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OCEANOGRAPHICAL CONDITIONS IN CANARY ISLANDS WATERS. I. OXYGEN AND NUTRIENTS.

by

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ABSTRACT

In September 1979 the cruise "Canarias I" was carried out in the R/V "Cornide de Saavedra", covering extensively the whole area of the Canary Islands (from 26°N to 30°N and from 12°W to 21°W). 69 stations from the surface to the bottom were studied to determine the basic oceanographic parameters. We analyzed all samples for oxygen, phosphate, nitrate, nitrite and silicate.

In general, the oxygen values on the surface are somewhat lower than 5 cc O₂/l, observing weak maximums in the first 100 metres. At a depth of 800 to 1000 metres, the values pass through a minimum of about 3 cc O₂/l, which coincides with the maximum of phosphates and nitrates due to more marked regeneration processes. The maximums found in the area were 2.08 µg-at P-PO₄/l and 33.3 µg-at N-NO₃/l to a depth of 1000 metres. The silicate, on the other hand, normally has its maximum next to the bottom with values of up to 40.0 µg-at Si-SiO₄/l at a depth of some 3000 metres. The nitrites usually show their typical maximum around the thermocline, observing weak values of about 0.10 µg-at N-NO₂/l. The highest concentrations in the thermocline occur in the stations near the African coast (about 0.50 µg-at N-NO₂/l).

The relations between the different parameters are discussed.

RESUME

En Septembre 1979, la mission océanographique "Canarias I" a été réalisée a bord du N.O. "Cornide de Saavedra" et a couvert extensivement toute l'aire des Iles Canaries (depuis 26°N jusqu'à 30°N et depuis 12°W jusqu'à 21°W). On réalisé 69 stations à partir de la surface jusqu'au fond afin de déterminer les paramètres océanographiques de base. Les analyses réalisées ont porté sur la détermination de l'oxygène dissous, Phosphates, Nitrates, Nitrites et Silicates.

En général, les valeurs de l'Oxygène dissous sont quelque peu inférieures à 5 cc O₂/l et on observe de faibles maximums dans les premiers 100 mètres. A une profondeur de 800 - 1000 metres les valeurs passent par un minimum autour de 3 cc O₂/l qui coincide avec un maximum de Phosphates et Nitrates dû a des procédés de régénération plus marqués.

Les maximums trouvés dans l'aire étudiée furent de 2.08 µat-g/l de P-PO₄ et de 33.3 µat-g/l de N-NO₃ a une profondeur de 1000 metres. Les Silicates d'autre

part ont leur maximum près du fond avec des valeurs proches à 40.0 $\mu\text{at-g/l}$ à une profondeur de près de 3000 mètres.

Les Nitrites montrent également leur maximum typique autour de la thermocline et on observe des valeurs de près de 0.10 $\mu\text{at-g/l}$ de N-NO_2 . Les concentrations plus hautes de N-NO_2 autour de la thermocline ont lieu dans les stations près de la Côte africaine (autour de 0.50 $\mu\text{at-g/l}$ de N-NO_2).

On discute aussi les relations entre ces différents paramètres océanographiques.

INTRODUCTION

Studies of oceanographic conditions in the Canary Islands waters have been carried out with reference to Physical Oceanography by Mascareño and Molina (1970), Mascareño (1972), Molina (1973, 1976 and 1981) and Molina and Laatzen (1986 a, b). Parallel to these, other studies of Chemical Oceanography and Plankton Ecology have been carried out some of which had, as their main objective, the finding out of stational variations.

This information can be found in the works of De León and Braun (1973), Braun and De León (1974), Braun (1980) and Braun, De Armas and Real (1982).

Systematically the most exhaustive oceanographic study to be conducted in the area of the Canary Islands, took place during the cruise "Canarias I" carried out on board the R/V "Cornide de Saavedra" in September 1979 and in which were determined physical, chemical and biological parameters from the surface of the ocean to the bottom covering an area stretching from 26°N to 30°N and from 12°W to 21°W. 69 stations from the surface to the bottom were studied to determine the basic oceanographic parameters. We analyzed all samples for oxygen, phosphate nitrate, nitrite and silicate (Fig. 1).

MATERIAL AND METHODS

The stations were sampled down to the bottom using Nansen and Niskin bottles. In the chosen stations the maximum bathymetric depth was 4440 metres and the maximum sampling depth 3548 metres.

The oxygen was determined by the Winkler method; the phosphate, nitrate, nitrite and silicate, following adaptations of Strickland and Parsons (1972).

In the present communication the average distributions of the parameters starting from the different profiles are presented, with analogies and differences being found. Average distributions have been outlined which could represent typical conditions in the Canary Archipelago.

RESULTS AND DISCUSSION

In Figure 2 the vertical distribution of the dissolved oxygen is represented, based on the average values obtained starting from all the stations. Although there exist some slight variations with regard to longitude and latitude which will be commented on later, this graph can be considered as representative of the typical summer conditions, with regard to superficial values and as representative of all-year-round conditions, with regard to deep water. The surface value is near to 5 cc O_2/l and increases with depth to obtain a typical maximum at a depth of 75 metres of 5.15 cc O_2/l . A progressive decrease of values continues until a minimum of 3.50 cc O_2/l is reached and following this a continuous increase down to the bottom, obtaining at a depth of 3500 metres,

values to the order of 5.33 O₂/l.

This type of distribution is characteristic in sub-tropical waters of the North Eastern Atlantic Ocean (Kester, 1975).

