Lamont - Doherty Geological Observatory of Columbia University | *Palisades, N.Y. 10964*

Cable: LAMONT, Palisades, New York State

Telephone: Code 914, Elmwood 9-2900
Twx: 710-576-2653

March 1, 1978

CRUISE REPORT

Ship Name: ROBERT D. CONRAD

Cruise No: 21-05

Departure: January 19, 1978

from: Rio de Janeiro, Brazil

Arrival: February 15, 1978

at: Buenos Aires, Argentina

Days at Sea: ~~28~~ 27

Days Foreign Port: 4
No. days in arrival port

Area of Operation: Western flank of Mid-Atlantic Ridge near 16°S and 17°W

Program Description: Detailed heat-flow measurements in half degree square, basement and sediment thickness survey and sonobuoy refraction studies.

Participants: (All L-DGO unless otherwise specified)

Ana Maria Dragonović
Jeffrey Hauptman
Daniel Hutchinson
Martin W. Iltzsche
Marcus G. Langseth (Chief Scientist)
David Roach
Wayne Robertson
Ross Tottier
Wm. Van Steveninck

All inquiries regarding cruise should be made to the Chief-scientist.

Shipboard Report; RC 21-05

On this leg of the CONRAD, we left January 19, 1978, made an abbreviated survey in the vicinity of 18°S and 30°W, then proceeded to an area near 16°S and 17°W and carried out a detailed heat-flow survey on the western flank of the Mid-Atlantic Ridge. Fifty one individual heat-flow measurements were made in the survey area and several east-west survey lines were made in an area about 30 miles on a side to establish the basement morphology and sedimentary distribution of the area. We returned to port in Buenos Aires, Argentina on February 15, 1978

Background and Objectives:

The principal objective of this leg was to continue investigations of the extent and nature of thermal convection of water in the oceanic crust. The technique used for these investigations is the measurement of heat flow and temperature profiles in the sediment overlying the crust. Water convection in the crust will lead to variations in temperature at the base of the sediment, at the same scale as the convection, which will lead to variations in heat flow through the sediment. Past heat-flow investigations have shown that in areas where the oceanic crust is not completely covered with sediment, i. e. there are frequent exposures of crustal rocks on the seafloor, oceanic bottom water will circulate directly into the crust. This so called 'open' circulation carries significant amounts of heat from the crust into the bottom water, and consequently, only a fraction of the heat will flow through the sediment. In these areas of incomplete sedimentary cover, lower than theoretically expected heat-flow is frequently observed within the pockets of sediment. These results indicate that the circulation of seawater is sufficiently vigorous to maintain the upper crustal rocks at lower temperatures than would be attained if heat flowed conductively from the mantle to the deep oceanic water. The average of many values taken in regions where 'open' circulation occurs is less than the heat flow predicted by lithospheric evolution models.

In areas where the sedimentary cover is relatively thick (300 m or more) and completely covers the basement, thermally induced convection may continue, but it is likely that it will be confined to the crust. In such areas, the lateral variations of temperature at the base of the crust will be less and more subtle variations in heat flow between the upwelling limb and the down-going limb will be detectable. For such 'closed' convection in the crust, the average of many heat-flow values over a sufficiently large area should be equal to that theoretically expected. Recently, evidence for this type of 'closed' circulation has been found by closely spaced stations along lines in the Indian Ocean.

There is evidence that in some ridge flank areas, where the sedimentary cover is relatively thin, water circulation may continue through the sediment if its permeability is high enough. At present, the main evidence we have that water is moving through the deep oceanic sediments at rates large enough to affect the thermal structure, is the frequent occurrence of conductive heat-flow that varies significantly with depth in the sediment. The temperature profiles at such sites have gradients that either increase or decrease exponentially with depth. Such temperature profiles could be explained if the vertical flux of water through the sediment is on the order of 10^{-6} to 10^{-5} cm/sec. The existence of this type of circulation would have important implications for chemical exchange between seawater, seafloor sediment and oceanic crust.

