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CCOP/SOPAC MOANA WAVE CRUISE 3 (MW87-02)

TO THE TERRITORIAL WATERS OF WESTERN SAMOA,

THE COOK ISLANDS AND KIRIBATI

- CRUISE REPORT

W.T. COULBOURN, P.J. HILL & SHIPBOARD PARTY

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ABSTRACT

As a part of the CCOP/SOPAC program of marine geological and geophysical exploration, in February 1987 portions of the territorial waters of Western Samoa, Cook Islands and Kiribati were surveyed for their resource potential.

RV MOANA WAVE surveys in the territorial waters of Western Samoa were split between one day on the Machias Seamount and one day offshore of the southern coast and western tip of Savaii. SeaMARC II images show that normal faults paralleling the local strike of the Tonga-Kermadec Trench dissect Machias Seamount. This edifice is flat-topped and the extensive remobilization of sediment from its summit and slopes greatly reduces the area of exposed and undisturbed substrate suitable for metalliferous crust growth and degrades the mineral potential of this edifice. The survey offshore of Savaii reveals a rocky sea-floor and numerous small cones aligned with the southwest rift onshore. These cones are too small to show on any bathymetric maps available to us prior to this survey. The platform area offshore of the western point of Savaii comprises mixed sediment and rock exposures. Debris flows cover half of the submarine slopes offshore of the south and southwest-facing coasts of Savaii. The offshore area surveyed is limited to a 20 km wide swath and no attempts were made to dredge the rocky substrate because of time constraints. The preliminary results, however, suggest that the economic potential of this area is probably limited to whatever value the sand accumulating offshore would have for future construction or beach replenishment needs.

Studies in Cook Island waters required six working days, split among Suwarrow Trough, the eastern escarpment of the Manihiki Plateau and the Rakahanga-Manihiki Island area. An excellent exposure of the potential copper-bearing beds of the Upper Cretaceous volcaniclastic sediments was located by seismic reflection profiling of Suwarrow Trough. Time constraints permitted only a single dredge attempt and this, unfortunately, returned only Recent foraminiferal ooze. Spectacular SeaMARC II coverage and successful dredging of the eastern escarpment of the Manihiki Plateau near 12-04' S and 160-57' W followed. Manganese-encrusted volcaniclastic and phosphatized, carbonate cobbles were recovered. A mud volcano of about 2200 m relief was discovered in the Rakahanga-Manihiki Island survey area. The edifice is composite, with numerous flows and satellite conical vents, some showing multiple flows. The side-scan images of the small satellite cones are remarkable in their quality and detail. A free-fall core was lost on one of these small cones and a grab sampler returned from its summit with no sample. Two free-fall cores were retrieved from the flanks of another cone. Manganese crusts on Eocene foraminiferal limestone were dredged from the center of the composite edifice, indicating mixing and outpouring of portions of the underlying sedimentary section. Sapropelic, Upper Cretaceous sediments correlative with those drilled at DSDP Site 317 are probably the source for the overpressured pore water

and gas necessary to produce such a feature. Dredging of a nearby excarpment retrieved Mn-coated, altered rock that may be phosphatic, plus samples of the Manihiki Plateau basal volcaniclastic rocks.

Six and a half days were devoted to surveying and sampling in the Line Islands area, Kiribati. These efforts included: discovering potential sites of metalliferous crust growth -- uncharted seamounts located by SEASAT/GEOS-3 satellite anomalies, SeaMARC II side-scan imaging of seamounts and ridge segments, and sampling for manganese crusts along depth and latitudinal transects. Three uncharted seamounts were located, two of these with a single SeaMARC II swath recorded in transit, and another two charted seamounts were surveyed with complete side-scan coverage. A seamount at about 0-91' S and 157-03' W is probably too young and too steep-sided to provide a suitable substrate for crust growth. Chapman seamount in the Central Line Islands is a guyot and sediment drapes its entire summit and portions of its flanks. In contrast to these unpromising sites, is a ridge segment located at about 1-19' S and 155-46' W. More than 500 lbs of rock were recovered from the northeast flank of that feature and about one third of the haul comprised manganese crusts in excess of 1 cm thickness, while some crusts were as thick as 5 cm.

ACKNOWLEDGMENTS

The success of our efforts depended on the cooperation, ability and advice of Captain Hayes and the crew of the RV MOANA WAVE. We greatly appreciate their interest in our project and their ability to help us succeed. Curtis See, with the assistance of Will Hervig efficiently coordinated deck operations and Carol Yasui expedited the pre-cruise travel and logistical arrangements for the HIG contingent.

INTRODUCTION

The third CCOP/SOPAC leg of the RV MOANA WAVE (cruise MW87-02) explored the territorial waters of Samoa, the Cook Islands and Kiribati to evaluate the submarine mineral resources of these island nations. The cruise followed the general track shown in Figure 1, beginning on February 5, 1987 in Pago Pago and ending mid-day March 3, 1987 in Honolulu. The survey in Samoan waters was a late addition to our expedition, necessitated by a revised sailing schedule of the RV MOANA WAVE. Our research mandate from the Co-ordinating Committee for Offshore Prospecting/South Pacific (CCOP/SOPAC) included the general objectives of

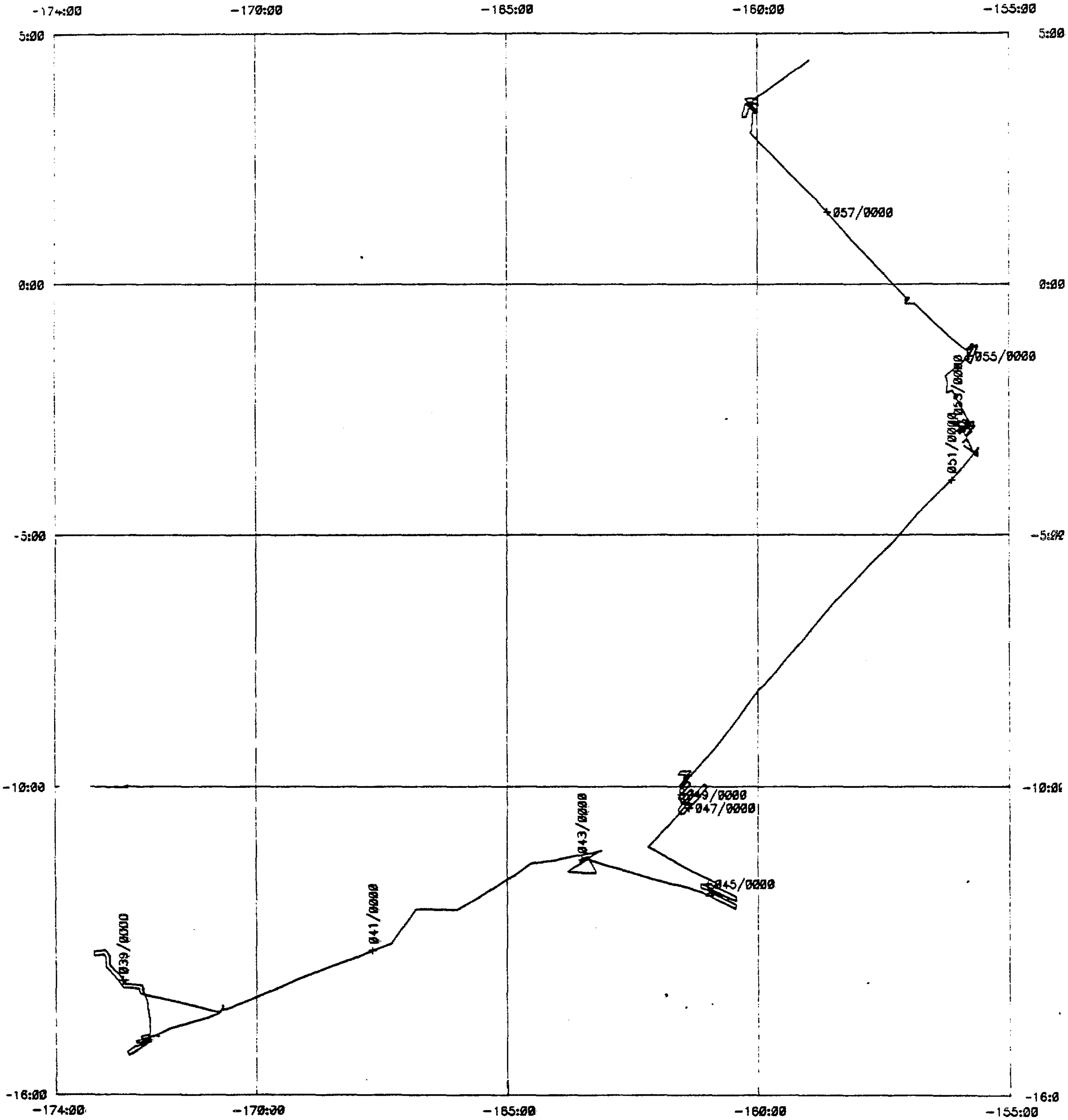
(1) examining the latitudinal, age and depth dependency and degree of cobalt enrichment of manganese crusts on seamounts in the central Pacific,

(2) determining the areal distribution, abundance and grade of manganese nodules in the Line Islands region and

(3) ascertaining the distribution and nature of mineralization within and above volcanic basement on the Manihiki Plateau.

These objectives were met by a survey plan designed to examine specific areas and to address specific geological problems on Machias Seamount, offshore of Savaii, Western Samoa(Fig. 2), in two areas on the Manihiki Plateau (Fig. 2) and on the slopes of several seamounts and ridges in the southern and central portions of the Line Islands chain (Fig. 3). Each survey and set of findings is discussed in detail in separate sections of this report. It is important to note that the pursuit aof the cruise objectives was limited by time constraints. CCOP/SOPAC Leg 3 was a 27 day cruise of which 11 days were devoted to transit between the various research areas and Honolulu.

The scientific party consists of researchers with a variety of geological backgrounds ranging from marine geophysics, to geochemistry, to paleomagnetics , to sedimentology and micro-paleontology. Two graduate students from the Department of Geology and Geophysics of the University of Hawaii and two representatives from member island nations participated in all aspects of the expedition. Anthony Utanga, a representative from the Cook Islands could not arrive in Pago Pago in time for our February 5 departure. Despite a second port-call of the RV MOANA WAVE to Pago Pago two days after our initial departure, Mr. Utanga was unable to meet the ship. Although it was regrettable that we had to sail without him, the return to Pago Pago did allow Dr. Alexander Shor and technician Mark Rongstadt to participate in the first days of our voyage. Their assistance is greatly appreciated for the much needed continuity it provided between the second and third voyages of this project.



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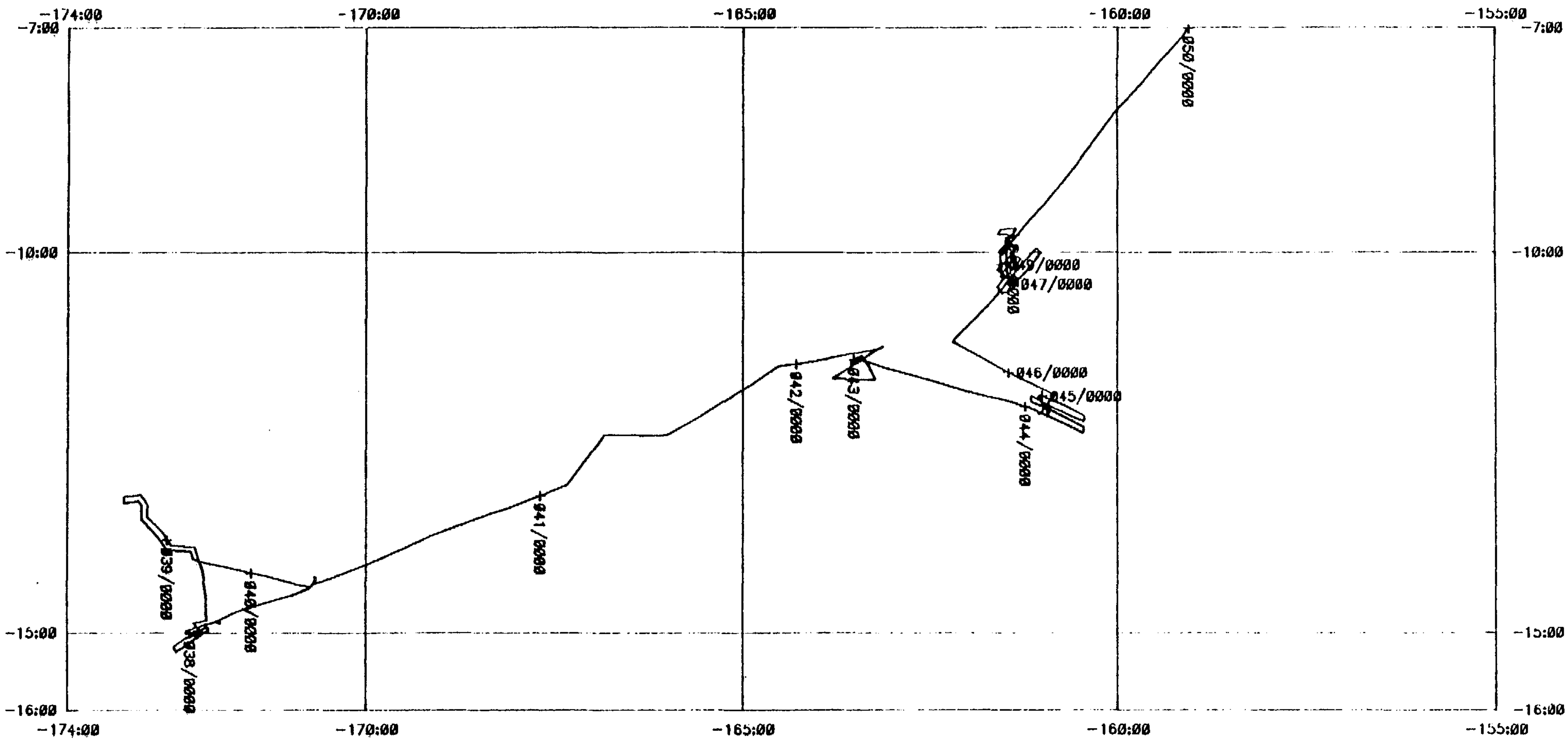
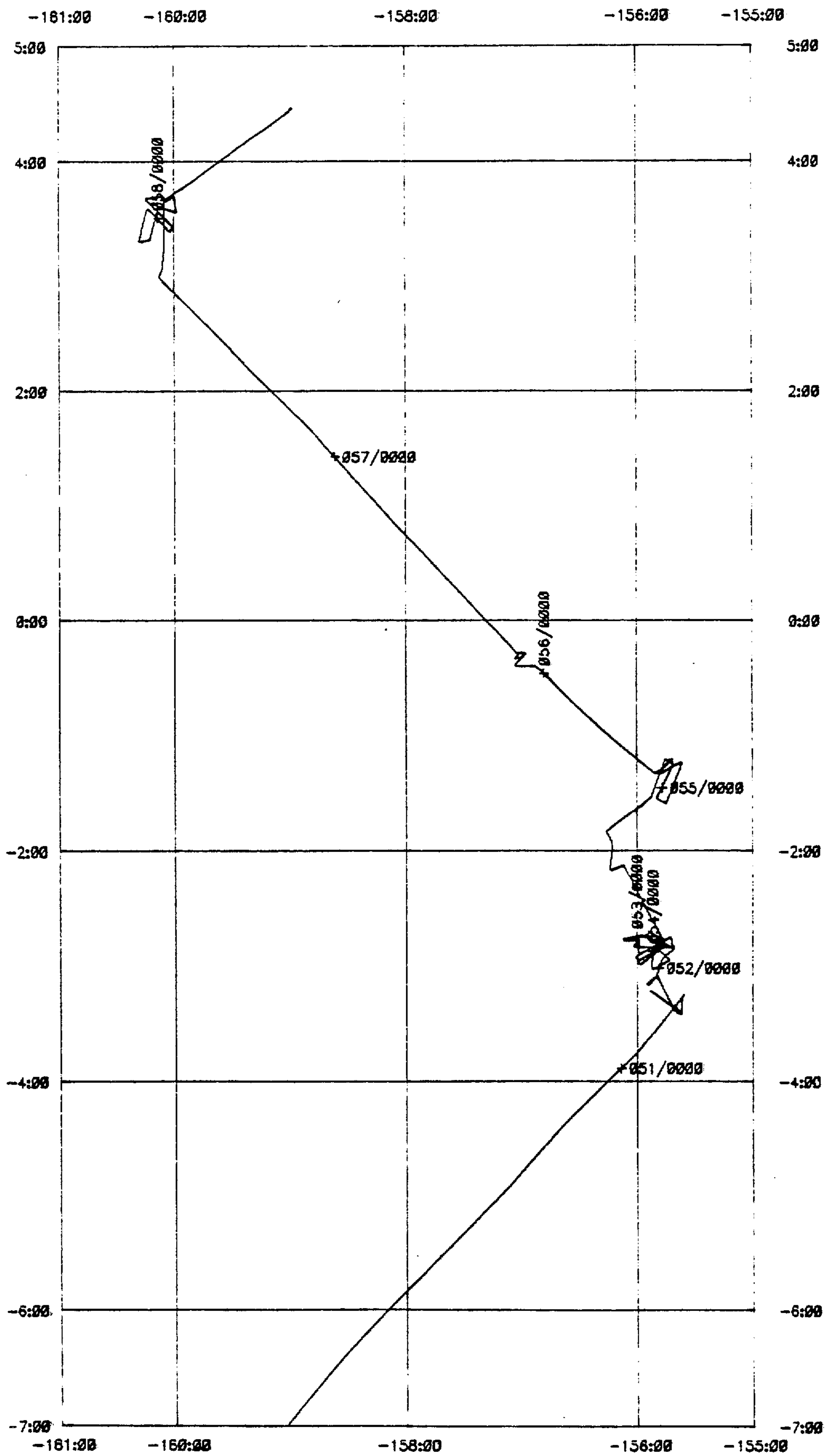


MW87Ø2: COOK ISLANDS

W SAMOA



MW8702: LINE IS.– KIRIBATI

CCOP/SOPAC RV MOANA WAVE CRUISE 3 (MW87-02) TO THE TERRITORIAL WATERS OF WESTERN SAMOA, THE COOK ISLANDS AND KIRIBATI

CRUISE REPORT

I. SAMOA SCIENCE REPORT

The CCOP/SOPAC campaign of 1987 enabled the RV MOANA WAVE to survey the territorial waters of several south Pacific island nations. During the third leg of that campaign (Cruise MW87-02), Friday February 6 to the morning of Sunday February 8, 1987 were devoted to geophysical surveys in the territorial waters of Western Samoa (Fig 1.1). In addition to gathering magnetic, gravity and bathymetric profiles, we also obtained seismic reflection profiles and SeaMARC II images of the sea-floor. The work was divided into two main parts: the first was devoted to surveying Machias Seamount and the submarine slope leading to the northern end of the Tonga-Kermadec Trench; the second was dedicated to surveying the southern and southwestern slopes of Savaii for sea-floor environment and for possible mineral potential. Of special interest was the possibility of hydrothermal mineral deposits produced by submarine vulcanism, and exposures of barren slopes suitable for growth of metallic crusts. The Machias Seamount and Savaii survey areas were tied by a single N-S track. The main aim of the tie line was to establish whether or not adjacent active tectonism had structurally modified the sea-floor between the trench and Savaii.

Machias Seamount

Machias Seamount is located to the south of Savaii, Western Samoa, on the seaward flank of the Tonga-Kermadec trench. The latter attribute imparts some curious distinctions to what might otherwise be an ordinary mid-ocean guyot, or flat-topped seamount. Along with the ocean crust it sits on, this guyot is in the process of being subducted at an oblique angle beneath the western flank of the trench.The incipient collision, dismemberment and possible subduction of this seamount as it enters the Tonga Trench makes this feature an extremely interesting target for surveying.

Convergent plate boundaries such as the Tonga-Kermadec trench type are common to much of the circum-Pacific region. Plate convergence and subduction involves rupture of the surface of the downgoing plate in response to tectonically imposed flexure as the plate bends to dive downward into the underlying mantle. In the case of Machias Seamount, flexure is occurring along the eastern flank of the Tonga trench. The expected rupture pattern is a series of normal faults striking parallel to the axis of the trench. This neo-tectonic fabric may be superimposed on a primary fabric generated at the mid-ocean spreading center along which the lithosphere initially formed.

Within the context of CCOP/SOPAC 1987 Leg III, our purpose in surveying Machias seamount was to produce a SeaMARC II side-scan mosaic to complement the existing network of geophysical profiles over this structure. Because the side-scan image results from contrasts in bottom roughness and reflectivity, it is an indicator of the distribution of rock and sediment on the sea-floor. Areas devoid of unconsolidated sediment may consist of exposures of volcanic rock or, more desirable from an economic point of view, of metalliferous crusts. With some geologic insight as to the nature of the survey area, the texture of the gray-tones displayed on the image and the shape of the forms revealed can be used to estimate the areal extent of lava flows, cones, fault scarps and metalliferous crusts. Smooth, featureless areas represented by light tones are probably undisturbed accumulations of sediment -- principally foram-nannofossil oozes deposited above the regional calcite compensation depth (CCD) of about 4000 m.

Our survey required about 20 hrs, the amount of ship time necessary to complete 5 parallel tracks across this guyot and to tie those tracks together with one single cross track (Fig. 1.2). One pair of tracks extends far enough to the southwest to cross the axis of the Tonga trench and to image the very base of the western slope, or Tongan fore-arc. To assure continuous bathymetric coverage, adjacent tracks were spaced at intervals of less than 10 km and a tie line was positioned to cross the shallow summit area where swath width is greatly reduced. GPS was available for about 8 hrs during the second half of the survey, positioning at other times depended on transit satellite fixes. Because our time in Samoan waters was limited to slightly more than 2 days, no sampling attempts were planned. This lack of "ground truth" is partly compensated by the sampling program of the 1986 HMNZS TUI cruise. That voyage collected sediment and rock from 6 locations dredged on this seamount.

Our survey produced a picture of the sea-floor that reveals a submarine mountain in the process of being sliced along subparallel, steeply dipping planes. This tectonic dissection is the first-order feature shown on this image and appears as a series of subparallel dark-gray lineations oriented approximately NNW to SSE, parallel to the strike of the trench axis (Fig.1.3). These offsets of the sea-floor form in response to normal faulting along the convex, surface of the Pacific lithospheric plate as it descends into the trench. In a few instances, the offsets are paired, forming horst and graben. The bathymetry produced simultaneously with the side-scan image is the key to determining the sense of offset (compare Figs. 1.3 and 1.4). Second order features include the flat, heavily-sedimented summit area, submarine canyon and fan systems, slumps, and exposed, rough volcanic terrain.

Tectonic dismemberment limits the mineral potential of this guyot. Faulting controls the distribution of numerous slides and slumps of sediment from the thickly mantled summit. Virtually the entire trench-facing slope has been remobilized and reworked downslope and the east-side is scared by several slides of large proportion. This downslope reworking of sediment and rock inhibits growth of crusts on the sparse rock exposures.

Savaii

The Samoan island chain is a series of shield volcanoes. The deeply eroded island of Tutuila, American Samoa is located to the east of Western Samoa (Fig. 1.1). Of the two islands forming the bulk of the landmass of Western Samoa; Upolu is moderately to deeply eroded, but by comparison, Savaii is relatively untouched by erosion and extensive recent lava flows cover much of the northeast flank of the island. This pattern of westward decrease in age is contrary to that predicted from hotspot theory, which calls for an eastward younging of these edifices in a pattern similar to that exhibited in the Hawaiian chain. Part of this departure from the predicted, general trend may arise from the proximity of these large shield volcanoes to the northern end of the Tonga trench.

