Department of the Interior
U.S. Geological Survey

CRUISE REPORT FOR CRUISE F3-87-AA, GLORIA SURVEY OF THE WEST-CENTRAL ALEUTIAN ARC AND ADJACENT NORTH PACIFIC OCEAN

by

Chief Scientists

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EEZ-SCAN PROGRAM

On March 10, 1983, President Reagan proclaimed an expansion of sovereign rights of the United States of America to all natural resources within an Exclusive Economic Zone (EEZ), a submarine region extending seaward from the coast to a distance of 370 km (200 nautical miles). With this proclamation, over 10 million square kilometers (3 million square nautical miles) of submarine lands were added to the national domain.

In 1984, a reconnaissance mapping survey of the EEZ was initiated as a cooperative scientific program between the U. S. Geological Survey (USGS) and the British Institute of Oceanographic Sciences (IOS). The primary search tool is a long-range side-scan sonar (GLORIA, for Geological Long-Range Inclined Asdic), developed by IOS in the early 1970's (Rusby and Somers, 1977; Somers et al., 1978). GLORIA transmits acoustic energy at a nominal frequency of 6.5 kHz and receives the energy backscattered from ocean bottom features. The data are recorded digitally aboard ship and are subsequently processed by computer. The processed data are presented as sonographs (photographic images of the backscattered energy) that are combined into a photo-mosaic of the insonified region.

Cruise F3-87-AA, a part of the EEZ cooperative scientific program, was conducted aboard the British ship M/V Farnella with a complement of scientists and technical support staff from the U. S. and U. K.. This cruise, the third leg of the 1987 field season in Alaska, surveyed parts of the west-central Aleutian EEZ. The objective was to produce an atlas of mosaicked sonographs that displays the geology and morphologic character of the seafloor in the Aleutian-North Pacific Ocean region. This is the initial step towards an overall understanding the economic potential of the western and west-central Aleutian part of the United States EEZ. To date, GLORIA surveys that have been conducted elsewhere in the EEZ include those in the: 1) western conterminous United States, 2) Gulf of Mexico and Caribbean, 3) eastern seaboard of the United States, 4) Bering Sea region, and 5) Hawaiian ridge region.

Leg 2 initiated the 1987 western Aleutian season by insonifying a region bounded by the 370 km (200 nautical mile) limit on the south, the U.S.-U.S.S.R. convention line of 1867 on the west, the Aleutian Arc on the north, and an irregular line to the west-southwest of Amchitka Pass. Leg 3 completed the survey of the North Pacific plate from the Aleutian trench to the 370 km limit west of Amchitka Pass and also surveyed the Aleutian fore-arc slope from Amchitka Pass eastward to approximately 174° west longitude and seaward to approximately the Aleutian Trench (Fig. 1).

In addition to GLORIA imagery, we also collected 10-kHz bathymetry, 3.5-kHz high-resolution acoustic profiles, 160- and 300-in^3 airgun seismic-reflection records, continuous magnetic and gravity potential-field measurements, and bathythermograph measurements of the thermal structure of the upper part of the water column throughout the study area. Navigation was by combined GPS and Loran positioning.

CRUISE NARRATIVE[1]

Departure from Dutch Harbor, Unalaska Island, was scheduled for Thursday morning, August 27, but was delayed until Friday, August 28, at 1630 local time (241/0030z) to allow delivery and installation of a repaired towing davit for the 3.5-kHz tow fish. That davit had been damaged at the end of F2-87-AA. We were also awaiting delivery from Anchorage of a backup cable for the 3.5-kHz system, but unfavorable weather conditions delayed delivery and we decided to sail without the cable. The scientific and support staff participating in the cruise are listed in Table 1.

[1] In the following description, local time is Anchorage daylight time (ADT). GMT is ADT plus 8 hours.

