TR-089

UNIVERSITY OF RHODE ISLAND • KINGSTON, RHODE ISLAND 02881

Narragansett Marine Laboratory *Graduate School of Oceanography*

J-G / (KRAUSE)

CRUISE REPORT - R/V TRIDENT

CRUISE TR-89 (TERCEIRA II)

5-25 October 1970

AZORES ISLANDS

ASAF ASHRAF

Core Laboratory
Graduate School of Oceanography
University of Rhode Island

C J-G / (KRAUSE)

SCHEDULE

A 21-day (20 days at sea) cruise was made in the Azores Islands region, North Atlantic during 5-25 October 1970. Investigations were carried on concerning bathymetry, magnetometry, seismic profiling, heat flow, rock dredging and sediment coring. In addition, geophysical data were collected in the region on cruise TR-88 into the Azores and magnetic data were collected (27 October - 4 November 1970) on the return from the Azores.

Leg I mainly devoted to rock sampling

3 October 1970. Arrive Ponta Delgada, San Miguel Island from Naples, Italy.

5 October 1970. Depart Ponta Delgada.

10 October 1970. Arrive Horta, Faial Island, for repairs.

11 October 1970. Depart Horta.

12 October 1970. Return to Horta for repairs.

12-14 October 1970. In port, Horta.

Leg II devoted to surveying and sampling

14 October 1970. Depart Horta.

25 October 1970. Arrive Ponta Delgada.

27 October 1970. Depart Ponta Delgada for Narragansett.

SCIENTIFIC PARTY

Dr. Jean-Guy Schilling, URI, chief scientist, Leg 1 (Leg I)
Dr. Dale C. Krause, URI, chief scientist, Leg II (Legs I, II)
Dr. Yoshio Oji, URI and Fukuoka University, Japan, petrologist (Legs I, II)
Bonnie A. McGregor, URI, research assistant (Legs I, II)
Thomas Johnston, URI, graduate student (Legs I, II)
Philip P. Bedard, URI, electronics engineer (Legs I, II)
Frank Rose, URI, marine technician (Legs I, II)
M. Dolores Martinez Tapia, University of Madrid, graduate student (Leg I)
Elaine Papworth, MIT, graduate student, heat flow (Legs I, II)
Robert Stevens, MIT, engineer, heat flow (Leg I)

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SHIP'S COMPANY

Barnes Collinson, master
C.A. Sawyer, chief mate
David LaCasse, second officer
Kyle Birk, radio officer
Henry Martin, bos'n
Pete Russell, AB seaman
Robert Jenkins, AB seaman
Robert Rakestraw , AB seaman
Oscar Ammons, ordinary seaman
Brad McGuire, ordinary seaman
Pat Neves, steward
David Bennett, second cook
J.P. Symonds, chief engineer
Elliot Fowler, first engineer
Joe Campagna, second engineer
Allen Stopyra, oiler
Joe Moscatelli, oiler
Hugh Hoxey, oiler
Harry Rougas, electrician

OPERATIONS

Cruise TR-89 is the second of a two-cruise investigation into the tectonic and geochemical development of the Azores region, North Atlantic. The first half of the investigation was undertaken on cruise TR-86 during 23 July - 4 August 1970. These cruises are designed in part (1) to test and extend the tectonic model of the Azores region presented by D.C. Krause and N.D. Watkins, (2) to apply the earlier Reykjanes Ridge investigations of J-G. Schilling and D.C. Krause to a more complex rifting environment and (3) to investigate more general crustal evolution. Preliminary work in the Azores has been carried out on TRIDENT cruises TR-21 (1964) and TR-28 (1965). Details of cruises TR-21, TR-28 and TR-86 are given in their respective cruise reports.

The Azorean development was investigated on both cruise TR-86 and TR-89 by using geophysical methods and by collecting rock samples for petrologic and geochemical studies. The collection of the rock samples was controlled by the geophysical data acquired either immediately before or on earlier cruises. In addition, the geophysical data was collected whenever the sampling program permitted. The emphasis during Leg I was on sampling and comparatively minor geophysical work was accomplished. The emphasis during Leg II was on geophysical surveying but sampling was continued in part due to loss of nearly fifty percent of shiptime on Leg I because of engine repairs and wire winding (see Table 1).