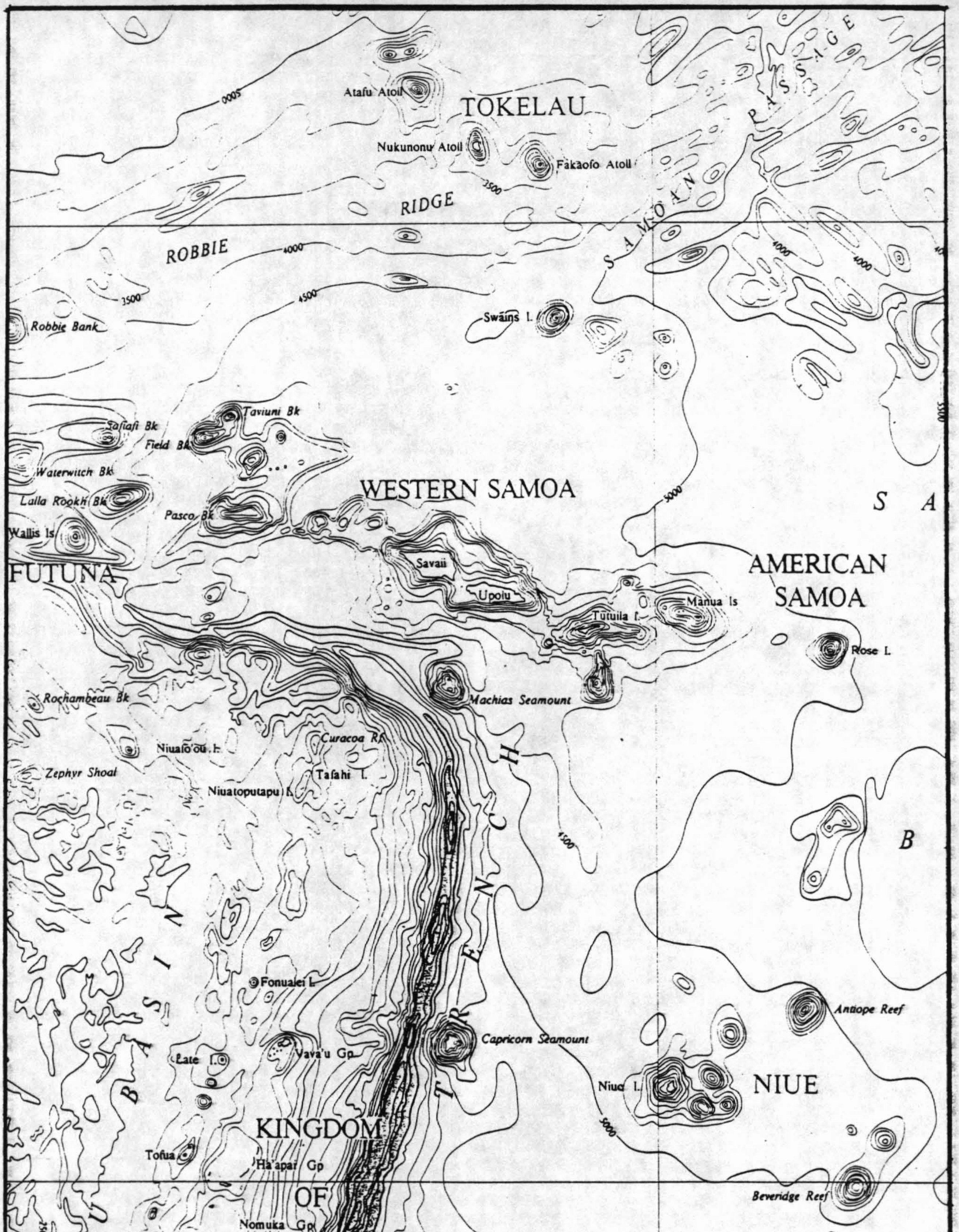
Irrespective of the cause of vulcanism, the most logical place to search for submarine resources in the form of near-surface, hydrothermal mineral deposits is in areas of active or recently active vulcanism. Because Savaii was last active during this century, its adjacent submarine slopes are the favored targets. Our prospecting strategy was based on the premise that the younger the activity, (1) the less the volume of detritus shed to its adjacent submarine slopes and the greater the potential for rock exposure, and (2) the greater the chance for submarine vulcanism and the presence of hydrothermal deposits. To accumulate a volume of deposit sufficient to form a viable resource, more than ephemeral submarine venting is required. Cones small enough to have escaped detection before SeaMARC II imaging are indicators of volcanic activity but are probably not ideal targets for exploitation. Their life-span of activity was probably too short to have accumulated even moderate volumes of metalliferous precipitates.

Our approach to the main islands of the Samoan chain was from Machias Seamount situated to the south. In the interest of conservation of transit time and because it presented a logical starting point for prospecting, we began our swath mapping along the southern side of the chain, offshore of the narrow straits separating Upolu from Savaii. Track lines were laid out parallel to and as close to the coastline of Savaii as SeaMARC II could be safely towed (Fig. 1.5). This side of the island was judged favorable for our purposes because of the general lack of deep canyons onshore, because the trend of cones aligned in the southwest rift might extend offshore across our ship-track, and because it allowed us direct access to the platform area offshore of the western tip of Savaii, an area where we expected to find evidence of relatively recent submarine vulcanism. Our track up the coast coupled with a return, parallel track assured nearly 20 km width of side-scan coverage, a swath width sufficient to allow confident assessment of the mineral potential of this island slope and at the same time to produce coverage sufficient to generate a map of the submarine geology. Thus, approximately 20% of the submarine slope of the country is thoroughly surveyed for its submarine mineral potential.

The side-scan image reveals two heavily sedimented segments of the submarine slope of Savaii (Fig. 1.6). The areas of debris flow and generally unstable sea-floor sediments extend seaward from the center of the south-facing and from the center of the southwest-facing coastline of the island. They flow completely across the nearshore swath (about 5 to 15 km from shore) and spill across portions of the deeper slope imaged along our return track (about 15 to 25 km from shore). Some of these deposits exhibit wave forms large enough to show up at a 100 m contour interval (Fig. 1.7). Exposures of rock, some punctuated by small cones, separate these areas and border them on both the east and west extremes of our survey area. Numerous volcanic cones occur offshore of the SW rift and all are too small to show on any bathymetric maps available to-date.

Our findings suggest that the mineral wealth of the submarine slopes immediately offshore of this section of the coastline of Savaii is limited to whatever value the sediment might have for construction or beach replenishment. The island is probably too young and the surrounding sea-floor too unstable for thick Co-rich crusts to have formed and the submarine volcanic cones located are too small to have produced even moderate quantities of hydrothermal mineral deposits.

LIST OF FIGURES



TOKELAU
Atafu Atoll
Nukunonu Atoll
Fakaofo Atoll
ROBBIE
RIDGE
S A M O A N P A S S A G E
Robbie Bank
Swains I.
Taviuni Bk
Field Bk
Waterwitch Bk
Lalla Rookh Bk
Pasco Bk
Wallis Is.
FUTUNA
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Upolu
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Machias Seamount
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Curacoa Rf
Tafahi I.
Zephyr Shoal
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Vava'u Gp
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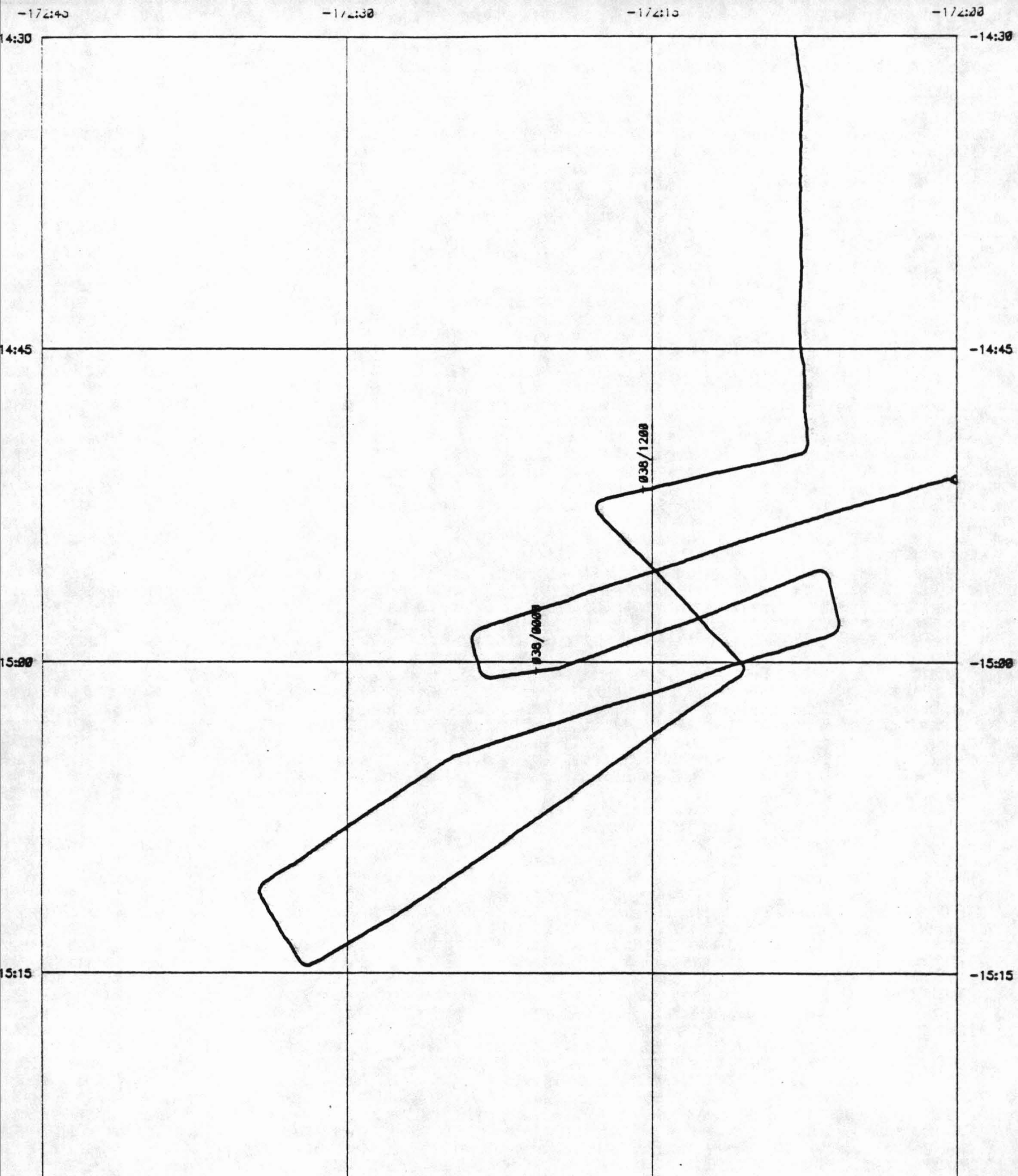

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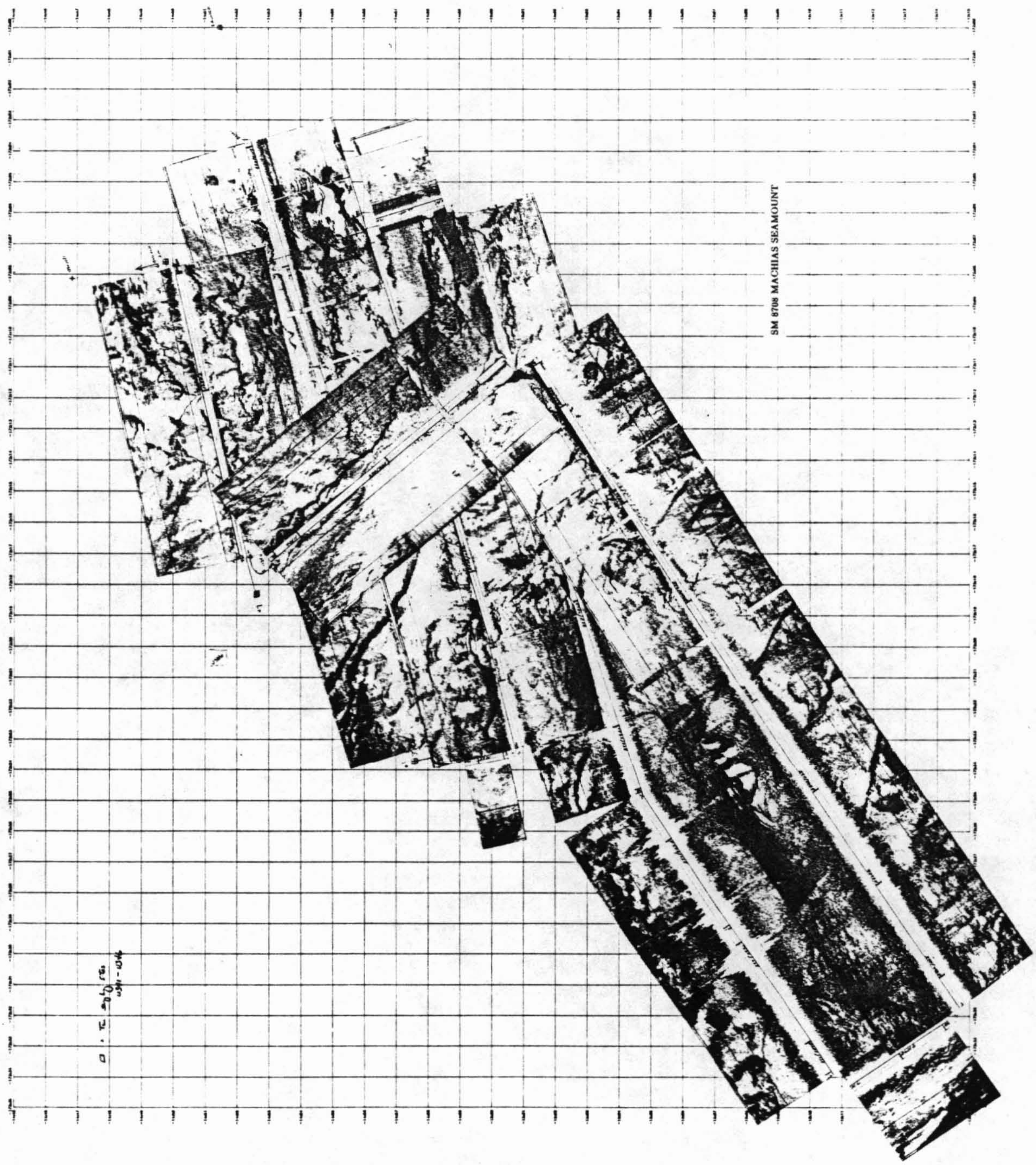
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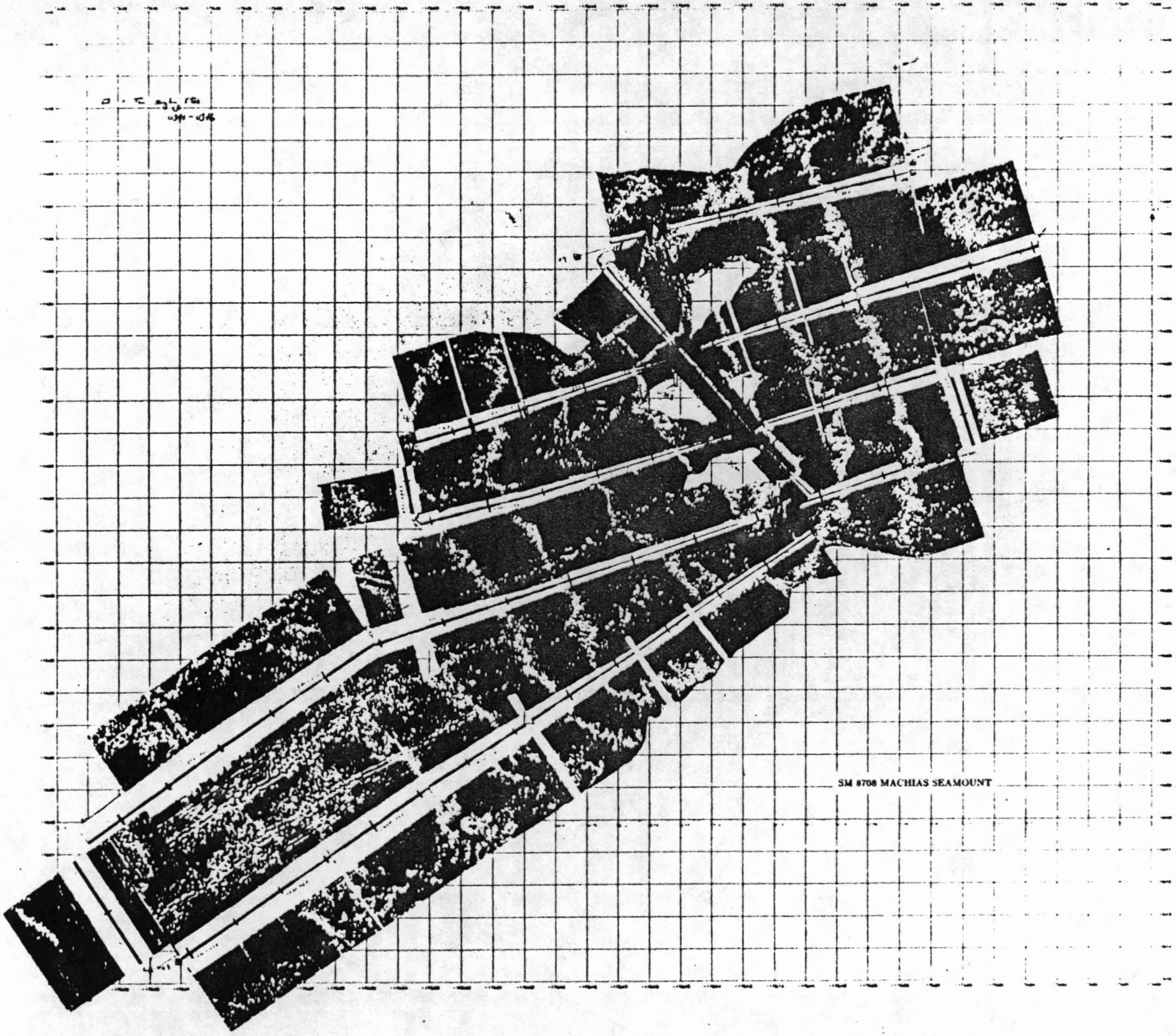
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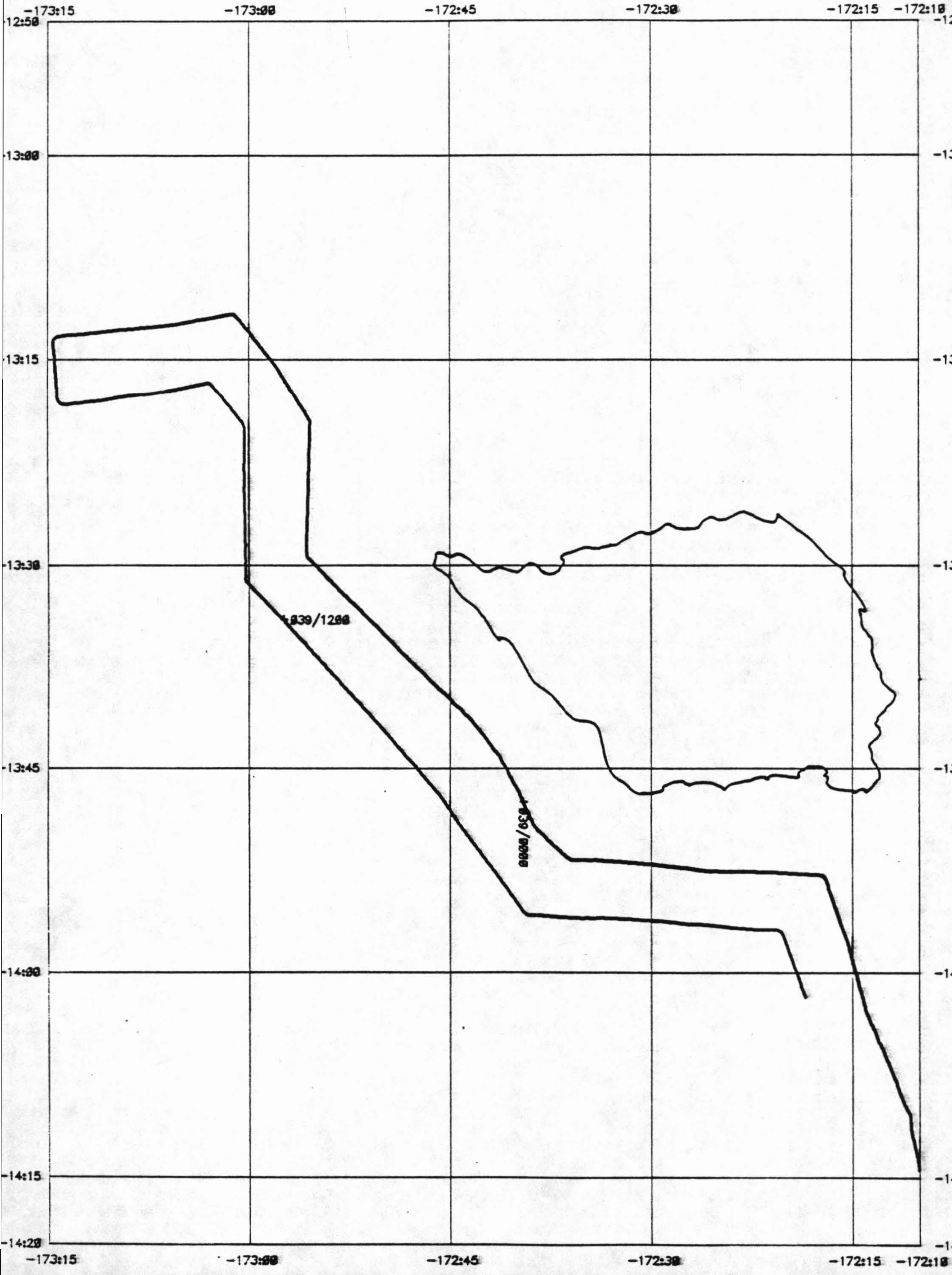

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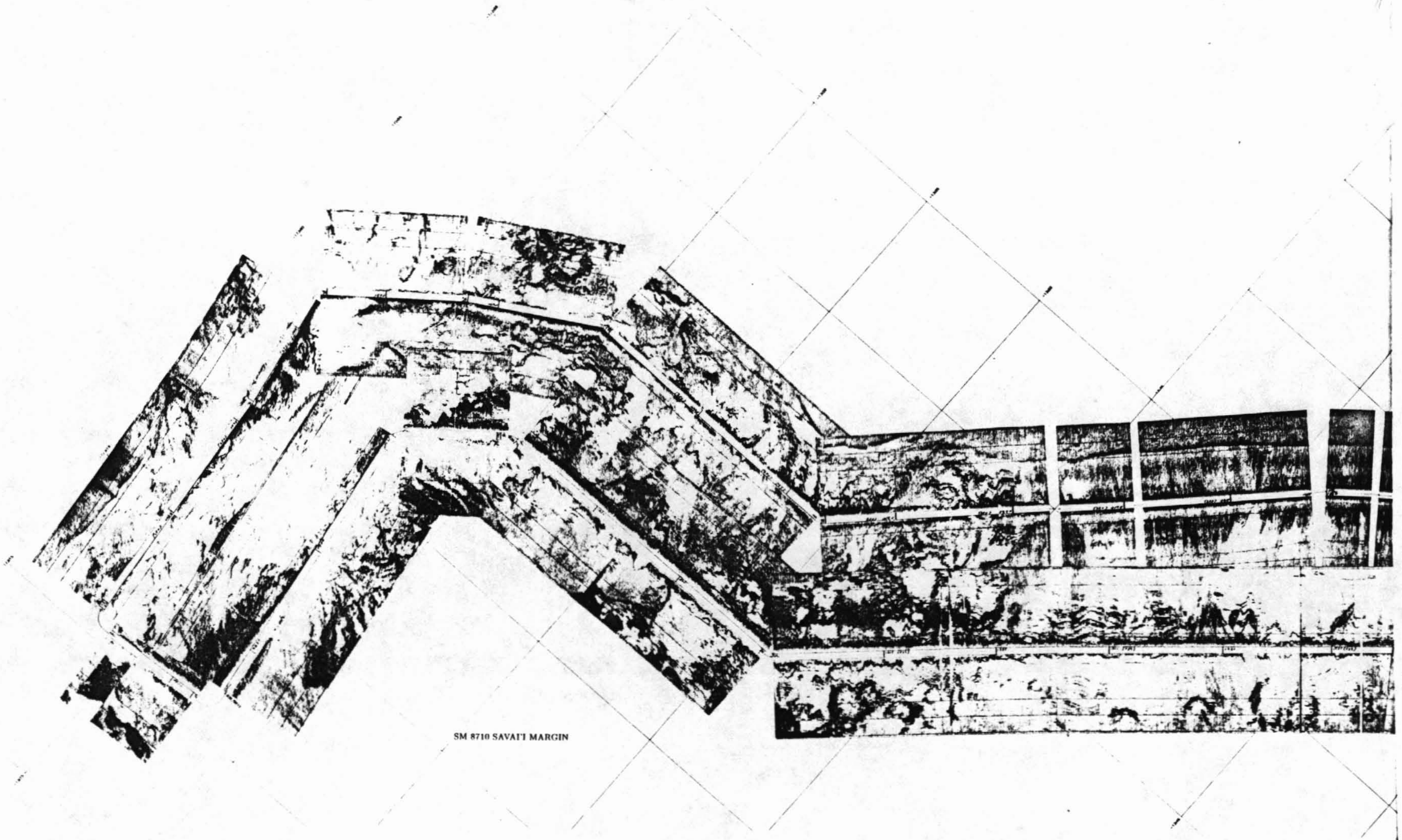