In the profile I the minimum value is higher (3.84 cc O₂/l). In all the profiles the minimum is presented around a depth of 800 metres, except in profile V which presents this minimum at a depth of 700 metres.

In profile I in the extreme stations can be observed groups of values around the position of the minimum which remain inferior to 3.50 cc O₂/l. An appreciable decrease occurs in the region of the minimum in the profiles II and III, specially in the eastern stations where values as low as 2.61 cc O₂/l are detected. Minimum values inferior to 3.00 cc O₂/l are only observed in certain oriental stations next to the African coast (see stations 39 and 40).

In Figure 3 we have represented the vertical distribution of the total average values of the phosphate for the waters of the Canary Archipelago. The surface values which are above the stationnal thermocline are small and are situated in the interval 0.04-0.09 µg-at P-PO₄/l. From a depth of 125 metres these increase noticeably from 0.19 to 1.76 µg-at P-PO₄/l. This value, situated at a depth of between 800 and 1000 metres is the maximum and coincides approximately with the region of the minimum of oxygen. After a slight decrease the value becomes almost constant down to the bottom, inside the interval 1.55-1.60 µg-at P-PO₄/l. This vertical distribution of the phosphate, although it presents values slightly inferior, coincides with the typical distribution for the Atlantic Ocean (Sverdrup, Johnson and Fleming, 1942; Spencer, 1975).

The profiles present characteristics similar to the general distribution. Only in the profiles I and II the bottom values are the same or slightly superior to the maximum intermediate. Profile V presents, as an average value, the maximum of the values which were found (2.06 µg-at P-PO₄/l).

On observing the distribution of each profile (Figure 6) a certain tendency in the increase of isolines in the eastern stations can be seen, which may be motivated by the dynamics of upwelling. The nucleus of the maximum values of the phosphates which is observed in the western stations of profile V coincide exactly with the minimum values of oxygen to the order of 2.61 cc O₂/l. This same value was observed, as we have already seen in the eastern stations of the profiles II and III (stations 39 and 40) which show zones specially rich in phosphates with values in the interval 1.70-1.80 µg-at P-PO₄/l, although, on the other hand, in other stations it is observed that to values relatively high in phosphates correspond others with normal oxygen values (Figures 6 and 7).

Similar to the distribution of the phosphate, the total average values of the nitrate present very small values in the first 100 metres interval 0.14-0.28 µg-at N-NO₃/l (Figure 4) starting from this depth, where a value of one µg-at N-NO₃/l is obtained, the values increase up to 24.13 µg-at N-NO₃/l around a depth of 800-1000 metres. After this maximum, the values remain constant down to the bottom and in the interval 19.74-22.54 µg-at N-NO₃/l. The same as with the phosphate, the vertical distribution is similar to that proposed by Sverdrup, Johnson and Fleming (1942) as typical for the Atlantic Ocean, although with absolute values, slightly inferior. The analogies continue in the average vertical distribution of the profiles where the quantity of nitrate of the bottom in the profiles I and II is similar to that of the maximum, which doesn't occur in the profiles III-V where a distribution similar to the total average exists.

In profile I zones high in nitrates are observed in the western stations and in the eastern stations at a depth of between 700-1200 metres which coincides with the zones of the minimum of oxygen. In the rest, characteristics of a relatively homogeneous water are observed on the bottom.

In the eastern stations of the five profiles the possible influence of upwelling is seen, by the tendency of the isolines to rise to the surface. In the profile II maximum values in nitrates superior to $30 \mu\text{g-at N-NO}_3/\text{l}$, again appear towards a depth of 800 metres, which coincides with the maximum values of phosphates and the minimum values of oxygen.

In the profile III in the stations to the east of Gran Canaria, a nucleus important in nitrates can be seen towards a depth of 1000 metres to the order of $30 \mu\text{g-at N-NO}_3/\text{l}$ much more noticeable than in the case of the phosphates.

The vertical distribution of the silicates obtained in the present cruise has some analogies and differences with regard to the two other basic nutrients (Figure 5). From initial values close to zero in the upper layers, these increase progressively down to the bottom, without producing the typical maximums around a depth of 1000 metres, as in the case of the phosphates and the nitrates. The majority of the values in the first 100 metres are situated in the interval $0.49-0.96 \mu\text{g-at Si-SiO}_4/\text{l}$. At a depth of 1000 metres a quantity of $17.31 \mu\text{g-at Si-SiO}_4/\text{l}$ is obtained which is practically doubled at 3000 metres, reaching a number of $33.24 \mu\text{g-at Si-SiO}_4/\text{l}$. On observing this distribution of total average values, we can see that, in general, there exists a rapid increase in the interval 600-1000 metres, which is better observed in the average values of the profiles, specially in II. On entering deeper water the variation is less and towards a depth of 2000-3000 metres, a rapid increase observed at around 1000 metres. In fact between 500 and 1000 metres there exists an average increase of $2.26 \mu\text{g-at Si-SiO}_4/\text{l}$ for every 100 metres and much greater than the increase between 1000 and 3000 metres of $0.80 \mu\text{g-at Si-SiO}_4/\text{l}$ for every 100 metres.

This distribution will affect, by layers, the relations Si/P and Si/N which will be variable and will depend on the depth.

In the profile I the bottom values present some irregularities, observing maximum alternatives to the order of $35 \mu\text{g-at Si-SiO}_4/\text{l}$. In the rest of the profiles the quantities on the bottom are usually more homogeneous. In the profile II there can be observed a certain tendency of the isolines to rise in the stations nearest the African coast.

