OBSERVATIONS OF CHLOROPHYLLS IN HIGH ARCTIC SEA ICE IN WINTER

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ABSTRACT

Measurements of chlorophylls a and c in ice cores obtained in Allen Bay, Cornwallis Island, N.W.T. (74°41'N, 95°12'W) during November and December of 1982 showed that the amount of chlorophyll present increased as the ice thickened. The concentration of chlorophyll c was six times that of chlorophyll a. The former absorbs blue light, the light available during dark winter months, more efficiently than the latter. The distribution of chlorophylls in the cores and their changes over time appear to support the theory that diatoms are incorporated into the ice, from the water column, during the freezing process although it is possible that the changes are in part a result of increased chlorophyll rather than a simple increase in diatoms.

The existence of living diatoms in sea ice was recognized early in the 19th Century (Ehrenberg 1941, cited by Clasby, Horner and Alexander 1973). Since then, the importance of ice diatoms in the arctic and antarctic marine ecosystems has been established by many studies. Apollonio (1961, 1965) and Buinitsky (1976), for example, found spring and summer concentrations of chlorophyll to be as much as one hundred times greater in sea ice than in the underlying water. Bradstreet and Cross (1983) show the ice diatom population to be the base of the arctic marine food web.

Most studies of ice diatoms have been undertaken during the months in which there is some daylight, many focussed on the 24-hour daylight period. As the diatoms' energy is derived from insolation, these months, naturally, are extremely important, as Matheke and Horner (1974) have shown, in that diatoms may inhabit the ice for their entire life cycle. The dark months form a period during which the diatoms must survive. As this is the time of most rapid ice growth, it is presumably an important phase in which diatoms may be incorporated into the ice sheet.

A study of diatoms in sea ice in Allen Bay, Cornwallis Island, N.W.T. (74°41'N, 95°12'W) was undertaken during November and December of 1982 as an offshoot of a detailed study of sea ice growth (Crocker 1983). The study period was the first part of the total darkness phase at that latitude. Chlorophylls a and c were used as indicators of diatoms in ice cores taken from a study plot 1.8 km offshore, over 75 m of water (Roberts 1983). Cores extracted at intervals during the time period were cut into 10 cm sections, melted and filtered through a 0.45 μ HA millipore filter. The filters were stored wet, frozen and in the dark for later determination of chlorophyll concentrations using the Strickland and Parsons spectrophotometric method (Strickland and Parsons, 1968:188).

There was an overall increase in the amount of chlorophylls a and c (mg/m^2) over the sampling period (Fig. 1a). It will be noted that the concentration of chlorophyll c was approximately six times more than that of chlorophyll a. This is interesting as Apollonio (1965) notes that chlorophyll c is at least six times more efficient than chlorophyll a at absorbing blue light, the light available during winter months. Chlorophyll c : a ratios in the literature are not as high as those found here presumably because they were based on samples collected during months with daylight.

In both cases, there was a significant correlation between the rate of ice growth (Fig. 1b) and the rate of chlorophyll accumulation. This appears to support the theory that diatoms were being incorporated from the water column into the ice during the freezing process (Horner and Schrader 1982). Presumably, in this scenario, there is a high