Table 1

SCIENTIFIC PARTY FOR F3-87-AA

Bohannon, Robert	USGS	Co-chief scientist/geologist
Campbell, Jon	IOS	Party chief
Dobson, Max	UCWA	Co-chief scientist/geologist
Edwards, Brian	USGS	Co-chief scientist/geologist
Cherriman, John	IOS	GLORIA technician
Coddington, Joseph	USGS	Watch stander/computer specialist
Fong, Grace	USGS	Watch stander/geologist
Gann, John	USGS	Navigator
Jacobs, Colin	IOS	Geologist/photographer
Kooker, Larry	USGS	Electronics technician
Lewis, Derek	RVS	Computer specialist
Ryan, Holly	USGS	Watch stander/geologist
Whittle, Steve	IOS	Mechanical technician

IOS: Institute of Oceanographic Sciences
RVS: Research Vessel Services
USGS: U.S. Geological Survey
UCWA: University College of Wales-Aberystwyth

Transit from Unalaska to the operations area near the 200-mile limit took 3 days in slowly building seas. Figure 1 shows the location of track lines occupied during the cruise. We launched the 10-kHz and 3.5-kHz fish on Saturday at 2140 local (242/0540z) in the lee of Great Sitkin Island and continued steaming toward the operations area. On Monday August 31, we launched the GLORIA vehicle and the remaining geophysical gear in rough seas at 2045 local (244/0445z) near 49°00' N 172°42' E. The launch went smoothly and we began collecting GLORIA data on the Pacific plate at 2100 local (244/0500z). Data collection continued smoothly for the next 14 days in marginal to good seas. During this period, there was minimal down-time to the airgun system for routine maintenance. We finished the Pacific Plate sector to the east of Amchitka Pass in poor weather on Monday September 14. We then began a north-south-trending line (line 24) toward Amchitka Pass on which we acquired an excellent airgun record from the Pacific Plate, across the trench, and up the fore-arc slope. The orientation of this line normal to the tectonic grain gave poor GLORIA records.

Upon arriving in the vicinity of Amchitka Pass the weather moderated and we continued operations in continually improving seas. We completed the survey of Amchitka Pass (lines 25 - 28) and the northern-most survey line eastward to Adak Canyon (line 29) by Wednesday, September 16 during good weather. By Wednesday evening, however, during our survey to the east near the shelf break, weather freshened quickly to the point that we were unable to recover GLORIA and we were forced to continue steaming to the east beyond our planned turn. The rough, following seas on this unplanned line extension caused a degradation of data quality in both 1)the airgun record due to noise from the streamer slapping the sea surface and 2)in the GLORIA record due to yaw of the tow vehicle.

We were blown east all night by gale-force winds and were not able to pull the geophysical gear. On Thursday at 0830 local (260/1630z) we turned south to collect airgun data across the trench (line 33) beginning near the east end of Amlia Island. The airgun data were noisy and GLORIA data were of poor quality on this line. Weather moderated somewhat by the end of the line and we were then able to pull gear. During the transit back toward Amchitka, weather moderated and we decided to redeploy all the gear and begin a survey line toward the west (line 34). At the end of that line, south of Amchitka Pass, the weather again deteriorated as a tropical storm (Typhoon Holly) slowly entered the Aleutian area. We were forced to recover GLORIA Saturday at 1948 local (263/0348z) and we were unable to re-deploy gear until Tuesday at 1446 local (265/2246z) due to the severity of the storm.

We continued collecting GLORIA data on the Aleutian Terrace and fore-arc slope in generally good seas until Thursday at 2330 local (268/0733z) when we ended data collection, secured all gear on deck, and

began our transit back to Dutch Harbor, Unalaska. We arrived at Dutch Harbor on Sunday, September 27, 1987, at 0940 local (270/1740z).

EQUIPMENT SYSTEMS

Navigation

The primary navigation systems used during F3-87-AA were GPS satellite, transit satellite, and Loran-C, in both hyperbolic and rho/rho modes. A line-following program, installed on M/V Farnella prior to the beginning of F1-87-BS, resulted in significantly improved trackline straightness throughout the 1987 Alaska field season.