A satellite navigator has been installed starting with cruise TR-87. It is a really fine addition allowing a significant improvement in scientific programs.

Geophysics. The geophysical operations included (see cruise track for location of data):

1. Echo-sounding using an Alpine PESR recorder with an EDO echo sounder. The echo sounder was run at all times.

2. Magnetometry using a modified Varian station magnetometer.

3. Seismic profiling using a Bolt Assoc. 10-cu. in. air gun, a WHOI-type 200-element hydrophone, standard electronics and a

Raytheon PFR recorder. Profiler system problems at times limited full use of the profiler. Where weather permitted, the profiler was towed at 9-10 knots.

4. Heat flow. This was a Massachusetts Institute of Technology program of Elaine Papworth and Robert Stevens using a corer with five elements. Five stations yielded usable sediment heat flow data after certain technical problems were corrected. All of the stations will be analysed for water temperature changes.

Sampling. Thirty-three sampling stations were made which included 16 rock dredging stations, 13 heat flow stations with sediment core, 3 gravity coring stations and one hydrographic station. Not all of the stations yielded results due to technical or environmental causes; in such cases, however, the bottom character of several sites could be estimated by the behavior of the rock dredge even though no sample was recovered.

Twelve rock dredge stations yielded bottom samples of which three contained fresh glassy basalts, 6 contained altered and metamorphosed basalt, 7 contained indurated calcareous ooze and 2 still contained soft calcareous ooze.

Twleve heat flow and gravity coring stations yielded sediment cores of calcareous ooze, silt and volcanic ash. Two stations yielded fresh basaltic glass (station 11GC and 23H).

Two samples of soft calcareous ooze were collected and frozen for Dr. Leonard Worthen of URI's Department of Pharmacognosy (station 2D and 31D).

The lone hydrographic sample (station 3HY) was taken to determine the bottom temperature (and hence also approximate sill depth) of the deep basin between Terceira and San Miguel. The bottom temperature (at 3000 meters) was 4.6° C. The sill depth is approximately 1600 meters depth. The sample was given to Dr. D. Kester for analysis.

Malfunctions of the tensionmeter for the dredging winch caused problems, such as unnecessary loss of rock dredges (3). All dredges were fixed with a primary weak link set for 10,500 pounds of tension and a secondary weak link on the safety cable set for 12,500 pounds. A pinger was used on station 12D, mounted 300 meters ahead of the dredge.

CRUISE SUMMARY (Leg I)

On 5 October 1970, at 1130, we left Ponta Delgada, San Miguel Island. A new 3 x 19 ½ inch dredging wire rope was spooled in Naples, Italy. The first 16 hours of this leg were spent paying out most of the wire rope and retrieving it in order that it be tight on the drum.

The first sampling operations were carried out on the north wall of the deep trough (rift) between San Miguel and Terceira at sites which had been crossed on cruise TR-86. The general dredging strategy on both cruises TR-86 and TR-89 was to select the site on the basis of geophysical data, then to sample at several different horizons up the given escarpment. The dredges yielded (station 1D, 2D and 6D) altered and metamorphosed basalt with columnar jointing and/or indurated ooze. Several heat flow stations were attempted but corer problems existed.

On 8 October, operations were moved to the Terceira-Graciosa trough (rift), the transit track being used to test TR-86 data. Two zones were investigated in the basin; 1) the southern wall of the trough and (2) a central zone of probable modern volcanic activity. Dredge hauls from the south wall (station 13D, 14D) yielded lithified calcareous ooze (weather grew increasingly stormy during these stations). A core (11GC) in the central zone yielded 20 cm of silty ash and ooze over fresh fragments of glassy basalt. Dredge 12D did not penetrate the mud far enough to sample the basalt. Another operation at this central zone concerned the reported site of a submarine volcanic eruption in June 1867. The site was surveyed by us but as a gravity core (17GC yielded only volcanic silt and as a storm was blowing, a dredge station was not attempted.