The average values of nitrites show the typical maximum around the thermocline of $0.10 \mu\text{g-at N-NO}_2/\text{l}$ to a depth of 75-125 metres. This value represents in reality a very weak maximum. The concentrations decrease somewhat on entering deep waters and, even with few samplings, starting from 2000 metres the values are situated in the interval $0.08-0.12 \mu\text{g-at N-NO}_2/\text{l}$. In the case of the nitrites the situation is a lot different to the rest of the nutrients which follow approximately similar models of distribution. Although this distribution represents the most general case, a good number of stations exist, specially some next to the African coast, which show much greater maximums in the thermocline zone (up to approximately $0.50 \mu\text{g-at N-NO}_2/\text{l}$) and there even exist stations with a completely irregular distribution. A typical case of appreciable maximum can be seen in Figure 8.

On comparing the vertical distribution of the nutrients considering the most eastern and western stations, there can be observed in the column superior to 500 or to 1000 metres, a greater concentration in the eastern ones originated

by the dynamics of upwelling. In Figure 9 the phenomenon in the case of phosphate can be observed. The same occurs in the case of the nitrate, observing at the same time equality in the concentrations in deep water. However, at practically every depth, the silicates show a superior value in the eastern stations.

Comparing the average vertical distributions of nitrate with phosphate, a relation of the integrated column $N/P = 13.11$ is obtained. Following the same criterion for the typical distributions of the Atlantic Ocean, proposed by Sverdrup, Johnson and Fleming (1942) and which are based on 6 stations of this ocean, one of which corresponds precisely to our area of study, a relation $N/P = 13.22$ is obtained.

Representing graphically the relation N/P starting from the average values of the profiles (Figure 10) the equation

$$N = 13.38 P - 0.08 \quad (r = 0.99)$$

is obtained.

As can be seen in the Figure, there exists a group of points close to the origin in which a low N/P relation is appreciated. Specifically in the first 100 metres the average relations tend to be inferior to 10. Although analytical errors here are greater, due to the fact that we are in a zone close to undetected quantities the average relations are systematically shown to be inferior. This coincides with the low relations found by different authors and recently confirmed by Sagi, Miyake and Saruhashi (1983) for the Pacific Ocean in more superficial waters observing a progressive increase of the relation with the depth and more exactly with the analyzed values of phosphorous and nitrogen.

In Figure 11 the vertical distributions of the nitrates and the silicates based on the average total values have been represented simultaneously. We can observe that the relation Si/N is less than one in the first 1500 metres. At this depth the relation is the same as the unit and starting from here, it is greater. In the upper section except at depths close to the surface and at 1500 metres, where the relation is close to one, this has in the intermediate zone an average value $Si/N = 0.59$, in the interval 0.43-0.72 which increases with the depth, as can be seen in Table 1. In previous observations inside the same zone, the relation which can be seen at a depth of 500-600 metres during a stational cycle is of $Si/N = 0.62$ (Braun, 1980) being similar to that found in the present work. In oceanic stations and slightly to the south of our area of study the relations which can be deduced are similar to the previous ones in the layer at a depth of 500 to 1000 metres giving an average value of $Si/N = 0.64$ (Manriquez and Fraga, 1978). In this same zone a specific study of the relation in waters to a depth of 100-200 metres produce a variable relation in the interval $Si/N = 0.36 - 0.65$ observing however an increase of relation while the stations get nearer to the coast (Friederich and Codispoti, 1978).

This situation contrasts with that produced in zones of high latitudes, as in the case of the Scotia Sea, where in the deep zone of the first 1000 metres, the relation is greatly superior to the unit reaching values to the order of $Si/N = 4$.

In our study the relation increases starting from 1500 metres and obtains its maximum in deep water (3000-3500 metres) with a value of $Si/N = 1.60$.

In some characteristic stations an estimation of pre-formed nutrients and nutrients of oxidative origin has been made, following basically Redfield,

Ketchum and Richards (1963).

In the more oceanic stations in the zone of minimum oxygen at a depth of between 700-1000 metres approximately which have values to the order of 3.32 cc O₂/l, it is observed that the P of oxidative origin possesses maximum values in the interval 0.93-1.04 µg-at P/l with an average value of 0.98 µg-at P/l. In deeper water this phosphorous is more constant and less, in the interval 0.63-0.90 µg-at P/l with an average value of 0.71 µg-at P/l. As a difference the preformed phosphorous for these deep waters starting from the minimum of oxygen would give a value of 0.59 µg-at P/l.

When in the same conditions minimum values of oxygen are obtained inferior to 3 cc O₂/l and to the order of 2.80 cc O₂/l, the maximum values of phosphorous of oxidative origin increase to 1.32 µg-at P/l followed by a decrease in deep water of 0.84 µg-at P/l. On this occasion the preformed phosphorous would have an average value of 0.81 µg-at P/l. In both cases an average value of P_p = 0.70 µg-at P/l would be obtained, somewhat similar to that proposed by Redfield, Ketchum and Richards (1963) of P_p = 0.74 µg-at P/l for North Atlantic deep water. In general it is observed that in deep water the preformed phosphorous is approximately half of the dissolved inorganic phosphorous.

A summary of this distribution of values can be seen in Table 2, where, on considering the water to be deeper in the coastal stations (700-1000 metres) with values lower than 3 cc O₂/l, once again are observed, the same as in oceanic stations, high values of phosphorous of oxidative origin, to the order of 1.21 µg-at P/l.

