U.S. Department of the Interior
U.S. Geological Survey

CRUISE REPORT

RV OCEAN ALERT CRUISE A2-98-SC

MAPPING THE SOUTHERN CALIFORNIA CONTINENTAL MARGIN

March 26 through April 11, 1998

San Diego to Long Beach, California

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Open-File Report
98-475

A jointly funded project by the U.S. Environmental Protection Agency, and the U.S. Geological Survey

Conducted under a Cooperative Agreement between the US Geological Survey and the Ocean Mapping Group, University of New Brunswick

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Cruise Objectives

The major objective of cruise A2-98 was to map portions of the southern California continental margin, including mapping in detail US Environmental Protection Agency (USEPA) ocean dumping sites. Mapping was accomplished using a high-resolution multibeam mapping system. The cruise was a jointly funded project between the USEPA and the US Geological Survey (USGS). The USEPA is specifically interested in a series of ocean dump sites off San Diego, Newport Beach, and Long Beach (Fig. 1) that require high-resolution base maps for site monitoring purposes. The USGS Coastal and Marine Geology Program has several on-going projects off southern California that lack high-precision base maps for a variety of ongoing geological studies. The cruise was conducted under a Cooperative Agreement between the USGS and the Ocean Mapping Group, University of New Brunswick, Canada.

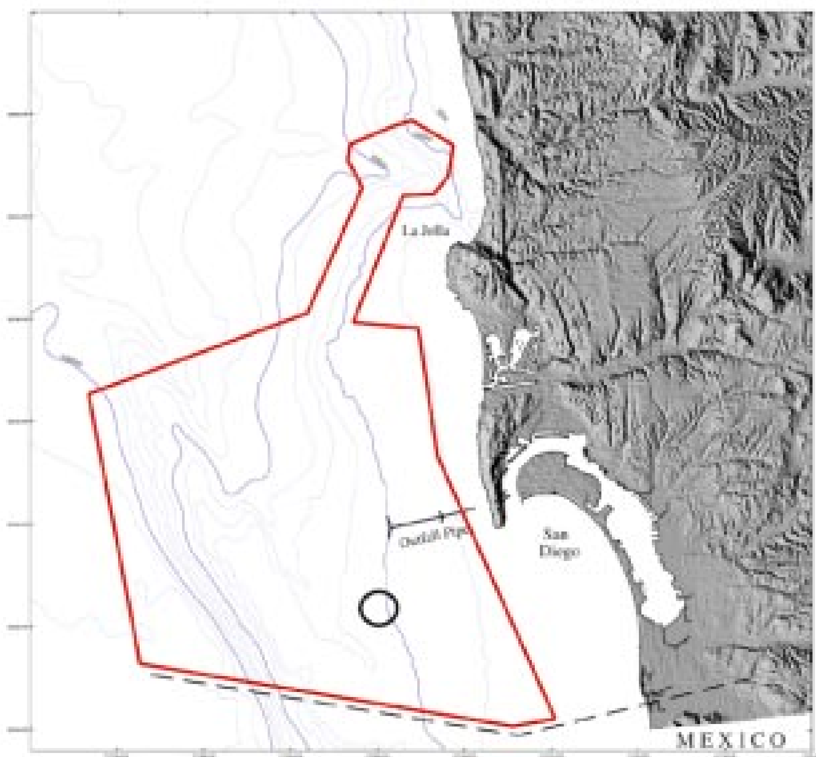

Figure 1a. Southern area mapped during cruise A2-98 with EM300 high-resolution multibeam system.USEPA ocean dump site LA-5 is indicated with circle. Dashed line is international border with Mexico.

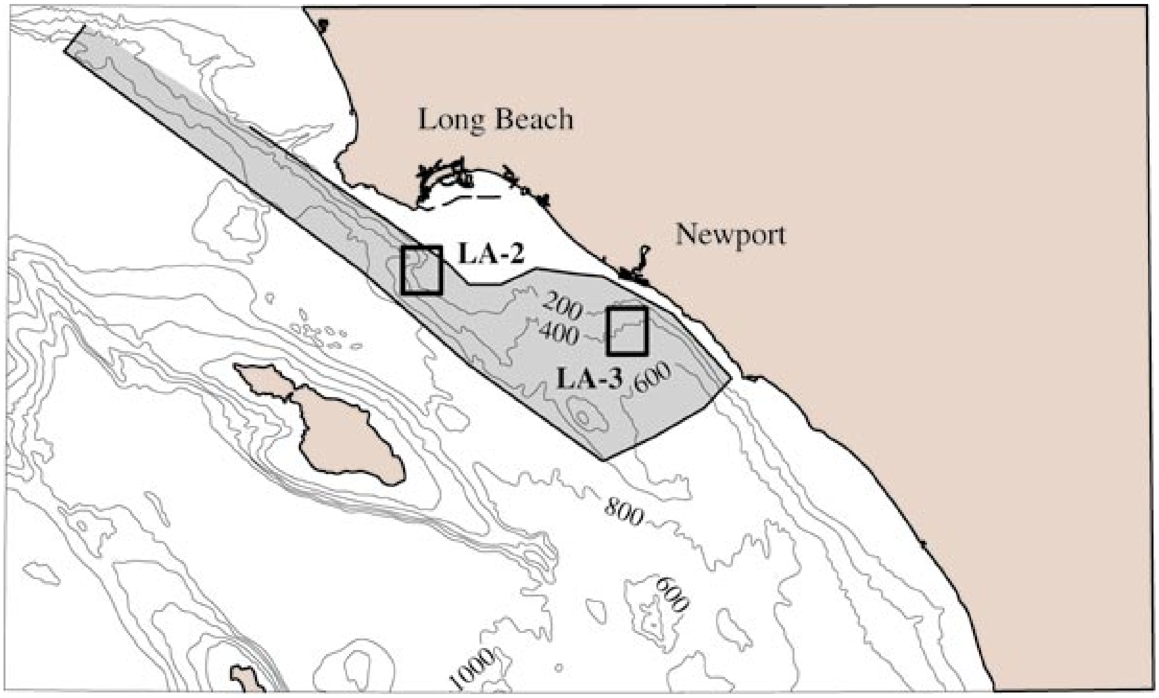

Figure 1b. Northern area mapping during cruise A2-98 with EM300 high-resolution multibeam system. USEPA ocean disposal sites indicated with boxes. Location of USEPA ocean disposal sites from coordinates given prior to the mapping cruise.