Cruise Leg Plan and Results:

For RC 21-05, we planned studies in three types of sedimentary environments in the Brazil Basin and on the western flank of the Mid-Atlantic Ridge, between latitudes 15° and 20°S. Near the continental margin, there are thick deposits of hemipelagic sediments, but these deposits thin eastward. At the distal end of this sedimentary wedge, the seismic reflection profiles show the sediment to be extraordinarily free of internal reflectors or scatterers. At longitude 30°W, oceanic basement highs pierce through the sedimentary blanket and, less than one hundred miles further east, the sedimentary cover becomes very thin, being largely confined to depressions in the basement rock. In this area, the Brazil Basin reaches its greatest depth. Farther eastward, the seafloor rises slowly to form the flank of the Mid-Atlantic Ridge. The zone where the basement first becomes exposed (the so-called 'transition zone') was the first target we planned to study; 1) by making detailed surveys of heat flow in an area where the basement was completely covered; and, 2) in an area where basement exposures were frequent. A few scattered values of heat flow from earlier cruises indicated that heat flow in the first type of area was essentially that theoretically predicted, whereas in the areas of partial sedimentary cover the heat flow was about half the expected value.

The third area we planned to study, time permitting, was on the flank of the Mid-Atlantic Ridge, where the seafloor lies above the $CaCo_3$ compensation depth. This area was crossed by a CONRAD 16 track and showed the basement to be relatively smooth and the sedimentary cover uniformly thick (about 150m) and pervasive. Here we could study the possibility of convection in a relatively young part of the ridge basement (19-20 m.y.b.p.) covered by a nearly complete lid of sediment and, since this sediment is entirely comprized of foraminifera, it may have a relatively high hydraulic permeability. To visit this area would require a 700 mile excursion to the east.

After a four day steam from Rio de Janeiro, during which we took a core to test the winch and coring equipment, and made a lowering to test the pressure cases of the heat-flow recording instruments, we began work in the transition zone at about 18°25'S and 29°30'W. Two 100-mile tracks were made twelve miles south and twelve miles north of the CONRAD 16 track to define the sedimentary distribution in the transition zone. We then began our first line of heat-flow , station DHFU # 1, in the area west of the transition boundary where the sedimentary cover is thick and complete.

After making three measurements, all of which showed extremely uniform heat flow, the core winch broke with nearly 2800 fm of wire over the side. As best we could determine, the planetary gear train was shattered and the winch drum could not be rotated more than an eighth of a turn in either direction with full torque applied. The performance of the winch did not improve after taking all the tension off of the wire. The winch was irreparably lost. To retrieve the cable and equipment over the side, an end of the wire was led forward and hauled in through the bull nose using the gypsy head on the anchor windlass.

The only realistic alternative for us to continue the program was to use the hydrowinch, requiring the fabrication of a completely new probe and instrument package light enough to be used on the thin hydrowire. Such an instrument was designed and built in three days from stock aboard the ship. We decided to abandon the plans in the transition zone because of the great water depth (about 2800-3000 fms) and move to the shallower younger site on the ridge flank where the water depth is only 2000 fms. The transit to the new site (at about 16°S and 17°W) was made while the new equipment was being fabricated. Before leaving the old site, we thoroughly checked the hydro-winch's performance because it had sat idle for nearly a year. We ran two sonobuoys in the area where the heat-flow measurements had been made.

Over the ridge's flank we surveyed the sedimentary cover in a region about thirty miles on a side, Figure 1. Generally, the basement was remarkably smooth for Mid-Atlantic Ridge crust of this age. On the west, the area is bounded by a relatively deep trough (400 m) trending north-south, see Figure 2. The seafloor east of this trough is smooth at a depth of about 3800 meters and covered by sediments varying between 150 and 200 m thick. We conducted our heat-flow survey in this area.

Between January 29th and February 5th, we made 51 individual heat-flow measurements at seven stations. Most of the measurements were made along a line trending 070 (line A-A' in Figure 3), or roughly perpendicular to the ridge's axis. Two other lines were run orthogonally to the main line (lines B-B' and C-C').

The new digital heat-flow unit (DHFU) worked perfectly. No measurement attempt was lost due to instrument malfunction. The temperatures measured by the probe are transmitted to and recorded on the 12 kHz PDR. Therefore, the measurements can be monitored while they are in progress. Because of the lighter instrument, we were limited to two meters maximum penetration with four sediment probes.

A large proportion of the measurements gave gradients below 0.8°C/10 m, which are significantly below the expected gradient over oceanic crust about 20 m.y. Only in a few locations were high gradients observed, see Figure 3. The gradients cited here are determined from the temperature difference between the uppermost and lowermost probe. If heat flows only by conduction through the sediment, these results would indicate that all of the excess heat is escaping through very localized regions.

