**Species. Salmon Fisheries: Atlantic. Salmon Fisheries: Pacific. Seabirds and Fisheries Interaction. Small Pelagic Species Fisheries. Southern Ocean Fisheries.**

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# FLOATS

*See* **DRIFTERS AND FLOATS**

# FLOC LAYERS

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## Introduction

Over much of the ocean area the deep seafloor receives a periodic supply of material from the overlying sunlit zone reflecting the seasonally varying rate of primary production (*see* **Primary Production Processes. Primary Production Methods. Primary Production Distribution**). In many regions this input of material forms a temporary detrital layer up to several centimeters thick resting on the seabed. This phytodetrital layer is subsequently eaten by organisms living on the seafloor, dissolved, or incorporated into the underlying sediment. It may also be advected to another region. This material is rich in certain biochemical entities and although it is expected to have a high organic carbon concentration, this has not always been found to be the case. It nevertheless supports some specialist species of organisms that grow rapidly in response to its deposition. The layer has very different physical characteristics from that of the underlying sediment being resuspended at low current velocities and this exposes the material to populations of near bottom zooplankton that are likely to use it as a food source.

## The Seabed as an Interface

The seafloor represents the interface between the ocean and the solid earth beneath it. It controls the exchanges of dissolved chemicals between these environments and furthermore supports a diverse and rich benthic fauna. This community remineralizes more than 90% of the material arriving on the seabed. The presence of such layers in shallow waters has been a familiar sight to subaqua divers for many years. However, in the deep sea it was only within the last two decades that this interface has been thought to show any seasonal change or in fact to be different from the underlying geological sediment recovered by aggressive gravity corers.

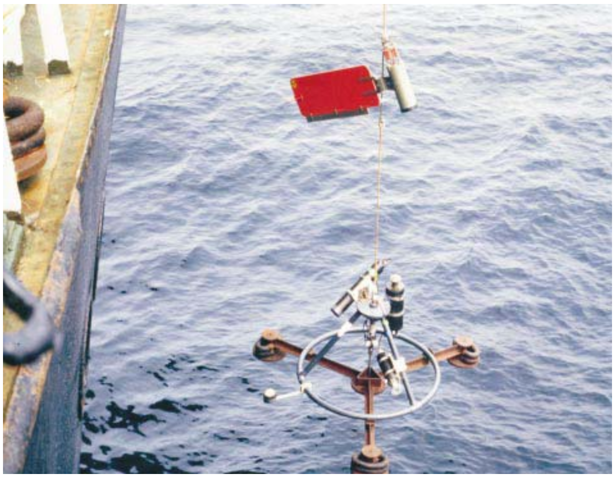

**Figure 1** Time-lapse camera system 'Bathysnap' during launch from the research vessel RRS *Discovery*.

This was in spite of the fact that nearly 100 years ago Hans Lohmann commented on the fact that there were fragile tests of phytoplankton suspended in the near bottom waters that he assumed must have been deposited very recently from the upper ocean where they were produced.

## Methods of Examination

One of the main reasons why the benthic phytodetrital layer has eluded researchers has been that the traditional techniques of coring create a bow wave that washes away lighter material from the surface of the sediment. As these layers are easily resuspended, they have almost always been lost from the interface. Time-lapse photography over prolonged periods of time has been the technique that has shown most convincingly the deposition, accumulation, resuspension, and loss of this material (**Figure 1**). This technique has the very significant drawback of not providing material for subsequent microscopic and chemical analysis. Furthermore, quantification of the benthic load has large errors. Development of the photographic method did, however, generate much interest and recently developed corers are now used that enter the sediment very slowly and hence retain this interface (**Figure 2**). Submersibles have also been used to collect undisturbed samples of the deep sea sediment interface but the cost of this precludes wide-scale use.

## Temporal and Regional Variations

In the deep-sea environment phytodetrital layers were initially noticed in the north-east Atlantic (**Figure 3**) where the strong seasonal variation in primary production at the surface might be expected to create the largest pulse of material. However, more recently they have also been found in the north-east Pacific and in the tropical equatorial Pacific where primary production is less seasonally pronounced.