The Simrad EM300 High-Resolution Multibeam Mapping System

This cruise used the Konsberg-Simrad EM300 high-resolution multibeam mapping system that simultaneously collects georeferenced bathymetry and coregistered backscatter (similar to a sidescan image) with precise spatial referencing). Details of high-resolution multibeam mapping systems can be found in Hughes-Clarke, et al. (1996). The advantage of the Konsberg-Simrad EM300 over all other competing systems is that each depth determination is calculated from a phase detection as well as an amplitude detection, and then the "best" solution is selected, based on a set of statistical, quality-control parameters. The only operational Simrad EM300 system presently in the U.S. is owned and operated by C&C Technologies, Lafayette, LA., and is hull mounted on the leased Canadian-flag RV Ocean Alert, a 1,750 ton, 71-m , converted Canadian Coast Guard ship (Fig. 2).

Figure 2. The RV Ocean Alert

The EM300 system is a 30-kHz multibeam sonar system with up to 135 individual 1° (vertical) x 2° (horizontal) electronically formed beams (see Appendix 1 for details). The swath width and number of beams used during a survey is dependent on the water depth and mode of operation (see Table 1). The system can be operated in either equal-angle or equal-distance mode. The equal-angle mode generates 135 1°x2° receive beams and is configured so that, as the beam number increases from nadir, the size of the area imaged by each beam progressively increases. The equal-distance mode varies the individual beam angles so that the same size area is imaged by each beam, regardless of the angle away from nadir the beam is pointing. The southern California surveys were operated in equal-angle mode because our initial sea trials and surveys off Honolulu (Gardner and Hughes-Clarke, 1998) showed this mode produced the best results in the 200 to 1500-m water depths we intended to survey. The EM300 incorperates roll, pitch, yaw, and heave compensations utilizing an Applied Analytic POS/MV motion sensor that detects motions to 0.01° (Table 2). Yaw steering electronically separates the receive beam into 3, 5, or 9 segments (a center beam and an equal number per side) and steers each segment to compensate for ship yaw. This innovation provides a much more accurate geographic determination of the location of individual depth/backscatter values on the seafloor. The ship's heading was determined with a dual differential global positioning system (DGPS) system with accuracies <0.1°. Positions and time stamps were provided with a kinematic DGPS system that gave reliable fixes one per second with ± 1-m accuracy.

Table 1 Optimum water depths vs modes for the EM300 system

water depth (m)	mode	fixed swath width (m)
10 to 50	very shallow	150°
50 to 200	shallow	1500
200 to 700	meduim	1500
700 to 2200	deep	3000
>2200	very deep	3000

Sound velocity profiles (SVP) were calculated several times each day so that raytracing techniques could be used to determine the effect of acoustic refraction in the water principally caused by variations in water temperature. Accurate ray tracing allows the precise location of each beam’s projection on the seafloor. A SeaBird CTD was deployed at least once a day to get a good reference SVP. However, this measurement requires the ship to hove-to and a typical cast takes about 30 minutes. Sippican T5 expendable bathythermographs (0 to 1830-m water depth), which can be obtained while underway, were routinely collected several times a day to determine water. Two additional sound velocity profilers are installed at the transducer arrays to determine the speed of sound in water directly at the transducer. All the SVP data are fed directly into the Simrad EM300 processor for instantaneous raytracing of the individual beams.

Table 2. Systems Specifications

Simrad EM300	see Appendix 1
	135 1°x2° beams
	6 kw output power
	source 240 dB (ref 1mPa @ 1 m)
mode	equal angle
active roll, pitch, heave, and yaw compensation	
positioning	DGPS
heading (gyro)	dual DGPS
motion sensing	POS/MV model 320
water velocity	daily SeaBird CTD several/day T5 XBTs

Like many of the state-of-the-art high-resolution multibeam mapping systems, the Konsberg-Simrad EM300 utilizes both amplitude (backscatter) and phase detection (bathymetry) for each determination of the bottom depth for each beam, resulting in a measurement accuracy of <0.2% of water depth (RMS).

The Party Chief, Mr. James Chance, oversaw a staff of surveyors and programmers from C & C Technologies, Inc. who operated the EM300 system. The data were processed aboard ship by the authors and a graduate student from the Ocean Mapping Group, University of New Brunswick (Table 3).

