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The Cholorophyll α Regime on the Flemish Cap, April-May 1979

by

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INTRODUCTION

As part of the Gadus 20 research cruise to Flemish Cap April 23-May 7, 1979, chlorophyll a was sampled at a large number of stations. This sampling was carried out in order to define both the absolute levels of phytoplankton biomass and production for the Flemish Cap area, and to describe its distribution as part of the Flemish Cap project. Previously, no known estimates of the trophic status of Flemish Cap has been made. Current interest linking energy transfers between trophic levels to fish yields (e.g. Jones 1973, Cohen et al. 1979unpubl.) has indicated the need for such studies. It is important to understand processes of primary and secondary production and their role as food sources affecting larval fish survival. Further, variation in abiotic parameters is thought to be significant in affecting larval survival and eventual stock recruitment. Phytoplankton are the closest link with the physical environment, and an understanding of this linkage is an important requisite to understanding such abiotic-biotic relationships.

METHODS

Between April 22 and May 10 1970 samples were collected at 22 stations for chlorophyll a, phaeopigments, primary producton (C^{14}), nitrate (NO_3), phosphate (PO_4) and silicate (SiO_3). At these same stations measurements of photosynthetic potential (α and Pmax) were made on samples from 10m. Detailed analysis and presentation of results on primary production measurements will be the subject of a future communication. At a further set of 51 stations, samples were collected for chlorophyll a and phaeopigment analysis only. In all cases water was collected from standard depths to 125 m, and 1 ℓ of water filtered across glass fibre filters. Samples were stored frozen and analyzed in the laboratory fluorometrically following standard procedures (Strickland and Parsons 1972). Concurrently, samples of temperature and salinity were also made. These samples were complimented by a further set of 100 chlorophyll a samples pumped through the hull while underway. During the survey 21 surface stations were sampled more than once (i.e. 2-4 times).

RESULTS AND DISCUSSION

Between April 22 and May 10, 1979, surface chlorophyll a ranged from 0.02-8.6 mg m^{-3}. The highest value observed, 19.2 mg m^{-3}, was at 20 m for Station 77, just north of the Flemish Cap area (49°N, 46°W). The average surface value of chlorophyll a was 2.8 mg m^{-3}, well above the average of 0.5 mg m^{-3} reported for temperate oceans (Strickland 1965) and above the range of 0.01-1.5 mg m^{-3} reported for the western North Atlantic by Sutcliffe (1970). These do compare with values of 3-4 mg m^{-3} reported for the slope waters off Nova Scotia and the upper ranges from Flemish Cap (6-8 mg m^{-3}) to the productive frontal zone (Fournier et al. 1979, Herman and Denman 1979). The seasonal fluctuation in chlorophyll a on Georges Bank ranges from 1 mg m^{-3} in winter to 15-20 mg m^{-3} in late spring (Cohen and Wright 1978), a highly productive area where annual production exceeds 400 gC $m^{-2}yr^{-1}$. From these comparisons it appears Flemish Cap is an area of relatively high oceanic production, comparable to areas of enhanced productivity like the slope waters off Nova Scotia but probably less productive than the Georges Bank area.

Chlorophyll _a_ on Flemish Cap was characterized by a high degree of variability, both for surface values and for samples taken throughout the water column. While this complicates spatial interpretation of distributions a general pattern did emerge. This pattern is best described as a central area low in chlorophyll _a_ and having a reduced variability between samples, surrounded by a larger area of higher values and greater variability (Fig. 1). Within this central area values were generally < 2 mg m^{-3}, with values over the shallowest part of the Cap being typically <1 mg m^{-3}. Surrounding this central area values were both low (1 mg m^{-3}) and also very high, often exceeding 6-7 mg m^{-3}.

Values in Table 1 indicate the extent of these differences. Dividing surface samples from Flemish Cap into the three areas described above we see that, while moving away from the shallowest part of the Cap, the mean value of chlorophyll _a_ increases from 0.82 mg m^{-3} to 3.55 mg m^{-3}. Simultaneously, the coefficient of variation increases from 23% to 69%, demonstrating a much larger variance of chlorophyll _a_ in the waters surrounding this central area of Flemish Cap.

