U. S. DEPARTMENT OF THE INTERIOR

U. S. Geological Survey

Cruise Report for EEZ-SCAN Cruise F13-90-CP Necker Ridge and Johnston Island

by

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Open-File Report 92-433

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INTRODUCTION

Cruise F13-90-CP was the 14th cruise to collect GLORIA (Geologic Long Range Inclined ASDIC) side-scan sonar images of the Hawaiian Island EEZ (Exclusive Economic Zone) and the first cruise to collect similar data in the Johnston Island EEZ. The M/V Farnella left Honolulu, Hawaii on December 5, 1990 to attempt to complete a geophysical survey of Necker Ridge in the Hawaiian Island EEZ and to start a survey of the Johnston Island EEZ, which is the northernmost of the Line Islands (Fig. 1). A total of 17 tracklines totaling 4275 km of GLORIA data were collected during 10 days of shipboard operations (Fig. 2). Table 1 is a list of the scientific staff on F13-90-CP.

Necker Ridge had been insonified on previous cruises . The northern third of Necker Ridge was first imaged using GLORIA during cruise F10-88-HW. Two tracklines were run along the southeast and northwest flanks of the ridge. However, the shallow depth of the ridge precluded imaging the ridge crest at those trackline locations. The rest of Necker Ridge that is located within the Hawaiian EEZ was surveyed during 3 subsequent cruises: F13-89-HW, F1-90-HW, and F2-90-HW. During these cruises, the tracklines were oriented approximately parallel to the Hawaiian Ridge and intersected Necker Ridge at an angle of about 55°. The angle of incidence of the tracklines coupled with the shallow depth of Necker Ridge, resulted in imaging the ridge as a series of 'doughnut' shapes (see Kayen and others, 1990; Pickthorn and others, 1991). In order to properly image this feature, it was determined to re-survey Necker Ridge prior to the start of the Johnston Island EEZ. We completed one 550 km pass of Necker Ridge along the southeastern flank of the ridge, immediately southeast of the ridge axis. Poor weather prevented collecting data along the northwestern flank of the ridge, which were collected during the next cruise (F1-91-CP).

3720 km of GLORIA data at 30-km line spacing were collected in the Johnston Island EEZ; the entire Johnston Island EEZ was completed during the next two cruises (F1-91-CP and F2-91-CP). Lines of the Johnston Island survey were oriented at an angle of about 110° in accordance with the predominant direction of the swell in the region. Occasionally, severe local weather conditions forced a different track orientation.

Other geophysical data collected included two-channel seismic reflection profiles using a 160 in^3 air-gun, 3.5 kHz high-resolution profiles, 10 kHz echo-sounding profiles, magnetic and gravity potential-field measurements, and upper water column temperature profiles using expendable bathythermographs.

Despite poor weather conditions, the cruise was a scientific success. The prominent features imaged during the cruise include the western flank of Necker Ridge, most of Horizon Guyot, assorted seamounts of the Mid-Pacific Mountains, and some unusual GLORIA images of features that may be manganese nodule fields.

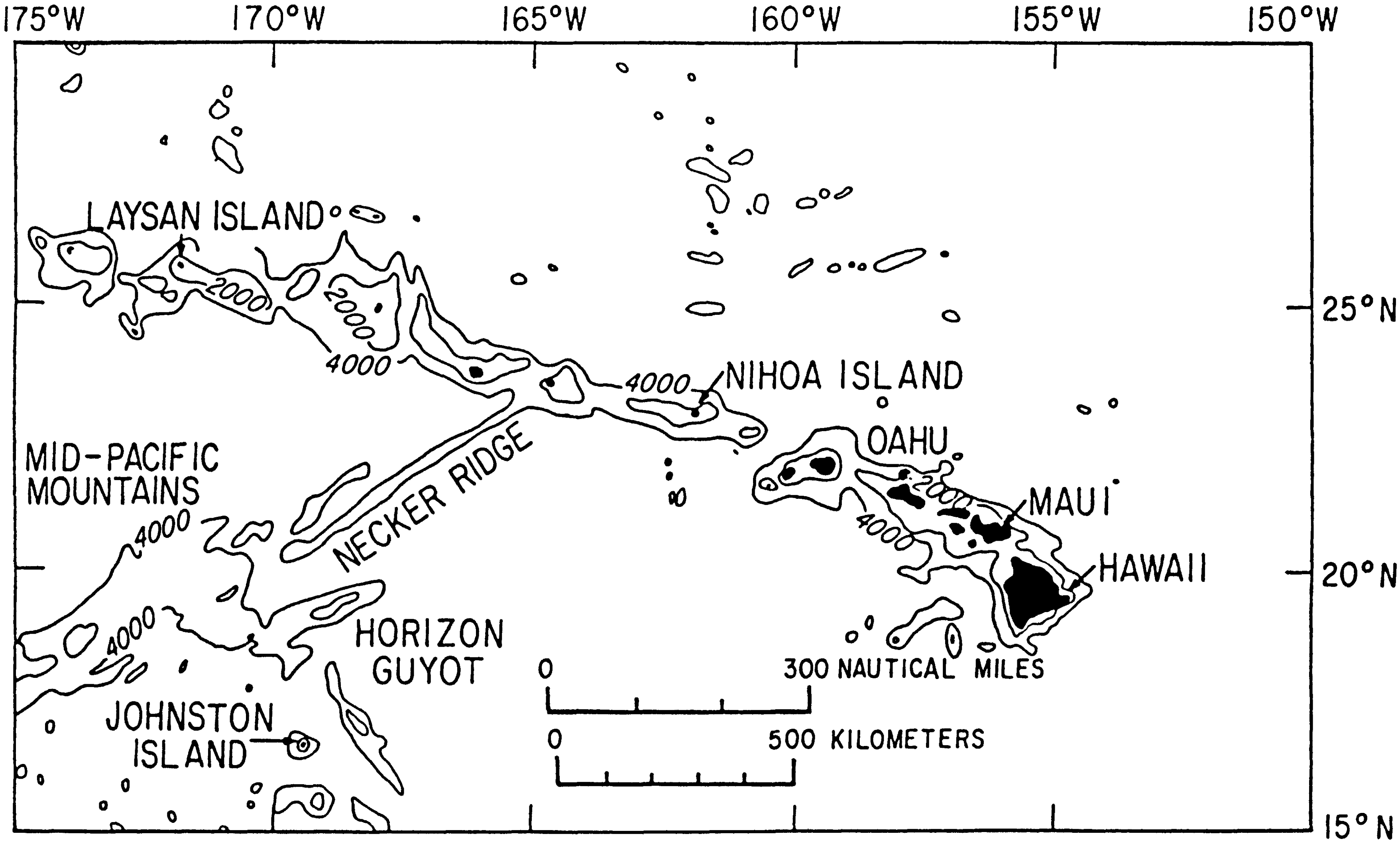

Figure 1 Generalized map of the central Pacific region showing the location of Johnston Island and Necker Ridge with respect to the Hawaiian Island chain. Modified from Schwab, 1986.

