# CRUISE REPORT
# EWING 9606

# **MID-ATLANTIC RIDGE EAST FLANK**

# **(MAREAST SURVEY)**

12 JULY - 17 AUGUST 1996

SAN JUAN, PUERTO RICO
TO
ST. JOHNS, NEWFOUNDLAND

**DATA POLICY**

All geological and geophysical data acquired during Ewing Cruise 9606 are proprietary to the Principal Investigators, Dr. Brian E. Tucholke, Dr. Martin C. Kleinrock, and Dr. Jian Lin. The EW9606 3-component magnetometer data are proprietary to Tomoko Tanaka. These data may not be distributed, analyzed, published or otherwise used without the written permission of the Principal Investigators.

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## BACKGROUND AND SCIENTIFIC OBJECTIVES

Over the past two decades, much geological and geophysical data has been collected at and near the axes of slow-spreading mid-ocean ridges. These data show that ridges are segmented along-axis on scales of tens of kilometers, and they provide largely a rift-zone perspective on crustal accretion and tectonism. If crustal accretion is episodic, as it is believed it to be, then a very large number of along-axis surveys in various segments are necessary to reconstruct all phases of a volcanic/tectonic cycle, particularly if most of the "action" occurs in only a fraction of the cycle. Judicious off-axis surveys, however, capture all elements of a number of cycles, with the important addition that they show time series of these elements. Off-axis data also provide information on side-to-side asymmetries in accretion and tectonism, on effects imposed by changes in plate motion, and on secondary "aging processes" of the ocean crust.

Very little detailed data has been acquired more than a few m.y. off-axis to investigate crustal structure and potential-field anomalies on slow-spreading ridges. On the northern Mid-Atlantic Ridge (MAR), the SARA survey at 28°-29°N and the ATLANTIS F.Z. survey reached ~10 m.y. off-axis, collecting multibeam and potential-field data on both the east and west ridge flanks, but they did not acquire the important, high-resolution morphological data which sidescan sonar provides. The SEADMA I survey south of Kane FZ collected Simrad EM12 multibeam and sidescan out to 10 m.y. on both flanks, but with wide line spacing (9-18 km) and hence with potential-field data that are not highly resolved in 3-D.

In 1992 we surveyed the MAR west flank (MARWEST; Ewing 9208) at 4-8 km line spacing from the ridge axis out to ~26-29 Ma crust, acquiring Hydrosweep multibeam bathymetry, HAWAII MR1 (HMR1) sidescan/bathymetry, magnetics, gravity, and watergun seismic and 3.5-kHz profiles over an area more than 200 km along isochrons by 400 km off-axis. These data provide the close line spacing needed to interpret potential fields reliably, as well as both sidescan and bathymetry extending far enough off-axis to cover critical tectonic changes (e.g., spreading vector changes and multiple accretion cycles). In 1993, Knorr cruise 138-14 further studied the detailed geology and geophysics of four sites within MARWEST, using the DSL-120 and Jason near-bottom survey systems. Both of these field programs were funded by the Office of Naval Research in support the Acoustic Reverberation Special Research Program. The MARWEST research provided a detailed, 26-29 m.y. record of accretion and tectonism of ocean crust that is unique within the ocean basins. However, since it covered only one flank of the Mid-Atlantic Ridge, it left unanswered many fundamental questions which can be addressed only by acquiring and analyzing comparable data on the east flank of the ridge. The NSF-funded Ewing 9606 field program (MAREAST) on the east flank of the MAR addresses these questions. MAREAST data acquisition is identical in instrumentation and survey style to that in MARWEST, with the exception that watergun seismic reflection profiling was not conducted.

Analysis of the combined MAREAST and MARWEST data will allow us to address the following fundamental scientific questions about the origin and structure of slowly spreading ocean crust:

•The nature and origin of spreading asymmetry across the rift axis, as well as the nature and origin of asymmetries in crustal structure along isochrons within individual spreading segments.

•The complete structural record and time scale(s) of episodicity in magmatic versus amagmatic extension.

•The detailed record of North Atlantic plate-motion changes over the past ~26+ m.y., together with quantitative evaluation of how the plate boundary responded structurally to those changes.

•The processes governing the evolution of non-transform offsets at segment boundaries, including a test of the propagating-rift model in slowly spreading crust.

•The origin of highly oblique structural discontinuities that strongly disrupt the structural integrity of the crust across spreading ridge segments.

The MAREAST program is directly relevant to the Crustal Accretion Variables objectives of the RIDGE and FARA programs and to similar objectives in the InterRIDGE program. These programs assigned high priority to obtaining comprehensive data sets that include a focus on the geological, geophysical, temporal and spatial variability along and across the slow-spreading ridge axis in the central North Atlantic. A particular interest of these programs is on/off-axis high-resolution mapping, including magnetics and gravity, to define the morphologic and kinematic evolution of the plate boundary.

Dr. Cecile Durand (Universite de Bretagne Occidentale, France) accepted our invitation to participate in the MAREAST survey and to work with us to compare our research results with those of the SEADMA I survey where a number of complex spreading segments have evolved. In addition, Tomoko Tanaka (Chiba University, Japan) participated in the cruise to obtain 3-component magnetometer data which will be of great value in helping to interpret the magmatic and tectonic evolution of MAR crust.

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**WATCH SCHEDULE**

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CHIEF SCIENTIST: Brian Tucholke - 0700-1500. On call 24 hrs.

CO-CHIEF SCIENTIST: Martin Kleinrock - 1500-2300. On call 24 hrs.

CO-CHIEF SCIENTIST: Jian Lin - 2300-0700. On call 24 hrs.

| Location | 0 - 4 | 4 - 8 | 8 - 12 |
|---|---|---|---|
| MAIN LAB | Cecile Durand<br>Jennifer Georgen | Ian Malin<br>Del Bohnenstiehl | Lori Dolby<br>Karen Worminghaus |
| BRIDGE | Mark Landow 2/O<br>John Vezina A/B | Lou Mello 1/O<br>John Shank A/B | Jeffrey Sylvia 3/O<br>David Wolford A/B |

| | Rob Hagg O/S | George Mardones O/S |
|---|---|---|
| HMR1 LAB | 0900-2100 Bruce Appelgate. On call 24 hours.<br>0900-2100 Steve Tottori. On call 24 hours.<br>0930-2130 Lynn Johnson-Conrad<br>2130-0930 Lisa Petersen | |

## SURVEY LAYOUT

Survey lines were laid out at about 50°-70° to the dominant, abyssal-hill fabric of the ocean crust. This allowed optimum insonification of primary fault structures associated with the abyssal hills, while at the same time allowing acquisition of potential-field data (e.g., magnetics) subparallel to plate flowlines. Line spacing was about 5.0 to 5.25 km near the ridge axis and increased regularly in deeper water off-axis to about 8.0-8.5 km at the eastern limit of the survey; this variation optimized the acquistion pattern of multibeam bathymetry, the swath width of which is directly related to water depth. The survey extended about 340 km from the MAR axis to magnetic anomaly 8r (27 m.y.), and about 220 km along isochrons, covering an area of 74,800 square kilometers (Figures 1 and 2).

## CRUISE NARRATIVE

We departed from San Juan, Puerto Rico at 1042 Local (1442Z) on 11 July 1996 and steamed for Way Point 1 near the southwestern corner of our survey area over the eastern flank of the Mid-Atlantic Ridge. Strong easterly winds reduced our speed over ground, and we arrived at Way Point 1 at 1225Z on 16 July. There we executed a figure-8 turn to provide calibration for the Japanese three-component magnetometer. The HMR1 was then deployed as we steamed toward Way Point 2. Within about 2 hours the system was fully deployed and operational. Initial tow speed was 9.0 knots, but at 1720Z we increased speed to 9.5 knots while on Line 2. About 1900Z periodic noise (2.5-3 min period) began to appear on the HMR1 record (about the time of course change onto Line 4), most prominently in the far range of the starboard side, and to a lesser extent on the port side. At about 2315Z we increased speed to 9.8 knots. This had no noticeable effect on the periodic noise or noise level of the record in general. Other possible sources of the noise were checked in lab, bridge, and engineering logs, but no apparent noise sources were identified.

On 17 July we reduced the ship speed to 6 knots for a period of time, then increased speed in 1-knot increments (7, 8, 9, 9.8 knots) while observing the effect on the periodic noise. There was little detectable periodic noise at 6 knots, but the noise appeared clearly at 7 knots and remained up to 9.8 knots without significant increase in intensity above about 8 knots. We also disabled the HMR1 ping for a ~25-minute period during the turns at the end of Line 16 (9.8 knots) in order to listen for the periodic noise. The noise continued to occur during this period, indicating that it is not caused by the transmit part of the HMR1 system. Also on 17 July, a faulty connection developed with the 3-component magnetometer, and the magnetometer had to be reinstalled. Only one figure-8 calibration had been made up to this time, so the magnetic data up to this time are unlikely to be of much value (lines 1-14). Succeeding lines (15 and onward) were all well calibrated by a later series of figure-8's and were successfully processed.

On 18 July the ship's engineering department conducted a series of changes in operation of ship's motors and mechanical and electrical systems on a roughly half-hour schedule while we monitored the periodic noise in the HMR1 record. None of these changes were found to affect the HMR1 noise.

After 2 1/2 days of HMR1 data acquistion, we noticed that the period of the noise cycle had decreased with time. Analysis of the records showed that the period initially was about 3 minutes, that it decreased to slightly less than 2 minutes over 30 hours, and that it remained constant at about 1.94-2.00 minutes afterward. It was also found that the noise level was high overall on the starboard side during CCW turns, with reduced period. Noise level was slightly reduced on the starboard side during CW turns, with slightly increased period. It appears that the noise may be generated by some mechanical means on the HMR1 vehicle, probably on the starboard side.

On 20 July, after some experimentation, Bruce Appelgate adapted a demicrostripe filter that removes virtually all of the periodic noise without degrading the real data. Although this treats the symptoms of the problem rather than the cause, we decided not to venture the time or risk that would be involved in recovering the HMR1 vehicle to search for the cause of the noise.

At 0340Z on 21 July (Line 34), the port-side sidescan on HMR1 failed, and we pulled the vehicle. A bad connection was found on the transmit monitor board and repaired. The entire fish was checked for a source of periodic noise; no obvious sources were located although some loose cables were found and secured. HMR1 was launched and we resumed Line 34 at the point where we initially lost port-side data. Unfortunately, shortly after the system became operational, the periodic noise reappeared. During the period when HMR1 was aboard for repairs we conducted three figure-8 turns for 3-component magnetometer calibration and we steamed along a line to obtain Hydrosweep bathymetry between Lines 36 and 37.

On 23 July at 1057Z the HMR1 developed a very noisy record. The vehicle was recovered and it was found that the drogue line had broken about 50 meters behind the vehicle. We steamed back to the position where the break had occurred and recovered the drogue line and buoy, then did a figure-8 turn for magnetometer calibration. The HMR1 was launched with a new drogue line and the old tail buoy. The old line was quite rotten at the location of the break; it apparently had parted by breaking rather than being cut. The new line was 300 m long whereas the old line was 500 m long. The shorter line, although the same length as that which formerly was used with HMR1, does not stabilize HMR1 as well as the longer line, and we observed noticeable noise in the HMR1 records because of this instability.

Following this deployment, HMR1 acquired sidescan and bathymetric data without further incident, excepting an occasional telemetry error. The periodic noise continued through the remainder of the survey, commonly with a ~2-minute period, but occasionally with very short periods (e.g., alternating pings, ~30-40 sec) for significant intervals of time. The source of the noise and the cause of the changes in period were never identified. On 29 July, about 1500Z, we increased our speed through the water to 10 knots and continued with this ship speed during the remainder of the survey. The HMR1 towed well at this speed, with no noticeable increase in noise.

The HMR1 was recovered beginning shortly after waypoint 109 (~ 0445 on 12 August) and was brought aboard at waypoint 110, marking the official end of the MAREAST survey. We immediately were underway for St. Johns, Newfoundland. Later the same day, figure-8's were done in the ship track at 28°N and 29°N for further calibration of the 3-component magnetometer.