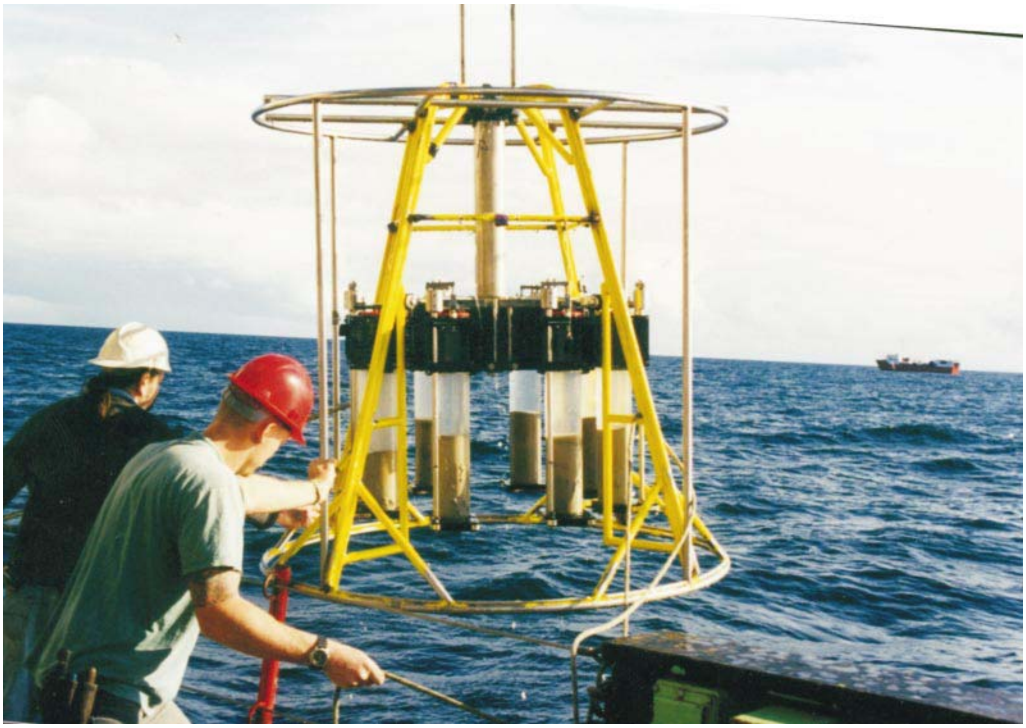

**Figure 2** The 'Bowers and Connelly Megacorer' after recovery with cores collected from the Porcupine Abyssal Plain.

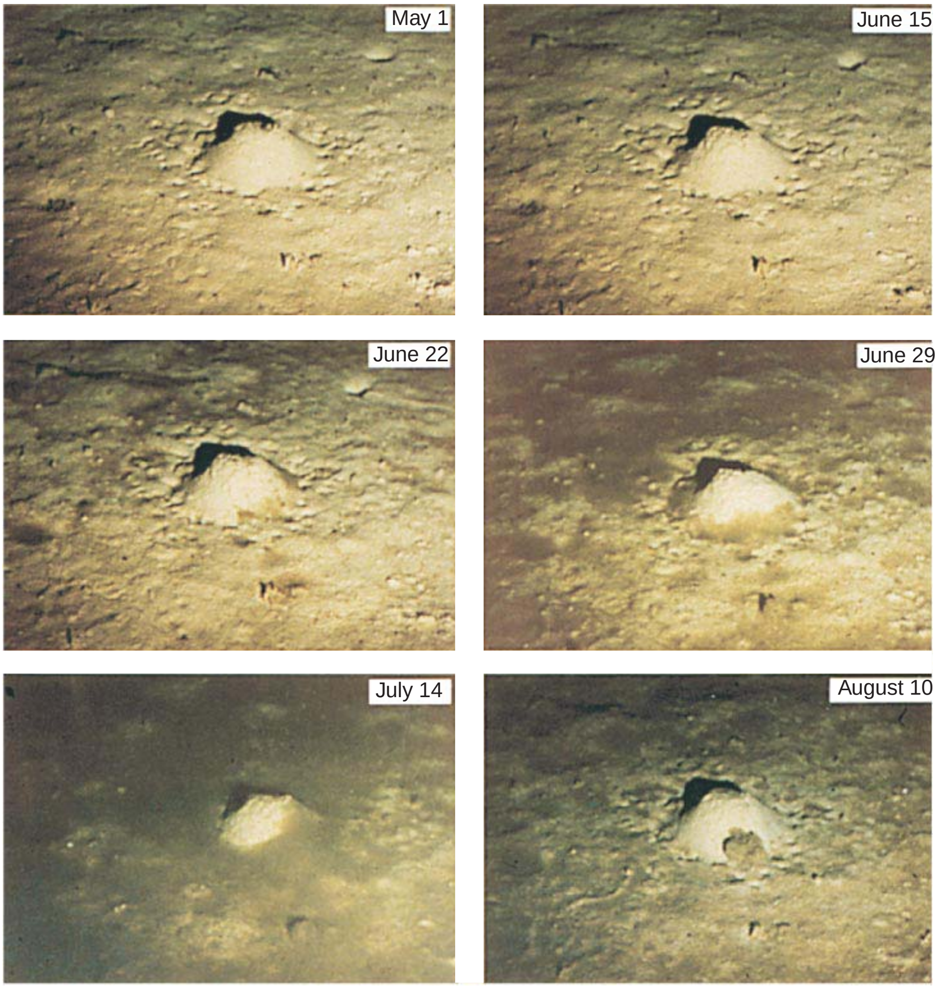


**Figure 3** Examples of time-lapse photographs of the seabed taken at 4025 m depth in the north-east Atlantic. The base of the mound in the center of the field of view is about 18 cm across.

The most conspicuous aspect of these layers is the seasonal variation in their arrival and disappearance. What can be seen in photographs and collected in cores as a distinct layer represents the difference between the supply from the overlying water and the loss at the seabed. This loss will be a combination of the processes of feeding by the benthic community, dissolution, and incorporation into the seabed as a result of bioturbation by the larger benthic animals. It was for this