Table 3. Scientific Staff of cruise A2-98-SC

Name	***affiliation***
Capt. James Swan	Alert Shipping
Mr. James Chance	C&C Technologies
Dr. Larry A. Mayer	OMG, Univ. of New Brunswick
Dr. James V. Gardner	USGS
Mr. Edouard Kammerer	OMG, Univ. of New Brunswick
Mr. Tim Petro	C&C Technologies
Mr. Guy Guidry	C&C Technologies
Mr. Ryan Larsen	C&C Technologies
Mr. Kevin Buffitt	C&C Technologies
Mr. Charles Gauvin	C&C Technologies
Mr. Pablo Mejir	C&C

All post-cruise processing will be performed by JVG. Data processing (Fig. 3) consisted of (1) editing the navigation to flag bad fixes; (2) editing each ping of each beam, flagging outliers, bad data, etc., (3) merging the depth and backscatter data with the cleaned navigation, (4) reducing all depth values to mean low low water based on predicted tides; (5) performing additional refraction corrections for correct beam raytracing; (6) separating out the amplitude measurements for conversion to backscatter, (7) gridding depth and backscatter at the highest resolution possible with water depth, (8) regridding individual subareas of bathymetry and backscatter into final map sheets, (9) gridding and contouring the bathymetry, and (10) generating the final maps. Nearly finalized maps were completed aboard ship during the cruise and final maps were completed within one month of the end of the cruise. The derivitive maps are available on the Seafloor Mapping web site (http://marine.usgs.gov) and final maps will be published as USGS Miscellaneous Investigations I-Map Series.

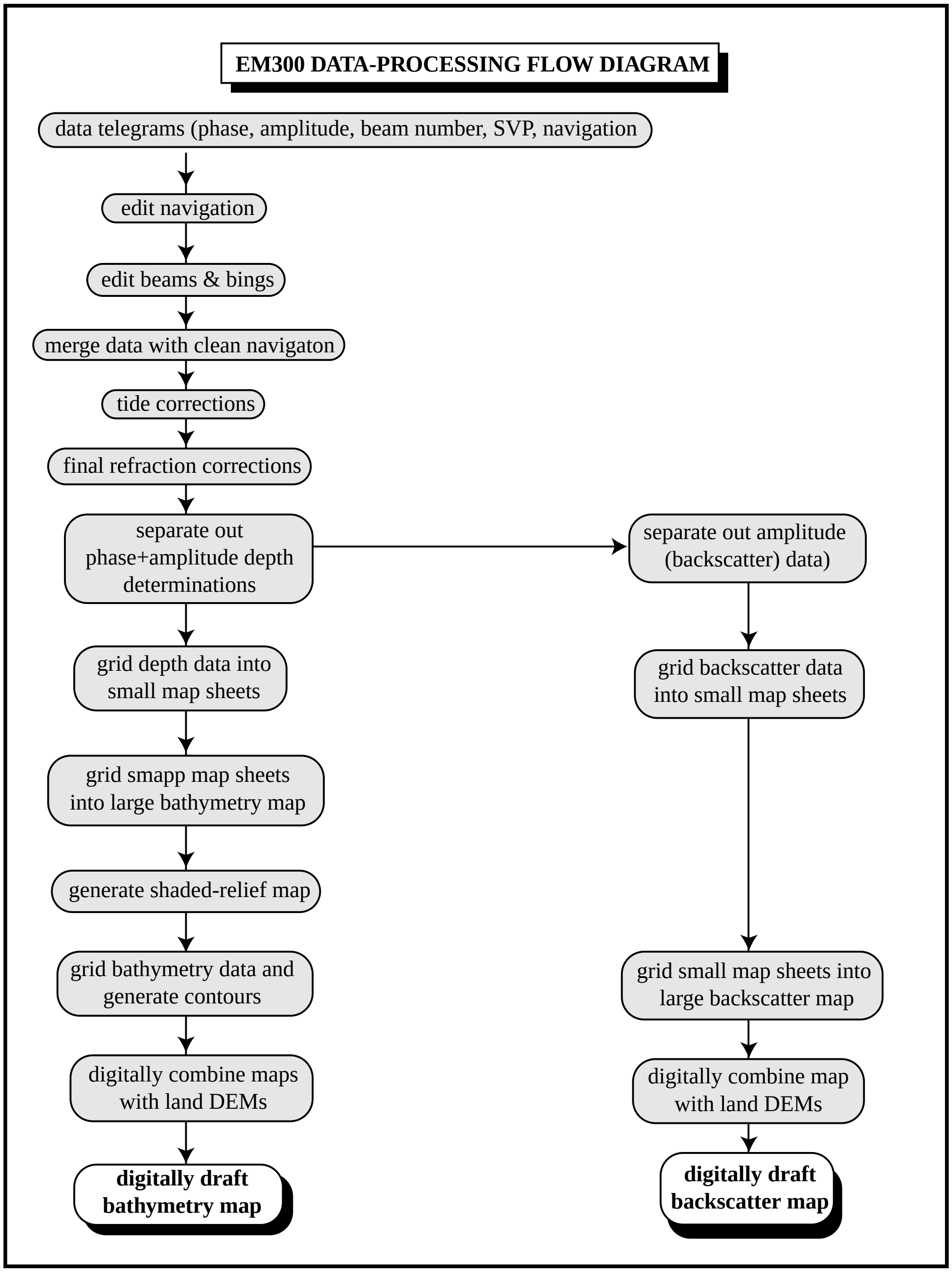

Figure 3. Processing flow diagram used to process the raw Simrad EM300 data telegrams.

The Maps

The large overview maps of backscatter and shaded relief that accompany this report were generated from large-scale subarea maps. The high-resolution subarea maps were regridded at the coarsest resoltuion of the subarea sheets within each area. This regridding reduces resolution in the shallower areas but allows the entire area to be mapped at a constant grid size. The detailed maps of each disposal site were produced at the maximum resolution allowable for the data. Both the backscatter and the bathymetry maps were gridded at the same scale for both the individual subarea (Appendix 2) and for the overview map.

The color-coded bathymetric charts represent the more traditional method of displaying bathymetry. The contours were derived from the gridded, tide-corrected depths. The resultant contours were smoothed by a 3-point running average in the overview maps, but are unsmoothed in the subarea maps. Even at the original contour grid, more than 90% of the data must be discarded so as to only show some chosen contour interval. A much better representation of bathymetry, using 100% of the data is a shaded-relief map.

