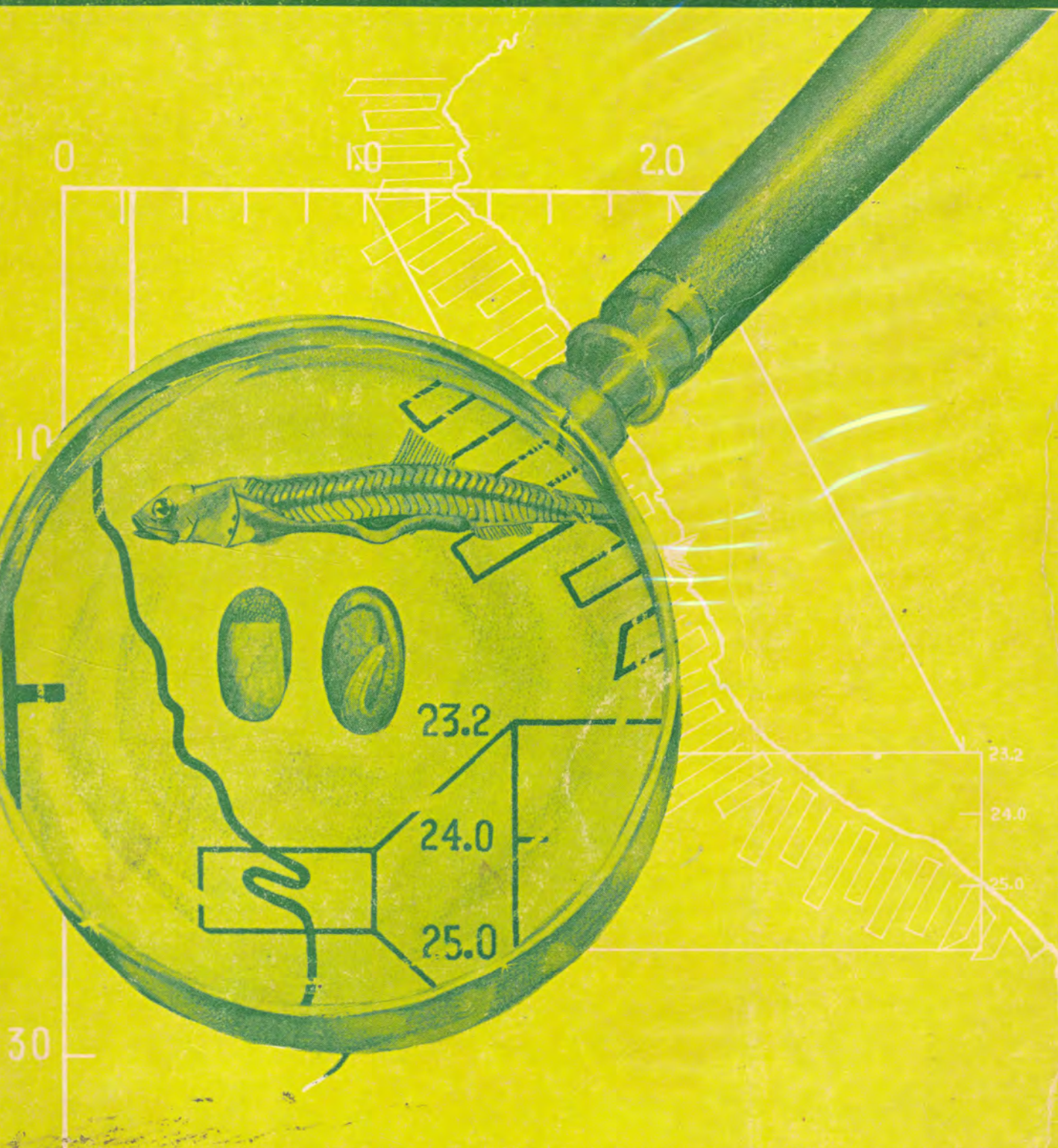




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**INVESTIGACION COOPERATIVA DE LA ANCHOVETA
Y SU ECOSISTEMA - ICANE - ENTRE PERU Y CANADA
CALLAO 1981 PERU**

INTERPRETATION OF PALEOCEANOGRAPHIC CONDITIONS ON THE PERU SHELF USING PALEOECOLOGY AND GEOCHEMISTRY

by

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ABSTRACT

A series of geochemical analyses of sediments from nine grab samples, six box core subsamples and two piston cores gave variable results. In many samples low molecular-weight fulvic acids dominate, suggesting sediment reworking and rapid breakdown of organic matter. Most δC^{13} values and C/N ratios indicate relatively low influx of terrestrial organic carbon.