**WINDS AND SEAS**

In general, winds and seas were gentle to moderate (see table below); no time was lost during the cruise due to weather, and weather posed no significant operational difficulties.

| DATE | AVERAGE WIND DIRECTION | AVERAGE BEAUFORT FORCE | CORRESPONDING AVERAGE WIND SPEED (KNOTS) | AVERAGE SEAS (FEET) |
|---|---|---|---|---|
| JULY 11 | SE | 5 | 18 | 4 |
| 12 | SE | 4-5 | 13-18 | 4 |
| 13 | SE | 5 | 13 | 4 |
| 14 | ENE | 4 | 13 | 3-4 |
| 15 | ENE | 4 | 13 | 3 |
| 16 | NE | 4 | 13 | 3 |
| 17 | ENE | 4-5 | 13-18 | 3 |
| 18 | E | 4 | 13 | 3 |
| 19 | ENE | 4 | 13 | 3 |
| 20 | ENE | 4-5 | 13-18 | 3 |
| 21 | NE | 4 | 13 | 3 |
| 22 | NE | 4 | 13 | 3 |
| 23 | NE | 4 | 13 | 3 |
| 24 | NE | 4 | 13 | 3 |
| 25 | ENE | 2-3 | 5-9 | 3 |
| 26 | NE | 2-3 | 5-9 | 2-3 |
| 27 | NE | 4 | 13 | 3 |
| 28 | NE | 4-5 | 13-18 | 3 |
| 29 | NE | 5 | 18 | 3-4 |
| 30 | ENE | 4 | 13 | 3 |
| 31 | ENE | 4 | 13 | 3 |
| AUG. 1 | NE | 4 | 13 | 3 |
| 2 | NE | 4-5 | 13-18 | 3 |
| 3 | NE | 4-5 | 13-18 | 3 |
| 4 | ENE | 5 | 18 | 4 |
| 5 | ENE | 5 | 18 | 4 |
| 6 | NE | 4-5 | 13-18 | 4 |
| 7 | ENE | 4-5 | 13-18 | 3 |
| 8 | ENE | 4 | 13 | 3 |
| 9 | ENE | 4 | 13 | 3 |
| 10 | E | 1-3 | 2-9 | 3 |
| 11 | SSE | 3 | 9 | 2 |
| 12 | ESE | 3-4 | 9-13 | 2 |
| 13 | Variable | 2-3 | 5-9 | 2 |
| 14 | Variable | 2-6 | 5-24 | 2-4 |

| | | | | |
|---|---|---|---|---|
| 15 | NW | 5-6 | 18-24 | 6 |
| 16 | Variable | 3 | 9 | 2 |
| 17 | ARRIVAL | IN | ST. JOHNS | NEWF. |

## TIME, DATE, AND LOG KEEPING

All science records and logs kept on Ewing Cruise 9606 were recorded in GMT (Zulu), which was three hours ahead of local, ship time during the survey. Date annotation was in either Calendar Day or Julian Day. The table below gives calendar days and corresponding Julian days for the cruise.

| CD | JD | CD | JD | CD | JD |
|---|---|---|---|---|---|
| 11 July (Th) | 193 | 24 July (We) | 206 | 06 Aug. (Tu) | 219 |
| 12 July (Fr) | 194 | 25 July (Th) | 207 | 07 Aug. (We) | 220 |
| 13 July (Sa) | 195 | 26 July (Fr) | 208 | 08 Aug. (Th) | 221 |
| 14 July (Su) | 196 | 27 July (Sa) | 209 | 09 Aug. (Fr) | 222 |
| 15 July (Mo) | 197 | 28 July (Su) | 210 | 10 Aug. (Sa) | 223 |
| 16 July (Tu) | 198 | 29 July (Mo) | 211 | 11 Aug. (Su) | 224 |
| 17 July (We) | 199 | 30 July (Tu) | 212 | 12 Aug. (Mo) | 225 |
| 18 July (Th) | 200 | 31 July (We) | 213 | 13 Aug. (Tu) | 226 |
| 19 July (Fr) | 201 | 01 Aug. (Th) | 214 | 14 Aug. (We) | 227 |
| 20 July (Sa) | 202 | 02 Aug. (Fr) | 215 | 15 Aug. (Th) | 228 |
| 21 July (Su) | 203 | 03 Aug. (Sa) | 216 | 16 Aug. (Fr) | 229 |
| 22 July (Mo) | 204 | 04 Aug. (Su) | 217 | 17 Aug. (Sa) | 230 |
| 23 July (Tu) | 205 | 05 Aug. (Mo) | 218 | | |

Several hard-copy cruise logs were maintained in the Main Lab. A set of paper Log Sheets (standard LDEO log sheets) were annotated every half hour and at every event with position, course, speed, etc. A Main Lab Scientific Logbook also was maintained, containing detailed notes on all events and observations during the cruise. Another Laboratory Scientific Logbook was kept by the Chief and Co-Chief Scientists; this log contains various daily notes on waypoints, operational calculations, example records from HMR1, and so forth. Finally, an HMR1 log was kept; it was annotated every 15 minutes and at every event with vehicle-attitude data and other HMR1 information. Copies of all logs are in the possession of the Chief Scientist.

**WAY POINTS**

| W.P. Number | Latitude °N | Longitude°W | End of Line | Start of Line |
|---|---|---|---|---|
| 1 | 25°13.5' | 45°30.0' | Transit from SJ | 1 |
| 2 | 25°28.6' | 45°03.7' | 1 | 2 |
| 3 | 25°11.0' | 44°51.3' | 2 | 3 |
| 4 | 25°12.4' | 44°48.6' | 3 | 4 |
| 5 | 25°28.6' | 45°00.0' | 4 | 5 |
| 6 | 25°30.3' | 44°57.3' | 5 | 6 |
| 7 | 25°06.6' | 44°40.8' | 6 | 7 |
| 8 | 25°08.1' | 44°37.9' | 7 | 8 |
| 9 | 25°30.5' | 44°53.1' | 8 | 9 |
| 10 | 25°32.0' | 44°50.0' | 9 | 10 |
| 11 | 25°04.1' | 44°31.3' | 10 | 11 |
| 12 | 25°05.5' | 44°28.4' | 11 | 12 |
| 13 | 25°42.4' | 44°52.2' | 12 | 13 |
| 14 | 25°43.9' | 44°49.5' | 13 | 14 |
| 15 | 24°59.5' | 44°20.0' | 14 | 15 |
| 16 | 25°01.3' | 44°16.7' | 15 | 16 |
| 17 | 25°47.9' | 44°48.6' | 16 | 17 |
| 18 | 25°49.2' | 44°45.8' | 17 | 18 |
| 19 | 24°53.4' | 44°06.7' | 18 | 19 |
| 20 | 24°55.2' | 44°03.1' | 19 | 20 |
| 21 | 25°51.8' | 44°44.0' | 20 | 21 |
| 22 | 25°53.3' | 44°41.4' | 21 | 22 |
| 23 | 24°49.1' | 43°53.7' | 22 | 23 |
| 24 | 24°51.1' | 43°50.2' | 23 | 24 |
| 25 | 25°58.8' | 44°42.0' | 24 | 25 |
| 26 | 26°00.3' | 44°39.7' | 25 | 26 |
| 27 | 24°48.5' | 43°43.0' | 26 | 27 |
| 28 | 24°50.5' | 43°39.6' | 27 | 28 |
| 29 | 26°02.8' | 44°37.9' | 28 | 29 |
| 30 | 26°04.6' | 44°35.1' | 29 | 30 |
| 31 | 24°34.3' | 43°21.2' | 30 | 31 |
| 32 | 24°36.7' | 43°17.6' | 31 | 32 |
| 33 | 26°11.2' | 44°36.9' | 32 | 33 |
| 34 | 26°12.8' | 44°34.4' | 33 | 34 |
| (HMR1 was recovered and redeployed on Line 34; waypoints 34A and 34B are intermediate locations to fill in Hydrosweep data between lines during this period) | | | | |
| 34A | 25°55.5' | 44°13.0' | | |
| 34B | 26°13.7' | 44°29.5' | | |
| 35 | 24°30.3' | 43°06.1' | 34 | 35 |
| 36 | 24°32.9' | 43°02.5' | 35 | 36 |
| 37 | 26°12.8' | 44°30.6' | 36 | 37 |
| 38 | 26°14.6' | 44°28.3' | 37 | 38 |
| 39 | 24°23.3' | 42°47.8' | 38 | 39 |

| | | | | |
|---|---|---|---|---|
| 40 | 24°26.0' | 42°44.0' | 39 | 40 |
| (HMR1 was recovered and redeployed on Line 40) | | | | |
| 41 | 26°20.4' | 44°29.5' | 40 | 41 |
| 42 | 26°22.2' | 44°27.3' | 41 | 42 |
| 43 | 24°16.3' | 42°28.6' | 42 | 43 |
| 44 | 24°19.1' | 42°24.9' | 43 | 44 |
| 45 | 26°26.3' | 44°27.3' | 44 | 45 |
| 46 | 26°28.0' | 44°25.1' | 45 | 46 |
| 47 | 24°07.2' | 42°06.7' | 46 | 47 |
| 48 | 24°10.5' | 42°02.9' | 47 | 48 |
| 49 | 26°32.2' | 44°25.0' | 48 | 49 |
| 50 | 26°33.9' | 44°23.1' | 49 | 50 |
| 51 | 24°15.0' | 42°00.5' | 50 | 51 |
| 52 | 24°18.3' | 41°56.9' | 51 | 52 |
| 53 | 26°37.8' | 44°23.1' | 52 | 53 |
| 54 | 26°39.7' | 44°21.1' | 53 | 54 |
| 55 | 24°22.5' | 41°54.3' | 54 | 55 |
| 56 | 24°25.8' | 41°50.6' | 55 | 56 |
| 57 | 26°43.8' | 44°21.2' | 56 | 57 |
| 58 | 26°45.8' | 44°19.2' | 57 | 58 |
| 59 | 24°31.1' | 41°49.2' | 58 | 59 |
| 60 | 24°34.4' | 41°45.7' | 59 | 60 |
| 61 | 26°48.5' | 44°17.8' | 60 | 61 |
| 62 | 26°50.2' | 44°15.7' | 61 | 62 |
| 63 | 24°39.9' | 41°44.3' | 62 | 63 |
| 64 | 24°43.2' | 42°40.9' | 63 | 64 |
| 65 | 26°53.8' | 44°15.3' | 64 | 65 |
| 66 | 26°55.8' | 44°13.1' | 65 | 66 |
| 67 | 24°48.4' | 41°39.8' | 66 | 67 |
| 68 | 24°51.8' | 41°36.2' | 67 | 68 |
| 69 | 26°57.9' | 44°11.6' | 68 | 69 |
| 70 | 27°00.1' | 44°09.3' | 69 | 70 |
| 71 | 24°57.0' | 41°35.1' | 70 | 71 |
| 72 | 25°00.5' | 41°31.7' | 71 | 72 |
| 73 | 26°50.7' | 43°52.7' | 72 | 73 |
| 74 | 26°52.8' | 43°50.5' | 73 | 74 |
| 75 | 25°05.1' | 41°29.7' | 74 | 75 |
| 76 | 25°08.5' | 41°26.5' | 75 | 76 |
| 77 | 26°42.2' | 43°31.1' | 76 | 77 |
| 78 | 26°44.8' | 43°28.8' | 77 | 78 |
| 79 | 25°13.2' | 41°24.6' | 78 | 79 |
| 80 | 25°16.5' | 41°21.5' | 79 | 80 |
| 81 | 26°34.2' | 43°08.9' | 80 | 81 |
| 82 | 26°36.8' | 43°06.5' | 81 | 82 |
| 83 | 25°21.6' | 41°20.7' | 82 | 83 |
| 84 | 25°25.0' | 41°17.6' | 83 | 84 |
| 85 | 26°24.2' | 42°42.2' | 84 | 85 |

| | | | | |
|---|---|---|---|---|
| 86 | 26°27.0' | 42°39.7' | 85 | 86 |
| 87 | 25°30.1' | 41°16.3' | 86 | 87 |
| 88 | 25°33.9' | 41°13.3' | 87 | 88 |
| 89 | 26°12.8' | 42°11.5' | 88 | 89 |
| 90 | 26°15.9' | 42°08.9' | 89 | 90 |
| 91 | 25°38.3' | 41°11.4' | 90 | 91 |
| 92 | 25°41.9' | 41°08.7' | 91 | 92 |
| 93 | 26°00.0' | 41°36.5' | 92 | 93 |
| 94 | 26°03.5 | 44°33.7' | 93 | 94 |
| 95 | 25°46.9' | 41°07.8' | 94 | 95 |
| 96 | 25°50.8' | 41°04.8' | 95 | 96 |
| 97 | 25°58.2' | 41°16.3' | 96 | 97 |
| 98 | 26°11.5' | 41°54.3' | 97 | 98 |
| 99 | 27°02.8' | 44°11.8' | 98 | 99 |
| 100 | 25°26.4' | 44°59.5' | 99 | 100 |
| 101 | 25°28.7' | 45°03.9' | 100 | 101 |
| 102 | 26°45.28' | 44°26.09' | 101 | 102 |
| 103 | 26°37.47' | 44°17.50' | 102 | 103 |
| 104 | 26°33.58' | 44°21.85' | 103 | 104 |
| 105 | 26°38.20' | 44°26.62' | 104 | 105 |
| 106 | 26°41.14' | 44°25.16' | 105 | 106 |
| 107 | 26°43.00' | 44°27.18' | 106 | 107 |
| 108 | 26°56.8' | 44°20.4' | 107 | 108 |
| 109 | 27°10.9' | 44°20.4' | 108 | 109 |
| 110 | 27°14.4' | 44°21.6' | 109* | Transit to St. Johns |

*End of HMR1 recording

## DATA ACQUISITION: SYSTEMS, PERFORMANCE, AND PROCESSING

### Positioning of Sensors

The sonars and other sensing instruments used on Ewing were not located directly under the GPS antenna. The displacement of each of the sensors with respect to the GPS antenna is as follows:

| | |
|---|---|
| -Magnetometer | about 280m aft |
| -3-Component Magnetometer | 1 m aft |
| -HMR1 | 630 m aft |
| -3.5 kHz | 6 m aft |
| -Hydrosweep | 14 m forward |
| -Gravimeter | 1 m aft |

(Note: MR1 data files have been corrected to account for these offsets; others have not.)

### Ewing Data-Logging System

The main logging system is built around a Sun Microsystems SPARCstation 2 computer running the SUNOS 4.1 UNIX operating system. From this computer, RS-232C serial lines go to the serial port of each of the instruments logged (e.g., GPS receiver, gravimeter). Each type of instrument has its own separate and slightly specialized logging program. In general, each data-record output by an instrument through its serial port is captured, time-stamped with the CPU's current time, and appended to the current daily file for the instrument. The GPS clock is also logged and the CPU clock is updated to UTC time each minute. The CPU time-tags are used for data from the Furuno speed log, BGM-3 gravimeter, magnetometer, pitch-roll, and Hydrosweep bathymetry. The GPS data records are also time tagged with the CPU time but the time of position comes from the times established by the receiver for the position. When a logging process receives a new record from an instrument, it also passes it to another process that in turn "broadcasts" the data on the real-time network. This allows other computers on the real-time network to receive the new data and do such things as draw real-time plots. The Sun computer logs all data directly except for the Hydrosweep data. The Hydrosweep has a Silicon Graphics (SGI) Personal Iris workstation as its direct-interface computer. The SGI workstation sends to Hydrosweep the navigation collected from the network broadcast, reads the Hydrosweep's output data, and broadcasts these data on the network. The Sun computer logs these Hydrosweep data broadcasts on its disk.

Daily data reduction generally started shortly after GMT midnight, and post-processed navigation, gravity free-air anomaly, magnetic anomaly and center-beam bathymetry were available within 3-4 hours. Data reduction was carried out on a SUN Microsystems SPARCstation 2.