We then started to move operations to the control rift of the Mid-Atlantic Ridge but had to put into Horta, Faial Island, for repairs to the electrical generator. We attempted another try at the Rift in the morning but again had to return the following day to Horta for repairs to the generator which could not be carried out in the stormy seas prevailing during this time. However, important seismic and magnetic data was collected on these tracks. The return to Horta at 1400, 12 October, marked the premature end of Leg I. Departing here were J-G. Schilling, M.D. Martinez Tapia and R. Stevens (with a crushed thumb).

Leg II. On 14 October at 1230 we departed Horta, weather good. Sampling operations began on the southeast margin of the outer zone of the Mid-Atlantic rift (Princess Alice Bank). Station 18D yielded altered basalt. Heat flow station 20H was made nearby in the flat trough at the foot of the escarpment and showed a low heat flow.

Sampling operations were then moved (15 October) to the axis of the Mid-Atlantic Rift. The central rift here is floored by a more or less level lava flow near 2900 meters depth. Samples 21D and 23H brought up fragments of fresh basalt glass from this flow. This deep is the deepest portion of the rift in this region (nearly 2900 m deep). The flat floor was originally thought to be flat due to local turbidites but a heat probe attempt dispelled this notion. However, the attempt did allow criteria to be set for recognizing other fresh flows in the Azores region on the basis of echo sounding and seismic profiling data, especially in terms of the character of the echo sounding record. A deep hydrographic station in this deep on 8 November 1965 (TRIDENT cruise TR-28) showed the basin to be well flushed with a sill depth near 2000 meters.

Samples from the flanks of the rift yielded altered basalt and/or lithified calcareous ooze (station 21D,22D,24D,25D). Wind began to rise during the last station (15 October) and soon grew into a gale which lasted until the evening of 18 October.

The original cruise plan had called now for a survey of the junction of the Mid-Atlantic Rift and the East Azores Fracture zone. The unexplored and uncertain nature of the junction of the Mid-Atlantic Rift and the Terceira Rift required that this instead be given priority, and hence the survey was carried out here after the completion of station 25D. During the gale, the survey was run under reduced speed. Profiler, magnetometer and satellite navigator malfunctions occurred but all of the systems were repaired in due course.

The survey was broken at the 2/3 point to make a series of heat flow stations (26H-29H) across the Terceira Rift. At the 3/4 point, dredge hauls were made in the central Mid-Atlantic Rift. Dredge 30D brought up 150 kg of fresh basalt (glass, pahoehoe and pillow). Dredge 31D brought up a breccia of vesicular basalt and calcareous ooze from the large scarp on the rift's east flank near a basement age of approximately 0.1 million years.

After completion of the survey (23 October), a track was made across the southern portion of the Azores Plateau, thence to the site of the 1800 submarine eruption south of Terceira for an attempted dredge haul and thence to Ponta Delgada where we docked at 1500, 25 October 1970.

On the Ponta Delgada - Narragansett return leg, magnetic data was collected from 0915, 28 October (departure) to 1610, 4 November (see index chart).

RESULTS

The as-yet unanalysed mass of data from cruises TR-86 and TR-89 make conclusions premature. However, the following preliminary conclusions seem tenable:

1. The Krause-Watkins model is valid to the first order for the last 13 million years.

2. The Terceira rift has a complex history in detail with perhaps three active volcanic lines in the west tapering to one at San Miguel.