From ten vertical plankton tows along the ship's track from Panama to survey sites only five contained planktonic foraminifera; the numbers diminishing from north to south. The numbers of preserved fish scales and planktonic foraminifera vary inversely suggesting low production of planktonic foraminifera during high organic production. Eight C^{14} dates from two piston cores range between 5,650 yrs BP to older than 37,000 yrs BP, with frequent older dates on top of younger. Both the organic geochemistry and foraminifera data suggest extensive sediment reworking or recycling.

RESUMEN

Los análisis geoquímicos de sedimentos de nueve muestras de draga de quijada, seis submuestras de "core" y dos de core de pistón dieron resultados variados. En muchas muestras dominaron los pesos moleculares bajos de los ácidos fúlvicos, lo cual sugiere una reconstrucción del sedimento y rápida descomposición de materia orgánica. La mayor parte de los valores de δC^{13} y de las razones C/N indican un flujo de carbón orgánico de origen terrestre relativamente bajo.

Entre las muestras verticales de plancton tomadas en el curso de Panamá al lugar de exploración solo cinco presentaron foraminíferos planctónicos y las cantidades disminuyeron de norte a sur. La cantidad de escamas de peces preservadas varía inversamente en relación a los foraminíferos planctónicos sugiriendo una baja producción de éstos durante períodos de producción orgánica intensa. Ocho determinaciones de edad en dos muestras de core de pistón mediante el C^{14} oscilaron entre 5650 años BP y mayores de 37000 años BP con frecuente sobreposición de edades mayores sobre jóvenes. Tanto los datos de geoquímica orgánica como los de foraminíferos sugieren una extensiva reorganización o reciclamiento de los sedimentos.

INTRODUCTION

Identification of past El Niño events in subsurface sediments of the Peru Shelf should be possible with fossil assemblages dominated by tropical species of planktonic foraminifera. During El Niño, relatively more tropical species are present in the water column, whereas during periods of strong coastal upwelling, the influence of colder,

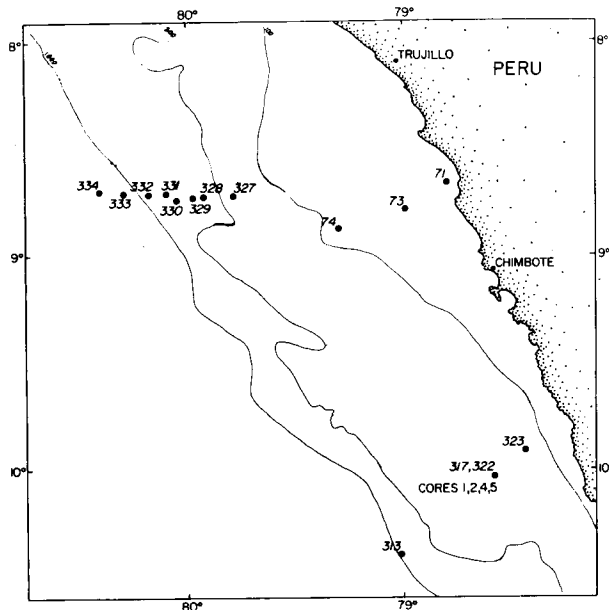
more polar waters are reflected by planktonic foraminifera of colder waters. For example, Thiede (1975) identified *Globigerina quinqueloba*, *Globobulimina dutertrei* and *Globobulimina inflata* as typical upwelling species of the continental margin off Northwest Africa.

Empty tests of planktonic species are ultimately carried to the sea floor and are buried in sediment. If there are no post-depositional distur-

bances and chemical dissolution of the tests, the biostratigraphic period of sediment cores should provide information on the frequency, extent and intensity of upwelling during the past.