CONCLUSIONS

From all that has been presented, we can draw the following conclusions:

- 1) Although differences in the real stations exist as to longitude and latitude, an average distribution of nutrients and oxygen can be obtained which would be representative for Canary waters. From low initial surface values, we pass to maximums in phosphates and nitrates around 1000 metres, followed by a certain stability of values down to the bottom. These maximums are parallel to the minimums of oxygen.
- 2) The silicates increase progressively from the surface down to the bottom with variations according to the layers.
- 3) In general a greater concentration of nutrients is observed in the stations close to the African coast, especially in the first 1000 metres.
- 4) Starting from selected stations, it is observed that nutrients of oxidative origin are approximately the same as preformed nutrients.

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Table 1.- Variations of Si/N ratios with depth.
(Layer : 500 - 1000 metres).

<u>Depth (m)</u>	<u>Si/N</u>
500	0.43
600	0.48
700	0.60
800	0.65
900	0.66
1000	0.72

Table 2.- Variations of oxidative origin phosphorous with depth and oxygen minimum values for some oceanic and coastal stations.

<u>Stations</u>	<u>Oxygen minimum</u>	<u>µg-at P/l</u>		
		<u>P_{ox}</u> <u>(700-1000 m)</u>	<u>P_{ox}</u> <u>(>1000 m)</u>	<u>P_p</u> <u>(700-3500 m)</u>
Oceanic	> 3 cc O ₂ /l	0.98	0.71	0.59
Oceanic	< 3 cc O ₂ /l	1.32	0.84	0.81
Coastal	< 3 cc O ₂ /l	1.21	-	-

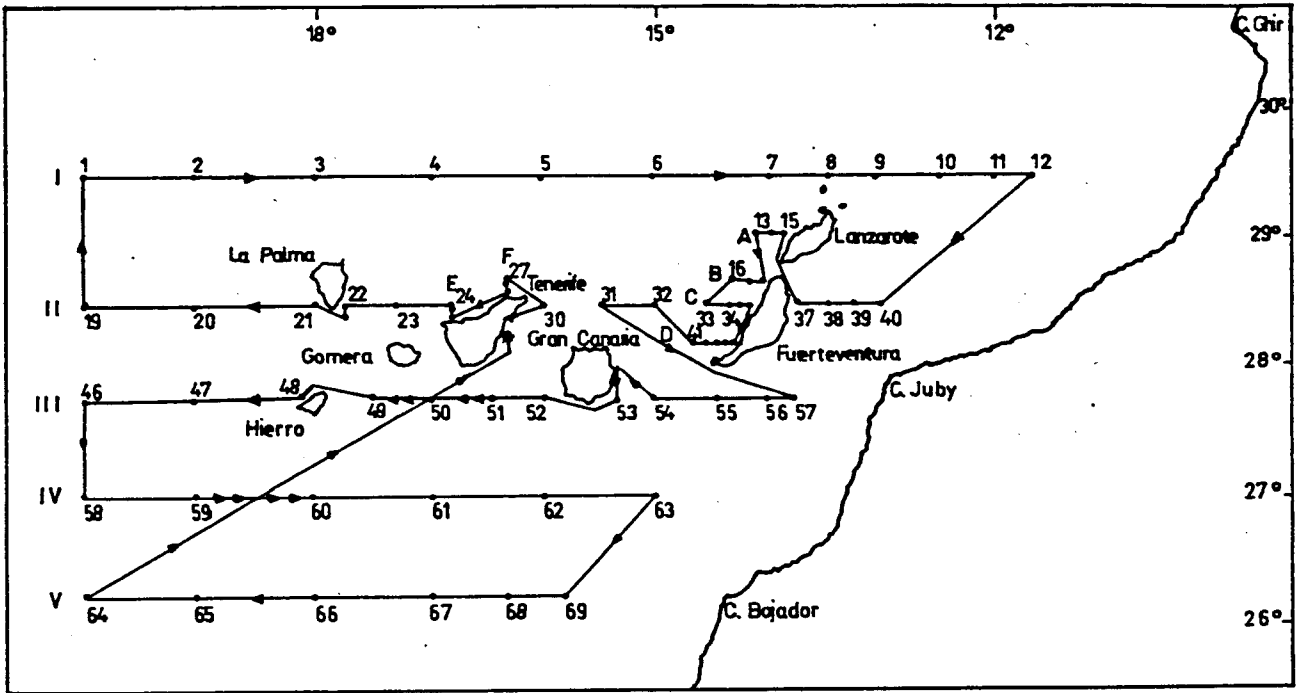


Figure 1.- Location of the "Canarias I" stations.