A further significant navigational improvement was the capability to use Loran C in rho/rho mode. The necessary hardware consists of (1) a Northstar 7000 Loran-C receiver modified to accept an external oscillator, (2) a Hewlett-Packard 5062C Cesium beam frequency reference, (3) an IBM PC with two serial ports and math co-processor, (4) a Trimble GPS 4000A locator, and (5) a black box data broadcaster. Software for the rho/rho system, developed by John Gann of the USGS during F3-87-AA, consisted of 45 C-language routines.

The rho/rho software computes real-time latitude and longitude. The output from the IBM PC rho/rho software is passed to the USGS line-following system and to the ABC system on M/V Farnella. The Trimble GPS receiver is used to calibrate the rho/rho system and to compute range biases for each Loran-C slave station. Of significant importance is the design capability of the rho/rho system to be calibrated at sea while underway.

During F3-87-AA local GPS coverage was from about 0530z thru 2200z. GPS was the primary data set passed to the line-following system during this period. During the six to seven hour hiatus in GPS coverage, Loran-C rho/rho became our primary navigation aid. The rho/rho position typically differed from the GPS position by less than 500 meters (commonly less than 100 meters) when recalibrated after the six to seven hour hiatus. During periods of GPS coverage, the absolute positional error was less than 500 meters and typically within 50 meters. Loran-C rho/rho was used intermittently during developmental stages in the early part of the cruise. We began substantial use of the rho/rho system on Friday, September 4 and began logging the data to the ABC system on Tuesday, September 8.

GLORIA Side-scan Sonar System

The GLORIA vehicle performed well throughout the cruise and was recovered only twice during times of bad weather. On the first recovery at the end of line 33, the tow cable became badly kinked but a cable change was not made due to the severity of the sea state. We chose to re-deploy GLORIA with the same cable for line 34 in order to take advantage of improving weather. Data quality was not impaired by using the kinked cable.

There is a significant defect in the GLORIA data through Thursday, September 17. The beam pattern of the starboard array was distorted during transmission such that each target was effectively insonified twice, producing a double image on the records. This defect, unrecognized at sea, affects only the starboard data and was likely caused by a wiring error in the spliced cable we were using. Thus, two sections of the array were swapped over with the result that the beam pattern had two maximas separated by a few degrees. We hope that Pat Chavez (NMD), the primary developer of the Mini-Image Processing Software (MIPS), can write a subroutine that will enable us to eliminate the problem through computer processing. An example of the double imaging is given in Figure 2. Other degraded GLORIA images occurred periodically as an apparent result of interference with the deep-scattering layer over parts of the Pacific Plate.

Bathymetry

The Mufax PES 10-kHz (BA10) bathymetric system worked well throughout the cruise. The Raytheon 3.5-kHz (BA35) with the IOS-built correlator worked well most of the time, but had several minor repair problems and developed a noise problem toward the end of the cruise. During the cruise, the BA35 data degraded due to adjustments in screw speed and pitch and the occurrence of a deep-scattering layer. On Friday, September 18 we developed problems with the programmer on the BA35 Raytheon LSR. The problem was corrected on Saturday when the ET discovered and replaced a damaged timing board. Later, the signal again became degraded, was isolated to the tow-fish but we were unable to recover the fish while underway. When we recovered GLORIA and the BA35 fish during Typhoon Holly, we found that part of the fairing on the BA35 tow cable had broken loose and was flapping against the side of the fish causing noise on the record. We also discovered seawater in the connector at the fish. We changed to the back-up fish and also changed the transceiver in the lab unit. BA35 data are marginal from this time through the rest of the cruise due to bottom topography, ship pitch, and tow speed.

Seismic Reflection

Throughout most of the cruise we used a 160 in^3 airgun source with a Geomechanique two-channel streamer. The two-channel airgun data (TCAG) were digitized and recorded on magnetic tape at a 4 msec rate using a USGS-designed MASSCOMP recording system. Simultaneously, one of the two channels was also displayed as an analog record (SCAG) on a Raytheon LSR recorder. While surveying part of the fore-arc near Hawley Ridge we changed guns to 300 in^3 in order to achieve greater penetration.