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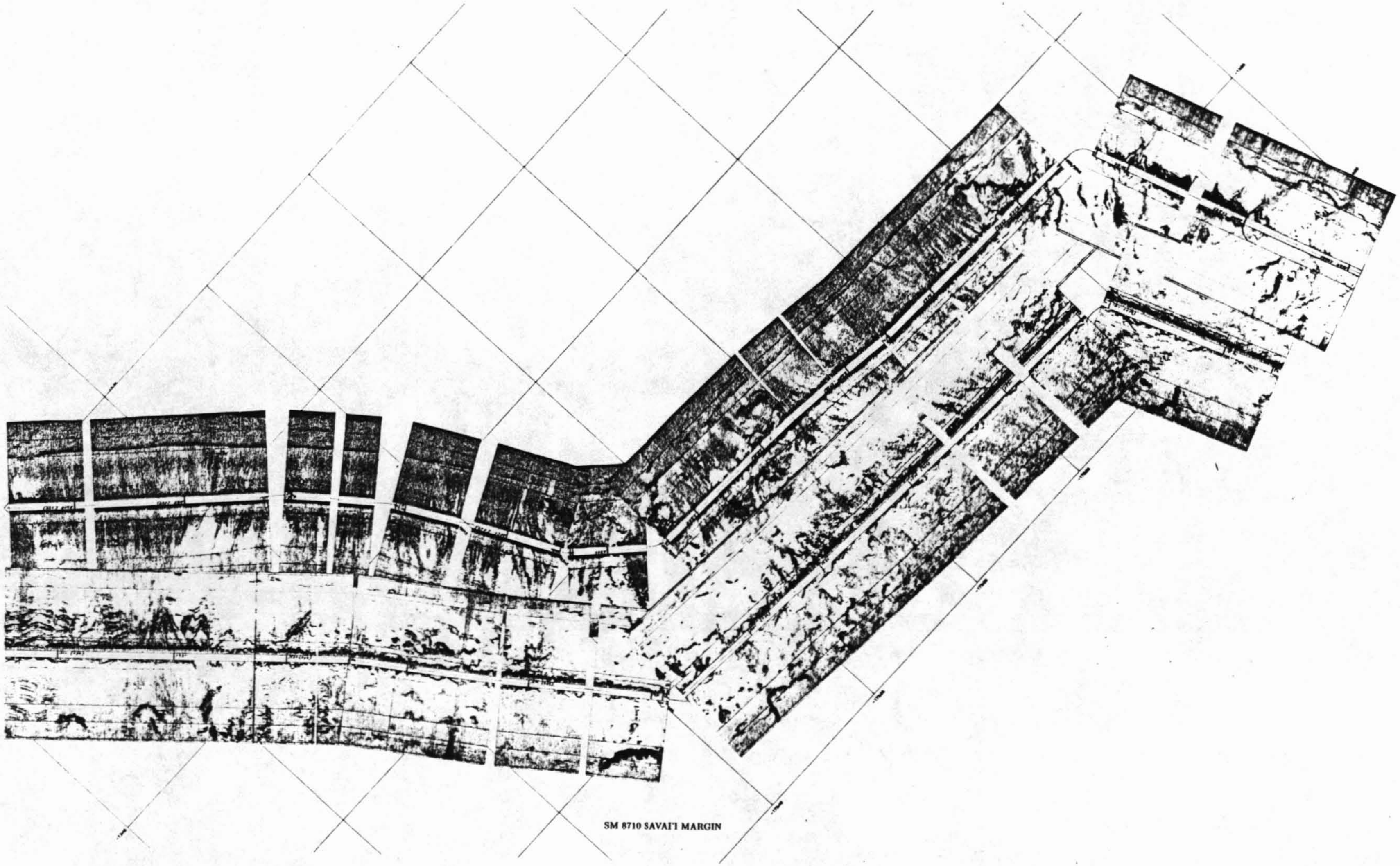

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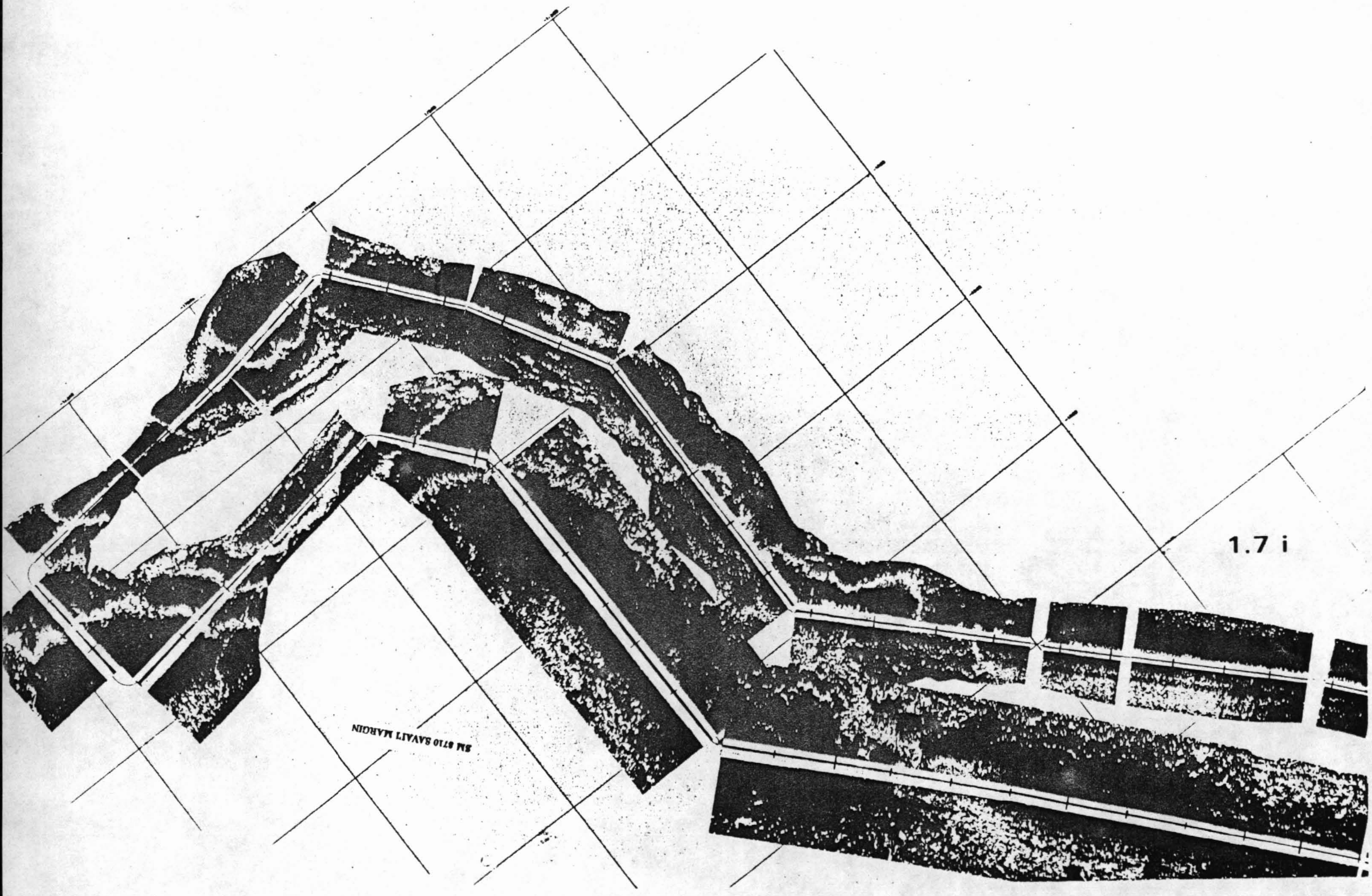

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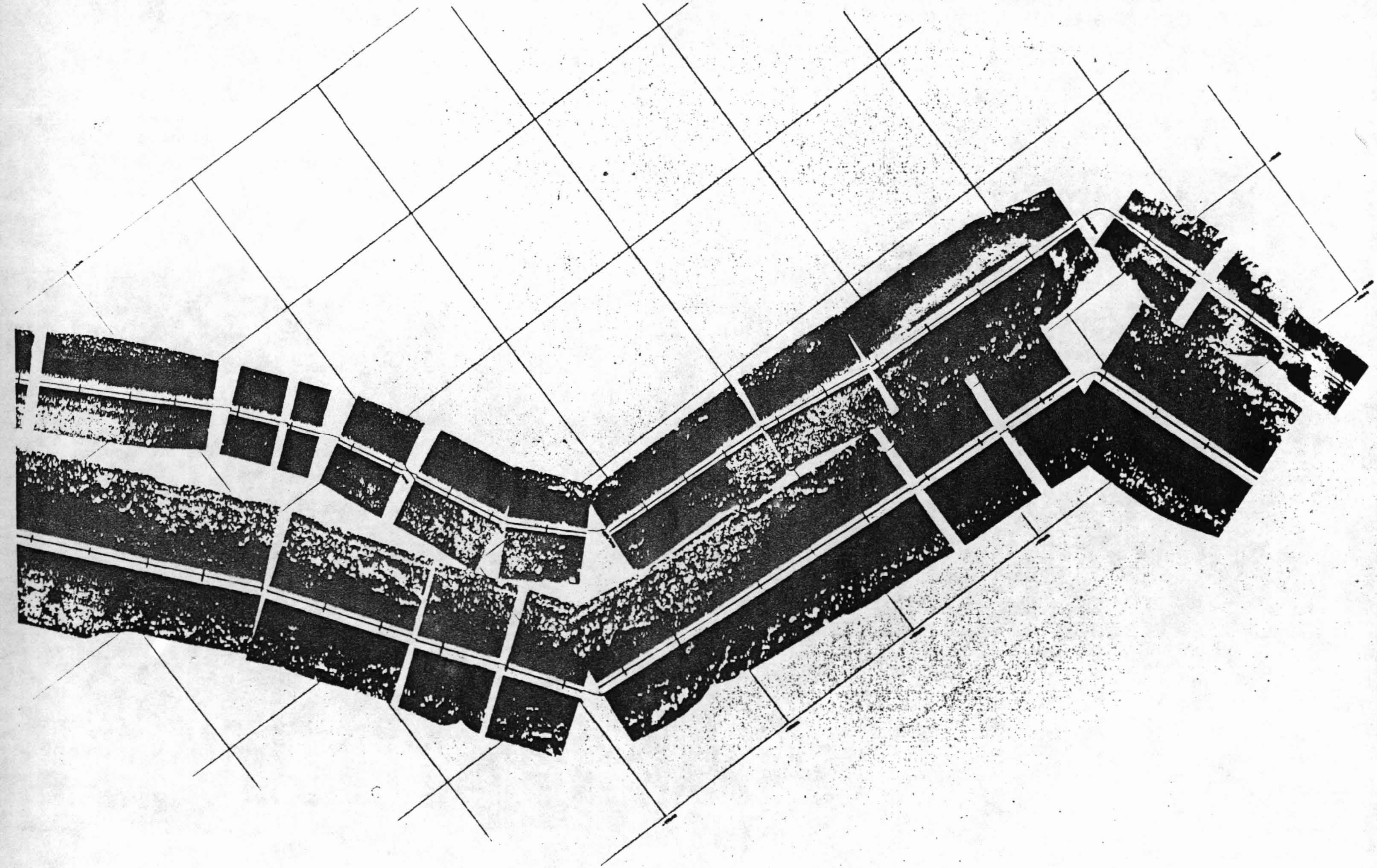

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CCOP/SOPAC MOANA WAVE CRUISE 3 (MW87-02) TO THE TERRITORIAL WATERS OF SAMOA, THE COOK ISLANDS AND KIRIBATI

CRUISE REPORT

II. COOK ISLANDS

Leg 3 of the RV MOANA WAVE CCOP/SOPAC expedition departed Pago Pago, American Samoa late in the afternoon of Sunday February 8, 1987. Our destination was the territorial waters of the Cook Islands and 4.5 days of research devoted to surveying and sampling three areas of the Manihiki plateau.

On leaving American Samoa, we steamed east at full speed for about 12 hours before deploying seismic gear in order to minimize our long transit to the Manihiki study areas. As we approached the plateau on mid-day Monday, we deployed two air guns and began collecting analog seismic reflection profiles (40 to 300 Hz bandpass). The flat sea-floor of the western portion of the plateau is an ideal setting for seismic refraction experiments and two sonobouys were deployed in an effort to determine the seismic velocity structure of the crust.

The transit incorporated slight changes in course in order to intersect SEASAT/GEOS-3 anomalies. One of the targets was an uncharted seamount discovered during the 1986 HMNZS TUI cruise. The seamount was crossed at a different azimuth and confirmed to rise 3000 m above the general sea-floor at 12-25'S, 166-27'W. The second anomaly investigated is also a seamount, this one at 13-02'S, 167-18'W and of 1400 m relief. Though time constraints prevented us from conducting a sampling program on these newly discovered seamounts, it is highly likely that the upper surface of these edifices possess a significant coating of Mn-crust. Their discovery, therefore, enhances the sea-floor mineral potential of the northern Cook Islands region.

Suwarrow Trough

The first target was Suwarrow Trough, a NNW trending graben crossing the south-central portion of the plateau. This collapse feature creates a west-facing submarine cliff of about 1000 m vertical relief. That cliff exposes the entire stratigraphic section drilled at Deep Sea Drilling Project (DSDP) Site 317, providing a chance to sample the metalliferous, volcaniclastic sediments overlying basalt. A Z-shaped track was planned to cross this feature (Fig. 2.1). After obtaining three seismic cross-sections (Fig. 2.2), we chose the central crossing as the most auspicious for sampling and began Station 15-RD14. We deployed a large, cylindrical rock-dredge to sample the volcaniclastic sequence over the depth interval between 4110 and 3800 m. The dredge was on the bottom at GPS coordinates 11-24.16 S, 163-28.99 W.

The dredge returned empty of rock but caught about 5 liters of carbonate-rich, red-brown abyssal clay in sampling tubes. Foraminifera in this sediment are all Recent forms typical of the tropical Pacific. Tests are well preserved even for the more delicate and solution susceptible forms such as Globigerionides siphonifera. The absence of evidence for partial dissolution of the assemblage, for older relict forms and for sorting by grain size suggest that this assemblage was in place at a site above 3300 m water depth.

The limited time available required us to abandon sampling attempts at the Suwarrow Trough and steam for our high-priority target, the eastern escarpment of the Manihiki plateau.

Eastern Escarpment

SeaMARC II was lowered into the water at about noon on 12 February and we began our approach to a survey grid of four WNW-ESE trending parallel tracks (Fig 2.3). Pre-cruise review of earlier surveys indicated that the large cliff forming the east-facing border of the Manihiki Plateau should expose the entire stratigraphic sequence drilled at DSDP Site 317, allowing us to sample the Cretaceous, metalliferous sediment near the base of the stratigraphic section.

The structure revealed in the mosaic is spectacular (Fig. 2.4 and 2.5). The flat, undisturbed sediment of the Manihiki Plateau is abruptly bounded on the east by a narrow horst. Immediately east of this ridge, the sea-floor drops 1700 m to a graben. Headward erosion along submarine channels is evident, as are large debris flows. A few isolated patches of undisturbed sediment stand-out within an image dominated by patterns of sediment flow and block-faulted sea-floor.

The SeaMARC image and accompanying bathymetry served as a guide for selecting a sampling site. The side scan image revealed varying heights of the escarpment and varying amounts of sediment and rock redeposited as slumps at the base of this cliff. One of the most promising exposures was examined in detail and a contour map was prepared prior to completing the grid of survey tracks. This type of on-line interpretation is a new capability and is extremely useful in selecting sampling targets. Our goal was to sample the basal, metalliferous, sedimentary section drilled at DSDP Site 317 and presumably exposed along this east-facing escarpment -- essentially the same goal as the sampling attempt in Suwarrow Trough.

Dredging at Station 16 was designed to sample the entire lithologic sequence, including basement, exposed on the eastern scarp of the Manihiki Plateau. The basal, volcaniclastic sequence was the main target at Station 17. For Station 16, a large cylindrical dredge was deployed with a 1 ton lead weight. This combination was chosen to compensate for our failure in sampling rock at Station 15. The dredge was lowered in 3700 m of water then the ship steamed westward at 1.5 kts, dragging the dredge upslope across the base of the escarpment. With 4300 m of wire out the winch was stopped and the wire-line tension rose to 10000 lbs as the dredge snagged the bottom. After several bites, the winch was started, wire-tension rose and reached 12000 - 13000 lbs with 3600 m of wire out. At this point we became firmly anchored to the sea-floor and began maneuvering the ship in an effort to free the dredge. After a sudden release in tension, we resumed hauling in at 10 m/min until we were free of the bottom, then at maximum speed until the weight reached the surface. The reason for the release was immediately clear when the weight was hauled to the surface without the dredge, which had become unfastened at a threaded mount with the cable. The threads were not stripped, therefore, the dredge had somehow spun sufficiently to release from its tether. Our decision to opt for a second attempt to sample this escarpment was influenced by the fact that SeaMARC was not ready for deployment because of an electronics problem. For this attempt, the weight was rigged with a smaller, standard rectangular dredge. We positioned the ship in 2600 m of water, just slightly to the east of the target, lowered 2800 m of wire while stationary and, once on the bottom at 12-04.05' S, 160-57.30' W, began steaming slowly westward and paying out a additional 10 % of wire while underway. After several large bites, the dredge was hauled from the sea-floor at about 12-04.27' S, 160-58.08' W, and we had samples on board at about 4:30 AM.

About 20 to 25 kg of rocks, which included the sought-after volcaniclastics, were recovered in RD 16, Station 17. These volcaniclastic rocks are approximately 20 x 15 x 15 cm, and consist of unconsolidated and consolidated volcanic sandstones, siltstones and claystones with phosphatized carbonate cobbles. Some specimens are merely stained with Mn oxides, but most are covered with 0.5 to 2 cm of crust. Two samples have very well-developed crusts up to 4.5 cm thick with admixed phosporite. The first specimen has a phosphatized substrate, whereas the latter is not underlain by substrate and appears to have been ripped from the underlying rocks. The largest rock in the haul is a 40 x 30 x 30 cm limestone boulder pock-marked with bore-holes, in part stained and in part encrusted with as much as 3 mm of manganese. Many of the borings were filled with Mn or coated with stains and some contained unconsolidated Recent foraminiferal ooze. Many specimens of solution resistant species such as <u>Sphaeroidinella dehiscens</u> and <u>Globorotalia tumida</u> are stained with iron oxide and others are partially replaced by manganese overgrowths. The rock is too lithified to disaggregate by washing and we lacked the capability to make thin sections on-board ship so that detailed examination with a petrographic microscope was impossible.

Departure from Station 17 and the Manihiki Plateau followed a track from the dredge site to the NE in order to obtain a tie-line for our SeaMARC coverage and to add a portion of a fifth parallel track to the coverage. Transit to the Manihiki-Rakahanga Island study area was along a NW track, plotted to investigate an unusual structural feature noted on a DV GLOMAR CHALLENGER line near DSDP Site 317, to cross complicated structure revealed on an HMNZS TUI profile and to pass nearby DSDP Site 317.

Manihiki-Rakahanga Islands

Early on Sunday 15 February we began our detailed track of the area around and to the west of Rakahanga Island (Fig. 2.6). The study area was selected for a variety of reasons, including the expectation of promising sample sites in the area extending southward from that surveyed by the SONNE in 1985, the presence of diapiric structures on earlier seismic reflection lines south of Rakahanga Island, an unusual and poorly mapped seafloor high and the presence of the thickest crusts sampled during the HMNZS TUI survey.

With SeaMARC deployed we obtained a record across the smooth, undisturbed sea-floor of the Manihiki Plateau. The monotonous light gray tone registered for the surface of that thick sedimentary cover gave way abruptly to a seafloor punctuated by field of steep conical protrusions about 50 km southwest of Rakahanga Island. When crossed by the ship track, these features produce a single, hyperbolic reflector, suggesting a point source (Fig. 2.7). For each of these reflectors, the side-scan image revealed conical, steep-sided peaks that rise several hundred meters above the adjacent sea-floor (Fig. 2.8). Moats partially surround some of these cones and others clearly show successive flows, presumably of mud (Fig. 2.9). These features become more densely spaced and cluster about a central point located about 50 km SSW of Rakahanga Island. Reflectors from the sedimentary section dip away from and pinch-out against rising acoustic basement of the island platform. Patterns revealed in the SeaMARC II bathymetric and side-scan mosaics suggest fluidized flow of sediment from and around these protrusions (Figs. 2.10 and 2.11). Most of the flows trend toward the NNE.

Complete loss of power to SeaMARC at about 4:30 AM on February 16 prematurely terminated the survey and prompted fears that the fish was lost. That fear proved unfounded with sighting of the instrument; the signal loss arose from a cable break at the depressor, which produced an electrical short-circuit to ground. Because events dictated a change in plan, we continued the survey to the north with air gun seismic profiles to map the anticipated fault and locate a site favorable for dredging the volcaniclastic sequence.

Station 18-RD17 was an attempt to sample basically the same horizon targeted at Stations 16 and 17, but at a site on a N-S trending escarpment northwest of Rakahanga Island. Interpretation of seismic reflection profiles across the outcrop indicated exposure of basal sediments at about 3700 m to 4000 m water depth and an accumulation of scarp-derived debris at the base of the slope. At about 2:00 PM, a rectangular-frame dredge with 2 ton weight reached the sea-floor at 9-46.37' S, 161-23.70' W, in 4240 m water depth, 1 km east of the escarpment. We began steaming west at 1.5 kts, paying out another 300 m of wire. With 4650 m of wire out we stopped the winch. Because of strong head currents, the speed of the ship was increased. Retrieval began, but by 5:00 PM the dredge was once again stuck on the outcrop, this time with about 4200 m of wire out. Maneuvering the ship on a reciprocal, easterly course freed the dredge at about 6:30 pm. Following a series of 12,000 lbs bites and quick releases of tension, routine retrieval began and the dredge was on deck by 8:00 PM with several small boulders. We immediately began steaming south to our next sampling target about 3 hrs to the south -- the mud volcanoes located southwest of Rakahanga Island.