A number of sediment samples were taken in support of the major objectives of the ICANE Project (Figure 1). The surface sediments were

Figure 1 Station Locations



analyzed for organic carbon content, nitrogen, the isotopic composition of organic carbon, relative concentrations of humic and fulvic acids, and spectral characteristics of humic compounds. The piston core samples were analyzed for major plant pigment concentrations and the pattern of n-alkene distribution in addition to organic carbon (Tables 1 and 2). For paleontological analysis, planktonic foraminifera were identified and counted in the piston core samples (Table 3)* and compared with foraminifera in ten vertical plankton tows taken through the upper 200 m of the water column along the ship's track from Panama to the working area (Table 4). In addition to foraminifera, fragments of fish scales were counted in each of the core intervals (Fig. 2). Eight subsamples from two cores were C^{14} -dated to provide a time framework for the biostratigraphic record (Table 5).

THE GEOCHEMICAL RESULTS

The amounts of organic carbon are highly variable, without a distinct trend between the shelf and continental slope sediments. Isotopic analysis of organic carbon indicates that the organic matter present in these sediments has originated mainly from marine organisms. This is true also for the

* Table 3, Planktonic foraminifera in sediment cores, is not published here because its long extension. Copies are available from the Editor.

TABLE 1.- Results of geochemical analyses of grabs and box cores.

Sample N°	Depth (m)	Depth (cm)	Organic Carbon (%)	Nitrogen (%)	C/N	δC^{13} of Organic Matter (vs PDE)	Ratio of HA/FA	E_4/E_6
Grab 313	885		4.08	0.48	8.50	-21.5	2.12	6.21
Grab 317	173		2.96	0.35	8.46	-21.0	1.78	5.52
Grab 323	123		5.28	0.63	8.38	-20.4	0.59	3.50
Grab 329	510		7.60	0.98	7.76	-20.9	1.59	2.14
Grab 330	707		5.58	0.69	8.09	-21.0	1.36	4.22
Grab 331	915		4.56	0.53	8.60	-21.0	0.73	5.30
Grab 332	1,210		0.44	0.55	0.80	-21.2	1.33	5.29
Grab 333	1,500		2.44	0.61	4.00	-21.1	0.70	4.46
Grab 334	1,800		4.80	0.48	10.00	-21.2	0.43	4.36
<u>Station 71</u>	17							
Box Core 2		0-5	1.28	0.36	3.56	-21.6	0.65	4.77
		10-15	0.98	0.17	5.76	-22.5	0.69	4.91
		20-25	1.40	0.20	7.00	-22.8	0.81	4.93
<u>Station 313</u>	885							
Box Core 15		0-5	1.08	0.14	7.71	-20.7	0.28	6.06
		10-13	0.94	0.22	4.27	-20.5	0.72	6.60
<u>Station 73</u>	72							
Box Core 18		0-5	1.60	0.20	8.00	-20.4	0.83	5.55
		10-15	1.16	0.14	8.29	-20.4	0.72	5.60
<u>Station 317</u>	173							
Box Core 42		0-5	2.56	0.27	9.48	-21.1	1.26	5.64
		5-10	2.46	0.25	9.84	-20.9	1.79	6.19
<u>Station 323</u>	123							
Box Core 53		0-5	3.00	0.42	7.14	-20.5	1.47	4.05
		10-15	1.16	0.17	6.82	-20.5	0.50	5.95
<u>Station 323</u>	123							
Box Core 62		0-5	4.36	0.54	8.07	-20.4	1.36	3.12
		10-15	1.28	0.26	4.92	-20.5	0.54	6.37

HA = Humic Acid
FA = Fulvic Acid

TABLE 2.- Results of geochemical analyses of core sediments.

Core	Organic Carbon (%)	Chlorophyll Content $\mu\text{g/g}$ of Sediment	Phaeophytin Content $\mu\text{g/g}$ of Sediment	Ratio of Ph/Chl	Ratio of HA/FA
Core 1					
0-25 cm	1.10	0.87	6.25	7.18	0 *
40-60 cm	1.20	0.57	6.93	12.16	0 *
70-80 cm	1.29	0.42	10.76	25.62	.06
95-105 cm	0.96	0.33	7.91	23.97	.03
145-155 cm	1.11	0.27	6.82	25.26	0 *
190-200 cm	1.15	0.29	7.88	27.17	.01
Core 5					
30-40 cm	1.22	4.77	28.66	6.01	.36
115-125 cm	1.35	5.45	40.75	7.48	.17
170-180 cm	1.30	3.28	36.77	11.21	0 *
220-225 cm	1.22	2.36	27.80	11.78	0 *
325-335 cm	1.62	2.96	59.51	20.10	.03
365-375 cm	1.17	1.87	36.65	19.60	.03
455-470 cm	1.21	0.42	15.29	36.40	0 *