3. All the measured heat flows were low due to low tectonic heat flow and/or recent warming changes of the water mass.

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TABLE 1. SAMPLING STATIONS

Station No.	Type	Provisional Position Latitude	Longitude	Date 1970	Time on bottom	Depth m	Chief Operator	Results
1D	Dredge	38°09.4'N	26°16.3'W	6 Oct.	1600-1830	2300-3000	Schilling	350 kg blocky altered basalt and 15 kg indurated calcareous ooze. North wall of Terceira San Miguel Trough
2D	Dredge	38°09.6'	26°16.2'	6 Oct.	2203-2335	2100-2600	Krause	20 kg of altered basalt and indurated and soft calcareous ooze/gastropod shell. North wall of Terceira-San Miguel Trough above dredge D-1
3HY	Hydro cast	38°05'	26°19'	7 Oct.	0200	3000	Rose	Water sample collected to determine bottom temperature (4.60°C). Sample preserved for Dr. Kester. Sea floor at 3080 m. In Terceira-San Miguel Trough
4H(b)	Heat flow	38°05'	26°19'	7 Oct.	0735	2675	Papworth	45 50 cm core of blue-grey calcareous ooze. Second attempt. In Terceira-San Miguel Trough
5D	Dredge	38°13'	26°14'	7 Oct.	1030-1115	1100	Schilling	Lost dredge - rough bottom. North margin of Terceira-San Miguel Trough
6D	Dredge	38°12.3'	26°26.1'	7 Oct.	1348-1620	1000-1225	Schilling	300 kg indurated calcareous ooze, ½ kg deep-sea corals. North margin of Terceira-San Miguel Trough
7H	Heat flow	38°20'	26°14'	7 Oct.	2113-2236	1550	Papworth	No penetration - two attempts North of Terceira-San Miguel Trough

TABLE 1. (continued)

Station No.	Type	Provisional Position Latitude	Longitude	Date 1970	Time on bottom	Depth m	Chief Operator	Results
8H	Heat flow	38°06'N	26°19'W	8 Oct.	-	3075	Papworth	No sample - some gear lost. In Terceira-San Miguel Trough
9H	Heat flow	37°59'	26°22'	8 Oct.	0628	2640	Papworth	No penetration. In Terceira-San Miguel Trough
10GC	Gravity core	38°49.5'	27°39'	8 Oct.	1753	2370	Krause	5 cm of silty ash and calcareous ooze. In Terceira-Graciosa Trough
11GC	Gravity core	38°50.3'	27°39.2'	8 Oct.	1850	2295	Krause	20 cm of volcanic glass and silty ash and calcareous ooze. In Terceira-Graciosa Trough
12D	Dredge	38°49.5'	27°38.6'	8 Oct.	2050-2154	2200	Krause	No sample - mud bottom. In Terceira-Graciosa Trough
13D	Dredge	38°41.4'	27°33.2'	9 Oct.	0430-0540	1375-1400	Johnston	100 kg indurated calcareous ooze and 2 kg deep-sea corals South wall of Terceira-Graciosa Trough
14D	Dredge	38°46.0'	27°37.5'	9 Oct.	1115-1415	1500	Schilling	50 kg indurated calcareous ooze and manganese coated breccia. South wall of Terceira-Graciosa Trough
15H	Heat flow	38°40.6'	27°39.4'	9 Oct.	1645	1285	Papworth	(30) 45 cm core of grey calcareous ooze. South of Terceira-Graciosa Trough
16H	Heat flow	38°41.6'	27°40'	9 Oct.	1835	1240	Papworth	(35) 40 cm core of grey calcareous ooze. South of Terceira-Graciosa Trough

TABLE 1. (continued)

