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REGIONAL GEOLOGICAL/GEOPHYSICAL STUDY OF THE CARIBBEAN SEA (NAV--ETC(U)
AUG 76 J E MATTHEWS, T L HOLCOMBE
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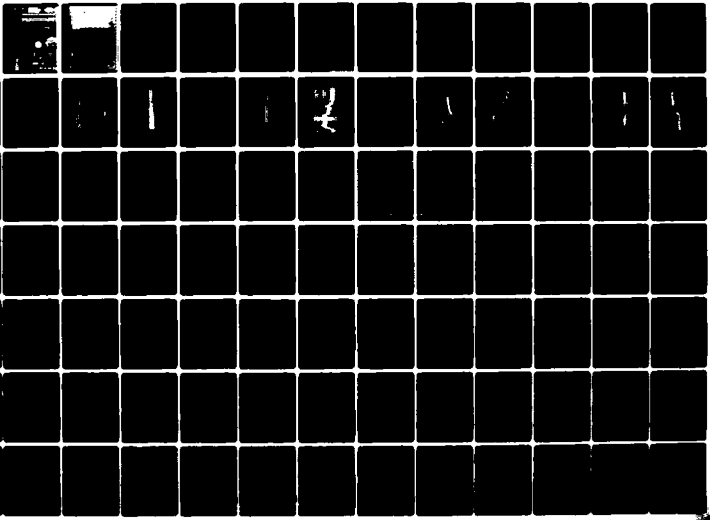

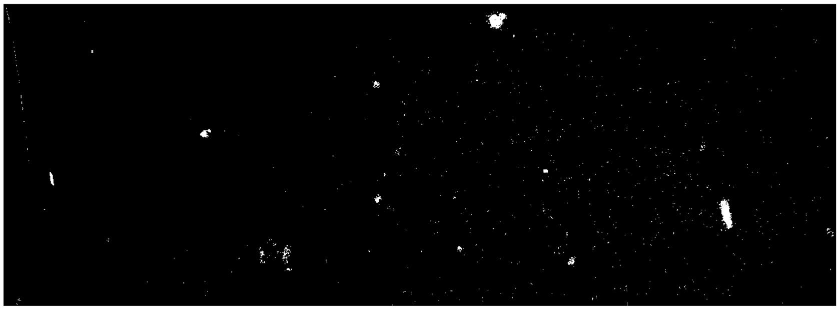

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(6) # REGIONAL GEOLOGICAL/GEOPHYSICAL STUDY OF THE CARIBBEAN SEA (NAVY OCEAN AREA NA-9).

1. Geophysical Maps of the Eastern Caribbean.

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FOREWORD

The combined marine geophysical data holdings of academic institutions, private companies, and government agencies are now sizable. The most rudimentary, qualitative product to be derived from such field data is generally a map. For many deep-sea areas the present data holdings are ample to allow geophysical mapping. The investigation, upon which this report is based, was initiated to compile all available bathymetric, magnetic, and seismic data to provide a foundation for future investigations. This report utilized maps to summarize existing data in a concise form suitable for future survey, systems, and research planning. In addition, the report will assist in the interpretation and the interpolation of numerous bottom-related phenomena, such as low-frequency acoustic propagation and the sedimentary environment for the determination of engineering properties. These interpretations will in turn be incorporated into Environmental Guides for Fleet Operations and Tactics.

J. E. AYRES
Captain, USN
Commander

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The contribution of Messrs. J. P. Flanagan, J. H. Rebman and C. R. Jones of NAVOCEANO, who compiled portions of the bathymetric map (plate 1) is appreciated.

The authors also wish to acknowledge the help of P. J. Fox of the State University of New York at Albany; G. Bloomer of Gulf Research and Development Co.; H. Wories of Union Oil Company of California; A. R. Green of Exxon Production Research Co.; J. E. Case of the U.S. Geological Survey, F. N. Spiess, C. W. Spofford, and D. F. Heinrichs of the Office of Naval Research, and M. G. Lewis of the Naval Electronic Systems Command, who critically read the manuscript and provided valuable criticism.

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INTRODUCTION

A series of maps of the eastern Caribbean Sea has been prepared during the course of a regional geophysical study. The mapped area lies within Standard Navy Ocean Area NA-9 and is outlined in figure 1. The maps are presented at two scales, PS-2 (in back pocket) and PS-1, plates 1 to 7 (at end of text). Included in the series are a bathymetric map (plate 1), a total-intensity magnetic field map (plate 2), and five subsurface seismic maps (plates 3 to 7). The subsurface maps consist of a structural fabric map, a sediment thickness map, and a structure contour map on acoustic basement of the Venezuela Basin and Aves Ridge (plates 3 to 5). Also included are maps of sediment thickness of the upper and lower sedimentary intervals of the western two-thirds of the Venezuela Basin (plates 6 and 7). Separate sheets show track control for the bathymetry, magnetics, and continuous seismic profiling (CSP) data (plates 8 to 10). Representative seismic sections are also presented. Figure 2 shows track locations of the sections (figures 3 to 10). Drill hole sites from the Deep Sea Drilling Project are plotted on all maps.

A number of previous reports have included geophysical maps of parts of the eastern Caribbean. In a synopsis of seismic reflection and refraction data in the Caribbean, Edgar et al. (1971) included a very general map of sediment thickness which included the eastern Caribbean. Silver et al. (1975) presented tectonic and gravity maps of the Venezuela Continental Borderland. Garrison et al. (1972) compiled and published bathymetry, magnetic, and tectonic maps of the northeastern corner of the Caribbean in the region of Puerto Rico and the Virgin Islands. A report by Roemer et al. (1973) included generalized bathymetry, total field and residual magnetics, and structure maps of the Beata Ridge. Kearey (1974), in a report on gravity and seismic reflection investigations of the Aves Ridge, presented bathymetry and gravity maps. Bowin (1972) has compiled gravity maps of the Caribbean. Other reports include data and maps of specific areas. In most cases, the data upon which the previously compiled maps were based have been combined with additional data in the compilation of the maps included in this report. However, in the bathymetry and magnetics maps, one or more blocks of previously compiled data were actually incorporated into the appropriate maps of this study, as noted in succeeding sections of this report.

Since distance on a Mercator projection chart is a function of geographic position, the scale stated as a ratio or shown graphically pertains only to a specific latitude. The U.S. Naval Oceanographic Office has adopted a system of labeling chart scale by the length in inches of one degree of longitude (Mercator projection only). For a given chart this scale is invariant, since the meridians are equi-spaced parallel lines. Thus, the designation PS-2 represents a plotting sheet graticule for a Mercator projection chart with one degree of longitude equal to 2 inches, PS-1 represents one inch per degree, etc.

The maps which constitute the basis for this report represent an attempt to systematically compile bathymetry, magnetics, sediment thickness, and structural fabric in a closely coordinated program of study, as opposed to compiling each set of data independently. They exceed in detail any previous compilations of geophysical data in the eastern Caribbean taken as a whole. Map resolution varies from one area to another, and from one parameter to another, depending on data density. The interpretative advantages of employing one or more of the maps as a guide in the preparation of another are obvious, considering that many of the parameters are related to a common structure, composition or history, and they are thus highly correlative in many cases. Even establishing a lack of correlation between certain parameters may be most informative in working out the geologic character of a region.

All data available up to the time of publication have been employed in the compilation. They include an estimated 90 to 95 percent of all geophysical data from the Venezuela Basin. In addition to NAVOCEANO data, data collected by the U.S. Naval Research Laboratory, U.S. Geological Survey, National Oceanic and Atmospheric Administration, Lamont-Doherty Geological Observatory of Columbia University, Woods Hole Oceanographic Institution, the Deep-Sea Drilling Project, Scripps Institution of Oceanography, Texas A&M University, University of North Carolina, University of Maine, and University of Miami have been made available for inclusion in the compilation.

The compilers hope that the maps will be useful to many areas of endeavor, which might be categorized as follows: (1) Survey Planning - NAVOCEANO or other marine science institutions planning survey efforts in the eastern Caribbean should find these maps useful in laying out tracklines, or picking station locations, which will best compliment previously collected data; (2) Acoustic Modeling and Prediction - variation in sediment thickness and depth along a shot azimuth or range line is an important input to any acoustic model which involves reflection from the bottom or propagation of sound through the bottom. When such data are needed along lines which do not coincide with CSP tracklines, the input must come from the best available bathymetry, isopach, and structure contour maps. These maps also provide the optimum means for extrapolating acoustic behavior between discrete stations, especially over large areas where acoustic measurements are sparse; (3) Weapons Systems Planning - structure, depth, sediment thickness, bottom slope, magnetic signature--any or all of these could be important in the selection, development, and deployment of a particular weapons system. More specifically, these maps allow more accurate extrapolation or interpolation of bottom physical and engineering properties. It is, therefore, implicit that the most detailed and accurate maps available are the most valuable in such planning; (4) Energy Exploration and Environment Protection - these often competing disciplines should find these maps useful directly or indirectly as a base from which to carry out further investigations into the occurrence of fossil fuel or mineral resources on the one hand, and possible environmental contamination on the other; and (5) Earth and Planetary Science Research - these compilations should be most useful as a base for the planning and conducting of further investigation and study in many specific areas of research.

An environmental acoustics report which includes this region has already been published (U.S. Naval Oceanographic Office Special Publication 189), and continuing geophysical studies are in progress. The maps presented here are intended to provide the "foundation" for additional environmental studies. The authors feel it is desirable to release and disseminate data as they become available rather than hold them for a final comprehensive report.

BATHYMETRIC MAP (PLATE 1)

The bathymetric map depicts uncorrected depth in meters utilizing an average sound speed in water of 1500 meters/second. In areas of steep bottom slope, contours have not been deleted in order to present an overall view of bathymetric gradient. The land contours were taken from existing Department of Defense topographic maps based on aerial photo interpretation and foreign maps. Tracks shown in the Atlantic Ocean were also used to update Navy charts BC 603, 604, and 704.

The bathymetric expression of the eastern Caribbean strongly reflects the subsurface structure (compare bathymetry with the structure contour map of the deepest acoustic reflector, plate 4). The sediments generally fill the structural lows and thin over the structural highs, producing a smoother surface at the present water-sediment interface than found in the subsurface horizons. In the southern Venezuela and Grenada Basins, abyssal plains have been formed by the deposition of thick turbidite fill in broad structural lows (see also plate 3). Smaller turbidite plains have formed in localized structural lows on the Beata Ridge and in the Muertos Trough (plate 3). In a few places, sediments are too thin to be detected in the seismic records, and the bathymetric surface appears to coincide with the surface of mapped seismic horizons. These areas are associated with steep slopes and prominences on the Beata and Aves Ridges, and a few isolated features to the south of the Greater Antilles. The relief on hand also strongly reflects crustal structure, although, in the subaerial environment, erosion rather than deposition is the dominant process. Some structures can be seen to extend into the marine areas (for example, the Muertos Trough extends seaward from the Enriquillo-Cul-de-sac Trough of western Hispaniola).

The 200-meter contour interval used for the map is generally adequate to show features of regional significance. One significant bathymetric feature not shown by this contour interval is the characteristic "hummocky" bottom of the Venezuela Basin (figure 4). These hummocks appear on the echo sounder records as coalescing hyperbolae, 5 to 30 meters in height with 1- to 2-kilometer wavelengths, and have the same appearance independent of profile direction. Although no map is presented, the distribution of these features was studied using narrow beam (2.7°) 12-kHz echo sounder records. They are absent in and near the areas of turbidite deposition (plate 3) and most prominent in the central and western portions of the basin, where the sediment section is predominantly pelagic.

There is evidence that bottom currents swept parts of the Caribbean Sea until the Miocene epoch (Edgar et al., 1973; Holcombe et al., 1975). Since the Miocene, Venezuela Basin sedimentation has been in a relatively quiet water environment. This event may correlate with the facies change represented by horizon "a" reported by Matthews and Holcombe (1974). Although not fully investigated, it is postulated that the Venezuela Basin hummocks may represent relics of pre-Miocene bottom current features which

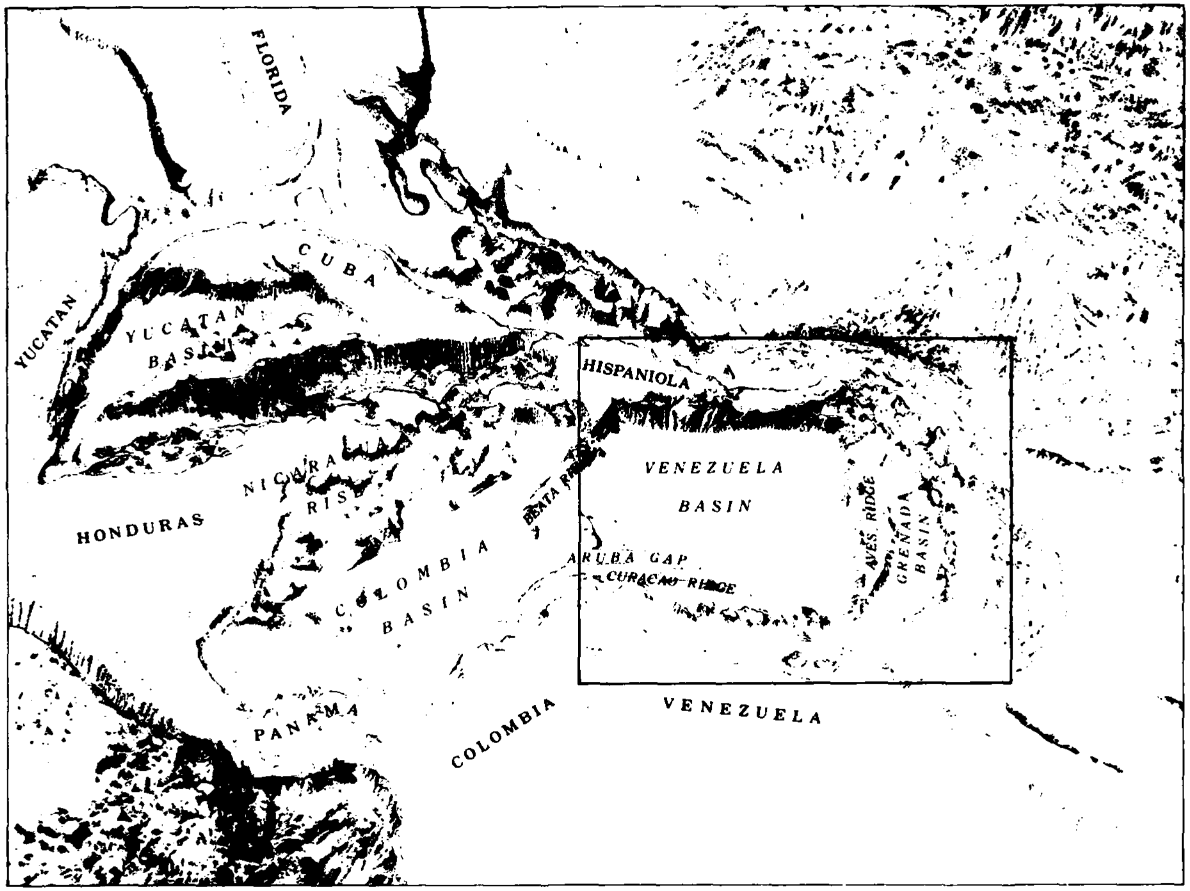

Figure 1. Index map of the Caribbean Region, showing the major physiographic features and the area included in the maps. Physiographic sketch by R.N. Bergantino, U.S. Naval Oceanographic Office (now with Montana Geological Survey).

have subsequently been buried. The original surface roughness could have been perpetuated up through the post-Miocene section, but with diminishing amplitude and increasing wavelength. In areas of thick turbidite deposition the surface expression of these features has been completely obliterated.

There is a high degree of correlation between bathymetry and structure, and in most areas the bathymetry has the largest data base of all the mapped parameters; therefore, the bathymetric map is of considerable value to geologic interpretation and can be used as a basis for the interpolation between data points of other geophysical and geological parameters.

MAGNETIC MAP (PLATE 2)

The total intensity magnetic field map does not have a regional field removed. Various detailed surveys are presented without any adjustment, utilizing a 50-gamma contour interval. The fact that the absolute value difference between adjacent surveys is as high as 1,200 gammas (10-year interval between surveys), has little bearing on the interpretation of crustal magnetization. The spatial change in secular variation over the mapped area is an order of magnitude less than the secular variation itself, and magnetic gradients and anomaly trends are in good agreement at survey boundaries. Breaks in the contours are based on the boundaries of detailed surveys, with preference of overlapping surveys given to data density and quality of navigation. In areas of detailed surveys, some random tracks from other cruises were adjusted and incorporated when good agreement was found at track intersections. Portions of the map were taken directly from or modified from published maps (Andrew et al., 1970; Ball et al., 1971; Bunce et al., 1974; Lagaay, 1969; Renard, 1967; and Peter, 1972).

Other portions of the mapped area for which there were no detailed data available (principally the west-central portion of the map) were constructed from a composite of random track data adjusted to a 1973.1 epoch. This adjustment was accomplished by applying a computed correction to each track based on track intersections with a single U.S. Naval Oceanographic Office cruise. The bulk of the data is from ship tracks, although one airborne survey over Puerto Rico is included (indicated by a dotted track, plate 9). Land station data reported by Lagaay (1969) were used for the Netherlands Leeward Antilles, and the dashed contours over the Lesser Antilles were interpolated on the basis of the surrounding marine data and land stations reported by Andrew et al. (1970).

Magnetic interpretation in the Caribbean region is an open debate. This debate is generally predicated upon an individual's interpretation of the origin and character of horizon B" and the material below it (horizon B" is the deepest acoustic reflector recorded by single-channel seismic reflection in the Venezuela Basin. See section on "subsurface maps" for further information regarding the nature and extent of horizon B").

It has been proposed by Christofferson (1973) that B" represents oceanic basement, hence magnetic basement. Saunders et al. (1973), Fox and Heezen (1975), and Matthews (1974) feel that horizon B" is a basaltic sill or flood basalt overlying or interbedded with sediments or metasediments, and thus does not represent true magnetic basement. The entire Caribbean-Gulf of Mexico region is a negative magnetic anomaly as determined by satellite data (Regan et al., 1973), a point which has not yet been explained.

In general the magnetic anomalies do correlate with known geologic structures, the highest anomalies being associated with the Antilles Island Chain, Island Ridge (the ridge extending from Aruba to La Orchilla), and Aves Ridge. The two linear trends in the Venezuela Basin (trending N55°E and N14°E) both correlate with sub-B" structure, and the magnetically smooth area in the southern Grenada Basin probably results from isostatically or tectonically depressed magnetic basement in that region. The anomalies in the northern Grenada Basin, Aves and Island Ridges, and Antilles Islands are associated with volcanics and intrusives.

The magnetic map is best used in conjunction with the seismic maps to develop an overall description of the eastern Caribbean crustal framework. Although the character of sub-B" material will remain a question until such time that it is sampled by drilling, the magnetic map is useful in determining whether various features appearing in the seismic records are magnetic (igneous) or nonmagnetic (sedimentary). These determinations have proven useful in the seismic interpretation and are invaluable when attempting to determine the nature of the materials forming the various mapped structures.

SUBSURFACE MAPS (PLATES 3-7)

The subsurface maps are maps of structural fabric, sediment thickness (isopach), and subsurface topography (structure contour) as revealed by the principal subsurface seismic reflecting horizons resolved by single-channel seismic data. These horizons are illustrated in figures 3 to 10.

Two prominent reflecting horizons exist in the western two-thirds of the Venezuela Basin (figures 3 and 4). These horizons extend westward over the eastern flanks of the Beata Ridge (figure 5). The character and extent of these horizons have been discussed (Ewing et al., 1967; Edgar et al., 1971; Holcombe 1974). They have been designated as horizons A" and B", to distinguish them from similar horizons of the Atlantic and Pacific, which have been named horizons A and B and horizons A' and B', respectively. Each "horizon" may be a single, well-defined reflecting interface, or it may consist of a zone of successive interfaces

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Lowrie and Opdyke (1973) have reported the magnetic properties of drilled samples of B" which yield arithmetic mean values of 4.8 x 10   emu/cc for NRL, 2.51 x 10   emu/cc for k and 1.61 for Q.

Figure 2. Index map of the eastern Caribbean, showing the location of the seismic sections in figures 3 to 10.

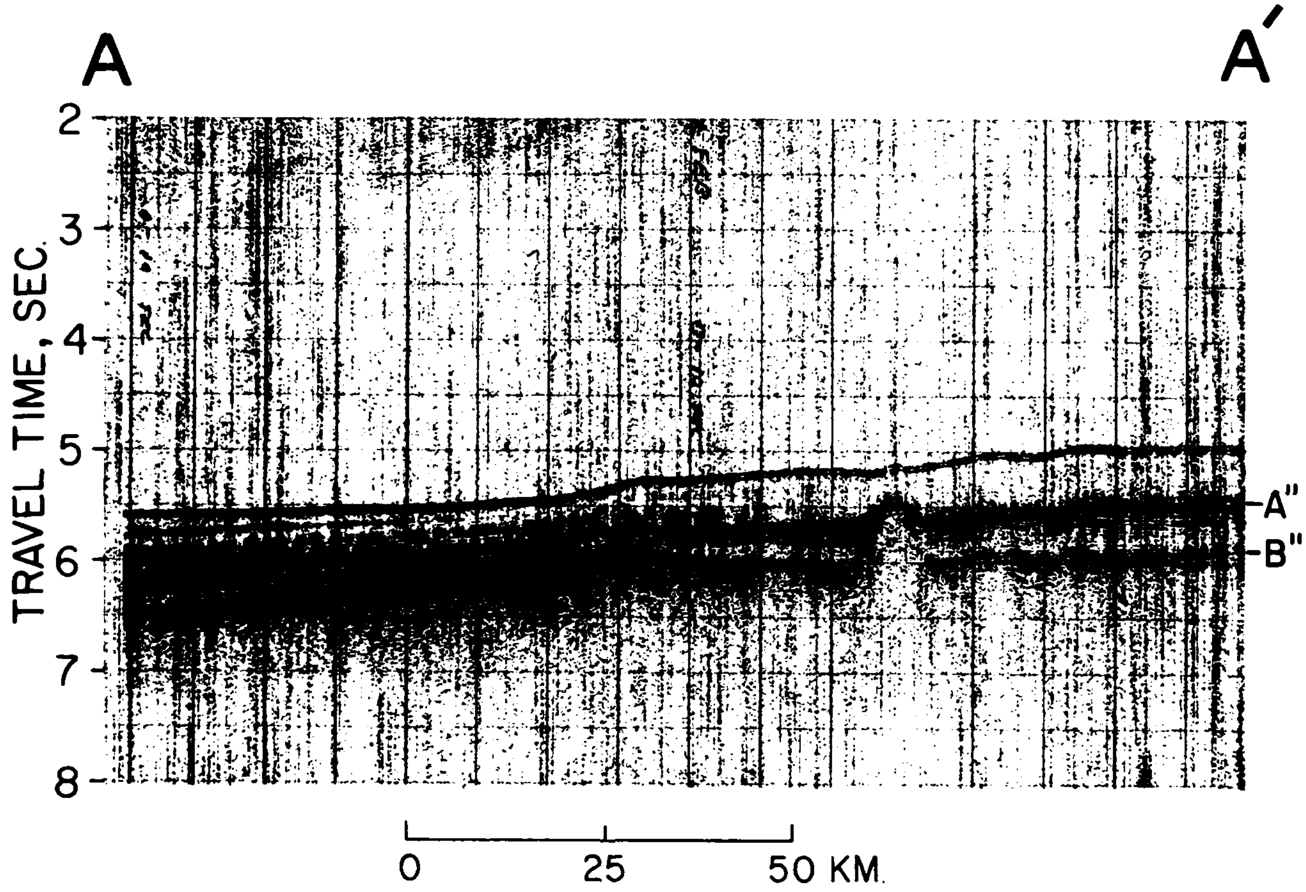

Figure 3 Seismic section A-A' across the central Venezuela Basin. Horizons A'' and B'' are clearly shown. Note the broad structural high at about the center of the section. The sediment section thins across the crest of this structure and to the left of it and thickens to its right. The change in sediment thickness is particularly apparent in the lower sedimentary interval. This is the belt of thin sediments which has resulted from the long-continued action of bottom currents. Sediment thickness patterns are largely conformable to the structure in this area, illustrating the antiquity of the structure. Note the cone-shaped buried feature and its minimal surface expression. Location is shown in figure 2.

of varying acoustic impedance. Deep-sea drilling has determined that horizon A" apparently marks the boundary between unconsolidated lower Eocene oozes and chalks above and well-lithified siliceous limestones interbedded with chert layers below (Edgar et al., 1973a). The relative importance of the occurrence of chert versus the coincidence of the interface between unconsolidated and consolidated sedimentary rocks in accounting for the reflecting interface has been debated, but it is thought that the ooze/rock boundary is the predominant factor in causing the reflection (Saunders et al., 1973). Horizon B" consists of basaltic sills, or lava flows, overlain by sedimentary rocks of late Cretaceous age.