The sections below list the instruments and steps in the data logging and reduction sequence for all instruments used during cruise Ewing 9606. Asterisks (*) indicate data logged on the Ewing data-logging system.

**Time***

*Instrument*: Kinemetrics GPS Synchronized clock, Model GPS-DC.
*Logging*: 60 second intervals.

**Speed and Heading***

*Instrument*: Furuno CI-30 2-axis doppler speed log.
*Logging*: 3 second intervals.
*Checking*: Visual check of plot of data.
*Smoothing*: Mean value of all good values within the same minute.

**GPS Satellite Fixes***

Primary navigation was from Trimble NT200D and Magnavox MX4200D Global Positioning System (GPS) receivers. Good GPS navigation generally was obtained for 24 hours per day. Dead reckoning based on Furuno speed and heading data was used to cover any small gaps in the GPS navigation.

*Instruments*: Magnavox 4200D and Trimble NT200D Global Positioning System receivers.
Note: The data sets "gp3" and "gp4" are from the two Magnavox receivers, and the data set "gp1" is from the Trimble receiver.
*Logging*: 1 second intervals, decimated to 10 second intervals
*Checking*:
- -minimum number of sats: 3
- -dilution of precision (DOP) maximum: north-4.0, east = 4.0
- -compare GPS speed and course with Furuno smooth speed and heading
- -reject fixes producing Eotvos correction errors in gravity

*Interpolation*: Interpolated positions at 00, 30 seconds of each minute.
*Smoothing*: Smoothed interpolated positions with 41-point running average.
*Notes*: The GPS data has a sinusoid-like wave which appears to come from DoD degradation of GPS quality (dithering) for civilian consumption. This wave seems to vary in period and shape and is not a perfect sine curve. The periods are less than 20 minutes. The amplitudes and period vary over 24 hours but they always seem to be present in the data. This degradation produces a false ship's track for real-time navigation and introduces extreme errors, up to 5 mGals, in Eotvos correction for the gravity. To handle this problem the following steps have been used to process the GPS:

1. The smoothing has been increased from a 9-point (4 minute) running average of the interpolated positions to a 41-point (20 minute) running average.
2. This smooth GPS data is deleted at turns because the heavy smoothing greatly "widens" the turns.
3. The remaining smooth GPS data is decimated to 20 minute intervals.

These GPS processing steps, together with using the smooth speed and heading data from the Furuno for dead reckoning between the decimated GPS positions, produces good navigation and gravity data.

**Navigation***

A "1-minute navigation" was produced from the shipboard GPS and Furuno sources. The smoothed speed and heading data are used to fill the gaps between the processed GPS position by computing 1-minute dead-reckoned position corrected for set and drift. The dead-reckoned positions are produced at 00 seconds of each minute.
Note: Final navigation used the Magnavox 4200D "gp3" data set.

**Center-Beam Bathymetry* (see Figure 3)**

*Instrument*:  Atlas Hydrosweep DS
*Logging*:  Every ping.
*Sound velocity*: Center beam depths were recalculated using the traveltimes and a sound velocity of 1500 meter per second.
*Checking*:  Visual check of plot of data.  Bad data points removed with an interactive graphics editor.  The beam-point editing was done by Elizabeth Jackson in two iterations.  Iteration 1 - First pass through beam-point data, ping-by-ping, eliminating obviously bad data points.  Iteration 2 - The edited data were plotted as swath plots, and these plots were checked for further errors; identified errors were then flagged in a second pass of the beam editing with interactive graphics editor.
*Final data*:  Interpolated depth value (meters) at 00 seconds of each minute.

**Magnetics* (see Figure 4)**

The magnetic field was recorded using a Varian 75 magnetometer with a bottle towed nominally 280 meters behind the GPS antenna on the ship.  Digital recording was provided by the LDEO data logging system, and a paper strip chart record was also obtained.  Aside from some noise during the initial startup, the magnetometer performed well throughout the cruise.

*Instrument*:  Varian V75 magnetometer.
*Logging*:  6 second intervals.
*Checking*:  Visual check of plot of data.  Bad data points removed with an interactive graphics editor.
*Reference field*:  International Geomagnetic Reference Field 1995 (IGRF 1995) model of the main field at 1995.0 and a predictive model of the secular variation for adjusting to dates between 1995.0 and 2000.0
*Final data*:  Median values at 00 seconds of each minute calculated from the values +- 30 seconds of this time.

**3-Component Magnetometer**

The 3-component magnetometer, its operation, and preliminary results from the survey are described in Appendix I.

**Gravity***

Gravimeter

The gravity field was recorded on a BGM-3 gravimeter. Performance was excellent and trouble-free.

*Instrument:* Bell Aerospace BGM-3 marine gravity meter.
*Logging*: 1 second counts.
*Filtering:* An observed gravity value in mGal is calculated by filtering the 1-second counts with a 360-second Gaussian filter, scaling the result, and adding a bias. A value in mGal is calculated for 00 seconds of each time.
*Merge with navigation:* Calculate Eotvos correction and Free Air Anomaly. The velocities (from the navigation) that are used in the Eotvos correction are smoothed with a 5-point running average for all days.
*Checking:* Visual check of plot of data to determine satisfactory Eotvos corrections; delete spikes of data at turns.
*DC shift:* 23.5 mGal.
*Final data provided by LDEO*: Free Air Anomaly value at 00 seconds of each minute. 1980 theoretical gravity formula.

The first gravity tie of the ship gravimeter was made on 10 July 1996 by LDEO Science Officer Joe Stennett at a dock tie-point in San Juan, Puerto Rico. A second gravity tie will be carried out by Stennett in St. Johns on 17-18 August 1996. It is expected that the total drift of the BGM-3 gravimeter will be less than 0.5 mgal for the entire 37-day cruise.

The gravity base stations in San Juan, Puerto Rico and St. Johns are not corrected for the 13.6 mgal "Potsdam Error". We therefore use the 1980 international formula in calculating the free-air anomaly, because this formula has a built-in correction for the Potsdam error.

Free-Air Anomaly

The raw gravity data were reduced to free-air anomaly (FAA, Figure 5) by Bill Robinson using the LDEO software "m_grv.c". This Eotvos reduction process corrects for artificial gravity effects due to changes in ship course and speed:

$$eotvos\_corr=7.5038*vel\_east*\cos(lat) + 0.004154*vel^2$$

where vel is ship speed in knots and vel_east is eastward velocity. These velocities were derived from a smoothed GPS and Furuno navigation using software developed by Bill

Robinson. Preliminary examinations revealed that the RMS cross-over error for the 12 cross-over points of ship tracks is less than 1 mgal.

The FAA was also corrected for a regional field based on a 1980 theoretical gravity formula:

$$gtheo=978032.7*[1.0+0.0053024*\sin^2(lat) - 0.0000058*\sin^2(2*lat)]$$

We note that the "m_grv.c" software also contains an option for the 1967 formula:

$$gtheo=978031.846*[1.0+0.005278895*\sin^2(lat) - 0.000023462*\sin^2(2*lat)]$$

and the 1930 formula:

$$gtheo=978049.0*[1.0+0.0052884*\sin^2(lat) - 0.0000059*\sin^2(2*lat)]$$

It appears that earlier LDEO cruises have used the 1967 and 1930 formula in calculating free-air anomalies. Since the 1980 formula differs by a constant from the 1930 formula, it is important to check the formula used in a specific LDEO survey when merging it with our current study.

Mantle Bouguer Anomaly

The primary purpose of this gravity survey is to determine the distribution of crustal and mantle density beneath the evolving ridge segments. To reveal the more interesting sub-seafloor density features, Jian Lin reduced the free-air anomaly to the mantle Bouguer anomaly (MBA) by removing the gravity effects of water/crust and crust/mantle interfaces. This modeling approach follows that of previous three-dimensional gravity mapping of Kuo and Forsyth (1988) and Lin et al. (1990).

The mantle Bouguer corrections were made based on Hydrosweep bathymetry data collected during this cruise. The gravitational effects of the topographic relief at the sea surface were calculated using a Fourier Transformation spectrum method of Parker (1972). The initial model assumes a 6-km constant-thickness crust and constant densities for water (1030 kg/m3), crust (2700), and mantle (3300). The mantle Bouguer anomaly directly reflects the deviations from this simple model.

Digital bathymetry in a region (46°-41°W, 24°-27.5°N) was reformatted into a uniform grid by Jian Lin using GMT software, with longitude and latitude spacings of 0.840144 and 1.08691 km, respectively. Several test calculations were carried out, which show that the chosen spacings were adequate in accurately modeling the gravity effects at the sea surface.

For every free-air anomaly measurement g_faa at point P (long, lat), we calculated the mantle Bouguer gravity effect c (long, lat). The mantle Bouguer anomaly at point P is then obtained as

$$g\_mb=g\_faa - c\ (long,lat)$$

Approximately 39,105 points of good free-air and mantle Bouguer anomalies were obtained using the above method. The mantle Bouguer anomaly increases away from the ridge axis at an average gradient of 0.28 mgal/km.

Thermal Correction and Residual Mantle Bouguer Anomaly

Jennifer Georgen performed a theoretical calculation of gravity effects due to 3-D lithospheric cooling using the crust age map of Mueller et al. (1992). Subtraction of lithospheric cooling effects from mantle Bouger anomaly yields residual anomaly. There are significant local residual anomalies (up to 40 mgal) within and across the ridge segment corridors, corresponding to up to 3-4 km variation in model crustal thickness. These anomalies will provide important constraints on models of crustal tectonics of the Mid-Atlantic Ridge.

**Hydrosweep**

Description

Hydrosweep is a 15-kHz multi-narrow-beam echosounding system that maps a seafloor swath nominally equal to twice water depth. For each insonification of the bottom, the system measures the round-trip travel times of 59 beams (29 port, 29 stbd, and 1 at nadir), each of approximately 1.5 degrees angular width athwartships, and estimates the depths. The system also logs echo amplitude and duration. An average sound velocity for the water column is used to convert the two-way travel times to estimates of depth and distance across track. The real-time processing estimates a depth, and cross-track distances do not take into account raypath bending due to variations in sound speed.

Throughout the cruise Hydrosweep cycled at its own rate, independent of HMR1. During our 1992 cruise, Ewing 9208, it was found that Hydrosweep calibration pings (directed fore and aft) produced noise on the HMR1 records. Thus, these calibration pings were disabled throughout the Ewing 9606 cruise.

Performance

The Hydrosweep during Ewing 9606 produced a narrower-than-expected swath of multibeam bathymetry, typically ranging between 1.5 and 1.7 times water depth and averaging ~1.6 times water depth (these values were measured from typical swath plots on maps). Beam drops (zero values recorded by the Hydrosweep system) averaged 7.4% throughout the survey, compared to an average of about 5.4% during the Ewing 9208 MARWEST survey (Figures 6, 7). Beam flags (bad data points identified during beam-point editing) averaged about 5.4%, compared to ~6.4% during Ewing 9208. The majority of the drops and flags were in the outer beams on both port and starboard sides (Figure 8). Compared to the Ewing 9208 data (Figure 9), the Ewing 9606 data show a strong increase in drops and flags in the outer 6-7 beams on each side, but better data return on the inner beams. As a result, the Hydrosweep returned 87% "good data" on Ewing 9606, compared to 88% "good data" on Ewing 9208. In port beams 14-22, it was not uncommon during the present cruise to observe "gopher holes" (anomalously deep values) which had to be flagged. This problem in beams 14-22 has been a persistent phenomenon over the history of the Hydrosweep system on Ewing; it also appears to a much lesser extent in the conjugate beams on the starboard side of the array.

Bathymetry Processing

*Sound-Velocity Corrections*

The bathymetry and range information generated by the Hydrosweep DS system are computed from travel times and angles combined with a mean sound velocity for the entire water column. While this yields satisfactory results for real-time display purposes, a more precise solution can be obtained by using a layered-model approach to correct for raypath bending. In order to use this technique, it is necessary to first construct an accurate sound velocity profile (SVP). This was accomplished using data from the Levitus database of temperature and salinity profiles for the geographic area of the survey. The SVP used in processing consisted of the mean of twenty-five Levitus profiles. The standard deviation of these profiles was generally less than 1 meter per second. This SVP was input to the program "mbbath," a part of the MB-System suite of programs used for processing multibeam data.

In order to validate the database values, a series of expendable bathythermograph (XBT) probes was taken at various points during the survey. The temperature values generated were then used to compute a new SVP, which was compared with the SVP generated from Levitus data. The XBT derived SVP generally agreed with the Levitus derived SVP on the order of +/- 2 meters per second.

*Roll and Pitch Bias*

In order to compensate for the discrepancy between the mounting of the Vertical Reference Unit (VRU) and Hydrosweep DS transducers, it is necessary to add a Roll and Pitch Bias value into the Hydrosweep system. The Roll Bias is determined by surveying across a patch of sea floor with a constant slope, using pairs of survey lines in opposite directions. The difference in slope in opposite directions is twice the Roll Bias. Previous testing on EWING resulted in determination of a Roll Bias of +0.15 degrees, which was entered into the Hydrosweep processor.

The Pitch Bias is determined by surveying up and down a constant slope. The offset between uphill and downhill isolines is used to determine the Pitch Bias. Previous testing on EWING resulted in determination of Pitch Bias of +1.67 degree, which was also entered into the Hydrosweep processor.

*Time Corrections*

The time associated with each ping is set by the Hydrosweep processor, which is fed the correct UTC time from the Lamont data logging system. The host computer that performs this function receives time updates and corrections via a GPS-based clock. No further corrections to the Hydrosweep ping time are anticipated.

*Shingling*

One artifact that appears in Hydrosweep bathymetry data, most notably when surveying over a flat bottom, are small errors in depth that seem to be consistently present in specific beams. The term "shingling" has been coined to describe this artifact, since when the affected data is viewed, particularly as a 3-dimensional, artificially illuminated surface, small ridges are seen that follow the ship's track and have the appearance of shingles.  The actual depth error seems to stay the same for any particular beam, suggesting some sort of consistent error for determining two-way travel times. In general, these errors visually appear to be in the 3 to 5 meter range, and do not seem to be depth dependent.

