would appear that conditions are favorable for the transport of significant amounts of dust to the Enewetak region for 3 or 4 months of the year, beginning perhaps in February or March. If our measured atmospheric deposition rate of 4 $\mu g\ cm^{-2}\ month^{-1}$ applies over a 3- to 4-month period, it would result in an accumulation rate of about 0.3 mm of wet sediment per 1000 years. This assumes an in situ sediment density (the ratio of the dry weight of sediment to the in situ volume occupied by the sediment) of 0.5 g cm^{-3} (*9*). The actual nonbiogenic sedimentation rates to the ocean floor in this region of the North Pacific are not well known but are probably about 1 mm per 1000 years (*9, 10*). We would expect that the atmospheric contribution of dust to Pacific deep-sea sediments would be even greater in the higher latitudes where transport conditions from Asia are more favorable.

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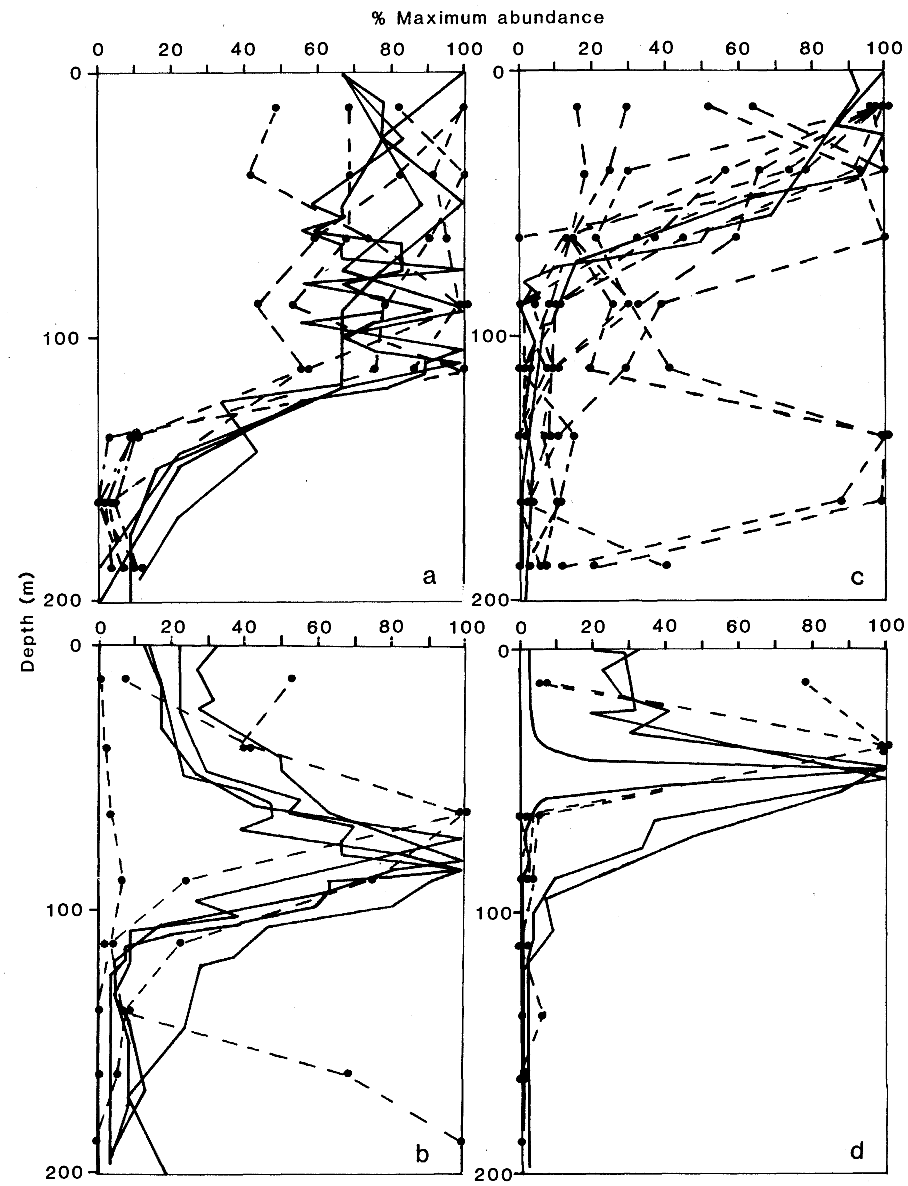
Foraminifera and Chlorophyll Maximum: Vertical Distribution, Seasonal Succession, and Paleoceanographic Significance