The three rocks recovered in RD 17 are very intriguing. One is a 7 x 5 x 5 cm red-stained foram-rich limestone with thin Mn coating and with dendrites within the specimen. The remaining two rocks have a maximum crust thickness of 1 cm. Mn-stained, Recent foraminifera were washed from the surface of these specimens. Examination of cut slabs under a binocular microscope at 80 x magnification reveals that substrates of both of these samples are a combination of filled vugs and foraminiferal limestone, which is partially to totally recrystallized. The matrix has a resinous luster and dark red-brown to amber color. Vug-filling often displays concentric layering, reminiscent of decorative, opaline geoids sold in gem stores. A teasing needle easily breaks the surface, suggesting that the replacement material is too soft to be quartz. The foraminifera display all degrees of alteration, from relatively coherent test outlines, to ghosts, to pockets devoid of microfossils. Several of the filled voids contain translucent, green crystals, probably apatite. These last two rocks are clearly diagenetic, and are probably phosphoritic.

Station 19 was designed to sample the field of mud volcanoes south of Rakahanga Island (Fig. 2.11). Since their first appearance on our side-scan images, these features were a source of intrigue. Because the central target was so complex, we chose to sample two of the clearly identifiable satellite cones just to the west of the main edifice (Fig. 2.8). We steamed south, gathering the profile shown in Figure 2.7, then north on a reciprocal course, dropping free-fall cores (FFC) 13 and 14 and free-fall grab sampler (FFG) 1 on the structure imaged in Figure 2.8. FFCs 15 and 16 and FFG 2 on a smaller cone to the north. FFG 2 triggered prematurely and was recovered immediately after retrieving the seismic gear towed astern of the ship. The free-fall apparatus requires about 15 min to travel 1000 m in the water column, therefore about 1.5 hrs is required for the round-trip at 3000 m depth. Accordingly, we steamed south to retrieve the first instruments dropped. Only two flashing lights appeared on the horizon; one was FFG 1, with no sample, and the second was FFC 13, with no core. FFC 14 was lost. Having no luck at that drop location, we returned to the northly site, and retrieved both FFC 15 and 16 each with almost 1 m of white pelagic clay. This operation concluded, we steamed south toward the center of the edifice for a final sampling operation.

The sediment cored at Station 19 includes two cores of foraminiferal pelagic ooze. Both cores were sampled at the top and bottom. All four assemblages examined are Recent, containing very fresh, well preserved delicate forms.

At Station 20, pipe dredge (PD) 1 was lowered in 1400 m of water at 10-19.7' S, 161-26.99' W and targeted at the central peak shown in Figure 2.11. Because we expected a slurry of sediment and rock of varying types, induration and age, the dredge was fitted with cloth sewn to the metal grid at its base and with a plastic bucket. The dredge was on the sea-floor at about 3:30 AM on Tuesday, February 17 and by 5:00 AM we were examining the sample.

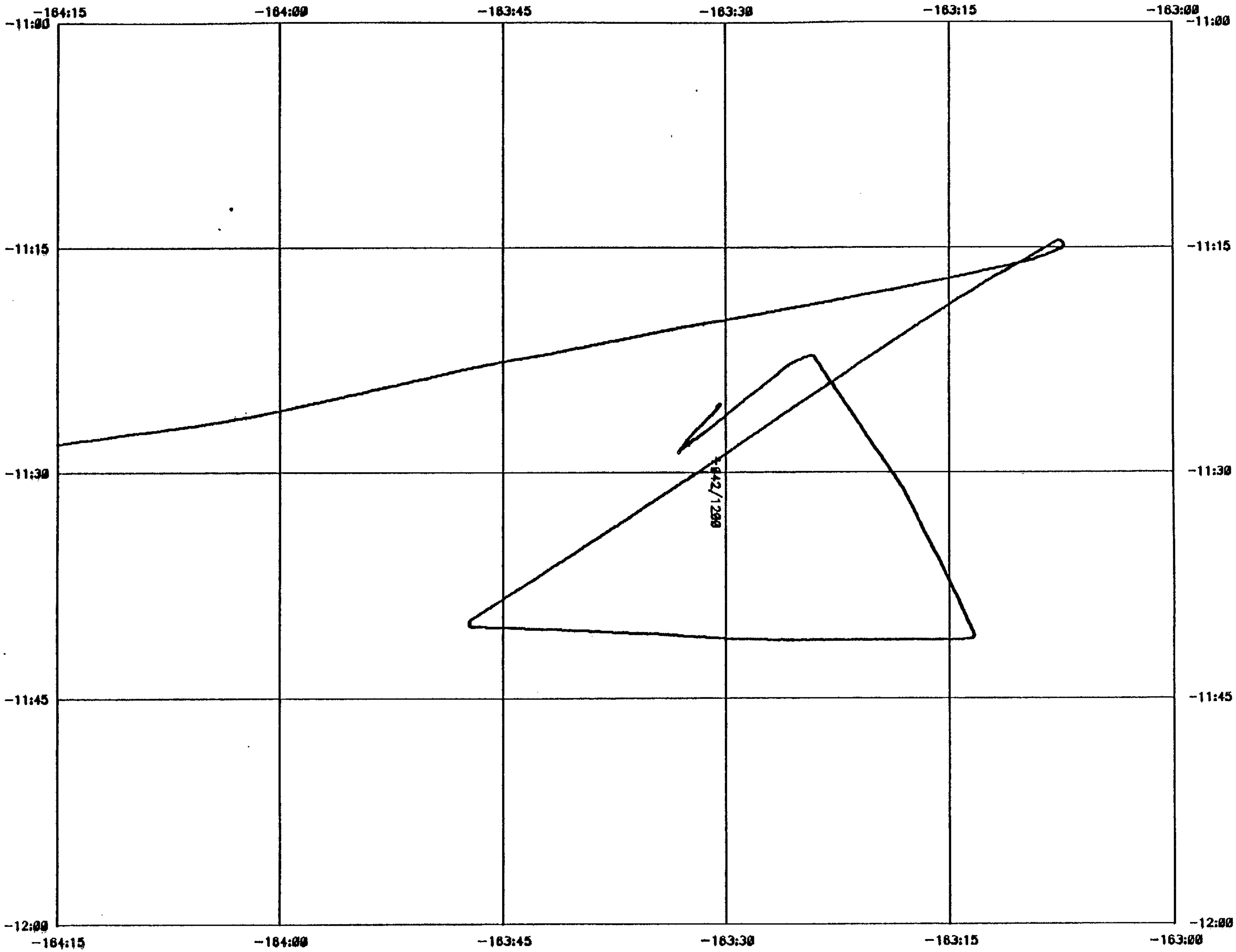
Yield from this dredge was 50 pieces of crust and substrate all torn from the sea-floor as well as an additional 40 cc of unconsolidated sediment. The largest sample is 8 x 5 x 3 cm and the majority are 2 x 2 x 1 cm. Manganese crusts vary from 0.5 - 2.5 cm thick and surfaces have micro-botryoids to 0.5 cm botryoids. Foraminifera were present on the surface and filled the crevices in these specimens. The substrate was burrowed on multiple occasions and some of those voids are lined with Mn. Two manganese-coated macro-fossils recovered are probably coral fragments.

The loose sediment from PD1, washed from the cloth and plastic lining the inside of the dredge, is a Recent foraminiferal sand. This assemblage contrasts markedly with that found in the chalk that comprises the substrate for the nodules. Because the chalk is too indurated to disengage the foraminiferal tests merely by washing, species and age determination was limited to those individuals exposed on broken and cut surfaces. One view was particularly good, however, and the tests and portions of tests visible are drawn in Figure 2.12 in their relative position in the matrix. The species composition of this assemblage indicates a late Eocene age for these rocks.

SeaMARC II was launched around 6:00 AM on February 17 in an effort to fill in missing bathymetric coverage and to complete the survey as planned. Unfortunately, the starboard side was generating only random noise; a problem traced to the tow-fish. Rather than retreive the instrument at that time, we decided to procede with only half-swath coverage. This decision was reached because we had only 8 hrs remaining in the area with the incomplete coverage en route to the next study area in the southern Line Islands. SeaMARC II and all seismic gear were retrieved from tow about 6:30 PM and we began the 2.5 day transit to the territorial waters of Kiribati.

Our interpretation of the spectacular image revealed in the SeaMARC II coverage is that these features are mud volcanoes. Such edifices are constructed by gas and fluid escaping from overpressured, organic-rich horizons within the sedimentary section. In this case, the individual cones occur in a field that is part of a large, blossom-shaped, multivent edifice of 2200 m vertical relief (Fig. 2.9). The structure is located about 25 nautical miles south of Rakahanga Island, a position controlled by the regional dip of sedimentary beds on the plateau. Because some of the individual cones are so symmetrical in shape and presumably untouched by submarine erosion, we assume that this field is active. Gas and pore water should be actively venting at the sea-floor. The source is probably from beds correlative with the sapropelic Upper Cretaceous interval drilled at DSDP 317. Recent surveys on active margins suggest that these features are common in tectonized geologic environments and are disposed along the traces of thrust faults on fore-arc slopes. To our knowledge this survey is the first report of such features on a mid-ocean plateau and represents an important, potential resource of natural gas for the Cook Islands.

LIST OF FIGURES



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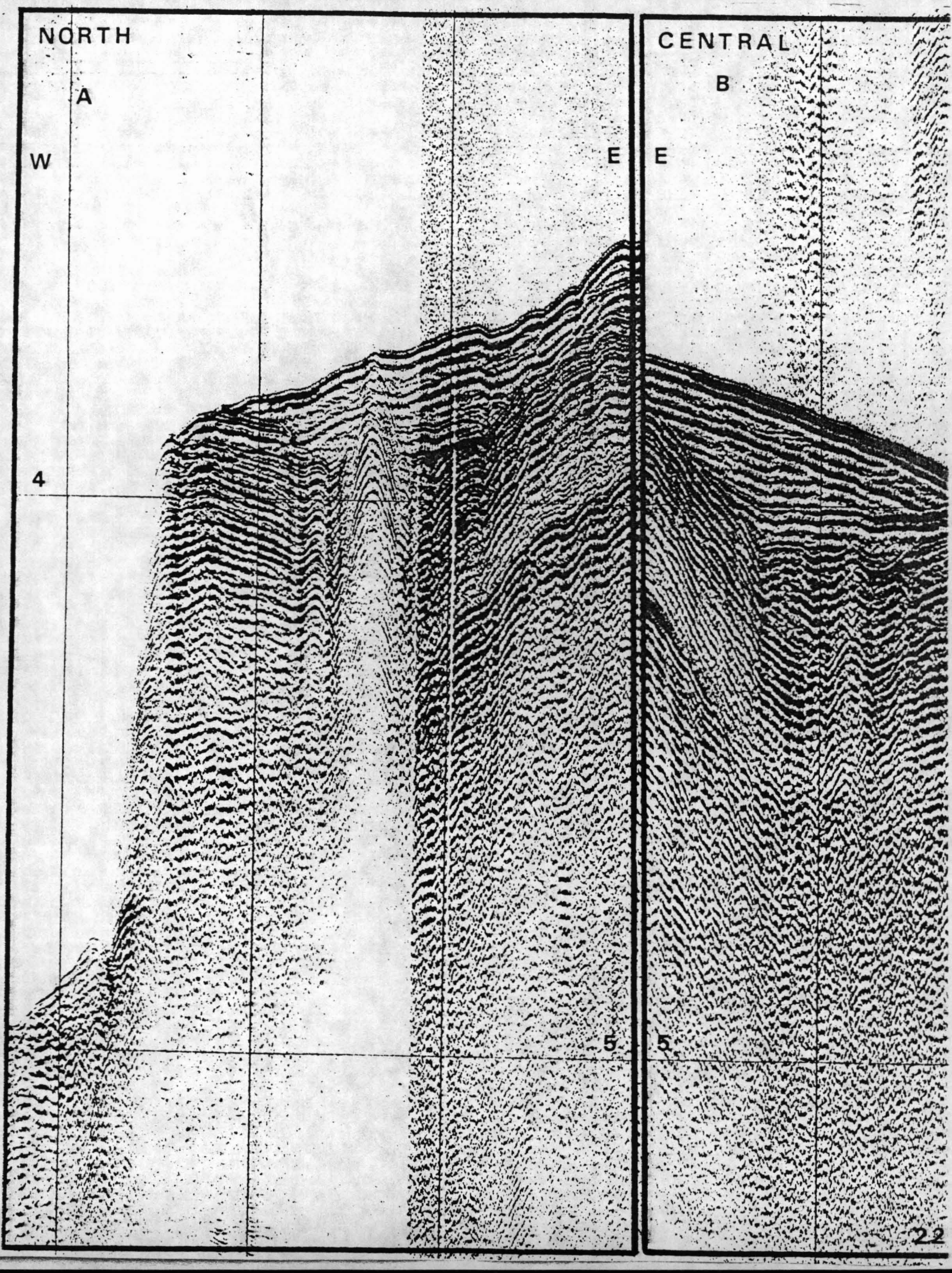
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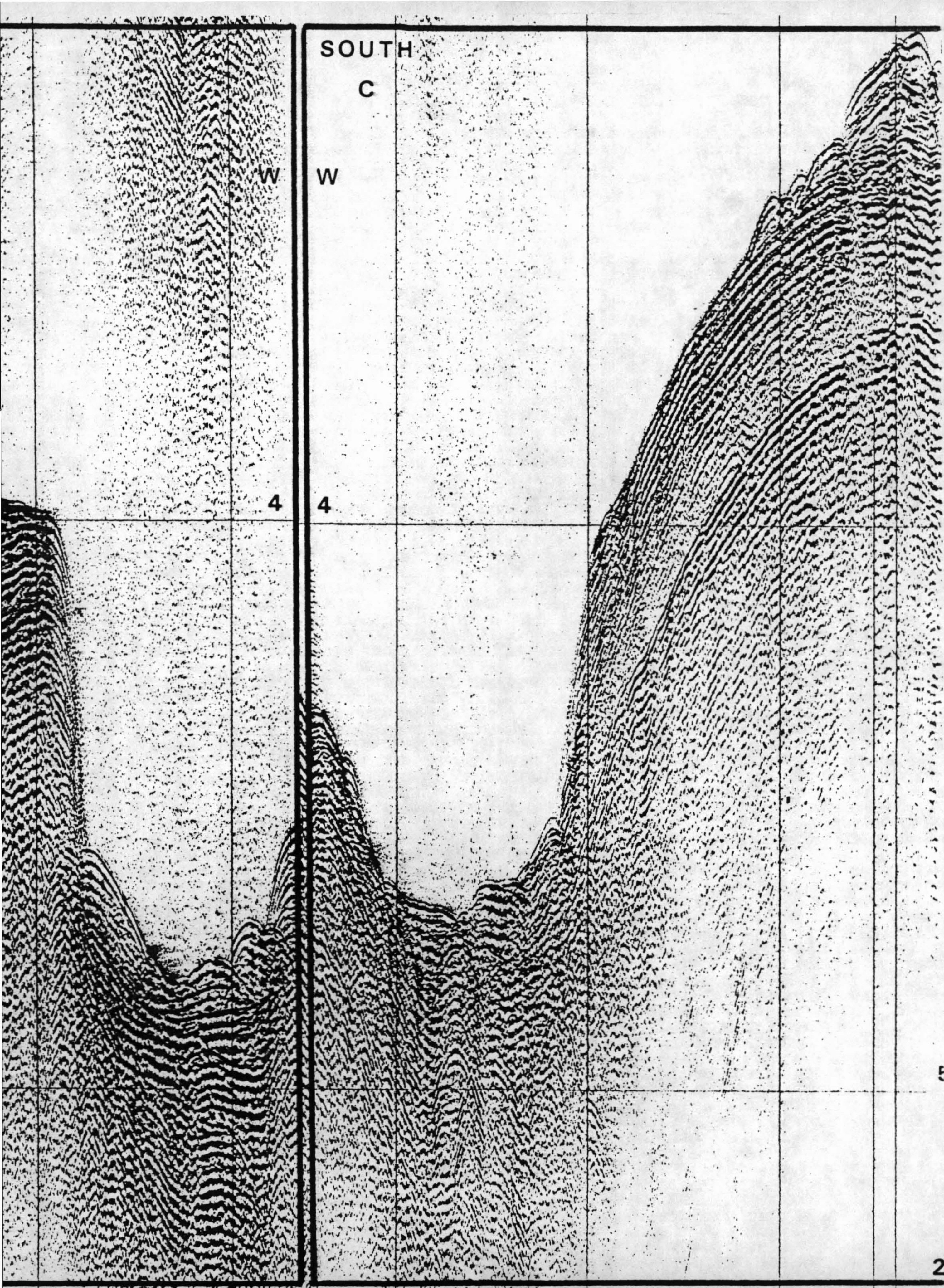

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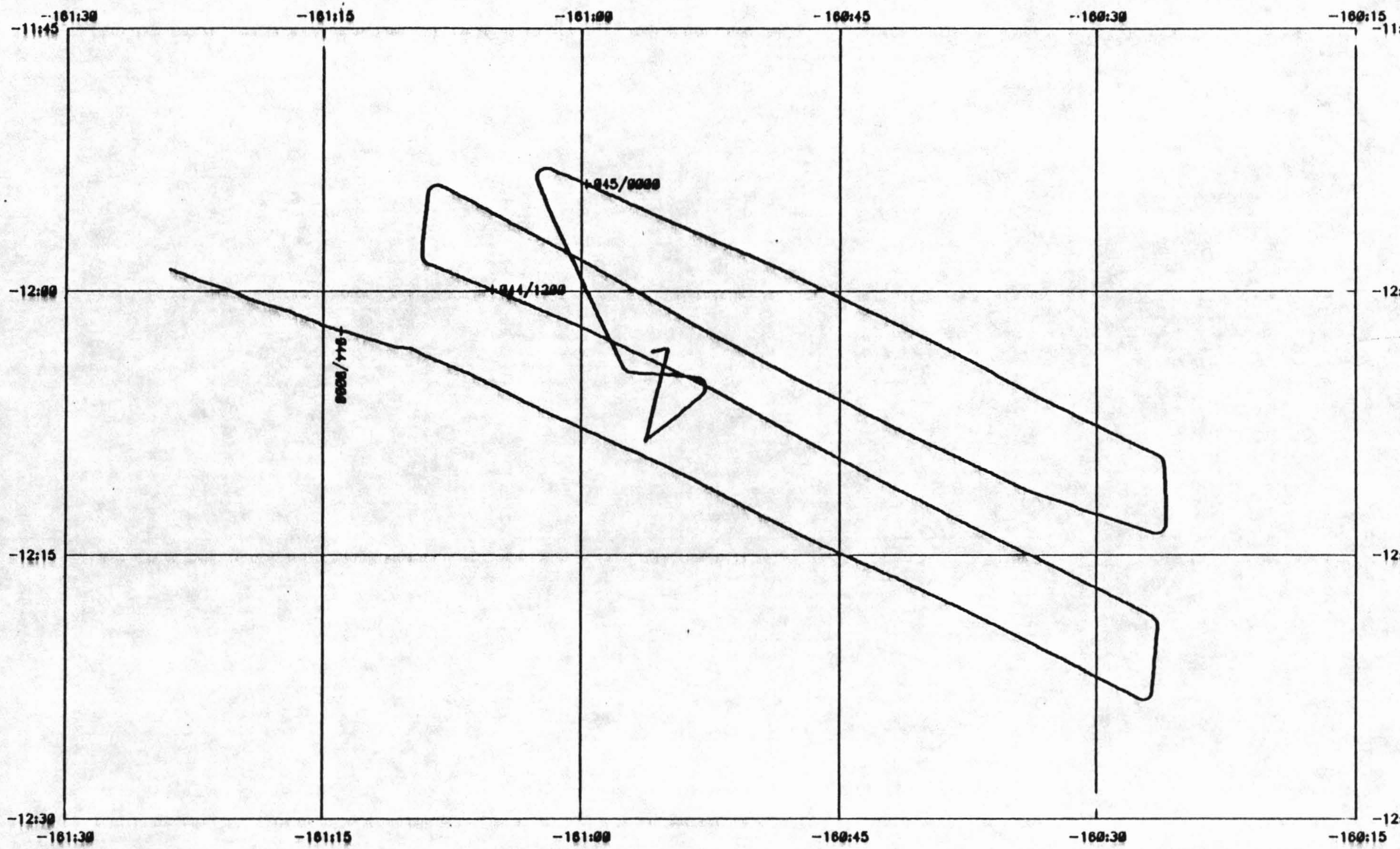

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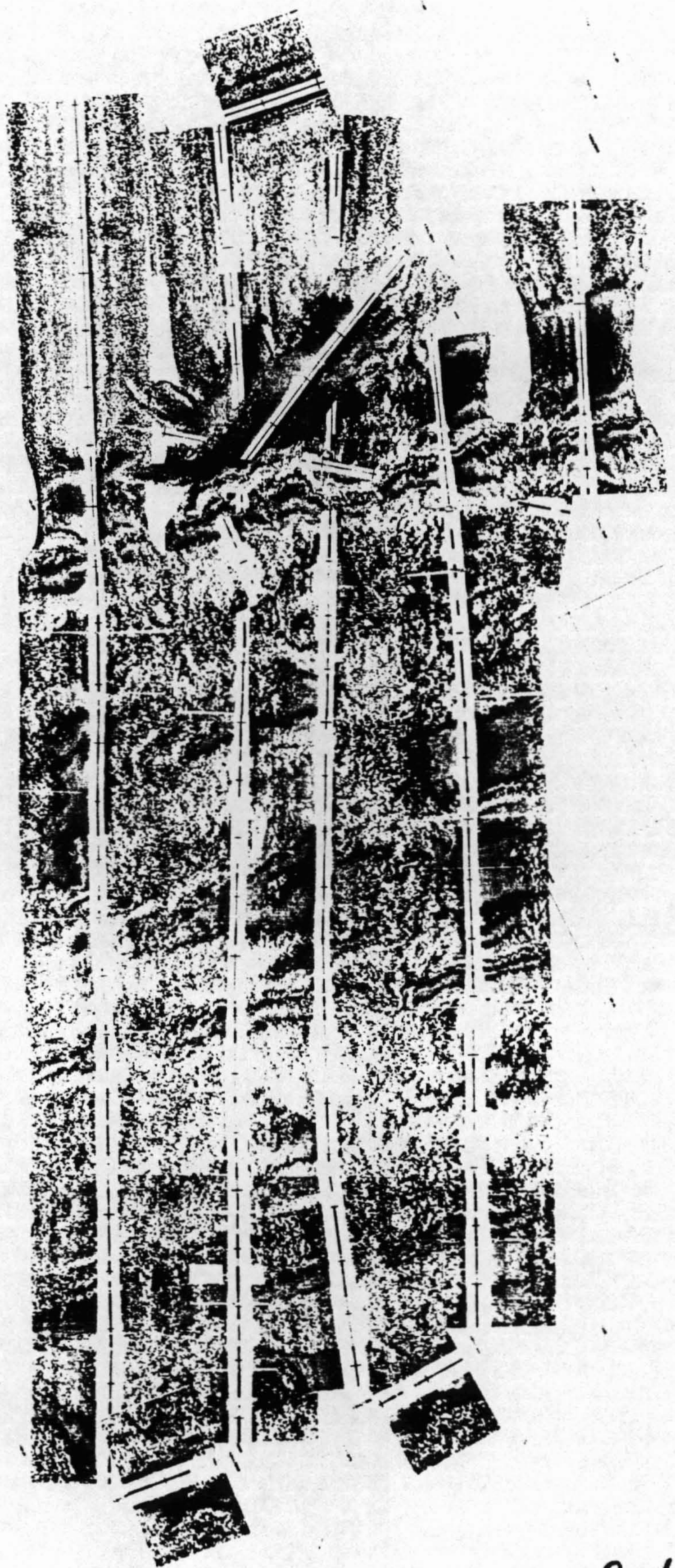