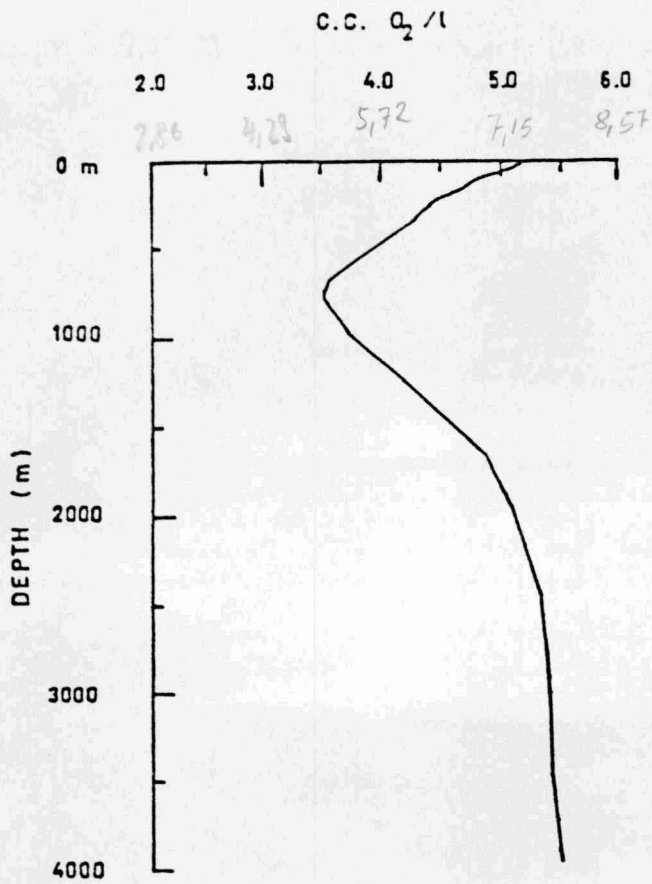


Figure 2.- Vertical distribution of oxygen.

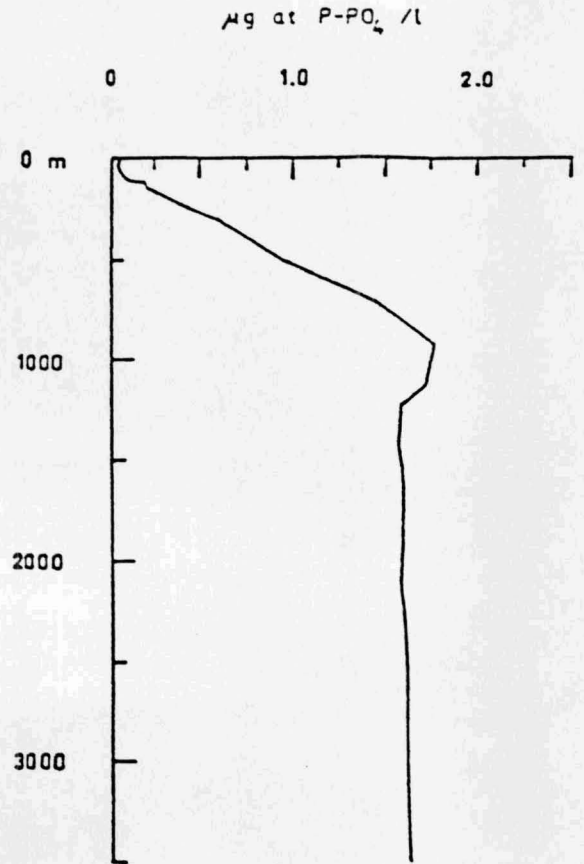


Figure 3.- Vertical distribution of phosphates.

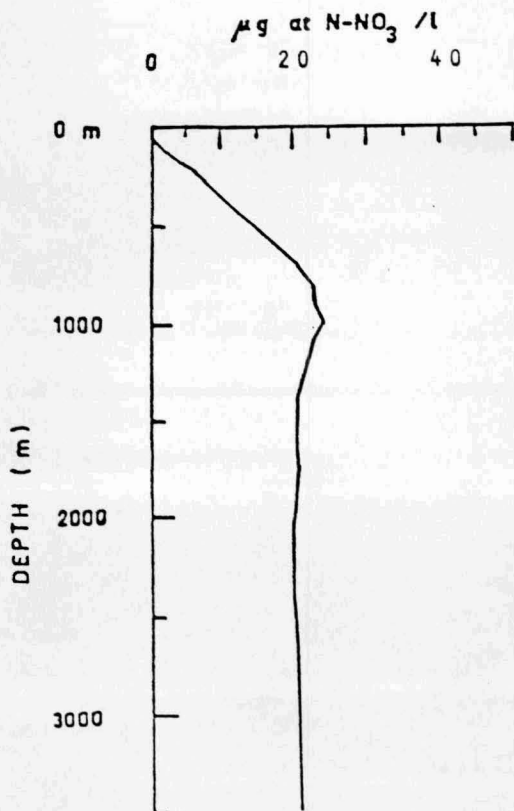


Figure 4.- Vertical distribution of nitrates.