reason that it was expected to be found only in regions where the downward flux of material has strong temporal variability. The benthic processes involved in its disappearance would then be unable to accommodate the sudden increase in supply and a layer would form. When initially observed in the north-east Atlantic, the occurrence seemed to be a regular and predictable event, but recent observations have shown that changes in the populations of larger benthic organisms can prevent its manifestation completely even when the downward particulate supply follows its usual temporal variation (**Figure 4**). Predictions about when and where layers will be found are therefore very difficult to make.

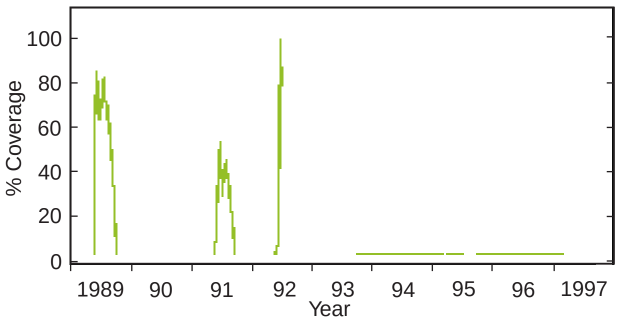


**Figure 4** Variation in the quantity of phytodetritus lying on the seabed in the abyssal north-east Atlantic. Note the zero offset.