At present, there is no quantified, technical explanation for the cause of these artifacts, and thus they are difficult to correct objectively.  In practice, it is possible, via post processing, to apply a depth correction on a per-beam basis. However, determining the actual correction to be applied would require extensive, multiple survey lines over the flattest of terrain in a variety of water depths. Since these errors appear to fall inside the manufacturer's specification for system precision, it is unlikely that further improvements will be forthcoming.

Beam-Amplitude Data

In addition to the travel-time data generated for the determination of bathymetry, the Hydrosweep DS system produces an eight-bit amplitude value per beam, along with the echo length.

At present, there is no standard, established procedure for processing Hydrosweep amplitude data. During this cruise, an effort was made to utilize some of the existing processing routines within the MB-System software to see if any interesting results could be obtained. The following general steps were used:

(1) Amplitude data was "de-striped," using the the "mbfilter" program. This operation takes the form of a boxcar median filter, with dimensions of three beams and three pings.

(2) A table of amplitude versus grazing angle was obtained in order to adjust for increasing sea-floor grazing angles, using the program "mbackangle." Once the table was obtained, new amplitude values were generated using the program "mbanglecorrect."

(3) Another run of the "mbfilter" was then made on the angle-corrected amplitude. In this case, data in the nadir region (which in not entirely cleaned up for the specular reflection present in these beams) was removed, and then another median filter was applied, this time with additional high-pass and low-pass filters.

(4) The data at this stage still exists as along-track, swath data. As a final step, all of the individual lines of data were combined using the "mbgrid" program set for a weighted mean technique.

Figure 10 shows the results of processing six days worth of data. In a page-sized presentation, it is difficult to discern much in the way of detailed geology or texture. When plotted in a large format, the amplitude data could certainly be considered interpretable; that is, shades of grey can be roughly correlated with bottom topography, and possibly with some form of gross geological character. If a true sidescan sonar (such as the Hawaii MR-1 system) was not available, it might be worthwhile to allocate resources toward better processing techniques and the considerable processing effort needed for this data. For this particular cruise, with the high quality imagery obtained from the HMR1 system, such efforts are not justified at the present time.

**The HAWAII MR1 Seafloor Mapping System**

Description

The HIG Acoustic Wide Angle Imaging Instrument Mapping Researcher 1 (HAWAII MR1, or MR1) is a shallow-towed, 11 kHz (port) - 12 kHz (stbd), phase-difference, split-beam sidescan sonar system designed to provide phase-derived bathymetry over a swath about 3.4 times water depth and 16-bit sidescan backscatter imagery over a swath up to 20 km wide. Quoted specifications for the system are that bathymetry at 50-m contour intervals should be reliable. Data are sampled at 1-ms intervals starboard and 11/12 ms port in slant-range, and continuously from the beginning of the ping until immediately before the beginning of the next ping. On each side, 500-1000 bathymetry samples (at ~10-20 m intervals) and ~2000 backscatter samples (at 5 m intervals) are produced and recorded. The system was operated full power. Pulse length was 10 ms during most of the survey. Real-time output consisted of imagery on a Raytheon TDU-850 grayscale printer, bathymetry on a color HP1200C printer, and display of both these on a Sun workstation. Data are stored on Exabyte 8mm tapes.

Operation

We towed the system at 8 knots through the water during the first few hours of the cruise and subsequently increased our speed through the water to an average of 9.8 knots and eventually 10 knots. Speed through the water during some intervals reached 10.2 knots, although we generally avoided these speeds. Towfish motion increased with increasing ship speed, although we did not find a noticeable decrease in the signal to noise ratio with increasing speed.

HMR1 was towed with approximately 590 meters of wire out. The resulting tow depths of the HMR1 vehicle at various survey speeds is given in the table below.

| Ship Speed (knots) | Turns | HMR1 Depth (meters) |
|---|---|---|
| ~6.0 | ~80-84 | ~169-175 |
| ~7.0 | ~96-97 | ~137-140 |
| ~8.0 | ~106 | ~116 |
| ~9.0 | ~120 | ~95-100 |
| ~9.8 | ~143 | ~85-90 |

Repetition Rate and Synchronization

The HMR1 repetition rate was set to 15 seconds throughout most of the survey, thus allowing acquisiton of 14.5 seconds of data per ping (~20 km total swath width). At the end of the survey, near the beginning of Line 107, the rep rate was decreased to 21 seconds, allowing recording of 20.5seconds of data and a total swath width of ~29 km.

HMR1 and the Hydrosweep were not synchronized, so each system operated independently of the other. Hydrosweep did not produce any noticeable noise on the HMR1 sidescan records.

HMR1 Data Processing

The following sections describe the general processing scheme for MR1 data. A detailed step-by-step description of each processing step and the parameters used is given as a separate appendix.

*Creation Of Angle-Angle Table*

MR1 bathymetry processing requires a look-up table to convert acoustic phase data to geometric angle. Geometric angle is used (with range) to calculate bathymetry across each ping. The look-up table (AKA angle-angle table, AA-table or flat-bottom table) is determined empirically, and takes into account the local water-velocity structure. The best way to generate an angle-angle table is to survey a flat area of seafloor. Sometimes this isn't possible early in the survey (or at all), and in these cases we use a statistical approach that involves binning multiple data files in order to approximate a flat seafloor.

The process of creating an angle-angle table involves collecting some data, generating bottom-detects for the data, and then running a program called STACK8 on the raw MR1 data. STACK8 creates separate AA tables for the port and starboard sides, which are subsequently used by program BTYP to generate bathymetry from raw MR1 data. This strategy empirically accounts for sound-velocity variation in the water column, and therefore standard MR1 processing does not involve other measurements of the water-velocity structure. A caveat of this technique is that a new AA table is required if the velocity structure changes spatially or temporally.

The angle-angle tables used for the initial processing of MR1 data during Ewing cruise 9606 were generated in flat areas near Puerto Rico during the previous cruise (Ewing 9605 immediately prior to Ewing 9606). Final AA tables for MR1 Tows 1 and 2 were created using the statistical approach outlined above, and were based on data from lines 32 and 34 (22 hour files total). The third MR1 deployment required a different set of AA tables to account for an additional 2.2 degrees of towfish roll (on average) relative to the first two tows. These tables were generated using the statistical approach on data from lines 56 and 58 (36 hour files total).

*Creation Of AVG Correction Table*

MR1 sidescan data require an Angle Varying Gain (AVG) correction to account for variations in intensity away from nadir that result from the shape of the acoustic beam pattern. To generate AVG correction tables, MR1 data are processed through BTYP to generate sidescan, and then processed using program MRAVG to generate a correction table that can subsequently be applied to these and other data. The corrections are determined by computing the average intensity value for all sidescan values falling within each 0.1-degree angle increment between nadir and the outer swath edge. Port and starboard sides are treated independently. The correction factor for a given angle is the ratio of the average intensity for that entire side to the average intensity for the angle in question. Once an appropriate AVG table is created it can be applied to all the processed MR1 files using MRAVG.

The AVG correction is depth dependent, and different correction curves were calculated every 200 m between 1000 and 6000 m, using data from Julian days 198 through 203. These corrections were applied to the entire data set, except line 104, which used a 21-second repetition rate and therefore requred corrections that extended to greater angles. Data from line 104 were processed to produce the AVG table for this last line.

Data processing for Ewing 9606 involved the steps described below.

*Program BTYP (Bathymetry and sidescan)*

BTYP generates bottom detects, bathymetry and sidescan from raw acoustic data, and writes the output in University of Hawaii MR1FILE format. Bottom detects are displayed graphically as a time series that can be interactively viewed and edited by a data processor. The quality of bottom detects is judged based on the near-nadir behavior of sidescan images generated using the bottom-detect time series. Sidescan data were generated using a flat-bottom assumption and assuming a constant speed of sound in water of 1500 m/sec. Travel times are converted to ranges and then to horizontal distance from nadir using the assumed seafloor depth.

When the bottom-detect data are considered to be correct, BTYP is used to generate bathymetry from the raw phase data. Occasionally rows A and B record each other's raw acoustic data, resulting in bathymetry pings that are out of phase by approximately 90 degrees. These points are visually evident and are interactively "flipped" by the HMRG data processors. Bathymetry and sidescan data are written to separate files for independent processing.

*Program MRNAVM (Bathymetry and sidescan)*

Ship navigation was merged into the headers of MR1 data files using the program MRNAVM. Ewing navigation was provided on a daily basis at sea by Bill Robinson. The ship-to-fish distance was estimated using the wire out and average depth of the towfish, and is based on a reference frame centered on the ship's GPS antenna. The approximate horizontal distance between the antenna and the towfish was 630 m, and a time offset of 125 seconds was used to estimate the position of the towfish throughout the survey. The HMR1 vehicle was assumed to follow exactly in the ship's track

*COMPASS filtering (Bathymetry and sidescan)*

To account for variations in towfish yaw, towfish compass data are incorporated into the positioning of individual depth soundings and sidescan measurements. MR1 files contain the towfish heading at the transmit time for each ping. This information is passed through a routine that removes spikes from the time series, applies a median filter, and then accounts for local magnetic declination. The resulting towfish heading information is stored in the headers of MR1 files, and is used by subsequent MR1 programs (MR2GMT and MRGRID) that assign latitude and longitude positions to individual ss/bathy data points.

*Program MR2GMT (Bathymetry)*

We commonly use the Generic Mapping Tools (GMT) software suite (Wessel and Smith, 1994) to grid, filter, and display bathymetry data. The HMRG program MR2GMT is used to produce ascii (x,y,z) triplets that can be used by GMT.

*Program MRDEMICROSTRIPE (Sidescan)*

This program identifies and replaces (or flags) stripe noise in sidescan data, where stripe noise is defined as any ping or part of a ping that differs in average intensity from neighboring data within the same ping or adjacent pings. Since MR1 sidescan amplitudes are not linearly distributed, the default behavior of MRDEMICROSTRIPE is to perform a histogram equalization of the data before scanning for stripe noise. Stripe noise detection is a two-step process. First, each sample within a ping is compared to the average of nearby samples from adjacent pings. If the sample exceeds a user-specified tolerance of this average, it is flagged as being either too low or too high. Second, an examination of these sample flags is made, and if the number of flagged samples within a given ping exceeds a user-specified tolerance, the entire ping is considered to be stripe noise. If this tolerance is not exceeded, the flagged parts of a ping are evaluated to determine if they constitute consecutive high or low values (a microstripe within the ping). Stripe noise thus identified can be flagged or replaced. The default replacement operation attempts to scale stripe noise samples either up or down into the same range as the intensities of samples in the sample neighborhood, which is desireable when striping is caused by momentary variations in towfish attitude which result in sequences of samples that are out of scale but not totally meaningless. In cases where stripe noise is pure noise and rescaling isn't appropriate, the preferable alternative is to replace stripe noise with the average of the samples in its neighborhood. If histogram equalization is in effect, the averaging is performed in histogram-equalized space and an inverse mapping to the original sample intensity domain is applied.

1. Speckle bands

Cruise Ewing 9606 data contains a quasi-periodic noise pattern characterized by groups of pings (5-9 pings long) that contain higher-than-normal speckle noise. These groups of noisy pings occur every 2.5 to 3.0 minutes along track. The source of the noise is unknown, but it may be related to ship speed. The amplitude of the noise decreased when ship slowed down, and the frequency of the noise increased going around clockwise turns, and the frequency of the noise decreased going around counterclockwise turns.

The speckle noise within the bands can be identified and replaced using a filter that is long in the along-track direction and short in the across-track direction. Initial attempts using MRDESPECKLE were unsatisfactory because even the most selective filters still flagged "good" pixels, and the replacement algorithm (a median filter) resulted in overly smooth output.

A better approach was found using MRDEMICROSTRIPE. By defining the search and replacement parameters so the filter shape was long in the along-track direction and short across-track, an appropriate filter shape could be formed. Demicrostripe also features a more selective means for flagging pixels, which allowed parameters to be defined that focus on the characteristics of the noise without flagging "real" data. Another appealing feature of MRDEMICROSTRIPE is its ability to change the value of a flagged pixel by scaling it to the approximate amplitude of its neighbors, rather than replacing it with some median value. The parameters used by MRDEMICROSTRIPE for this application are:

High threshold: ................................................100
Low threshold ..................................................100
Ping neighborhood...............................................3
Sample neighborhood ...........................................0
Full strip percentage...........................................85
Trigger length.......................................................2
Test window length..............................................2
Test window percentage ...................................100
Minimum microstripe length ...............................2

Replacement mode .......................................scale

2. Low-amplitude stripes

Data from cruise Ewing 9606 also contained pings that exhibit a low amplitude relative to their neighbors. This type of striping is often caused by rapid variations in towfish yaw (heading), a condition known to exist in tow 3 when the system was running with a 300 m drogue line. Low-amplitude stripe noise was identified and accounted for using MRDEMICROSTRIPE using the following parameters:

High threshold: ....................................................0
Low threshold ....................................................60
Ping neighborhood ...............................................3
Sample neighborhood ........................................15
Full strip percentage...........................................85
Trigger length.......................................................5
Test window length..........................................200
Test window percentage ....................................65
Minimum microstripe length ...........................200
Replacement mode .......................................scale
Replacement sample neighborhood .....................3
Replacement constraint margin ......................3

*Program MRAVG (Sidescan)*

MRAVG is used to generate and apply the Angle Varying Gain (AVG) correction, which removes track-parallel intensity variations caused by the shape of the acoustic beam pattern. At this stage in the processing pipeline we simply applied the AVG correction generated earlier.