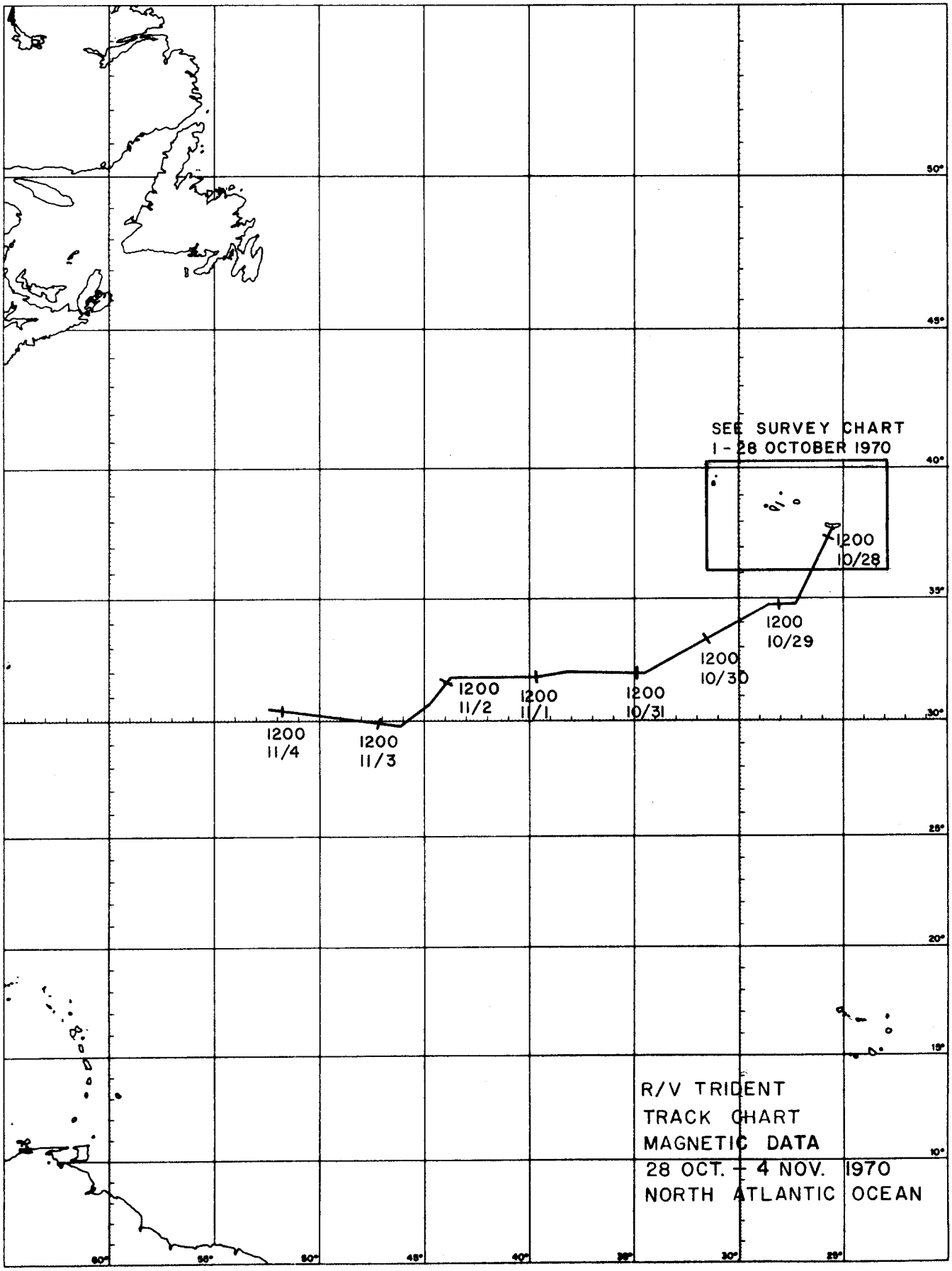
Station No.	Type	Provisional Position Latitude	Longitude	Date 1970	Time on bottom	Depth m	Chief Operator	Results
17GC	Gravity core	38°52.1'	27°31.1'	10 Oct.	0413	1675	Johnston	150 cm core of calcareous volcanic silt. From probable site of June 1867 submarine volcanic eruption in Terceira-Graciosa Trough
18D	Dredge	38°01.0'	29°31.2'	14 Oct.	2130-2215 2300-2345	2000-2100	Johnston	1 kg altered basalt pebbles and cobble. NW face of Princess Alice Bank
19D	Dredge	37°58'	29°29'	15 Oct.	0135-0205	1020	Johnston	Lost dredge - rough bottom. NW face of Princess Alice Bank
20H	Heat flow	38°02.1'	29°57.5'	15 Oct.	0728	1900	Papworth	core 89 cm/of grey calcareous ooze. Trough east of Mid-Atlantic Rift
21D	Dredge	38°26.0	30°21.4'	15 Oct.	1415-1510	2700-2850	Krause	2 kg volcanic glass and altered basalt, 2 kg blue-grey ooze, 1 kg siliceous sponges. West scarp of Mid-Atlantic Rift
22D	Dredge	38°25.3'	30°27.0'	15 Oct.	1730-1810	1750-1850	Krause	2 kg altered basalt, 2 kg deep-sea corals. West scarp of Mid-Atlantic Rift
23H	Heat flow	38°24.3'	30°22.6'	15 Oct.	2238	2855	Papworth	Fragments of volcanic glass. Center of Mid-Atlantic Rift
24D	Dredge	38°20.3'	30°21.0'	16 Oct.	0155-0350	2050	Johnston	10 kg indurated calcareous ooze, thin Mn-coat. East flank of Mid-Atlantic Rift.