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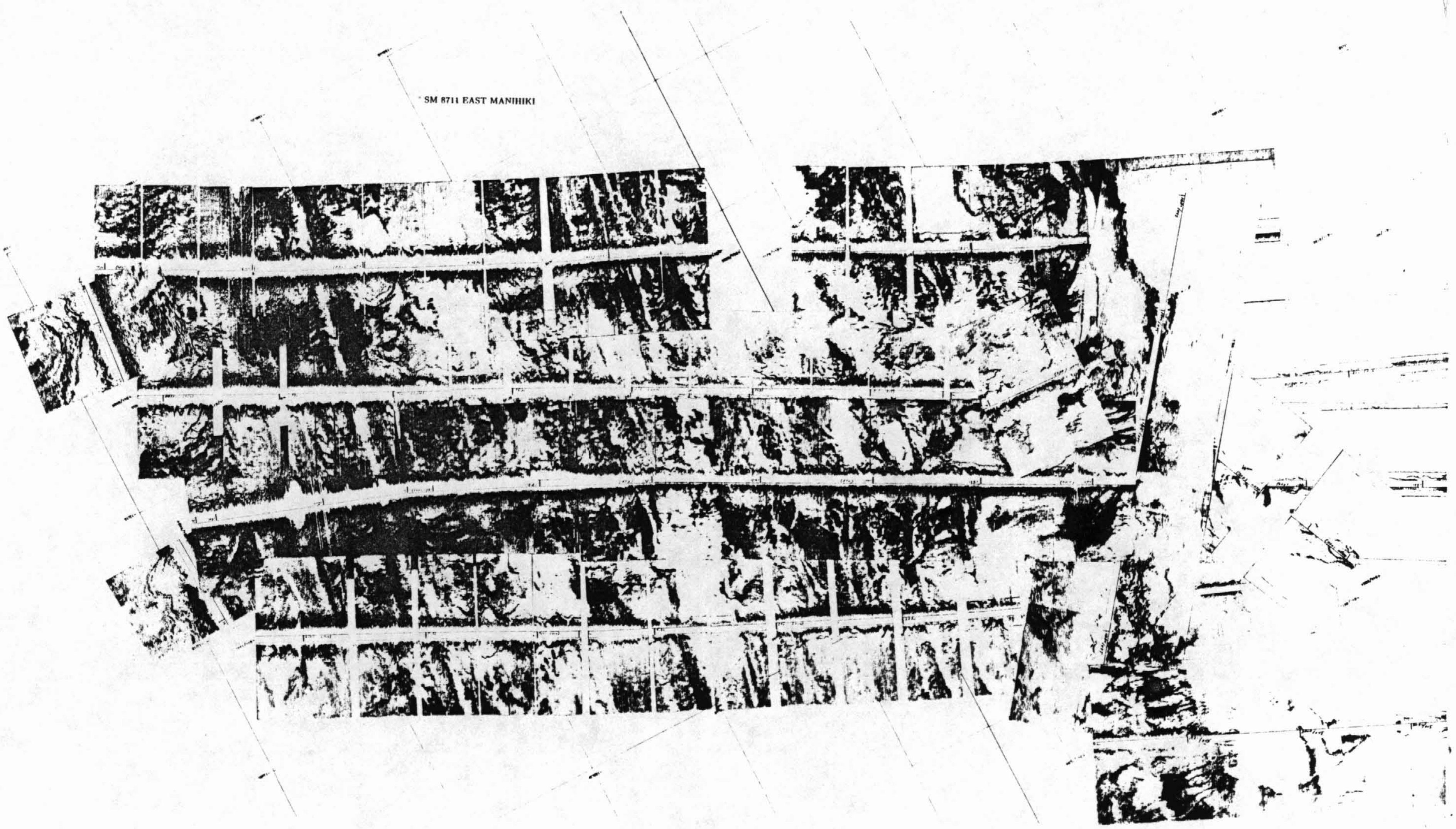

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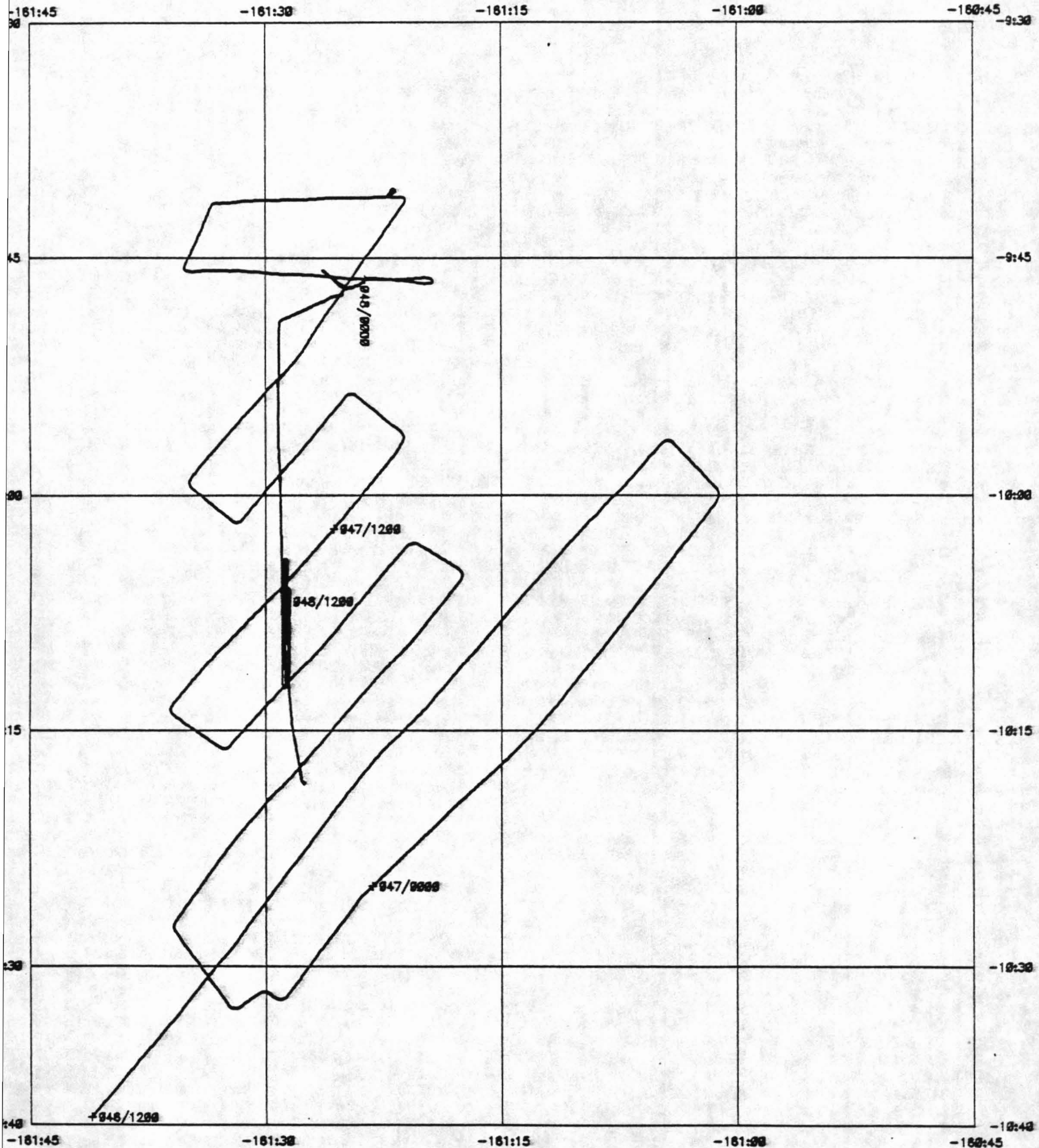

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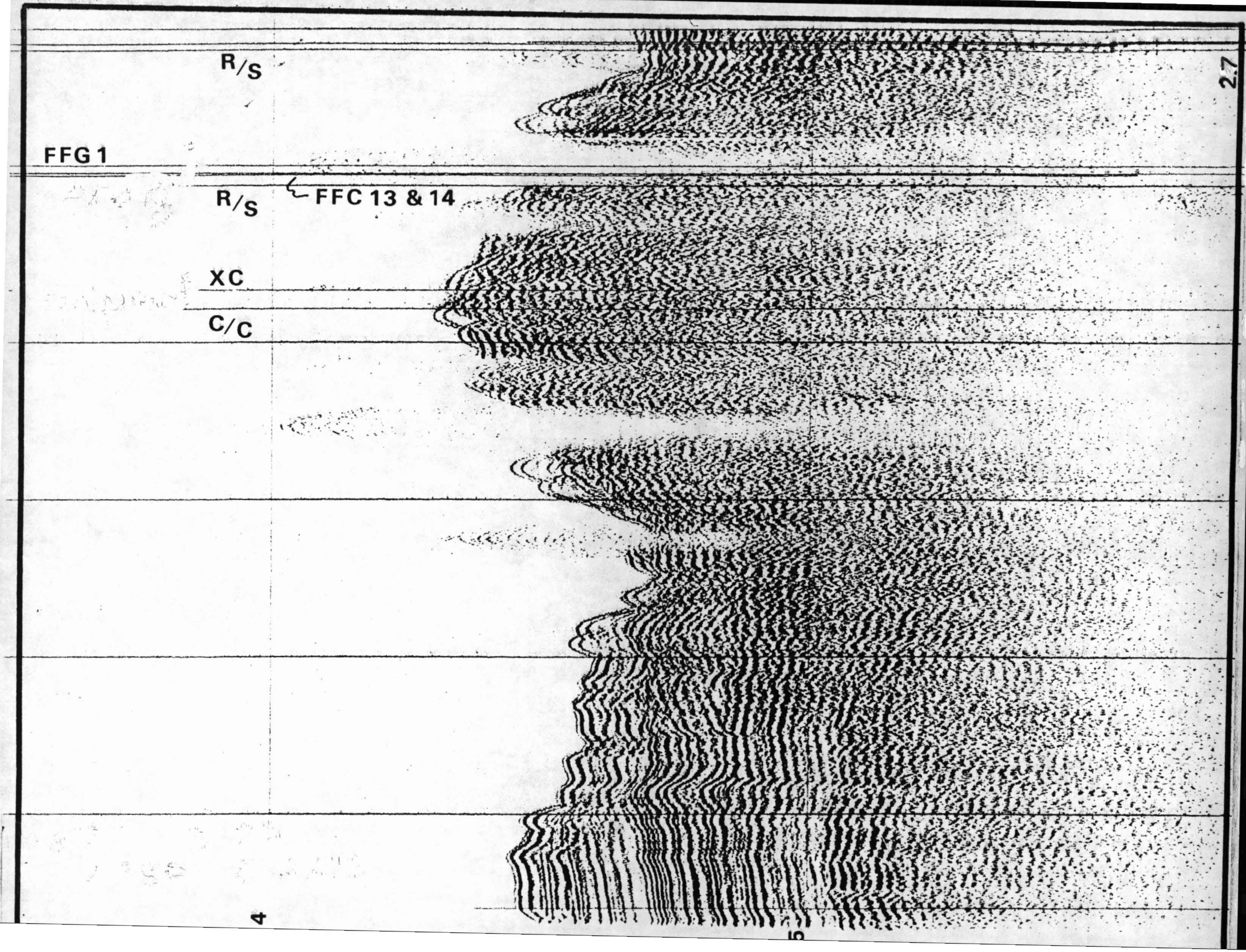

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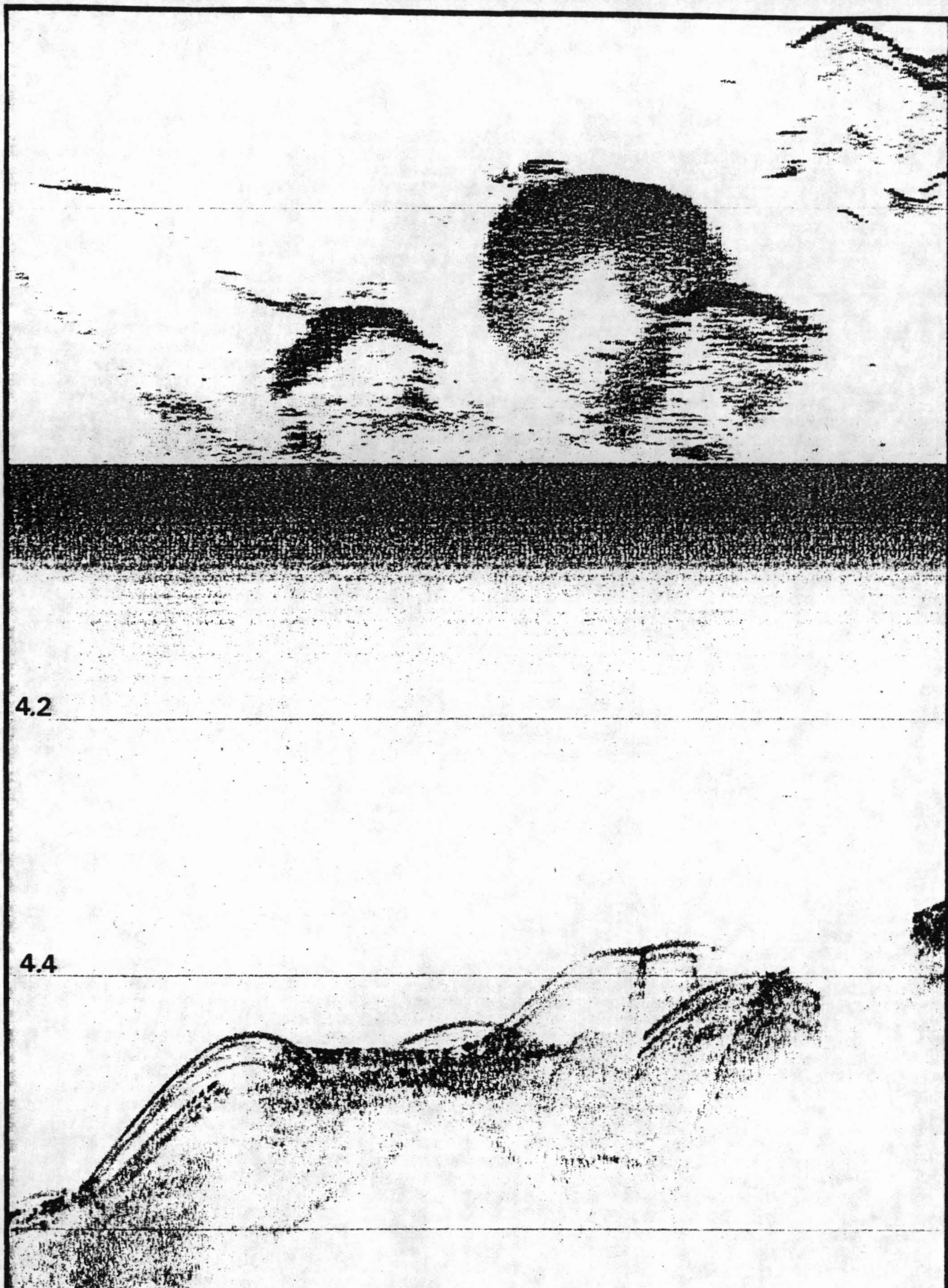
R/S
FFC 13 & 14
XC
C/C
2.7
4
5



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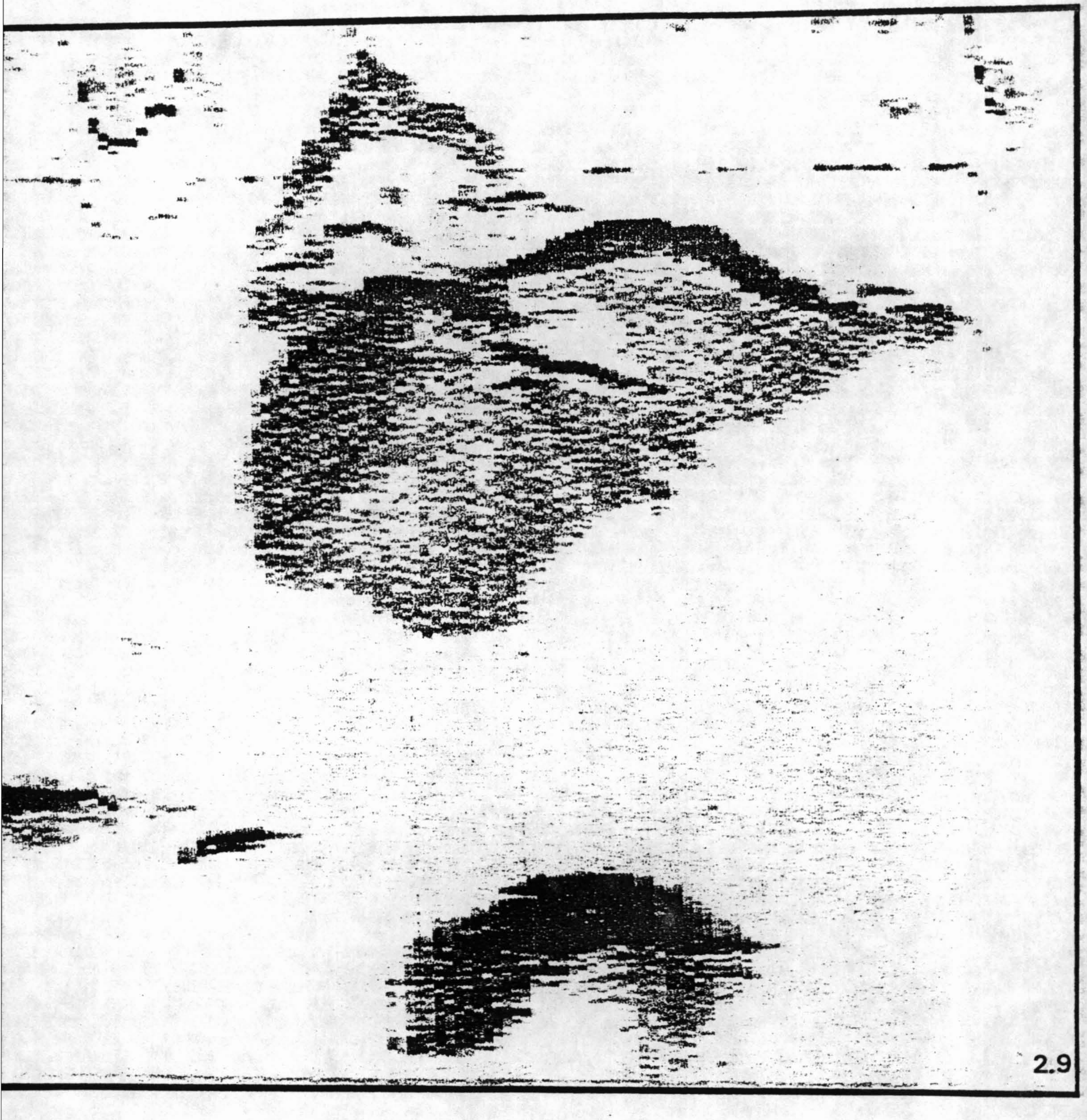

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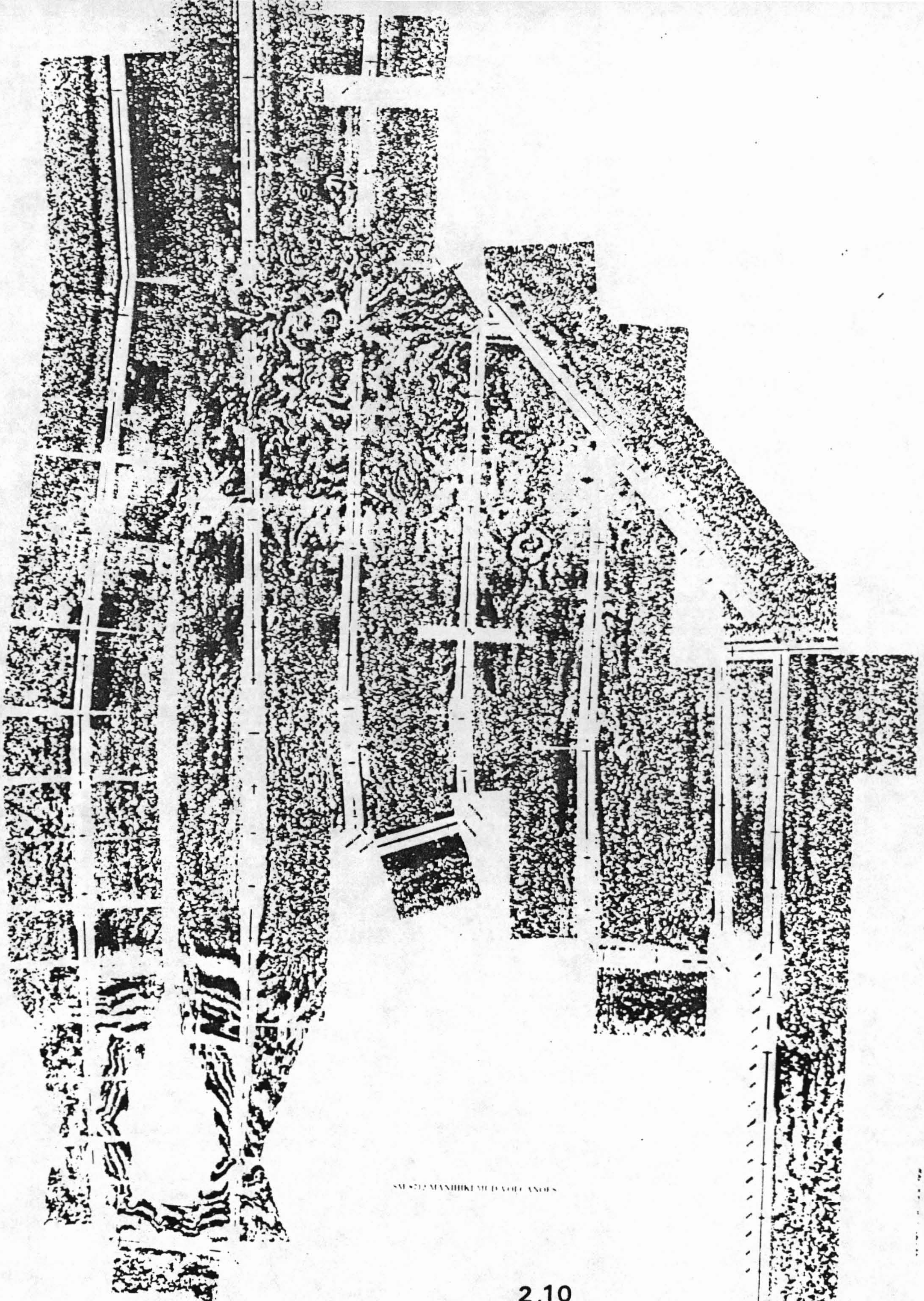