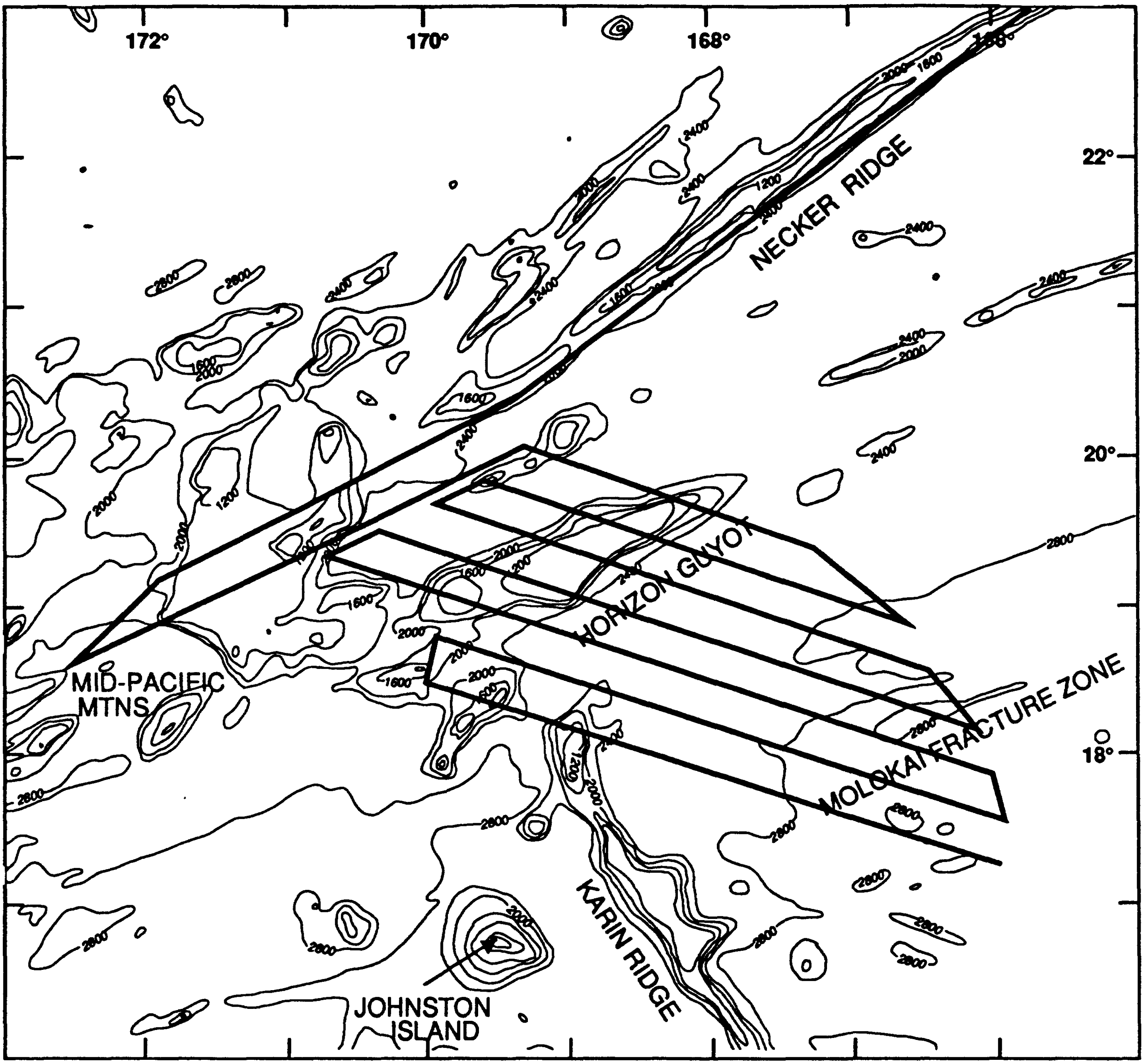

Figure 2 Bathymetric map modified from Chase and others, 1972, showing major sea floor features between Johnston Island and Necker Ridge, and tracklines for F13-90-CP cruise. Bathymetric contours are shown at 400 fathom intervals.

Table 1. List of scientific staff

Holly Ryan (USGS)	Co-chief Scientist
Alice Davis (USGS)	Co-chief Scientist
Quentin Huggett (IOS)	Co-chief Scientist
Derek Bishop (IOS)	Senior GLORIA engineer
Jon Campbell (IOS)	GLORIA engineer
Ed Cooper (RVS)	Software engineer
Kaye Kinoshita (USGS)	Chief navigator
Larry Kooker (USGS)	Electronics technician
James Hamilton Patterson	Writer
Libby Prueher (USGS)	Geologist
Bill Weber (USGS)	Geologist
Ian Westlake (IOS)	Geologist
Steve Whittle (IOS)	Mechanical technician

OPERATIONS

The GLORIA survey was conducted from the R/V Farnella under lease to the U. S. Geological Survey through the Institute for Oceanographic Sciences (IOS) in Wormley, England. The Farnella arrived into Honolulu one day late on December 4, 1990 after completing a test cruise. All data acquisition systems operated without any problems during the test cruise, and continued to do so for the duration of F13-90-CP.

