



**Lamont-Doherty
Earth Observatory**
of Columbia University

EW 9707 DATA REDUCTION CRUISE SUMMARY

September 8, - October 25 1997

ARAD 3-D Reflection Experiment

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Science Overview

This cruise consisted of a 3-D MCS reflection and tomographic survey along the East Pacific Rise to test competing models of magmatic separation beneath a fast spreading center. The experiments took place across the 9° 3' N overlapping spreading center where significant changes in magma chamber structure are known to occur. This project was the first combined 3-D seismic reflection and tomographic experiment to be conducted along a mid-ocean ridge/unsedimented environment and hopes to address some of the following geologic topics:

- 3-D mapping of magma chamber structure across a large non-transform offset to determine melt sill morphology and connectivity.
- 3-D mapping of velocity structure across the discontinuity through innovative tomographic and prestack depth migration techniques.
- 3-D mapping of seismic layer 2A thickness to investigate variations in upper crustal structure across the offset, and to better understand the nature of the 2A/2B boundary.
- 3-D mapping of Moho structure to ascertain lower crustal continuity, and determine the nature of Moho transition beneath the ridge axis.
- 3-D mapping of the physical properties of the melt sill through waveform and amplitude with offset analyses.

This study was a joint venture between Scripps and BIRPS/Cambridge (UK)

The STARFIX-MN8 Virtual Base Station provided differential corrected position.

Shooting occurred over a period of approximately 36 days with over 160,000 shots fired and recorded.

Navigation Processing

Throughout the cruise, a STARFIX-MN8 differential receiver provided realtime differential ship navigation. RTCM was fed to the trimble to provide the trimble with differential capability as well. Logging of the STARFIX data was effectively started on day 262, several days into the MCS process. After examination (by Paul Henkart) of the Trimble GPS vs. STARFIX gps, it was decided to reprocess all data with the SKYFIX navigation, as opposed to the Trimble.

The following pages describe the GPS and shot processing pipeline used to create all the navigation based files: shot, hydrosweep centerbeam, magnetics, gravity, as well as the MCS navigation data.