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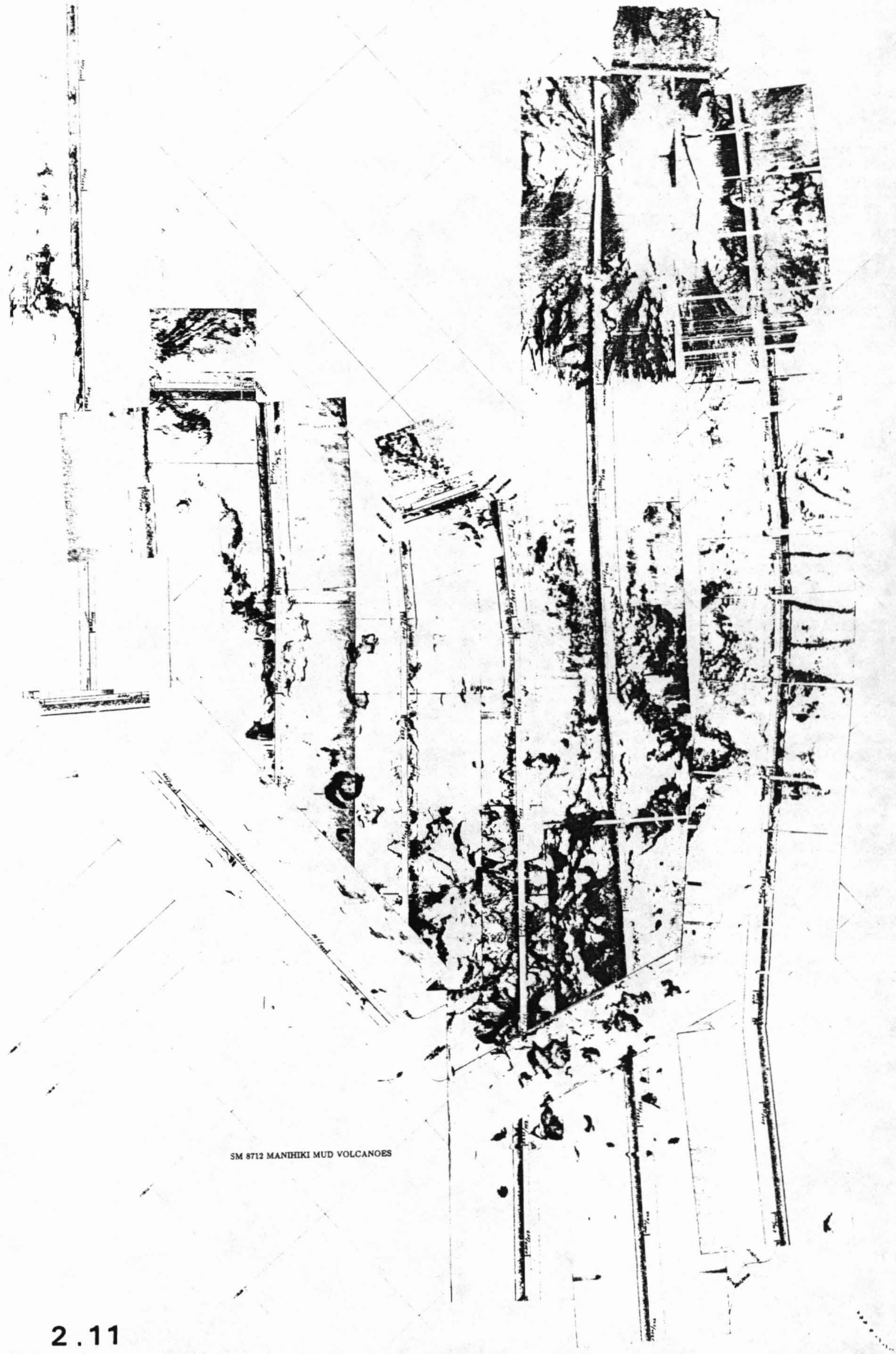

SM 8712 MANIHIKI MUD VOLCANOES

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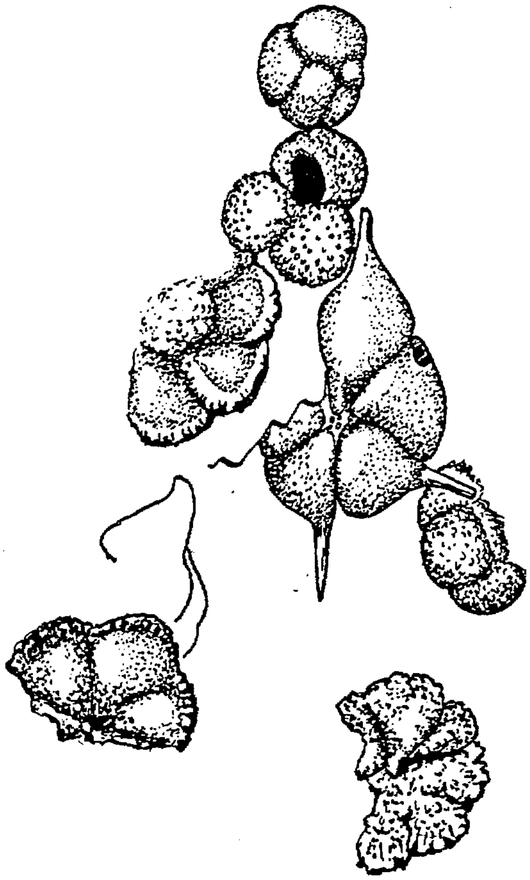

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CCOP/SOPAC MOANA WAVE CRUISE 3 (MW87-02) TO THE TERRITORIAL WATERS OF WESTERN SAMOA, THE COOK ISLANDS AND KIRIBATI

CRUISE REPORT

III. KIRIBATI SCIENCE REPORT

The Line Islands seamount group is an area of high ferromanganese-oxide crust (FeMn-oxide) resource potential. To evaluate the geological environment, seamount morphology and distributions of representative Mn-crust sites, four SeaMARC II surveys were completed and eight sites were dredged in the six and a half working days alotted to the southern and central Line Islands region.

We departed the territorial waters of the Cook Islands on Tuesday, February 17. With light winds and calm seas we made 11 kts with only 3.5 kHz bathymetry and the magnetometer in tow and arrived in the southern Line Islands on the evening of 19 February. The research program involved SeaMARC II surveying and sampling of seamounts and ridge segments, beginning in southern Line Islands near Malden Island and ending in the central Line Islands near Fanning Island. We left the field area about noon on February 27 for the 4 day transit back to Honolulu.

Southern Line Islands

A slight change in the direct transit was made in order to intersect a SEASAT/GEOS-3 anomaly at 3-22' S and 155-41' W. To map the predicted seamount at this location, we intended to begin SeaMARC II coverage in advance of the target and to continue with side-scan into the southern Line Islands study area. Unfortunately, in the course of deployment in the mid-afternoon of 19 February another electrical fault occurred in the SeaMARC II system, necessitating retrieval of the tow-fish. We deployed the 120 cu. in. air-gun to record a seismic profile across the feature and to allow the SeaMARC II technicians sufficient time to repair the system. Fortunately, we found the seamount on our first transect, even without side-scan capability. This seamount rises to 1205 m below the surface. A cross line also passed over the summit (Fig. 3.1) and by that time the target had become too tempting to pass by without an attempt to sample metalliferous crusts.

The initial sampling attempt at Station 21 was aborted due to inappropriate local set and drift conditions but in a second try, Station 22, the summit of the seamount was sampled. A rectangular frame dredge was deployed at 3-27.07'S and 155-41.2' W in 1455 m of water and with 1848 m of wire out we became anchored to the bottom. Maneuvering the ship suceeded in freeing the dredge about two hours later after a series of 11,000 lb bites.

Station 22, RD 19 resulted in a haul of about 20 kg of FeMn-oxide encrusted cobbles. The dimensions of the five rocks in the haul range from 45 x 35 x 14 cm for the largest, a heavily FeMn-oxide encrusted specimen (2 to 5 cm), to a minimum of 13 x 12 x 8 cm for the smallest hyaloclastite cobble, which is merely stained with FeMn oxides. Although the crust thicknesses in RD 19 were relatively thin, we believe that this unnamed seamount is covered with much more extensive FeMn-oxide deposits than the dredge recovery indicated. The seismic reflection survey reveals little or no sediment on the flanks of the edifice and only slight accumulations on the summit. These aspects and the number of strong bites on the dredge suggest extensive crusts pave this mountain. Although only FeMn-oxide encrusted cobbles were recovered, past experience in the Hawaiian Archipelago and in the Mid-Pacific Mountains has shown that dredging preferentially collects loose cobbles and under-represents crust pavement. Additionally, statistical analyses of dredge hauls that have recovered both pavement fragments and cobbles show that crust on pavements is about twice as thick as on cobbles. Application of these analyses to our survey indicates that this seamount has a potential for pavement with Fe-Mn oxides between 4 and 10 cm.

After this unexpectedly long but profitable investigation, we continued steaming northeast to the site of our next primary study area. We designed a survey to assess the mineral wealth contained in metalliferous crusts precipitating on the flanks of seamounts in the southern and central Line Islands. The goal was not only to determine the areal extent and volume of the deposit, but also to relate elemental ratios of metallic components of the crusts to water depth, to sea-water chemistry, and to latitude. Several seamounts were suitable candidates for these purposes and we decided on an unnamed peak, located at 3-04' S and 155-49' W. Because its summit is relatively deep, about 1580 m below sea-level, the flanks of this edifice should not be contaminated with slope deposits of coralline rubble. The relatively deep summit should also permit good SeaMARC II bathymetric coverage within the depth range deemed optimum for high metal values (Co, Ni). The remaining three sampling sites, chosen for their mineralization potential, are a seamount near the equator and ridges at 1-25' S and at 4-26' N.

Photographic surveys were planned for comparison of visual images with the textural and roughness signature displayed in the SeaMARC II side-scan mosaics and to better evaluate the extent of FeMn-oxide crust coverage on the flanks of the edifice. Such confirmation is necessary because neither SeaMARC II images nor dredging can unequivocally ascertain the areal extent of FeMn-oxide encrustation. The former because images from hard rock substrates are very similar to those from crust-covered slopes, and the latter because the method generally is biased by sampling loose FeMn-oxide coated cobbles rather than continuous pavement.

The seamount at 3 degrees south latitude was the most thoroughly surveyed sampling target in Kiribati territorial waters (Fig. 3.1). A rosette of track-lines was plotted in advance to maximize the side-scan coverage by obtaining various look-directions. The side-scan image was intended to serve as a base map from which optimal dredge sites could be selected. The SeaMARC II survey began about noon on Friday, February 20 and the first pass at the target seamount was close enough to indicate that it lay to the northwest of its charted position. Once the survey was in progress, it also became obvious that this seamount was smaller than the bathymetric maps indicated. Additionally, navigational errors altered our track orientations. As a result, the track pattern was modified while the survey was in progress. By noon the following day, the multiple track and look-direction, side-scan coverage of this peak was completed, preliminary contours drawn, and an optimum dredge site was located on the north flank of the edifice.

The bathymetric and side-scan mosaics require post-cruise processing to correct navigational and bottom-detect errors (Figs. 3.2 and 3.3). The satellite navigation unit and "dead-reckoning" update in the electronics laboratory had failed by this time, requiring the bridge to report fixes to the laboratory at 15 min intervals. This loss of resolution was compounded by a strong set and drift toward the SW, therefore, it was very difficult to pace the recorder speed with the actual velocity of the ship over the sea-floor. Additionally, the SeaMARC II system had difficulty tracking the sea-floor over this rugged and steep seamount, producing numerous bottom-detect errors, which are displayed as large scallops in the real-time mosaic. These shortcomings are all correctable with shore-based processing of the information stored on computer tapes.

Station 23 began in the mid-afternoon on Saturday, February 20 and finished more than a day later after four dredges and one camera deployment. Despite laying out 4600 m of wire in 4000 m of water at 2-46.57' S and 155-47.44' W, no sudden increases in tension occurred during the retrieval of RD 20. We suspect that the dredge merely kited through the water column, even though we placed four, 100 lb weights on each arm of the bridle. This kiting is probably the result of a combination of two factors: (1) spooling out of insufficient length of cable beyond the water depth and (2) effects of local currents, which required the ship to make several adjustments to achieve the proper course across the seamount flank. The dredging attempt was repeated for RD 21, located slightly to the northeast at 2-46.57' W and 155-47.44' W (GPS) to take advantage of the easterly wind and westerly-flowing current. For this attempt, we deployed the rectangular dredge harnessed with a 1 ton weight. The dredge reached the sea-floor at 4400 m depth, but despite numerous bites, it also came to the surface empty. The next dredge, RD 22, was aimed slightly shallower. The sea-floor was reached at 3350 m, 2-48.45' S and 155-46.54' W; and an additional 550 m of wire were laid out as the ship drifted. This effort returned three specimens: a weathered basalt with metalliferous crust, a weathered basalt without crust and a FeMn-oxide encrusted limestone cobble. The next attempt was a conservative one, aimed at retrieving a large sample. RD 23 reached the sea-floor at 2340 m depth and 2-51.98' S and 155-53.39'W and an additional 900 m of wire were paid out in order to assure retrieval of a sample. R23 was on deck by noon with a sizable sample.

The four rocks in RD 23 are vesicular basalts. Each has an alteration rind of about 1.5 cm and an FeMn-oxide crust of 1 to 2.5 cm thickness. The vesicles are filled with zeolites or calcite.

Station 23 was concluded with a camera run (BC 5) from 1780 m to 3487 m on the northeast side of this seamount. The camera was submersed for about four hours and for the first two hours was flown within a few meters of the bottom. After passing over a ravine, however, the bottom was lost and never regained. A final assessment of the success of this effort awaits shore-based development of the film.

With the completion of Station 23, we departed for the next study area, a ridge-seamount complex, approximately 8 hrs transit to the north. We deviated slightly from a straight-line transit in order to cross a SEASAT/GEOS-3 satellite anomally at 1-54.0' S and 156-12.0' W. Because the existing bathymetric charts show no significant sea-floor relief at that position, there was the probability of a large, uncharted seamount at that location. A single, SeaMARC II swath across this location was recorded as a part of the transit to the ridge survey area to the north. The side-scan coverage shows that our course first passed across the eastern flank of a large seamount, then crossed directly over the summit of a second mountain (Fig. 3.4). The closed contours displayed in the bathymetric mosaic reveal a conical mountain, which rises 2000 m above the surrounding sea-floor.

A NW-SE trending ridge located at 1-20' S and 155-40' W was the second area chosen for detailed SeaMARC II coverage in the Line Islands (Fig. 3.5). Up to this point, we had only investigated the seamounts of this region; samples from the first seamount were all hyaloclastite and those from the second were all vesicular basalt. This area was chosen to ascertain if ridges of the area differ from seamounts in terms of sea-floor roughness and texture, and in terms of potential mineral wealth. Additionally, this survey and attendant sampling would permit the determination of basement rock composition and the age of the ridge.

The SeaMARC II survey of this area required about 12 hours on Monday 23 February. We were beset with the same navigational and oceanographic difficulties, which hampered the shipboard compilation of the image for the previous study-area, however, bottom-detect errors were much fewer. The SeaMARC II side-scan images reveal a ridge of rough topography, capped by several summits reaching to within 1800 m of the sea-surface (Figs. 3.6 and 3.7) and provide an assessment of the geological setting of

Station 24.

Station 24, RD 24 was the most successful sampling effort for this cruise. The station began in the early evening of 23 February. We used a rectangular-frame dredge and one ton weight. The dredge reached the sea-floor on the northeast flank of the ridge at 1-18.49' S and 155-46.25' W and about 2200 m depth. We attempted to compensate for the strong southwesterly set and drift in the region by offsetting to the northwest. This offset was somewhat conservative and the dredge was deployed virtually across the summit of the edifice. The dredge, with about 500 lbs of rock, was on deck about 11 PM. Next, we moved to a location farther down the northeast flank of this ridge in an attempt to acquire a sample from greater water depth. RD 25 reached the sea-floor at 4:00 AM on 24 February at 7-17.22' S and 155-49.14 W at a depth of about 3200 m. After an hour on the sea-floor without any large bites, the empty dredge was retrieved and on deck at about 6:00 AM.

Despite the disappointing result of the deep sampling attempt at Station 25 RD 25, the initial attempt, RD 24 was a spectacular success. The chain-link dredge bag was filled almost to capacity. About 2/3 of the sample are weathered basalts covered with FeMn-oxide stains or crusts less than 1 cm thick. Crusts account for the remaining third and some of these are quite thick, ranging from 1 to 6 cm. Shore-based cutting of the larger samples may reveal thicker crusts, because some of these specimens are noticably less dense than equivalently-sized pieces of hyaloclastite or basalt.

We located the third seamount we intended to sample in the Line Islands area in the early afternoon of 24 February (Fig. 3.8). A short, Z-shaped pattern of seismic lines was used to find the summit, which is several miles north of its charted position. Dredging for Station 25 RD 26 was underway by mid-afternoon. The large cylindrical dredge, weighted with 400 lbs on each bridle arm reached the sea-floor in about 3150 m of water at 0-19.47'S and 157-02.93' W. An additional 400 m of wire was paid out. Because the dredge site is on the southwest flank of this seamount, the ship had to maintain a course into the wind and current in order for us to dredge upslope. After several bites, the dredge was hauled in and on deck by 8:30 PM. The sample in RD 26 comprised brecciated volcanic cobbles and several large boulders, all hyaloclastite. None of the specimens were encrusted with significant thicknesses of FeMn-oxide and several of the cobbles were well rounded. All samples, however, showed slight staining and deposition of FeMn-oxides in cracks and depressions on the volcanic breccia. The steep slopes of this seamount, the rounded shape of the specimens and the lack of crust growth all suggest that this edifice is too unstable to afford a promising site for metalliferous crust formation.

Station 25 RD 26 was an attempt to sample near the summit, at 1500 m depth. The dredge reached the bottom at about 10:00 PM at 0-18.86' S and 157-1.91' W and was on-deck, but without a sample by midnight. With the available station time for MW87-02 rapidly waning, sampling attempts at this location were abandoned in favor of a last effort in the central Line Islands. Accordingly, shortly after midnight we began the 24 hr transit to our next and last SeaMARC II survey area.

Central Line Islands

The latter portion of our work in the Southern Line Islands and all of our efforts in the Central Line Islands were devoted to achieving a better understanding of the morphology of this island chain in order to define the geologic environment in which Mn-crusts are formed.

The origin of the Line Islands chain is undetermined, with researchers advocating formation by a hot spot, by an aborted rift system, by a leaky fracture zone or by mid-plate volcanism. The most recent information places the formation of the chain in late Cretaceous time (about 70 Ma), and volcanic reactivation in the Eocene (about 40 Ma). The morphology of seamounts in the Line Island chain differs markedly from the typical Hawaiian shield volcanoes and may reflect this peculiar two-stage volcanic history. The chain is divisible into three morphological parts. Massive seamounts of 50 to 250 km diameter characterize the northern sector, large ridges 150 to 1200 km in length dominate the central portion and small isolated seamounts of 10 to 15 km diameter form the southern third. Compared to most seamounts, those of the Line Islands chain display unusually rough topography, probably resulting from numerous volcanic features on their summits. In contrast to the Hawaiian chain, reef platforms, sea-level notches or benches are absent.

In the last few working days of MW87-02 a SeaMARC II survey was planned to examine in detail the morphology of three seamounts in the central Line Islands. The prime target is Chapman Seamount, seen on existing maps as a large, complex seamount located 1 degree WSW of Fanning Island (Fig. 3.9). Tracklines were plotted to examine this feature from optimal look-directions within the limitations of a 24 hr survey. The remaining day available for surveying in this area was to be devoted, either to dredging the edifice, or to moving to the northeast of Fanning Island to accomplish a reconnaissance survey of the backbone of the ridge itself and of two seamounts forming a ridge segment located just to the north of Fanning Island.

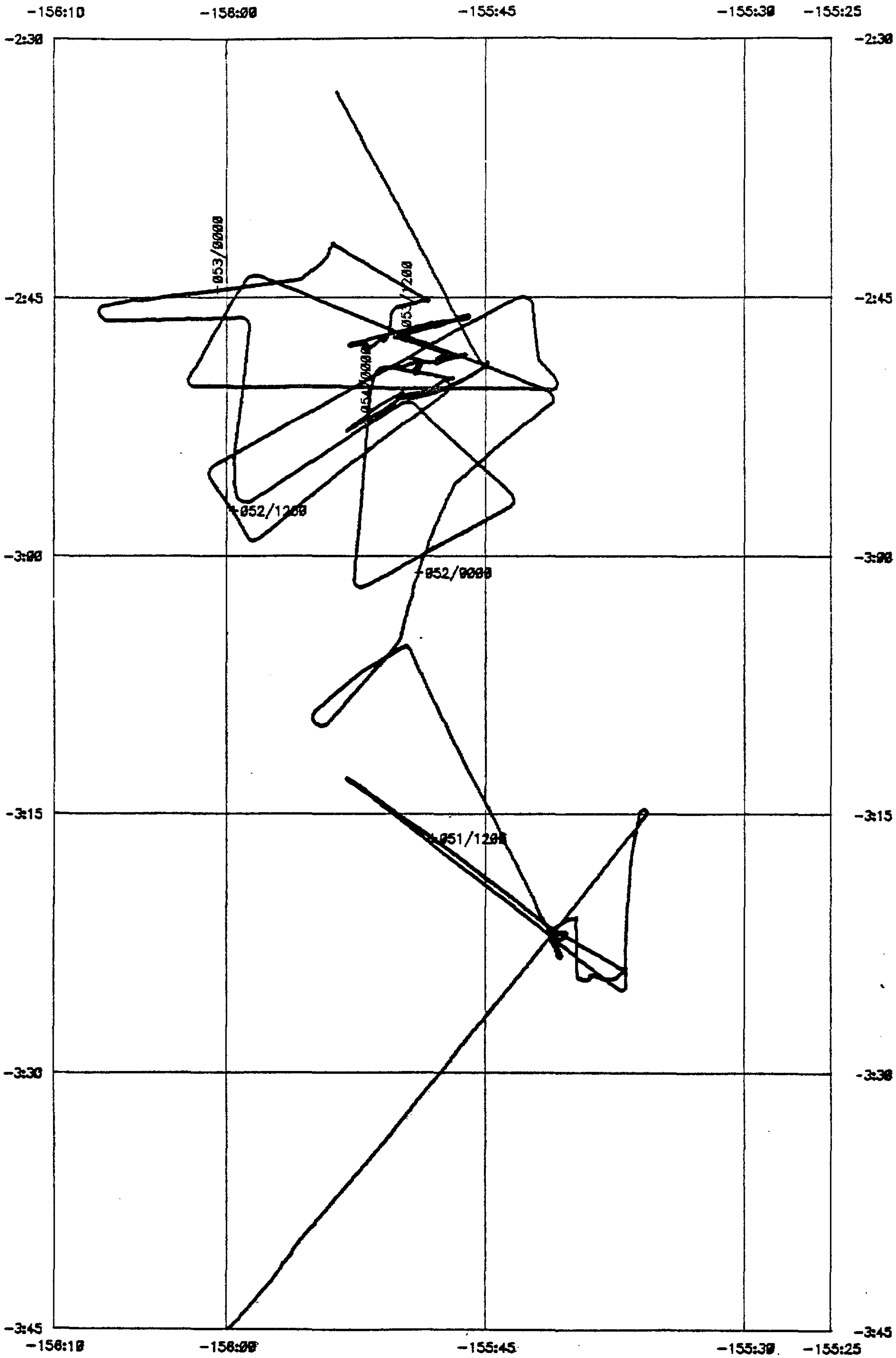
The SeaMARC II survey began in the early evening of Wednesday 25 February. The summit was located slightly to the west of our initial south to north traverse but by the morning of 26 February we had completed a third pass and closed contours on all but the southwest corner of this guyot (Fig. 3.9 and 3.10). We were compelled to modify our initial track pattern, first in the initial stages of the survey because the summit lay to west of our second traverse, and again, later in the survey because we crossed a long-line fishing array. The fishing vessels were within sight and despite our display of symbols indicating our inability to maneuver and attempts to establish radio communication with them, we received no response. The ship inadvertantly crossed one line of buoys in the mid-afternoon, and a second line of buoys blocked our intended turn to the east. These two long-lines formed an X pattern. To turn to starboard would have meant crossing at least one line again and certain risk of catching the array on the SeaMARC II tow-fish, deployed at a depth of about 120 m. With no choice but to steam to the end of the string of buoys to port, we continued south for an hour before finally turning. Unfortunately, the line was crossed at this location too. The SeaMARC II signal had become noisy after the first crossing and continued intermittently noisy for the remainder of the survey. The high pitch noise was episodic, an indication that fishing lines might have become ensnared on the towed gear. Because only one additional swath was necessary to complete coverage of this guyot, examination of the towfish was delayed until the mosaic was complete.

The SeaMARC II bathymetric and side-scan mosaics of this guyot form almost complete bathymtric coverage to the 4000 m depth contour (Figs. 3.10 and 3.11). The mountain is smaller and located farther to the NW than indicated in earlier bathymetric maps. One diapir pierces the sediment cover at the base of this mountain. Sediment drapes the flat-summit and portions of the flanks of this feature; the images have sufficient resolution to display sand waves and late-stage volcanic cones on the summit (Fig. 3.12). Time was insufficient to dredge at this location, which because of its extensive sediment cover is not a promising site for metalliferous crust growth at depths less than 2500 m.