However, many of the temperature profiles show a systematic decrease of gradient with depth. In some regions, the decrease is by a factor of 2, which could not be explained by conductivity changes with depth. It seems likely that these profiles result from the vertical flux of water through the sediment. Based on a model of the phenomenon, which assumes uniform vertical flux of water through the sediment, the temperature profiles can be analyzed to yield the flux rate. For water flux to produce detectable variations in gradient in the upper two meters, values on the order of $5 \times 10^{-6} - 5 \times 10^{-5}$ cm/sec are required. A few profiles analyzed by this model give water fluxes on this order. This amount of water flow through the sediment would carry significant amounts of heat. Two analyzed measurements give values greater than 200 MW/m^2. Thus, if vertical water flux is assumed and accounted for, the heat flow in the region is much closer to that expected from theory. The results of this preliminary analysis indicate that the flow of water through sediments is an important phenomenon over young ridge flanks.

Eight sonobuoy refraction measurements were made in the area with generally good results. At many stations, the uppermost refractor had an anomalously low velocity for crustal rock (3.5 to 4 km/sec) suggesting that the upper layers of the crust are rather porous. Deeper refractors yielded velocities typical for Layer 2 and Layer 3. Some of the profiles yield strong critical mantle reflections.

In summary, our survey indicates that:

1) Thermally driven circulation of water through the crust is vigorous over this portion of the ridge's flank and is the predominant mode of heat transfer.
2) Heat transport by the flow of water through the sediments is important and, in this area, is a widespread phenomenon.
3) Refraction studies show an anomalously low velocity layer of oceanic crust underlying the sediments of this area.

Marcus G. Langseth

MGL:at

enclosures (3)