The airguns performed reliably throughout the cruise with minimal downtime for maintenance. The two-channel Geomechanique streamer provided data of good quality, but was degraded in comparison to the 1986 field season, due to streamer age and a history of use in heavy seas. The streamer began showing noticeable signal degradation on Saturday, September 5 and the signal quality varied during the following days. On Saturday, September 19, we brought the streamer onto the deck and dismantled it just ahead of both active sections. We also inspected the connections for the deck-leader at the winch. Testing showed no open conductors, so the system was reassembled and subsequently gave somewhat improved signals. Signal drop-outs again appeared on Tuesday, September 22 with channel 2 giving slightly better data than channel 1. The problems were isolated to the forward active section and on Wednesday, September 23 we pulled gear to replace that section with the spare active section. That spare section proved to be old and, on reassembly, we acquired data on only one channel (Channel 1). Those data were of moderate quality.

Gravity

Gravity was measured with a LaCoste and Romberg sea gravimeter S-53 that was located in the main lab. The meter operated continuously and reliably throughout the cruise. Base ties were made in Dutch Harbor at the beginning and the end of F3-87-AA.

Magnetics

A Geometrics G801 magnetic gradiometer system recorded as simple magnetic data at 20 second intervals throughout the cruise. All data are of high quality as the instrument performed reliably.

Expendable Bathythermograph (XBT)

Thirty-seven XBT's (type T-6 and T-7) were dropped at selected sites throughout the study area (Fig. 3). Most of the XBT's recorded data through the full working depth range of each type (460 meters for the T-6; 760 meters for the T-7). These data were routinely transmitted to NOAA via satellite. The XBT's and computer-related equipment were provided by NOAA.

DAFE

The DAFE data logging system was installed on the MASSCOMP computer. Priority for DAFE was set at 'nice -18' and the program worked without interference to real-time data-logging. Table 2 shows the DAFE codes used throughout the cruise.

Table 2.

DAFE NOMENCLATURE FOR F3-87-AA

CODE	SYSTEM
BA35	3.5-kHz bathymetry
BA10	10-kHz bathymetry
GRVS	Paper record of shipboard gravity
GRVM	Magnetic tape of gravity with magnetics
GLOR	GLORIA data (paper roll and magnetic tape)
MAGS	Paper record of shipboard magnetics
SCAG	Single-channel airgun monitor record
TCAG	Two-channel airgun data (recorded digitally by MASSCOMP)
XBTG	Expendable bathythermograph

PRELIMINARY SCIENTIFIC RESULTS

Pacific Plate Region

On the Pacific Plate, the GLORIA data clearly show the Stalemate Fracture Zone, separating Cretaceous lithosphere to the southwest from Paleogene lithosphere to the northeast. The Buldir fracture zone parallels the Stalemate Fracture Zone and consists of several anastomozing shears between which small basins and ridges have developed on the Cretaceous lithosphere. This fracture appears to have both strike-slip and extensional features. The Rat Fracture Zone cuts the Paleogene crust, offsetting the magnetic anomalies mapped by Lonsdale (in press). A multitude of ridges that parallel the magnetic anomalies are evident on the GLORIA images.

A large number of normal faults, with east-northeast trends, appear on the GLORIA images as ridges on the outer slope of the Aleutian trench. Most of the older physiographic features on the Pacific Plate are fractured and obliterated by these faults as part of the subduction process. The extensional tectonism represented by the normal faulting on the downgoing plate appears to be sufficient to smooth the old morphologic features on the plate.

Aleutian Fore-Arc Region

The seafloor at Amchitka Pass is heavily scoured and shows only strong returns on the GLORIA sonographs and seismic-reflection profiles. Numerous submarine canyons, cut between the arc and the fore-arc, have fed sediment into several localized summit basins. These basins are primarily half-grabens and imply a period of extensional tectonism and possibly strike-slip faulting between the arc and the base of the fore-arc slope. At the base of the fore-arc slope, a complex pattern of lobate ridges that are convex to the south is evident on the sonographs. This pattern is likely caused by numerous thrust faults, folds and slump features on the accretionary wedge.