*Program MRGRID (Sidescan)*

This is the program we use to grid MR1 data. Due to the large amount of time required to grid MR1 data, the gridding stage is separate from the subsequent gray mapping and display stage. MRGRID creates a series of subset grids defined by the geometry of the towfish trackline, and differentiates straight sections, port and starboard side of the swath, and inboard and outboard turns. The relationships of each subgrid are recorded in a control file that allows different parts of the swath to be overlain, underlain or suppressed when the grids are imaged later.

*Program MROVL (Sidescan)*

MROVL applies a gray-scale or color look-up table to gridded MR1 data, and writes output as a Sun raster image. The program uses a control file generated by MRGRID to establish whether or not a given grid subset is to be displayed, and in cases where different swaths overlap, it establishes the order of superposition of grids.

During the survey, sidescan data were processed on a line-by-line basis, and were gridded and plotted at 1:400,000 scale Mercator projection. Final hardcopy deliverables will be at 1:200,000.

<u>Performance</u>

The HMR1 system performed well overall. The vehicle had to be recovered twice, once for electronics repair and once to recover and replace a broken drogue line. Vehicle motion clearly is increased when a 300-m, rather than a 500-m, drogue line is used; however, we did not feel that a third recovery of the vehicle to install a 500-m drogue was justified, considering the time and the possible risks that this would have entailed. The main problem with the HMR1 data was the persistent occurrence of periodic noise, discussed elsewhere in this report. Processing removed much of this noise, and the noise is most prominent in the outer parts of the sidescan swath where we have overlapping coverage. Thus the occurrence of the noise did not have significant impact on the overall success of the survey.

**3.5-kHz Profiler**

Echosounding with hull-mounted EDO 3.5-kHz transducers (12-bottle array), an EDO 550 transceiver, and a 10 kW booster was conducted continuously throughout the cruise. Profiles were recorded on an EPC 9800 Thermal Plotter using an ungated 1-sec sweep. The hardcopy profiles were recorded on a plasticized medium, in roll form, and then accordion folded and stored in large envelopes for easy access. The original records were taken to Woods Hole Oceanographic Institution for analysis and archiving.

During the cruise, Karen Worminghaus and Ian Malin identified sediment ponds from the records, recorded their locations (by times) and their characteristics, and plotted the results on 1:200,000 track maps. The data picked from the 3.5-kHz records were written in a logbook (archived at WHOI) and they also were keypunched to make digital files for later manipulation and plotting. Characteristics recorded include: observed sediment thickness (limited to penetration of signal, or by basement depth), attitude of sediment surface (flat, slanted, hummocky, wavey), and character of subbottom (laminated, etc.).

## RECOMMENDATIONS - EWING CRUISE 96-06

### Hydrosweep

The effective swath width of Hydrosweep data is 1.5 to 1.7 times water depth, averaging about 1.6 times water depth. The Ewing User's Manual advertises the Hydrosweep system as mapping 2x water depth, and this should be corrected in the manual.

### HMR1

HMR1 produces sidescan data of visually good quality at survey speeds of 10 knots. It was noticed that towfish motion increased at higher speeds (sinuous track), but this could be corrected for with the vehicle compass data and might be attenuated with a longer drogue line (500 m versus 300 m). We found that any degradation in data quality appears to be minor and is more than offset by the survey time gained at the higher speeds.

It was found that the 300-meter drogue line did not damp HMR1 vehicle motion as effectively as the 500-meter drogue. We recommend that a 500-meter drogue be used as standard equipment in the future.

The source of the periodic noise on the HMR1 sidescan-sonar records has not been identified. The cause of this noise needs to be determined and corrected.

## ACKNOWLEDGMENTS

Ewing Cruise 9606 was supported by the National Science Foundation. We are greatly indebted to the HMR1 staff, the LDEO technical support team, and the scientific party who all contributed to the success of the cruise. We also thank the crew of R/V Ewing for their assistance and professionalism that contributed significantly to a successful field program.

## APPENDIX I - METHOD OF MAGNETIC VECTOR FIELD MEASUREMENT

(Tomoko Tanaka)

### INTRODUCTION

Vector data of the geomagnetic field were collected with the Shipboard Three Component Magnetometer (STCM) during the EW9606 cruise by the R/V Maurice Ewing. The vector magnetic data provide more useful and detailed information than total intensity data in order to obtain the magnetic structure of the oceanic crust. One of the advantages of this measurement is that the amplitude of vector magnetic anomalies is not affected by the direction of the ambient geomagnetic field and the strike of magnetic lineations. The STCM system has been developed and improved since 1977 (Isezaki et al., 1981; Isezaki, 1986; Seama et al., 1990). It has been used in many oceanic areas successfully to measure the geomagnetic vector field (e.g. Seama and Isezaki, 1990; Nogi et al., 1990; Seama et al., 1993). The geomagnetic field observed by the STCM is superimposed on the magnetic field produced by the induced and permanent magnetic moments of the ship. The ambient geomagnetic field vector is calculated by reducing those artificial magnetic fields. For this calibration, we ran the ship along a track in a figure "8" at 7 locations during this cruise. In this chapter, we present a method of the magnetic vector field measurement by the STCM.

### PRINCIPLE OF MEASUREMENT

A magnetic field vector, $\mathbf{H}_{ob}$, observed on board consists of the ambient geomagnetic field, $\mathbf{F}$, and the magnetic fields produced by the induced and permanent magnetic moments of the ship. Thus these magnetic fields are represented as follows:

$$\mathbf{H}_{ob} = \mathbf{F} + \mathbf{H}_i + \mathbf{H}_p \qquad (1)$$

where $\mathbf{H}_i$ and $\mathbf{H}_p$ are the fields due to the induced and permanent magnetic moments. Since $\mathbf{F}$ is a weak field, the induced magnetic field $\mathbf{H}_i$ is proportional to $\mathbf{F}$. (When the ambient magnetic field is weak, the induced magnetic moment is proportional to the field. Because $\mathbf{H}_i$ is proportion to the induced magnetic moment, $\mathbf{H}_i$ also has a linear relation to the ambient field.) Therefore equation (1) can be rewritten as;

$$\mathbf{H}_{ob} = \mathbf{F} + \mathbf{AF} + \mathbf{H}_p \qquad (2)$$

where $\mathbf{A}$ is a 3x3 constant matrix including the sensors' location and the ship's magnetic susceptibility distribution.

Equations (1) and (2) have been presented in the geographic coordinate system. Next, we will show the above relation for an equation in the ship's coordinate system, because the sensors are fixed to the ship (Figure 1). The ship's coordinate system axes are along the heading, starboard and downward directions, respectively. Two gyro-compasses (a horizontal gyro-compass and a vertical gyro-compass) provide yaw, roll and pitch data of the ship. Equation (2) can be expressed in the ship's coordinate system using those ship's attitude data.

$$\mathbf{H'}_{ob} = (\mathbf{RPY})\mathbf{F} + \mathbf{A}(\mathbf{RPY})\mathbf{F} + \mathbf{H'}_{p} \qquad (3)$$

where $\mathbf{H'}_{ob} = (\mathbf{RPY})\mathbf{H}_{ob}$, and $\mathbf{H'}_{p} = (\mathbf{RPY})\mathbf{H}_{p}$. **R**, **P** and **Y** are coordinate transform matrices due to the roll, pitch and yaw of the ship. From equation (3),

$$\mathbf{F} = (\mathbf{RPY})^{-1}((\mathbf{1} + \mathbf{A})^{-1}\mathbf{H'}_{ob} - (\mathbf{1} + \mathbf{A})^{-1}\mathbf{H'}_{p})$$

$$\mathbf{F} = (\mathbf{RPY})^{-1}(\mathbf{BH'}_{ob} + \mathbf{H'}_{pb}) \qquad (4)$$

where $\mathbf{B} = (\mathbf{1} + \mathbf{A})^{-1}$, and $\mathbf{H'}_{pb} = -(\mathbf{1} + \mathbf{A})^{-1}\mathbf{H'}_{p}$. Note that $\mathbf{H'}_{ob}$ and $\mathbf{H'}_{pb}$ are expressions in the ship's coordinate system and **F** is in the geographic coordinate system. If 12 constants, **B** and $\mathbf{H'}_{pb}$, are known in equation (4), **F** can be obtained from the observed magnetic field and ship's attitude data.

The transform matrix $\mathbf{B} = (B_{ij})$ and $\mathbf{H'}_{pb} = (H'_{pbh}, H'_{pbs}, H'_{pbv})$ can be defined where the data $\mathbf{H'}_{ob}$ are obtained in all directions. In practice the data for determining the transform matrix are collected while the ship sails along a track in a "figure-8". There are 12 unknown values (9 in **B** and 3 in $\mathbf{H'}_{pb}$) that are determined by the least squares method. The yawing angle varies from 0° to 360° while the rolling and pitching angles typically vary only between -10° to 10° during the calibration. Therefore $B_{i1}$ and $B_{i2}$ are determined better than $B_{i3}$ and $\mathbf{H'}_{pbv}$. To correct this defect, several figure-8 rotations are needed at places with varying downward components of the geomagnetic field.

## INSTRUMENT AND DATA ACQUISITION

The STCM system used in this cruise consisted of a flux-gate magnetometer, two horizontal gyro-compasses, a personal computer, a vertical gyro-compass and a navigation system (Figure 2). The flux-gate magnetometer, one of the horizontal gyro-compasses and the personal computer belong to Chiba University. The other instruments were provided by the ship. The flux-gate magnetometer was a Gauss SMG-811. The magnetometer sensors consisted of three-axial flux-gate coils. The magnetometer measured individual x, y and z components of the magnetic field with resolution of 1 nT. The gyro-compasses gave information about a ship's attitude. The horizontal gyro-compasses (Tokyo-Keiki ES11-A and SPERRY MK27) provided yaw data with resolution of 0.01° and 0.1°, respectively . The gyro transmission signals of the ES11-A (Chiba Univ.) were converted to digital data outputs by an interface of the SMG-811. Furthermore, the signals were transfered to the PC through a parallel I/O interface. The vertical gyro-compass (HIPPY) provided roll and pitch data with resolution of 0.1°. The navigation system was a hybrid system consisting of a GPS (Magnavox42000), a speed meter, gyro-comapsses and so on. The navigation data included date, time, latitude and longitude of the ship. The personal computer (NEC PC9801ns) collected in real time the magnetic field data (x, y, z), the yaw data and the navigation data via the parallel I/O and one RS-232C interfaces. A magnetic optical disk drive (MO3120) was connected with the PC9801ns.

The magnetometer sensor package was rigidly mounted on the upper deck (flying bridge) of the ship. The sensor package consisted of a transparent cylindrical case including the flux-gate sensors atop an aluminum bar with a height of 2 m; the bar stands on the deck and is fastened to a handrail. A sensor cable was 30 m long. The magnetometer, the horizontal gyro-compass (ES11-A) and the PC were installed in the main laboratory. The R/V Maurice Ewing provided AC 120V power supplies. A downstepping transformer was used to get AC 100V power for our instruments (made in Japan).

The observed data included x, y and z components of the magnetic field, yaw, roll, pitch, date, time (GMT), latitude and longitude. The x, y, z, yaw, roll and pitch data were sampled every 1 second. The navigation data were collected every 1 minute. The above data were stored on a magnetic optical disk (MO disk) in a TEXT format. The file name for the observed data was "960?????" . The data size was 3.9402 MB/day. Those data were logged using "EW3.B" written in BASIC language.

## ON-BOARD DATA PROCESSING

The observed data were processed on board in order to obtain the preliminary results of magnetic vector anomalies. Figure 3 shows a flow chart of the data processing. After calibrating and removing the magnetic contribution of the ship and substracting out the reference field, vector data of magnetic anomalies were corrected for white noise (high frequency component) and a linear trend. Finally, the obtained magnetic anomalies were plotted on maps. This procedure followed a basic processing of the STCM data. Plotting programs were coded using GMT (Wessel and Smith, 1991 and 1995).

To calibrate the system, twelve constants in **B** and $\mathbf{H}'_{pb}$ in equation (4) were derived using all the data of figure-8 rotations in 4 calibration sites (No. 2 to No. 5). As we carried out 7 calibrations in total, the 12 constants will be recalculated after the cruise and all the data will be fully reprocessed. The calibration sites and the 12 constants are shown in Tables 1 and 2, respectively. The data of No.1 were corrupted by a faulty connection and were not processed. A program to calculate the constants was "b360.f". The other rotation data were made by a data logging program, "EW3.B", during the rotations. Those rotation data were saved as "R960???? ".

The geomagnetic field was derived from the magnetic field observed on board using the 12 constants and the ship's attitude data to remove the ship's magnetic effect. Magnetic anomalies were calculated by subtracting the International Geomagnetic Reference Field 1990, called IGRF 1990 (IAGA Division V, Working Group 8, 1990) from the obtained geomagnetic field data. This process was achieved by "calanoEW.f".

The magnetic anomaly data obtained in the previous process include a large variety of noise and some bias due to measurement error of the ship attitude, an assumption that the IGRF represents the ambient geomagnetic field in calibration sites, and the time variable effects of viscous remanent magnetization (VRM) of the ship (e.g., Seama, 1992; Yamazaki, 1994; Korenaga, 1995). We performed a filtering ("smooth1.f") and a trend-correction ("cuttrend.f") for the magnetic anomaly data sampled every 1 second in order to reduce the noise and the bias. The trend-correction was applied only to the filtered data along ship's tracks. Filtered, selected and trend-corrected magnetic anomaly data were saved as "W??.DAT", "L??.DAT" and "T??.DAT", respectively.

All the original observed data files were stored on two MO disks. The observed data files between 14 July to 16 August, the processed data files and the programs were stored on two additional MO disks. The programs, the texts and the figures which were made on board were also copied on floppy disks and an MO disk (MS-DOS format ).

Data from survey lines 1-14 were corrupted because of a faulty connection. After fixing this problem, there were no further problems with the instrument, and all subsequent lines (15-103) were succesfully processed. Preliminary results are shown in Figure 4.

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## FIGURE CAPTIONS

Figure 1. The geographic coordinate system (x,y,z) and the ship's coordinate (h,s,v). $q_h$, $q_s$ and $q_v$ are heading, rolling and pitching angles, respectively.