Horizons A" and B" extend to the northern and southern margins of the Venezuela Basin, deepening toward the continental margin beneath the Muertos Trough (figure 6) and the Aruba Gap (figure 7). Both horizons also extend beneath the turbidites of the Venezuela Abyssal Plain (figure 8). In the eastern Venezuela Basin, east of a prominent northeast-southwest-trending basement ridge complex occurring at about longitude 66°W, the identity of horizons A" and B" is obscured in a thicker wedge of sediments containing several (4 to 6) prominent reflectors. These reflectors are probably volcanic ash layers, the ash most likely being derived from volcanic sources in the Lesser Antilles Island Arc (Saunders et al., 1973). Beneath the Aves Ridge, the horizon which has been designated as "the reflector whose identity is uncertain," is the deepest mapable reflector. It may correlate in a time-stratigraphic sense with horizon A", or it may occur above horizon A" in the section (figure 9). A prominent younger reflector, which may be time transgressive, extends beneath the plateau of the Aves Ridge and beneath most of the eastern Venezuelan Basin and the Grenada Basin (figures 9 and 10).

STRUCTURAL FABRIC MAP (PLATE 3)

This is a map of the structural trends of the eastern Caribbean. It was constructed as follows: The structure observed on each seismic reflection line is plotted along its respective navigation track. Then, the trends of the structures are studied, using observed map trends and a comparison of the character of the structure between adjacent CSP records. Most of the observed structures are apparently linear in nature and fit one of the two major regional trend directions in the Venezuela Basin. The trends are readily determined in areas where track spacing is dense, but trends must be inferred in areas of sparse coverage. This map of the tectonic fabric forms the basis for interpretation of all the contour maps of subsurface intervals and structure as well as the bathymetry. Conversely, the bathymetric trends have been employed in the structural trend interpretation in areas where bathymetric control is good but seismic control is not.

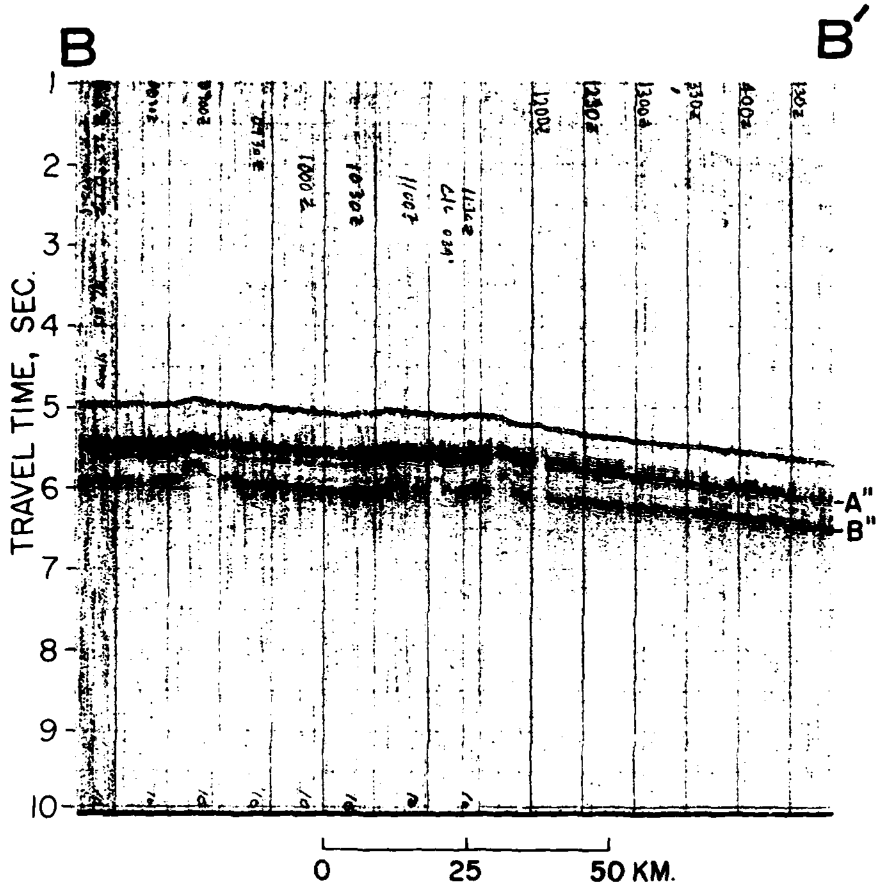

Figure 4. Seismic section B-B' across the Venezuela Basin. This section is *a northward continuation* of section A-A' and is a typical section illustrating *the uniformity of sediment thickness and the well-defined* nature of the seismic reflectors in the western two-thirds of the Venezuela Basin. Also *note the fine textured* hummocky nature of the surface relief. The hummocky terrain is typical of a large part of the Venezuela Basin. Location is shown in figure 2.

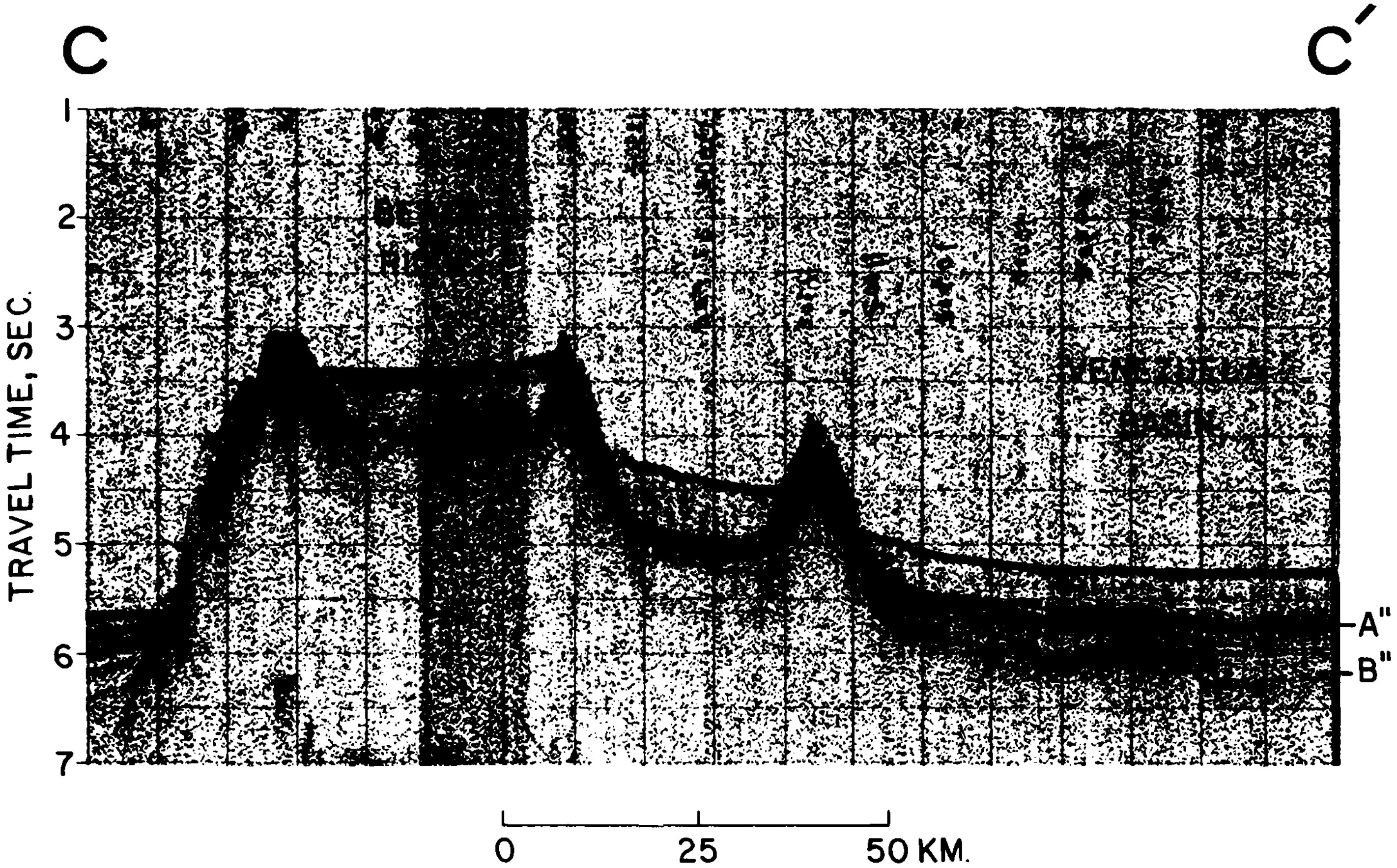

Figure 5. Seismic section C-C′ across the northern Beata Ridge. The principal west-facing fault scarp is on the extreme left. Several ridges coincide with faults or fault zones which form a series of "steps" along the eastern margin of the ridge. Note the difference in thickness between the sediments in the basin between the two ridges on the right, and the sediments in the Venezuela Basin. Neither basin section shows appreciable structural disturbance. This may be taken as one line of evidence favoring the structural antiquity of the northern Beata Ridge. Location is shown in figure 2.

Two sets of structural trends are present in the western two-thirds of the Venezuela Basin, northeast and northwest. Together they produce a roughly orthogonal fabric for the basin as a whole (Holcombe and Matthews, 1973). There is no evidence to suggest that most of this structure is significantly younger than the oldest sediments overlying horizon B". Most of the sediment thickness patterns exhibit structural control (compare plate 3 with plates 6 and 7). Structurally, these trends consist of very broad, low swells and swales; faults occur locally. A northeast-trending fault trough is present in the south-central part of the basin. Locally, volcanism has probably occurred along some of these trends, as evidenced by the occurrence of lines of conic-shaped (?) protrusions above the general level of horizon B". These features are concentrated in the north-central part of the basin.

In the southwestern corner of the Venezuela Basin, northwest-trending younger displacements of higher structural relief occur. In contrast to the rest of the Venezuela Basin, sedimentary thickness trends in the southwest sector are not in agreement with structural trends. Young structures, principally normal faults, occur along the Muertos Trough and the Aruba Gap, at the north and south margins of the Venezuela Basin (figures 6 and 7). These features parallel the respective island and continental margins, along flexures where the crust has been depressed adjacent to the margins of the basin. They seem to be preferentially located across the major structural highs of the basin where they intersect the foot of the continental margins. Most of the faults are downthrown toward the margin of the basin. In a few places what may be thrust faults occur. Most of the structures of the Venezuela Basin are truncated by the continental margin of South America and the island margin of the Greater Antilles, suggesting encroachment upon the basin by the adjoining lithospheric plates.

The northern Beata Ridge is characterized by a steep westward-facing fault scarp of large displacement and several smaller-displacement faults which form a series of steps on its eastward flank (figure 5). Some volcanism and tilting probably accompanied the faulting. The close correspondence between sediment thickness and structure (figure 5), and the occurrence of unconformities on the ridge detected by drilling (Edgar et al., 1973a), suggest that most of the structural activity resulting in the formation of the Beata Ridge probably occurred in pre-Cenozoic time. Younger structures occur along the ridge, however, particularly in its southern part. Some of the younger structures appear to be associated with volcanism and intrusion.

Volcanism and intrusion may have occurred along the belt of northeast-southwest-trending ridges, at about longitude 66°W, which have strong magnetic expression (compare plates 2 and 3). Between these buried ridges and the Aves Ridge, most of the structure appears to be older than the observed sediment sequence. At the western approaches to the Aves Ridge shallow structures occur which are probably related to the gravity slumping of unconsolidated sediments.

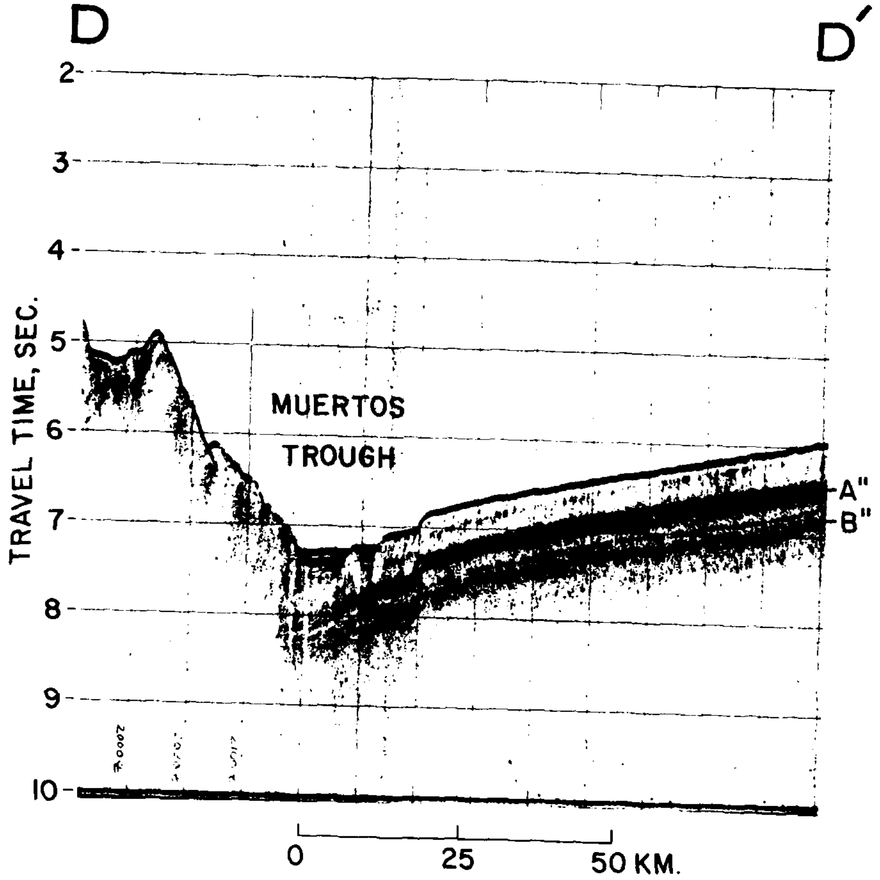

Figure 6. Seismic section D-D′ across Muertos Trough. Venezuela Basin, on right, deepens toward the trough which forms its northern margin. Structurally disturbed landward margin of trough is on left. Horizons A" and B" are clearly defined *beneath the trough* as far as the toe of the landward slope. Several normal faults are downthrown toward the trough proper. These faults, which parallel the landward slope, displace the entire sediment section, hence they are geologically young. Location is shown in figure 2.

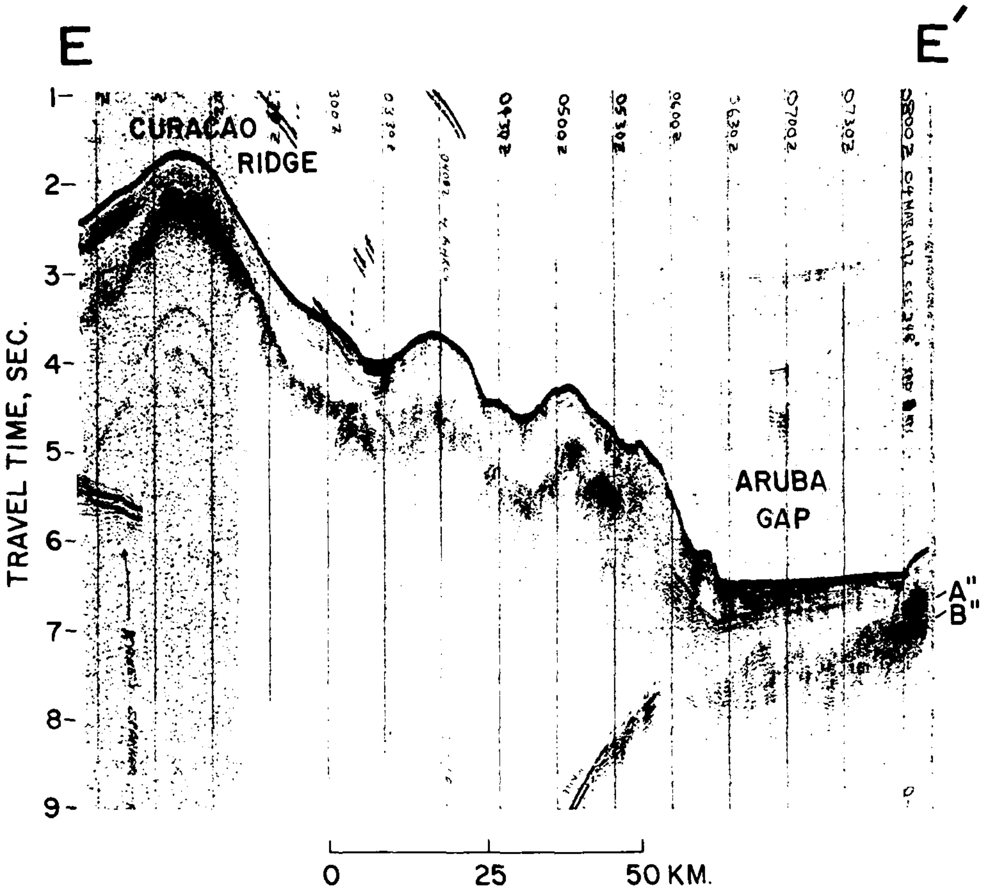

Figure 7. Seismic section E-E' across the Aruba Gap. The Curacao Ridge, a structurally deformed belt which constitutes the outer part of the Venezuela Continental Borderland, occupies the center and left of the section. Horizons A" and B", not as clearly defined as they are beneath the Muertos Trough, are nevertheless present beneath the Aruba Gap. Note the structurally young normal fault forming the northern boundary of the Gap, and the tilting of older turbidites in the Gap proper. The small fold at the Curacao Ridge-Aruba Gap boundary appears to have incorporated turbidites in the structure. Location is shown in figure 2.

The structure of the Aves Ridge consists of a series of north-south-trending ridges and pedestals, probably volcanic in origin, sitting atop a broad plateau (figure 9; Fox et al., 1971; Nagle, 1972; and Marlowe, 1968). The structures forming the core of the ridge apparently are older than the prominent seismic reflector which is observed beneath most of the Aves Ridge and Grenada Basin, although many obviously younger structures, some of which disturb even the youngest sediments, are observed, particularly along the northern half of the ridge. Here younger volcanic activity also is in evidence. As on the Beata Ridge drilling has confirmed the existence of a pre-Miocene unconformity (Edgar et al., 1973a). The north-trending structures of the Aves Ridge are apparently imprinted on an older set of broad, swell-like structures which agree in trend with, and are hence correlated with, those of the Venezuela Basin (note the northwest-trending structural depression which extends through the Aves Ridge from the northeastern Venezuela Basin into the Grenada Basin).

As on the Aves Ridge, younger structures occur principally in the northern half of the Grenada Basin. The structures are principally north- and northwest-trending faults and linear highs and lows of modest (generally 1 sec) displacement. The southern half of the basin is structurally depressed, and it is the site of extensive turbidite deposition.

Areas of turbidite ponding are shown on this map. In addition to the quite large Venezuela and Grenada Abyssal Plains, smaller plains occupy structurally low areas.

STRUCTURE CONTOUR MAP (PLATE 4)

This map is a structure contour map of the deepest acoustic reflector observed on single-channel seismic reflection records. In the Venezuela Basin, the datum is the top of horizon B". Over the Aves Ridge, it is the top of the reflector of uncertain identity. As previously noted, the identification of horizon B" is not certain in the eastern portion of the Venezuela Basin. A dashed line approximately coinciding with the western margin of the Aves Ridge divides horizon B" contours to the west from contours of the uncertain horizon to the east.

The broad, low structural relief of the Venezuela Basin is well illustrated by this map, as is the greater structural relief which occurs at longitude 66°W and in the southwest corner of the basin. Much of the low swell-and-swale relief in the central part of the basin is less than 0.2 seconds in magnitude and hence it is only partially resolved by the contour interval. As previously noted, deep structural troughs occur adjacent to the north and south margins of the basin and adjacent to the Aves Ridge. However, no such trough occurs adjacent to the Beata Ridge. The present Venezuela Abyssal Plain occupies a structurally negative area (compare plates 3 and 4).

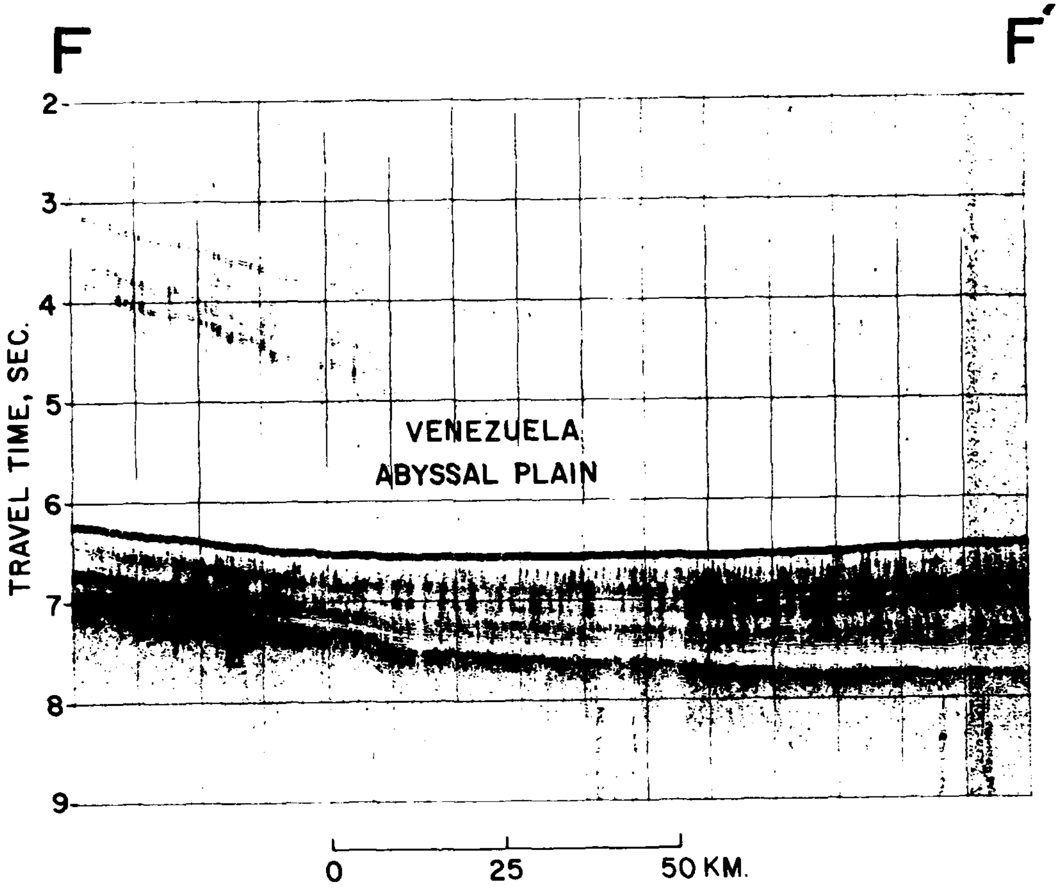

Figure 8. Seismic section F-F' across the Venezuela Abyssal Plain. This is an east-west section across the northern arm of the abyssal plain which illustrates the extension of Horizons A" and B" beneath the plain and the gradual thickening of the sediment section toward the east. The thickening continues to the eastward toward the Aves Ridge. Additional acoustic reflectors appear in the section. These may mark the occurrence of volcanic ashes having a source in the Lesser Antilles. Location is shown in figure 2.

