

Layer of Abnormally Cold Bottom Water over Southern Aves Ridge

Abstract. A thermograd record obtained over the Aves Ridge indicated existence, at the time of observation, of a cold layer of water in the lowest 13 meters, undergoing high-frequency internal oscillations. The great discontinuity in temperature across the sediment-water interface and the lack of agreement with the normal temperature structure indicate that the layer was a transient feature. This abnormal condition may be related to the passage of a hurricane 3 days earlier.

On 28 September 1963 ocean-bottom heat flow and near-bottom water temperatures were measured by R/V *Conrad* in a depth of 1060 m over the southern part of the Aves Ridge in the Caribbean at 13°06'N, 63°09'W. The instrument used, the Ewing thermograd (1), records the temperatures of three or more thermistor probes arranged along a core pipe. The heat flow measured at station C7-2, a subject of this report, was $1.1 \mu\text{cal cm}^{-2} \text{sec}^{-1}$ (2).

Four temperature probes were used, but only three entered the sediment. Sediment adhering to the outside of the coring pipe, and the length of the extruded core, indicated that the pipe had penetrated between 7.7 and 7.8 m. The uppermost probe in the pipe was 10.5 m above the pipe's cutting edge; thus it was 2.7 to 2.8 m above the sea floor. The original record is shown in Fig. 1. The water temperature recorded by the upper probe varied with time while the core pipe was in the sediment; these variations are shown graphically in Fig. 2; the time scale is approximate because the speed of the motor that translated the recording film is not constant nor exactly known, but, the error is probably less than 10 percent. Within the 6 minutes of observation the temperature clearly fluctuated by 0.17°C , with a period of about 2 minutes.

In Fig. 3 the measured temperatures are plotted against distance above and below the sea floor. The scale for distance above bottom is approximate; it depends on the rate at which the instrument was lowered, which is not exactly known. The temperature gradient above 13 m from the bottom is about 0.30°C per 100 m but became much greater closer to the bottom. Points A and B in Fig. 3 are the maximum and minimum temperatures recorded by the uppermost probe while on the bottom. The temperature gradient in the sediments was almost constant with depth. The bottom temperature, found

by extrapolating this thermal gradient to the water-sediment interface, was approximately 4.9°C ; this should be the normal bottom temperature if one assumes constant thermal conductivity with depth.

The data indicate that the bottom water was abnormally cold. There were two divisions to this water: an upper

layer above 13 m, and a colder lower layer in which the temperature gradient was very steep.

Water temperatures measured by the thermograd were lower at all depths than those found by standard hydrographic techniques (3). However, the difference decreases with increasing distance from the bottom, so that no clear upper limit of the colder water can be defined. While the absolute accuracy of the thermistor probes can only be estimated, the relative accuracy of temperature measurements by one probe in the water is about 0.01°C (1). Temperatures recorded by three of the thermistor probes in the water agree within 0.01°C . The lowermost probe indicated a temperature 0.5°C lower than the average of the others; this dif-

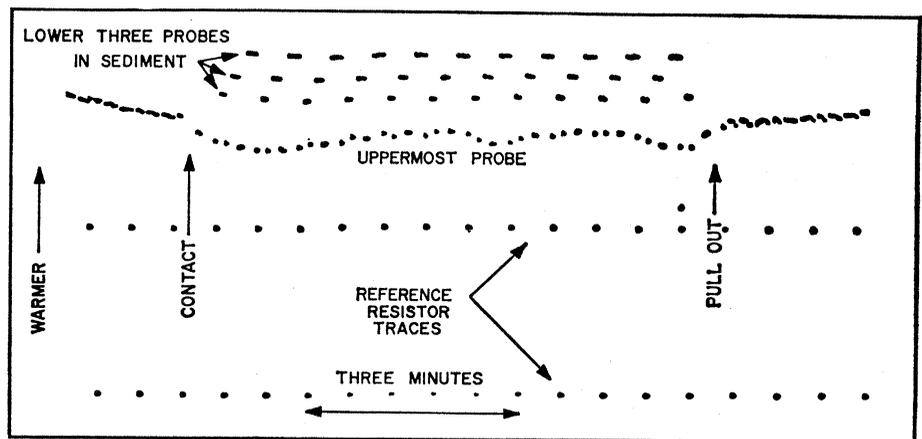


Fig. 1. Original photographic record of thermograd station C7-2, showing the displacements of each temperature-probe trace during the time the instrument was in the sediment and for approximately 2 minutes before and after penetration of the sediment. Variations in trace displacement are almost proportional to temperature changes of the probes.

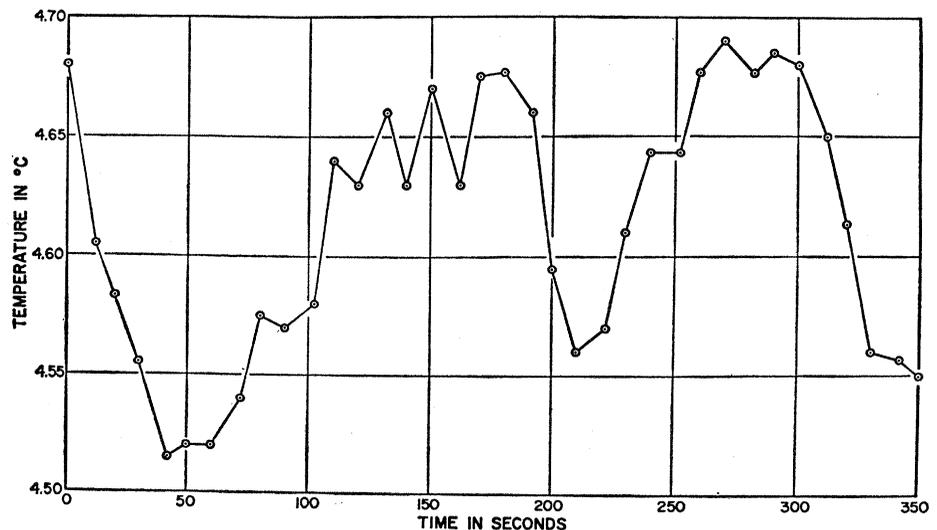


Fig. 2. Temperature fluctuations recorded by the uppermost thermistor 2.7 to 2.8 m above the water-sediment interface over the Aves Ridge.