Figure 2. Block diagram of the STCM system.

Figure 3. Flow chart of data processing on board.

Figure 4. Magnetic vector anomalies and total intensity anomalies along the ship tracks in the study area. Figures 4-a, -b and -c present x (north), y (east) and z (downward) components of magnetic anomalies, repectively.

# APPENDIX II - MR1 DETAILED DATA PROCESSING INFORMATION

(Bruce Appelgate)

**Cruise EWING 9606**

**Data Processors:**
Lisa Petersen
Lynn Johnson-Conrad
Bruce Appelgate

## 1. Load and verify acquisition tapes:

Read and verify the raw tapes:
On olomana:
tarx >& $VERIFY/tape_number.red
or (tar -xvf /dev/rmt/tps1d4nrnsv.8500 > & tape_number.color)
On malei:
tar tvf /dev/rst4 >& $VERIFY/tape_number.blue

Copy Log* files into $RAWLOG
Copy verification logs into $VERIFY

## 2. BTYP processing:

On olomana:
btyp filename -a ew9606.parms

Procedure:

a. Generate bottom detects
b. Generate sidescan and save as filename.ss
c. View sidescan in ssp and evaluate accuracy of bottom detects
d. Repeat a through c above until sidescan's OK
e. Save bottom detects
f. Generate and save bathymetry as filename.bty

Enter depth and btyp => bd parameters into the documentation files $DOC/bd.doc

## 3. Separate sidescan and bathymetry data into separate MR1 files:

When pau with btyp processing, strip the sidescan data out of the .bty files, and strip the bathymetry out of the .ss files.

In the $RAW2 directory (or wherever the files are) do this (you can cut & paste the whole block into your shell):

```
ls *bty > bty.files
foreach file (`cat bty.files`)
  echo "Processing file: "$file
  set f = $file:r
  mrtrim -a 90 0 90 0 < $file > $f.btyt
end

ls *ss > ss.files
foreach file (`cat ss.files`)
  echo "Processing file: "$file
  set f = $file:r
  mrtrim -a 0 90 0 90 < $file > $f.sst
end
```

View a couple files with btyp/ssp to make sure the stripping worked OK, then change the names of the stripped files back to .ss or .bty:

```
$SCRIPTS/replace .btyt .bty
$SCRIPTS/replace .sst .ss
```

**4. Move the processed files out of the $RAW2 directory into the appropriate day directories.**

```
mv *ss  $SSRAW/ssr---   (where --- is the julian day number)
mv *bty $BTYR/btyr---   (where --- is the julian day number)
mv *bd  $BD
```

**5. Navigate the files:**

*5.1. Get nav and other shipboard geophysical data from ewing computer:*

```
> cd $NAV
> ftp hess
ftp> cd /net/hess/science/data
ftp> prompt
ftp> mget *225
ftp> quit
```

Key:
  fu.s***        Furuno speed and heading

| | |
|---|---|
| hb.r*** | hydrosweep center beam data after "cleaning" |
| hb.n*** | hydrosweep 1-minute center beam merged with navigation |
| mg.r*** | magnetics (total intensity) after cleaning stage |
| mg.n*** | magnetics median filtered at 1-minute, merged with navigation; reduced using 1995 IGRF |
| vt.n*** | gravity (FAA) at 1-minute, smoothed and EOTVOS corrected |
| ***.xt* | XBT xz data |

*5.2. Compress and move data to appropriate directories:*

```
compress hb* mg* vt* *xt*
mv hb*  $HS_CNTRBM
mv mg*  $MAG
mv vt*  $GRAV
mv *xt* $XBT
mv fu*  $NAV/raw
mv n.*  $NAV/raw
```

*5.3. Reformat ship's navigation to STAG kind:*

```
cd $NAV/raw
ewing2stag n.225 ../jd225.nav
furno2spd fu.s225 ../jd225.avgspd
cd $NAV
```

*5.4. Add recent nav to ew9606 and mr1 nav files:*

```
cp ew9606.nav ew9606.nav.old
cat jd225.nav >> ew9606.nav

cp ew9606.tow3.nav ew9606.tow3.nav.old
cat jd225.nav >> ew9606.tow3.nav
compress jd*nav
```

Make a new navigation plot showing the latest MR1 trackline:

```
cd $NAV
nplot L -46 -40 24 28 six

lpr ew9606.mr1_trax.ps
```

*5.5. Calculate and apply layback and merge navigation with sidescan data*

Use $SCRIPTS/navjob to navigate the sidescan files. The navigation merging requires a ship-to-fish horizontal layback measured in seconds. For ew9606, the layback is 125 seconds, based on the following calculation and empirical evaluation of the data.

wire out measured at winch ~ 103
distance from winch to stern ~ 2 turns
meters per turn ~ 5.84
Wire out ~ 590 m
depth ~ 93 m
Stern-to-fish horizontal distance ~ 582 m
Stern to GPS antenna ~ 48 m
GPS antenna to fish ~ 630 m ~ 0.34 nautical miles
Speed ~ 9.8 knots
Time delay ~ 0.34 x (3600/9.8) ~ 125 seconds

Check to make sure the suffixes used in the example below
(ss d n c) are correct.

```
cd $SSRAW/ssr225
ls MR*ss > navjob.files
navjob navjob.files ss ssn 125
```

Navigate the previous day's 23:00 file: change day designation in
command below

```
cd $SSRAW/ssr224
ls *23.00.ss > navjob.files
navjob navjob.files ss ssn 125
```

*5.6. Apply layback and merge navigation with bathymertry data:*

```
cd $BTYR/btyr225
ls MR*bty > navjob.files
navjob navjob.files bty btyn 125
```

**6. Smooth the towfish compass data:**

To correct for yaw variation in the towfish we use the compass data collected by the the MR1 towfish to correct the heading of the fish prior to creating navigated gridded data. The procedure involves stripping the compass data out of a processed MR1 file, running a median filter over the data and reinserting the smoothed data back into the MR1 file.

*6.1. Strip out compass data*

Use the script getcomp to strip out compass data from processed sidescan or bathymetry files. The script uses the MR1 program mrstrip.  In this example we'll use sidescan:

```
cd $SSRAW/ssr225
ls MR*.ss > getcomp.files
foreach file (`cat getcomp.files`)
    echo "Stripping compass data from file: "$file
    set f = $file:r
    mrstrp -compass < $file > $COMPASS/raw/$f.comp
end
```

*6.2. Make a control file to direct how the files are processed filtering*

```
cd $COMPASS
filtcontrol 225
```

The filtcontrol script writes a file called jd225.control in the directory you're working in.

*6.3. Create an executable job to filter the compass data.*

In the $COMPASS directory, execute the following:

General form...

```
make_filtcomp control_file_name filter_width year > jd###_filtcomp
```

For example...

```
make_filtcomp jd225.control 7 96 > jd225_filtcomp
```

Make the job runnable and then execute it...

```
chmod +x jd225_filtcomp
jd225_filtcomp >& jd225_filtcomp.log
```

The job calls a script called $SCRIPTS/filtcomp, which in turn runs the GMT program filter1d.

*6.5. Insert the filtered data into the processed sidescan files*

```
cd $SSRAW/ssr225 ls *ssn > recomp.files recomp recomp.files ssn ssnc
```

*6.6. Insert the filtered data into the processed bathymetry files*

cd $BTYR/btyr225 ls *btyn > recomp.files recomp recomp.files btyn btync

**7. Sidescan image processing using ssjob:**

Cruise ew9606 had a unique noise characteristic ("speckle bands") that required special processing using demicrostripe. The filtering pipeline that worked best is hard-wired into the script $SCRIPTS/ssjob, and involved two passes through mrdemicrostripe. To process a day's worth of sidescan data, run the following:

```
cd $SSRAW/ssr224
ls MR*ssnc > ssjob.files
ssjob ssjob.files ssnc ssdnc
```

To process a single file, try

```
cd $SSRAW/ssr223
ls MR19622323.00.ssnc > ssjob.files
ssjob ssjob.files ssnc ssdnc
```

The first arguement to ssjob is the input file suffix, the second is the output file suffix. Processing can be done before or after nav merging and/or compass filtering. If it is done in a different order, however you must adjust the suffix variables in the scripts above.

For detailed description of the sidescan processing, see the "COMMENTS" section at the end of the ssjob script (shown below).

Inspect the files using ssp, (or ssp.show.all) or the for-loop below and if they're OK move them to the approporiate $SSINT directory:

```
foreach file (`ls *ssdnc`)
    echo 'displaying' $file
    ssp $file
end

cd $SSRAW/ssr224
mv *d* $SSINT/ssi224
```

SSJOB script:

```
#ssjob file_list infile_suffix outfile_suffix
#
# Cruise ew9606 -- Tucholke: East flank of Mid-Atlantic Ridge, 26N
#
# Process sidescan using mrtrim, mrfill, mrdespeckle, mrdemicrostripe,
# mrdestripe, and mrtrim.  This takes your sidescan to an intermediate
# stage before final AVG corrections are applied.
#
# Requirements:
# 1. Run in the $SSRAW/ssr### directory (where### is the Julian day)
# 2. Needs to read an existing file list that contains the names of
#  the files to be processed.
# 3. Output files are given the suffix indicated by the second arguement
#  on the command line, and are written in the same directory you
#  executed the script in.
# 4. When you're pau, check the files visually and then move them to
#  the $SSINT/ssi### directory
#
# Parameters for each of the programs are hard-wired into the script.
# Don't change the parameters or the order the programs are run without
# careful testing.
#
# To check out your output, try using
# ssplot MR19520916.00.dddt  70000
#
# See comments at end of script regarding the parameters used and order
# of programs. For more info on parameters, check out the man pages for# the program
in question.

if( $1 == "h" || $1 == "help" ) then  echo " "  head -21 $0  echo " "  goto end endif

# Set up variables:

set flist = $1 set sufin = $2  set sufout  = $3

#demicrostripe parameters
# zap the ew9606 high-amplitude "banded speckles":  set lo1 = 100  set hi1 = 100
# zap low amplitude microstripes:  set lo2 = 10  set hi2 = 100

foreach file (`cat $flist`) set out = $file:r echo ' ssjob: ' $file `date`
    nice mrtrim < $file > tmp
    nice mrfill tmp                              \
```

```
    -sspm                           \
    -sssm                           \
     |                              \
    nice mrdemicrostripe        \
    -h                          \
    -dt $lo1 $hi1                   \
    -pn 3                           \
    -sn 0                           \
    -fsp 85                         \
    -tl 2                           \
    -twl 2                          \
    -twp 100                    \
    -mml  2                     \
    -drs                            \
    -rsn 1                          \
    -rcm 30                         \
     |                              \
    nice mrdemicrostripe        \
    -h                          \
    -dt $lo2 $hi2                   \
    -pn 1                           \
    -sn 15                          \
    -fsp 85                         \
    -tl 5                           \
    -twl 300                    \
    -twp 60                         \
    -mml  200                       \
    -drs                            \
    -rsn 3                          \
    -rcm 30                         \
     |                              \
    nice mrtrim > $out.$sufout

    /bin/rm tmp

end

goto end

# COMMENTS
```

1. Speckle bands

Cruise ew9606 data contains a quasi-periodic noise pattern characterized by groups of pings (5-9 pings long) that contain lots of speckle noise. These groups of noisy pings occur every 2.5 to 3.0 minutes along track, the end result in the sidescan being dark bands that extend across track every 2-3 minutes.

The source of the noise is unknown, but we suspect that it is related to speed. The noise amplitude decreased when ship slowed down, the frequency of the noise increased going around clockwise turns, and the frequency of the noise decreased going around counterclockwise turns.

The speckle noise within the bands can be identified and replaced using a filter that is long in the along-track direction and short in the across-track direction. Initial attempts using despeckle were unsatisfactory because even the most selective filters still flagged "good" pixels, and the replacement algorithm (median boxcar) resulted in overly smooth output.

A better approach was found using demicrostripe. By defining the search and replacement parameters so the filter shape was long in the along-track direction and short across-track, an appropriate filter shape could be formed. Demicrostripe also features a more selective means for flagging pixels, which allowed parameters to be defined that focus on the characteristics of the noise without flagging "real" data. Another appealing feature of demicrostripe is its ability to change the value of a flagged pixel by scaling it to fit in with its neighbors, rather than replacing it with some median value.

The end result was pretty appealing -- the filter preferentially selects pixels near the edge of the swath where the noise is most obvious, and doesn't effect the inner half of the swath where noise is not obvious. The filter does a remarkable job of leaving high-backscatter structures alone while effectively flagging and rescaling noise. To illustrate this, try looking at the files below using ssp in the "highlight" mode.

Test - Open 5 ssp windows on the same file using different parms...

```
ssp MR19620114.00.ss -a $RAW2/bruce.ssp.parms
```

Run demicrostrip module using highlight mode and parmeters...

```
-dt 100 xxx  (where xxx is 40,70,100,130,160)
-pn 3 -sn 0 -fsp 85 -tl 2  -twl 2 -twp 100 -mml  2 -drs
```

A good value for the high threshold is 100.

Now open 5 ssp windows on different files...
ssp MR19620100.00.ss -a $RAW2/bruce.ssp.parms
ssp MR19620105.00.ss -a $RAW2/bruce.ssp.parms
ssp MR19620107.00.ss -a $RAW2/bruce.ssp.parms
ssp MR19620108.00.ss -a $RAW2/bruce.ssp.parms
ssp MR19620109.00.ss -a $RAW2/bruce.ssp.parms

Run demicrostrip in highlight mode using parmeters above with...
-dt 100 100

Conclusion: these parameters look pretty good.