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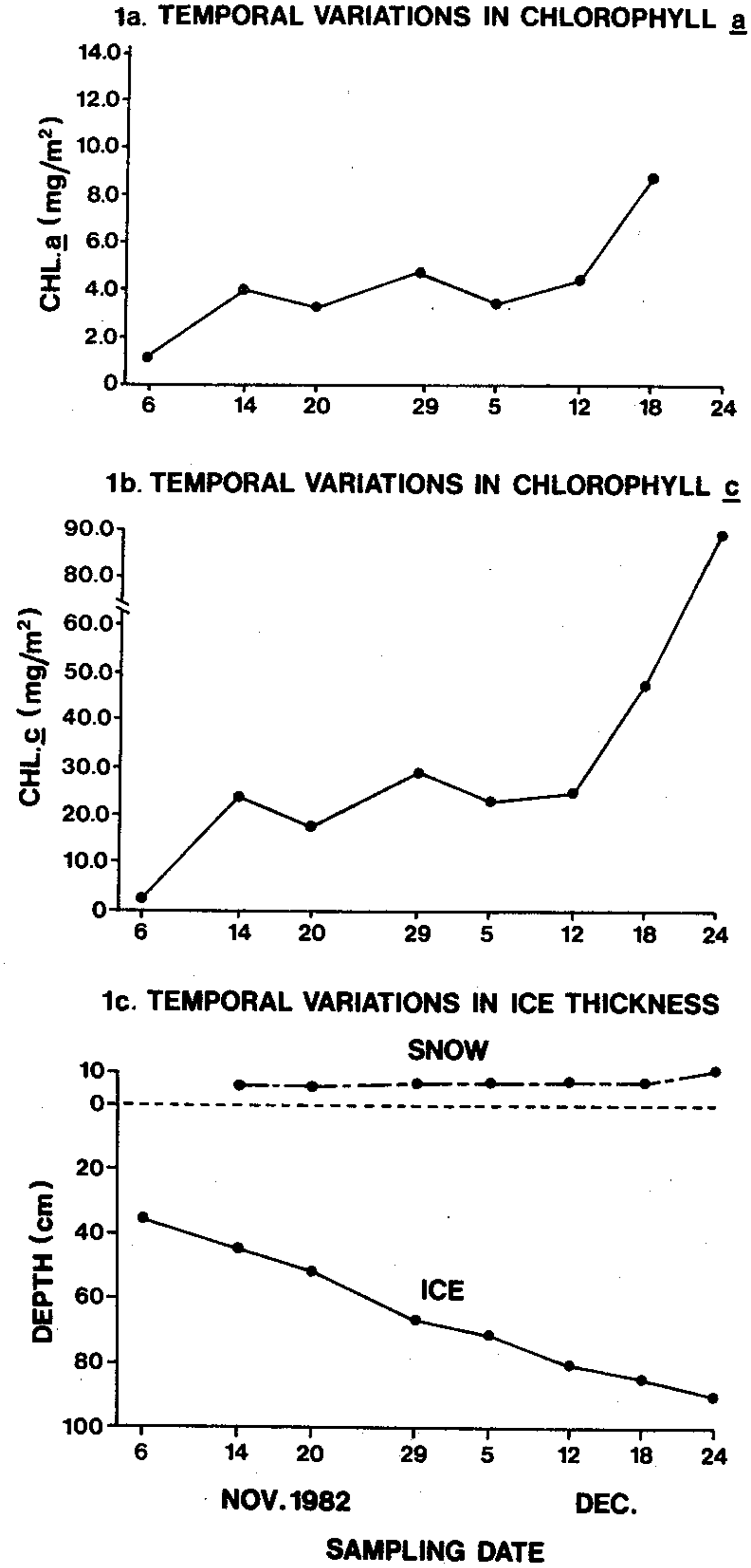

Figure 1a and b. Variations in the concentrations of chlorophylls during the sampling period, a dark phase of rapid ice growth at this latitude. Figure 1c. Ice growth during the sampling period.

concentration of diatoms on the bottom of or immediately below the ice as daylight fades. These diatoms are trying to take maximum advantage of available radiation. Removal of such a layer of diatoms would account for very low concentrations remaining in the unfrozen water column.

It is also possible that the pattern in Fig. 1a is the result of increased chlorophyll in ice diatoms rather than a simple increase in diatom population. However, the relatively fixed chlorophyll *a* : *c* ratio, over time, suggests that this is not the case (since a relatively greater increase in chlorophyll *c* would be expected). Unfortunately, data collected in this study do not allow a full explanation of the temporal patterns shown.

Growth of ice and vertical variation of chlorophylls can be discerned from Figs. 2 and 3. It is notable that there is an increase in chlorophyll both with time and with depth. With regard to the latter, in addition to the efficient incorporation of high concentrations of diatoms at the base of the ice sheet during this post-light phase of rapid ice growth, there does appear to be some evidence of downward migration over time. For example, on 12 December, there is a concentration peak at 40-50 cm with low concentrations at 50-60 cm. By 18 December, concentrations are low at 40-50 cm, high at 50-60 cm. The same pattern can be detected between December 18 and 24. This suggests that the drainage of brine, in which diatoms become concentrated (Meguro, Ito and Fukushima 1967), is already operative at this time. Horner and Schrader (1982) suggest that diatoms become concentrated in the bottom layer of ice in March before the spring bloom. They, too, cite gravity drainage through brine channels.