The ship departed Honolulu at JD 340/1925Z (Julian day /Greenwich Meantime, GMT-- local Hawaiian time is 10 hours later). After a 36-hour transit to the northern end of Necker Ridge, all of the equipment except for the two-channel air gun system was deployed at 342/0616 GMT. Since Necker Ridge had already been surveyed with air guns during previous cruises, the air gun system was not used in order to allow the collection of data at a faster ship speed (about 10.5 kts). Approximately 3 hours after the deployment of the gear (at JD 342/0922Z GMT), a power failure occurred in the main laboratory on the ship. All systems were shut down and the ship steamed back to the original way point at the start of the line. Data acquisition recommenced at JD 342/1155Z GMT. The first 2 tracklines covered an approximately 20-km wide swath parallel to and centered approximately 5 km east of the crest of Necker Ridge, starting from the northern edge of the ridge to the 200 nm limit of the Hawaii EEZ, and covered an additional 100 km of the ridge between the Hawaiian and Johnston Island EEZ's.

The ship reached the Johnston Island EEZ at JD 344/1215Z GMT where an attempt was made to change course to a bearing of about 110°, which is the orientation of the predominant swell of the region. However, poor weather did not allow data acquisition along this course and it was decided to continue on a course to the southwest (245°) to collect data in the western perimeter of the EEZ. At this time, the two-channel air gun system was deployed and data were collected at a ship speed of about 8.5 kts. After completing 2 tracklines, spaced 30 km apart along the northwest corner of the EEZ, the weather improved and the trackline orientations were changed to a bearing of about 110° and trackline spacing of 30 km, which continued for the rest of the cruise. A total of 17 lines of geophysical data were collected (Appendix 1).

Data acquisition was terminated and equipment retrieval commenced at JD 353/2330Z GMT. The weather had further deteriorated by this time, and the ship could only make between 8-10 kts on the transit back to Honolulu. We arrived at the dock in Honolulu at JD356/0300Z GMT, approximately 8 hours late.

Equipment Report

Navigation

The navigation system used on the cruise was a combination Global Positioning System (GPS) and real-time, rho-rho Loran positioning system. Navigation problems were minimal since GPS was available 24 hours a day for most of the cruise.

3.5 and 10 kHz Bathymetry

The 3.5-kHz high-resolution profiling system was deployed at JD 342/0527Z GMT. The system performed well throughout the cruise. Data quality was excellent except during times of poor weather and at water depths greater than about 5000 m, when the data were degraded. Most of the 3.5 kHz data collected from about JD 352/2215Z GMT until the end of the cruise are of poor quality as the result of inclement weather. The 10-kHz echo-sounding system was also deployed at JD 342/0527Z GMT Except for minor problems with the paper jamming at the beginning of the cruise, the system worked flawlessly, and down time was restricted to routine maintenance.

Gravity and Magnetics

A LaCoste Romberg S-53 gravimeter was operated during the entire cruise without any problems. A gravity tie was made both at the beginning (at pier 40B in Honolulu), and at the end of the cruise (at pier 40E in Honolulu) in order to apply a drift correction to the data. During the final 2 days of the cruise, 30 kt winds resulted in the collection of poor quality gravity data. The magnetometer was deployed at JD 342/0616Z GMT; there were no problems with the magnetometer during the entire cruise. Both the gravity and magnetic data were recorded on strip-charts and on magnetic tape. The recording system operated without any problems throughout the cruise.

Two-channel seismic reflection system

3820 km of two-fold seismic reflection data were collected during the cruise within the Johnston Island EEZ; no air gun data were collected during the first two days of data acquisition along Necker Ridge. The energy source for the system was a 2600 cm^3 (160 in^3) air gun, which fired every 10 seconds. The data were collected using an 100-m-long streamer (each active section was 50 m long), and recorded on a MASSCOMP computer. Analog data were displayed on a Raytheon line scan recorder (LSR), with a constant orientation (west and north end to the left of the profile). Shot spacing was about 45 m at a speed of about 8.5 knots. A total record length of 6 seconds two-way travel time were collected.

The seismic reflection system performed well during the survey. There was only one unscheduled air-gun swap when the system was down from JD 350/0740Z GMT to JD 350/0835Z GMT to repair the solenoid wires. Gaps in the recording of the data occurred twice: from JD 345/1029Z GMT to JD 345/1042Z GMT when there was a problem with the tape drives, and from JD 348/0946Z GMT to JD 348/1012Z GMT when the MASSCOMP computer crashed. Maximum subsurface penetration with this system was about two seconds two-way travel time over basinal areas.

Expendable Bathythermographs (XBT's)

The XBT probes were deployed daily to measure the temperature and thickness of the surface mixed layer, and the temperature profile of the thermocline. The data were sent to NOAA, and also used to determine the swath width for the GLORIA system, which depends upon the gradient of the thermocline. A total of eleven probes were deployed; each probe was capable of profiling to 460 m. The XBTs are interfaced with a computer that records, plots, and transmits the data via satellite. The system performed well throughout the cruise. The following is a listing of the location of the daily XBT drops:

Table 2. XBT deployments

GMT	XBT drop	record length	Latitude	Longitude
343/0005	114	460 m	22° 04.0N	167° 03.0W
344/0001	115	460 m	19° 54.2N	170° 15.0W
345/0004	116	205 m	18° 57.7N	171° 38.0W
346/0058	117	205 m	19° 39.1N	168° 12.0W
347/0104	118	460 m	19° 23.7N	168° 17.0W
348/0113	119	250 m	19° 07.6N	168° 18.0W
349/0115	120	460 m	18° 31.6N	167° 17.0W
350/0009	121	460 m	19° 23.9N	170° 34.0W
351/0117	122	460 m	18° 15.6N	167° 19.0W
352/0058	123	460 m	18° 08.8N	167° 51.0W
353/0128	124	460 m	18° 10.4N	168° 56.0W

GLORIA

The GLORIA system was deployed at JD 342/0940Z GMT and functioned well throughout the entire cruise until the fish was recovered at JD 353/2230Z GMT. The GLORIA system was towed 400 m behind the ship at a water depth of about 50 m. GLORIA generated a 6.5 kHz pulse every 30 s. The cross-track swath width was usually about 22.5 km, with an across track resolution of about 45 m, and a vertical resolution of about 25 cm. Line spacing was set at 30 km (16 nm). The only down time for the GLORIA system was when the power failed in the main laboratory at JD 343/1007Z GMT, and during course changes. Owing to rough weather, trackline orientations had to be adjusted to decrease the strain on the GLORIA tow cable. A summary of the GLORIA passes is presented in Appendix 2.