2. Run demicrostripe to remove low amplitude stripes. Low amp stripes tend to be relatively long.

Here's how to test...
ssp MR19620107.00.ss -a $RAW2/bruce.ssp.parms
- Remove "band noise" using demicrostripe parms above
- on resulting file, run demicrostripe using parms:
-dt 0 60 -pn 3 -sn 15 -fsp 85 -tl 5 -twl 200 -twp 65 -mml 200 -drs -rsn 3 -rcm 30

3. Demicrostripe wasn't used to remove high amplitude stripes, becasue there weren't any. When they're present, high amplitude microstripes tend to be relatively short, so a different scheme can be used to flag and rescale them...

```
mrdemicrostripe -h -dt 80 0 -pn 1 -sn 15 -fsp 85 -tl 5 -twl 150 -twp 65  \
-mml  200 -drs -rsn 1 -rcm 30
\
 |
\
mrdemicrostripe -h  -dt 200 15 -pn 1 -sn 20 -fsp 85 -tl 5 -twl 300 -twp 45        \
-mml  200 -drs -rsn 1 -rcm 30
end:

echo 'All pau.' `date`
#
# END SSJOB Script
```

**8. Generate and apply AVG corrections to sidescan**

This is a method to generate depth dependent angle varying gain (AVG) corrections. AVG correction curves sometimes benefit from spike removal and smoothing.

Nadir specular reflection, water bounce and multiple reflections may introduce spikes in AVG curves. These features are not universally present in the sidescan data.

CREATING AVG CORRECTIONS

Try using the script buildavgcorrs to creat AVG corrections for groups of sidescan files. The buildavgcorrs script can be restarted at any one of it's process steps.

The steps include:

mkjob: create the avg_stack.job.
runjob: run the avg_stack.job to create the raw avg corrections.
split: split the multidepth raw table up into individual tables
this step creates *.port and *.stbd individual depth
tables which can be interactively edited in program xvgr.
paste : paste the port and starboard individual tables together.
cattab: concatenate the individual tables back together.

Here's an example of the format (see script header for more info):

buildavgcorrs flist strt_flg dep_wndw port_thresh stbd_thresh beg_dep end_dep
eg
buildavgcorrs ew9606 start 200 20000000 20000000 1000 6000

COOKBOOK FOR EW9606

*8.1. Create a list of sidescan file names with their complete path name.*

The name convention for the file list is jdhrmin.jdhrmin.avglist where the first and second jdhrmin values are the beginning and ending times of the included files.

Execute from the $AVG directory...

```
cd $AVG/jd198
buildavgcorrs 1980000.1982359 start 200 20000000 20000000 1000 6000
cd $AVG/jd199
buildavgcorrs 1990000.1992359 start 200 20000000 20000000 1000 6000
cd $AVG/jd200
buildavgcorrs 2000000.2002359 start 200 20000000 20000000 1000 6000
cd $AVG/jd201
buildavgcorrs 2010000.2012359 start 200 20000000 20000000 1000 6000
cd $AVG/jd202
buildavgcorrs 2020000.2022359 start 200 20000000 20000000 1000 6000
```

```
cd $AVG/jd203
buildavgcorrs 2030000.2032359 start 200 20000000 20000000 1000 6000
```

Create a composite AVG correction file using all available data:

```
cd $AVG/ew9606    ls $SSINT/ssi*/*ssdnc > ew9606.avglist
```

*8.2. Applying the AVG correction:*

```
set corr = $AVG/ew9606/ew9606.raw.avgcorrs
    set jd = 223    cd $SSINT/ssi$jd
    foreach file (`ls *.ssdnc`)
    echo "Correcting AVG on file: "$file
    set f = $file:r
    mravg $file -rcf $corr > $SSFIN/ssf$jd/$f.ssdnca
end
```

Check out the results:

```
mrcat MR1*ssdnca > jd200.ssdnca
mrspl -l jd200.ssdnca -sc 400000 -ti 10 -tc 1 -tw 2 -r -pr 1 < $file | rpf
```

## 9. Grid the sidescan and generate a mosaic

Gridding Sidescan and Generating Mosaics
Cruise ew9606

Chapter One (of Two) - General Overview

1. Establishing Common Parameters For All Grids

Results from the following 4 steps are incorporated into the script $SCRIPTS/gridss, which will be used to grid each line.

1.1 Scale

The grid cell size controls the scale of the final output image, and is controlled by the output device resolution (dots per inch).

For a 300 dpi output device (IRIS plotter, HP750, etc)
scale 1:100,000    =>  cell size   8.466666

scale 1:200,000 => cell size 16.933333
scale 1:400,000 => cell size 33.866666

For a 203 dpi output device (Raytheon thermal printer)
scale 1:100,000 => cell size 12.5123153
scale 1:200,000 => cell size 25.0246306
scale 1:400,000 => cell size 50.0492612

For shipboard processing we select a grid size that wil result in as large a plot as feasible given the amount of processing time available. For ew9606 we selected a grid size of 50.0492612 to produce plots on the Raytheon printer at 1:400,000 and 1:200,000 (the latter is done by pixel replication).

1.2. Declination

The local declination calculated from the bridge navigation sheets is 18.4 degrees west. This value will be good to within a few tenths of degree throughout the entire survey because there is no regional change in the magnetic field in this area (also no change w/time). After plotting several lines this value was changed to 17.4 degrees west in order to improve line-to-line continuity of features. The disparity between predicted and actual magnetic declination may result from systematic towfish yaw, or a consistent offset in the magnetic compass on board the towfish.

1.3. Reference point

Run a dummy mrgrid job using the ultra-verbose option to calculate the reference point to be used in all gridding. This job only needs to run until it spits out the voibage that reports the reference point -- then you can kill it.

```
cd $SSFIN/ssf198
mrgrid MR19619813.54.ssdnca -v 2 -ss -mc -18.4 -plon -43 -pmerc      \
-cs 33.866666 -cf junk.cf -mpcw 3 -mspd 80 -adct 1.3 -tt 3
```

Output:
refxorigin = -267916.13 refyorigin = 2886567.43

1.4. Graymap

We use a logarithmic look-up table because it results in a more appropiate range of grays than the default histogram equalization. Here's a way to produce a logarithmic gray scale that maps high backscatter to black:

```
cd $SSFIN/ssf201
mrgrm  -lh 500 30000 -log < MR19620100.00.ssdnca > log.500.30000.grm
```

Invert the graymap so that black is high backscatter:

```
cp log.500.30000.grm $SSGRID/graymap
cd $SSGRID/graymap
invgrm log.500.30000.grm > log.inv.500.30000.grm
```

1:1,200,000
Looks good on the screen:   log.inv.700.250000.grm
Looks good on the Raytheon: log.inv.800.11000.grm

1:400,000
Looks good on the Raytheon: log.inv.500.50000.grm (a bit light)
Looks good on the Raytheon: log.inv.500.30000.grm

2. Gridding By Line

Here's a general overview of each of the steps involved in gridding.

A step-by-step cookbook of how each line was actually gridded and overlain is contained in $DOC/ssgrid.50m.doc

2.1. Create symbolic links from the line directory to the data directories.

```
cd $SSGRID/line020
ls $SSFIN/ssf200/MR1962000[7-9]*ssdnca                  \
$SSFIN/ssf200/MR1962001[0-3]*ssdnca                     \
> line020.files
ln-files line020.files
/usr/bin/ls *ssdnca > line020.files
```

2.2. Grid a line's worth of data:

```
gridss line020.files 50.0492612
```

...then move the gridded data to the grid directory:

```
foreach file (`ls *cswr`)
    /bin/mv $file $SSGRID/grid50m
    ln -s $SSGRID/grid50m/$file .
end
```

2.3. Organize the control files (bury the inside of turns, etc):

```
fixcf line020.files
```

2.4. Generate a mosaic of a line's worth of data:

```
ovlss line020.files $SSGRID/graymap/log.inv.500.25000.grm
```

3. Gridding the entire survey using "compare" option in mrovl

The "compare" option in mrovl produces a sidescan mosaic that preferentially plots data closest to nadir. The result is that, in the case of adjacent or crossing tracks, the midpoint between the tracks behaves as a seam between data from each track (end therefore different look direction).

In the appropriate mosaic directory (ie mosaic50m etc), create symbolic links to the .cswr files that are in the appropiate grid directory (ie grid50m etc):

```
cd $SSGRID/mosaic50m
foreach file (`ls $SSGRID/grid50m/*cswr`)
    ln -s $file .
end
```

Create a list of all the control files you want to combine. If the control files are in different directories, you need to specify the full path to each:

```
cd $SSGRID/mosaic50m
ls $SSGRID/line*/*[0-9].cf > ew9606.compare.cf.list
catcf ew9606.compare.cf.list ew9606.compare.cf
fixcf ew9606.compare.cf
```

Use the program mrovl to create a Sun raster file of the gridded mosaic using the control file generated above.

```
mrovl     ew9606.compare.cf                     \
-rf ew9606.compare.ras                          \
-os -45.5 24 10270 8200                         \
-gmf $SSGRID/graymap/log.inv.800.11000.grm      \
-movl 0 0 0                                         \
-mbg 255 255 255                                \
-mti 2m 2m                                          \
-mtw 1                                              \
-mtl 6                                              \
```

```
    -fbw 3                                              \
    -fti 10m 10m                                        \
    -ftw 3                                              \
    -ff Times-Roman 6                                   \
    -ftl 4                                              \
    -v 2
```

4. Create a north-looking mosaic

```
cd $SSGRID/grid50m/mosaic
ls $SSGRID/grid50m/line004/*[0-9].cf  > ew9606.stbd.cf.list
ls $SSGRID/grid50m/line008/*[0-9].cf >> ew9606.stbd.cf.list
ls $SSGRID/grid50m/line012/*[0-9].cf >> ew9606.stbd.cf.list
ls $SSGRID/grid50m/line016/*[0-9].cf >> ew9606.stbd.cf.list
ls $SSGRID/grid50m/line020/*[0-9].cf >> ew9606.stbd.cf.list
ls $SSGRID/grid50m/line024/*[0-9].cf >> ew9606.stbd.cf.list
ls $SSGRID/grid50m/line028/*[0-9].cf >> ew9606.stbd.cf.list
catcf ew9606.stbd.cf.list ew9606.stbd.cf
fixcf_stbdup ew9606.stbd.cf

ls $SSGRID/grid50m/line002/*[0-9].cf  > ew9606.port.cf.list
ls $SSGRID/grid50m/line006/*[0-9].cf >> ew9606.port.cf.list
ls $SSGRID/grid50m/line010/*[0-9].cf >> ew9606.port.cf.list
ls $SSGRID/grid50m/line014/*[0-9].cf >> ew9606.port.cf.list
ls $SSGRID/grid50m/line018/*[0-9].cf >> ew9606.port.cf.list
ls $SSGRID/grid50m/line022/*[0-9].cf >> ew9606.port.cf.list
ls $SSGRID/grid50m/line026/*[0-9].cf >> ew9606.port.cf.list
ls $SSGRID/grid50m/line030/*[0-9].cf >> ew9606.port.cf.list
catcf ew9606.port.cf.list ew9606.port.cf
fixcf_portup ew9606.port.cf

ls ew9606.port.cf ew9606.stbd.cf > ew9606.north.cf.list
catcf ew9606.north.cf.list ew9606.north.cf
fixcf_timesort ew9606.north.cf

ovlss ew9606.north.cf $SSGRID/graymap/log.inv.800.11000.grm
```

5. Scripts used in gridding/overlaying

5.1. gridss

```
#gridss data.list grid_cell_size
#          :
#          :.......... File list containing names of new hour files
#                      being added
#
# Gridding:
# 1. File list of new files being added to existing grid -- give only the
#    prefix of this filename as the first arguement in the command line.
#    The filename convention is JDbeg-JDend.mrgrid.files
# 2. The output .cf file from mrgrid is automatically named using
#    the first command line arguement as a prefix.
#
# Control file operations:
# 1. The new .cf file is automatically added to ew9606.cf.list
# 2. The new and old .cf files listed in ew9606.cf.list are combined
#    using $SCRIPTS/catcf
# 3. A composite .cf file is created that overlays the grids according
#    to the order set out in $SCRIPTS/fixcf.ew9606
#
# Overlaying
# Use script ovlss to construct a mosaic using mrovl.
#
# Scale/grid cell table:
#   scale 1:100,000    =>  cell size   8.466666
#   scale 1:200,000    =>  cell size  16.933333
#   scale 1:400,000    =>  cell size  33.866666

if( $#argv > 0 && $1 == "h" ) then
  head -23 $0
  echo " "
  goto end
endif

# Customizations for Cruise ew9606 (Tucholke East Flank MAR)
# See $DOC/ssgrid.doc for info on how these numbers were obtained

set cellsiz = $2
set mc      = -17.4
set rpx     = -267916.13
set rpy     = 2886567.43

set datalist = $1
set outfile  = $1:r

echo " "
echo 'Begin gridding:  ' `date`
echo 'File list is: ' $datalist
echo " "
```

```
/bin/rm $outfile.cf.old
/bin/mv $outfile.cf $outfile.cf.old

nice    mrgrid `cat $datalist`                  \
        -v 2                            \
        -ss                             \
        -mc $mc                                 \
        -plon -66                       \
        -rp $rpx $rpy                   \
        -pmerc                          \
        -cs $cellsiz                    \
        -cf $outfile.cf                 \
        -mpcw 3                         \
        -mspd 80                        \
        -adct 1.9 -tt 2

echo "Pau gridding." `date`
echo " "
goto end
end:
```