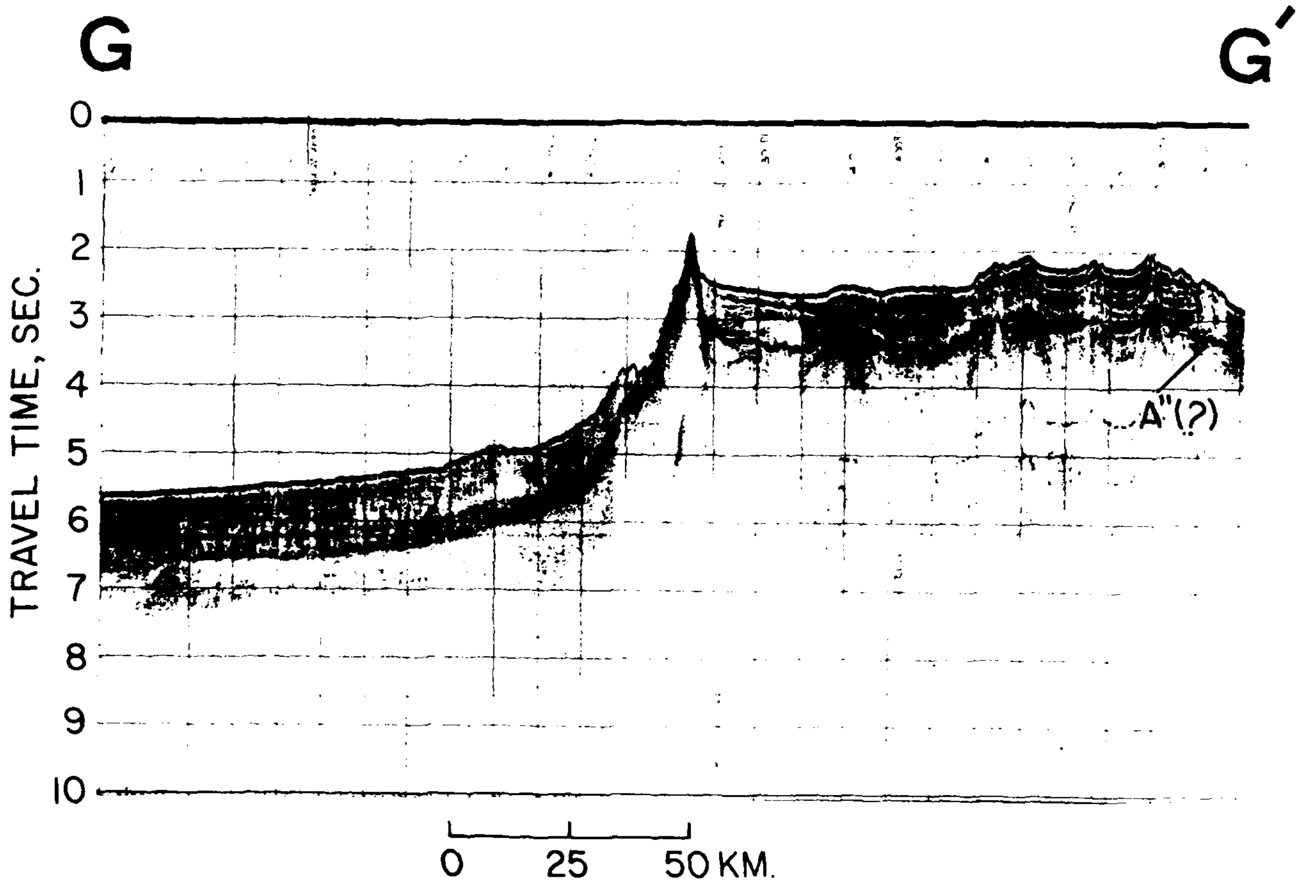

Figure 9. Seismic section G-G′ across the Aves Ridge. West of the ridge, on the left, a thick sediment wedge obscures the identity of the seismic reflecting horizons. Across the ridge and to the east in the Grenada Basin, the strong reflector is probably younger than the horizon A″, in the Venezuela Basin. The major crest of the ridge has been swept free of young sediments. Location is shown in figure 2.

SEDIMENT THICKNESS ABOVE DEEPEST ACOUSTIC REFLECTOR (PLATE 5)

This map is of sediment thickness down to the same reflectors employed in construction of the structure contour map.

The sediment thickness is a relatively uniform 0.5 to 1.0 sec of two-way travel time (500 to 1,000 m at 2 km/sec) over most of the central Venezuela Basin (figures 3 and 4). However, an axis of thin sediments (500 m) occurs in the south-central portion of the basin, where the section thins to a minimum of less than 0.2-sec two-way travel time (plate 5). This belt is not associated with major structural or topographic relief but it does coincide with a very low, broad structural high. Drilling has determined that major unconformities occur within this belt of anomalously thin sediments (Edgar et al., 1973a). The thinning may thus be explained as having resulted from nondeposition due to ocean currents moving through the Venezuela Basin for long periods of geologic time, from the late Cretaceous until the Miocene or later (Holcombe et al., 1975; Edgar et al., 1973b).

Current action through the eastern Caribbean, past and present, has succeeded in sweeping the higher crests of the Beata Ridge and the Aves Ridge relatively free of sediments (plate 5; figure 9). The thickened wedge of sediments, 1 to 2 sec in thickness, which occurs immediately west of the Aves Ridge, in part might be explained by sediments being swept off the Aves Ridge (or through the Lesser Antilles and over the Aves Ridge) by westward flowing currents. Post-Miocene rates of sedimentation over the Aves Ridge exclusive of the higher crests are 2 to 5 cm/1,000 yr, several times greater than typical pelagic carbonate rates (Bader et al., 1970; Saunders et al., 1973).

SEDIMENT THICKNESS ABOVE HORIZON A" AND HORIZON A" TO HORIZON B" (PLATES 6 AND 7)

The thin-sediment belt in the south-central Venezuela Basin is clearly portrayed on the A"-to-B" thickness map (plate 6). Above horizon A" the thinning is not so pronounced in the thin-sediments belt (plate 7), but the location of the axis is the same, implying a uniform current pattern during the time interval of deposition of both the upper and lower sediment intervals. A ridge of thickening, or sediment "drift" feature, occurs north of the axis of thinning in the post-A" sediments. Farther north, localized centers of thinning coincide with the occurrence of volcanic cones and structural ridges.

For these maps velocity corrections in the sediment column have been applied, yielding thickness in meters. This has been done using interval sound velocity data from drill hole 146/149 in the center of the Venezuela Basin (Edgar et al., 1973a). The velocities used were 1.62 km/sec in the upper strata (above horizon A"; principally unconsolidated

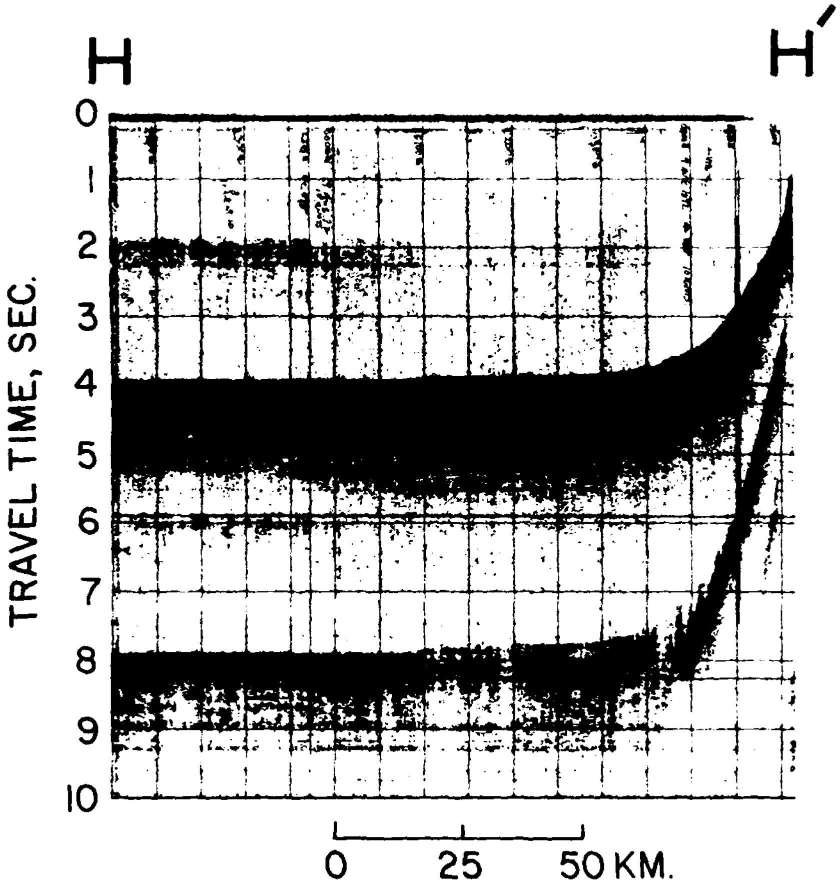

Figure 10 Seismic section H-H' across the Grenada Abyssal Plain. The Grenada Abyssal Plain contains a sequence of highly reflective horizons. The deeper reflectors are masked by highly reflective, presumably volcanic, materials at the approaches to the Volcanic Islands of the Lesser Antilles shown on the extreme right. The deepest recorded reflector is thought to correlate with the strong reflector which persists elsewhere in the Aves Ridge Grenada Basin region. Location is shown in figure 2.

oozes) and 2.47 km/sec in the lower strata (between horizons A" and B"; principally lithified rocks). These were determined from drilled depths to horizons compared with their reflection times, and they were confirmed by sediment velocimeter measurements made aboard ship (Fox and Schreiber, 1973), as well as sonobuoy refraction measurements in adjacent areas (Ludwig et al., 1975). Due to the uniformity of the pelagic section in the western two-thirds of the basin, such conversion yields thicknesses which are reasonable except in the areas having a substantial turbidite section. However, it is thought that normally the best practice would be to map in units of two-way travel time. Velocity corrections at discrete points can be easily applied to travel-time maps, and results in travel time units will be more easily reproducible in future data collection efforts.

DATA CONTROL (PLATES 8-10)

The reliability of the maps varies throughout the mapped region and from one parameter to another. In general, the reliability of the maps is proportional to the data density. Plates 8-10 illustrate track control: Bathymetry (plate 8), magnetics (plate 9), and seismic reflection data (plate 10). The errors in navigation or the measurement errors along a track are at least an order of magnitude less than the possible errors in the interpolation of parameters between widely separated tracks. Because of this factor, the only means of improving the reliability of a given map (without additional data) is to map several parameters simultaneously. Since the characteristics of each parameter are the result of a common geologic history, each map area must fit into an integrated interpretation.

Survey navigation ranged from dead reckoning/celestial navigation, with a probable accuracy of ± 5-10 kilometers for older data, to satellite navigation with a probable accuracy better than ± 0.5 kilometer for recent surveys. More recent navigation has been used as a standard to adjust the navigation of older surveys, where necessary. Bathymetric data along a track can easily be timed and read to within 0.002 second (1.5 meters). In converting travel time to depth, a sound speed in water of 1,500 meters/second was assumed. This translates to an error of 42.8 meters in 4,600 meters of water (average depth for the Venezuela Basin) when actual velocities in water are used. The timing accuracy of the seismic systems is quite high, but reading accuracy is primarily a function of the sweep speed of the recorder. Utilizing a 10-second sweep (generally the maximum value for deep-water seismic surveys) on 19-inch records, sharp returns can be picked to within 0.01 second. The total magnetic intensities along a track can be measured and read to within ±2 gammas. These navigational and measurement accuracies are of value only in the case of specific, detailed analysis and have little effect on regional mapping, the accuracy of which is controlled by data density. Revisions of the maps based on additional data can be effected quite easily, with the exception of the velocity-corrected isopach maps (plates 6 and 7). It is suggested that revision of the maps would be desirable as soon as sufficient new data become available, probably within 5 to 7 years.

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REPORT DOCUMENTATION PAGE

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Regional Study
Bathymetry
Magnetics
Seismic Reflection
Sediment Thickness
Tectonics

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A series of seven geophysical maps and three track control maps has been compiled for the eastern Caribbean Sea. These maps are based upon bathymetric, magnetic, and seismic data from all available sources, and are estimated to contain between 90 and 95 percent of all data in existence for the Venezuela Basin. A comparison of the seismic maps with the bathymetric map indicates that eastern Caribbean bathymetry is primarily controlled by structure. Sedimentary processes have tended to subdue the structural expression by

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partially filling depressions. The geomagnetic map shows generally low relief resulting from the low magnetic latitude of the mapped area. High amplitude, short-wavelength anomalies are associated with igneous activity along the island chains and the Aves Ridge. Interpretations are limited, with emphasis placed on criteria used for compilation of the maps. References to the open literature have been cited in sufficient number to provide a general reading guide for further study.


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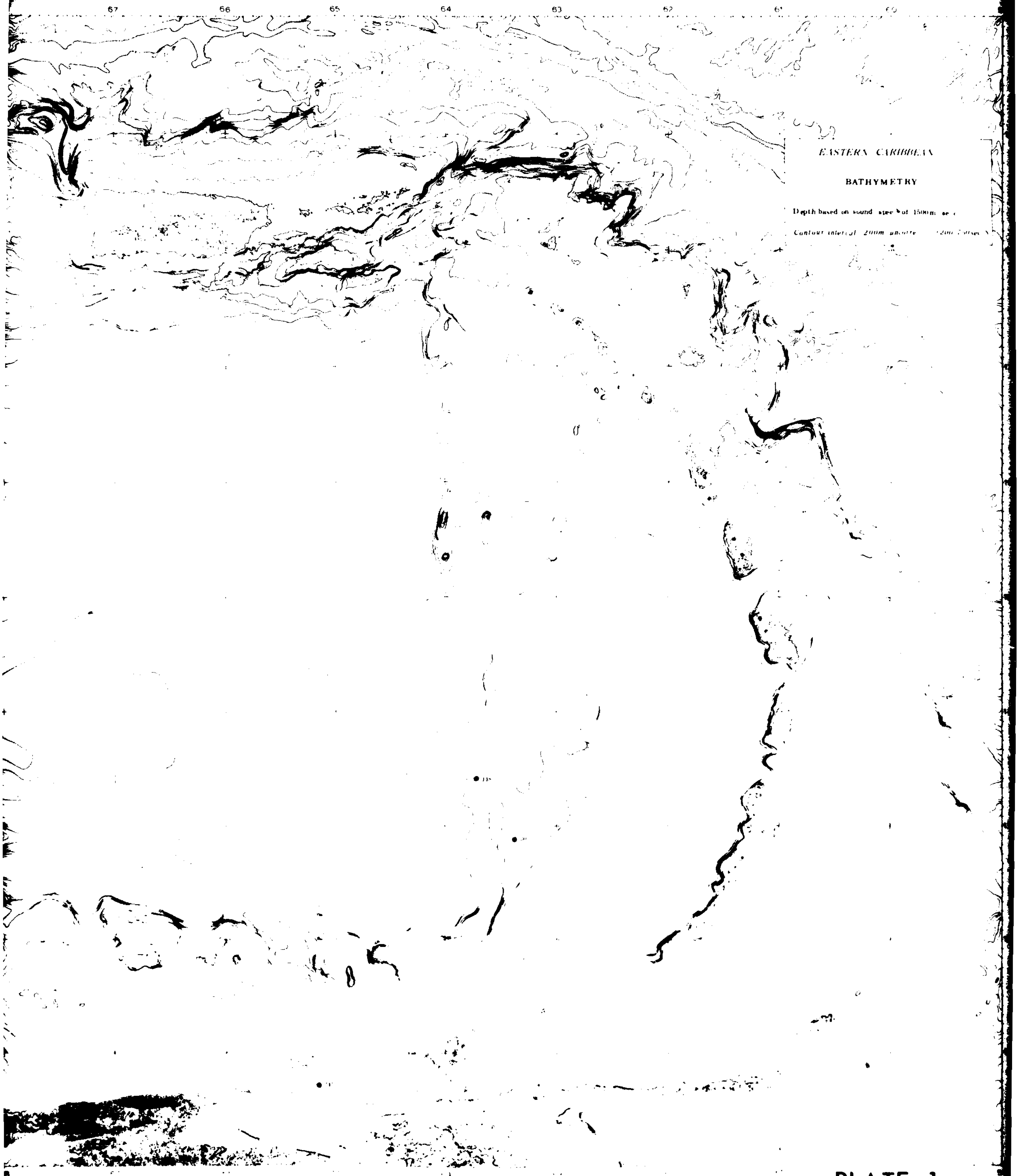
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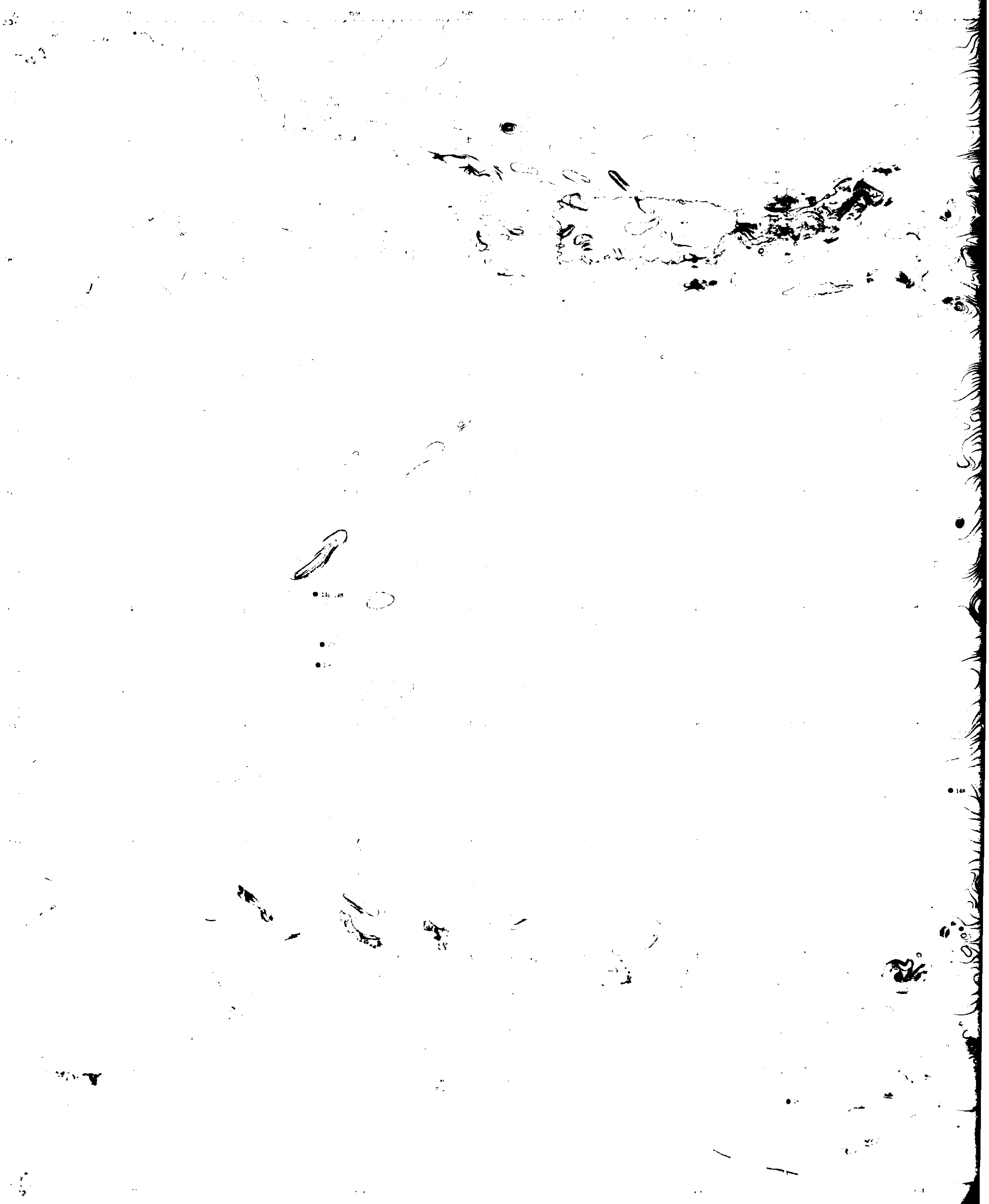
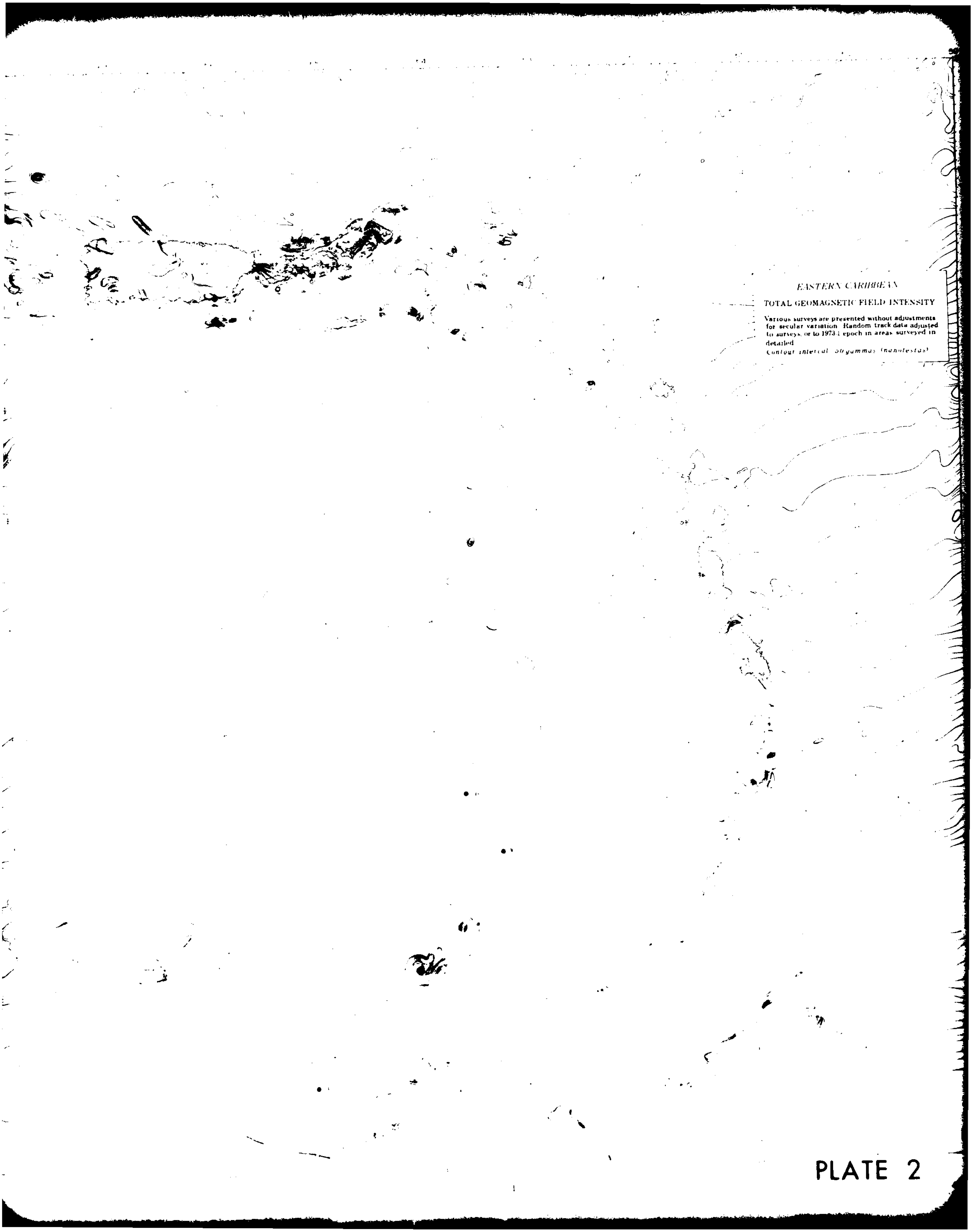
EASTERN CARIBBEAN
BATHYMETRY
Depth based on sound speed of 1500m/sec
Contour interval 200m uncorre (200 ...