Over short time periods, phytodetrital layers can be resuspended in response to near bottom currents and at speeds that would not normally resuspend the older sediment material (**Figure 5**). Once the current speeds decrease, the resuspended material rapidly settles again onto the seabed (**Figure 6**) suggesting that it does not rise very far into the water column but may be retained within the benthic boundary layer. The currents may not, therefore, contribute in a major way to nepheloid layers (*see* **Nepheloid Layers**). Even if the current speeds are insufficient to resuspend the material, they usually cause it to drift over the sediment surface like a thin layer of fog. On short spatial scales ($<1$ m) the distribution is often very patchy settling preferentially in depressions in the sediment when coverage

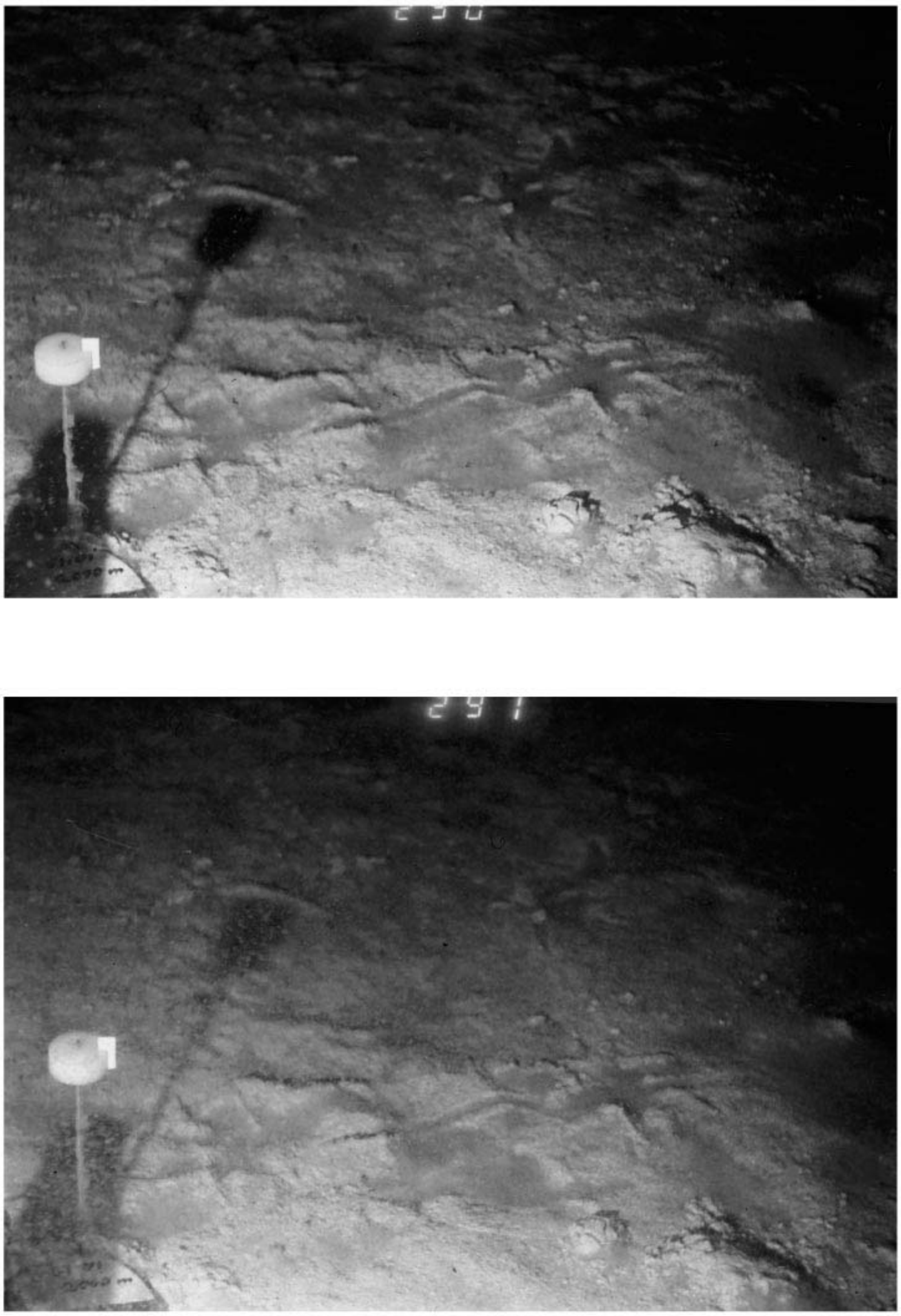

**Figure 5** Examples of two time-lapse photographs taken 15 min apart at 2000 m in the north-east Atlantic. During this time period the current speed has increased to cause resuspension of the recently deposited phytodetrital layer. The resuspended material can be seen most clearly against the dark shadow in the lower left corner.

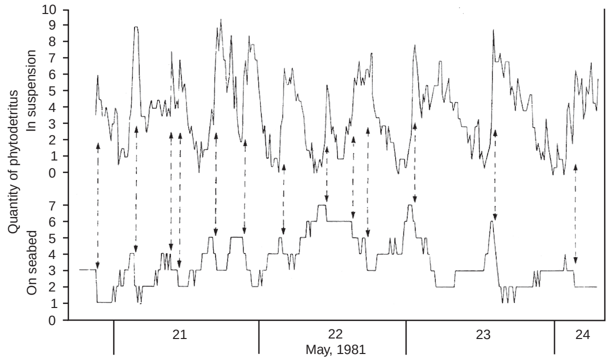


**Figure 6** Results from time-lapse photography at 2000 m depth in the north-east Atlantic showing semiquantitative estimation of the quantity of phytodetritus in suspension (upper) and lying on the seabed (lower). Neither measure is quantitative. The arrows indicate times when there was a significant reduction of the quantity lying on the seabed and it can be seen that this relates to times when there was a sharp increase in the quantity in suspension.

is slight. At other times the entire sediment surface may be covered with material.

## Characteristics and Composition

The most obvious and consistent feature of the phytodetrital material that distinguishes it from the underlying sediment is the cohesive and sometimes mucous consistency of the material. It is this which makes it obvious in photographs of the seabed (**Figure 3**) and in cores where the boundary between the phytodetrital layer and the underlying seabed is often sharp (**Figure 7**). Aggregates are often observed and these are thought to be the most recently deposited material and are the marine snow particles (*see* **Marine Snow**) after arrival on the bottom. Material in these layers have high concentrations of plant pigments and breakdown products reflecting their recent origin in the euphotic