5.2. ovlss

```
#ovlss newdata graymap
#       :       :....... Name of graymap
#       :............... File list containing names of new hour files
#                        being added
#
# Control file operations:
# 3. The new .cf file is automatically added to ew9606.cf.list
# 4. The new and old .cf files listed in ew9606.cf.list are combined
#    using $SCRIPTS/catcf
# 5. A composite .cf file is created that overlays the grids according
#    to the order set out in $SCRIPTS/fixcf.ew9606
#
# Overlaying
# 1. Grids are rendered using ew9606.grm and plotted using the max
#    and min values of the data set as map boundaries.
#
# Scale/grid cell table:
#   scale 1:100,000    =>  cell size   8.466666
#   scale 1:200,000    =>  cell size  16.933333
#   scale 1:400,000    =>  cell size  33.866666
#
# Customizations for Cruise ew9606 (Tucholke East Flank MAR)
# See $DOC/ssgrid.doc for info on how these numbers were obtained

set outfile = $1:r
set graymap = $2
```

```
if( $#argv > 0 && $1 == "h" ) then
  head -23 $0
  echo " "
  goto end
endif



echo 'Overlaying grids...' `date`

    mrovl       $outfile.cf                 \
        -rf $outfile.ras \
        -gmf $2                 \
        -movl 0 0 0             \
        -mbg 255 255 255        \
        -mti 2m 2m              \
        -mtw 1                  \
        -mtl 6                  \
        -fbw 3                  \
        -fti 10m 10m            \
        -ftw 3                  \
        -ff Times-Roman 6       \
        -ftl 4                  \
        -v 2
echo 'pau overlaying: ' `date`

goto end
end:
```

5.3. catcf

```
#catcf control_file.list output.cf
#
# This script combines control files created by mrgrid.
# To work, the control files should have all been generated using the
# same projection, central longitude and reference point.
#
# The input file to this script should contain a list of the control files
# to be included. If the control files are not in the directory where this
# script is executed, full path names need to be given.

set list    = $1
set outfile = $2
set first   = 1

/bin/rm $outfile

foreach file (`cat $list`)
```

```
    cat $file \
    |           \
    nawk '{            \
        if( NR < 7 && first == 1 ) print $0     \
        if( NR > 6 ) print $0                   \
    }' first=$first >> $outfile

set first = 0
end
```

5.4. fixcf

```
#fixcf input.files
#
# Behavior:
#
# 1. Backs up original .cf file as filename.orig.cf
# 2. Reorganizes .cf files to bury turns etc.
# 3. Prints a filesize comparison of the .cf files before and after
#    reorganization

set chart = $1:r

/bin/rm $chart.orig.cf
/bin/rm -f $chart.tmp
cp $chart.cf $chart.orig.cf

echo ' '
echo 'Filesize comparison:'
wc $chart.cf
head -6 $chart.cf > $chart.tmp

grep P $chart.cf | grep str                    >> $chart.tmp
grep S $chart.cf | grep str                    >> $chart.tmp
grep S $chart.cf | grep tcw  | sed s/suppress/display/g >> $chart.tmp
grep P $chart.cf | grep tccw | sed s/suppress/display/g >> $chart.tmp
grep P $chart.cf | grep tcw  | sed s/suppress/display/g | sed s/compare/underlay/g >>
$chart.tmp
grep S $chart.cf | grep tccw | sed s/suppress/display/g | sed s/compare/underlay/g >>
$chart.tmp

wc $chart.tmp

echo ' '
cat $chart.tmp \
| \
nawk '{ if( NR < 7 ) print $0                    \
     else print $1, $2, $3, $4, $5, $6, $7, $8, NR-6}'\
    > $chart.cf

/bin/rm  $chart.tmp
```

5.5 fixcf_portup

```
#fixcf input.files
#
# Behavior:
#
# 1. Backs up original .cf file as filename.orig.cf
# 2. Reorganizes .cf files to bury turns etc.
# 3. Prints a filesize comparison of the .cf files before and after
#    reorganization

set chart = $1:r

/bin/rm $chart.orig.cf
/bin/rm -f $chart.tmp
cp $chart.cf $chart.orig.cf

echo ' '
echo 'Filesize comparison:'
wc $chart.cf
head -6 $chart.cf > $chart.tmp

grep P $chart.cf | grep str  | sed s/compare/overlay/g  >> $chart.tmp
grep P $chart.cf | grep tccw | sed s/compare/underlay/g >> $chart.tmp
grep P $chart.cf | grep tcw  | sed s/compare/underlay/g >> $chart.tmp

grep S $chart.cf | grep str  | sed s/compare/underlay/g >> $chart.tmp
grep S $chart.cf | grep tccw | sed s/compare/underlay/g >> $chart.tmp
grep S $chart.cf | grep tcw  | sed s/compare/underlay/g >> $chart.tmp

wc $chart.tmp

echo ' '
cat $chart.tmp \
| \
nawk '{ if( NR < 7 ) print $0                              \
       else print $1, $2, $3, $4, $5, $6, $7, $8, NR-6}'\
      > $chart.cf

/bin/rm  $chart.tmp
```

5.5 fixcf_stbdup

```
#fixcf input.files
#
# Behavior:
#
# 1. Backs up original .cf file as filename.orig.cf
# 2. Reorganizes .cf files to bury turns etc.
# 3. Prints a filesize comparison of the .cf files before and after
```

```
#    reorganization

set chart = $1:r

/bin/rm $chart.orig.cf
/bin/rm -f $chart.tmp
cp $chart.cf $chart.orig.cf

echo ' '
echo 'Filesize comparison:'
wc $chart.cf
head -6 $chart.cf > $chart.tmp

grep S $chart.cf | grep str  | sed s/compare/overlay/g  >> $chart.tmp
grep S $chart.cf | grep tccw | sed s/compare/underlay/g >> $chart.tmp
grep S $chart.cf | grep tcw  |sed s/compare/underlay/g >> $chart.tmp

grep P $chart.cf | grep str  | sed s/compare/underlay/g >> $chart.tmp
grep P $chart.cf | grep tccw | sed s/compare/underlay/g >> $chart.tmp
grep P $chart.cf | grep tcw  | sed s/compare/underlay/g >> $chart.tmp

wc $chart.tmp

echo ' '
cat $chart.tmp \
| \
nawk '{ if( NR < 7 ) print $0                              \
      else print $1, $2, $3, $4, $5, $6, $7, $8, NR-6}'\
     > $chart.cf

/bin/rm  $chart.tmp
```

5.7 fixcf_timesort

```
#fixcf_timesort cf_file
#
# Behavior:
#
# 1. Backs up original .cf file as filename.orig.cf
# 2. Reorganizes a control file according to time (earliest first).
# 3. Prints a filesize comparison of the .cf files before and after
#    reorganization

set chart = $1:r

/bin/rm $chart.orig.cf
/bin/rm -f $chart.tmp
cp $chart.cf $chart.orig.cf

echo ' '
echo 'Filesize comparison:'
```

```
wc $chart.cf


cat $chart.cf | awk '{if ( NR >= 7 ) print $0}' | sort > $chart.tmp

head -6 $chart.cf > $chart.tmp2

grep str $chart.tmp                          >> $chart.tmp2
grep P $chart.tmp   | grep tcw               >> $chart.tmp2
grep S $chart.tmp   | grep tccw              >> $chart.tmp2
grep S $chart.tmp   | grep tcw               >> $chart.tmp2
grep P $chart.tmp   | grep tccw              >> $chart.tmp2

wc $chart.tmp2

echo ' '
cat $chart.tmp2 \
| \
nawk '{ if( NR < 7 ) print $0                          \
      else print $1, $2, $3, $4, $5, $6, $7, $8, NR-6}'\
     > $chart.cf

/bin/rm  $chart.tmp  $chart.tmp2
```

**10. Convert bathymetry to weighted (x,y,z) format, grid and image using GMT**

*10.1. Switch tables...*

```
  All bathy data from ew9606 were generated in btyp using the same set
  of initial tables. These aren't the best final tables, so we use
  tblsw2 to swap the original tables for the best tables.  See the file
  $DOC/aatable.doc for info on how ew9606 tables were generated. The
  tables used during ew9606 were:

  All first-pass bathymetry generation in program btyp:
    port: ew9605.tow6.77d.portmap
    stbd: ew9605.tow6.73d.stbdmap
  Reprocessed data (tables swapped using tblsw2):
    Tow1 (198/1400 to 203/0300):
      port: ew9605.tow6.77d.portmap
      stbd: ew9605.tow6.73d.stbdmap
    Tow2 (203/0900 to 205/1200):
      port: ew9605.tow6.77d.portmap
      stbd: ew9605.tow6.73d.stbdmap
    Tow3 (205/1900 to ---/----):
```

```
 port: ew9606.tow3.69d.portmap
 stbd: ew9606.tow3.68d.stbdmap
```

Do the switch...

```
cd $BTYR/btyr224
foreach file (`ls *23.00.btync`)
  echo "Table switching "$file `date`
  set f = $file:r
  tblsw2 -os $TABLES/ew9605.tow6.73d.stbdmap \
       -op $TABLES/ew9605.tow6.77d.portmap \
       -ns $TABLES/ew9606.tow3.68d.stbdmap      \
       -np $TABLES/ew9606.tow3.69d.portmap           \
       < $file > $f.btynct
end
```

*10.2. Clip outlying high and low soundings (windowing)...*

Sometimes there's speckle noise (unrealistically high and low data points) that will screw up subsequent filtering/imaging. These points can be removed using mrbdw:

```
mrbdw -sb min max -pb min max < infile > outfile
```

10.2.1. An easy way to accurately determine max/min depth values for each hour file involves using the bty4bdw script. This script prepares a postscript plot of the data consisting of stacked pings. From this plot you can easily determine the min/max windowing values.

```
cd $BTYR/btyr222
```

Run bty4bdw on each file:

```
foreach file (`ls *.btynct`)
     echo 'ping plotting 4 bdw' $file
    bty4bdw  $file
end
```

10.2.2. Create a job file with all the desired values in it in the form of:

```
mrbdw -sb min max -pb min max  < infile > outfile
```

Determine all values and run job. When pau, view the results to make sure the selected windowing values are appropriate.

```
 cd $BTYR/btyr222
      foreach file (`ls *btynctb`)
     btyp -mr $file -a view.parms
end
```

10.2.3. When you are sure all your windowed values are correct all the min/max values are recorded in the file $DOC/bdw.doc, which contains mrbdw command lines for each file from ew9606. Output files from mrbdw have the suffix .btynctb

*10.3. Trim outer edge of swath...*

Frequently the outer part of the swath exhibits curl or scatter that you want to remove. You can use the programs mrtrim or mrfill to trim files to a constant angle or horizontal distance, respectively, but you usually get better results by trimming the files interactively.

You can interactively trim files using program btyp and selecting the bathy => delete => swath edge option. Files trimmed this way from cruise ew9606 have the suffix .btynctbt

```
cd $BTYR/btyr222
foreach file (`ls *btynctb`)
      btyp -mr $file -a view.parms
end
```

*10.4. Convert data to weighted lat/lon/depth (xyzw) values...*

Although the mr1 software allows you to grid and display bathymetry data, many people want to generate xyz bathymetry for their own evil purposes. The programs mr2gmt and mr2xyzw allow you to do this. We'll use mr2xyzw to convert the data to values that are weighted such that points closest to nadir have the most significance.

```
set jd = 225
cd $BTYF/btyf$jd
foreach file (`ls MR19622123.*.btynctbt`)
  echo "Converting to xyzw format: "$file `date`
  set f = $file:r
  mr2xyzw -bty -mc -17.4 $file > $f.xyzw
  echo "Running blockmedian: "$file `date`
  xyzw2bm50 $f.xyzw
```

```
  /bin/rm $f.xyzw
 end
 mv *blk50m.xyzwb $XYZ/xyz$jd
 cd $XYZ/xyz$jd
 replace MR1962 2
```

*10.5. Grid and image using Wessel and Smith's Generic Mapping Tools (GMT)*

Here's a filtering scheme that works well with MR1 bathymetry data. This scheme uses a noise supression technique that involves generating a smooth surface, subtracting it from the original surface, clipping the outlying high/low values, and then interpolating across gaps using a nearest- neighbor gridding algorithm.

```
cd $XYZ/plots

#  define grid cell sizes...
 set lat200 = `echo 26 200 lat | cellsize`m
 set lon200 = `echo 26 200 lon | cellsize`m
#  Bounds...
 set l = 315
 set r = 315.5
 set b = 25
 set t = 25.667
 set midlon = `echo $l $r | awk '{print ($1-$2)/2 + $2}'`
 set R = $l/$r/$b/$t
 set J = t$midlon/1:300000
 set I = $lon200/$lat200
 set B = "5mg1mNeWs"
#  Create the initial grid:
  blockmedian $XYZ/xyz198/*blk100m.xyzwb $XYZ/xyz199/*blk100m.xyzwb \
  $XYZ/xyz200/*blk100m.xyzwb -I$I -R$R -W -bd -V                  \
  |                                                          \
  xyz2grd -Gtest.200m.grd -R$R -I$I -bd -V
# Create a smooth surface:
  grdfilter test.200m.grd -D2 -Fc.5 -I$I                     \
  -R$R -Gtest.200m.fc5x5.grd -V
 Create residual surface and clip the outliers:
  grdmath test.200m.grd test.200m.fc5x5.grd - = diff.grd
  grdclip diff.grd -A25/NaN -B-25/NaN -Gdiff.cln.grd -V
 Recombine clipped surface with smooth surface:
  grdmath test.200m.fc5x5.grd diff.cln.grd + = test.200m.cln.grd
 Make xyz file and regrid using nearest neighbor:
  grd2xyz test.200m.cln.grd                                  \
```

```
    |                                                               \
    awk '{if ($3 != "NaN") print $0}' > test.200m.cln.xyz
    nearneighbor test.200m.cln.xyz -Gtest.200m.cln.nn900m.grd     \
    -I$I -R$R -N4 -M -S.9 -V
#  Imaging:
    grd2cpt test.nn600m.grd > test.cpt
    cptinv test.cpt > test.inv.cpt
    echo 0 0 | psxy -J$J -R$R -K -P -Y.7 > beg.ps
    grdimage test.200m.cln.nn900m.grd -J$J -R$R    \
    -Ctest.inv.cpt -O -K -V > image.ps
    grdcontour test.200m.cln.nn900m.grd -J$J -R$R \
    -Z.01 -C1 -A5f6a0 -Wc1/0/0/0 -Wa3/0/0/0 -O -K -V > cont.ps
    psbasemap -J$J -R$R -B$B -O > base.ps
    cat beg.ps image.ps cont.ps nav.ps base.ps > tow1.blk100.ps
```