Abstract. *Many planktonic foraminiferal species deposit their shells at the chlorophyll maximum zone, and it is the temperature range here that is relevant to oceanographic models which use ratios of oxygen-18 to oxygen-16 in fossil foraminifera and foraminiferal fossil assemblages to ascertain past climates. During periods of stratification of the upper water column, the temperature at the chlorophyll maximum may differ from the sea surface temperature by 10°C in the western North Atlantic.*

Culture experiments on planktonic foraminifera (*1*) show that shell growth rate, size, and productivity are positively correlated with feeding frequency. The first step in assessing the possible significance of this relationship in nature is to examine the association of planktonic foraminifera and phytoplankton in the water column. During the months in which the upper water column remains well stratified in slope water, Sargasso Sea, and Gulf Stream cold core rings in the North Atlantic, plant chlorophyll develops a maximum at the bottom of the euphotic zone. This feature is known as the deep chlorophyll maximum (DCM) (*2*). Numerous investigators have suggested that particular zooplankton species are associated with the DCM (*3-7*).

Ortner and Wiebe (*5*) obtained vertically stratified samples of macrozooplankton and microzooplankton at DCM depths in these regions. Based upon results from cruises *Chain* 125 and *Knorr*



53, Ortner and Wiebe concluded that zooplankton biomass was enhanced about the DCM. These results confirm the conclusions of Hobson and Lorenzen (6) that the depth of the DCM in the North Atlantic and the Gulf of Mexico is influenced by the depth of the local pycnocline. Plant cells of the DCM utilize nutrients diffusing into nutrient-poor surface water (7). The flux of nutrients to shallow, nutrient-depleted surface waters is greatest in the pycnocline. The maximum depth to which the DCM follows the seasonal pycnocline is regulated by the minimum light intensity necessary for the growth of the particular phytoplankton taxa inhabiting the area. Chlorophyll accumulates in many oceanic environments to which 1 percent of the ambient light penetrates (7, 8).

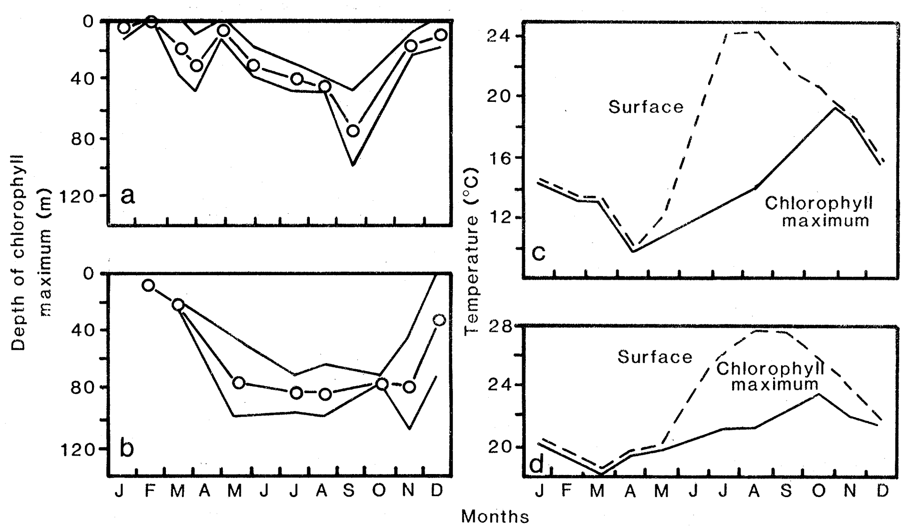


Fig. 2. Seasonal record of the depth of the chlorophyll a maximum and temperature in the northern Sargasso Sea and the slope water. (a and b) The monthly range and midrange values for the depth of the chlorophyll maximum for the slope water and northern Sargasso Sea, respectively. (c and d) The monthly sea surface temperature and temperature at the chlorophyll maximum for the slope water and northern Sargasso Sea, respectively.

Many species of planktonic foraminifera are markedly more abundant in the DCM than in surrounding waters, an indication of an association between foraminifera, other zooplankton, and algal cells of the DCM (Fig. 1) (9, 10). Apparently the DCM is a major food source zone, which is exploited by foraminifera. In addition, planktonic foraminiferal species have specific temperature tolerance ranges (11), and therefore the seasonal pycnocline can provide an ecologic niche for multiple species.