An overall time trend in low and high values of chlorophyll _a_ was not evident: values of chlorophyll _a_ from the first coverage of Flemish Cap April 22-29, 1979 was not significantly different from the second coverage April 30-May 9 1979. Similarly, correlation of surface chlorophyll _a_ (upper 30m) versus the progression of days through the survey was not significant.

Table 1. Comparisons of chlorophyll _a_ (mg m^{-3}) at the surface for three areas of Flemish Cap.

Area	n	x	s.d.	CV
Central area < 1 mg m^{-3}	11	0.82	0.19	23%
Central area < 2 mg m^{-3}	17	1.40	0.67	48%
Outside area	58	3.55	2.45	69%

Plots of values sampled along two transects (Fig. 2) demonstrate the pattern of distribution with depth (Fig. 3 and 4). It is evident that surface values are representative of chlorophyll _a_ in the mixed layer, there being no significant difference within the top 30m. Over the top of Flemish Cap, chlorophyll _a_ is relatively low throughout the euphotic zone compared to values away from this central area. This is especially true to the north and west of central Flemish Cap.

Reasons for these distributions are likely explainable as the result of water dynamics in the Flemish Cap region and the resulting production due to nutrient availability and water column stability. Chlorophyll _a_ was significantly and linearly related to levels of primary production measured concurrently (r^2 = .96); and therefore indicative of production. It may be that low chlorophyll _a_ observed over the shoal waters of Flemish Cap is a function of seasonal stratification. The development of a summer pycnocline would eventually result in nutrient depletion and reduced production in the surface waters overlying central Flemish Cap. The low variation of observed values in this central area would be due to the stability of the water mass in this central area. This stability in enhanced vertically by increasing seasonal stratification and horizontally by the T-S uniqueness of the water overlying Flemish Cap.

On the other hand, waters surrounding Flemish Cap are probably subject to much greater turbulance, both horizontal and vertical, as a result of the impingement on the Flemish Cap bank of Labrador Current waters to the north and west and North Atlantic Current waters to the south. The results would be a large boundary area of dynamically mixed water, transitional between Labrador Current water, for instance, and Flemish Cap water which overlies Flemish Cap.

This higher turbulance should result in higher nutrient availability through mixing and subsequently higher production. The high variability observed in chylorphyll a values would indicate this area to be quite dynamic, and probably subject to considerable horizontal advection of water masses into and out of this area.

Simple correlations were run for a wide number of variables measured in the upper 30m of the water column. Interpretation of correlation analysis is difficult at best, and results of this study did not always indicate clear relationships. However, some relationships were evident. Chlorophyll a was negatively correlated with both nitrate (-.33; n = 68) and phosphate (-.40; n = 68), indicating high biomass and production to be associated with reduced nutrients. Such relationships could be expected under dynamic conditions where patches of high production had, or were, exhausting available nutrients. Beyond this any further interpretation of nutrient correlations is probably naive due to their nonconservative properties.

The most significant and interpretable correlation results are those versus progression of time through the survey period, in days. Nitrate, nitrite, and silicate were all negatively correlated with increasing days (-.60, -.63, -.54 respectively; n = 68), indicating decreasing nutrient concentrations from the start to the end of the survey. Also, density was negatively correlated with days (-.63; n = 68). As these observations were all in the upper 30m this indicates a decreasing density in the surface water and, by inference, increasing vertical stratification. There was, however, no significant relationships for vertical stability or mixed layer depth. There was a significant rise in temperature through the survey (.45, n = 99) while salinity decreased (-.55; n = 68). While there was some inherent bias in the sampling distribution, this was felt to be minor in nature. Thus, there is an indication from this survey that seasonal stratification is progressing concurrent with a decrease in nutrients.