* No HA, all FA
 HA = Humic Acid
 FA = Fulvic Acid

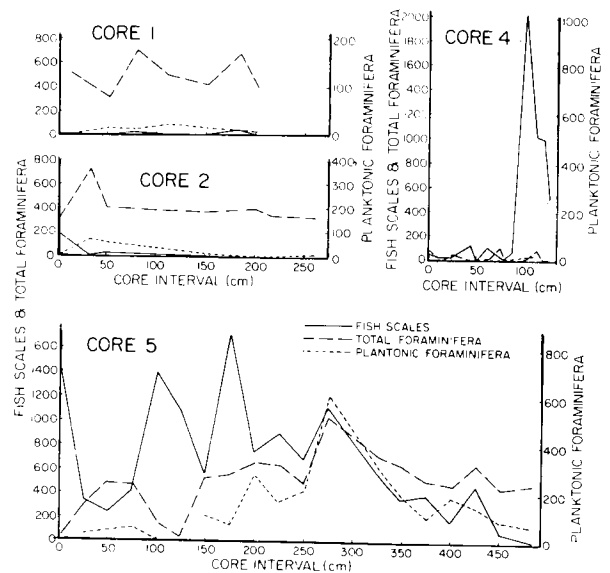
nearshore sediments of this area. In our samples the $\delta^{13}\text{C}$ values ranged between -20.4 and -22.8 ‰ (vs PDB), which is generally typical of marine organisms. The isotopic composition of planktonic flora is reported to be -18 ‰ to -19.0 ‰, whereas that of soil organic matter is about -27.0 ‰ (Smith and Epstein, 1971; Brown et al., 1972).

The preponderance of marine organic matter in the surface sediments is further confirmed by the C/N ratios, which range between 4 and 10, with an average of about 7. A typical ratio of terrestrial material is in the order of 15 or higher. The low concentrations of terrestrially-derived organic matter is also indicated by the distribution of n-alkanes (aliphatic hydrocarbons). The sediments that we analyzed were found to be dominantly the low molecular weight (<C₂₄) n-alkanes.

The Peruvian shelf sediments are characterized by relatively low ratios of humic to fulvic acids. The dominance of the low-molecular weight fulvic acid indicates an environment of sediment reworking that leads to a rapid breakdown of organic matter. Dominance of the fulvic acid is particularly noticeable in the sediments of Cores 1 and 5. Humic compounds extracted from many intervals of these cores were either totally devoid of the high-molecular weight humic acids or contained insignificant amounts suggesting extensive reworking of sediments (Table 2). By comparison, the humic/fulvic ratios are much higher in the basins off Nova Scotia and Labrador. For example, on Labrador Shelf the HA/FA ratio in one core ranged from 12.5 at surface to 4.7 at 10 metres below the surface (Rashid and Vilks, 1975). Although the rates of sedimentation and post-depositional conditions may affect the relative distribution of HA and FA, it appears that in the cold-temperate and subarctic environments the degree of organic degradation is much lower than on the Peruvian Shelf. In view of the extreme variability of the Peruvian Shelf data, this conclusion should be verified with more information.

The concentrations of plant pigments, i. e. chlorophyll and phaeophytin, are significantly different in sediments of Cores 1 and 5 (Table 2). The higher chlorophyll and phaeophytin values of

Figure 2 The numbers of fish scale fragments, total foraminifera and planktonic foraminifera.



Core 5 are comparable to the sediment of the Chaleur Trough, Gulf of St. Lawrence, where methane was found in excess of 10,000 ppm (Rashid and Vilks, 1975).

PALEONTOLOGICAL RESULTS

Foraminifera distributions are discussed from four piston cores that were taken from the same locality. Because of the poor quality of the cores, e.g. suspected mixing of sediments, the core subsamples are considered as replicates of a single sample in time and space.

The planktonic foraminifera consist of 15 species ranging from tropical to polar, according to the classification of Bé and Tolderlund, 1975. The most abundant species are the sinistral *Neogloboquadrina pachyderma* followed by the dextral *N. pachyderma*. Both these forms are the only planktonic foraminifer found in polar waters. Next in abundance are the subpolar *Globigerina bulloides*, the subtropical *Globoquadrina dutertrei* and the subpolar *Globigerina quinqualoba*.