The floor of the Aleutian Trench is featureless and inclined slightly toward the arc. Locally, the trench approaches 7600 meters in depth and is filled with undeformed, bedded sediment. The GLORIA imagery does not indicate the sediment transport direction on the trench floor. Little sediment appears to reach the trench from canyon systems cutting across the fore-arc. Sediment failures appear to be important locally and head in the accretionary complex.

ACKNOWLEDGEMENTS

We thank the officers and crew of the M/V Farnella who contributed significantly to the success of the cruise by their enthusiastic cooperation and attention to detail. Sue Hunt and Steve Wallace, both of the USGS Marine Facility, provided outstanding logistical support.

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LIST OF FIGURES

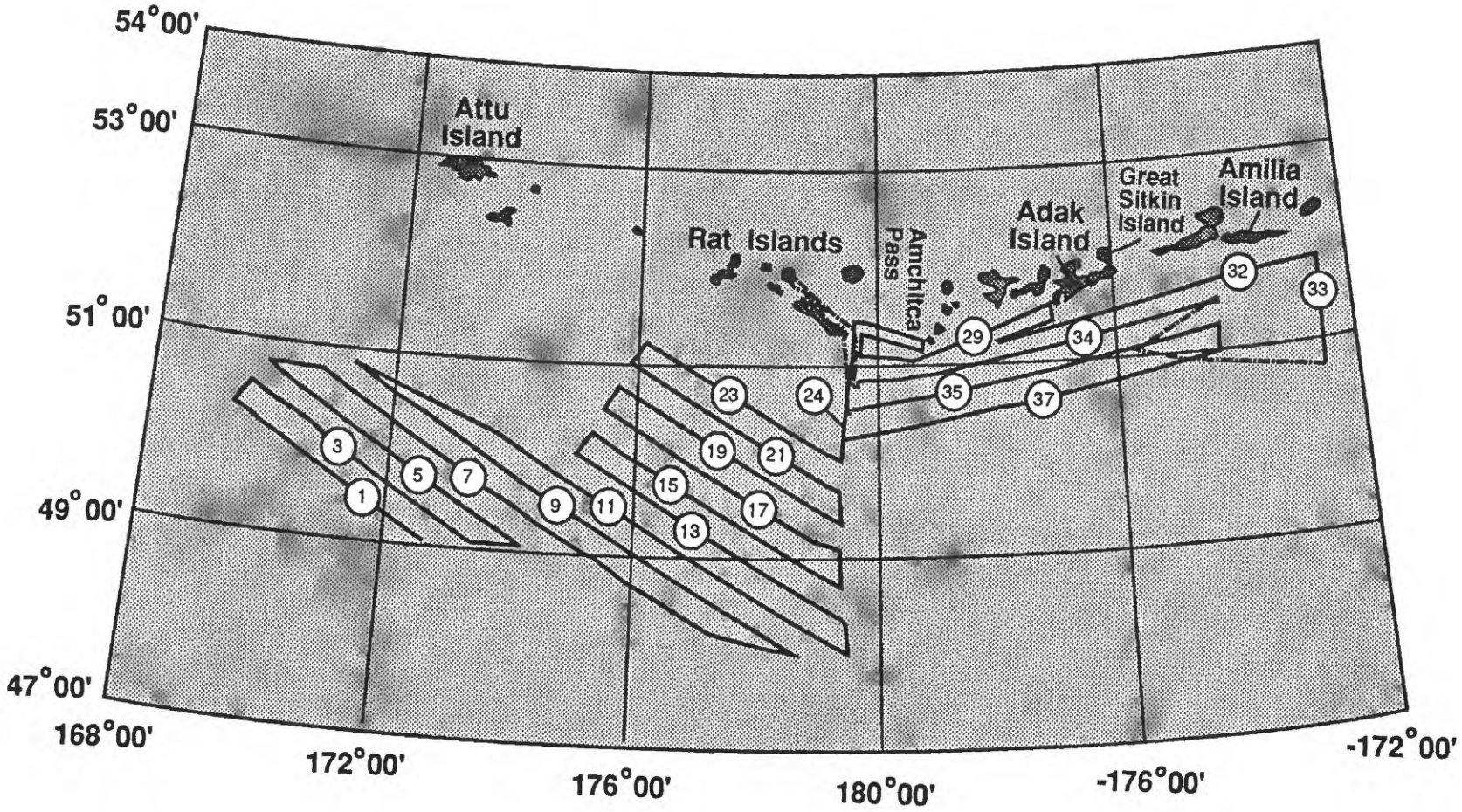
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Figure 1