GLORIA data were processed for along-track speed variations and slant-range distortion. The GLORIA images were printed on board the ship to correlate with the ship navigation at a scale of 1:375,000. These photos were then mosaicked and a preliminary interpretation was made of the data. As a result of the sharp thermocline in the area, the swath width of the GLORIA image was significantly reduced over shallow bathymetric features (Fig. 3). In water depths of less than about 1800 m (about 1000 fathoms), the swath range decreased to about 8-10 km. Major bathymetric features in the study area occur at a variety of orientations, so it was not possible to adjust our line spacing to a shorter distance to accommodate the imaging of all of these features. Therefore, since our line spacing was set at 30 km, gaps in coverage occurred over shallow seamounts and ridges. Some of these data gaps were filled during subsequent cruises (F1-91-CP and F2-91-CP).

PRELIMINARY SCIENTIFIC RESULTS

Several prominent linear bathymetric features of variable orientation, age, and tectonic origin were imaged by GLORIA during F13-90-CP. These features include Necker Ridge, Horizon Guyot, Karin Ridge, and Molokai Fracture Zone (MFZ) (Fig. 2). Owing to the short number of days of data acquisition during this cruise (10 days), many of these features were incompletely imaged during our cruise, but were imaged on subsequent legs (Fl-91-CP and F2-91-CP). During F13-90-CP, we imaged the southeast flank of Necker Ridge, part of the southwestern extension of the MFZ, the northern tip of Karin Ridge, and the eastern edge of the Mid-Pacific Mountains, including most of Horizon Guyot. We discuss in more detail the results from Necker Ridge, Horizon Guyot, and the MFZ. In addition we present data from an area north of the MFZ, which may indicate the presence of large fields of manganese nodules.

Necker Ridge

Necker Ridge is an elongate ridge that extends from Necker Island along the Hawaiian Ridge, southwest to near the northern end of the Line Islands (Fig. 1). Along most of its length, Necker Ridge trends about 054°, but curves slightly more easterly as it approaches the Hawaiian Ridge. Necker Ridge is over 600 km long, varies in width from about 20 km at its northern and southern ends to over 40 km along the central segment of the ridge. It has a relief of as much as 3 km above the surrounding abyssal plain with slopes that average between 12-20 °; the shallowest segment of the ridge is less that 1600 m below sea level (Hein and others, 1985). The origin of Necker Ridge is not well understood. Alkalic basalts dredged from the southern end of the ridge indicate an age of 82 Ma (Saito and Ozima, 1977). Volcaniclastic breccia, hyaloclastite, and tholeitic and alkalic basalt have also been dredged from other parts of the ridge (Hein and others, 1985; Davis, 1987).

The northern two thirds of Necker Ridge lie within the Hawaiian EEZ. During F10-88-HW, the northern 100 km of Necker Ridge was imaged, except for the top of the ridge crest as a result of its shallow water depth. Therefore, we collected data about 5 km southeast of the ridge crest (so that the nadir

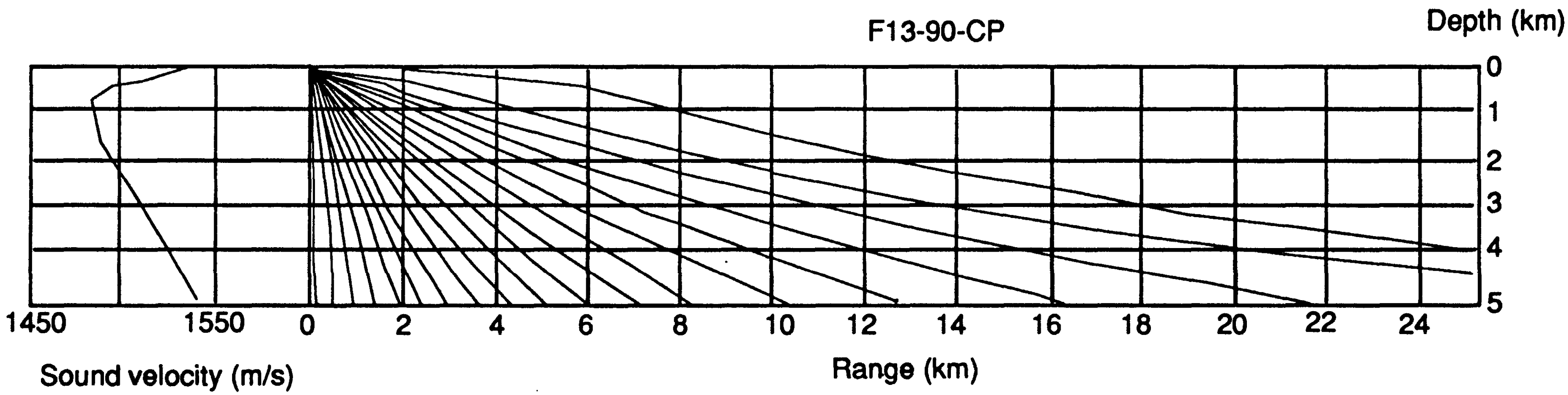

Figure 3 Graph of range of GLORIA signal versus water depth based on the sound velocity profile of the water column in the vicinity of Horizon Guyot.

would not obscure the ridge crest itself), at water depths that generally ranged between 2-4 km. Our data clearly imaged the upslope ridge crest, but more poorly imaged the downslope ridge flank. At the northernmost end of Necker Ridge, the entire ridge was imaged in one pass. However, as the ridge broadens to the south, we were only able to partially image the ridge; the northwest crest and flank of the ridge were imaged during the following cruise, F1-91-CP.