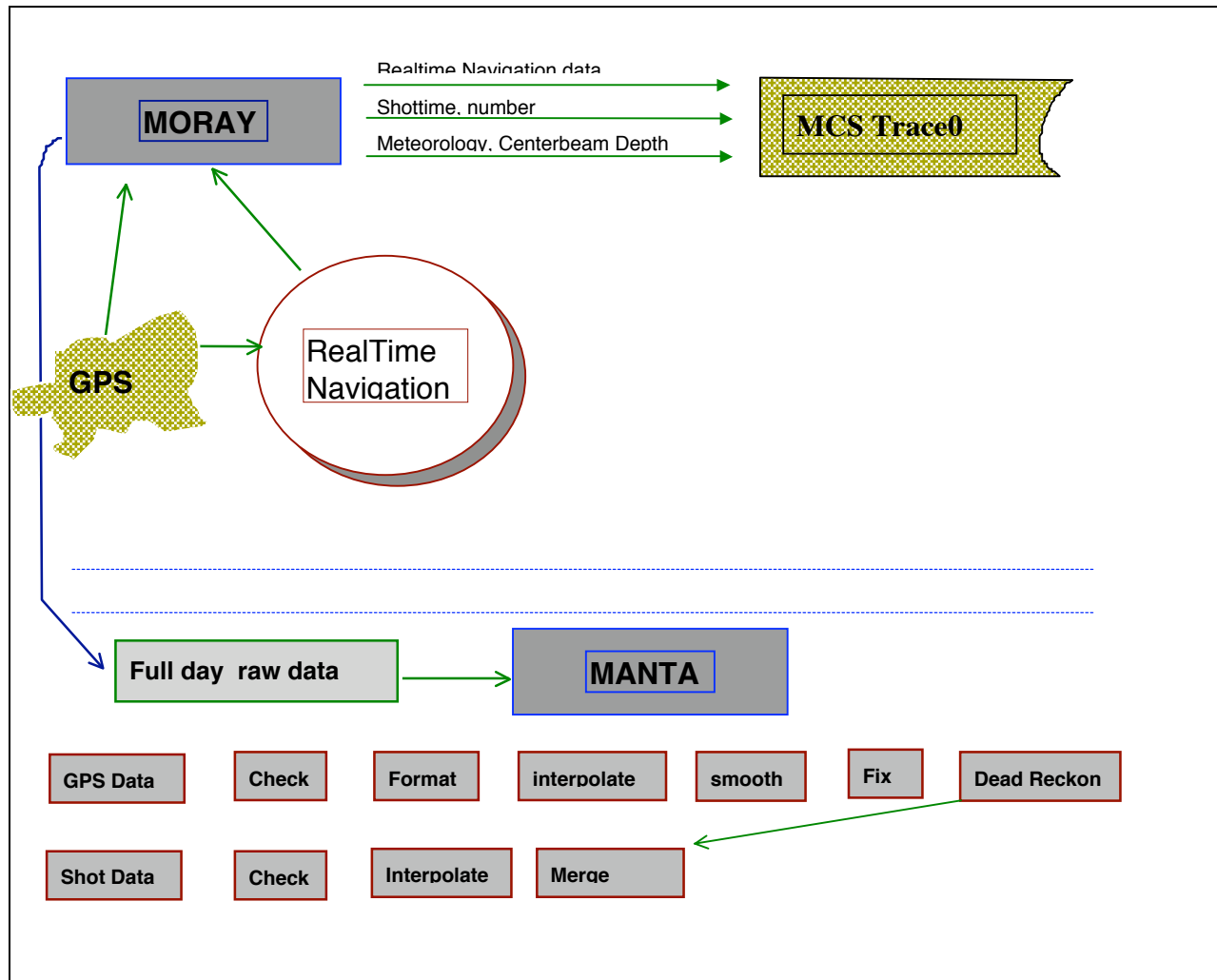


Figure 1. *Navigation Processing Pipeline*

Navigation Pipeline

Referring to Figure 1

1. MORAY

Moray is the main logging system and is responsible for logging all the realtime data as well as controlling the intervals in which it is logged. This is also the system which controls the firing of the guns. In order to determine the time to fire, as well as the precise location the guns were fired, it relies on the ***RealTime Navigation Process***.

2. RealTime Navigation Process

This process uses the navigation from the selected GPS to provide a means of removing some of the randomness of the selective availability GPS by determining our current speed based on two points taken *filter_length* minutes apart. If available, the same information for the tailbuoy is reported. Simultaneously, the meteorological information and centerbeam data is collected. The output from this process (for both ship and tailbuoy) is:

- The last lat/lon position (directly from the GPS) and the time (in seconds) of the last fix
- ship speed in the east direction, ship speed in the west direction
- Furuno speed and heading
- Meteorological data

3. Using this data, **MORAY** determines the shot position based on the shot time and the time of the last GPS position fix. All this data is then passed on to the MCS system for Trace Zero data.

Range	Description	Size Bytes	Position	Format
0-999999	shot number	6	00-05	ascii
\s	space	1	06	ascii
yy+ddd:hh:mm:ss.mm	true time tag via Joes box	19	07-25	ascii
\s	space	1	26	ascii
yy+ddd:hh:mm:ss.mm	shot cpu clock tag	19	27-45	ascii
\s	space	1	46	ascii
N/S	North/South Lat	1	47	ascii
\s	space	1	48	ascii
0-90	Latitude in degrees	2	49-50	ascii
\s	space	1	51	ascii
0.0000-60.0000	Latitude in minutes	7	52-58	ascii
\s	space	1	59	ascii
E/W	East/West Lon	1	60	ascii
\s	space	1	61	ascii