The overall lack of strong correlations is probably a result of the variable nature of Flemish Cap boundary waters and the fact seasonal stratification over central Flemish Cap in April-May has not been fully established. However, the persistently low chlorophyll a values over central Flemish Cap do indicate production is limited even at this time of year.

This situation described for Flemish Cap is very similar to the cyclonic Anticosti Gyre situated west of Anticosti Island in the Gulf of St. Lawrence. This gyre is bounded by the strong Gaspe current to the south and a return current to the north. Typical conditions for this gyre result in low nutrients and phytoplankton standing stock within the strongly stratified gyre as a result of nutrient limitation (Sevigny et al. 1979). Production was variable but significantly higher in the waters outside the gyre, especially within the Gaspe current. Thus, both areas appear to form gyres of stable water masses low in production, which are surrounded by areas of less stable but more productive waters.

In contrast, the water overlying the central portion of Georges Bank have the highest values of chlorophyll and primary production (Cohen and Wright 1978). Here waters are always well mixed over the central portion and stratification does not occur, consequently nutrients are continuously mixed into the upper waters, both from bottom sediments and due to advection onto the bank of nutrient-rich deep water from either side of Geoges Bank.

In summary, chlorophyll a values from Flemish Cap indicate it to be an area of relatively high production and biomass, although this production is largely confined to waters surrounding the central area, >200 m. The observations demonstrate surface waters are probably limited by some degree of nutrient limitation due to seasonal stratificaton in waters overlying Flemish Cap. Surrounding this central area on all sides, but especially to the north and west, is a dynamic boundary area of variable but much higher biomass and production. This boundary area should be subject to considerable mixing, largely from the Labrador Current water impinging on the north and west slopes of Flemish Cap bank, and therefore not subject to nutrient limitation. This overview is largely conceptual in nature and further data on the seasonal progression of spring phytoplankton production followed by seasonal stratification is needed to demonstrate a clear relationship.

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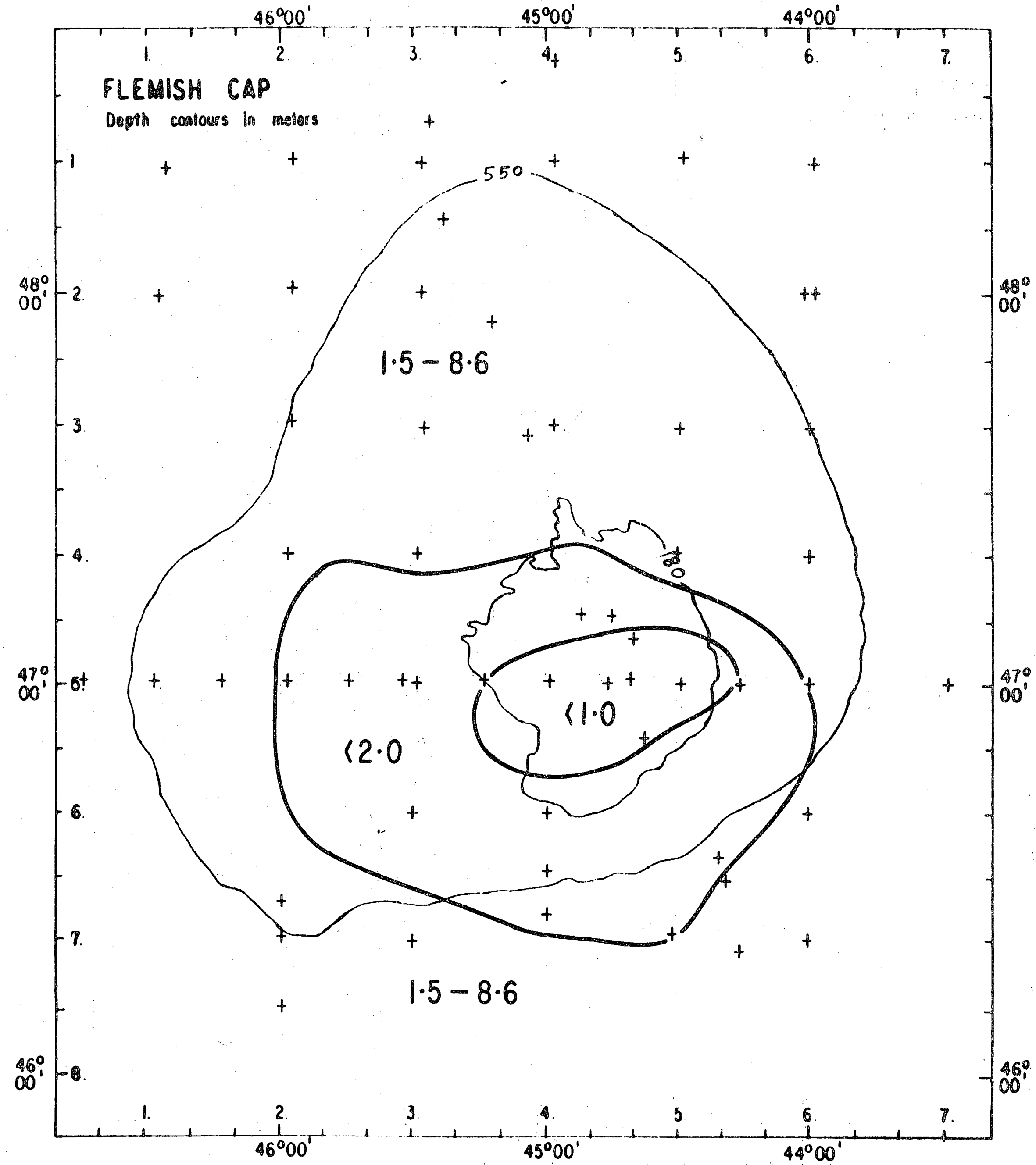