The results obtained from cruises *Chain* 125 and *Knorr* 53 point to an important correlation, which is amenable to modeling paleoceanographic conditions by means of transfer functions or algebraically less abstract methods (12). If temperature is a major factor regulating foraminiferal species composition (11), then for a large portion of the year the temperature at the DCM depth is the most useful predictor of foraminiferal vertical and seasonal distribution and oxygen isotopic composition. In addition, it follows that the level of chlorophyll and the zooplankton concentration are related to the standing stock of foraminifera.

Fig. 1. Planktonic foraminiferal species as the percentage of the maximum abundance level versus depth (dashed lines): (a) MOC-1-28 (November), cold core ring D; (b) MOC-1-12 (August), northern Sargasso Sea; (c) MOC-1-38 (November), slope water; and (d) MOC-1-16 (August), slope water. A total of 15 species or morphotypes are represented. The solid lines indicate relative chlorophyll concentrations, also plotted as the percentage of the maximum abundance level versus depth. The chlorophyll profiles were taken before and after the multiple opening-closing (MOC) tows. The criterion for including a species is that at least one sampling level must have ≥ 50 individuals per 1000 m^3. Foraminiferal data are plotted as the midpoint of the 25-m sampling interval. Faunal data for MOC-1-12, MOC-1-16, MOC-1-28, and MOC-1-38 are presented in (9, 10).

A DCM develops seasonally in the pycnocline in the northern Sargasso Sea and the slope water, but the DCM concentration is greater and its duration is shorter in the slope water than in the Sargasso Sea. The DCM is near or at the surface in the winter months and submerges from May to September in the slope water and from April through November in the Sargasso Sea. The DCM reaches a maximum depth in the slope water of 75 m in September and 85 m during July in the Sargasso Sea (4, 13) (Fig. 2). The annual temperature range at the DCM is attenuated by 66 percent in the slope water and 57 percent in the Sargasso Sea as compared to the overlying sea surface (Fig. 2). Slope water surface temperatures range from 9.8°C in April to 24.2°C in August as compared to a range of 9.8°C in April to 19.4°C at the end of October for temperatures at the DCM; the maximum difference between sea surface and DCM temperatures is 10°C in July. Sargasso Sea surface temperatures range from 18°C in March and April to 28°C in August, whereas the temperature at the DCM ranges from 18°C between March and April to 23.6°C in October. Here the maximum temperature difference is approximately 6°C in August. Winter and early spring surface temperatures are coincident with temperatures at the DCM. However, the sea surface maximum temperature leads the maximum annual temperature of the DCM by 3 months in the slope water and 2 months in the Sargasso Sea.

Transfer function paleotemperature predictions based on seabed foraminiferal samples (12) may be less accurate in regions where the DCM temperature departs significantly from the surface temperature. In many regions of the world's oceans, the DCM occurs in the well-mixed layer during part of the year. Where sufficient geographic and seasonal data on chlorophyll concentrations in the water column are lacking, the temperature at the DCM can be mapped as the temperature at the top of the nutricline. This level can be approximated as the stability maximum in the photic zone (about 0 to 80 m) where $d\sigma_t/dZ$ is greatest (Z is the depth, and σ_t is the specific gravity of water).

Where chlorophyll concentrations are high and relatively constant throughout the euphotic zone as, for example, in MOC-1-28 (Fig. 1a), spinose and nonspinose, or symbiont-bearing and symbiont-barren, foraminifera species show no depth differentiation within the euphotic zone (9, 10). The association of the DCM with the pycnocline may be the reason why earlier investigators related the depth distributions of foraminifera species to the density of seawater (14).

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24 March 1980

A Comparison of Thermal Observations of Mount St. Helens Before and During the First Week of the Initial 1980 Eruption

Abstract. *Before and during the first week of the March-April 1980 eruptions of Mount St. Helens, Washington, infrared thermal surveys were conducted to monitor the thermal activity of the volcano. The purpose was to determine if an increase in thermal activity had taken place since an earlier airborne survey in 1966. Nine months before the eruption there was no evidence of an increase in thermal activity. The survey during the first week of the 1980 eruptions indicated that little or no change in thermal activity had taken place up to 4 April. Temperatures of ejected ash and steam were low and never exceeded 15°C directly above the vent.*

Mount St. Helens, which is located in southwestern Washington (45°12′N, 122°11′W), started to erupt on 27 March 1980 after a dormant period of 124 years. To study this recent sequence of eruptions, we established a research site 9 km northwest of the summit at an elevation of 840 m. During the time period between 30 March and 4 April 1980, we monitored the thermal and seismic activity associated with the volcanic eruptions. We conducted the thermal monitoring by using an infrared scanner and an infrared thermometer (*1*), as a follow-up investigation to a survey conducted during a 5-day period in August 1979.