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0-180	Longitude in degrees	3	62-64	ascii
\s	space	1	65	ascii
0.0000-60.0000	Longitude in minutes	7	66-72	ascii
\s	space	1	73	ascii
0.0-9999.9	Hydrosweep Center Beam Depth	6	74-79	ascii
\s	space	1	80	ascii
0.0-99.9	Sea Temperature in deg. C	4	81-84	ascii
\s	space	1	85	ascii
0.0-99.9	Wind Speed in knots	4	86-89	ascii
\s	space	1	90	ascii
0-999	Wind Direction	3	91-93	ascii
\s	space	1	94	ascii
N/S	Tail Buoy North/South Lat	1	95	ascii
\s	space	1	96	ascii
0-90	Tail Buoy Latitude in degrees	2	97-98	ascii
\s	space	1	99	ascii
0.0000-60.0000	Tail Buoy Latitude in minutes	7	100-106	ascii
\s	space	1	107	ascii
E/W	Tail Buoy East/West Lon	1	108	ascii
\s	space	1	109	ascii
0-180	Tail Buoy Longitude in degrees	3	110-112	ascii
\s	space	1	113	ascii
0.0000-60.0000	Tail Buoy Longitude in minutes	7	114-120	ascii
\s	space	1	121	ascii
0.0-9999.9	dist. between ship and tailbuoy	6	122-127	ascii
\s	space	1	128	ascii
0.0-360.0	bearing ship - tailbuoy	5	129-133	ascii
line_name	Current line_name	10	134-143	ascii
0.0-99.9	Furuno speed over water	4	144-147	ascii
\s	space	1	148	ascii
0.0-360.0	Furuno course	5	149-153	ascii

Range	Description	Gun	Size	Pos	Format
0-255	gun depth	1	1	190	binary
0-255	gun depth	2	1	191	binary
0-255	gun depth	3	1	192	binary
0-255	gun depth	4	1	193	binary
0-255	gun depth	5	1	194	binary
0-255	gun depth	6	1	195	binary
0-255	gun depth	7	1	196	binary
0-255	gun depth	8	1	197	binary
0-255	gun depth	9	1	198	binary
0-255	gun depth	10	1	209	binary
0-255	gun depth	11	1	200	binary
0-255	gun depth	12	1	201	binary
0-255	gun depth	13	1	202	binary
0-255	gun depth	14	1	203	binary

0-255	gun depth	15	1	204	binary
0-255	gun depth	16	1	205	binary
0-255	gun depth	17	1	206	binary
0-255	gun depth	18	1	207	binary
0-255	gun depth	19	1	208	binary
0-255	gun depth	20	1	209	binary

Table 1. LDEO Trace Zero Information

4. For non-realtime processing, raw data is transferred to Manta and processed. Navigation data is processed, then merged with all location specific information: hydrosweep center beam, shot-time, magnetic, and gravity. However, not all data is accumulated on every cruise.

5. GPS Processing

- Check Data for mutant records and inconsistent times
- Format the data into a standard format

NMEA: Time Lat/Lon gps string

Magnavox: Time PMVXG proprietary NMEA string

- Interpolate the data where GPS coverage has been lost for any amount of time 3 minutes or less. In the case where differential coverage is in effect, throw away all values that are differentially corrected before interpolation. This will make a file with a fix at every 30 second interval:

97+297:00:08:00.000 N 10 19.2790 W 104 25.4930

97+297:00:08:30.000 N 10 19.4500 W 104 25.4380

- Smooth the values with a 9 point running average algorithm. If there is a gap, the window is cleared. Output remains fixed at 30 second intervals
- Fix the values to 1 minute intervals
- Perform dead reckoning based on the furuno for any gaps in the data. At this point, if there are any gaps, they will be gaps greater than 3 minutes. This is the final navigation, fixed every minute, and all data is fixed to this.

97+295:03:49:00.000 N 8 59.9698 W 104 9.7289 gp2 56.0 0.1

97+295:03:50:00.000 N 8 59.9459 W 104 9.7394 dr 1.8 0.3

6. Shot Data

- Check the raw navblock file for mutant records and inconsistent times.
- Interpolate between the missing shots using a simple interpolation algorithm, not correcting for latitude. Interpolated shots are marked with a "-" in the time header field.
- Merge the shot times and lat lon positions with the final navigation prepared in the *Step 5*. The distance travelled between the two fixes is determined, allowing us to calculate the point where the shot was fired based on the time:

$$\text{lat} = \text{final_nav}[i].\text{lat} + (\text{final_nav}[i+1].\text{lat} - \text{final_nav}[i].\text{lat}) * (\text{navblock_sec} / (\text{final_nav}[i+1].\text{tot_secs} - \text{final_nav}[i].\text{tot_secs}));$$

```
lon = final_nav[i].lon + (final_nav[i+1].lon - final_nav[i].lon) * (navbock_sec / (final_nav[i+1].tot_secs -  
final_nav[i].tot_secs));
```

Data Collected During Cruise

All times are specified in GMT.