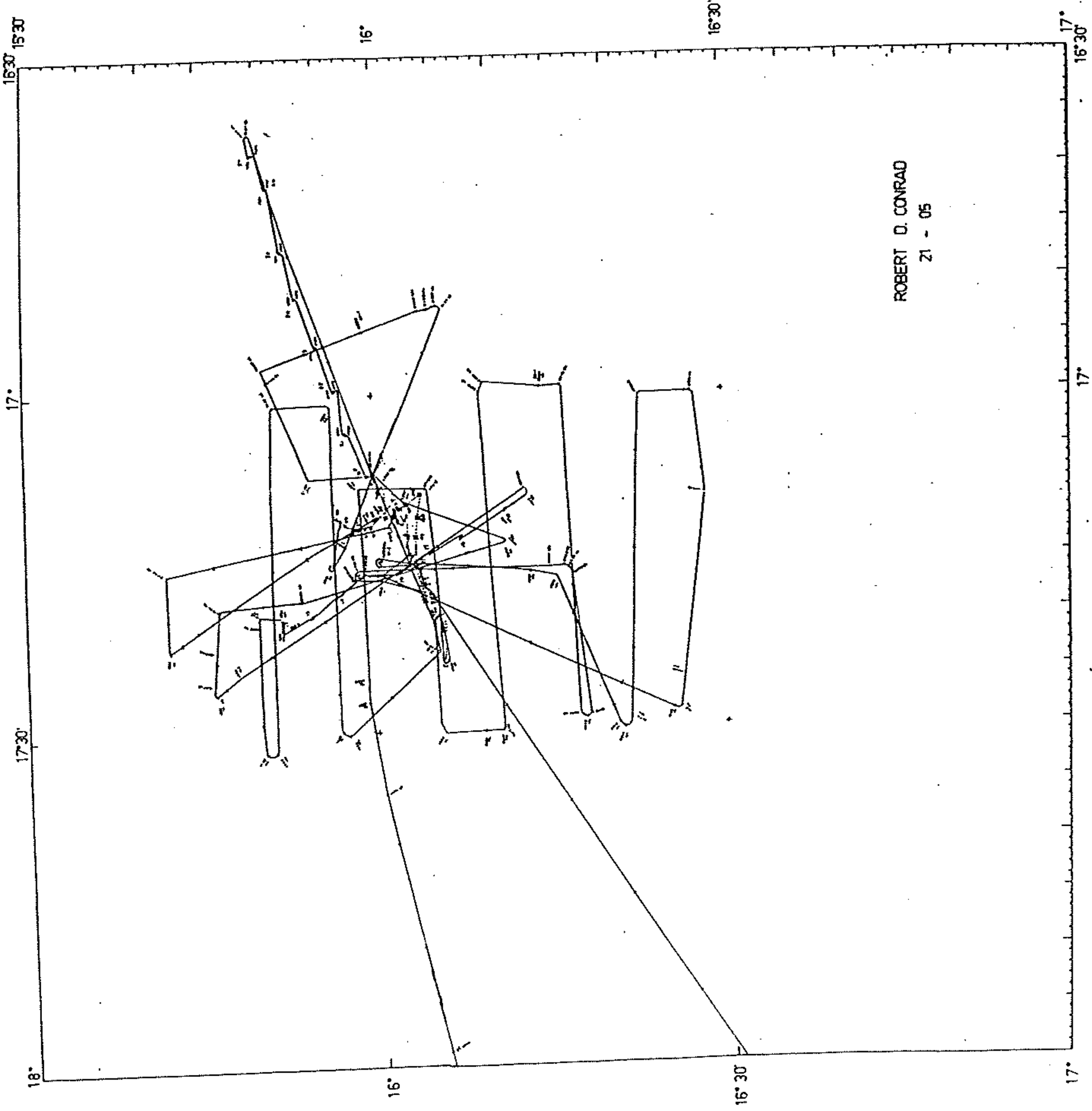


Figure 1

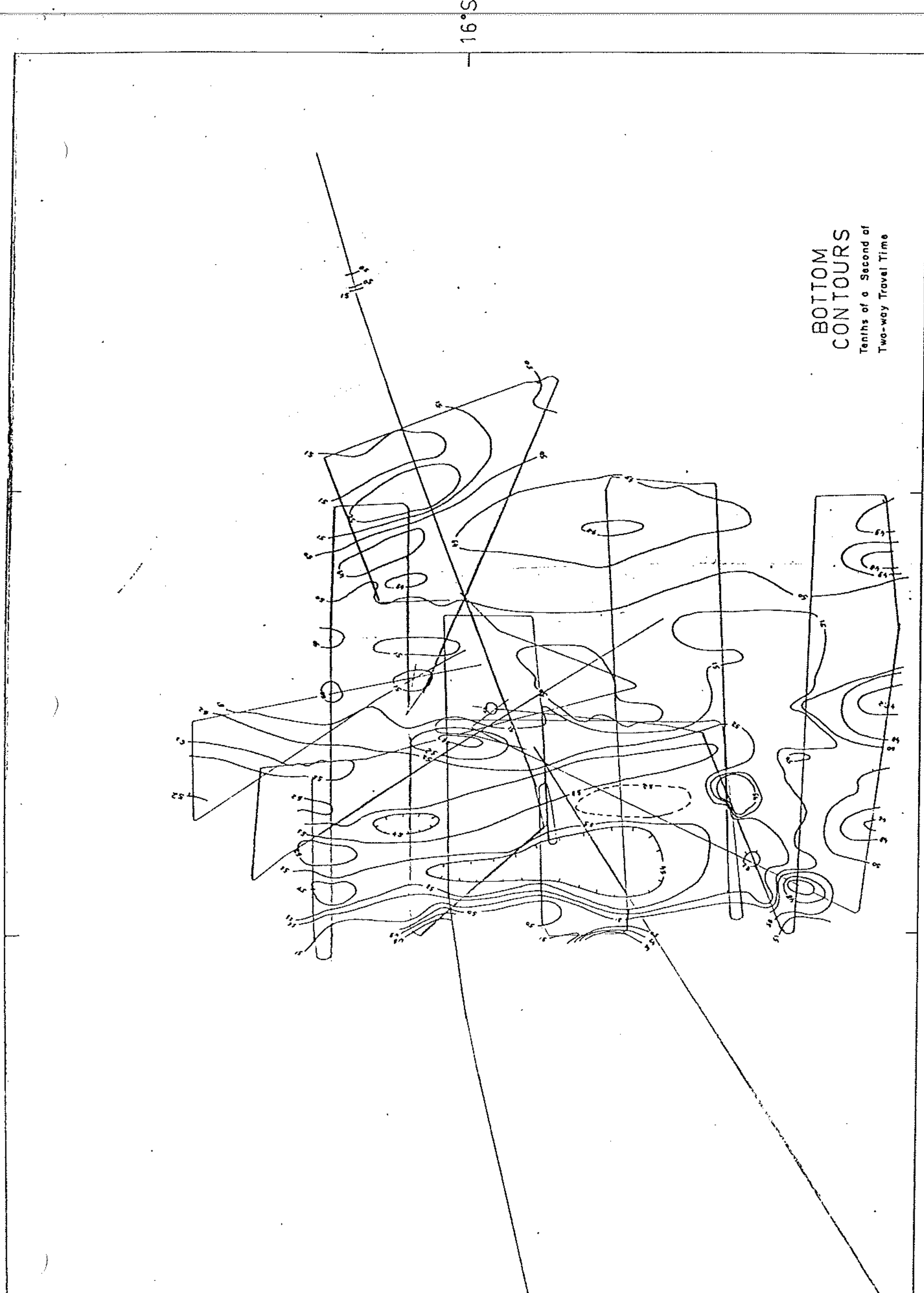
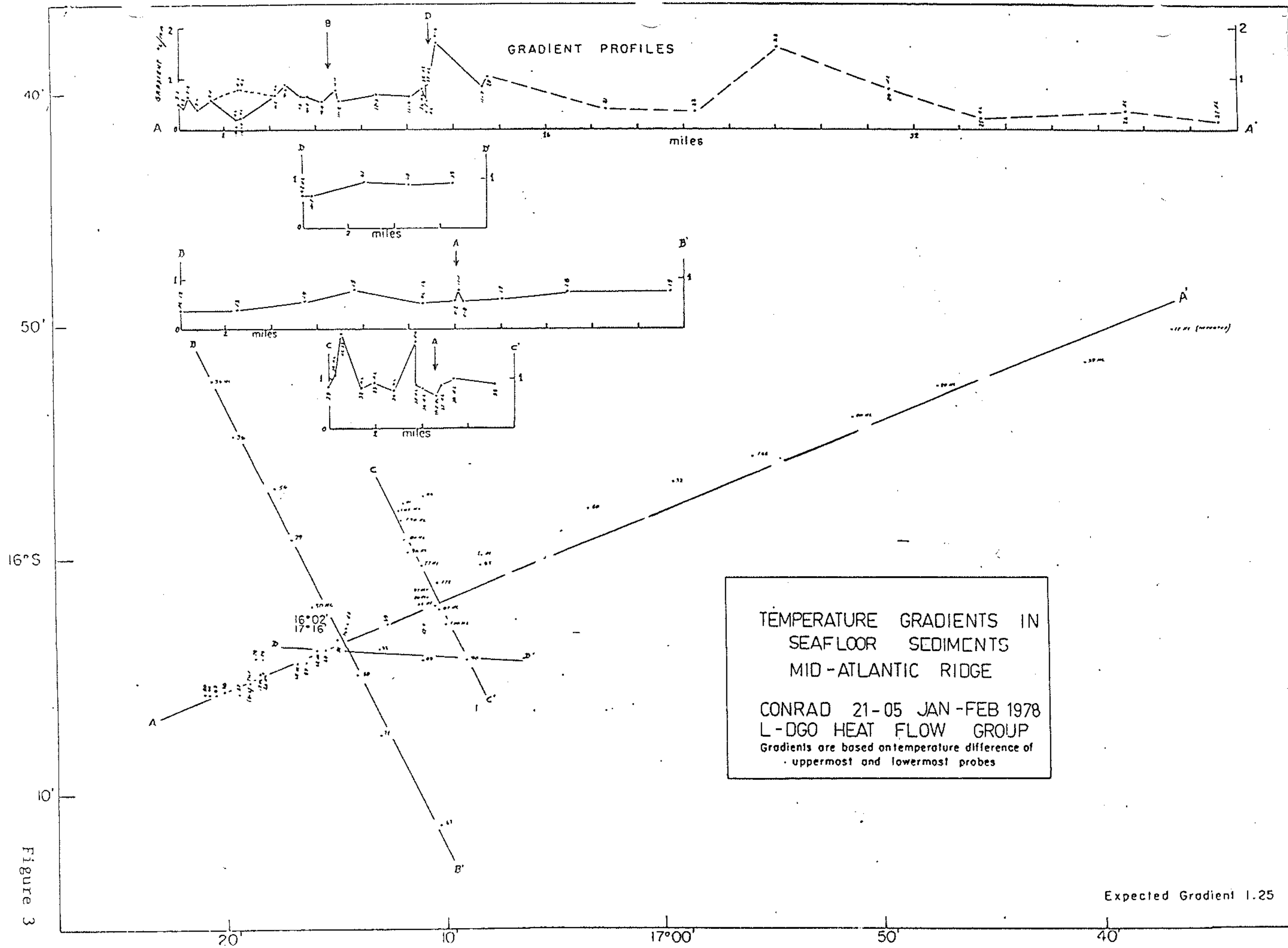

16°S
BOTTOM
CONTOURS
Tenths of a Second of
Two-way Travel Time

Figure 2



GRADIENT PROFILES
miles
TEMPERATURE GRADIENTS IN SEAFLOOR SEDIMENTS MID-ATLANTIC RIDGE
CONRAD 21-05 JAN-FEB 1978
L-DGO HEAT FLOW GROUP
Gradients are based on temperature difference of uppermost and lowermost probes
Expected Gradient 1.25
16°02'
17°16'
40'
50'
16°S
10'
20'
10'
17°00'
50'
40'

Figure 3