A shaded-relief map (Fig. 4) is a pseudo-sun-illumination of a topographic surface using the Lambertian scattering law (equation 1), where B is the pseudo-sun brightness, I is the maximum brightness, and F is the angle between the pseudo sun and a normal to the bathymetric surface.

$$B = I(\cos F) \tag{1}$$

The backscatter map (Fig. 5) is a representation of the amount of acoustic energy, at 30 kHz, that is scattered back to the hull-mounted receiver. Backscatter can be thought of as albedo; that is, the actual reflectance of the seafloor to 30-kHz sound. The Simrad EM300 system has been calibrated at the factory (to an rms pressure referenced to 1 mPa at 1 m from the transmitter) and all gains, TVGs, etc. that are applied during signal generation and

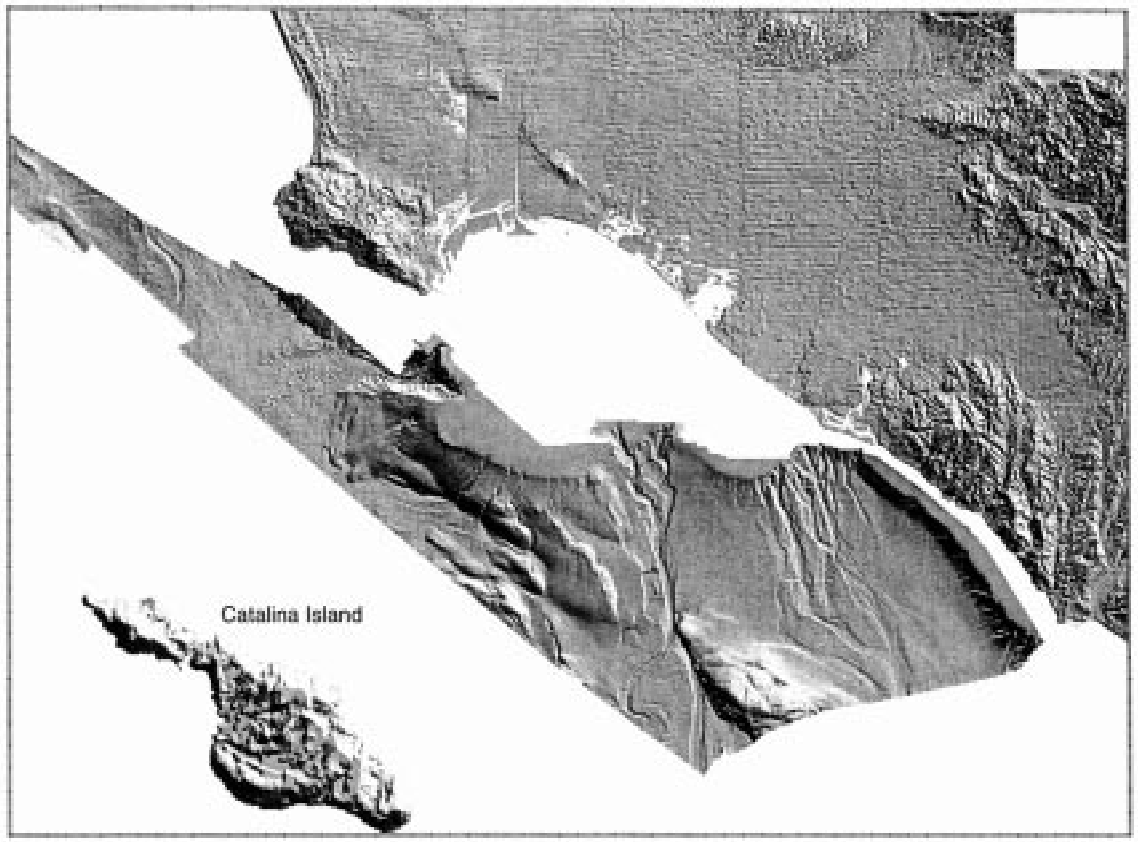

Figure 4a. Shaded-relief map of Newport mergin generated from data collected with the EM-300