PLATE 1





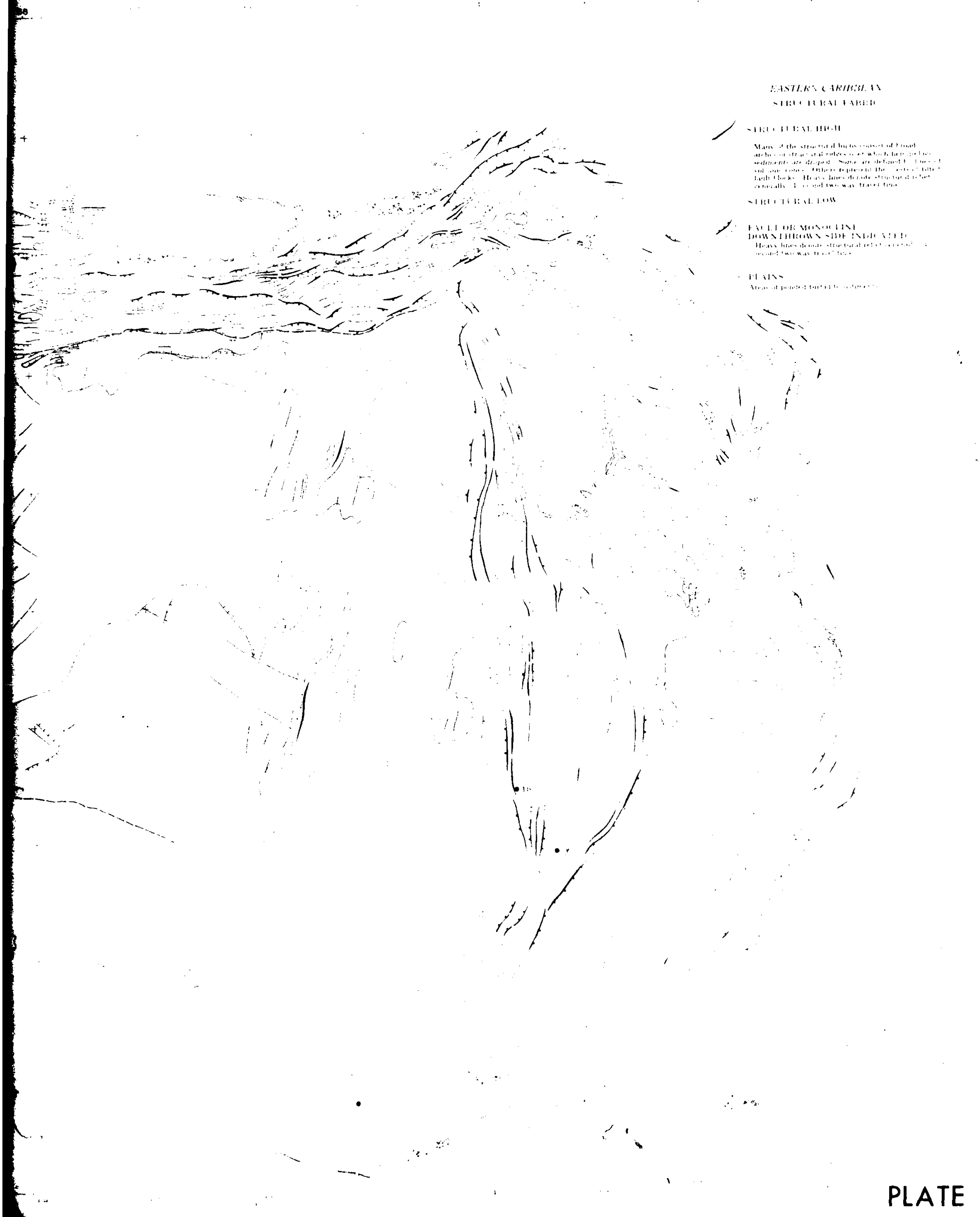
EASTERN CARIBBEAN

TOTAL GEOMAGNETIC FIELD INTENSITY

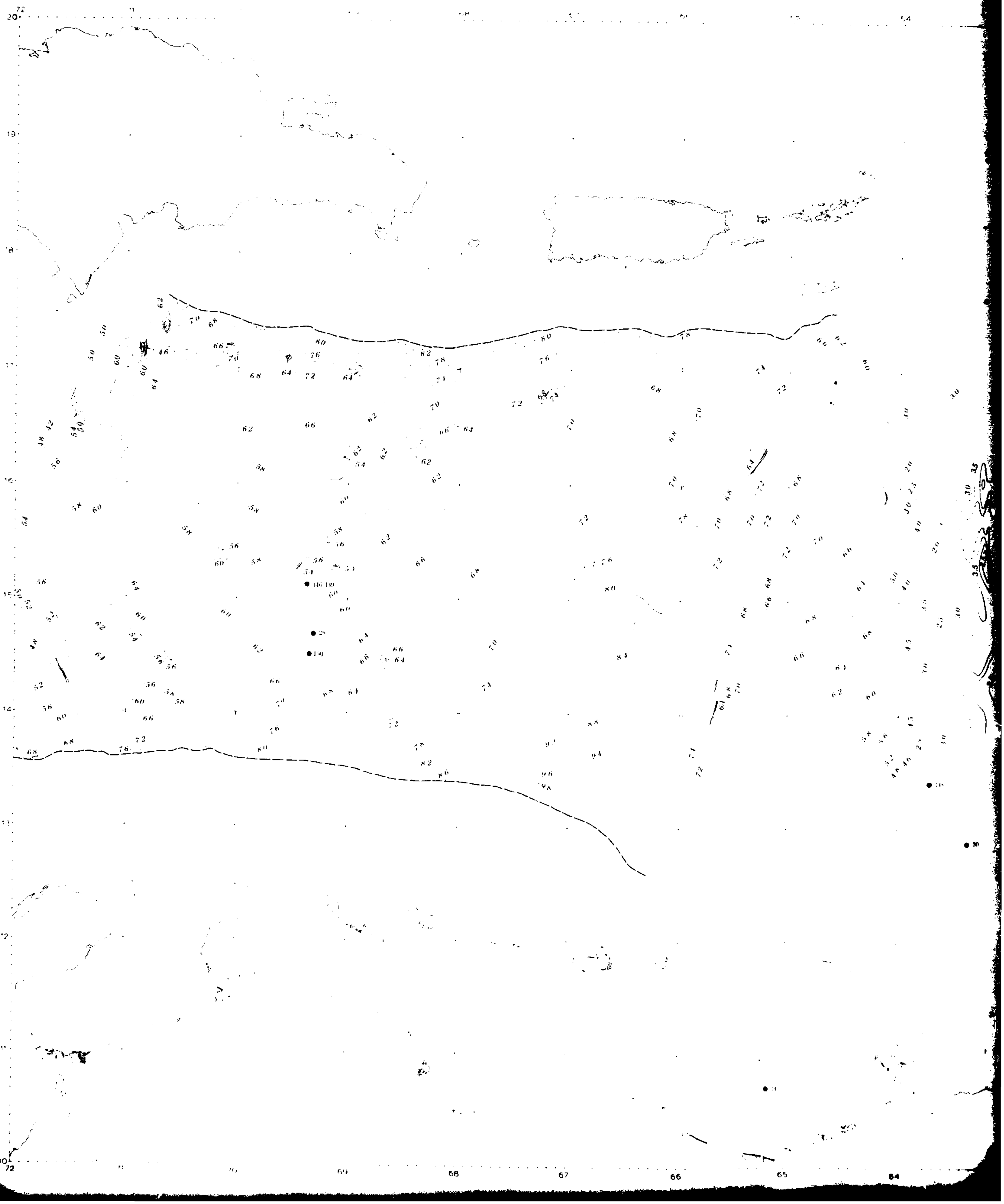
Various surveys are presented without adjustments for secular variation. Random track data adjusted to surveys, or to 1973.1 epoch in areas surveyed in detailed

Contour interval 50 gammas (nanoteslas)

PLATE 2


EASTERN CARIBBEAN
STRUCTURAL FABRIC
STRUCTURAL HIGH
Many of the structural highs consist of broad arches or structural ridges over which [illegible] sediments are draped. Some are defined by [illegible] volcanic cones. Others represent the crests of tilted fault blocks. Heavy lines denote structural relief generally 1 second two-way travel time.
STRUCTURAL LOW
FAULT OR MONOCLINE
DOWNTHROWN SIDE INDICATED
Heavy lines denote structural relief [illegible] second two-way travel time.
PLAINS
Areas of ponded turbidite sediments

PLATE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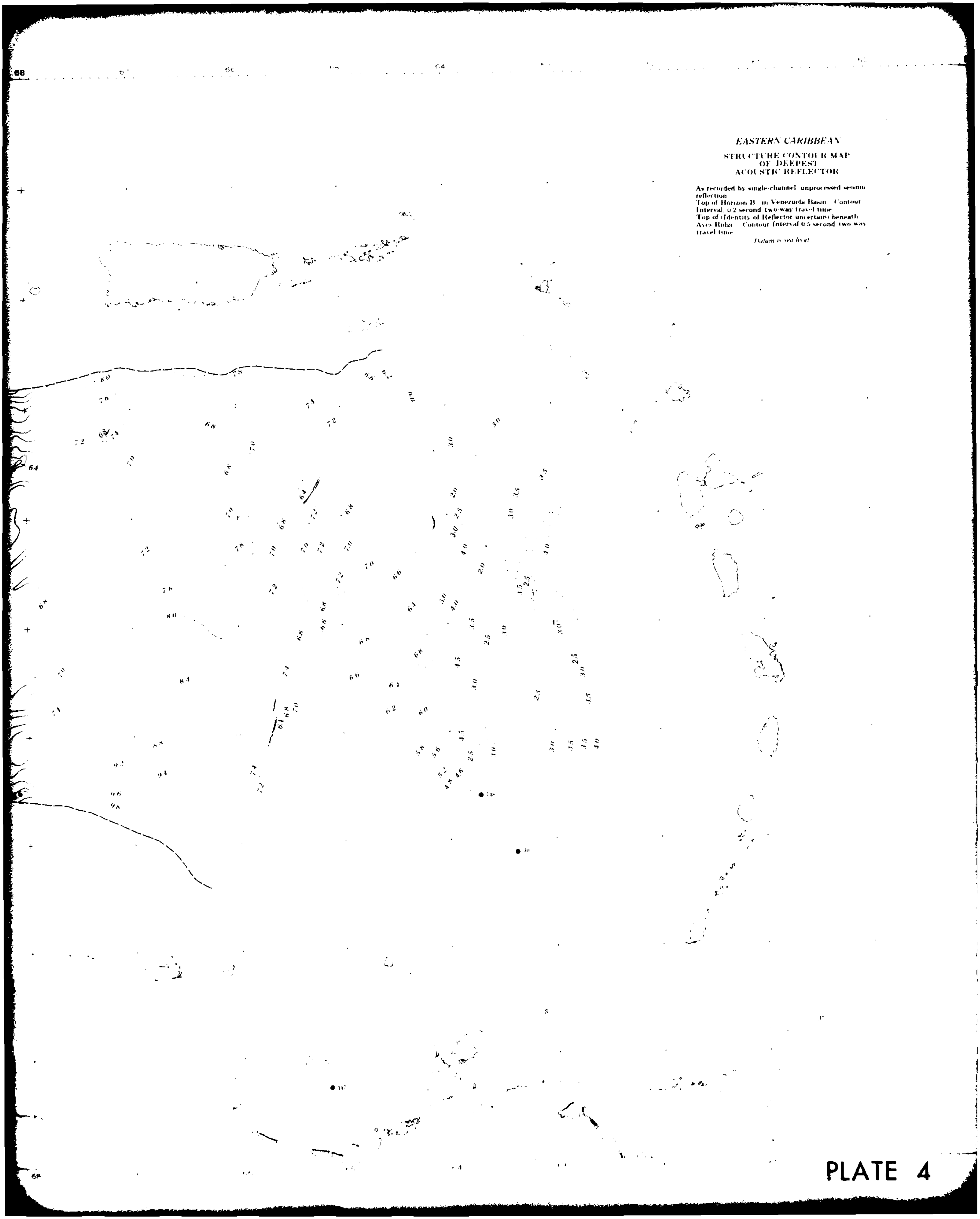


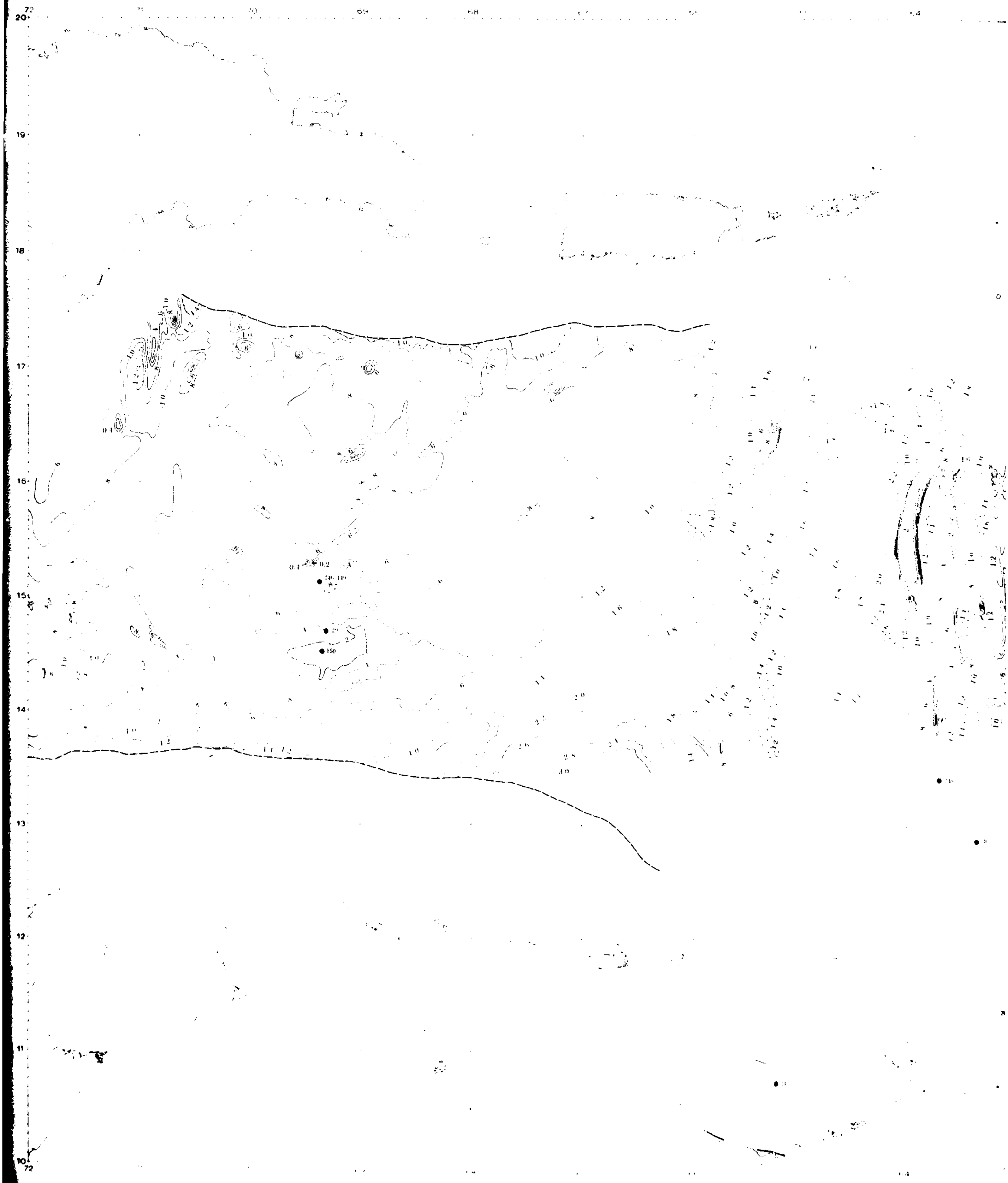
EASTERN CARIBBEAN

STRUCTURE CONTOUR MAP OF DEEPEST ACOUSTIC REFLECTOR

As recorded by single-channel unprocessed seismic reflection
Top of Horizon B in Venezuela Basin Contour Interval, 0.2 second two-way travel time
Top of (Identity of Reflector uncertain) beneath Aves Ridge Contour Interval 0.5 second two-way travel time

Datum is sea level

PLATE 4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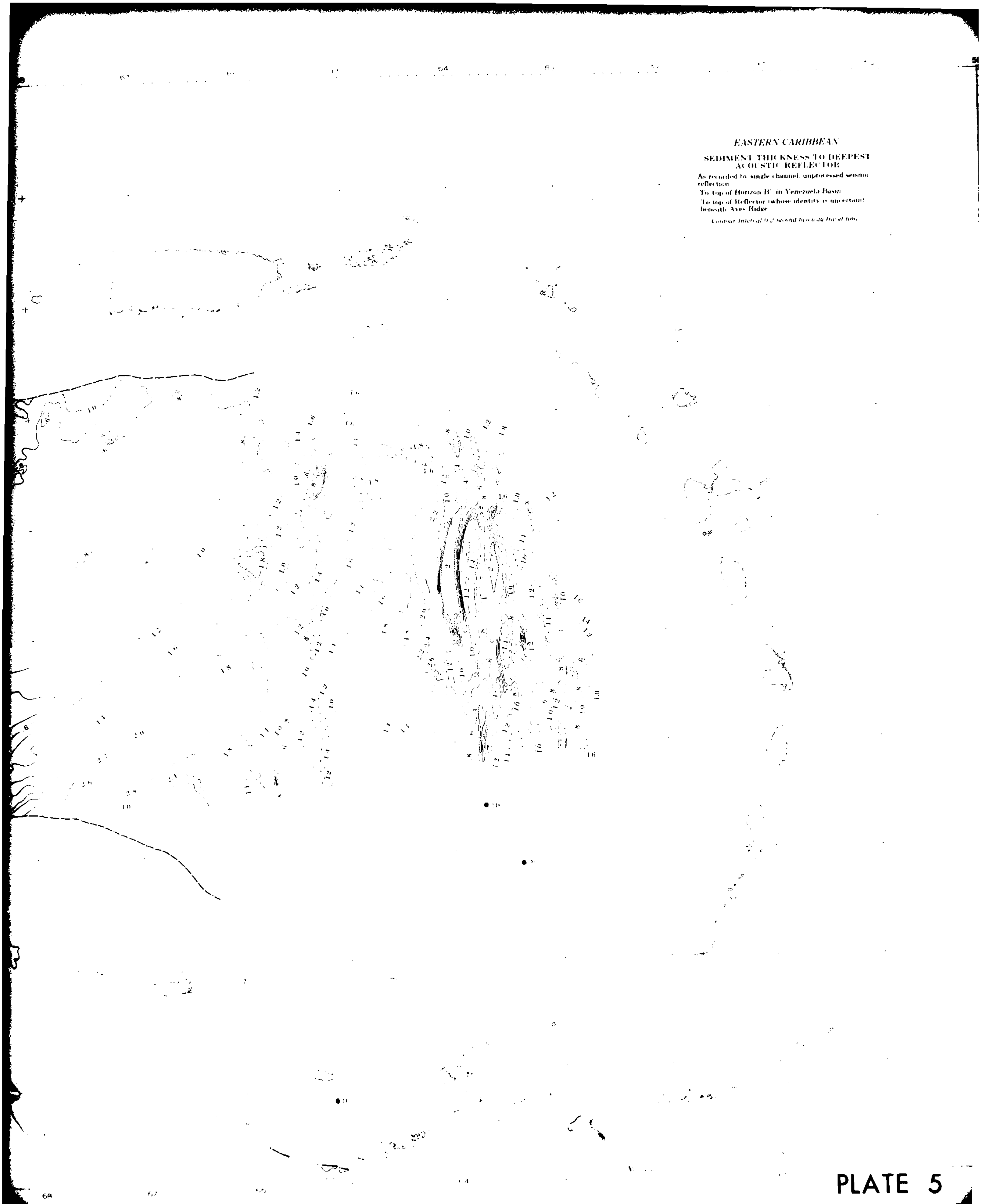

EASTERN CARIBBEAN

SEDIMENT THICKNESS TO DEEPEST ACOUSTIC REFLECTOR

As recorded by single channel, unprocessed seismic reflection

To top of Horizon B″ in *Venezuela Basin*

To top of Reflector (whose identity is uncertain) beneath Aves Ridge

Contour Interval 0.2 second two-way travel time

PLATE 5

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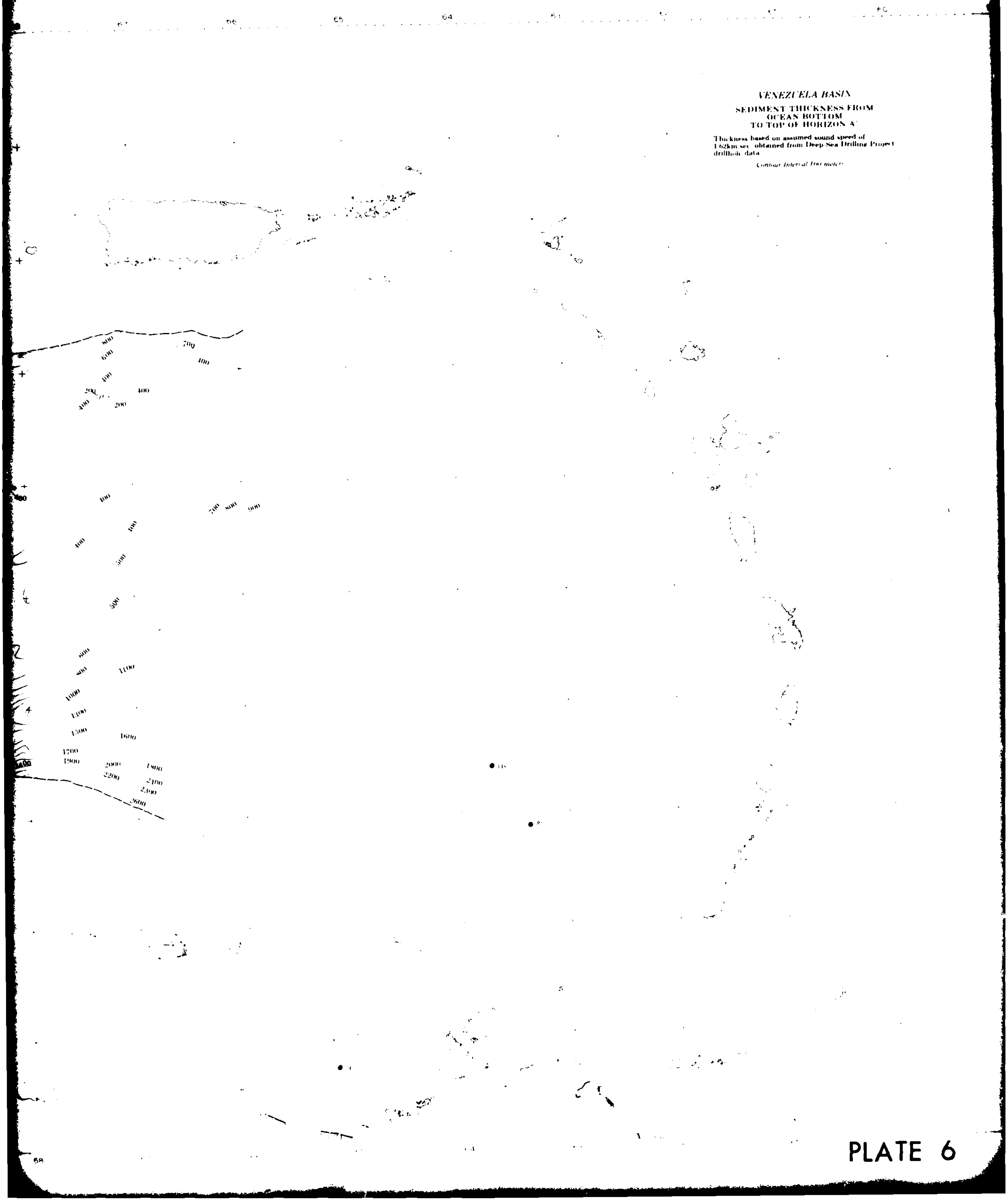