Fig. 1. Distribution of surface chlorophyll a sampled on Flemish Cap, April 22 to May 10, 1979 (mg m^{-3}).

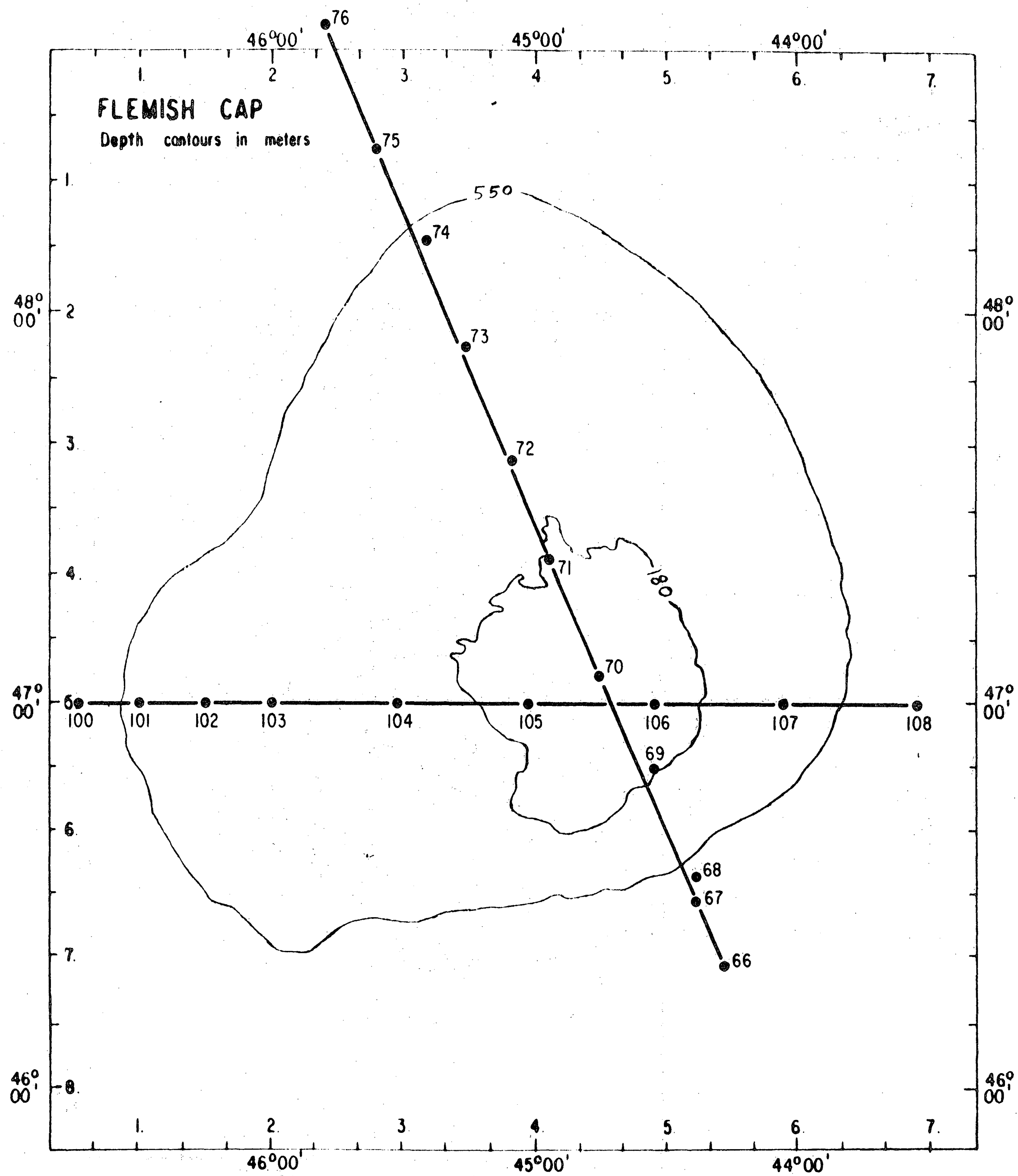

Fig. 2. Station locations of chlorophyll a values plotted in Fig. 3 and 4.