Taking into consideration the optimum temperatures of each species and its average abundance in all cores, an average paleotemperature of 13.7°C was calculated using the method of Vilks et al., 1979. Assemblages of living planktonic species collected in plankton were used to compare the calculated paleotemperature with the existing oceanographic setting.

The species composition of the planktonic assemblage changes progressively from tropical to colder species along a line of stations between the equator and the study area (Table 4). The calculated "paleotemperatures" reflect the change from 26°C at station 37 (Lat. $0^{\circ}41.6'\text{N}$) to 9.4°C at station 309, Latitude $10^{\circ} 48'\text{S}$. Thus, the mean water temperature within the study area, according to

TABLE 4.- Planktonic foraminifera in plankton tows.

Foraminifera	Stations									
	Lat. 0°41.6'N Long. 80°22.0'W	Lat. 3° 7.4'N Long. 81°22.0'W	Lat. 6°46.7'S Long. 80°29.0'W	Lat. 8°55.4'S Long. 79°29.0'W	Lat. 8°49.8'S Long. 79°10.8'W	Lat. 9°20.0'S Long. 78°50.1'W	Lat. 9°21.2'S Long. 78°44.4'W	Lat. 10°48.9'S Long. 79°29.8'W	Lat. 10°16.0'S Long. 78°50.1'W	Lat. 10°16.0'S Long. 78°36.0'W
<i>Globorotalia menardii</i>	26.9	27.9	6.1	10.5	6.8					
<i>Neoglobobulimina pachyderma</i>	1.1	7.2	16.3		18.2					
<i>Globigerinoides ruber</i>	6.1	2.2	2.0	5.3						
<i>Globigerinoides trilobus</i> (Reuss) forma typica	31.2	10.1	4.1							
<i>Globigerina bulloides</i>	4.5	18.1	65.3	78.9	75.0					
<i>Globobulimina dutertrei</i>	14.7	30.1								
<i>Globigerinella aequilatoralis</i>	7.3									
<i>Bullenistina obliquiloculata</i>	3.6									
<i>Globigerinoides conglobatus</i>	.7									
<i>Orbulina universa</i>	3.0									
<i>Globigerinita glutinata</i>	.9	4.3	6.1	5.3						
Total Specimen	558	276	49	19	44					
"Paleotemperature" °C	26	22.9	11.4	11.2	9.4					

TABLE 5.- C¹⁴ dates from sediment cores.

