On the Measurement of Bottom Water Temperatures

T. V. Ryan

Pacific Marine Environmental Laboratory, University of Washington, Seattle, Washington 98195

Sclater and Klitgord [1973] show a thermal profile from the Panama basin (Figure 13, Scan 10 heat flow station 20) with a superadiabatic increase of about 0.005°C in the bottom 30 m of the water column. *Ryan* [1973] cites several earlier reports listing numerous other superadiabatic gradients measured with heat flow instrumentation in the near-bottom waters of the Pacific. His measurements at several sites in the Panama basin showed that superadiabatic heating, if it exceeded 0.002°C, did not extend more than 2 cm above the bottom.

The magnitude and vertical extent of the reported gradients, some of which are relatively large (e.g., 0.03°C in 17 m [*Chung et al.*, 1969, p. 54]), is puzzling, since theory [*Filippov*, 1966] indicates that if the water is otherwise homogeneous, vertical convection resulting from instability should limit measurable gradients to within a few centimeters of the bottom.

In an attempt to determine the cause of anomalous thermistor data [*Ryan*, 1973, p. 1736], the author recently conducted laboratory tests on the magnitude of frictional heating and possible self-heating of Fenwal model K411 thermistors when they were injected into a sediment from a water bath. Thermistors were injected 5 cm into a temperature-controlled (2.007°C ± 0.0005°C) sediment sample and after dissipation of frictional heat were extracted. Surprisingly, frictional heating on extraction was significant (ranging from 0.02° to 0.08°C), exceeding 35% of the injection heating. (Thermistor self-heating degrades thermistor performance if the heat generated by the sensing current exceeds the heat dissipative capacity of the sensor. The temperature rise reduces the resistance of the sensor, which, allowing more current, generates more heat.) The laboratory tests proved that self-heating is not a problem in the sediment. The Fenwal model K411 thermistor has been used in heat flow measurements by this and other laboratories. The sensing element is at the end of a 0.318-cm-diameter 19.4-cm-long closed end stainless steel tube.

Apparently, most (if not all) of the reported superadiabatic gradients were observed as the heat flow instrumentation was being lifted off the bottom after penetration into the sediments. In those cases in which the probe is injected one or more meters into the sediment, substantial heating of the probe and related apparatus must occur upon withdrawal. As it is extracted from the sediments, the abrupt reduction in temperature may mask the excess heat developed due to frictional heating. The excess heat, dissipated as the instrumentation is raised through the isothermal (potential temperature) water column near the bottom, thus may be recorded erroneously as a superadiabatic gradient.

Obviously, the above conjecture is inconclusive. The purpose of this note is to encourage careful measurements of the thermal structure near the bottom so as to clarify the somewhat contradictory data now available.

References

Chung, Y., M. L. Bell, J. G. Sclater, and C. Corry, Temperature data from the Pacific abyssal water, *Ref. 69-17*, Scripps Inst. of Oceanogr., Univ. of Calif., La Jolla, 1969.

Filippov, D. M., Near-bottom convection at abyssal depths, *Izv. Acad. Sci. USSR Atmos. Oceanic Phys.*, *2*, 403–405, 1966.

Ryan, T. V., Deep water thermal structure at several sites in the northeast Pacific, *J. Geophys. Res.*, *78*, 7129–7138, 1973.

Sclater, J. G., and K. D. Klitgord, A detailed heat flow, topographic, and magnetic survey across the Galapagos spreading center at 86°W, *J. Geophys. Res.*, *78*, 6951–6975, 1973.

(Received January 17, 1974;
accepted July 5, 1974.)