zone and this often gives the layers a green or brown tinge. Although it might be expected that this material would have a high concentration of organic carbon, this has been found to be highly variable and not always very different from the underlying sediment. The reason for this is partly due to the degradation to which the material has already been subjected and partly because of incorporation of older sediment as the material drifts across the sediment surface. The composition of the material varies greatly but frequently contains identifiable phytoplankton cells which may or may not be associated with fecal material (**Figure 8**).

**Figure 7** Example of a core tube taken with the SMBA Multicorer to show the layer of phytodetritus lying on top of the older sediment. This was taken in May 1981 from a depth of 2000 m in the north-east Atlantic.

## Significance for the Benthic Environment

The most obvious significance is that the layer of phytodetritus changes radically the nature of the interface between the solid earth and the water above it. Although it was initially expected that this would greatly alter the chemical exchanges (e.g., nutrients and oxygen) across the boundary, to date the effects have been found to be modest and variable. In some instances patches of the seabed have significantly higher oxygen consumption whereas in other experiments the effect has been negligible. Much of this probably depends on the state of degradation of the material prior to the experiments.

In terms of the benthic community, evidence of reproductive periodicity in the large so-called megafauna has been available since the late 1970s but this is not the case for all species and even in areas subject to seasonal variations in supply, there are some species which demonstrate no periodicity. Certain species have been shown to feed enthusiastically on the phytodetrital layers (**Figure 9**) and on capture, their guts may be full of phytodetritus during the summer. The situation is similar for organisms that live within the sediment in that for some species their population levels increase substantially in response to the development of phytodetrital layers whereas for other species no response is evident. The response of certain species of foraminifera, which has been better documented than other faunal groups, has offered the possibility of using their distribution in the sedimentary record as an index of paleoceanographic conditions in terms of the type of organic supply to the seabed.