Our ground-based infrared survey of Mount St. Helens during the summer of 1979 was prompted by reports (*2*, *3*) that this volcano was possibly the most active and most violent of the volcanoes in the coterminous United States. Mount St. Helens is younger than its three neighboring peaks, Mount Rainier, Mount Adams, and Mount Hood (*2*, *3*). Although its existence can be traced back some 37,000 years, nearly all of the present cone was formed in the last 2500 years. Radiocarbon dates indicate that the dormant period has not exceeded 500 years; more recently, the dormant periods have lasted only 100 to 200 years. The frequency and volume of eruptions produced by Mount St. Helens are similar to those of Mount Vesuvius, Mount Fuji, and Mount Hekla. However, eruptions of Mount St. Helens have never produced as much material as the eruption of Mount Mazama (Crater Lake, Oregon) 6600 years ago.

Because of the possibility that Mount St. Helens might erupt before the end of this century (*2*), we included it, along with Mount Shasta and Mount Lassen (located in California), in ground-based infrared surveys during August and September 1979. The purpose of our surveys was to document changes in existing hot areas on each mountain and to look for any new hot areas that might have appeared since the 1966 infrared thermal survey of the mountain (*4*). The survey during the summer of 1979 seemed particularly timely since interest in Cascade volcanoes was renewed after reports of increased heat flow from Mount Baker (*5*), 290 km north of Mount St. Helens.

The infrared scanner that we used in our initial survey of Mount St. Helens (August 1979) and during the first week of the 1980 eruptive activity (30 March to 4 April 1980) produces a visual image on a cathode-ray tube (Figs. 1 and 2) of the infrared radiation emitted from the object observed. The infrared scanner quantifies the temperature differences on

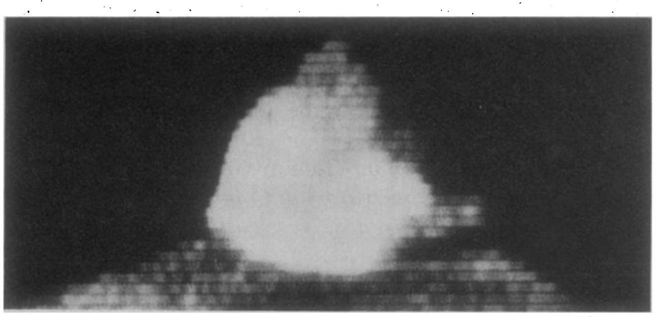

Fig. 1 (above). Thermogram of the summit area of the northwestern side of Mount St. Helens at the beginning of an eruption that took place at 1826 P.S.T. on 30 March 1980. The lightest areas of the photo represent the highest temperatures (the portion of the eruptive plume closest to the crater), and the darkest portions represent the lowest temperatures (the clear night sky). For this photo the instrument has been set so that variation from darkest to lightest tones occurs for a temperature change of 2°C.

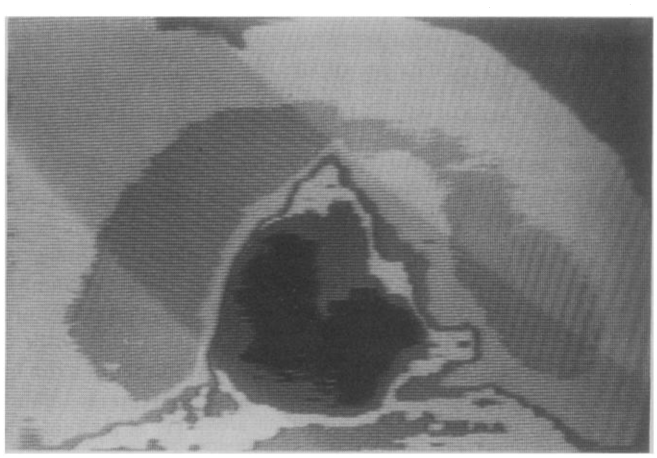

Fig. 2 (right). Thermogram with areas of equal temperature derived from Fig. 1 depicted as the same shade. The absolute temperature is not recorded here; only the relative temperature differences between areas of equal grayness are significant. The warmest area is represented as black (just above the crater).