SeaMARC II was hoisted on board in the late evening of Thursday 26 February. The retrieval required almost two hours due to the mass of lines and fishing hooks snared on the cable grip, depressor, tow-fish and drogue line. The tow cable connector was so damaged that it was unservicable, and consequently was cut. The drogue buoy with radio and flasher was missing, probably caught in the tangle of line and float balls we ultimately cut away. Because repairs to the system would have required a minimum of 12 hours, and a maximum of only 16 working hours remained for this voyage, any hope of further SeaMARC surveying had to be abandoned. We had planned to image and to dredge a ridge to the northeast of Fanning Island and now those plans were reduced to simply dredging an appropriate target.

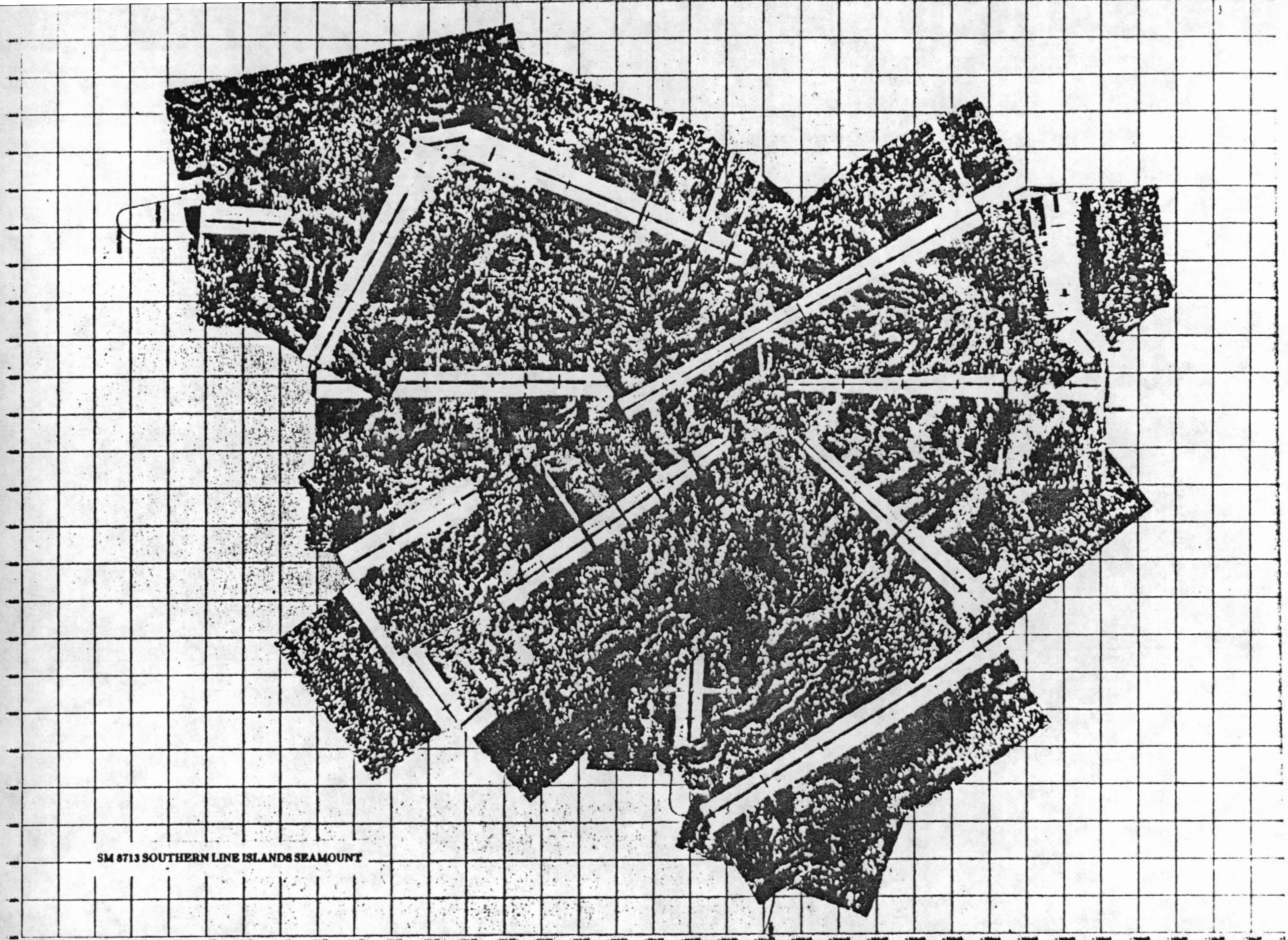
Station 26 RD 28 was a final attempt to sample for metalliferous crusts on a ridge in the Line Islands area. By 9:30 AM the dredge was on the sea-floor on the northeast flank of this ridge in 2070 m of water at 4-26.8' N and 158-58.86' W. After several bites of 12000 lbs tension and about an hour on the bottom the dredge reached the deck with two cobbles of weathered basalt, a starfish and a delicate, flower-like branch of deep-sea coral, preserved in almost perfect condition. With this symbolic reward for our efforts, we concluded the scientific surveys for MW87-02 and got underway for the transit to Honolulu.

LIST OF FIGURES

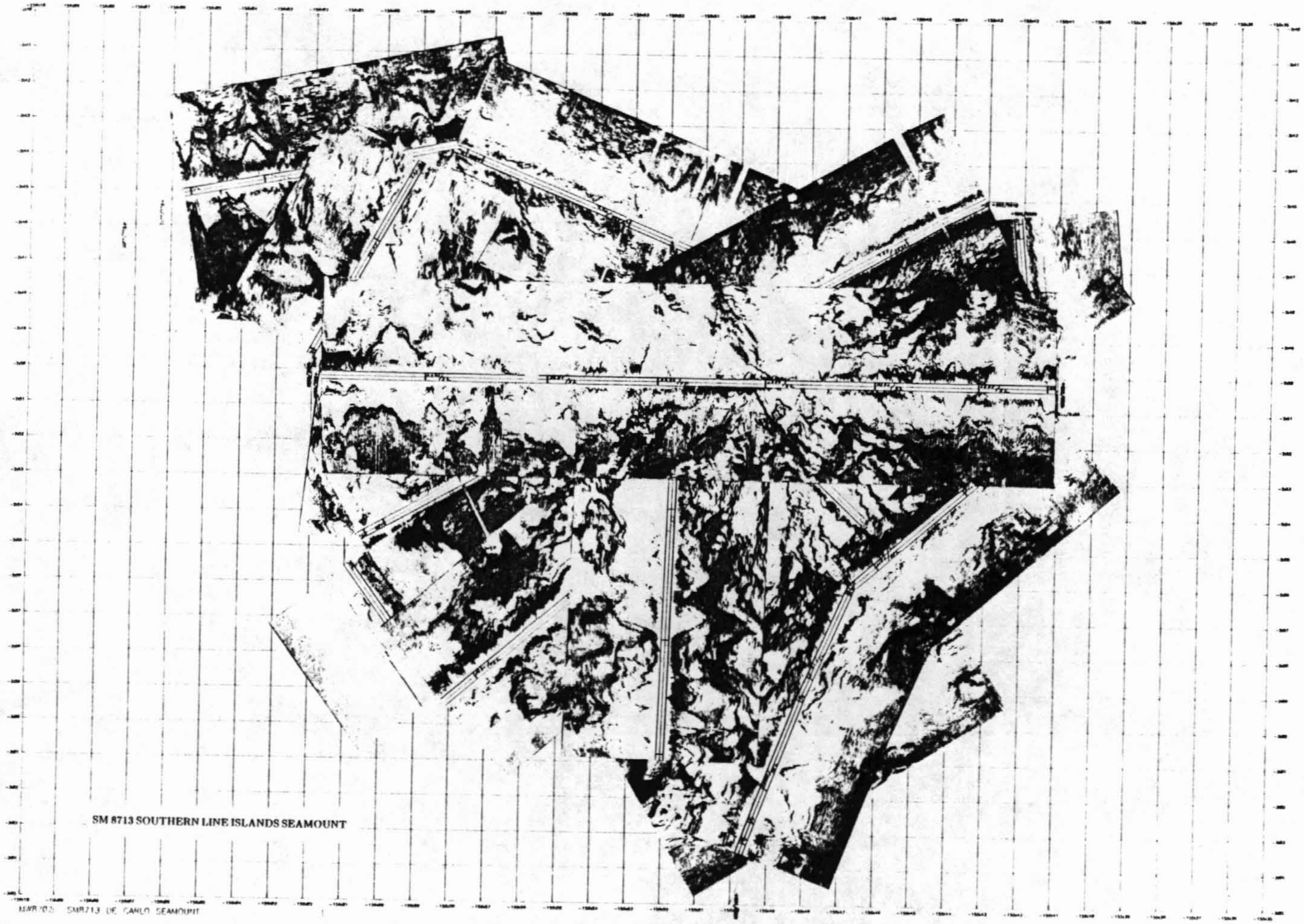


SO.LINE ISLAND SEAMOUNT

3.1



MW8702: SM8713 DE CARLO SEAMOUNT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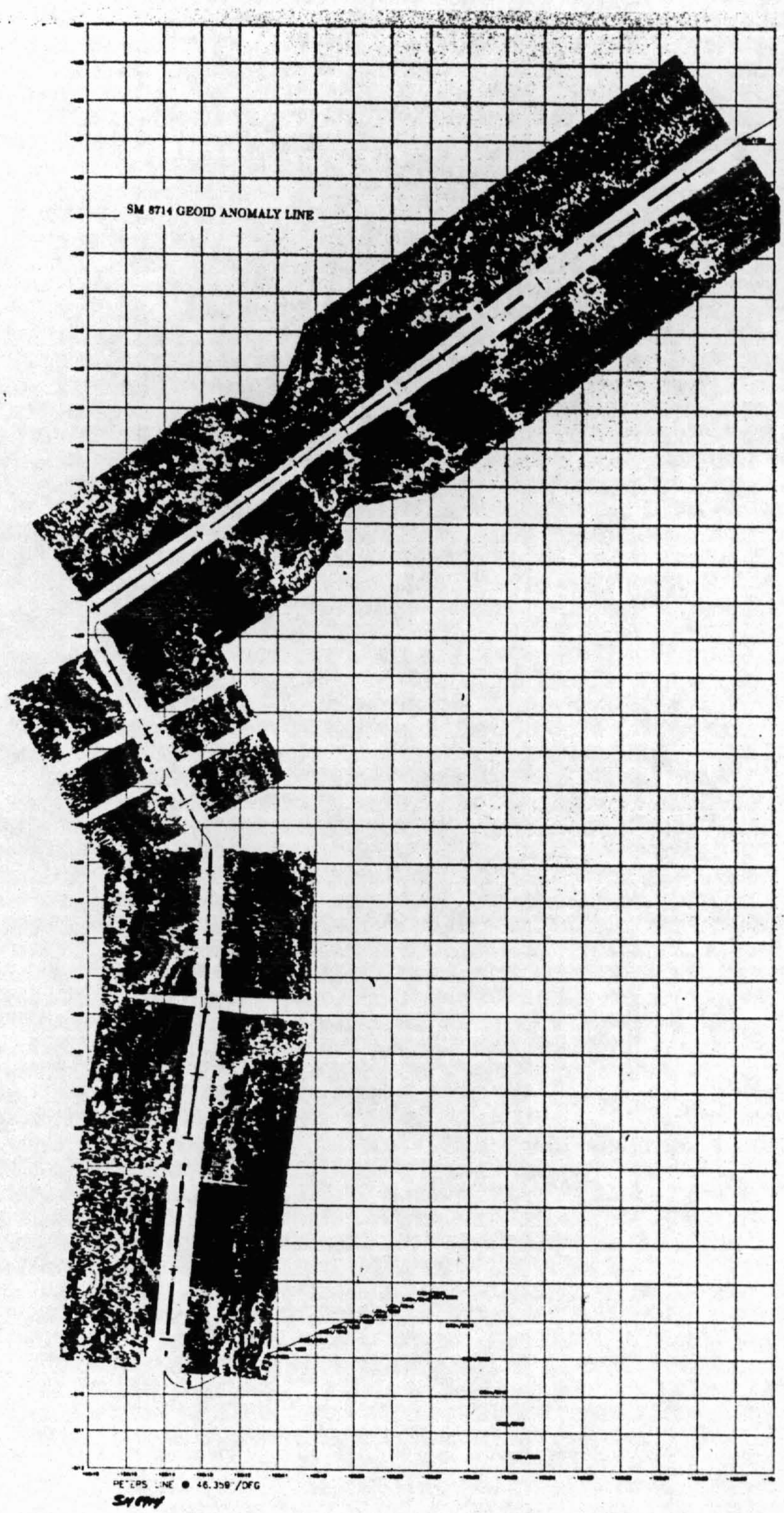
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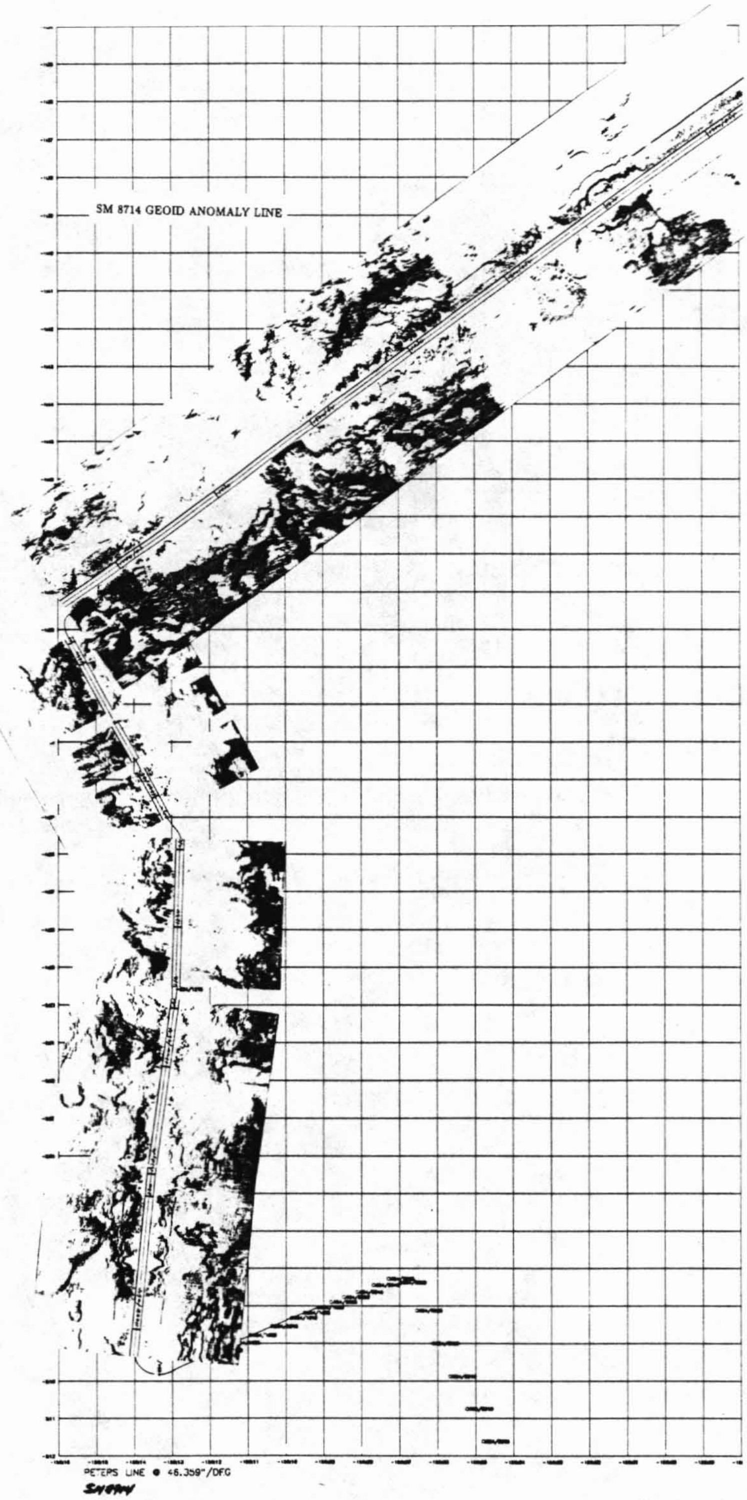

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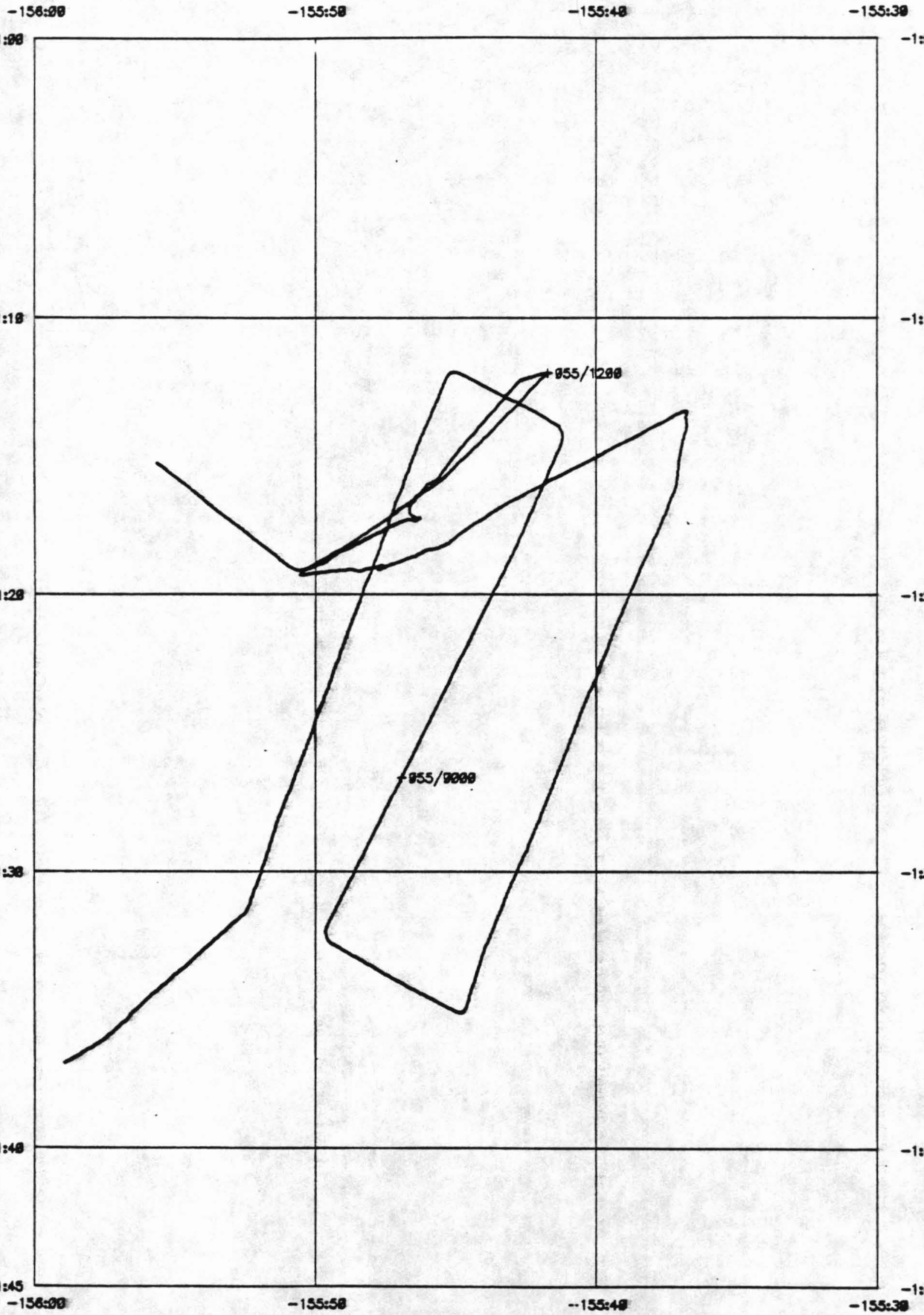