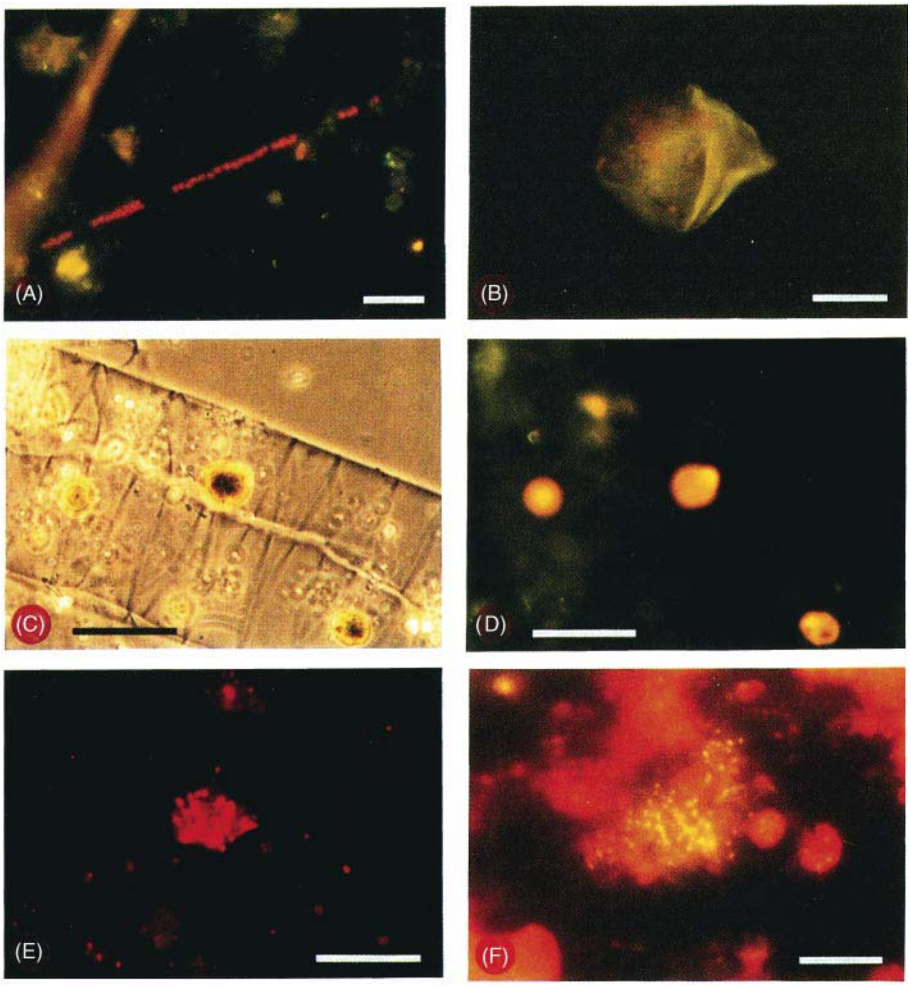


**Figure 8** Autofluorescence photomicrographs of material collected from phytodetrital layers in the north-east Pacific at 4100 m depth. Scale bars (A–E) 25 μm (F) 10 μm. (A) Diatom fragment with chloroplasts fluorescing red; (B) dinoflagellate with chloroplasts fluorescing red; (C, D) fragments of Rhizosolenia borealis; (E) small fecal pellet with cyanobacteria fluorescing green; (F) bacteria fluorescing yellow. Courtesy Dr Stace Beaulieu, Woods Hole Oceanographic Institution.