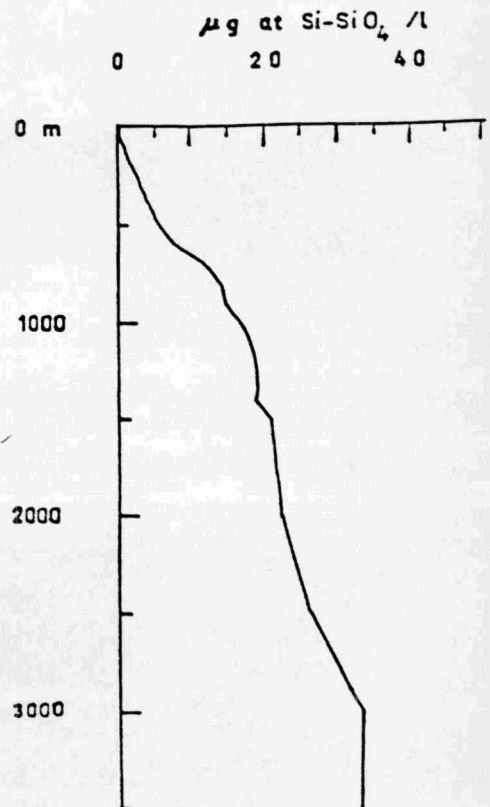
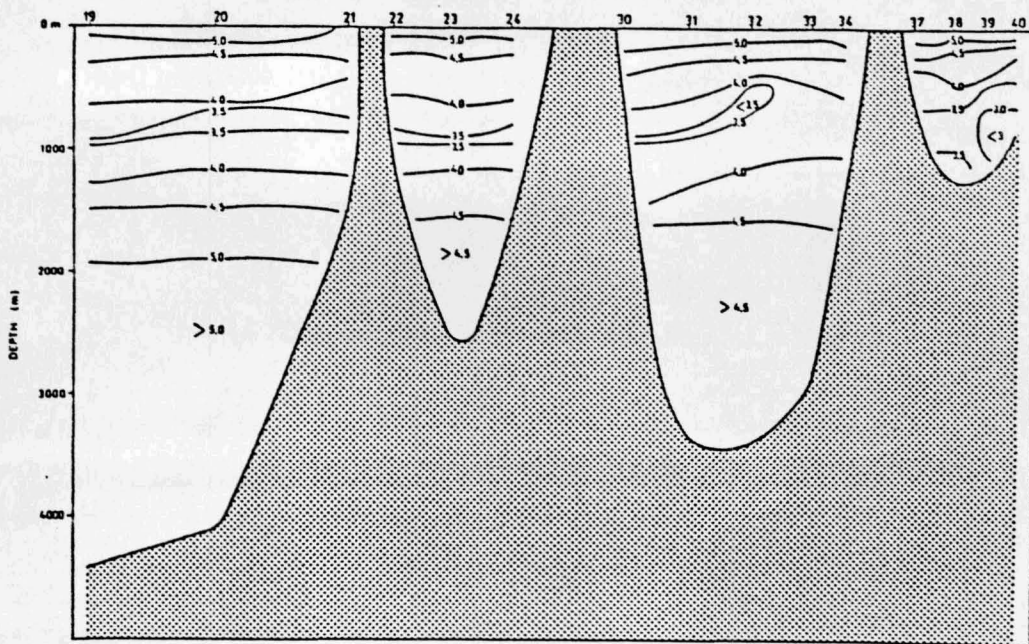
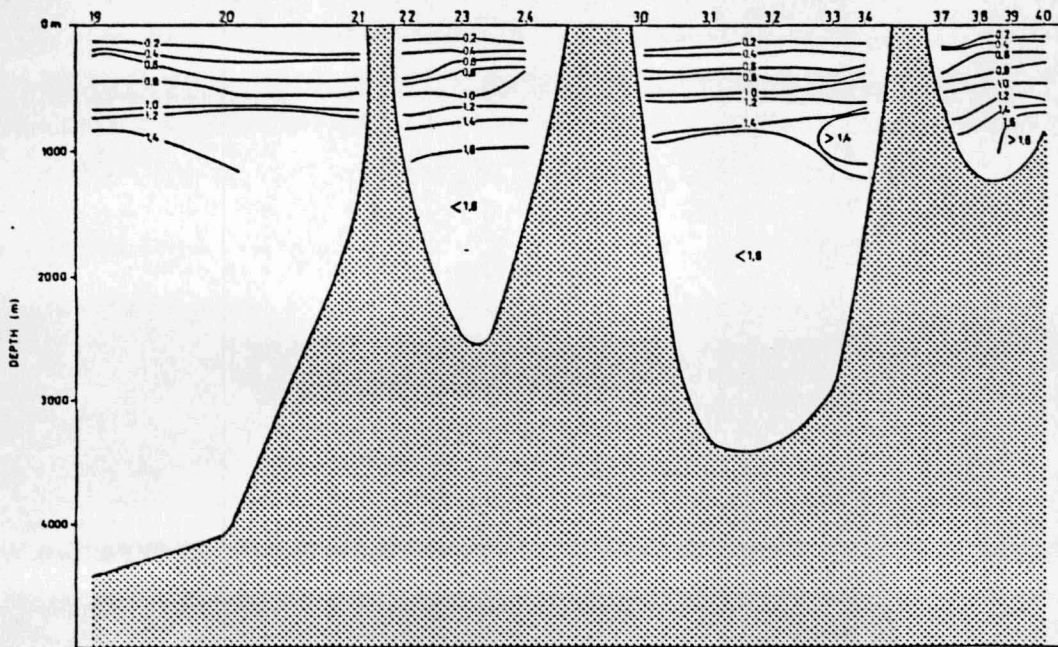


Figure 5.- Vertical distribution of silicates.