The GLORIA data show that the ridge crest has a very irregular topography that has a hummocky appearance. There is little evidence for accumulation of large amounts of sediment on the ridge. Numerous bulbous, semi-circular features of less than a km in diameter are scattered along the ridge crest and upper ridge flank. Along most of Necker Ridge, narrow zones of high reflectivity occur in a scalloped-pattern that parallels or sub-parallels the ridge crest; the reflectivity may be from bedrock exposed in the head scarps of landslides. Along the flanks of the ridge, numerous small gullies and canyons, and curvilinear slump-like features are evident. Semi-circular fan-like bodies as much as 10 km in diameter occur on the abyssal plain immediately adjacent to Necker Ridge. Our preliminary interpretation is that, particularly in consideration of the age of the ridge and the abundance of pyroclastic material exposed along the ridge, both the ridge crest and ridge flank features are related to mass-wasting processes.

Data from a previous GLORIA cruise that crossed Necker Ridge at a high angle showed evidence for a central rift graben along the ridge crest (Pickthorn and others, 1991). However, our data show no evidence for any linear, fault-related structures on the ridge crest, except at the very southernmost end near the location where Necker Ridge intersects the Mid-Pacific Mountains. Here, a linear ridge that is a minimum of 35 km in length (we did not image the northwest extension of this ridge) intersects Necker Ridge at an oblique angle of about 30°. The origin of this feature is unclear but is probably related to regional tectonic adjustments and not to the constructional formation of the ridge.

A more complete interpretation of Necker Ridge awaits the compilation of GLORIA and other geophysical data from all 6 cruises that surveyed the ridge.

Johnston Island EEZ

Johnston Island is the northernmost island of the Line Island chain, which trends to the southeast for 4200 km to Tuamotu Island. The Line Islands are composed of a complex array of seamounts and linear ridges. Rocks dated from the Line Islands indicate that an episode of volcanism occurred during the Late Cretaceous along the northern part of the chain (Schlanger and others, 1984). The origin of the Line Islands is controversial, but may be related to the activity of one or more hot spots (Epp, 1984; Schlanger and others, 1984; Duncan and Clague, 1985). In the vicinity of the Line Islands, the age of the seafloor is poorly known since it is within the Cretaceous magnetic quiet zone (83-118 Ma). The Line Islands form a junction between the geologically complex Mid-Pacific Mountains and the well-defined fracture zones and magnetic anomalies associated with Pacific-Farallon spreading, which includes the Molokai Fracture Zone. The easternmost Mid-Pacific

Mountains have an approximate ENE trend, although this trend can vary considerably along strike. This mountain chain was proposed to have been formed by a mantle hot spot that was active during the Early Cretaceous (Winterer and Metzler, 1984).

During F13-90-CP, we insonified the eastern end of the Mid-Pacific Mountains. This area is characterized by a complex distribution of seamounts that, in general, are sub-parallel to Necker Ridge. The seamounts show evidence for slumping and other mass-wasting processes along their flanks. Many of the seamounts have a characteristic magnetic signature that may be useful in assigning relative ages. Between the seamounts lie isolated basins that have accumulated perhaps as much as 1 km of sediment (based on assuming a velocity of 2 km/s). A pervasive acoustically transparent layer occurs on the 3.5 kHz records over much of the basinal areas. In general, this layer thins away from bathymetric highs, and therefore is most likely not pelagic in origin, but perhaps was formed by debris flows. Sediment observed in the far western edge of our study area are more chaotic and show minor evidence for faulting.

Horizon Guyot

Horizon Guyot is a northeast-trending, flat-topped volcanic ridge that is about 300 km long and 70 km wide, and lies southeast of and sub-parallel to Necker Ridge. The guyot rises 3500 m above the adjacent abyssal sea floor to depths as shallow as 1440 m (Schwab, 1986). Basement rocks are as old as the Cenomanian-Turonian boundary, a Tertiary nannofossil-foraminiferal ooze with interbedded chert layers caps the guyot (Winterer and others, 1973). At DSDP site 171, tholeitic and alkalic basalt were recovered from the guyot (Bass and others, 1973); transitional and alkalic basalt and hyaloclastite have been dredged from the guyot (Davis, 1987). The guyot has been submerged since the Late Cretaceous (Winterer and others, 1973).

Horizon Guyot is one of the best studied of the Mid-Pacific Mountain seamounts. Well-developed talus aprons are present at the base of the guyot's flanks attesting to pervasive mass-wasting processes (Lonsdale and others, 1972; Schwab, 1986). Erosional beveling of the northern flank of the guyot is well-documented, where interfingering volcanic terraces that have been exhumed along the guyot rim are observed (Lonsdale and others, 1972; Schwab, 1986). These terraces most likely formed as the result of the topographic intensification of internal tides that eroded the sediment cap (Cacchione and others, 1988). Large slump blocks also occur along the northwest flank of the guyot as the result of current-induced beveling of the seafloor and infrequent earthquakes (Kayen and others, 1989). Large-scale faulting occurs at the west end of the guyot (Winterer and Metzler, 1984).

An asymmetrical pattern of mass wasting is evident from GLORIA data collected over Horizon Guyot. Exhumed terraces that expose basement rock are evident along the western rim of the guyot where they appear as strong backscatter returns that occur as finger-like projections (Fig. 4). Unfortunately, the shallow depth of the guyot results in a narrow swath width across the guyot top, such that the terraces are incompletely imaged. Chaotic, slump-like features predominate along the western flank of the guyot. In contrast, the eastern flank of the guyot shows a predominance of rills and gullies that occur in a dendritic pattern. Slumping also occurs along the