TABLE 1. (continued)

Station No.	Type	Provisional Position Latitude	Longitude	Date 1970	Time on bottom	Depth m	Chief Operator	Results
25D	Dredge	38°15.0'N	30°18.9'W	16 Oct.	0640-0730	900-1050	Johnston	5 kg altered basalt and indurated calcareous ooze. East flank of Mid-Atlantic Rift
26H	Heat flow	39°05.0'	28°54.9'	20 Oct.	0012	1985	Papworth	45 cm core of blue-grey calcareous ooze. West of San Jorge Island
27H	Heat flow	39°20.8'	28°52.0	21 Oct.	0455	2020	Papworth	110 cm core of grey calcareous ooze. NW of San Jorge Island
28H	Heat flow	39°32.7'	28°56.2'	21 Oct.	0756	2030	Papworth	86 cm core of grey calcareous ooze. NW of San Jorge Island
29H	Heat flow	39°01.7'	29°22.2'	21 Oct.	1338	2150	Papworth	60 cm core of grey calcareous ooze. West of San Jorge Island
30D	Dredge	39°37.9'	29°44.4'	22 Oct.	0635-0750	1950-2100	Johnston	150 kg fresh basalt with glass crust, pahoehoe structure and pillow structure. Center of Mid-Atlantic Rift
31D	Dredge	39°37.6'	29°42.3'	22 Oct.	1115-1240	1700-1800	Krause	25 kg altered basalt and soft indurated calcareous ooze. East scarp of Mid-Atlantic Rift.
32H	Heat flow	37°21.3'	28°57.0'	24 Oct.	0059	2151	Papworth	60 cm core of grey calcareous ooze. Azores Plateau south of Faial
33D	Dredge	38°24'	27°18'	25 Oct.	0000-0045	1000	Johnston	Lost dredge - rough bottom. Site of 1800 submarine volcanic eruption south of Terceira

TABLE II. Seismic profiling runs during TR-89

Date (1970)	Time	Distance (km)
9-10 October	2055-0134	15
10 October	0519-1200	96
11-12 October	0835-0206 0335-1157	362
16-17 October	0832-0846	250
17 October	1410-2127	126
18 October	1551-2000	67
19-20 October	1843-2206	436
21-22 October	1451-0731	217
22-24 October	1511-2043 (with short breaks)	675
25 October	0200-0800 0851-1329	167
	Total	2411 km