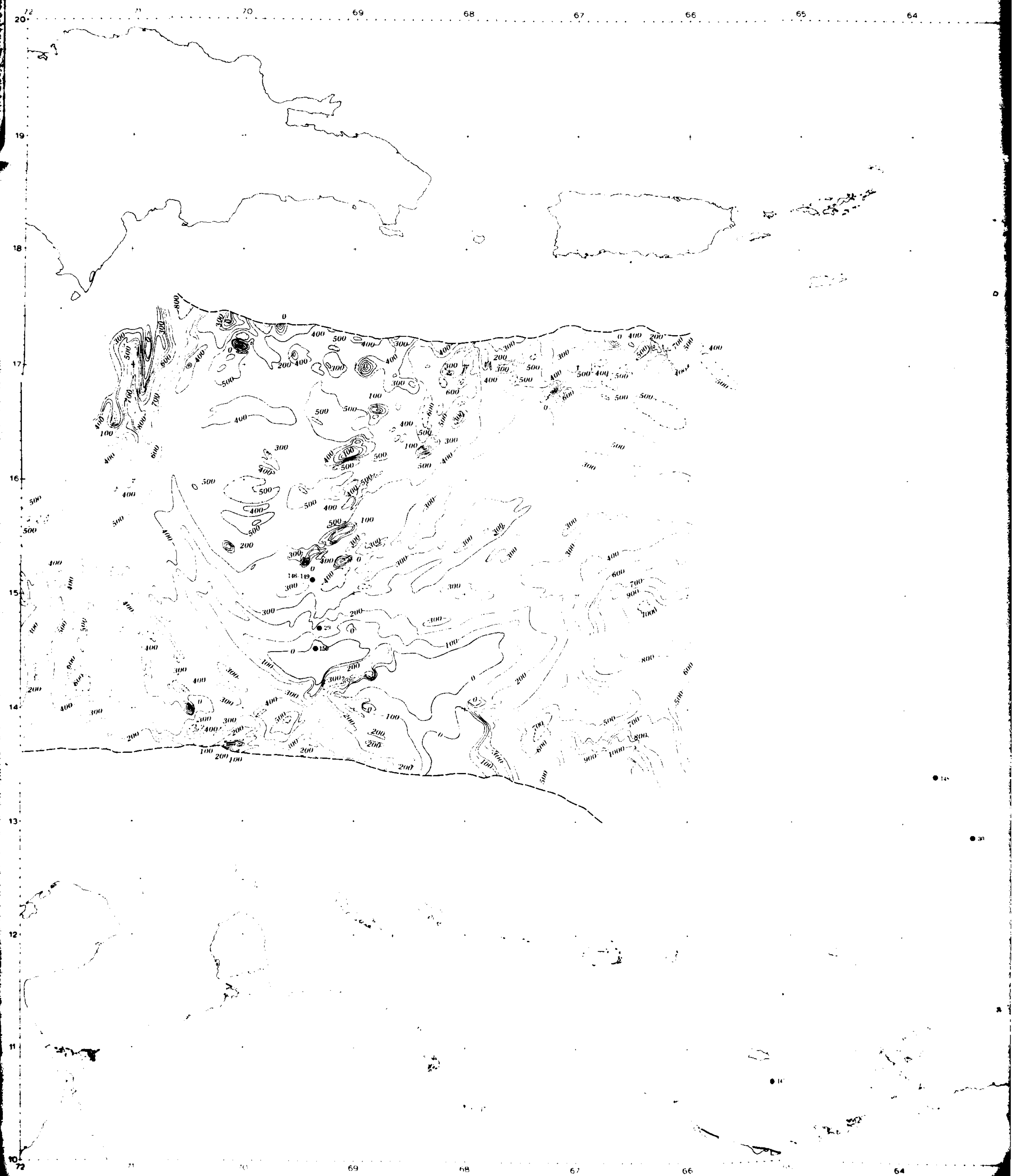
VENEZUELA BASIN

SEDIMENT THICKNESS FROM
OCEAN BOTTOM
TO TOP OF HORIZON A″

Thickness based on assumed sound speed of 1.62km sec obtained from Deep Sea Drilling Project drillhole data

Contour Interval 100 meters

PLATE 6



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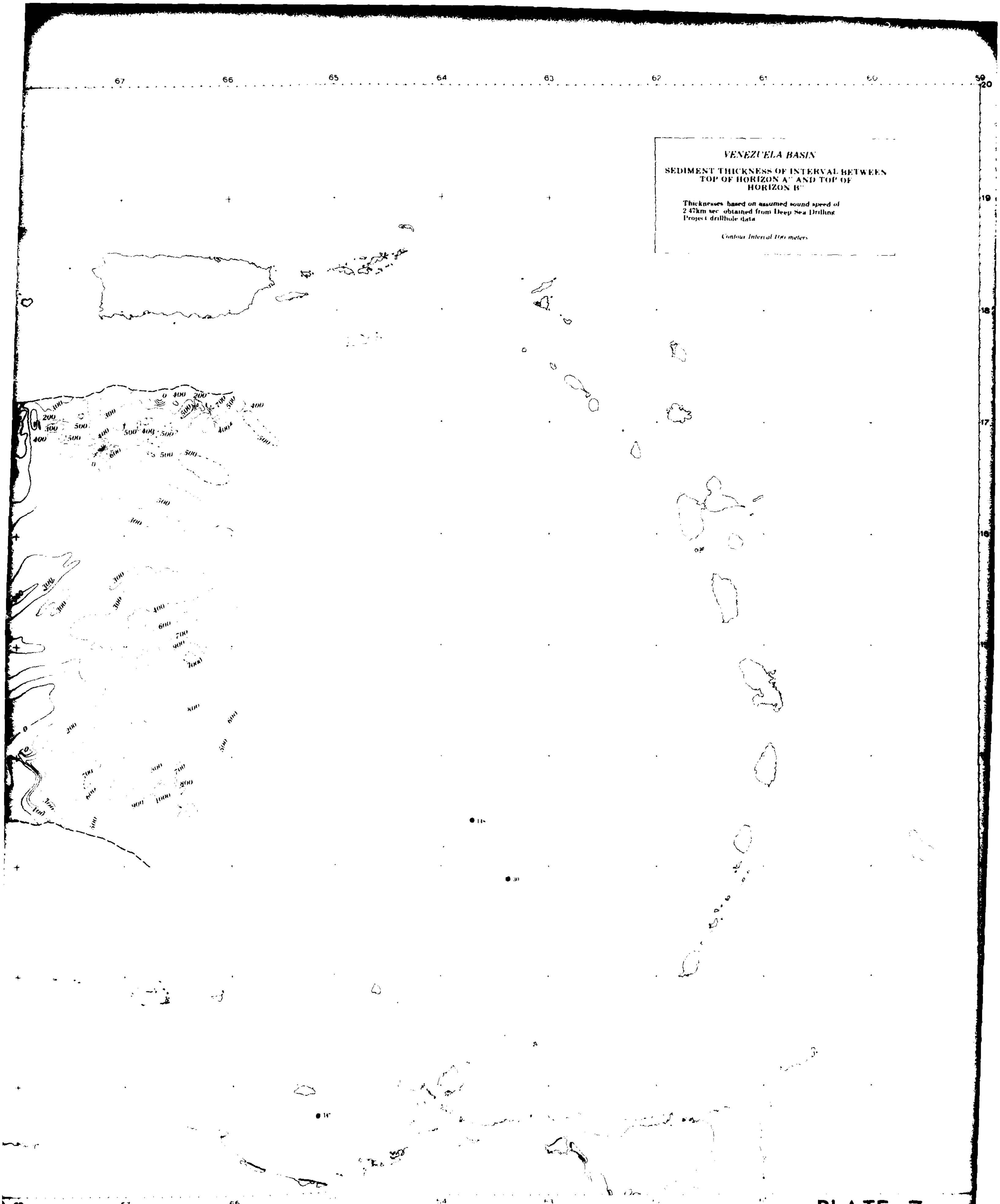


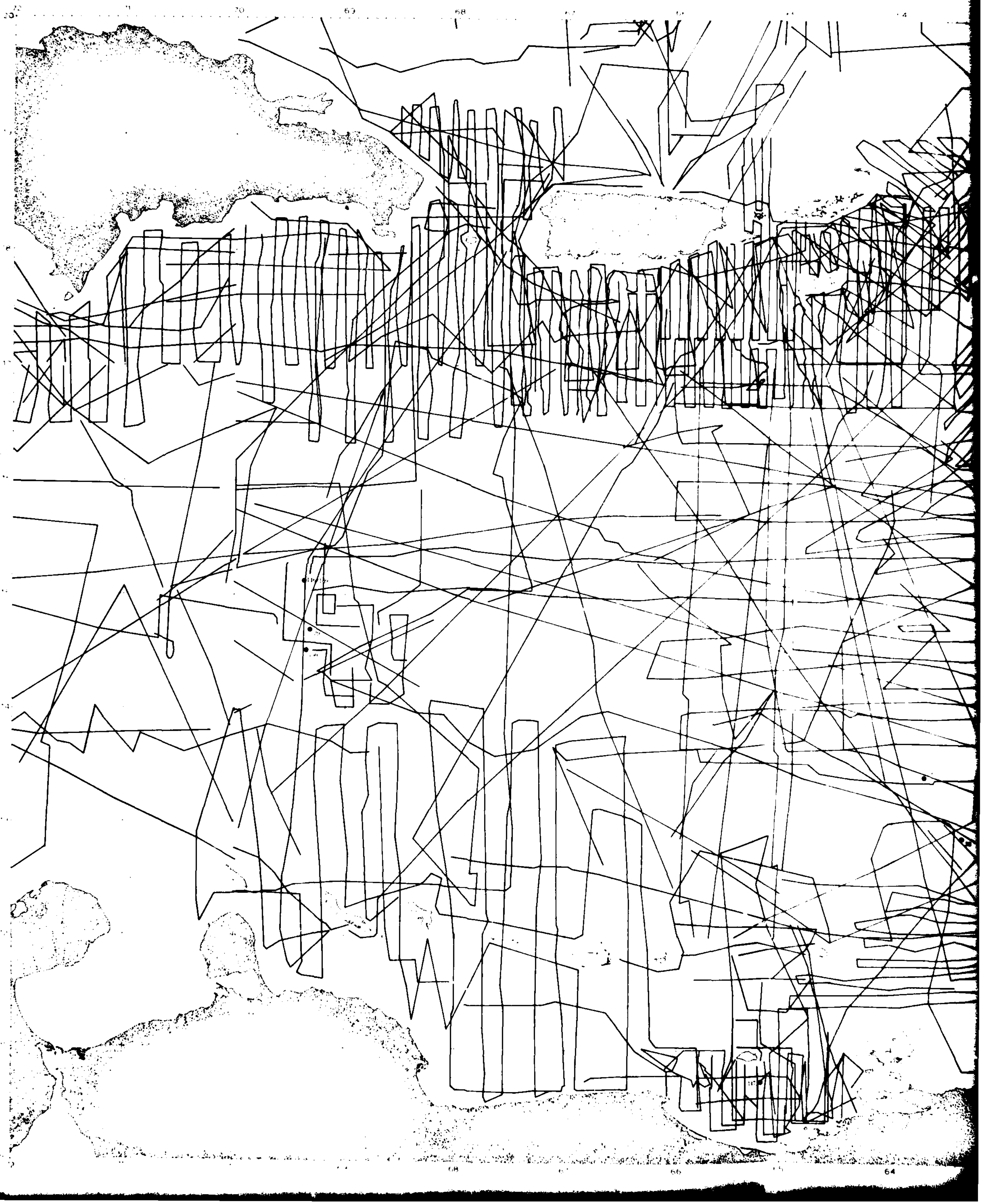
VENEZUELA BASIN

SEDIMENT THICKNESS OF INTERVAL BETWEEN TOP OF HORIZON A" AND TOP OF HORIZON B"

Thicknesses based on assumed sound speed of 2.47km sec. obtained from Deep Sea Drilling Project drillhole data

Contour Interval 100 meters

PLATE 7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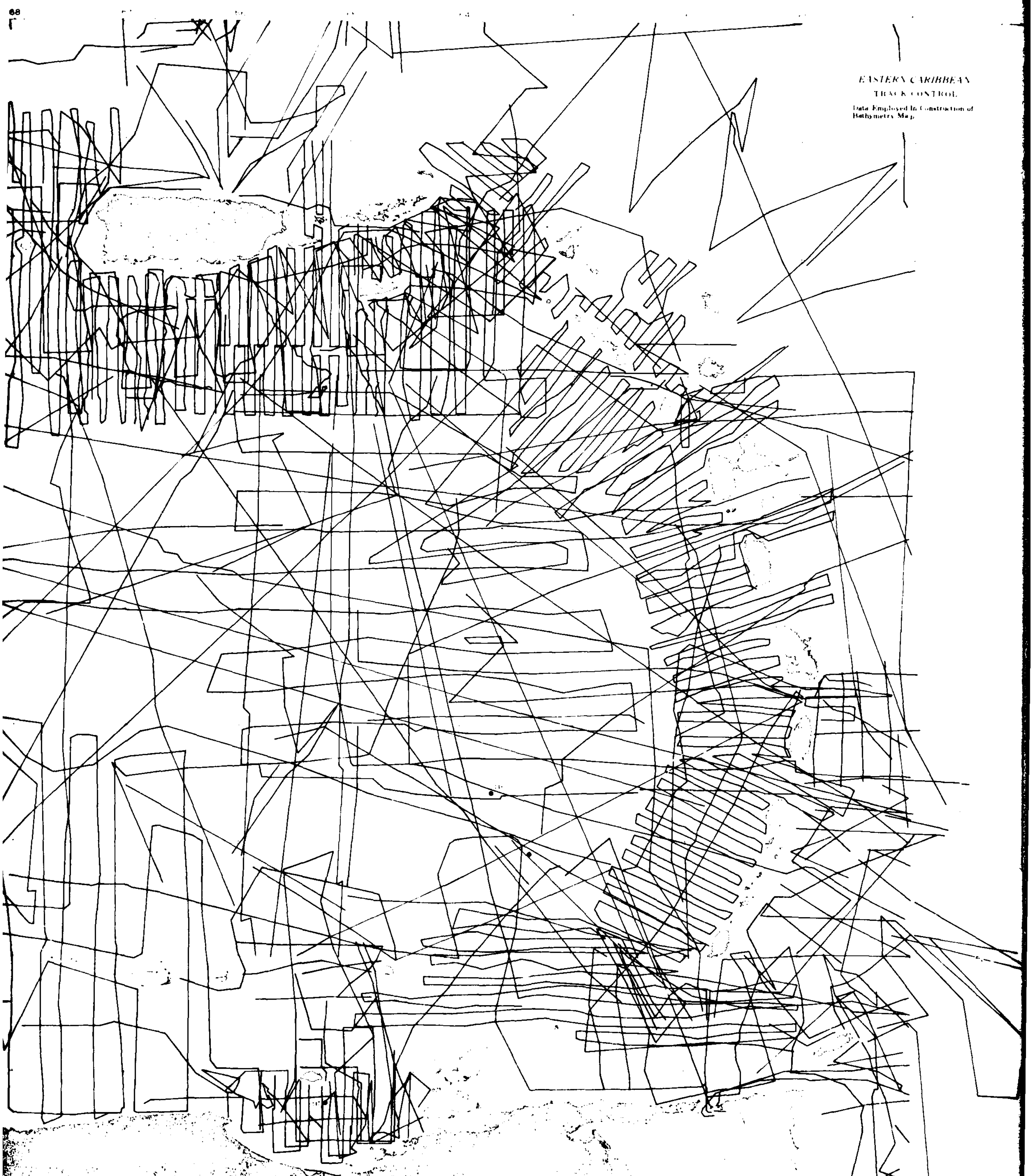

EASTERN CARIBBEAN

TRACK CONTROL

Data Employed In Construction of
Bathymetry Map

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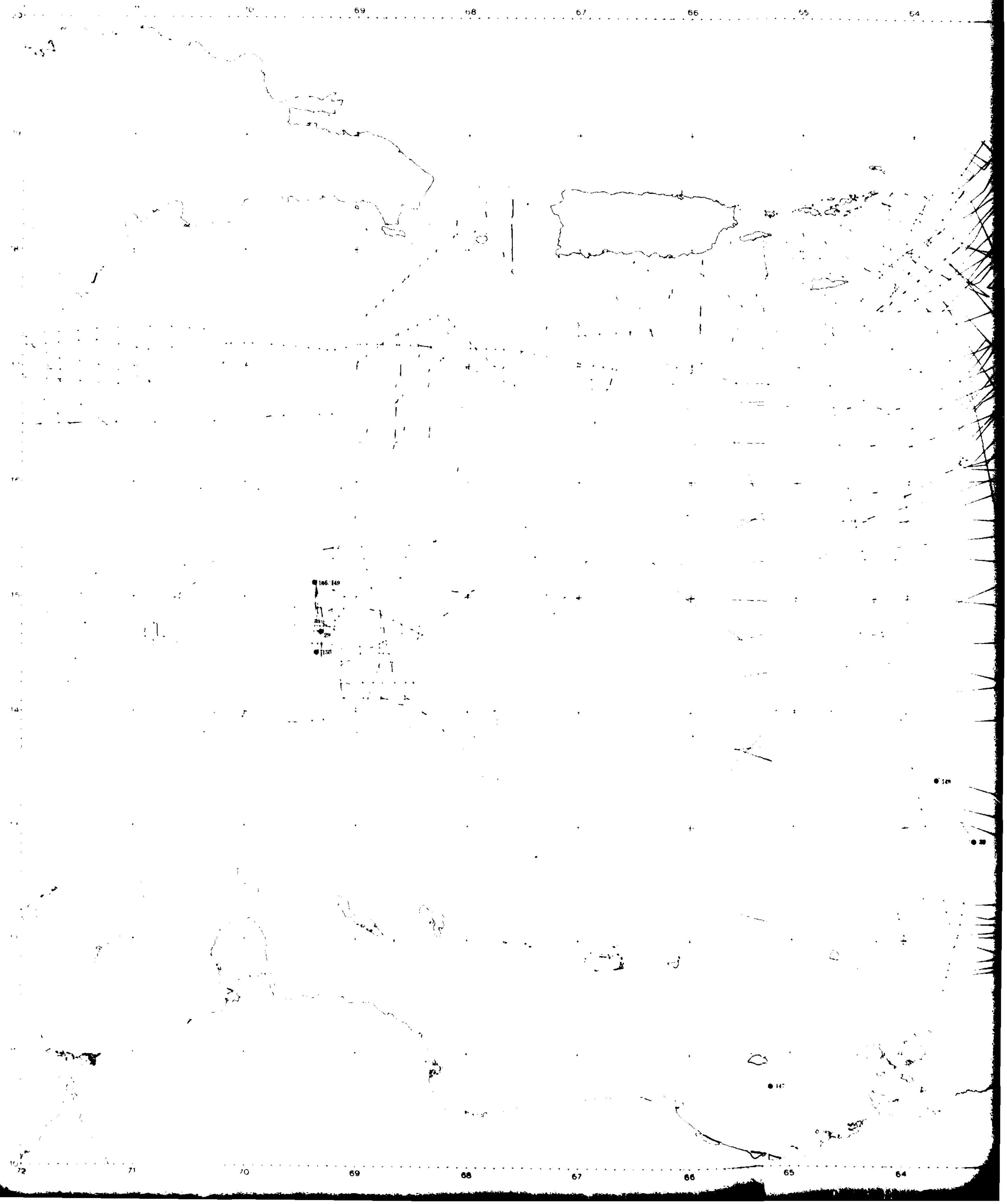
EASTERN CARIBBEAN
TRACK CONTROL
Data Employed In Construction of
Magnetic Map

PLATE 9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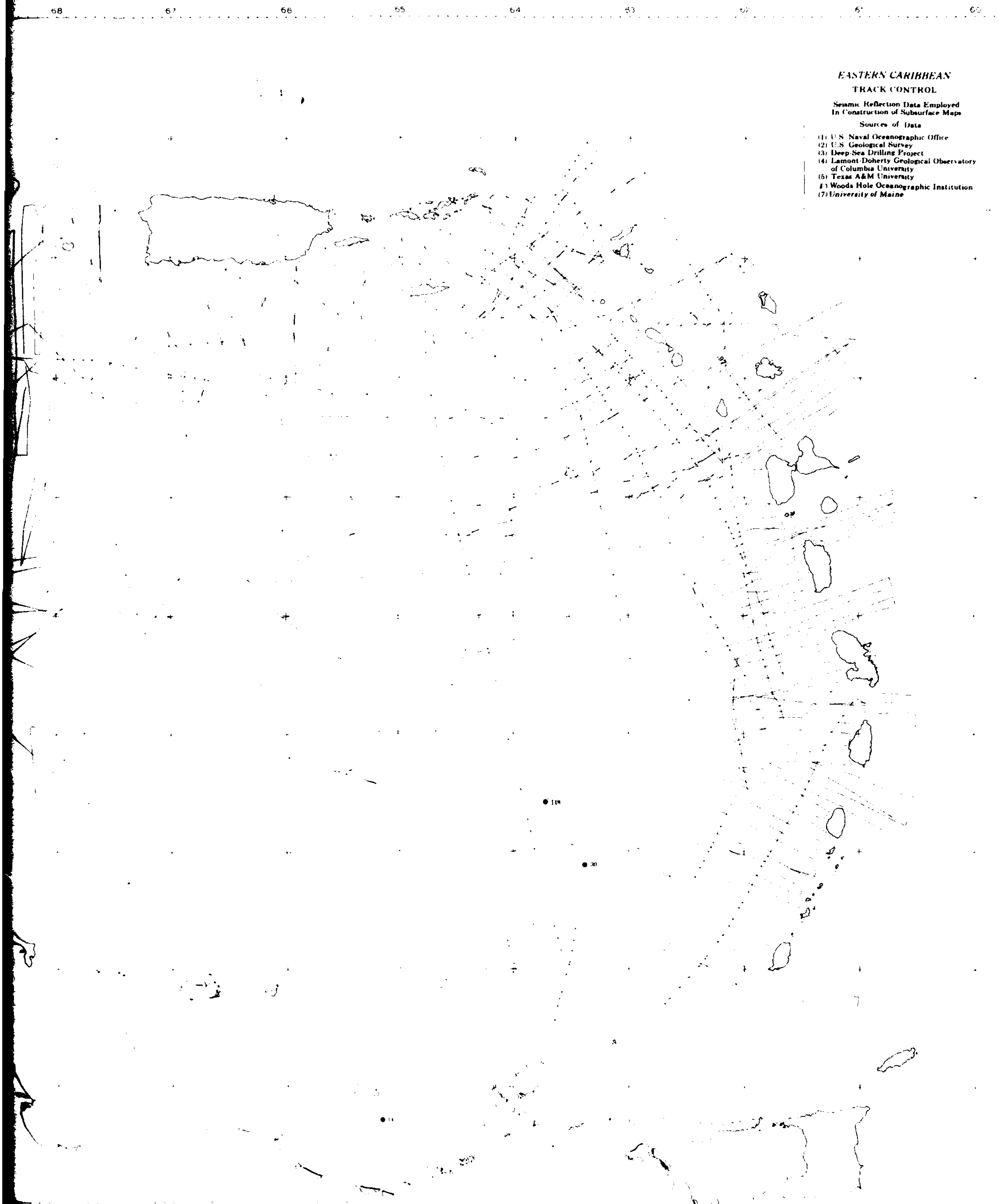