The data presented here confirm the existence of diatoms in sea ice during the dark winter months. Increased chlorophyll concentrations over time probably indicate a population of active diatoms which is being incorporated into the thickening ice sheet. It is most likely that these are living in an inactive state (Hoshiai 1976) within brine cells to act as seed populations for spring algae blooms (Bursa 1961). There was possibly some tendency for diatoms to concentrate at lower levels in the ice over time but not at rates reported for warmer, melting, ice conditions.

Further understanding of these communities would be gained from a study of population dynamics and ice growth designed to determine definitely whether the observed increase in chlorophyll *c*, at this time of year, is a more or less direct response to the growth of a living community. Such a study would also cast light on the nature and significance of the seasonal change in chlorophyl ratios.

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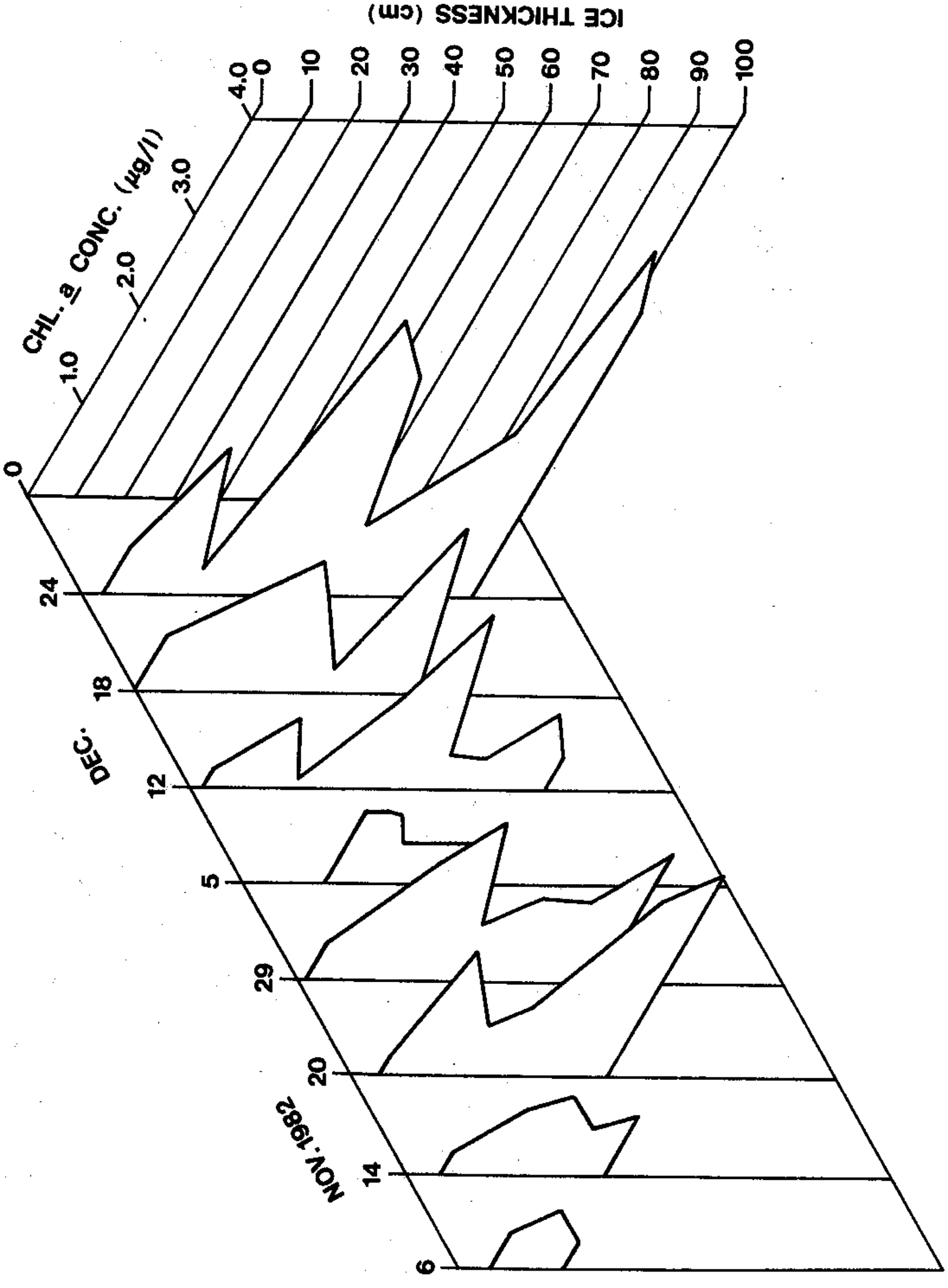

Figure 2. Three-dimensional profiles of chlorophyll a concentrations at each sample date in relation to ice thickness.