SEE SURVEY CHART
1 - 28 OCTOBER 1970
1200
10/28
1200
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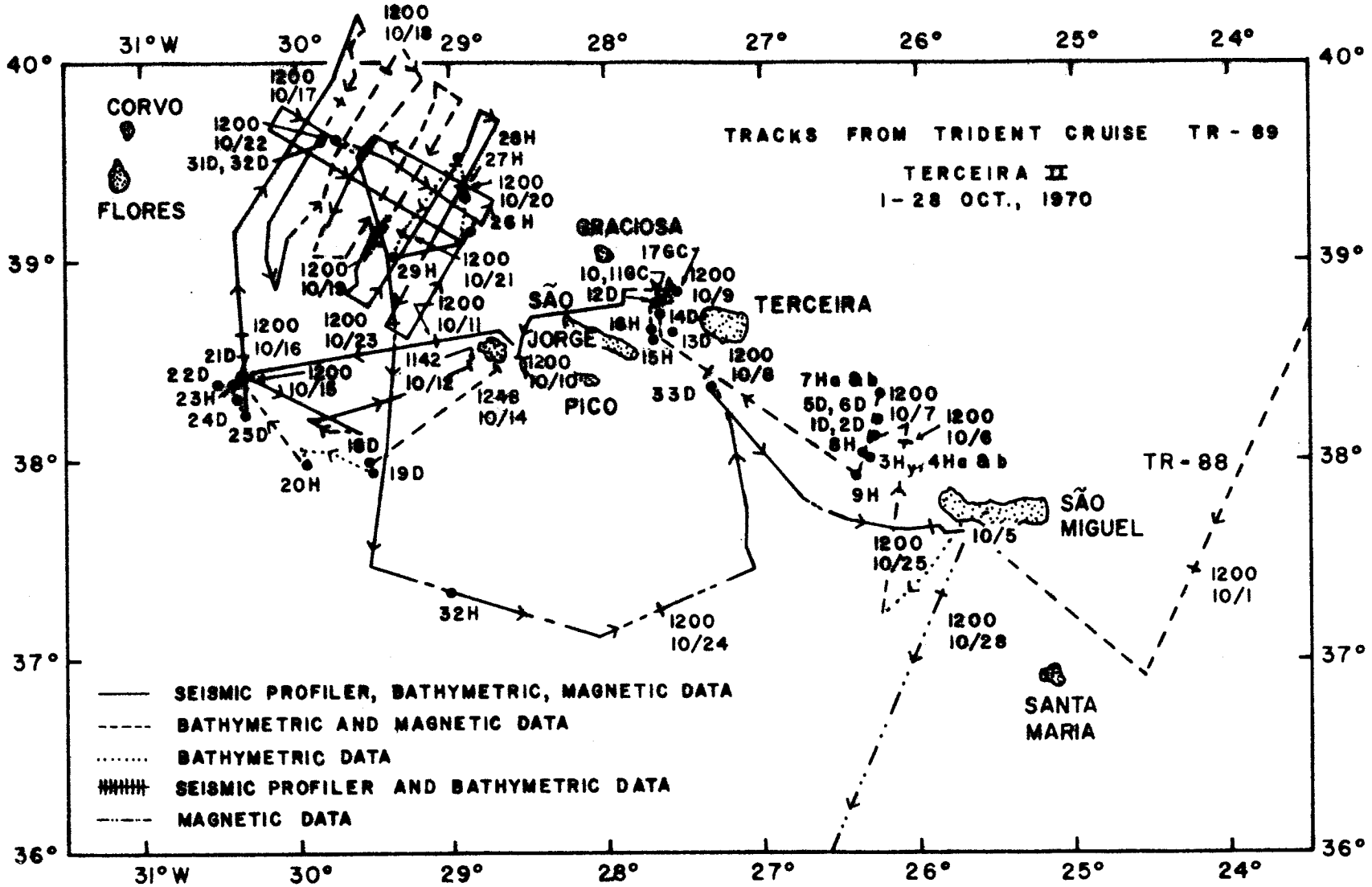
R/V TRIDENT
TRACK CHART
MAGNETIC DATA
28 OCT. - 4 NOV. 1970
NORTH ATLANTIC OCEAN