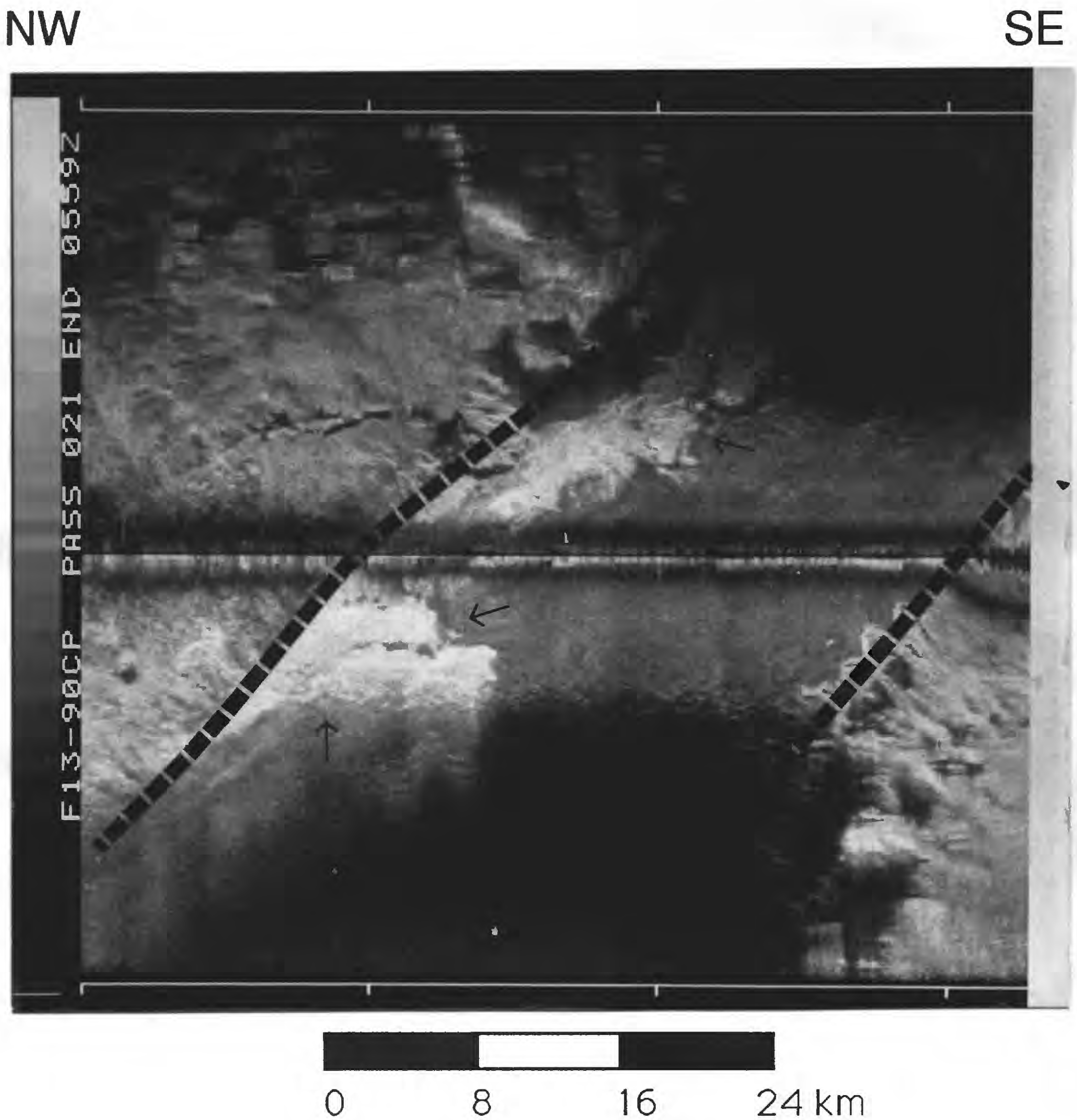

Figure 4 GLORIA photograph showing the high intensity backscatter from exhumed terraces on the western rim of Horizon Guyot (shown by arrows). Dashes show edges of the top of the guyot. Note the narrow swath width across the guyot top. The western flank of the guyot is characterized by slumping; gullies are more prevalent on the eastern flank.

eastern flanks, but is of a lesser importance. Faulting is also observed in single-channel data at the western end of the guyot.

Molokai Fracture Zone

The Molokai Fracture Zone (MFZ) was formed during the Cretaceous in conjunction with sea floor spreading between the Pacific and Farallon plates. During previous GLORIA cruises to the Hawaii EEZ, the MFZ was insonified both north and south of the Hawaiian Ridge (Normark and others, 1989; Torresan and others, 1989). The fracture zone was imaged as multiple strands that branch and diverge, showing a complex internal morphology (Normark and others, 1989). North of the Hawaiian Ridge, MFZ consisted of 4 distinct bands of lineations, whereas south of the ridge, these bands converge into 2 distinct bands of lineations.

In the Johnston Island EEZ, we also observed 2 distinct bands of lineations with a bearing of about 75° associated with the MFZ (Fig. 5). The lineations correspond to areas of high backscatter from ridges, with basins occurring between them. The most prominent, highly reflective lineations occur within the southern strand of the MFZ. Along the southern strand, low-angle reflectors (normal faults?) are observed on single channel data associated with the ridges. The northern strand of the MFZ is broader, and could perhaps be split into 2 separate strands (Fig. 5). The westernmost strand has much lower relief and shows much less backscatter on the GLORIA data. This is probably the result of sedimentation from the adjacent Horizon Guyot masking the fracture zone.

Other lineations occur in the vicinity of the MFZ (Fig. 5). These lineations are oriented approximately at right angles to the main strands of the MFZ, although in detail they show a more complex geometry. Near the intersection of these lineations with the fracture zone, they often curve to more closely parallel the fracture zone. These lineations are most likely related to the spreading fabric of the oceanic crust.

Although the MFZ appears to die out at the southern limits of data collected during F13-90-CP, the fracture zone was again imaged southwest of Karin Ridge during subsequent cruises (F1-91-CP and F2-91.CP) to about 170.5°W near the west end of the Johnston Island EEZ (Drake and others, 1991). This is the farthest west that this feature has been imaged. Since this area is within the Cretaceous quiet zone, topographic features are often the only clues to plate reconstructions (Atwater, 1989), and therefore the location of the MFZ farther west than previously known has important implications in determining plate reorganizations.

Manganese nodules (?)