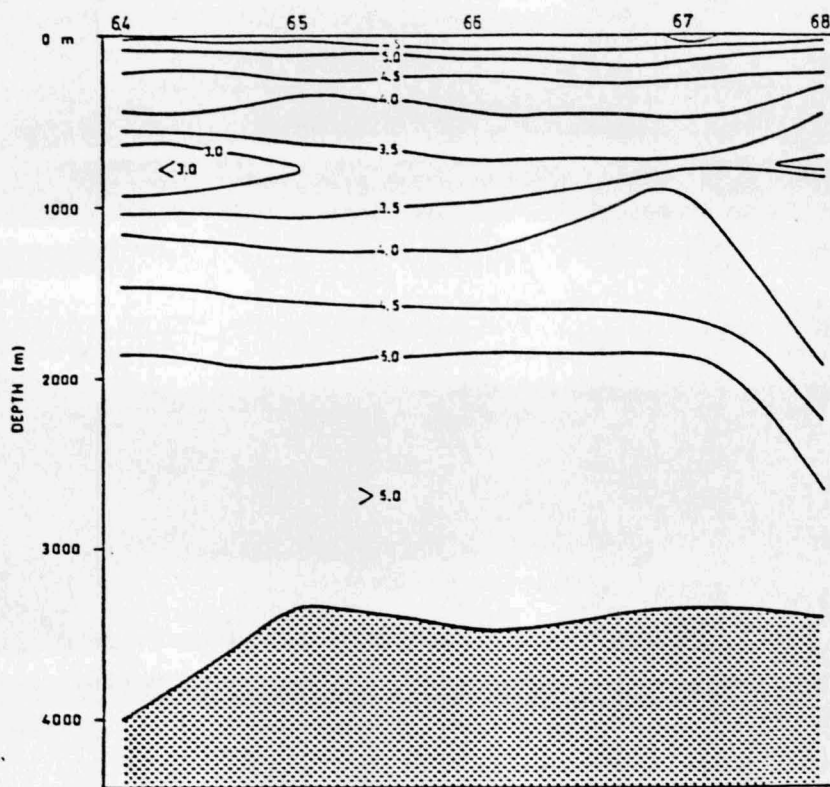


(a) cc O₂/l.

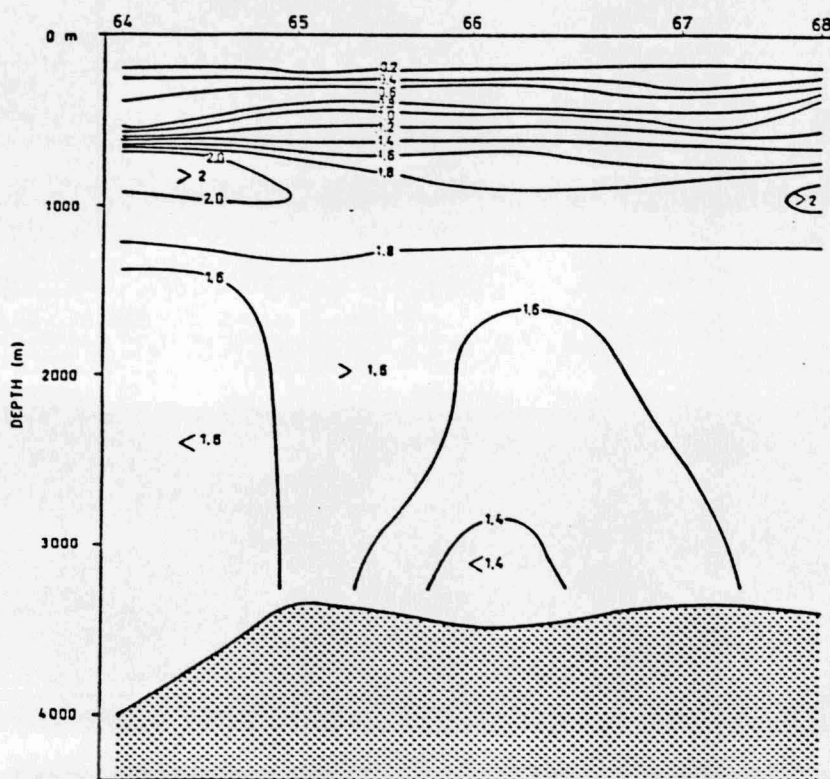


(b) µg-at P/l.

Figure 6.- Oxygen (a) and phosphate (b) distribution along profile II.



(a) cc O₂/l.



(b) ug-at P/l.

Figure 7.- Oxygen (a) and phosphate (b) distribution along profile V.

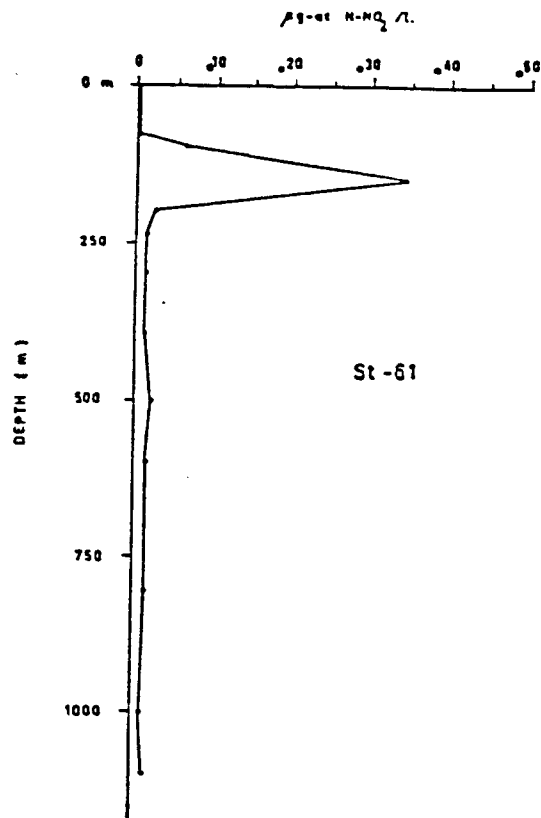


Figure 8.- Vertical distribution of nitrite in St. 61.