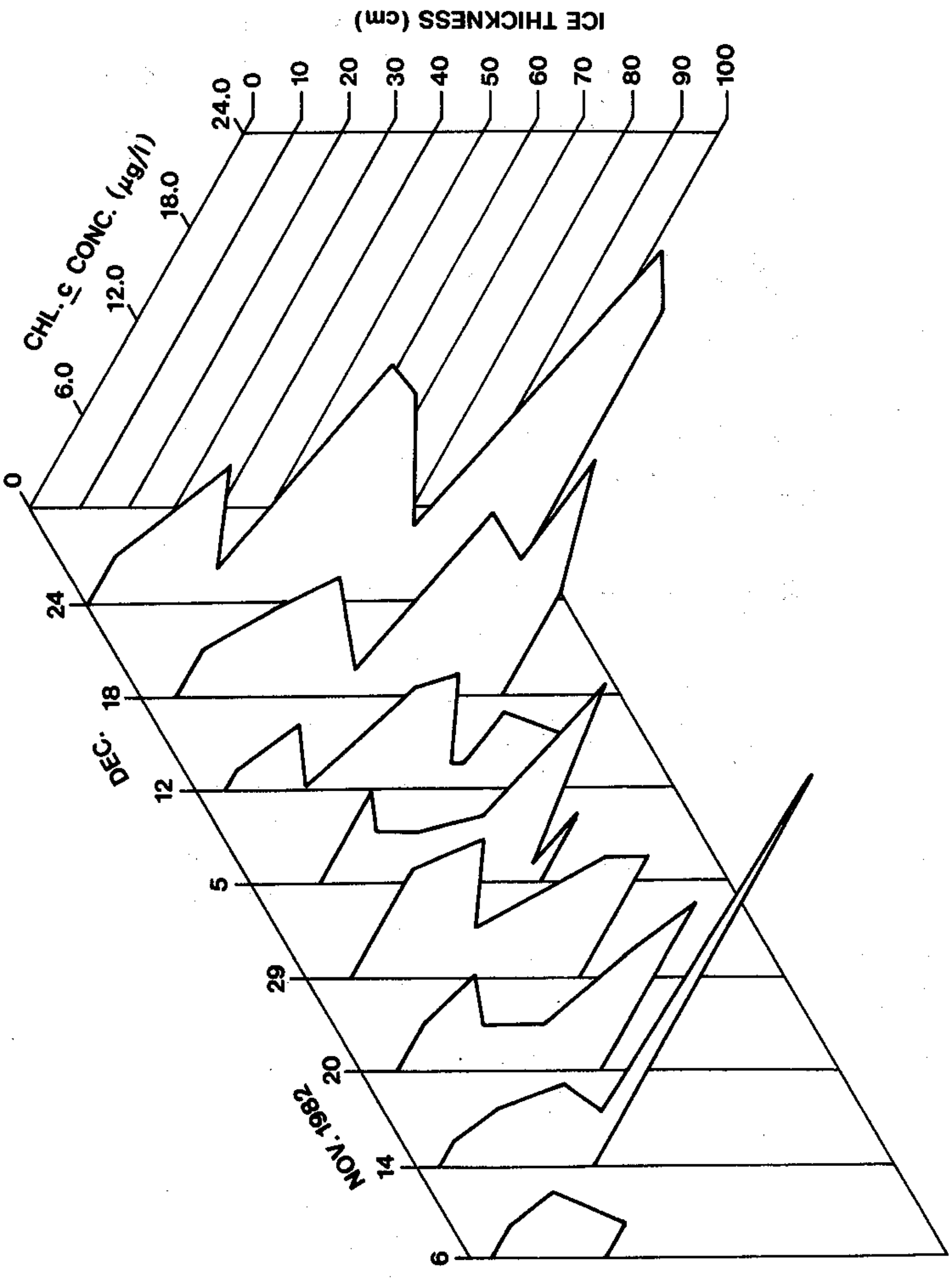

Figure 3. Three-dimensional profiles of chlorophyll c concentrations at each sample date in relation to ice thickness. Note that these values are approximately six times higher than those in Figure 2.