During F13-90-CP, GLORIA data collected over the seafloor east of Horizon Guyot and Karin Ridge (the northeast sector of the Johnston Island EEZ) showed an unusual mottled backscatter pattern of moderate intensity (Fig. 5). This backscatter pattern was significantly different than the high intensity backscatter typical of bedrock, and the very low backscatter from abyssal plain sediment. The location of areas with this type of backscatter is shown in Figure 6, with areas that have a more pronounced mottled appearance highlighted by a cross-hatch pattern. Areas delineated by the

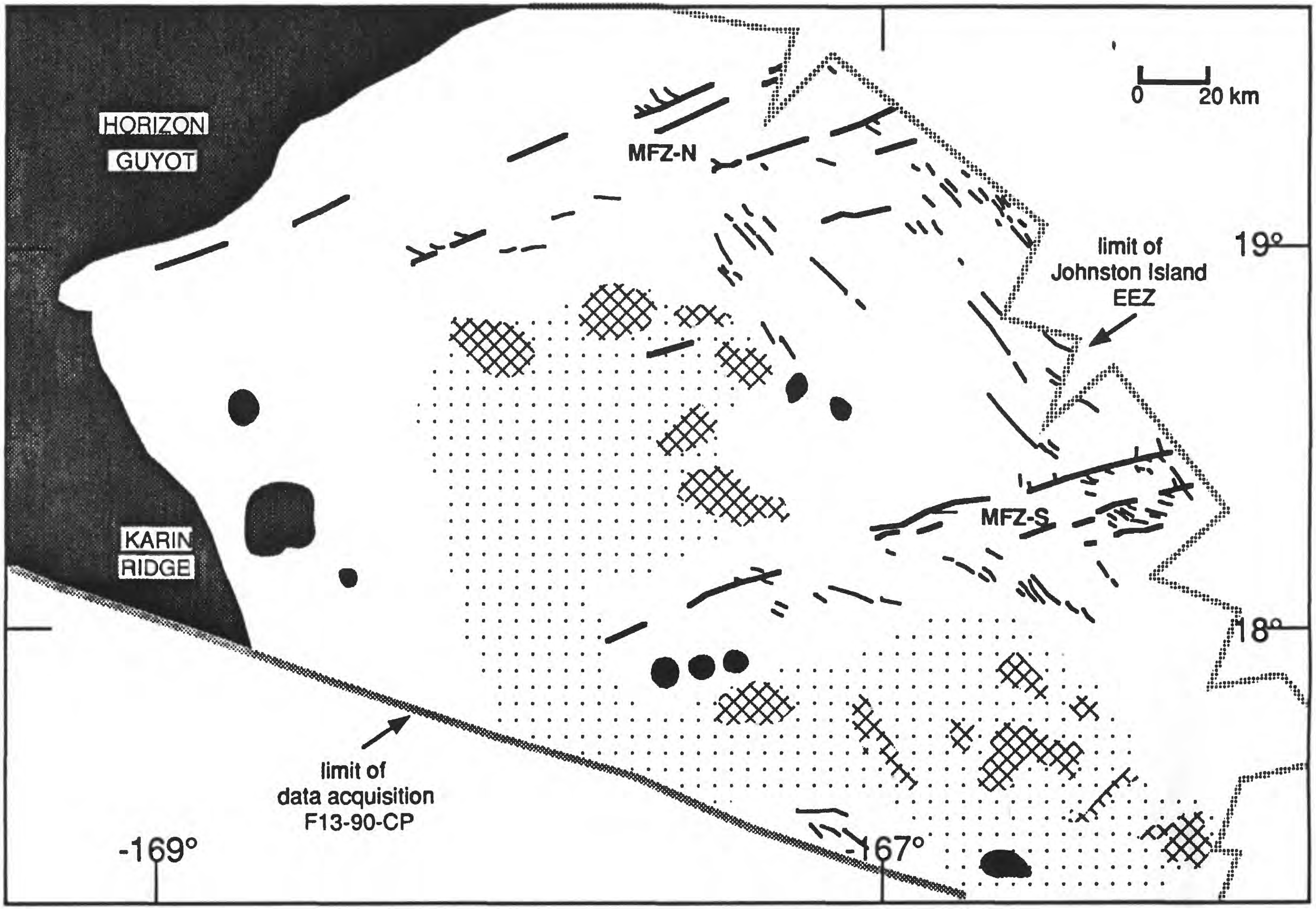

Figure 5 Map of northeastern part of the Johnston Island EEZ showing lineations from the Modokai fracture zone (MFZ) and the location of backscatter pattern that may occur from manganese nodules. The bold lines are lineations related to the MFZ itself (MFZ-N is the northern strand; MFZ-S is the southern strand); the thin lines are most likely related to the tectonic spreading fabric. The dotted area is the region of the mottled, moderate intensity backscatter pattern that may be from manganese nodules; the cross-hatched areas are location where this pattern is particularly pronounced. Darkly shaded areas correspond to seamounts and ridges.