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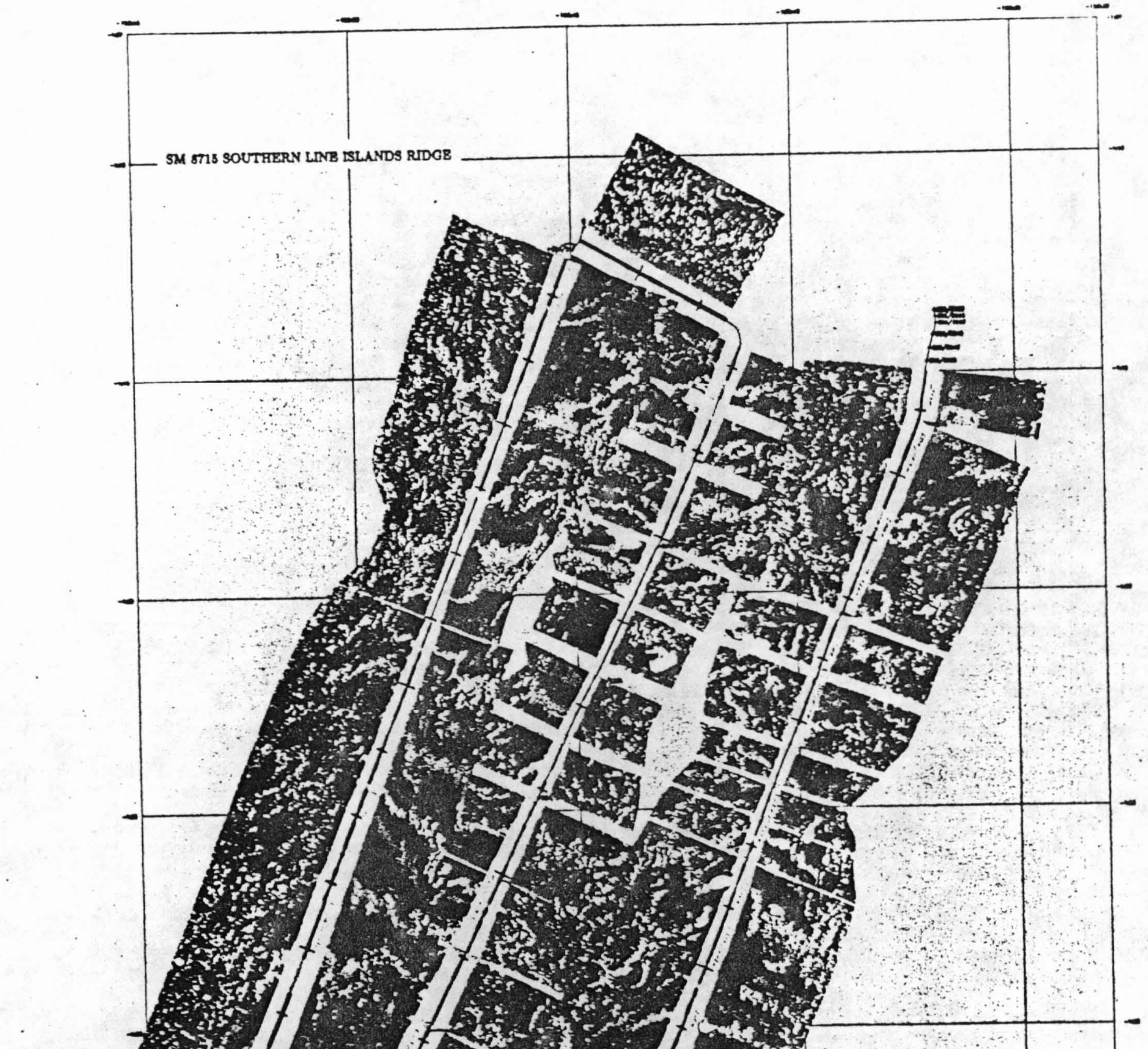
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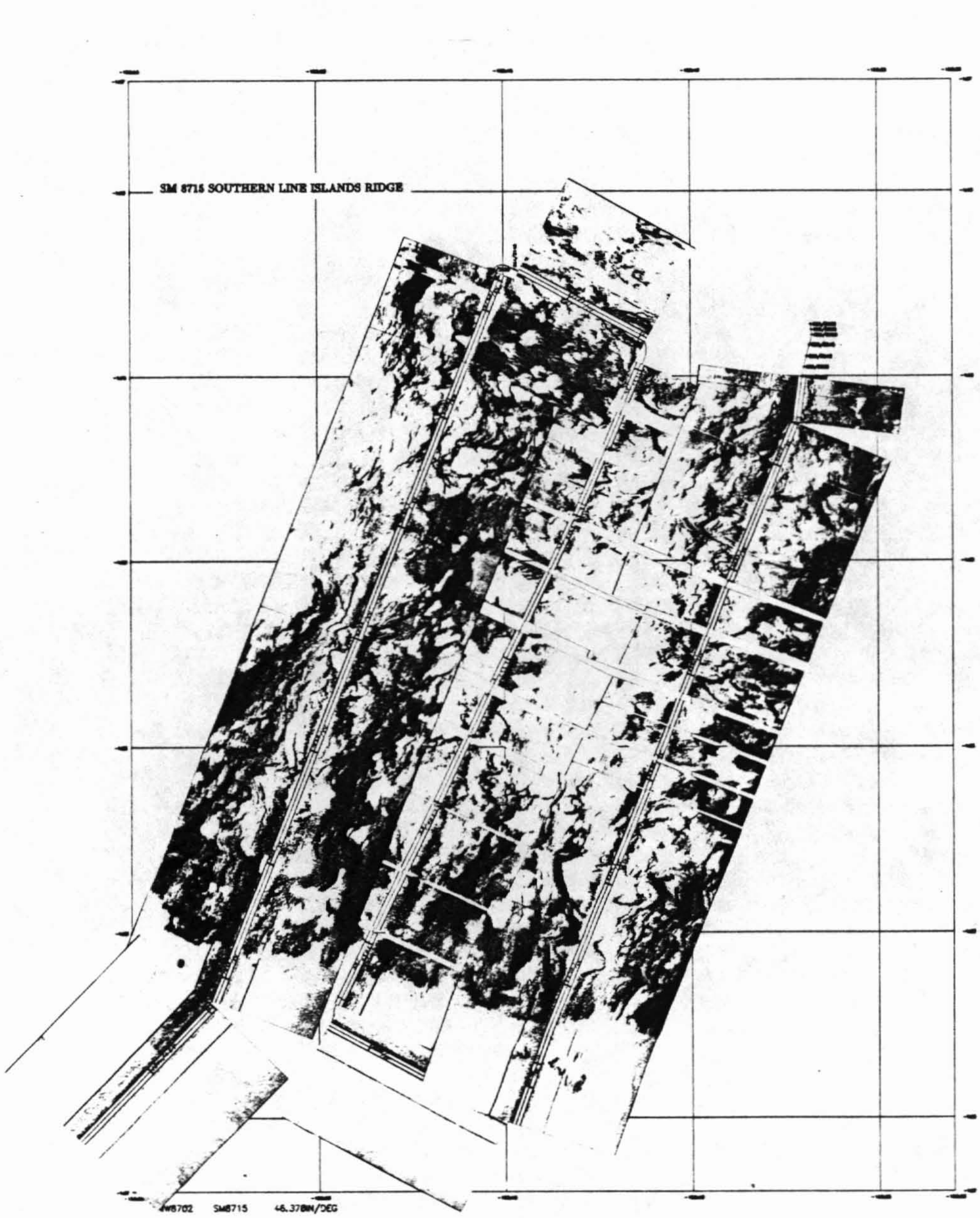
SM8715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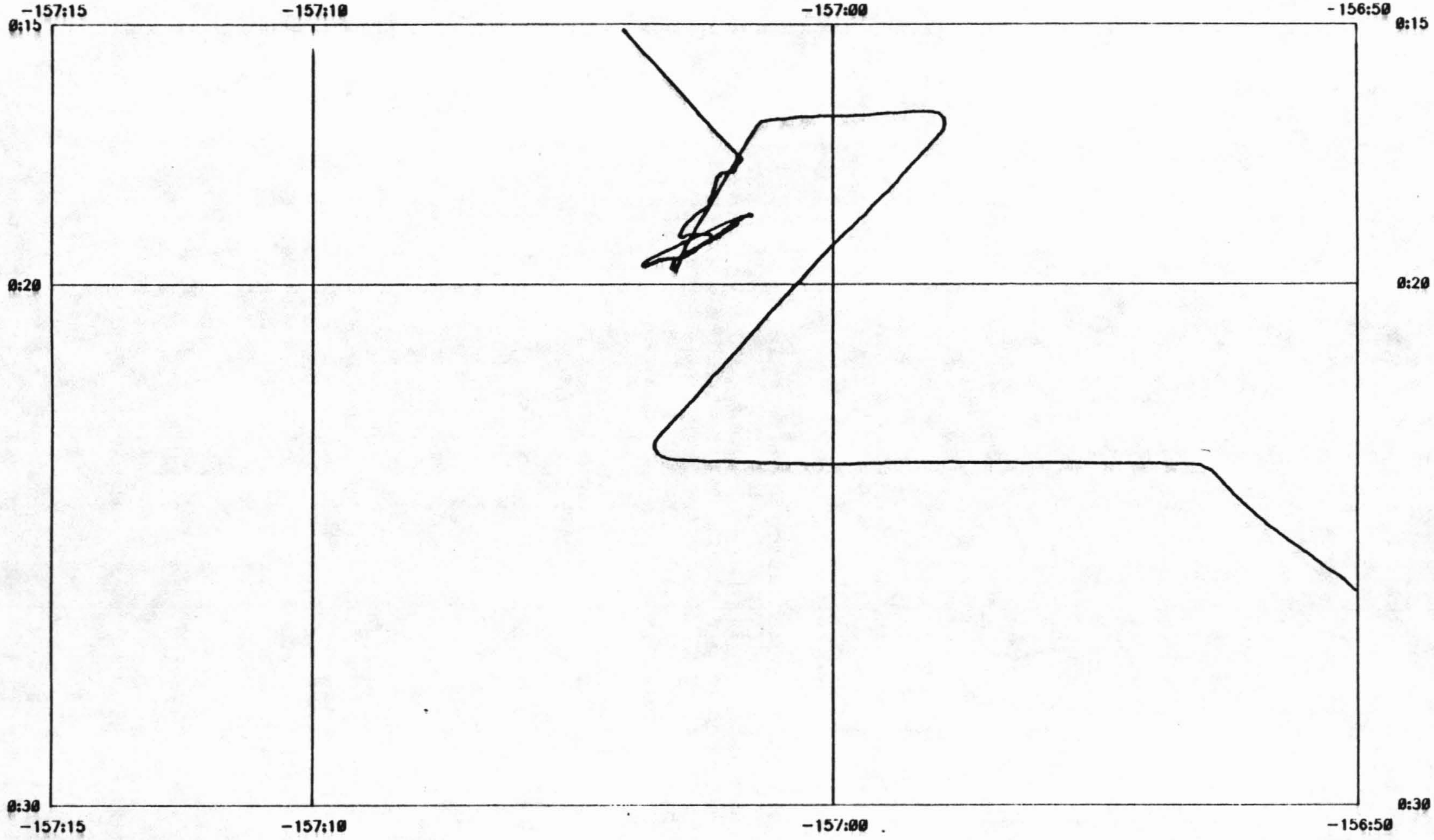
SM8715



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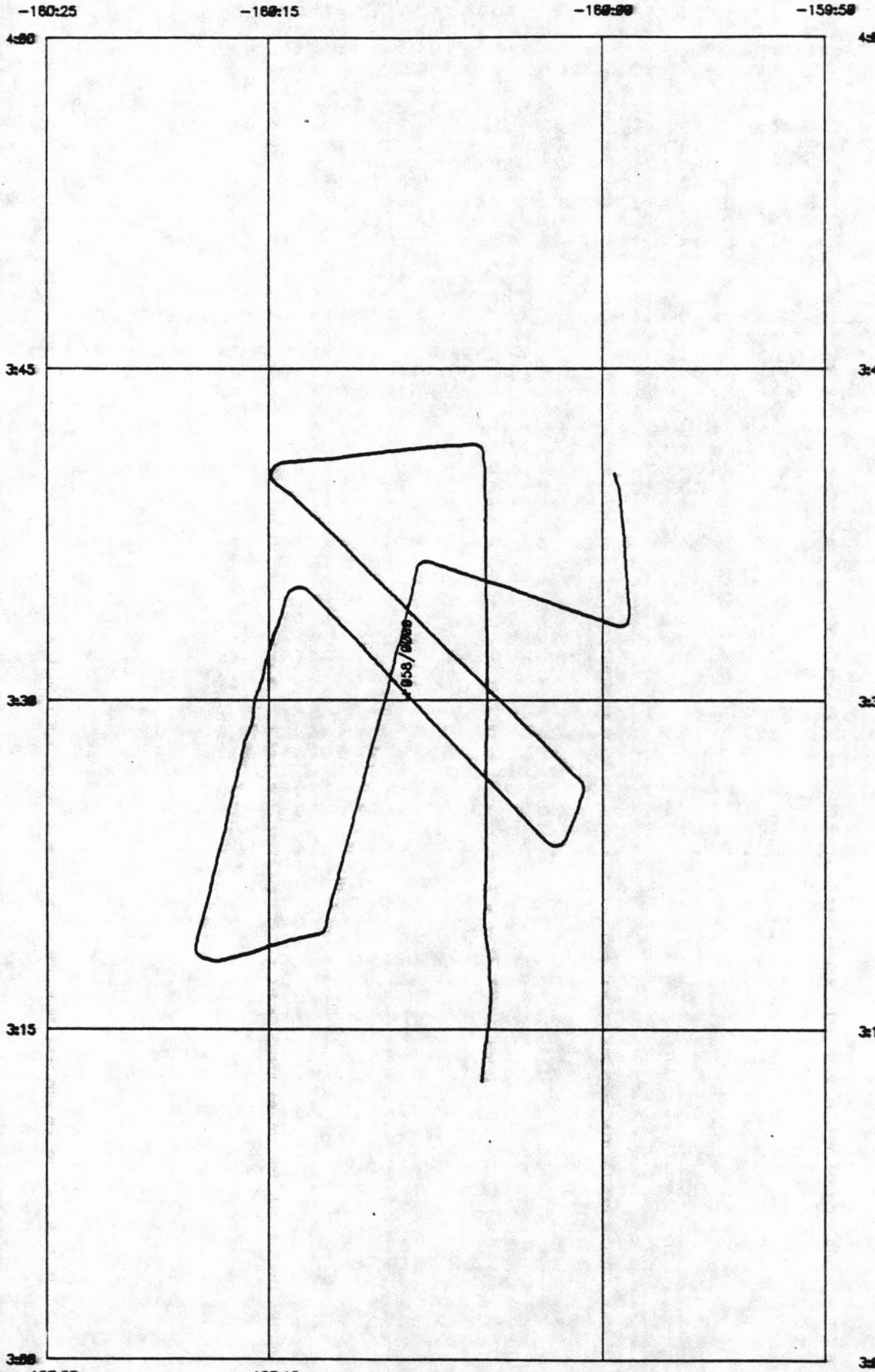
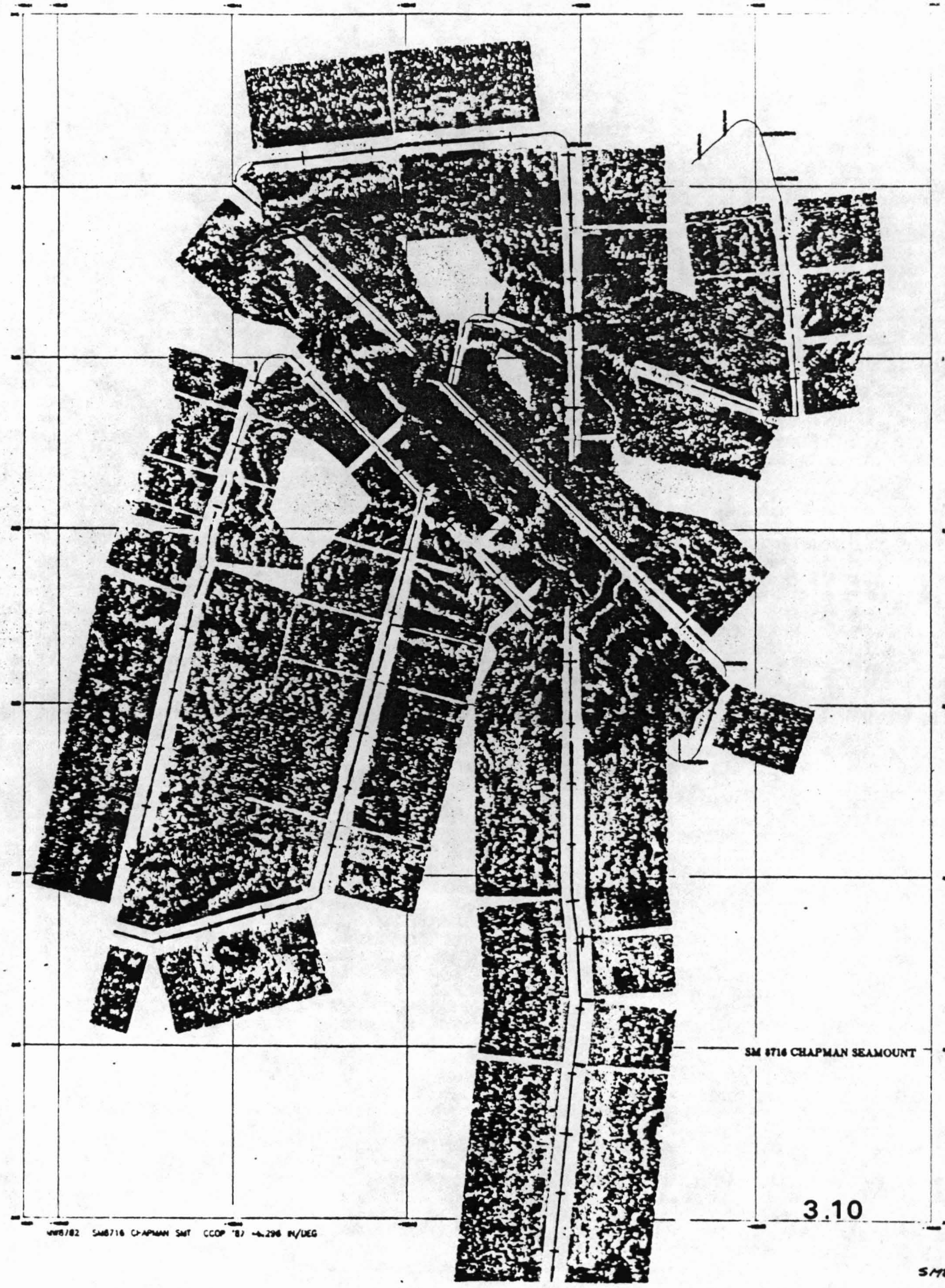


CENTRAL LINE ISLAND GUYOT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3.10

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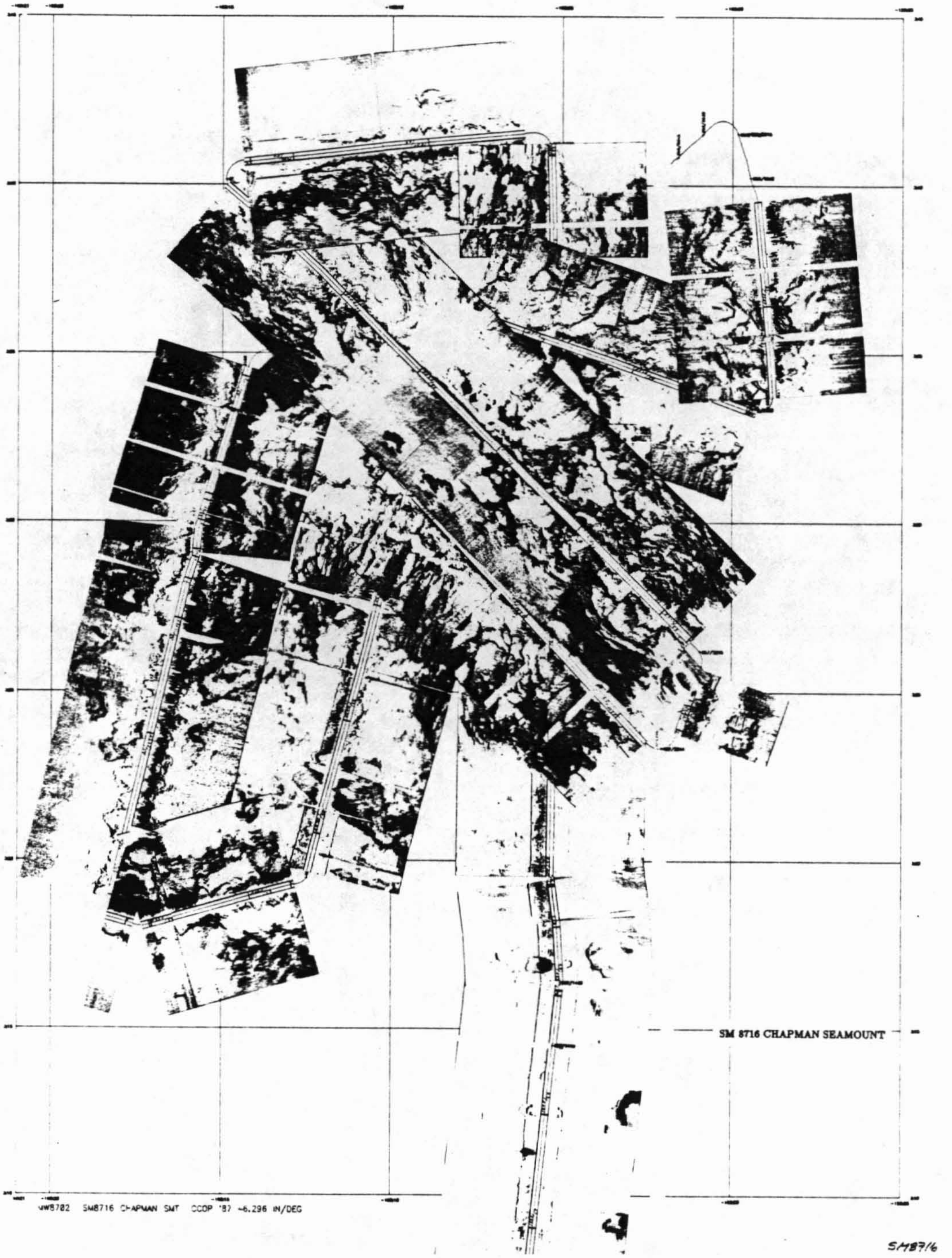
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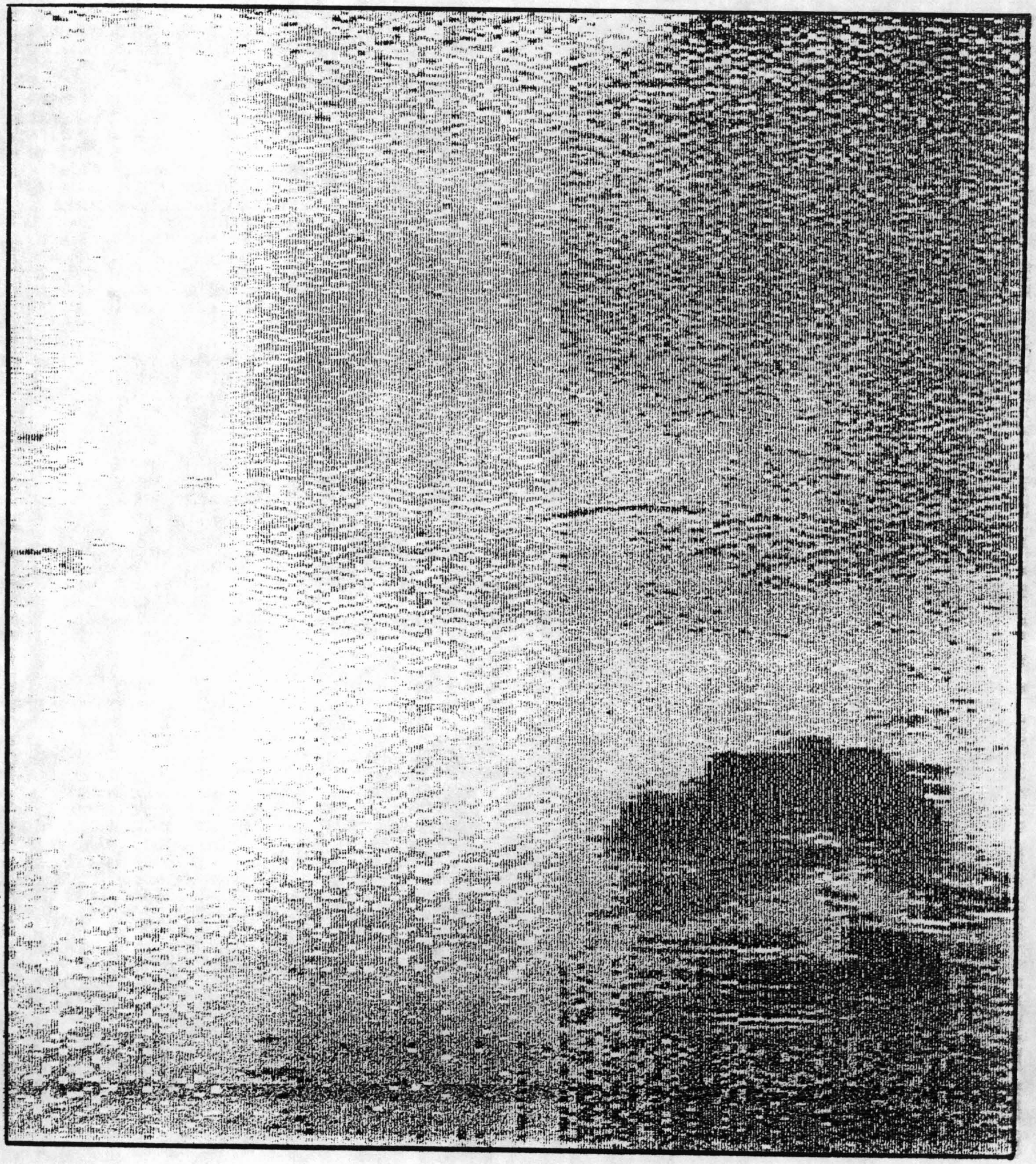

APPENDIX

NAVIGATIONAL AND GEOPHYSICAL EQUIPMENT

Navigation

- Trimble Model 4000A GPS Locator
- Magnavox Satellite Omega Navigator MX 1105
- Magnavox MX 4102 (bridge satnav)
- Sperry Mark 37 Gyro
- Ametek MRQ-4015R Sonar Doppler Speed Log
- RD Instruments Acoustic Doppler Current Profiler (ADCP)

Bathymetry

- 3.5 kHz Edo (Western Corp.) Model 248A Transceiver
- ESRPR-1 Precision Sonar programmer (Grifft & Assoc.)

Magnetics

- Geometrics G801-3 Marine-airborne Proton Magnetometer
- Hewlett-Packard 7130A Recorder

Gravity

- LaCoste-Romberg S-33 Gyro-stabilized Marine Gravity Meter

Seismic

- Two 120 cubic inch Bolt Airguns
- 117 m Multi-element Streamer
- Krohn-Hite Model 3700 Filters
- EPC Recorders (Models 4100, 3208 and 3200)
- Sonobouy Receiver R-962/ARR-52
- Sonobuoys SSQ-57A

XBT

- Sippican MK-9 Digital XBT Recorder-processor system
- T6 Surface-launched Temperature Probes

Data Logger

- Digital Micro PDP-11/23