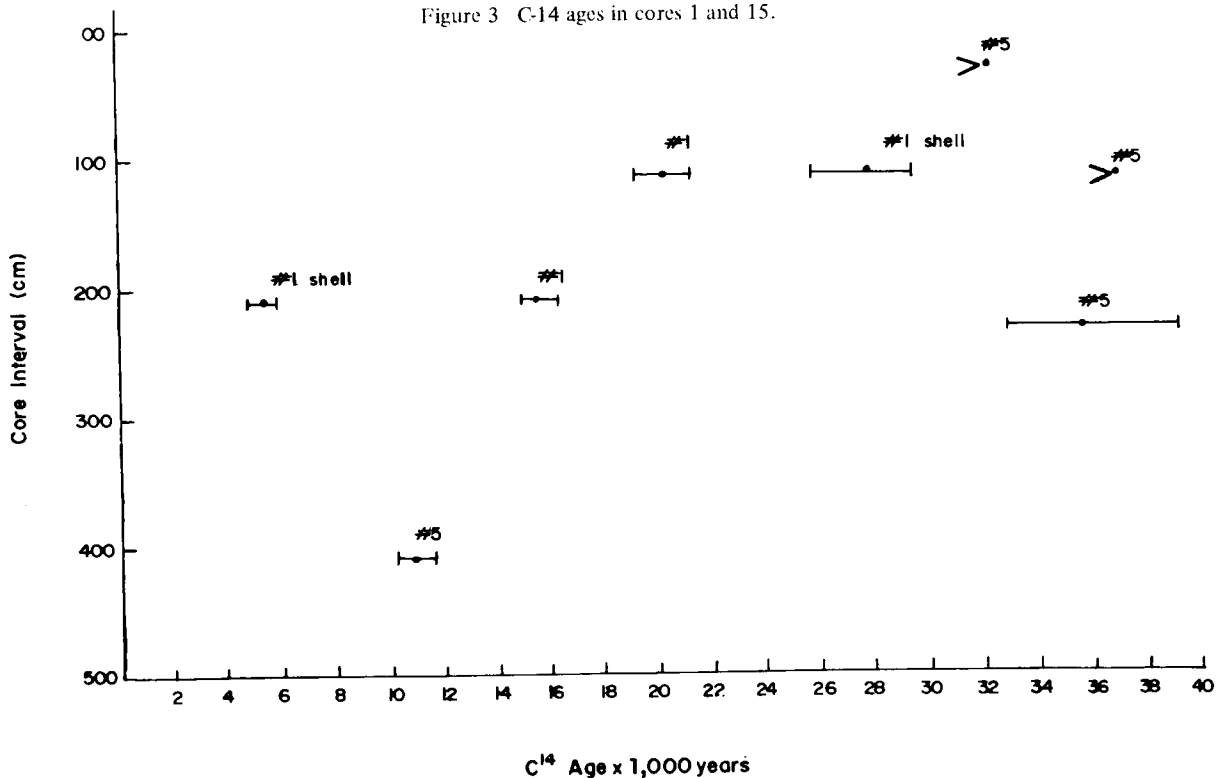
Core	Interval (cm)	C ¹⁴ Carbon	Age Years BP	Carbonate	Laboratory Number
1	115-125	20,300 ± 1,100	28,000	+ 1,800 - 1,500	GX-5854
	210-220	15,700 ± 530	5,650 ± 170		GX-5855
5	32- 42	>32,000			GX-5850
	132-142	>37,000			GX-5851
	257-267	35,200 ± 4,500 - 2,800			GX-5852
	407-417	10,780 ± 650			GX-5853

the living planktonic foraminiferal indicators, was in the order of 10°C during the time of the survey. The higher paleotemperature of 13.7° observed in sediment cores suggests that, at the time of survey, there was very weak influence of the northern (warmer) waters, or that on the average, the waters have been slightly warmer in the past.

DISCUSSION

The hard parts of fish and total number of foraminiferal tests preserved in the sediment column could reflect fluctuations in biological activity, both in the water column and on the sea floor. The numbers of foraminifera and fish scale fragments fluctuate drastically in the four cores, as shown in Figure 2. The disappearance of all foraminifera most likely indicates carbonate dissolution at the sediment-water interface. Relatively low numbers of planktonic tests without appreciable reduction of the benthonic tests suggest a favorable carbonate preservation but low production of planktonic foraminifera in the water column. The relatively low numbers of living planktonic foraminifera caught in the plankton tows in the upwelling area reflect a situation in which the flux of tests to the sea floor is drastically reduced. The inverse relationship between the numbers of fish scale fragments and planktonic tests in the sediments may indicate that during times of exceptionally high organic production the waters are poor in planktonic foraminifera or that planktonic tests are poorly preserved in sediments supporting high rates of organic

Figure 3 C-14 ages in cores 1 and 15.



degradation.

The most scientifically discouraging aspect of the sediment cores is the extreme mixing of sediment as indicated by the C^{14} dates (Table 5, Fig. 3) and the total absence of any correlation of sedimentary or faunal features between the cores taken a short distance from each other.

The eight C^{14} dates were obtained from shell fragments as well as organic carbon. The range of ages is $5,650 \pm 170$ years BP to older than 37,000 years BP. The correlation between C^{14} dates and core intervals is extremely poor (Fig. 5), with older sediments on top of younger. In Core 1 at the 115-125 cm interval, the date of organic carbon is in the order of 7,000 years younger than the carbonate

carbon date. At the 210-220 cm interval, the organic carbon date is older by 10,000 C^{14} years as compared with carbonate material from the same horizon. These dates make any stratigraphic interpretation of these cores highly questionable.

Both the organic chemistry data and foraminifera data suggest extensive sediment reworking or recycling. Without additional information, such as detailed bottom or subbottom surveys of the coring site, it is difficult to suggest the possible processes. However, it seems that older sediments mixed with younger are in transit across the continental shelf, and evidence suggests that at the coring site sediments are not accumulating in a continuous sequence.

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