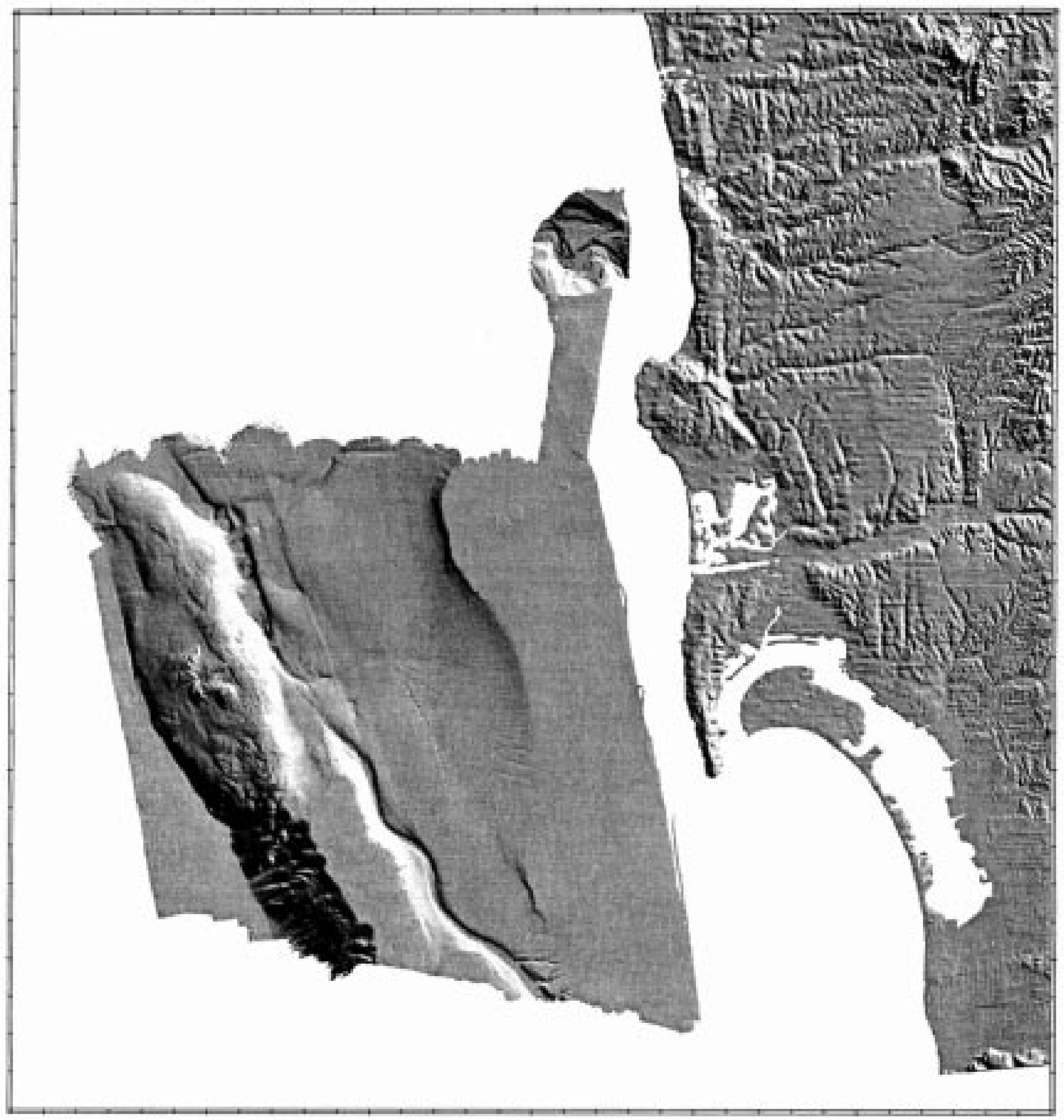

Figure 4b. Shaded-relief map of San Diego margin generated from data collected with the EM-300

detection are recorded for each beam and removed from the backscatter amplitude value prior to recording. Consequently, the backscatter can be calibrated to an absolute reflectance of the seabed . However, the amount of energy, measured in decibels (equation 2), where I_1 is the measured backscattered amplitude and I_2 is the reference pressure of 1, is some

$$dB= 10\log (I_1/I_2) \qquad (2)$$

complex function of constructional and destructional interference caused by the interaction of an acoustic wave with a volume of sediment (Gardner et al., 1991) or, in the case of hard rock, the seabed. The backscatter recorded by the EM300 from a sedimented area represents volume reverberation to at least 2-m subbottom depth caused by seabed and subsurface interface roughnesses above the Rayleigh criteria (a function of acoustic wave length), volume inhomogenieties larger than about half the wavelength (50 cm), the composition of the sediment, and its bulk properties (water content, bulk density, sound velocity, etc.). Although, it is not yet possible to determine a unique geological facies from the backscatter value, reasonable predictions can be made based on the local geology.

It cannot be stressed too strongly that one of the great advantages of this survey is that the bathymetry is completely georeferenced with the backscatter. That means that each pixel on the map has a latitude, longitude, depth, and backscatter value assigned to it.