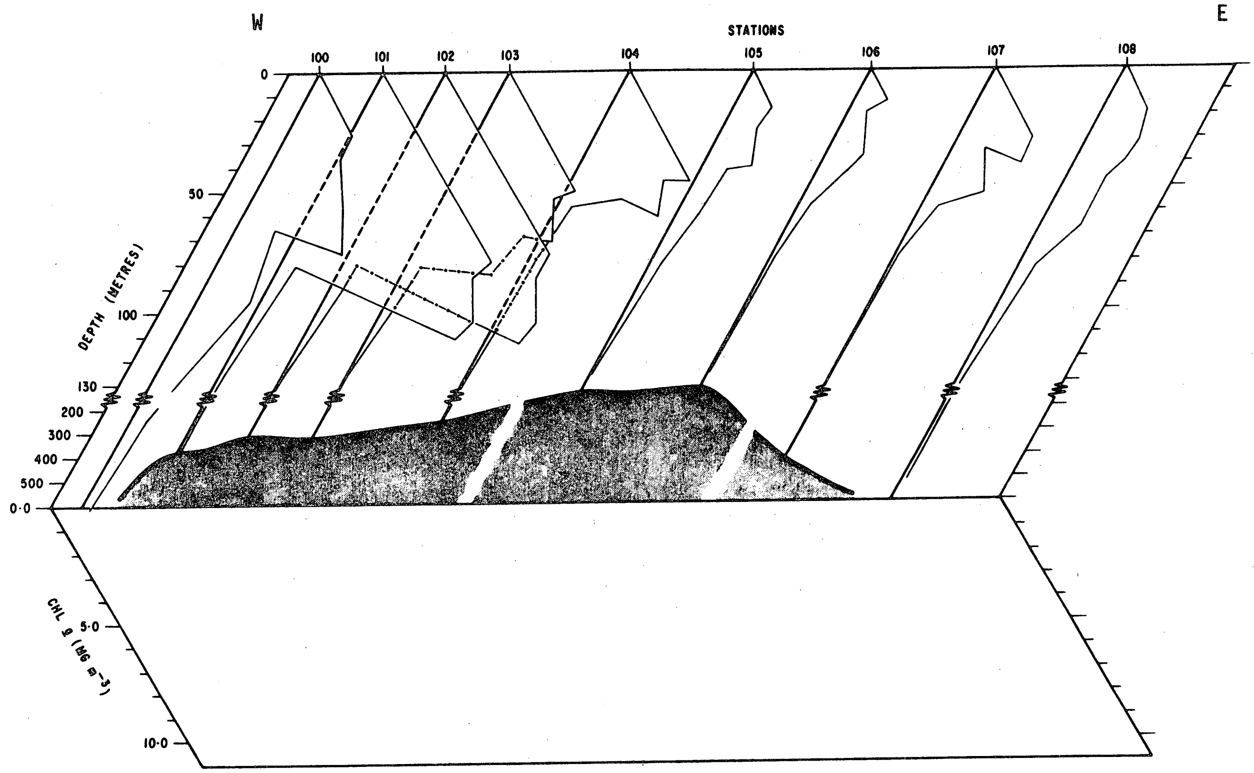

Fig. 3. Vertical plots of chlorophyll a (mg m^{-3}) sampled along the 47°N line, May 3-4, 1979.