Reply

JOHN G. SCLATER

*Department of Earth and Planetary Sciences, Massachusetts Institute of Technology
Cambridge, Massachusetts 02139*

Y. CHUNG

University of California, San Diego, Scripps Institution of Oceanography, La Jolla, California 92037

R. P. VON HERZEN

Woods Hole Oceanographic Institution, Woods Hole, Massachusetts 02543

Ryan has questioned on theoretical grounds the validity of the very near bottom (within 10-m) superadiabatic temperature gradients observed on many heat flow stations [*Chung et al.*, 1969, 1972; *Von Herzen and Anderson*, 1972; *Sclater and Klitgord*, 1973]. Further he has suggested that most of these gradients may arise through the frictional heating of the temperature-sensing thermistors on pullout from the sediment and hence are artifacts of the technique of measurement. This suggestion is reasonable and was in fact the initial reaction of two of us (R. P. Von Herzen and J. G. Sclater) to the first such gradients that we observed. As a consequence the water-temperature-sensing portion of the apparatus was redesigned, and for the Bullard probe [*Corry et al.*, 1968] used in the observations quoted by Ryan and on later versions of the outrigger-corer apparatus, the water thermistor was placed on the very top of the instrument. This placement significantly reduced the likelihood of penetration of this thermistor into the sediments and hence the possibility that all the observed superadiabatic gradients resulted from frictional heating on pullout.

We have given our measurements careful thought both before and since Ryan's comments. We have three good reasons why we believe these gradients are not the result of frictional heating on pullout.

1. In the *Chung et al.* [1969] study, superadiabatic gradients were observed on both the lowering and the hoisting portion of many of the records. This specifically includes the station Nova 03 A004 at 18°09.0′N, 170°26.0′W on page 54 of *Chung et al.* [1969] mentioned by Ryan.

2. On the Bullard probe used for the observations presented by *Chung et al.* [1969] and *Sclater and Klitgord* [1973], the water thermistor sits 60 cm above a heavy flange specifically designed to prevent the instrument's superpenetrating into the sediment.

3. The thermal time constant of our water thermistor sensors is a few seconds or less, and the measurements in many cases were made over periods of at least 5 min while the instrument was resting on the bottom or over several minutes during hoisting.

Though we do not accept his explanation, we agree with Ryan that the observed superadiabatic gradients are puzzling, since theory indicates that if the water is homogeneous, vertical convection should limit these gradients to within a few centimeters of the bottom. However, we believe some of them have a simple explanation. In a basin in which the bottom water is most likely stagnant, an adiabatic temperature gradient can be expected and observed because of free convection, as Ryan has shown in the case of the Panama basin. In the open deep-sea region, complicated processes such as scouring, turbidity current, and transient advection are affecting the bottom water temperature structure as well as the gradient. Thus a superadiabatic gradient can and will result if a colder layer is flowing over a warmer layer of approximately equal density (i.e., the water column is not homogeneous). This is our explanation of the superadiabatic gradient on the Nova 03 A004 station, which is in the middle of Antarctic bottom water flowing east through the Horizon passage [*Edmond et al.*, 1971].

However, superadiabatic gradients may not be related just to bottom water flow, since *Von Herzen and Anderson* [1972] have observed superadiabatic gradients in the Nasca basin, where no deepwater currents have been reported. We are at present working on documenting the occurrence of superadiabatic gradients and on possible explanations but have as yet reached no satisfactory conclusion.

REFERENCES

Chung, Y., M. L. Bell, J. G. Sclater, and C. Corry, Temperature data from the Pacific abyssal water, *Ref. 69-17*, Scripps Inst. of Oceanogr., Univ. of Calif., La Jolla, 1969.

Chung, Y., C. Down, and J. G. Sclater, Temperature data from the Pacific and Indian abyssal waters, *Ref. 72-85*, Scripps Inst. of Oceanogr., Univ. of Calif., La Jolla, 1972.

Corry, C., C. Dubois, and V. Vacquier, Instrument for measuring terrestrial heat flow through the ocean floor, *J. Mar. Res.*, *26*, 165–177, 1968.

Edmond, J. M., Y. Chung, and J. G. Sclater, Pacific bottom water: Penetration east around Hawaii, *J. Geophys. Res.*, *76*, 8089–8097, 1971.

Sclater, J. G., and K. D. Klitgord, A detailed heat flow, topographic, and magnetic survey across the Galapagos spreading center at 86°W, *J. Geophys. Res.*, *78*, 6951–6975, 1973.

Von Herzen, R. P., and R. N. Anderson, Implications of heat flow and bottom water temperatures in the eastern equatorial Pacific, *Geophys. J. Roy. Astron. Soc.*, *26*, 427–458, 1972.

(Received June 28, 1974;
accepted July 5, 1974.)