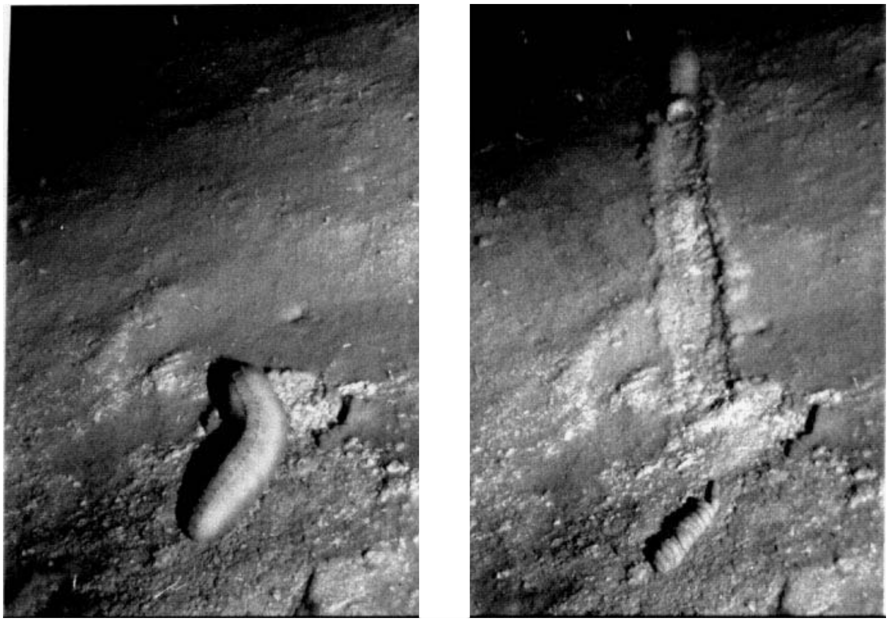

**Figure 9** Time-lapse photographs from 2000 m in the north-east Atlantic showing two frames taken 30 min apart during which the holothurian *Benthogone rosea* has moved across the surface of the sediment feeding on the phytodetrital layer. The specimen which has a body length of about 16 cm has deposited a fecal cast during this time interval.

## See also

**Marine Snow. Nepheloid Layers. Primary Production Distribution. Primary Production Methods. Primary Production Processes.**

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# FLORIDA CURRENT, GULF STREAM AND LABRADOR CURRENT

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## Introduction

The swiftest oceanic currents in the North Atlantic are located near its western boundary along the coasts of North and South America. The major western boundary currents are (1) the Gulf Stream, which is the north-western part of the clockwise flowing subtropical gyre located between 10°N and 50°N (roughly); (2) the North Brazil Current, the western portion of the equatorial gyre located between the equator and 5°N; (3) the Labrador Current, the western portion of the counterclockwise-flowing subpolar gyre located between 45°N and 65°N; and (4) a deep, swift current known as the Deep Western Boundary Current, which flows southward along the whole western boundary of the North Atlantic from the Labrador Sea to the equator at depths of around 1000–4000 m.

The swift western boundary currents are connected in the sense that a net flow of warmer upper ocean water (0–1000 m very roughly) passes northward through the Atlantic to the farthest reaches of the North Atlantic where the water is converted to colder, denser deep water that flows back southward through the Atlantic. This meridional overturning circulation, or thermohaline circulation as it is also known, occurs in a vertical plane and is the focus of much recent research that is resulting in new ideas about how water, heat, and salt are transported by ocean currents. The combination of northward flow of warm water and southward flow of cold water transports large amounts of heat northward, which is important for North Atlantic weather and climate.

## History

The Florida Current, the part of the Gulf Stream flowing off Florida, was described by Ponce de León in 1513 when his ships were frequently unable to stem the current as they sailed southward. The first good chart of the Gulf Stream was published in 1769–1770 by Benjamin Franklin and Timothy Folger, summarizing the Nantucket ship captain's knowledge gained in their pursuit of the sperm whale along the edges of the Stream (**Figure 1**). By the early nineteenth century the major circulation patterns at the surface were charted and relatively well known. During that century, deep hydrographic and current meter measurements began to