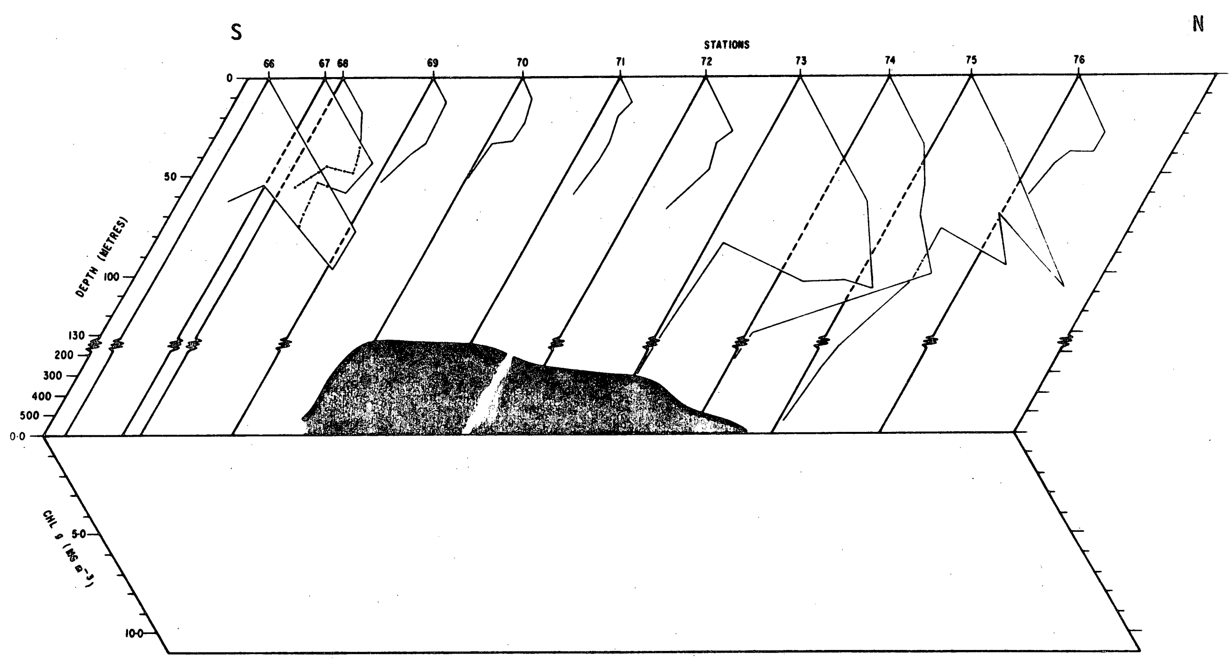

Fig. 4. Vertical plots of chlorophyll a (mg m^{-3}) sampled along the SE-NW line April 29-30, 1979.