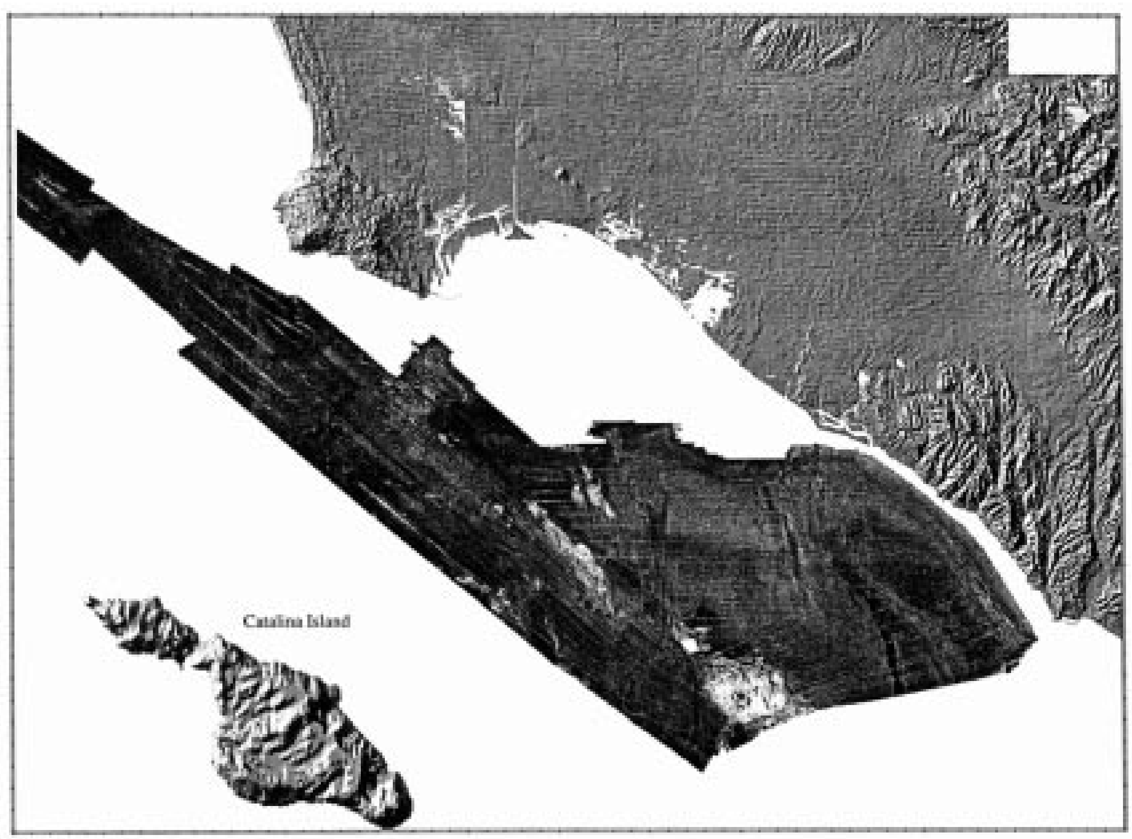

Figure 5a. Backscatter map of Newport mergin generated from EM-300 data.

Figure 5b. Backscatter map of San Diego marginn generated from EM-300 data.

Cruise Daily Log

The following is a daily log of noteworthy events during the cruise. All times are local standard Pacific Standard Time (GMT-8) and designated as "L". The ship arrived in San Diego, CA on March 25. All computer equipment was loaded on March 25 and set up with the usual minor problems. All the computer networking, etc. were completed on March 26. We departed the dock at 2050 L on March 26.

Thursday, March 26 (JD85)

We departed the dock at 2050 L and steamed out of San Diego Harbor. The swell was so big (>8 ft) that the pilot could not get off the ship and onto the pilot boat. It took until 2300 L to get the pilot off. We were finally on our way to run a short patch test over the Pt. Loma outfall pipe to insure the alignment of the systems. The swell was running ~10 ft with some seas that produced a 10° roll, but it was not a concern.

Friday, March 27 (JD86)

The Simrad computers crashed at 0005 L. The cause of the crash is unknown. While the C&C computer specialist worked on the computers the ship hove-to to collect a CTD profile. The computers were back on line by 0030 L while the CTD cast was still underway. One of the two velocity probes at the transmitters was not reading correctly, compared to the CTD and XBT casts so this probe was disconnected. The Simrad software rejected a few bottom points and a few near-surface points of the CTD velocity profile for unknown reasons. Once the points were deleted from the CTD profile, the Simrad system accepted the inputs. However, on the first patch1 line, an apparent roll artifact occurred throughout the data that apparently was not being compensated by the Simrad system. The artifact in the depth data appeared to be in phase with roll, but the artifact in the backscatter data appears out-of-phase with roll. The problems might be a cascading affect of improper roll compensation coupled with bad sound-velocity compensation.

No survey had begun yet because we continued to run patch test lines to identify the cause of the apparent roll artifact. We continued testing throughout the afternoon and determined that the system worked acceptably well in shallow water. We terminated testing and transited (Line 1) at 1800 L to a point to begin the survey. We arrived at the 50-m contour at 1820, changed course to 180° and began the survey with Line 2.

Saturday, March 28 (JD87)

We ran 18 lines off Pt. Loma but began to notice larger and larger heading offsets. It appeared that the POS/MV was not locked on the correct cycle and it was inducing a 5° heading offset. This problem, coupled with the roll bias we have had all along, compounded the errors in attitude and produced the artifacts that plagued us from the beginning. We broke off the survey at 0300 L and began to run a series of calibration runs and patch tests over the outfall pipe so that the POS/MV could be recalibrated. Timing also began to be a suspected problem.

The weather continued to be marginal with 10-ft confused swells and 40-kt winds. At 1300L C&C decided that we were out of options trying to figure out our multiple problems. There were POS/MV problems, timing problems, a problem with a missing board within the Simrad system, and a sector-artifact problem. Then, to make matters worse, JVG's Mac 8500 suddenly died from a suspected power spike. Nothing JVG did would bring it back to life. It appeared the hard drive and the RAM were fried.

The decision was made to steam over to the 30-m contour south of Pt. Loma and see if we could collect acceptable data in a shallow, more protected area. However, even in the shallow-water areas the data were marginal so C&C decided to collect some calibration data then go back to port in San Diego and await the arrival of the Simrad engineer and a new motion sensor. We met the San Diego Harbor pilot at 1900 L and were at the pier at 2000 L.

Sunday, March 29 (JD88)

The day was spent checking out the alignment of the motion sensor and tracking down a timing error of the order of 70 ms. It was suspected that a timing error on the order of the pulse rate might produce a roll artifact. At the same time, Simrad engineers were consulted on the phone and it was decided that one of them should immediately fly to San Diego because Simrad software was suspected to be the cause of some of our problems. Pablo Mejia, a software engineer from C&C Technologies arrived in mid afternoon. In addition, Applied Analytic (maker of the POS/MV) was consulted and a TSS motion sensor was sent from Texas.

JVG spent some time buying a new MacOS on CD-ROM and Norton Utilities to try to reboot his Mac, but neither avenue worked. His Mac was dead.

Monday, March 30 (JD89)

The day was spent continuing to track down potential timing errors, running to Scripps Institution of Oceanography to ftp download new versions of DelayEditor from John Hughes-Clarke (JHC) at OMG. JVG dropped his Mac off at the UCSD Bookstore Computer Center and by 1700 L they had diagnosed the problem as a dead hard drive and fried RAM. They promised a repaired Mac by Tuesday.

The Simrad engineer arrived at 1500 L and we brought him back to the ship where he immediately started checking out the Simrad system. Work continued through most of the night. The **DelayEditor** tool allowed us to independently determine that there was indeed a 70 to 90 ms timing offset that might be producing some of our errors. In addition, JHC sent a new version of **makess** that fixed the artifacts in the amplitude record caused by the induced roll artifact.