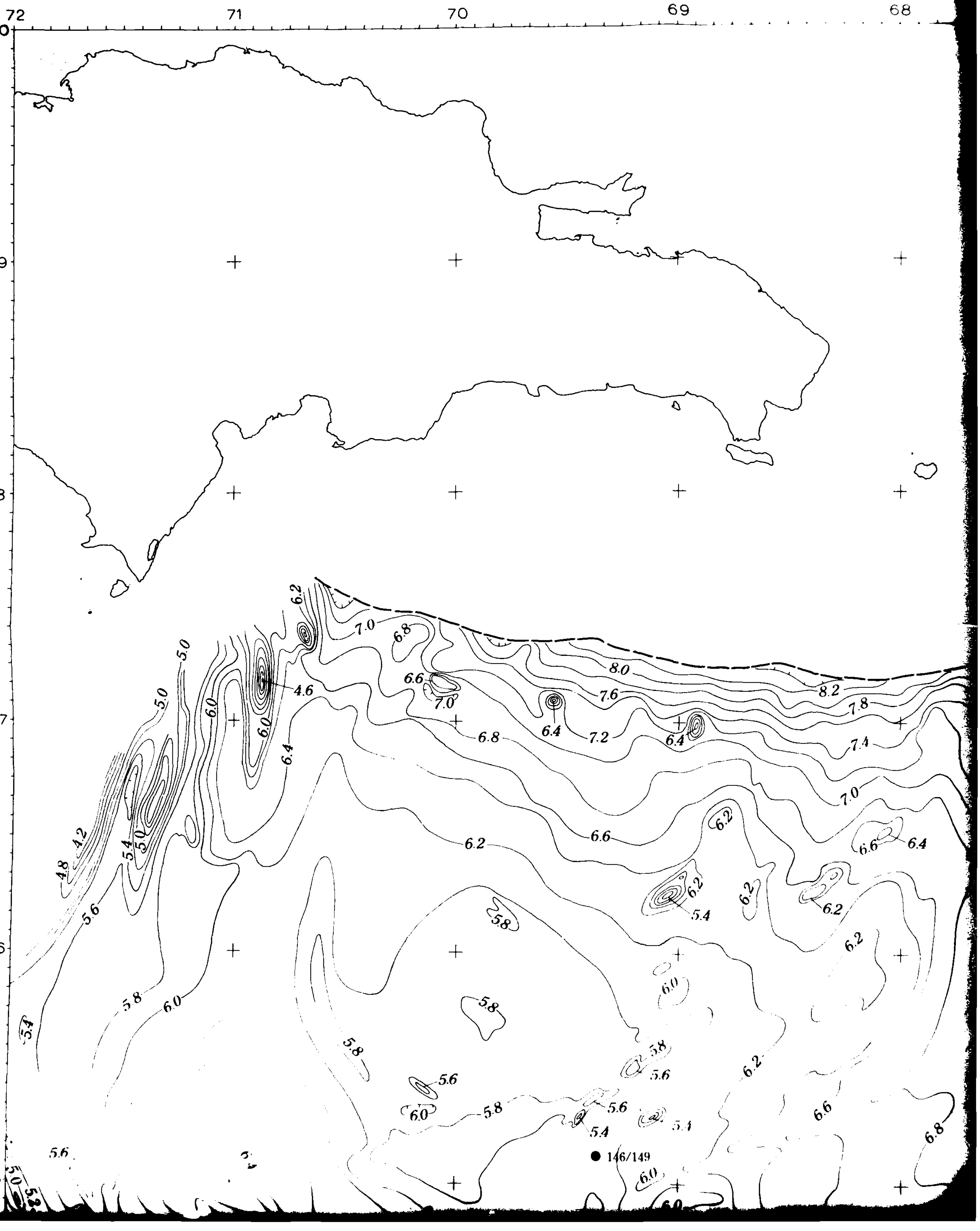
EASTERN CARIBBEAN
TRACK CONTROL

Seismic Reflection Data Employed
In Construction of Subsurface Maps

Sources of Data

(1) U.S. Naval Oceanographic Office
(2) U.S. Geological Survey
(3) Deep-Sea Drilling Project
(4) Lamont-Doherty Geological Observatory of Columbia University
(5) Texas A&M University
(6) Woods Hole Oceanographic Institution
(7) *University of Maine*

PLATE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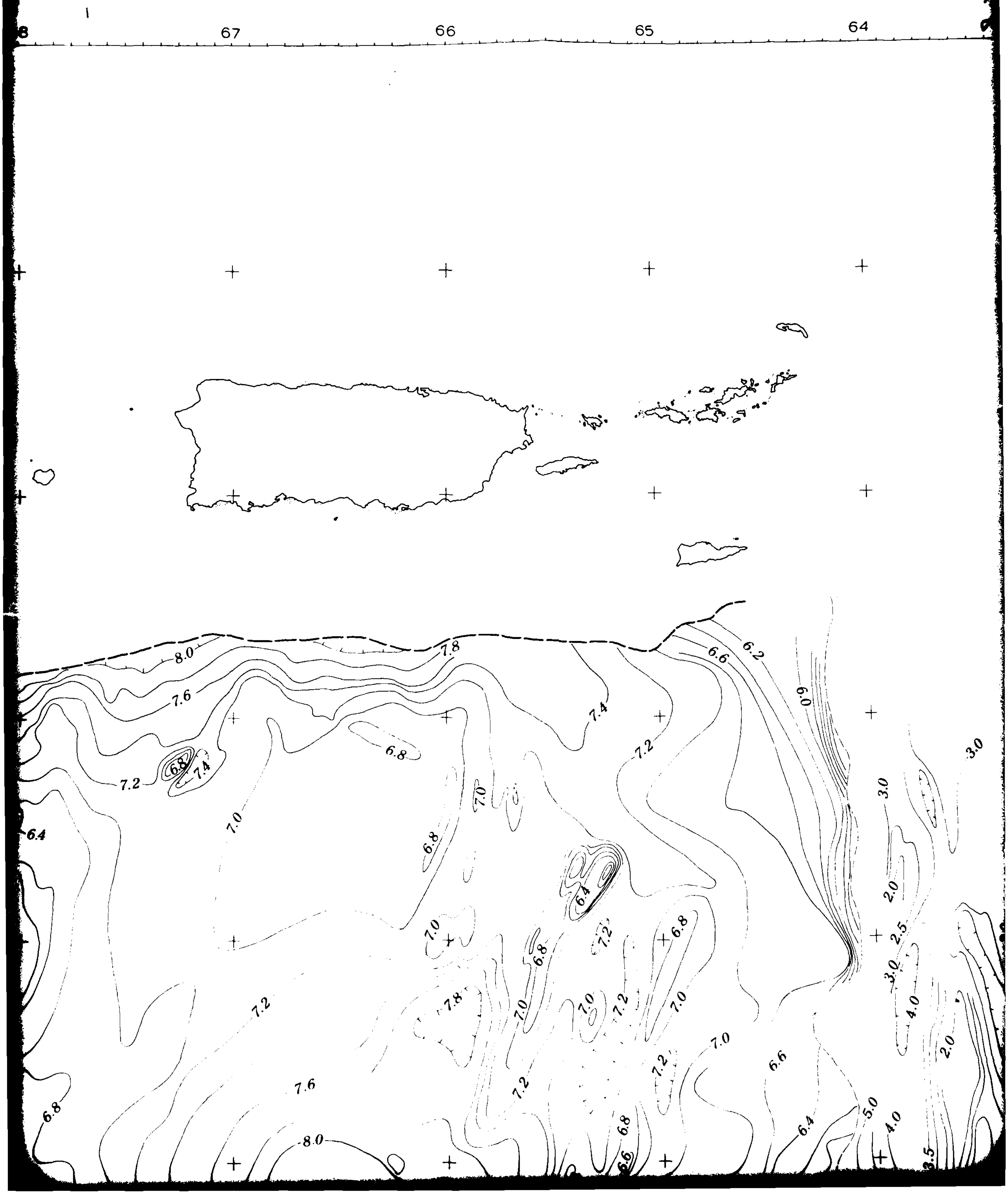
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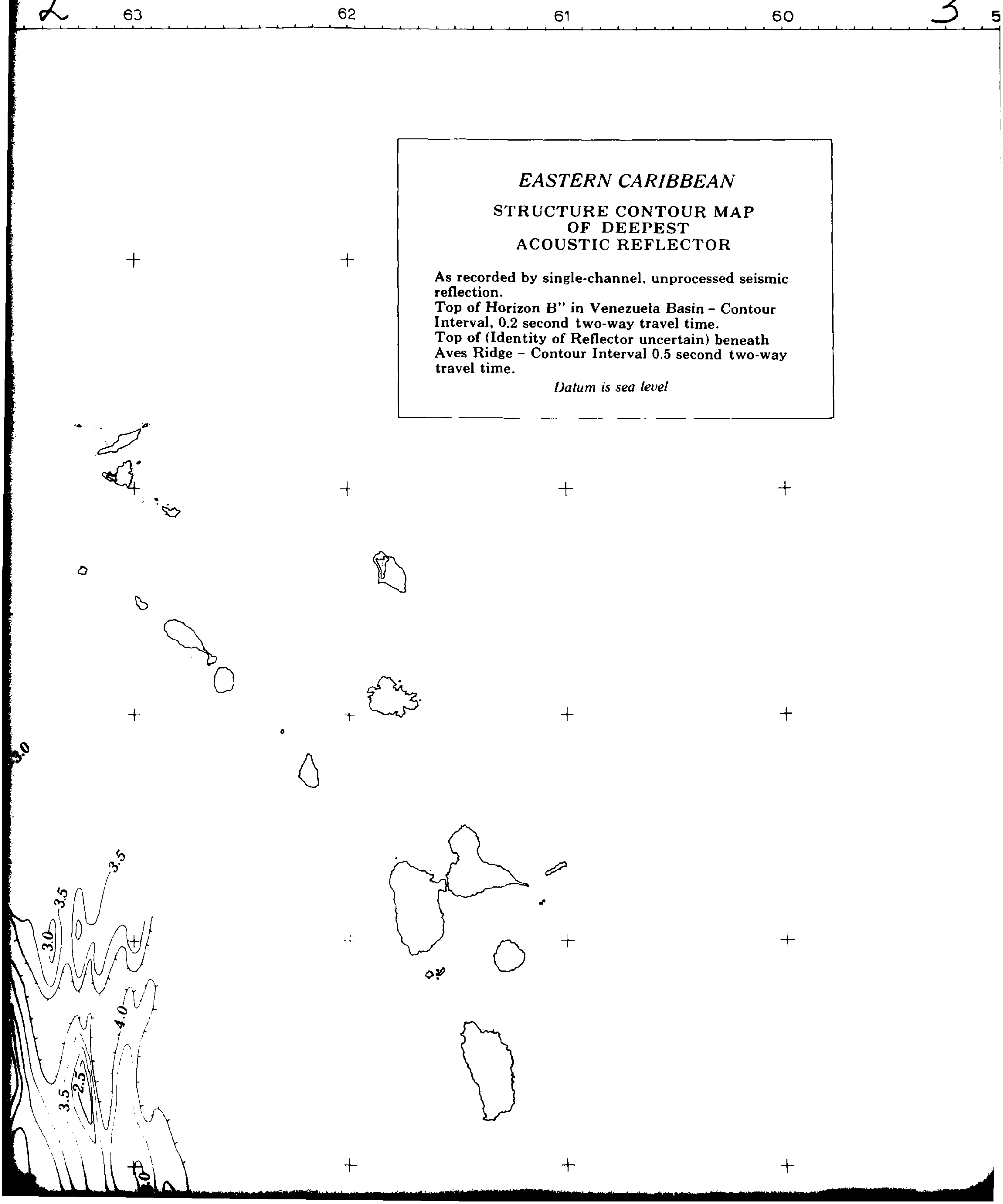
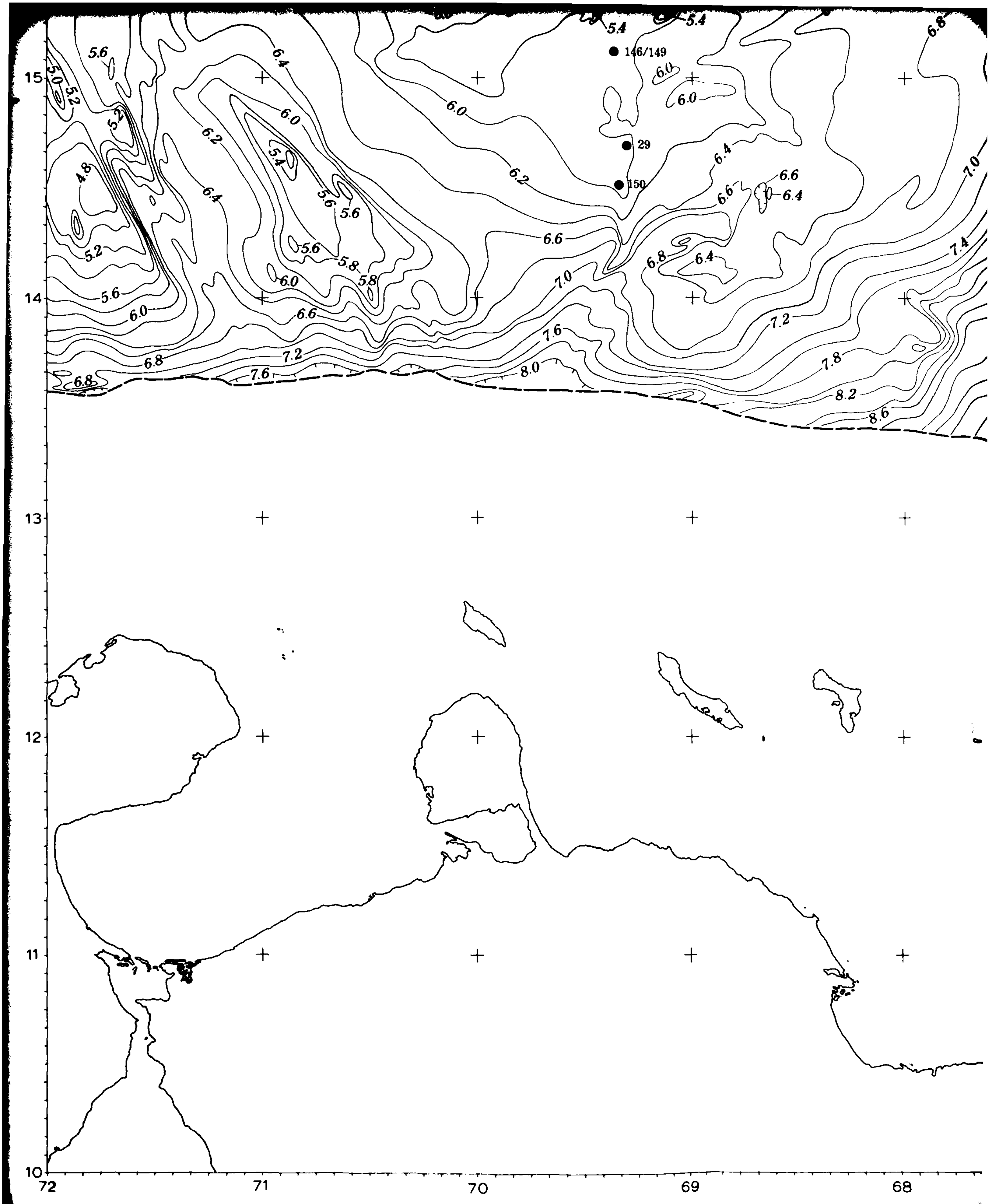


EASTERN CARIBBEAN

STRUCTURE CONTOUR MAP
OF DEEPEST
ACOUSTIC REFLECTOR

As recorded by single-channel, unprocessed seismic reflection.
Top of Horizon B" in Venezuela Basin - Contour Interval, 0.2 second two-way travel time.
Top of (Identity of Reflector uncertain) beneath Aves Ridge - Contour Interval 0.5 second two-way travel time.

Datum is sea level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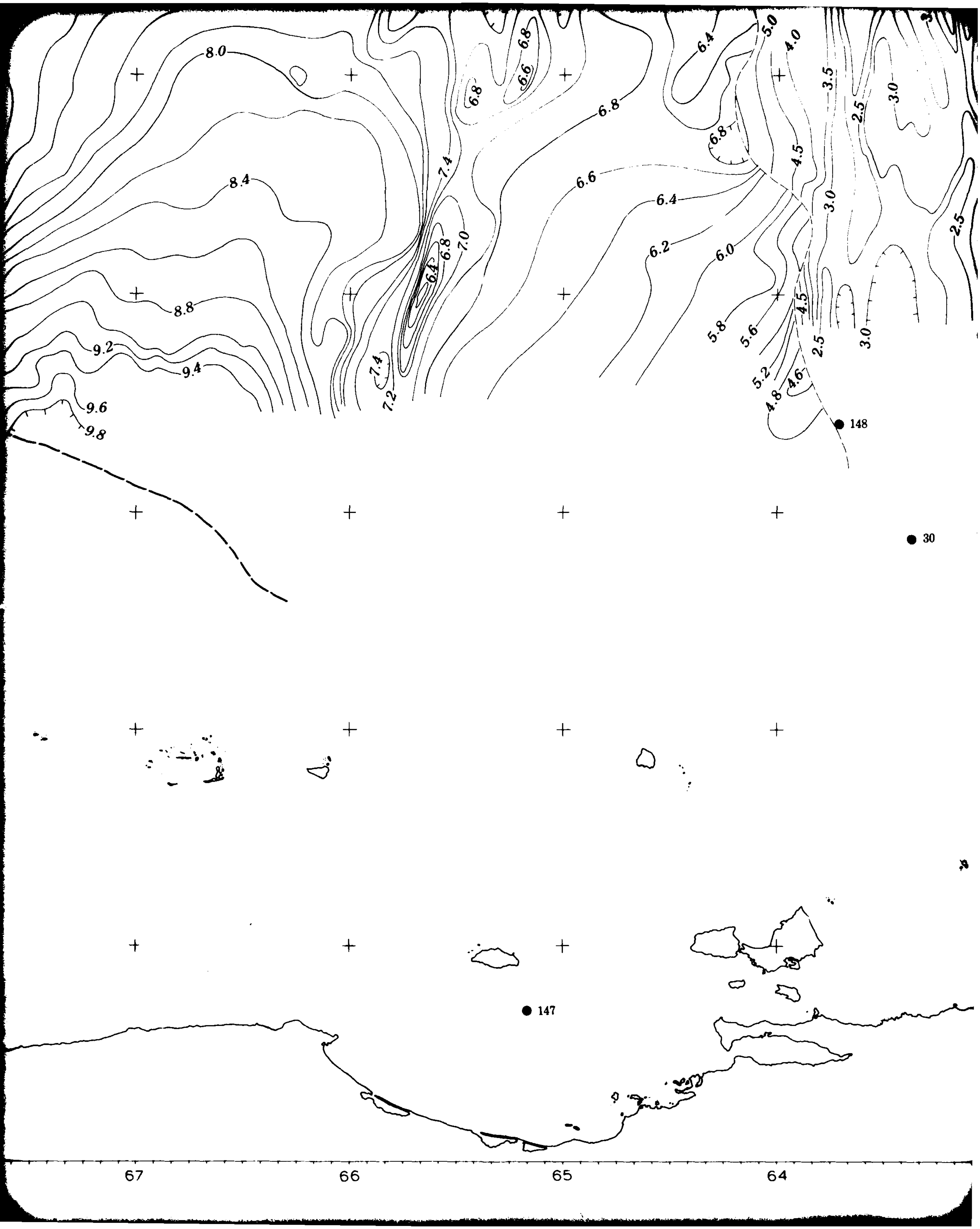
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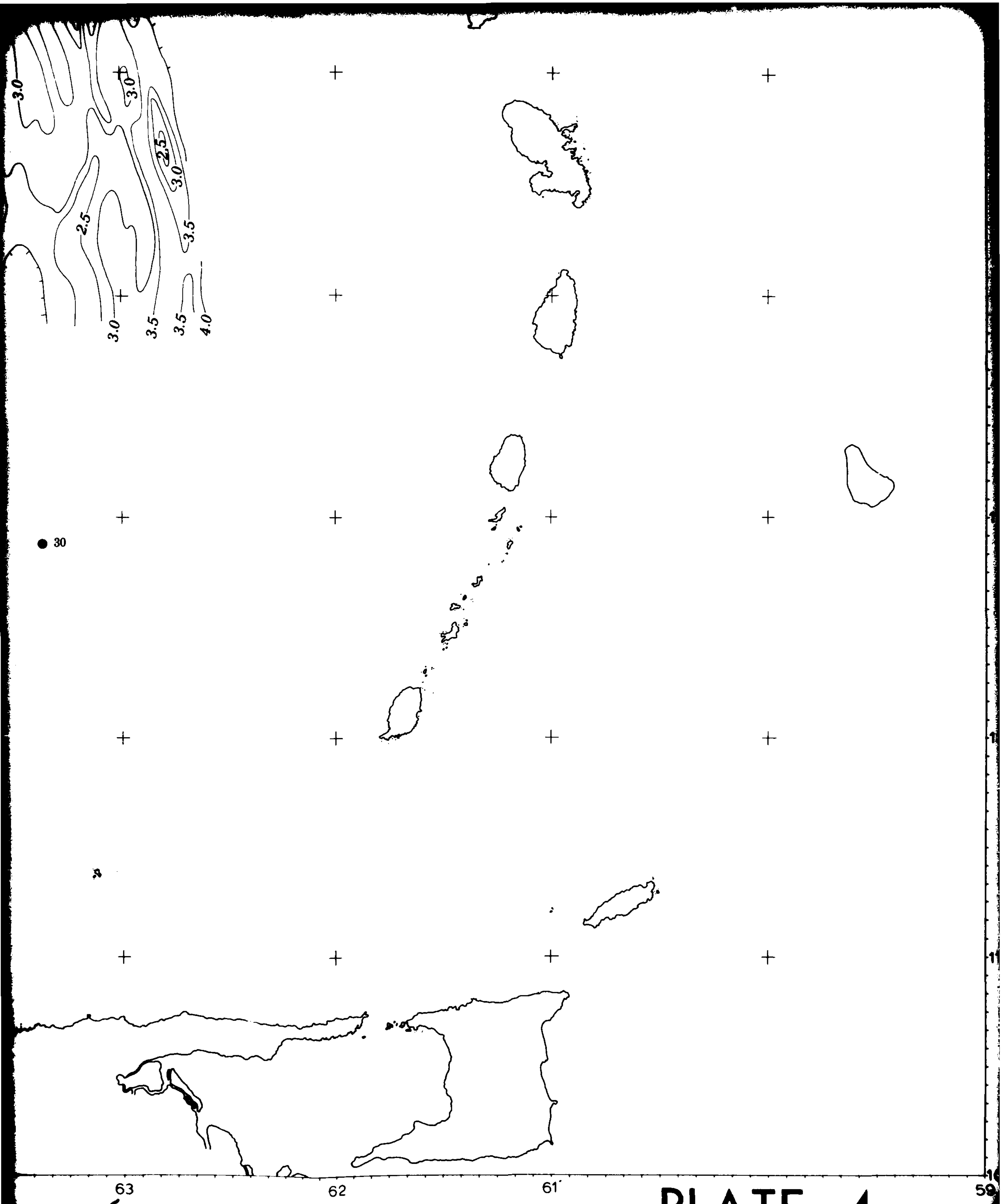
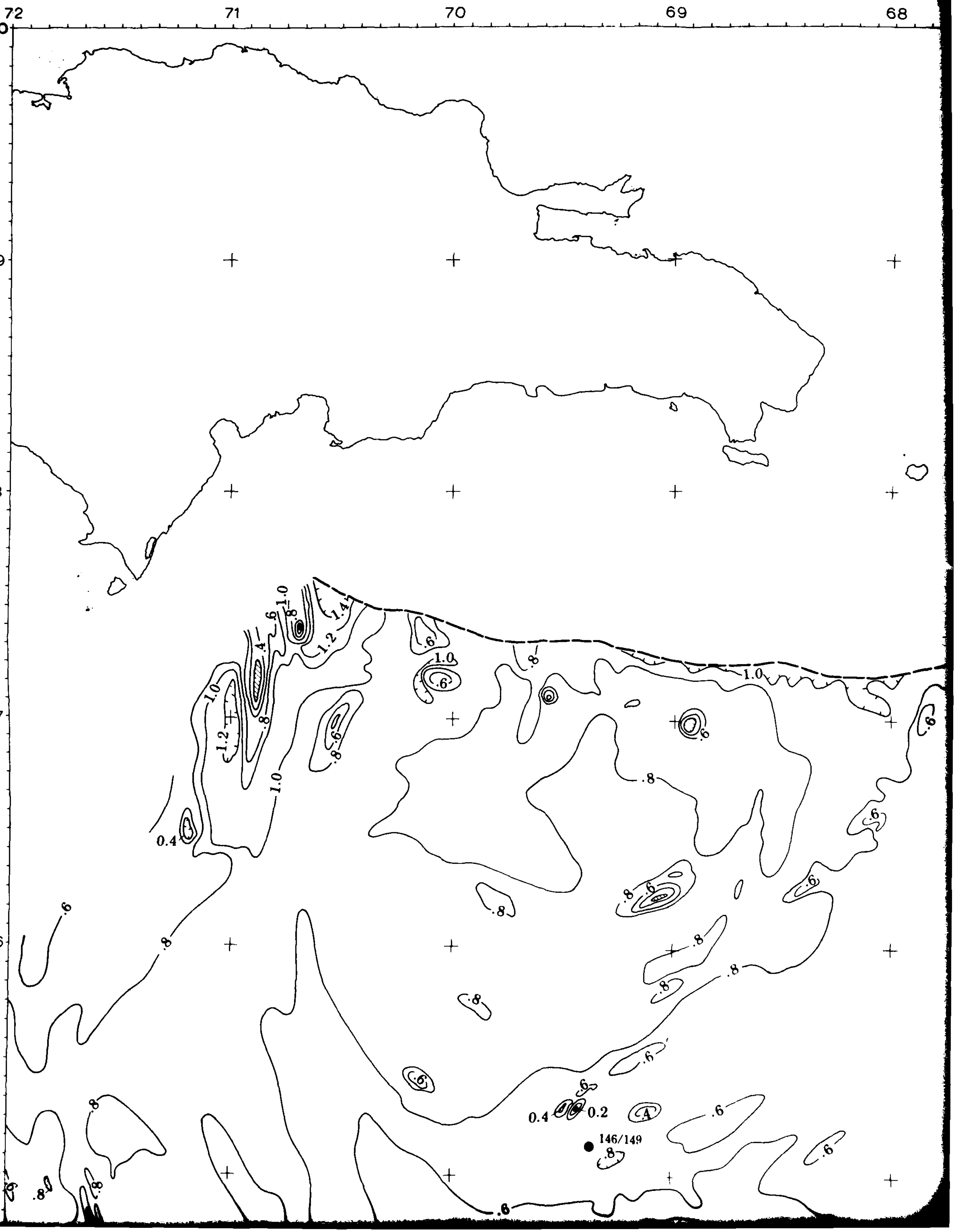