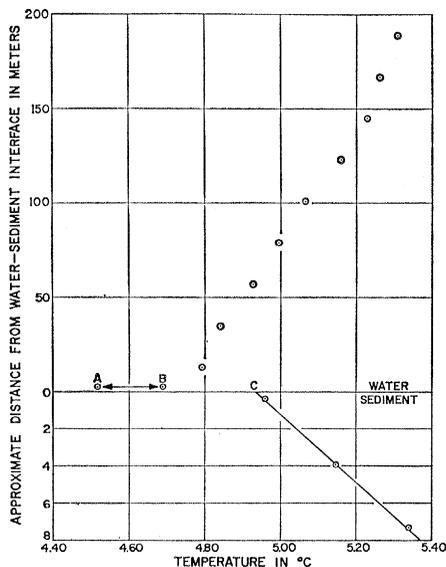


Fig. 3. Temperature versus distance from the water-sediment interface below C7-2.

ference could result from a small electrical resistance in series with the thermistor.

The variation of temperature with time in the near-bottom water (Fig. 1) was probably a manifestation of internal waves. If the normal temperature gradient was present, this range of variation would represent vertical motion of 100 m. Because of the boundary conditions internal waves of such amplitude are impossible so close to the bottom; moreover, the observed frequency was higher than would be expected in the nearby homogeneous deep water of the Caribbean. However, high-frequency internal waves can occur with the large temperature gradient observed in the lowest 13 m, which fact would explain the temperature fluctuations.

The observed cold bottom water must be a transient feature. Hurricane Edith passed within 2 deg. north of C7-2 only 3 days before the measurements were made; the passage of the hurricane may be related to these observations. Leipper (4) has reported great upwelling of water during passage of hurricane Hilda through the Gulf of Mexico; he believes that a 150-m vertical migration of water may have occurred at depths below the Ekman Layer. The cold water layer over the Aves Ridge may have been a residue of deeper cold water that moved up the flanks of the ridge during the passage of the storm. A second possible relation to the hurricane may derive from its initiation of large internal waves: impinging on the ridge,

these waves would break and form a "surf zone" on top of the ridge, resulting in the thin layer of much colder water near the bottom and short period oscillations. The breaking of internal waves as they pass over areas of decreasing depth has been reported (5). Cooper (6) hypothesized a similar mechanism to explain nutrient-rich water on the continental shelf of the western English Channel.

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References and Notes

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 7. We thank ONR for support [contract Nonr 266(48)], and Manik Talwani, chief scientist aboard R/V *Conrad*. Lamont Geological Observatory contribution No. 889.
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Dislocations in a Campo del Cielo Meteorite

Abstract. Thin-film transmission electron microscopy showed that a Campo del Cielo meteorite has an immobile dislocation network of high density. The network is not related to attendant precipitates.

Recent studies of the nature of the distributions and configurations of dislocations in metallic meteorites have revealed an interesting situation in a section of a Campo del Cielo meteorite. Slices were spark-machined from the bulk specimen and were thinned with a saturated solution of anhydrous sodium chromite in acetic acid as electrolyte. Selected areas were examined by transmission electron microscopy (Philips E.M. 200); micrographs were taken from areas 1- μ square.

Diffraction patterns showed that all the areas examined were the body-centered-cubic (bcc) α or kamacite phase. Figure 1 shows a typical area

containing dislocations and precipitation particles. Although the dislocation density is high (about 10^9 cm⁻²), the general appearance is not that of a plastically deformed bcc metal, despite the fact that, under optical examination, extensive deformation effects such as Neumann bands, flow zones, and fractured inclusions are observed. (For example, compare this micrograph with the deformation structures observed in vanadium by Edington *et al.*, 1.) It is evident from Fig. 1 that none of the dislocations is held up by precipitates, as would be expected if they had been introduced by plastic deformation. The indication is that these dislocations were not generated by impact. On the other hand, none of the precipitates have grown at or along the dislocations—that is, if the precipitates were nucleated after the generation of the dislocations, then there was no elastic attraction between the dislocations and the precipitate atoms. An explanation for this is that the dislocations contain a sufficient concentration of foreign atoms to neutralize their strain fields, but that the concentration is too low to be resolved by the electron microscope. Figure 2 shows an area at high magnification; although no precipitates are seen on the dislocation lines, the lines sometimes have a jagged appearance which could be indicative of dislocation pinning.

There is little or no strain contrast surrounding the precipitate particles. This means that there are no strains due to coherence or to differential thermal expansion that occurred between precipitate and matrix during cooling. Also, the absence of dislocation loops near the precipitates shows that there has been no need to relieve strain by "punching out" prismatic dislocations. All of this evidence indicates that the precipitates were formed during the cooling of the meteorite at a very slow rate. The question of how such a slow cooling rate can be compatible with the observed high dislocation density which, in the foils so far examined, is of the order of at least 10^9 dislocation lines per square centimeter can be answered in part by considering the nature of the dislocations.

In Fig. 2 the foil plane is (201) and the long dislocation lines which, because of their length, must lie in or nearly in the foil plane, are parallel to the [211] direction. Now [211] is the intersection of (011), a normal bcc slip plane, with the foil plane. Conse-