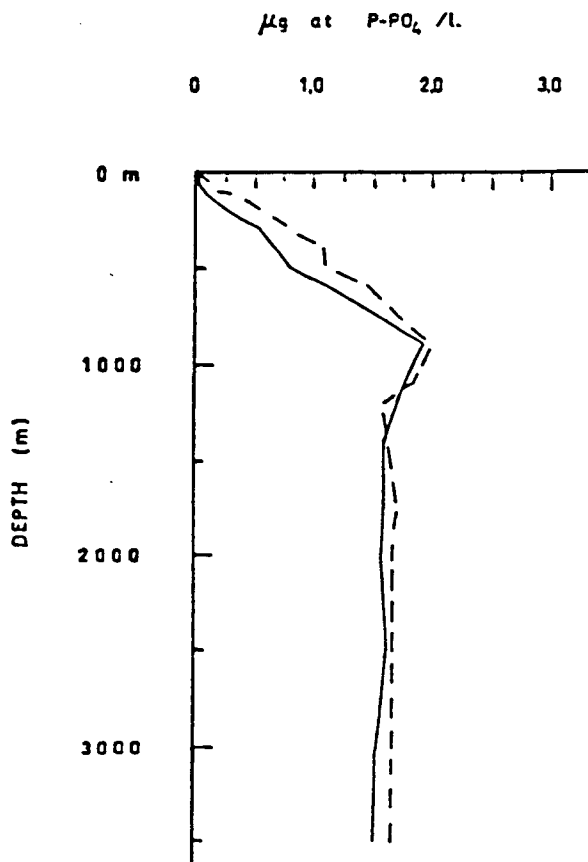


Figure 9.- Vertical distribution of phosphates comparing western (—) and eastern (---) stations.

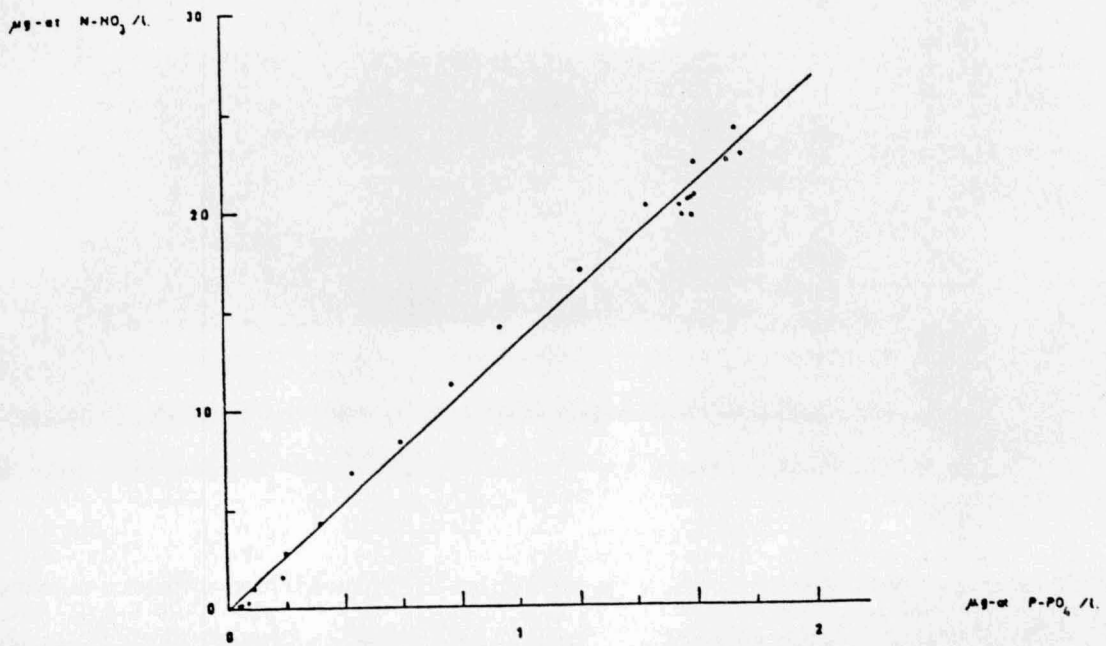


Figure 10.- Relation between nitrate and phosphate concentration.

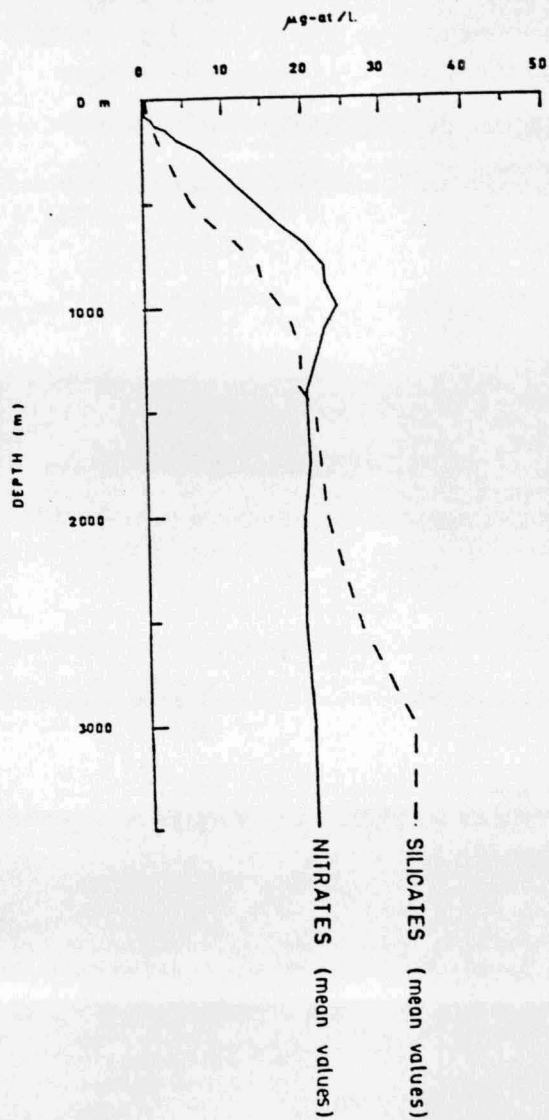


Figure 11.- Vertical distribution of nitrates and silicates.