PLATE 4



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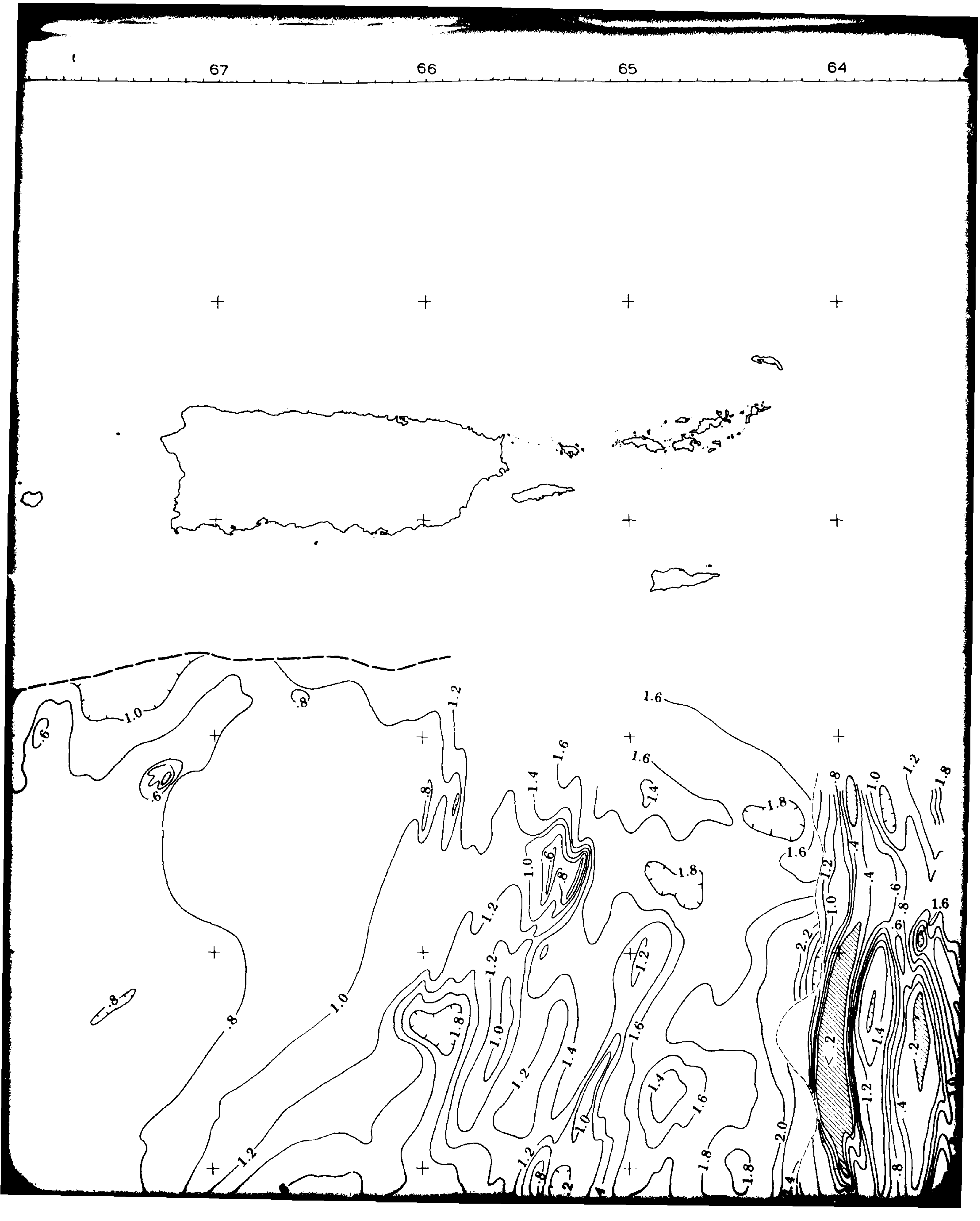
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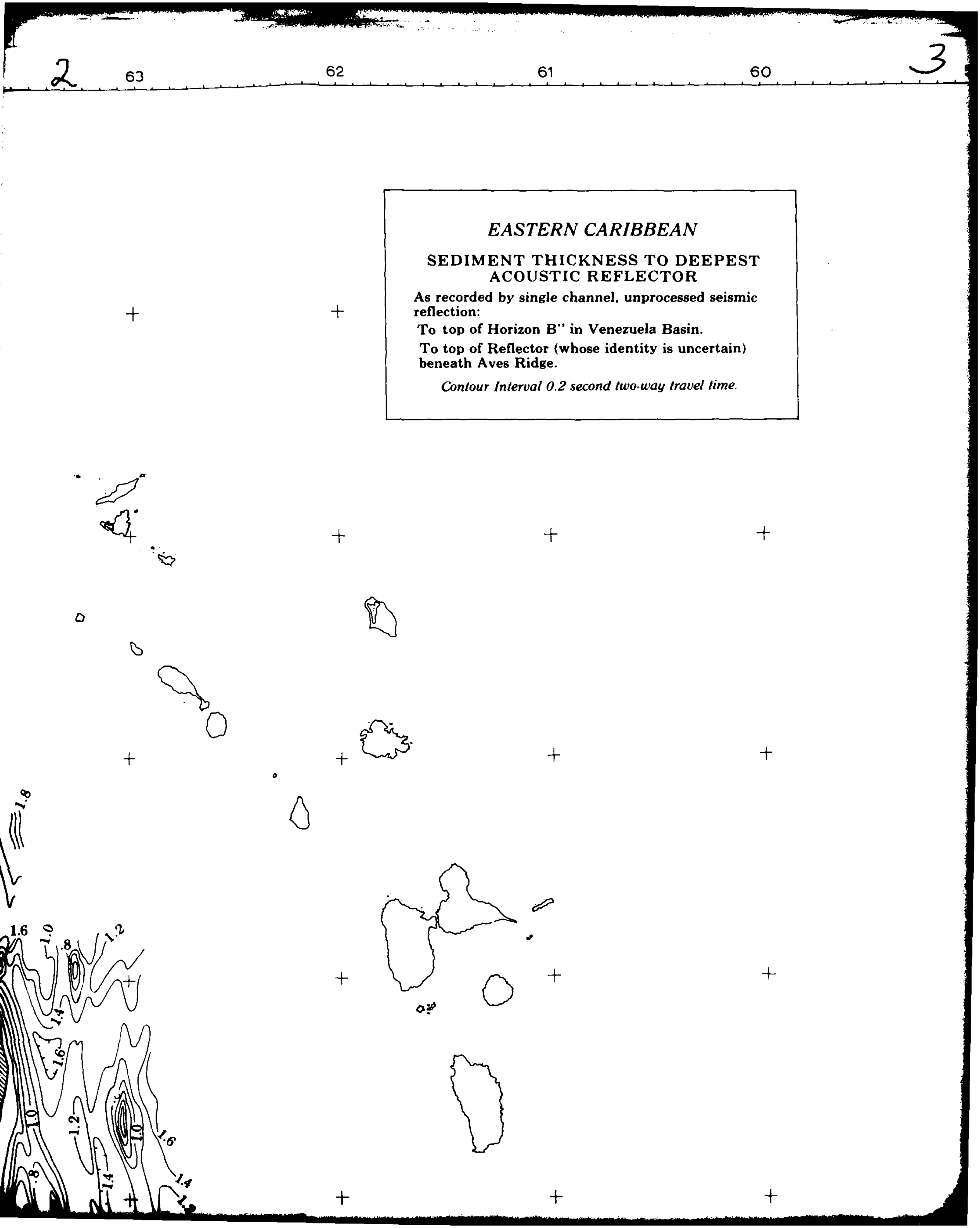


EASTERN CARIBBEAN

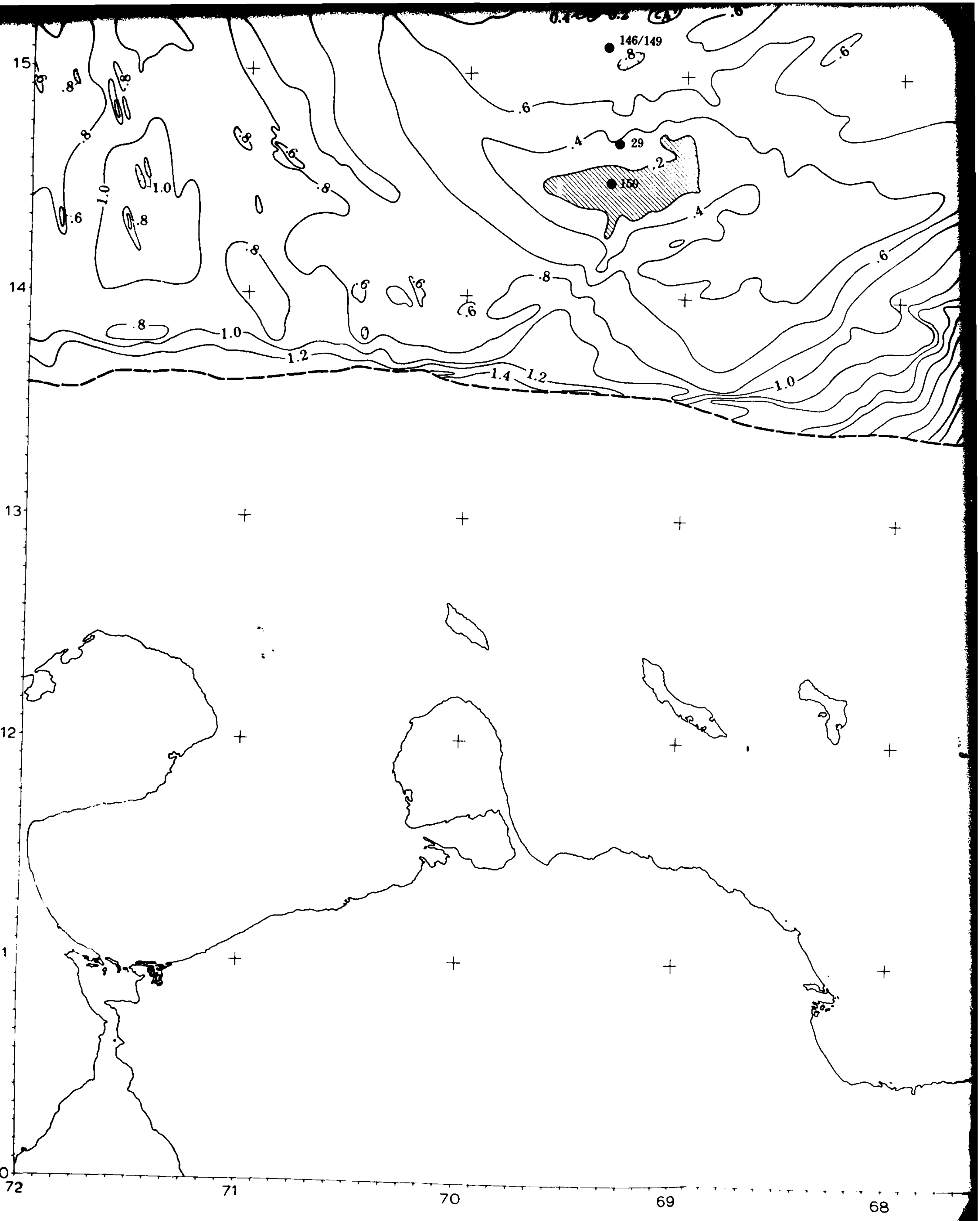
SEDIMENT THICKNESS TO DEEPEST ACOUSTIC REFLECTOR

As recorded by single channel, unprocessed seismic reflection:

To top of Horizon B" in Venezuela Basin.

To top of Reflector (whose identity is uncertain) beneath Aves Ridge.

Contour Interval 0.2 second two-way travel time.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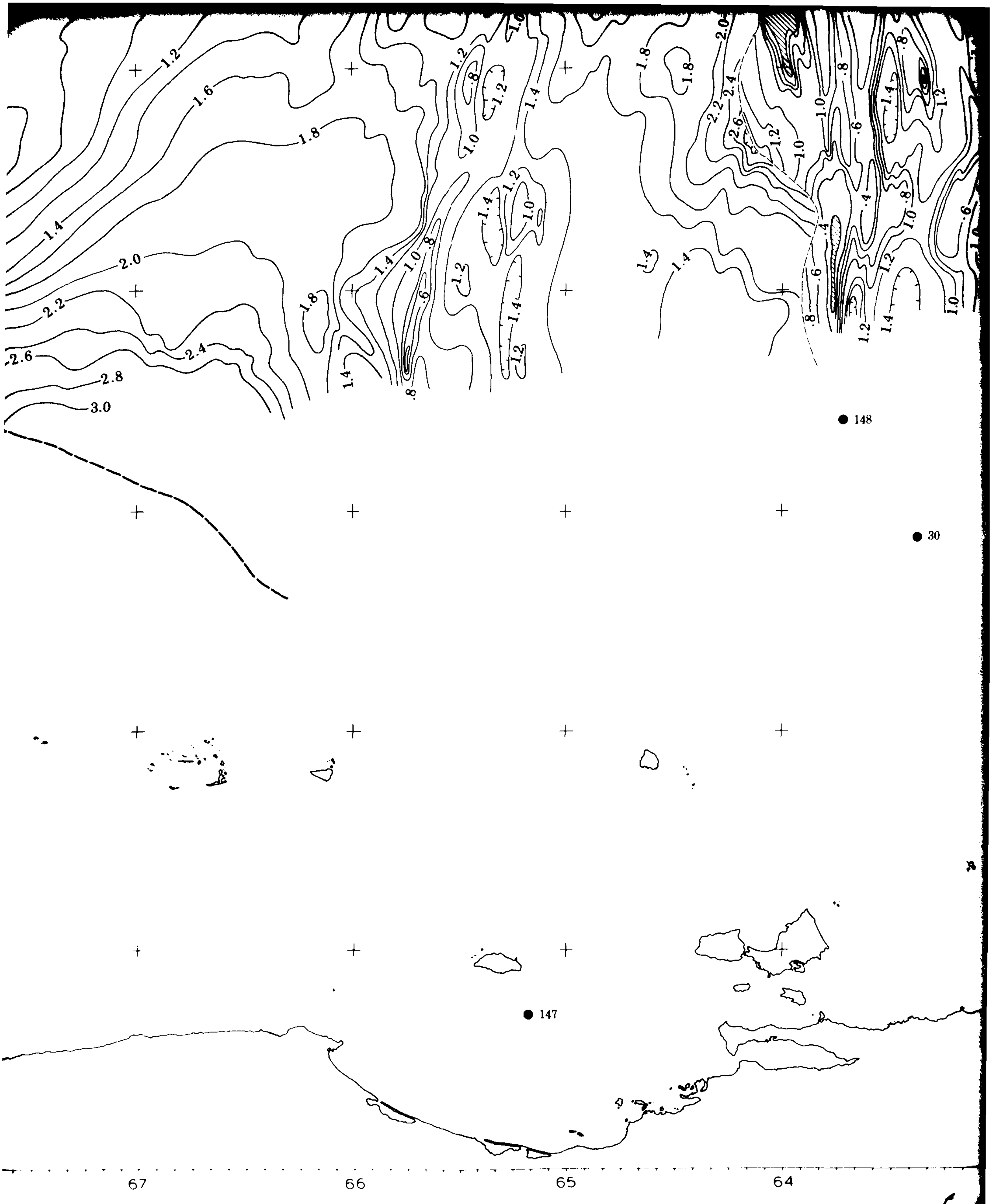
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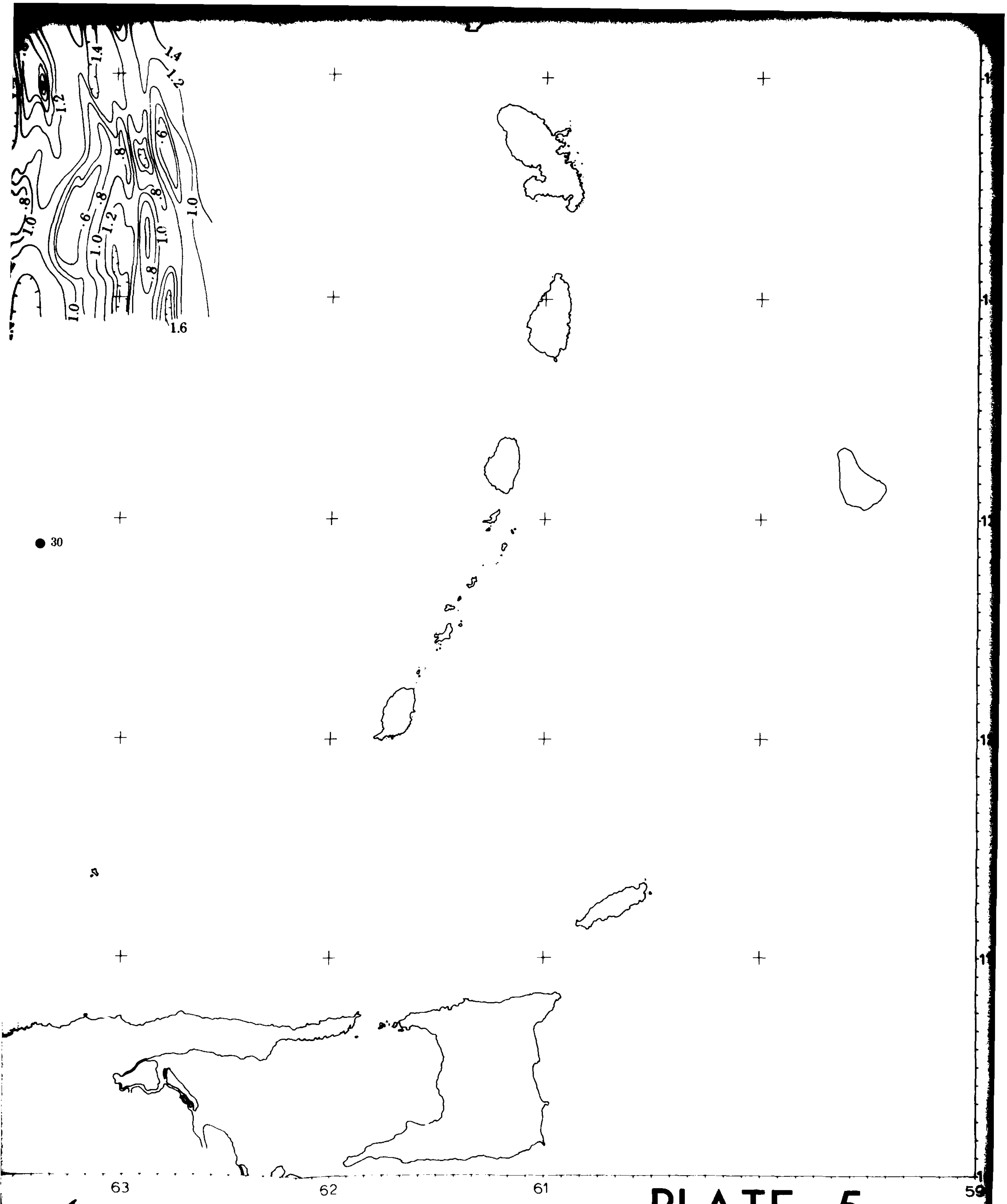