Tuesday, March 31 (JD90)

JVG’s Mac was ready at 0900 L and at 1200 L we cast off for trials off San Diego. We had the Simrad engineer and a TSS motion sensor aboard, as well as JVG’s repaired Mac.

Our next problems were that the seas were flat calm, whereas we needed large rolls to check the motion sensors. We even went to the extent of asking a US Navy destroyer escort, that was parallelling our course but at 25 kts, to cross our bow to create a bow wake so that we could test the roll corrections. The US Navy accomodated but unfortunately both the amplitude and duration of the roll were not enough to test our roll sensors. In fact, the seas were so flat that we decided to reestablish our survey lines, and we began to survey line 19 at 1736 L.

While we were running the survey lines, we tested out the software John Hughes-Clarke sent from OMG via ftp and found that his **fixss** script corrected the sidescan artifacts, so we regridded all the sidescan data. We determined that lines 1 through 19 were of sufficiently high quality that, once reprocessed, they could be used for survey lines. All of the "test" lines were not of a high-enough quality to be used for the survey. The seas were flat and the wind calm throughout the afternoon and the data looked acceptable.

The wind and seas began to build in the late evening and this gave us the perfect opportunity to test out all the presumed fixes we had tested in the calm conditions.

Wednesday, April 1 (JD91)

By 0700 L the seas were big enough, although not very big, to test out the corrections and we discovered that our fixes were not compensating for roll. We stopped logging data at 0700 L. The problem was tracked down to a timing delay problem that the Simrad system was accepting, but not using to calculate roll compensation. It was deemed to be a software bug, and we awaited a fix to be emailed from Norway. The onboard Simrad engineer was a hardware engineer, not a software engineer. He only confirmed that the hardware was all properly working.

By 1200 L we had a hack that could correct for the roll and yaw artifacts so we started collecting data. The weather calmed and we had very good conditons through the rest of the day and the data looked reasonably good. We continued to collect data throughout the rest of the day.

Thursday, April 2 (JD92)

We continued to collect data until 1030 L when we broke off the survey to meet the water taxi to offload the Simrad hardware engineer. The Simrad engineer was away by 1100 L and we were back collecting data at 1415 L. The water taxi brought out an eprom from Applied Analytic that was designed to reduce a saw-toothed jitter in our POS/MV. However, the first survey line with the new eprom continued to show a motion artifact at high resolution even though the saw-toothed jitter appeared to be eliminated from the POS/MV output.

We continued to collect very acceptable-quality data throughout the rest of the day.

Friday, April 3 (JD93)

If anything, the seas were the calmest we had witnessed to date. We had almost no vessel motion and the data were very high quality. We were told by the US Navy to leave the area we were working in because of some unspecified submarine operations. Consequently, we have a gap in our coverage in the southern part of the area that will have to be filled in later.

We decided to steam north to the La Jolla Canyon area and spend the allocated 24 hours surveying there. Next we would return to the area off San Diego to fill in gaps when we have to pick up an air-mailed CD-ROM of Simrad software. Within an hour of steaming north toward La Jolla the ship lost two engines because of various mechanical problems. Having these engines off line reduced our survey speed to about 5 kts, thereby considerably reducing our mapping efficiency. The Simrad timing/motion-sensor problems continued to plague us but, because of very calm seas, we were able to collect acceptable-quality data throughout the day.

Saturday, April 4 (JD94)

The weather continued to be mild and the seas calm. We finished the La Jolla Canyon survey by 1000 L and returned to the area immediately west of San Diego to fill in the gaps while awaiting the arrival of the Simrad CD-ROM that was advertised to clear up all our timing problems. However, at 1330 L we heard from the agent that the CD-ROM from Simrad would take until at least Monday (April 6) to clear customs. Consequently, we finished filling in the coverage gaps by 1700 L, put Pablo Mejir on a water taxi, and begain the transit to Newport area at 1730 L. We transited to the Newport area at 12 kts even though we realized the data would be noisy. We changed clocks for Pacific Daylight Savings Time and continued north.

Sunday, April 5 (JD95)

The Newport survey began at 0130 L with line 144. The directory file was changed to usgs_newport_98 but the line numbers continued on from the San Diego survey. The weather was bright and warm and the seas were very flat. The Simrad problems appeared much reduced because the major problem has been related to motion sensing and the flat seas meant we had no vessel motion.

Areas in the vicinity of Newport and Long Beach shallower than ~25-m water depth could not be surveyed because of a number of oil rigs that occupy that depth zone. Consequently, our survey was restricted to depths deeper than ~50-m water depth to provide a margin of safety for our ship.

Much of our time was spent reprocessing the San Diego data to correct for a yaw problem (with a variable -declin line in the weigh_grid program) in the first 19 lines. This required identifying the yaw correction and then re-swatheding those 19 lines. Once re-swatheded, each of the map sheets (9 total) had to be regridded.

The data quality was superb throughout the day.

Monday, April 6 (JD96)

We continued mapping in the Newport area. The weather deteriorated somewhat so we ran some roll tests to see if the Simrad system still had a timing and/or roll artifact. The tests were inconclusive. The seas were only moderate and lumpy even though the wind continued to blow at 20 to 30 kts throughout the day. The data quality continued to be very high.

Tuesday, April 7 (JD97)

The weather continued to be choppy seas and stiff breezes, but the data were not adversely affected. We ran two long lines along the western border of the Santa Monica survey and then concentrated on the ocean dump site off Long Beach. By 1200 L we had completed all the area deeper than 100 m.

A water taxi arrived at 1400 L with the long-awaited Simrad CD-ROM with software upgrades. We spent two hours adrift installing the software and testing the new system. The new additions made no appreciable difference in our data. We were back on line surveying at 1615 L.