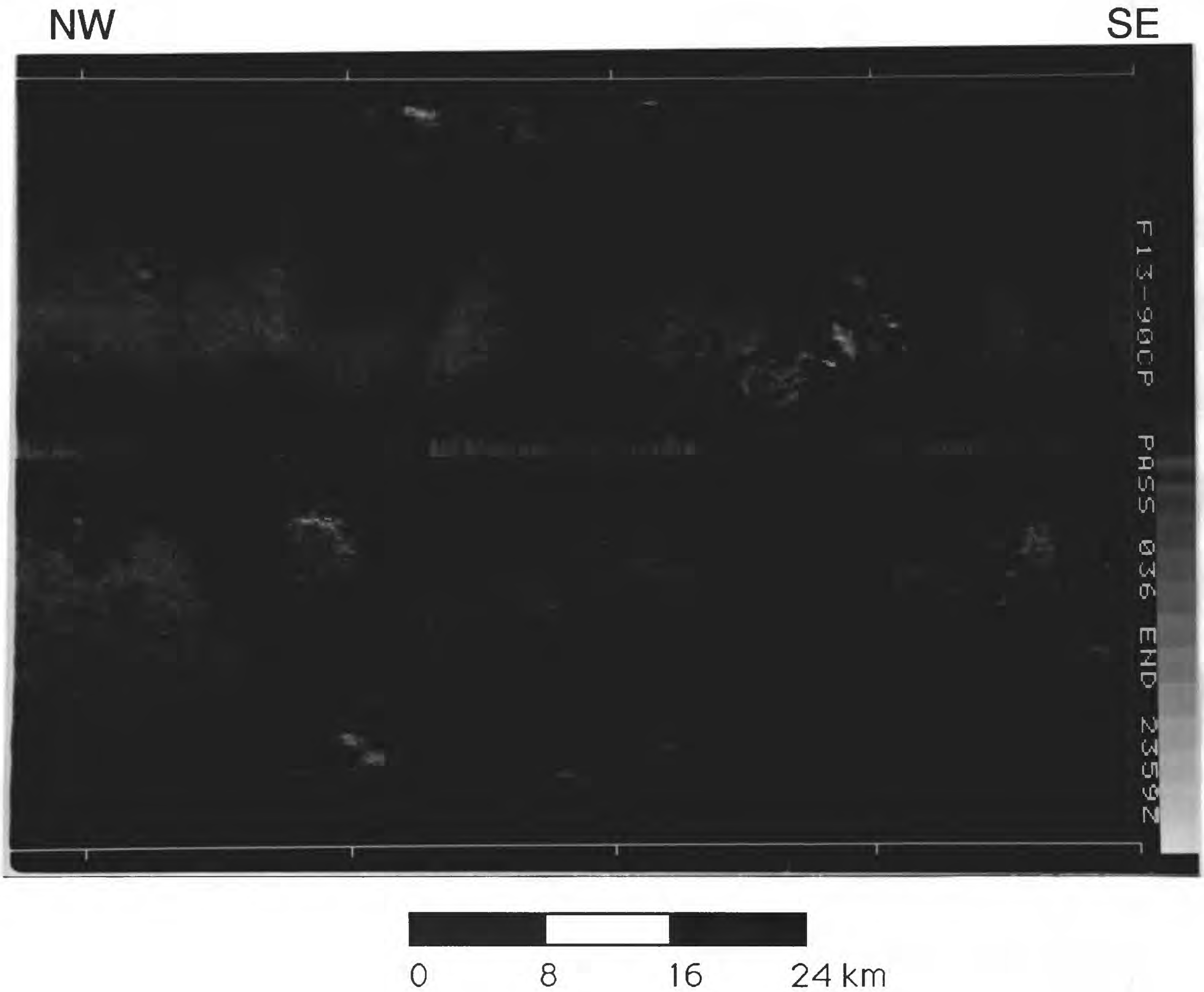

Figure 6 GLORIA photograph showing the mottled, moderate intensity backscatter from an area of the sea floor that may be underlain by a manganese nodule field.

cross-hatch pattern tend to correspond to the location of small abyssal hills of low relief (on the order of 50-100 m of relief).

Huggett and Somers (1988) observed a similar type of backscatter in GLORIA data collected over a well-documented manganese nodule field that occurs on abyssal hills in the Eastern Atlantic Ocean. Because of the similarity in backscatter patterns between that observed in the Atlantic and what we observed near Johnston Island, and since manganese encrustations are ubiquitous on many ridges in the area (Hein and others, 1985), we propose that this region of the Johnston Island EEZ may be underlain by a manganese nodule field of significant size. However, until sampling of this area is undertaken, this hypothesis must remain speculative. Other interpretations for the origin of this backscatter pattern include relatively recent lava flows and/or sedimentation patterns (Drake and others, 1991).

ACKNOWLEDGEMENTS

The cooperation of the officers and crew of the M/V Farnella contributed significantly to a successful cruise. We thank Sue Hunt for logistics support, and football scores! We thank Dave Drake for his review of the manuscript.

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APPENDIX 1--Latitudes (LAT) and longitudes (LONG) of start of line (SOL) and end of line (EOL), and total line length for the trackline shown in Figure 2.

LINE #	SOL--LAT	SOL--LONG	EOL--LAT	EOL--LONG	LENGTH-KM
001	23.16	-165.31	20.20	-169.62	554
002	20.18	-169.67	19.15	-171.91	261
003	19.15	-171.91	18.61	-172.47	083
004	18.59	-172.46	20.00	-169.34	362
005	20.00	-169.32	19.37	-167.31	222
006	19.36	-167.30	18.90	-166.70	081
007	18.88	-166.65	19.81	-169.63	328
008	19.80	-169.64	19.68	-169.97	037
009	19.65	-169.98	18.58	-166.55	380
010	18.57	-166.54	18.21	-166.20	054
011	18.20	-166.24	19.48	-170.36	457
012	19.48	-170.40	19.33	-170.70	035
013	19.30	-170.71	17.88	-166.09	512
014	17.86	-166.07	17.60	-166.00	030
015	17.59	-166.02	18.76	-169.92	432
016	18.75	-169.95	18.52	-170.02	026
017	18.50	-170.01	17.29	-166.05	239

APPENDIX 2--Start and end time for the GLORIA passes.

tape #	pass #	start time	finish time
1	1	342/0558	342/0926
1	2	342/1009	342/1559
1	3	342/1600	342/2159
1	4	342/2200	343/0359
1	5	343/0400	343/0600
1	6	343/0601	343/1159
1	7	343/1200	343/1759
1	8	343/1800	343/2359
1	9	344/0000	344/0559
1	10	344/0600	344/1159
1	11	344/1200	344/1759
1	12	344/1800	344/2359
1	13	345/0000	345/0559
1	14	345/0600	345/1159
1	15	345/1200	345/1759
1	16	345/1800	345/2359
2	1	346/0000	346/0559
2	2	346/0600	346/1159
2	3	346/1200	346/1759
2	4	346/1800	346/2359

2	5	347/0000	347/0559
2	6	347/0600	347/1159
2	7	347/1200	347/1759
2	8	347/1800	347/2359
2	9	348/0000	348/0559
2	10	348/0600	348/1159
2	11	348/1200	348/1759
2	12	348/1800	348/2359
2	13	349/0000	349/0559
2	14	349/0600	349/1159
2	15	349/1200	349/1759
2	16	349/1800	349/2359
3	1	350/0000	350/0559
3	2	350/0600	350/1159
3	3	350/1200	350/1759
3	4	350/1800	350/2359
3	5	351/0000	351/0559
3	6	351/0600	351/1159
3	7	351/1200	351/1759
3	8	351/1800	351/2359
3	9	352/0000	352/0559
3	10	352/0600	352/1159
3	11	352/1200	352/1759
3	12	352/1800	352/2359
3	13	353/0000	353/0559
3	14	353/0600	353/1159
3	15	353/1200	353/1759
3	16	353/1800	353/2229