TRACKS FROM TRIDENT CRUISE TR - 89
TERCEIRA II
1 - 28 OCT., 1970
CORVO
FLORES
GRACIOSA
SÃO JORGE
TERCEIRA
PICO
SÃO MIGUEL
SANTA MARIA
TR - 88
SEISMIC PROFILER, BATHYMETRIC, MAGNETIC DATA
BATHYMETRIC AND MAGNETIC DATA
BATHYMETRIC DATA
SEISMIC PROFILER AND BATHYMETRIC DATA
MAGNETIC DATA
31° W
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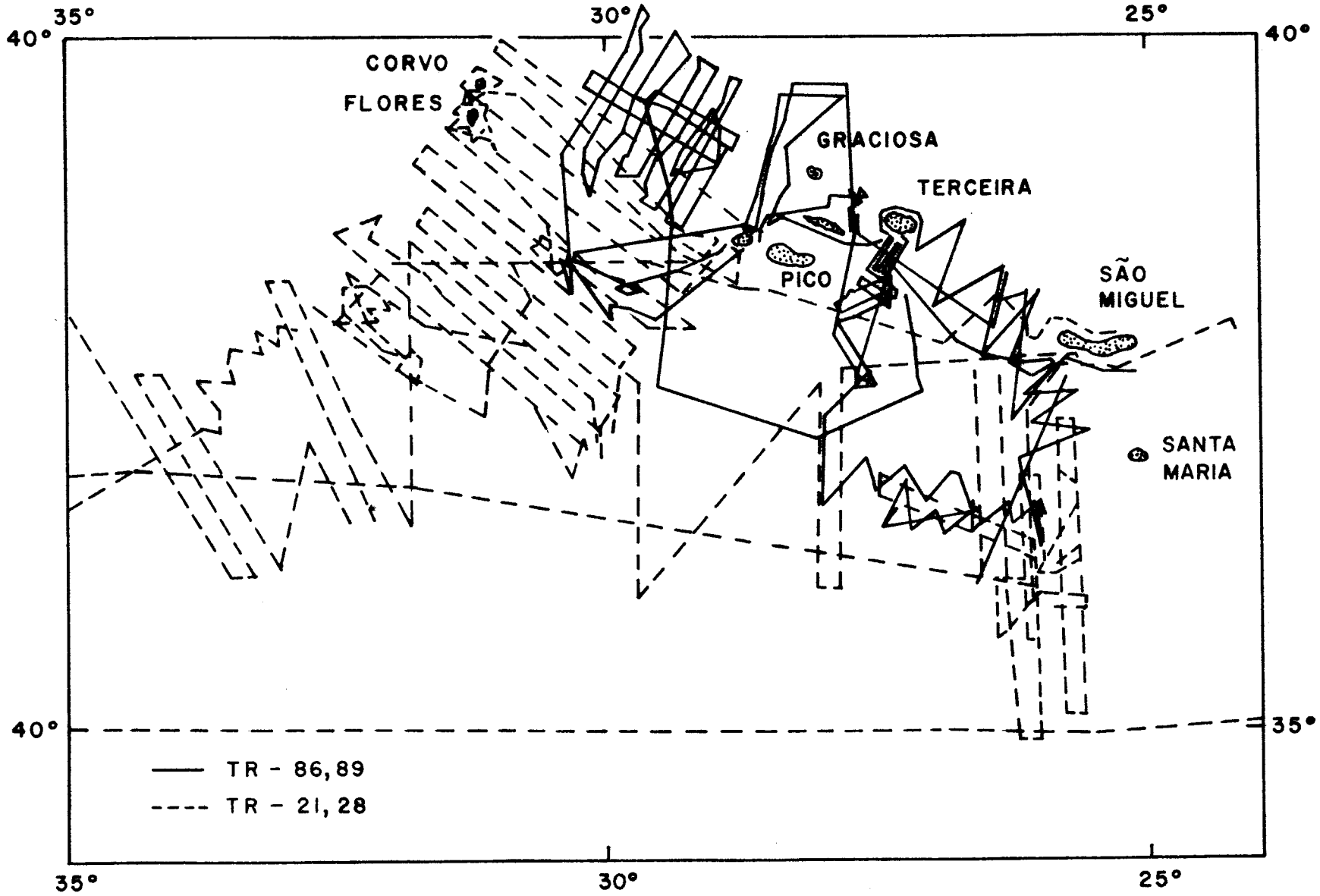

TRIDENT TRACKS IN THE AZORES ISLANDS