Wednesday, April 8 (JD98)

We surveyed through the night and then stopped surveying at 0600 L to try more testing to eliminate artifacts while we could talk directly to Simrad engineers in Norway. The lastest version of the Simrad software was reloaded. A series of tests laying in the trough for roll, in both deep and shallow water, gave no conclusive results. Timing between the DGPS and the Simrad system was still considered to be a problem. Fortunately, the sea state continued to be very good and our data were little affected by the artifacts.

We began to collect data again at 1230 L but immediately noticed that the gain on the backscatter data was down by almost 10 dB. Something in the new software was changing the initial gains in the amplitude data over the settings on the original software. We spent another two hours testing, trying to find the proper gain settings. By 1500 L we gave up on the new software and reinstalled the old software. This improved the image quality over what we got from the new software, but at 1715 L the ethernet link between the Simrad data-collection computer and the other computers died. The problem was tracked down to a loose connection and we got back on line at 1830 L. The rest of the day was routine.

Thursday, April 9 (JD99)

The Simrad computer crashed in the middle of the night, and it took 1.5 hr to get it back up. There was no apparent reason for the crash. The rest of the day was routine mapping around the head of Newport Canyon and then adding onto the south border of the survey to extend the area covered. The seas remained calm and the wind was only a breeze.

Friday, April 10 (JD100)

The day was spent mapping along the west and south sides of the survey area. A decision was made not to devote the remaining time mapping on the shelf because the unmapped portion of the shelf is in water depths less than 50 m. The Simrad EM300 is not very efficient in water depths less than 50 and we would not map much area for the time and expense. The weather was bright and the seas calm.

Saturday, April 11 (JD101)

We broke off the survey at 0645 L, met the harbor pilot at 0830 L, and were tied up to the pier in Long Beach by 0900 L.

Table 4. Time spent on each survey area

San Diego	108 hours	4.5 days
Long Beach	120 hours	5.0 days

Table 5. Cruise statistics

Average speed	9.5 kts
total line kms	4075 km
total area mapped	km^2
days at sea	17 days
days mapping	9.5 days
patch test	0.5 days
system testing	7 days
transit	s0.5 days

References Cited

Gardner, J.V. and Hughes-Clarke, J.E., 1998, Cruise report RV Ocean Alert Cruise A1-98-HW, Mapping Hawaii Insular slopes, U.S. Geol. Survey Open-File Rept. 98-

Gardner, J.V., Field, M.E., Lee. H., Edwards, B.E., Masson, D.G., Kenyon, N., and Kidd, R.B., 1991 Ground truthing 6.5-kHz sidescan sonographs: What are we really imaging?. J. Geophys. Res., v.96, p. 5955-5974.

Hughes-Clarke, J.E., Mayer, L.A., and Wells, D.E., 1996, Shallow-water imaging multibeam somars: A new tool for investigating seafloor processes in the coastal zone and on the continental shelf. Marine Geophysical Researches, 18: 607-629.

Appendix 1. Details of Simrad EM300

RX

sample rate:	4509 Hz
Bandwidth:	5000 Hz
Demod. frequency:	32565 Hz

TX

Power reduction 10 dB, 20 dB

Mode-dependent parameters:

Parameter/Mod e	Very Deep	Deep	Medium	Shallow	Very Shallow
Depth Range	1000-5000 m	500-3000 m	100-1000 m	30-300 m	5-50 m
Pulse length	5 MS	5 MS	2MS	0.7 MS	0.7 MS
Delay between TX pulses	24 samples 5.32ms	24samples 5.32 ms	12 samples 2.66 ms	5 samples 1.11 ms	5sample s 1.11 ms
TX pulses TX frequency beam angle (positive angles to port)	31 44° 1 32.5 31.5° 3 34 20.5° 5 32 -10° 7 33.5 0° 9 30.5 -10° 8 33 20.5° 4 31.5 -31.5° 4 30 -44° 2	31 69° 1 32.5 48° 3 34 33° 5 32 17° 7 33.5 0° 9 30.5 -17° 8 33 -33° 6 31.5 -38 4 30 -69° 2	31.5 60° 1 33 0° 3 30 -60° 2	31.5 60° 1 33 0° 3 30 -60° 2	31.5 60° 1 33 0° 3 30 -60° 2
Estimated max SL	240/234 dB (1°/2° beam)	238/232 dB (1°/2° beam)	230/dB (2°beam)	224 dB (2° beam)	
RX/TX Beamwidth	1° or 2°	1° or 2°	1° or 2°	2°	4°
Manually selected RX sector width	98°, 80°, 64°	150°, 140°, 128°, 114°, 98°, 80°, 64°	150°, 140°, 128°, 114°, 98°, 80°, 64°	150°, 140°, 128°, 114°, 98°, 80°, 64°	150°, 140°, 128°, 114°, 98°, 80°, 64°
BSP bandwidth (for beams close to normal incidence)	200 Hz (350 Hz)	200 Hz (350 Hz)	550 Hz (1000 Hz)	1000Hz	1000 Hz
RX beams	135	135	135	111	111
OUTPUT SAMPLE RATE	563 HZ	1127 HZ	2254 HZ	4509 HZ	4509 HZ

Appendix 2. Grid sizes for subarea sheets and overview maps for each survey area.

area	subarea sheet	grid size	overview map
San Diego			16
	area0	4 & 8	
	area1	8	
	area2	4 & 8	
	area3	8	
	area4	8 & 16	
	area5	8	
	area6	8	
	area7	8	
	area8	8	
Long Beach			16
	area0	4	
	area1	4	
	area2	8	
	area3	8	
	area4	8	
	area5	8	
	area6	8	
	area7	8	
	area8	8	