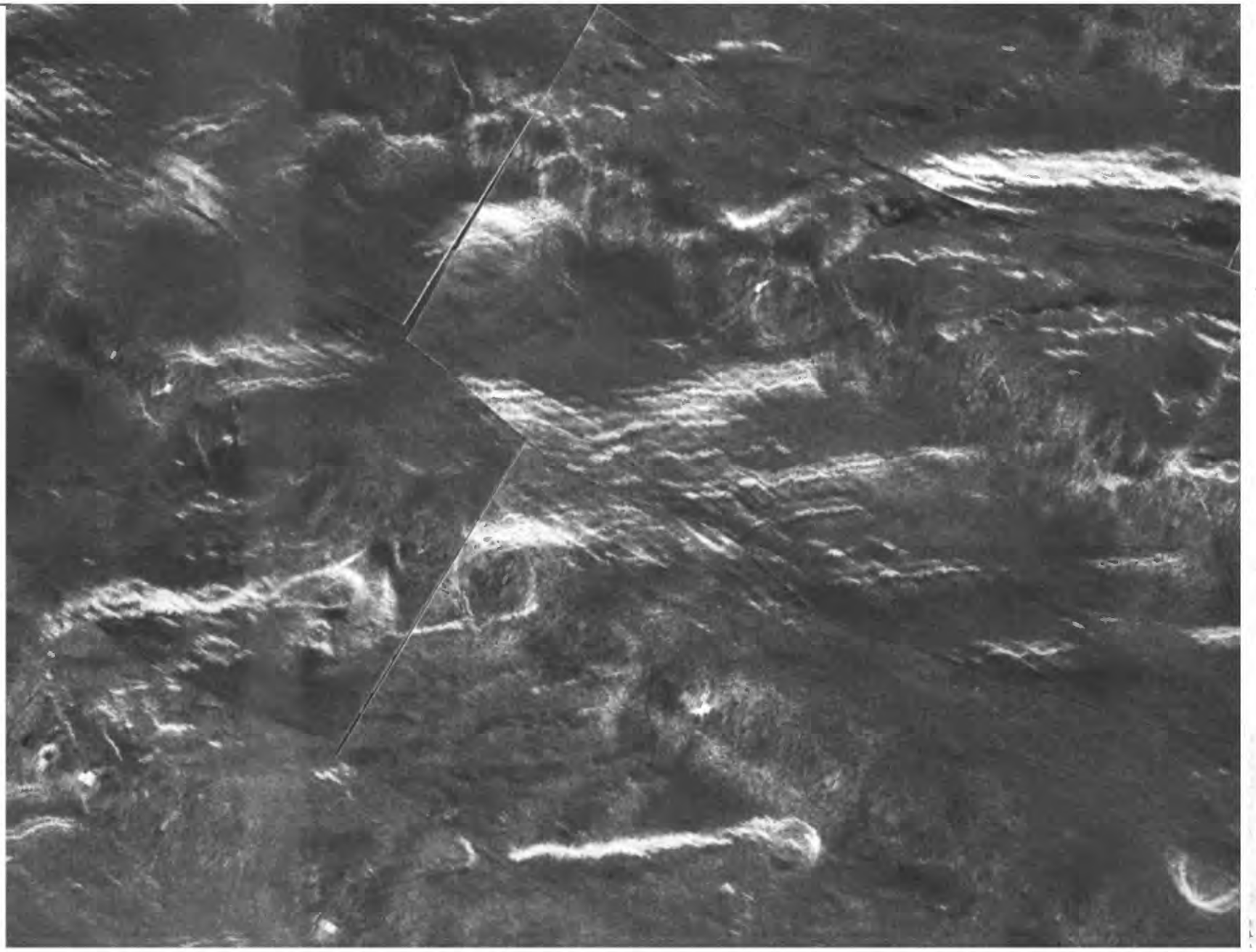

Figure 2

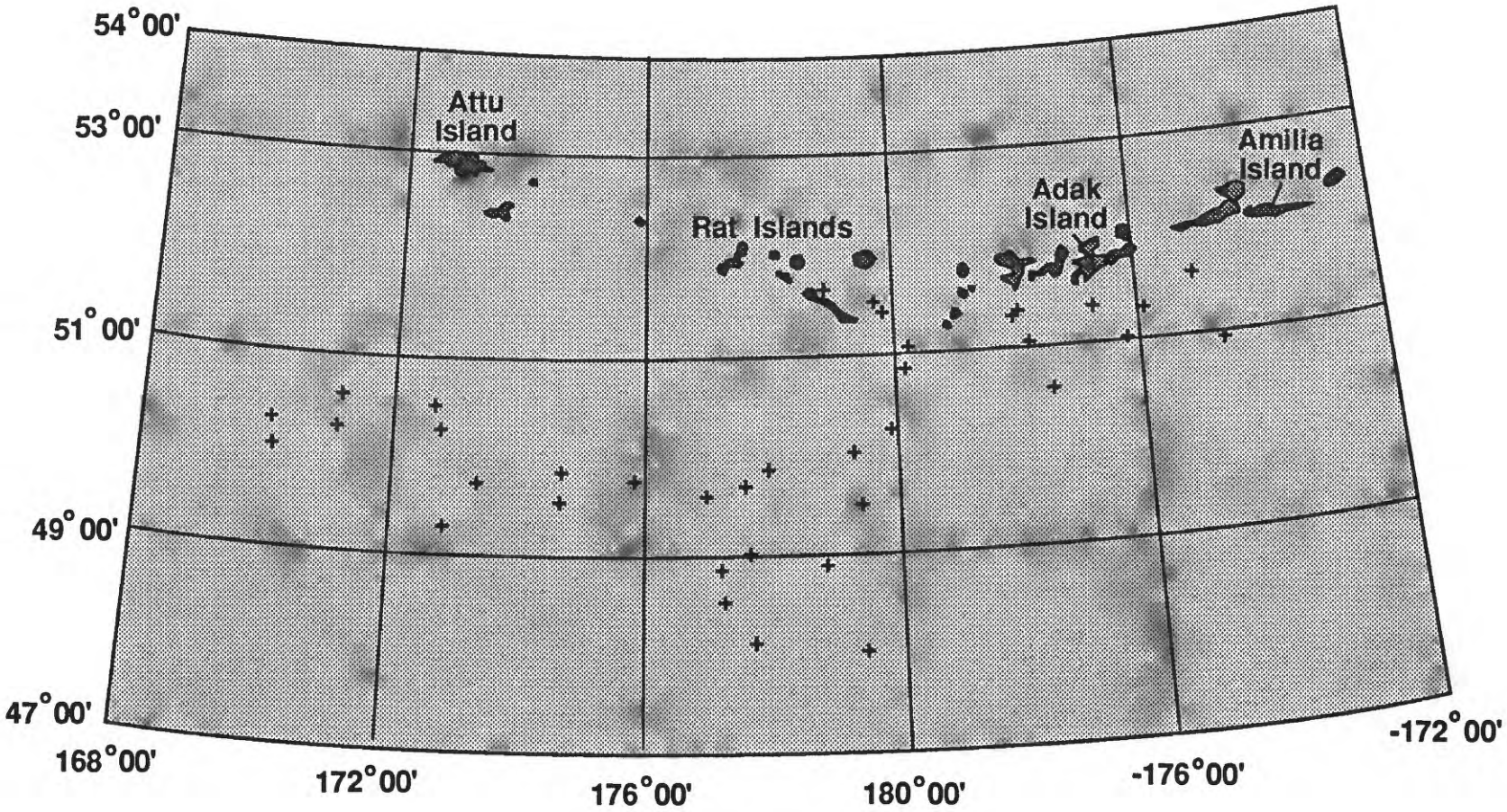
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Figure 3