True Time Clock

Instrument Kinematic/TrueTime Division Model GPS-DC GPS Synchronized Clock

Logging 1 minute intervals

The True Time clock is used to adjust the CPU clock of the logging computer. The logging computer captures the continuous time records from the clock and provides these as a service to the rest of the network via a UDP broadcast. This enables the computers on the network to adjust their CPU times to UTC time.

Day	Time	Comments
251	1612	Start Logging True time for EW-9707
296	2359	End Processing True time for EW-9707

Speed and Heading

Instrument: Furuno CI-30 2-axis Doppler speed log, Sperry MK-27 gyro

Logging: 3 second intervals

Processing: The raw Furuno data is processed by taking the mean of all values within the even minute range and outputting the speed and heading on the even minute. All values taken during the 30 seconds before and after the even minute are used to calculate the median.

Day	Time	Comments
251	1610	Start Logging of Furuno Data
296	2359	End Processing of Furuno data

Format: fu.ddd

97+251:16:10:26.491 - 0.8 199.3 42.5

Time spd hdg gyro

GPS SATELLITE FIXES:

Instruments gp1: GPS Trimble NT200D
gp2: STARFIX-MN8 Virtual Base Station
gp3/4: Magnavox MX-4200 Global Positioning System

Logging 10 second intervals on all receivers
Checking

gp3/4: Minimum number of SATs: 3

Dilution of precision maximum: north = 4.0, east = 4.0

Speed maximum: 20.0

Compared GPS speed and course with Furuno smooth speed and heading
Reject fixes with high drifts in navigation

Processing *See previous Section*

Day	Time	Comments
251	1671	Started Logging of GPS Data
296	2359	End GPS Data Logs

STARFIX: Logging of GPS data

Day	Time	Comments
262	0621	STARFIX data logging began
296	2359	End STARFIX Logs

Final Data 1 minute navigation.

Format: *n.ddd*

yy+ddd:hh:mm:ss.mmm N 12 12.1234 E 123 12.1234 id 123.1 12.1
yr. day time lat. lon id set drift

where **id** is one of *gp1*, *gp3*, *gp4*] or *dr*, if dead reckoning was necessary.

BATHYMETRY:

Instrument: Krupp Atlas Hydrosweep Center Beam

Logging: Each Hydrosweep Ping is logged, and center beam data is extracted and logged separately.

Processing: Raw data is checked to process only good centerbeam records that were acquired in *survey* mode.

This data is then processed to produce a median value for each even minute. The median is the median of all records 30 seconds before and after the even minute.

Final Data: The median is merged with the one-minute navigation fixes to provide the final centerbeam data.

Notes: During the cruise, hydrosweep data was occasionally turned off when retrieving the OBS and OBH. There was also at least one equipment failure where the hydrosweep failed to pick up the rapid change in depth.

Format: *hb.nddd*

yy+ddd:hh:mm:ss.mmm N 12 12.1234 E 123 12.1234 2222.0
date/time lat lon depth/meters

Day	Time	Comments
251	2022	Data logging/processing begins
293	1700	Suspend Hydrosweep for instrument recovery
296	2126	Resume Hydrosweep
296	2359	End of Hydrosweep Logs

Sound Velocities

Instrument: Sparton Expandable BathyThermograph (5 & 7) *XBT*
Processing: Data is processed using the MB-System 4.3 to convert the depth/temperature readings to depth/sound velocity.
Note: Due to an inconsistency in one of the XBT files with regards to the correct Lat/Lon I re-checked Lat/Lons based on the completion of the XBT. Therefore, pre-9704xxx.xtX.[57] contain the Lat/Lons just prior to releasing the XBT, and post-9704xxx.xtX.[57] are the Lat/Lons after the XBT data had been saved. In both cases, the Lat/lon pairs should be correct.

