between Al and silica of 0.90. This correlation suggests that the concentration of dissolved Al in the water column is controlled by the same mechanism that controls dissolved silica.

Several investigators (*3*, *10*) concluded that the distribution and concentration of dissolved silica in the oceans are regulated by the biological activity of diatoms. Our profile of dissolved Al and its covariance with dissolved silica observed in the Mediterranean Sea support the hypothesis that there is a link between the Si and Al cycles in the oceans through the activity of diatoms. The coupling of the cycles of Al and Si within the oceans through the activity of diatoms implies that the Al cycle is very similar to the Si cycle established by Wollast (*10*). If we assume that the Al/Si ratio in diatom frustules is approximately 0.001 (*11*) and the average concentration of dissolved Al in river waters is 25 μg/liter (*12*), then a cycle for Al in the oceans, completely analogous to that for Si, can be constructed (Fig. 4). This cycle may maintain the oceans at steady state with respect to dissolved Al. Furthermore, Fig. 3 gives an average Al/Si ratio in seawater near Corsica of about 0.008. This is within the range of values observed for Al and Si in diatom frustules (*11*).

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12. Measurements of dissolved Al in river waters are suspect because of particulate contamination [see, for example, discussions by W. H. Durum and J. Haffty, *ibid.* **27**, 1 (1963); V. C. Kennedy, G. W. Zellweger, B. F. Jones, *Water Resour. Res.* **10**, 785 (1974)]. Our estimate for the average dissolved Al concentration of the world's rivers is based on the following recent work: (i) B. F. Jones, V. C. Kennedy, and G. W. Zellweger [*Water Resour. Res.* **10**, 791 (1974)] reported that waters from small streams in California, after filtration through 0.1-μm filters and extraction with oxine, showed Al concentrations of 1 to 10 μg/liter. (ii) D. J. Hyde [thesis, University of East Anglia (1974)], using the fluorometric method for Al (*7*), observed Al concentrations of 5 to 42 μg/liter in waters of the Conway, Ouse, and Yare rivers, North Wales. (iii) M. Stoffyn (*4*), using the fluorometric method for Al (*7*), observed 17 μg/liter in the Scheldt River, Belgium.
13. We thank R. M. Garrels for a critical review of this report and S. Caschetto for the analysis of the Al in the frozen samples. Supported by NSF grant EAR 76-12279.

20 September 1977

1400-Million-Year-Old Shale-Facies Microbiota from the Lower Belt Supergroup, Montana

Abstract. *Carbonaceous shales of the Middle Proterozoic Newland Limestone, Belt Supergroup, Little Belt Mountains, Montana, contain abundant and well-preserved filamentous and spheroidal microfossils. The filamentous forms, ranging from less than 1 to 12 micrometers in width, are interpreted as representing the preserved sheaths of at least four species of nostocalean cyanophytes. The spheroidal forms, ranging from 15 to 108 micrometers in size, are evidently planktonic forms and are tentatively interpreted as representing the encystment stage of eukaryotic algae. The Newland microbiota is adaptable to petrographic thin-section work, and useful for evaluating the potential of such microfossils for intercontinental biostratigraphic correlation. It is the oldest shale-facies microbiota presently known from North America.*

During the past 15 years, knowledge of Precambrian life has advanced rapidly with the discovery of more than 30 well-preserved microfossil assemblages (*1*-*3*). Most of the Precambrian microbiotas studied in North America occur in stromatolitic cherts; the constituent microfossils largely represent shallow-water, benthic mat communities (*2*). Such communities may not embrace the entire spectrum of Precambrian life (*2*, *4*-*6*). Furthermore, some of these microbiotas

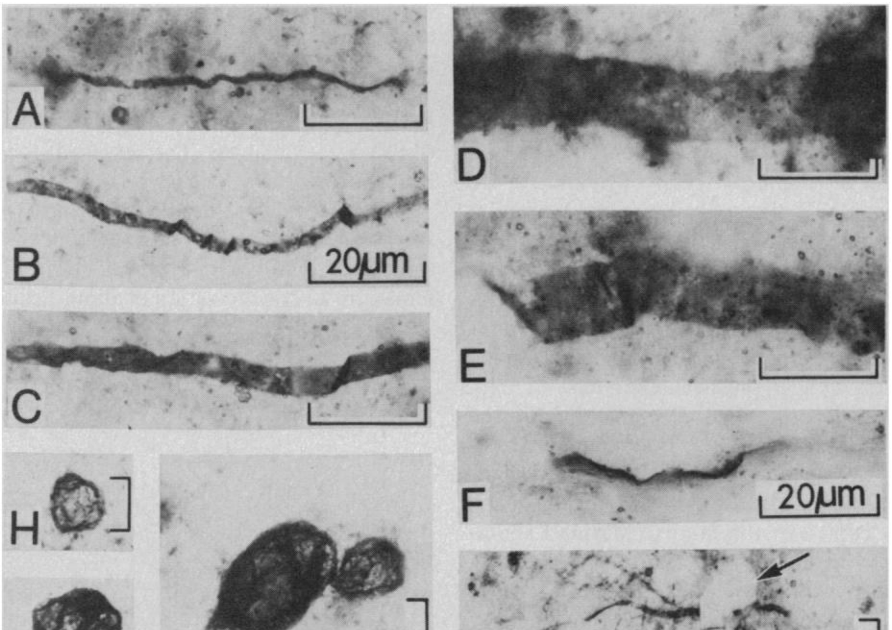

Fig. 1. Optical photomicrographs (transmitted light) of microfossils in petrographic thin sections of carbonaceous shales from the Newland Limestone, Little Belt Mountains, Montana. All thin sections, except (F), are oriented parallel to bedding; (F) is oriented perpendicular to bedding. Small-diameter filaments (A to C, F, and G), large-diameter filaments (D and E), and spheroids (H to J) are shown. Filaments shown in (C) and (F) are of comparable dimension and degree of preservation but are viewed in different orientations [(C) is viewed in a thin section ground parallel to bedding; (F) in a section ground perpendicular to bedding]. In (G), a diagenetic feldspar grain (arrow) is shown disrupting a filament. Bar for scale is 20 μm in each photomicrograph.