XBT	Location
9707001	09:09.13N, 104:06.74W
9707002	08:57.13N, 104:07.19W
9707003	09:02.74N, 104:20.97W
9707004	09:06.12N, 104:16.66W

Guns

Logging: Varying intervals
Processing: Gun Shot data is created initially with a fifteen minute filter for the navigation data to reduce the effects of the random GPS error introduced by the government. This data is then combined with the one-minute navigation and corrected for course and speed to produce the final formatted data.

Format: *ts.n*
 yy+ddd:hh:mm:ss.mmm 000913 N 53 17.4459 W 166 59.4171 mcs1
 shot date/time shot # lat lon line name

Day	Time	Line	Shots
259	1455-1546	test1, test1a	2 - 12
260	0947	start test3	401 - 1795
262	0433	end test3	
262	0442	start arad-1	2001 - 8434
263	1133	end	
263	0614	start obh-mabc	9013 - 10301
264	0708	end	
264	0711	start arad-2	10303 - 70875
276	0015	end	
276	0020	start arad-3	70904 - 116004
284	1810	end	
284	1811	start arad-4	116025 - 160583
293	1406	end	
295	1645	start xx	2 - 2471

296	1347	end	
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Magnetics**Instrument:** Geometrics G-886 magnetometer**Logging:** 6 second intervals**Checking:** visual check of plot of data**Reference Field:**International Geomagnetic Reference Field 1995 (IGRF 1995)
model of the main field at 1985.0 and a predictive model of the
secular variation for adjusting to dates between 1995.0 and 2000.0.**Residual field:** Applied by bi-linear interpolation across a 1 degree square.**Final Data:** Median total intensity value at 00 second of each minute, merged
with navigation data.**Notes:** This magnetometer was used as a test this cruise, and was not
tuned to optimal performance. Use data at your own risk.**FORMAT:** mg.nddd

yr+ddd:hh:mm:ss.mmm	N 12 12.1234	E 123 12.1234	41200.8	-367.1
Date/time	lat	lon	total_intensity	anomaly

Day	Time	Comments
278	0306	Start Magnetic logging/processing
293	1405	End Magnetic logging/processing

SEA TEMPERATURE:**Instrument:** Omega DP10 Series**Logging:** 1 minute intervals**Checking:** none**Smoothing:** none

Chief scientist's final data: raw.

Lamont database (m.ddd): one minute data, merged with navigation.

Day	Time	Comments
251	0411	Sea temperature logging began
298	0446	ends

WEATHER STATION:**Instrument:** R.M./ Young Precision Meteorological Instruments 26700 Series**Logging:** 1 minute interval**Final Data:** raw.**Notes:** Bird 2 is damaged**Format:** wx.rddd

Port bird is bird #1

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97+185:00:07:00.747	13.7	130	20.9	19.3	20.7	22.7	29	27	2	21.5	20.0	21.4
date/time	tspd	tdir	ws1	wss1	wsm1	wsx1	wdc1	wds1	wdm1	ws2	wss2	wsm2
23.2	36	33	2	22.4	22.6	22.4	22.5	47	47	47	1030.7	
wsx2	wdc2	wds2	wdm2	tcur	tavg	tmin	tmax	rh	rhn	rhx	baro	

tspd	=	true speed	tcur	=	temperature, current
tdir	=	true wind direction	tavg	=	temperature, 60 minute average
ws1/2	=	wind speed, instantaneous	tmin	=	temperature, 60 minute minimum
wss1/2	=	wind speed, 60 second average	tmax	=	temperature, 60 minute maximum
wsm1/2	=	wind speed, 60 minute average	rh	=	relative humidity
wsx1/2	=	wind speed, 60 minute maximum	rhn	=	relative humidity, 60 minute minimum
wdc1/2	=	wind direction, current	rhx	=	relative humidity, 60 minute max
wds1/2	=	wind direction, 60 second average	baro	=	barometric pressure
wdm1/2	=	wind direction, 60 minute average			

Day	Time	Comments
251	1610	Logging Begins
298	0504	Ends