PLATE 5

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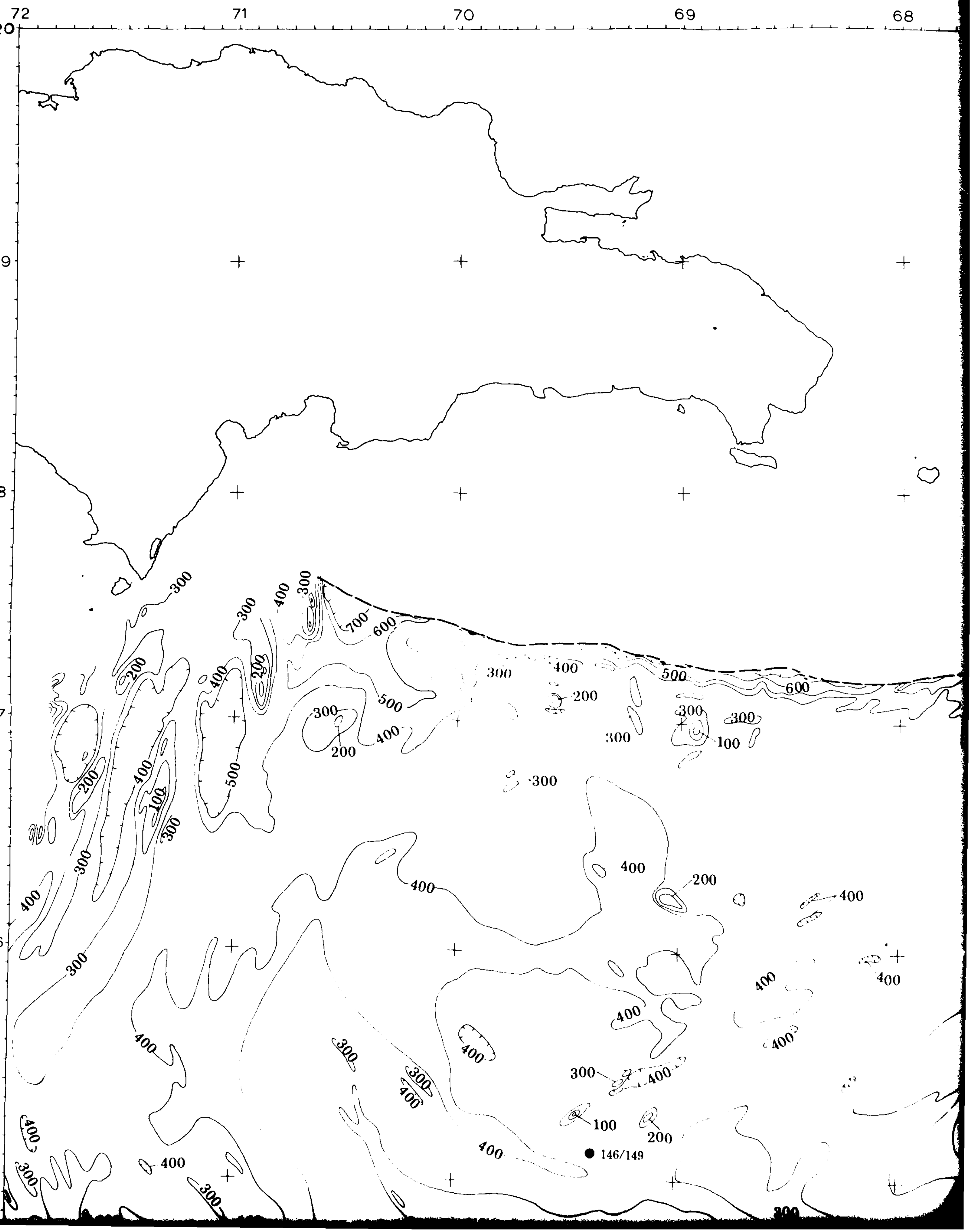
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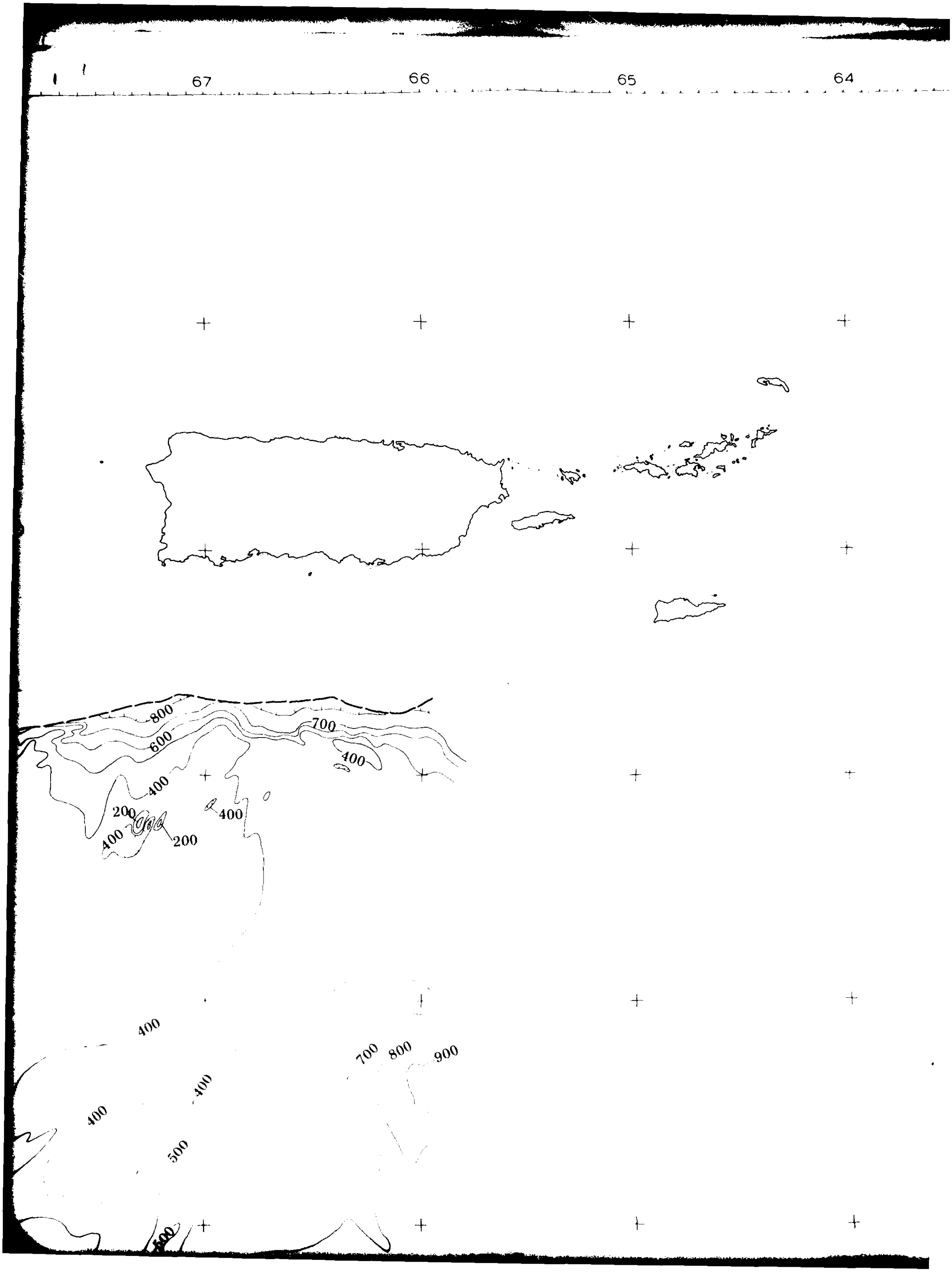
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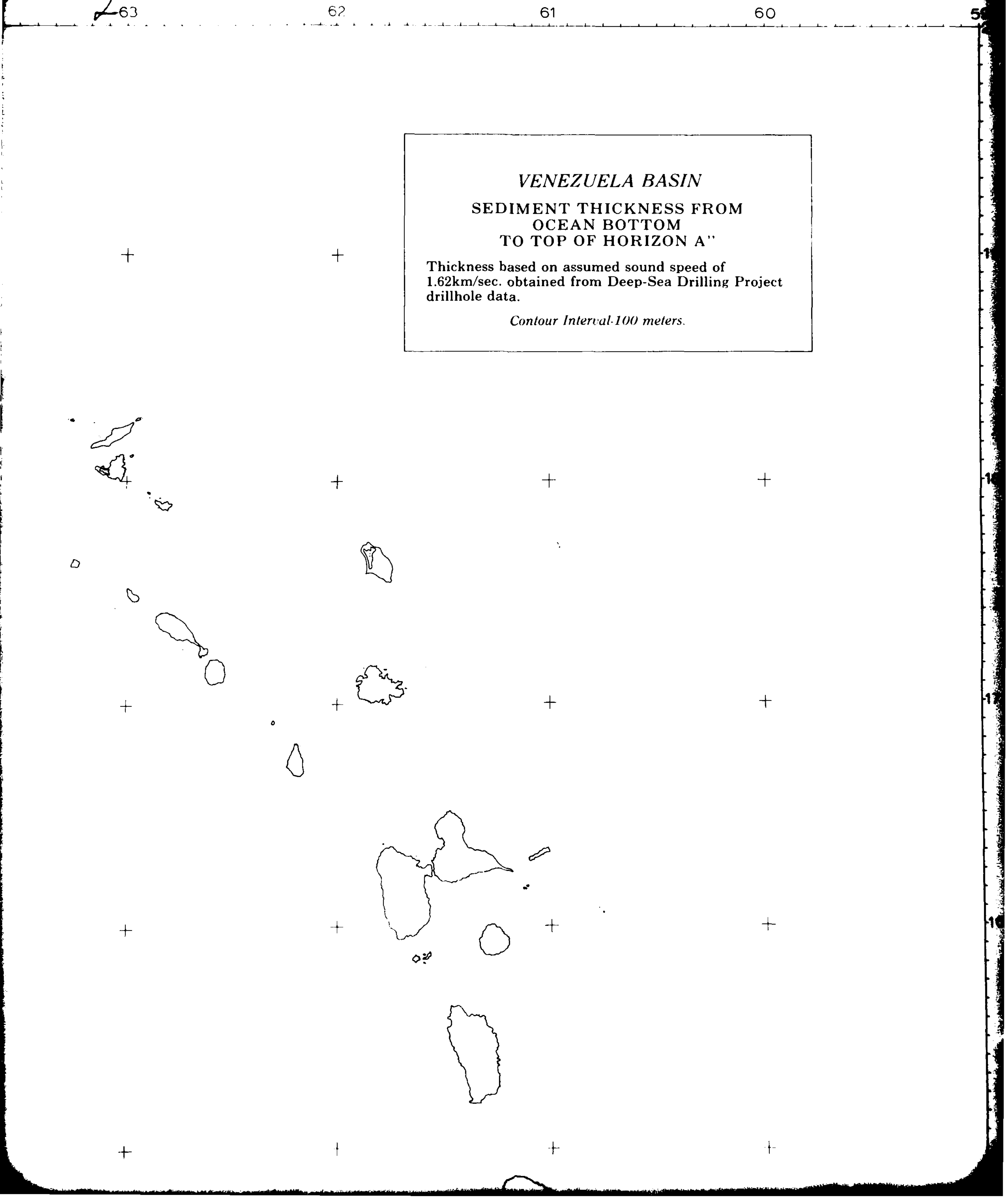
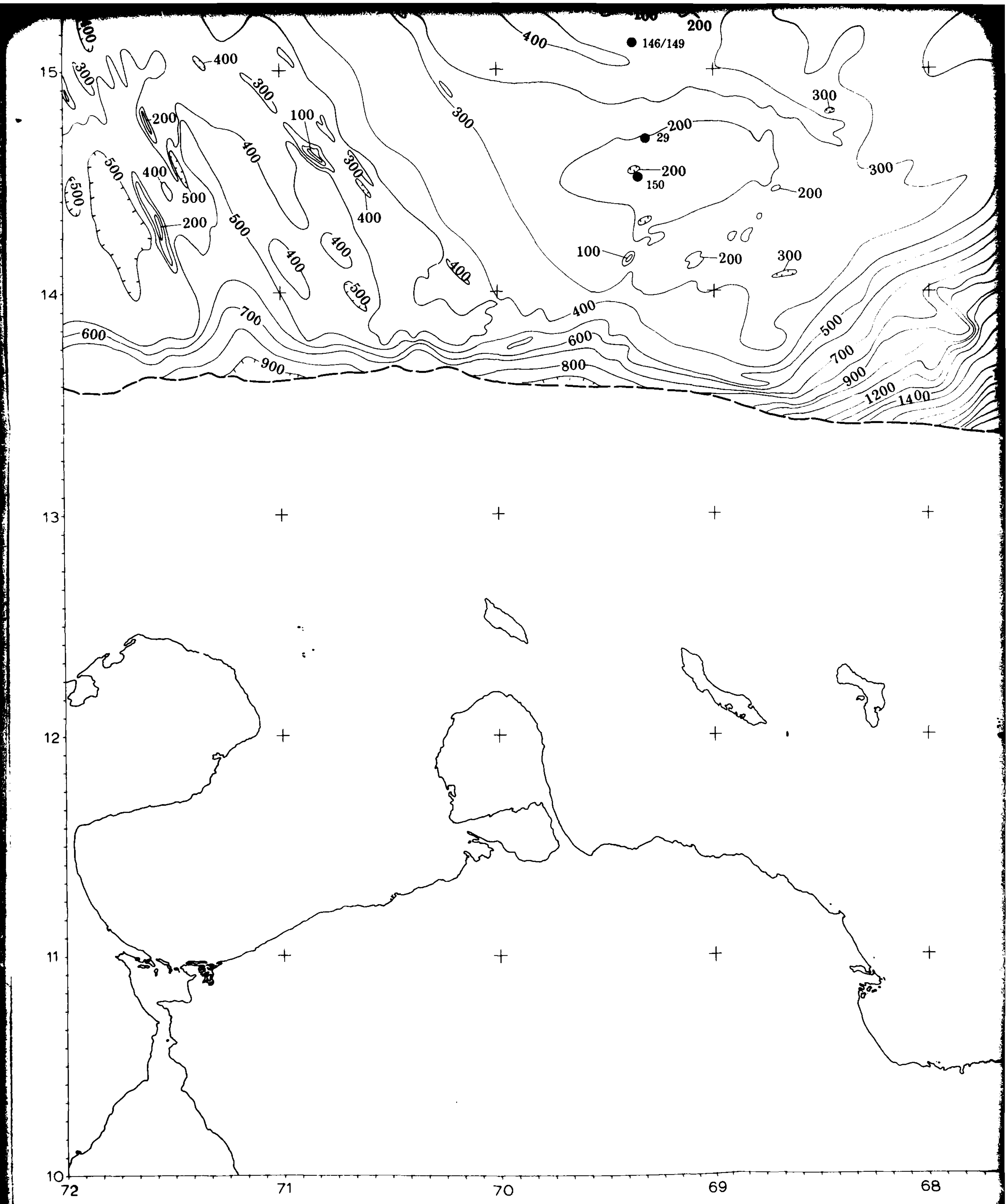


VENEZUELA BASIN

SEDIMENT THICKNESS FROM OCEAN BOTTOM TO TOP OF HORIZON A''

Thickness based on assumed sound speed of 1.62km/sec. obtained from Deep-Sea Drilling Project drillhole data.

Contour Interval-100 meters.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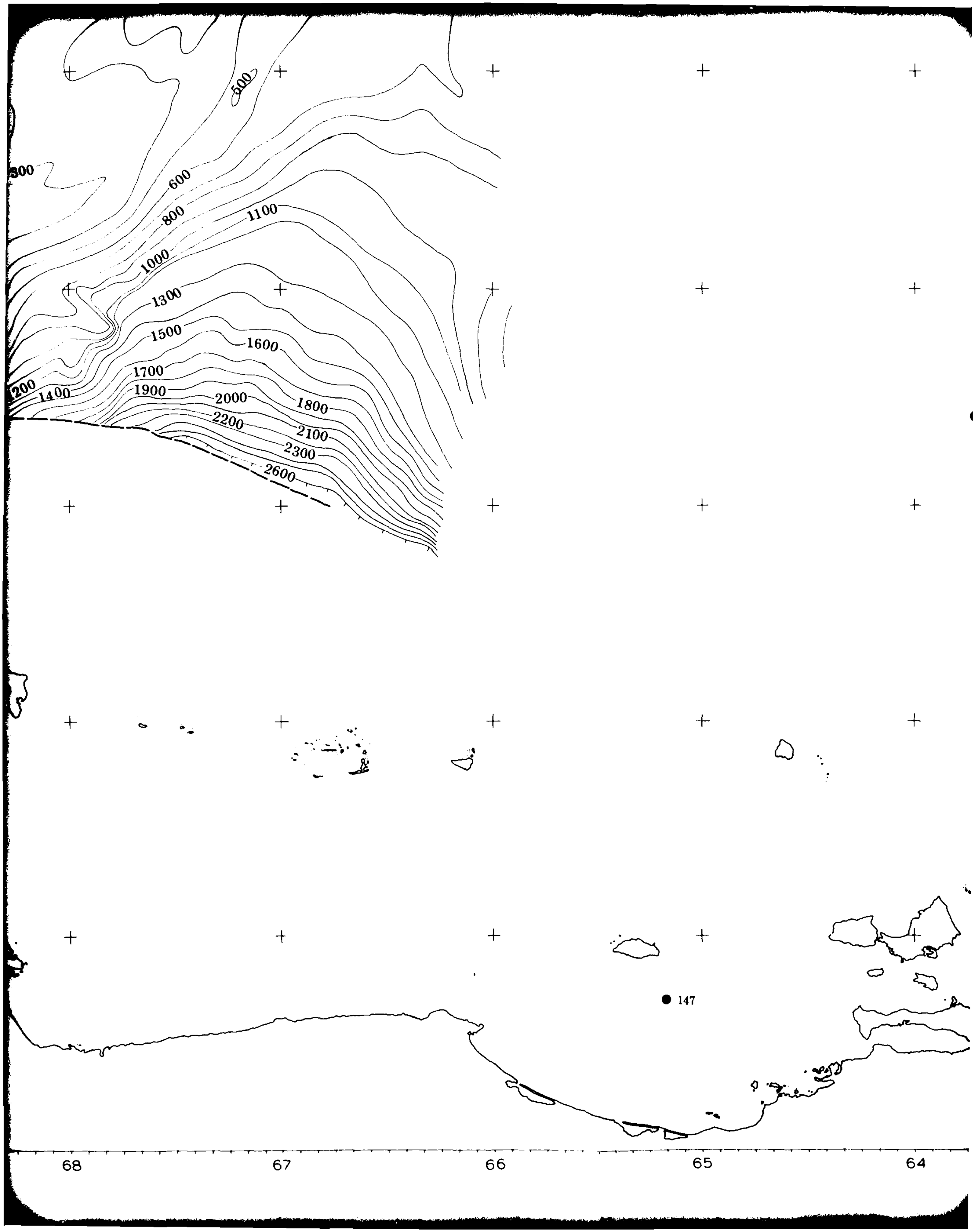
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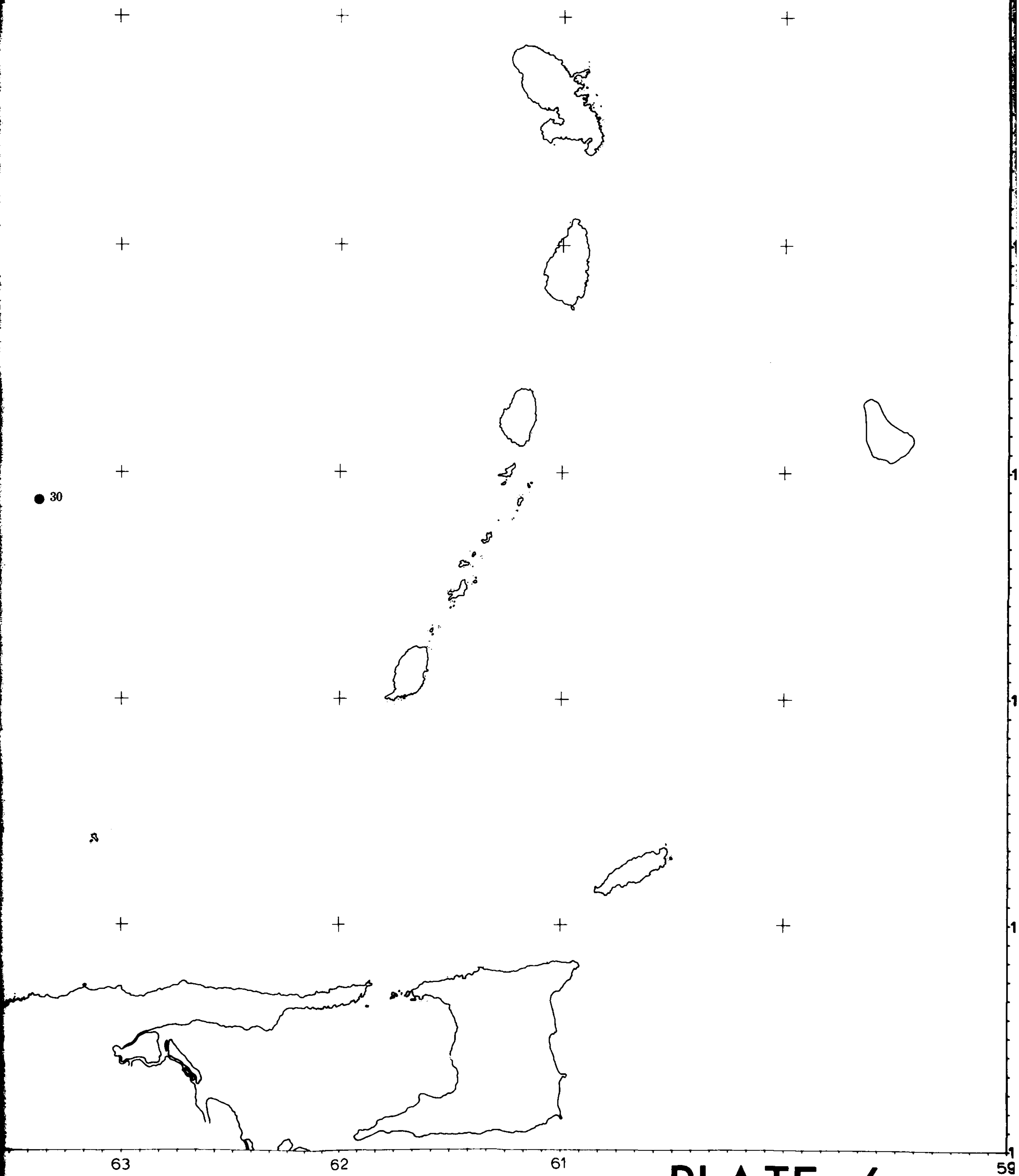
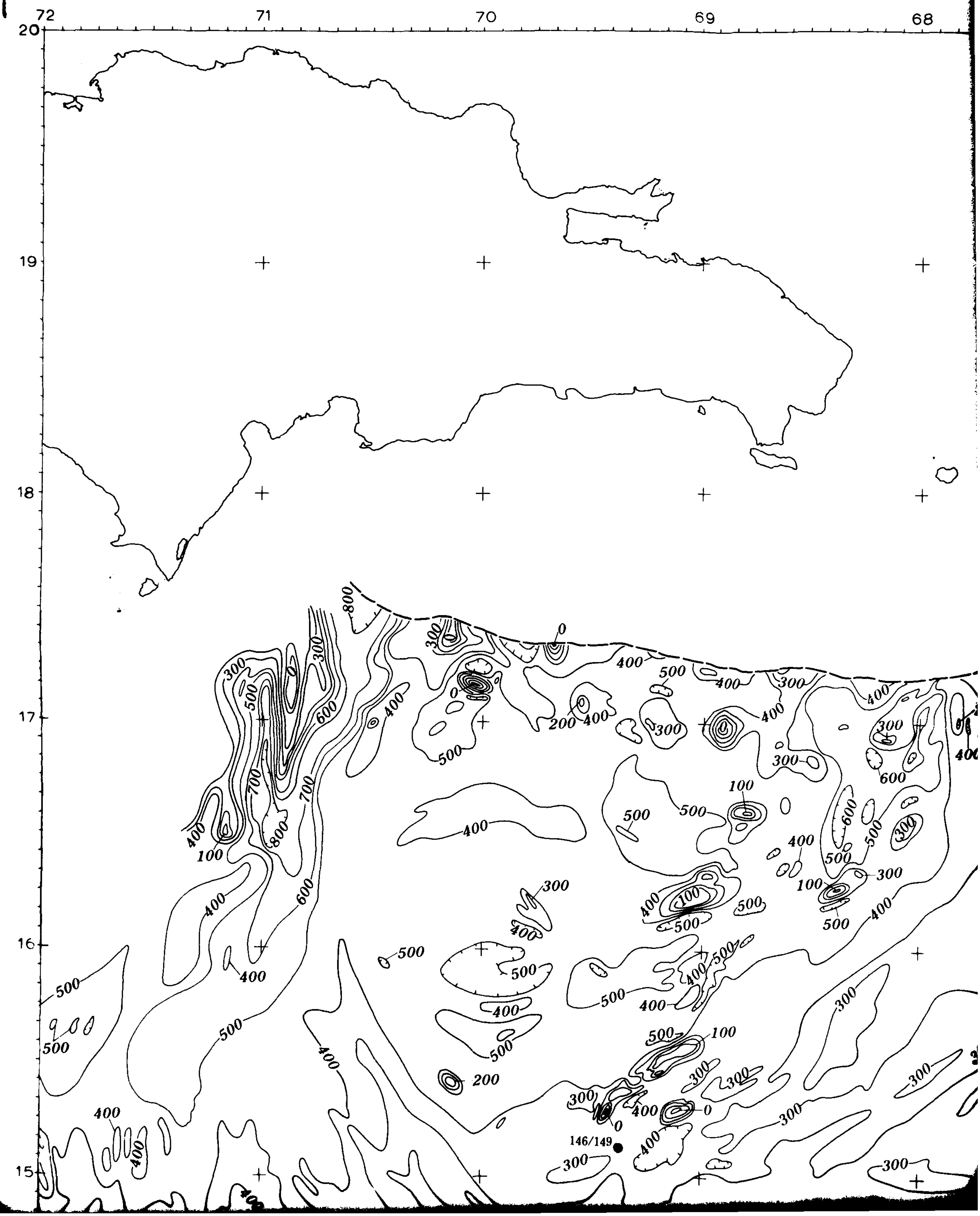


PLATE 6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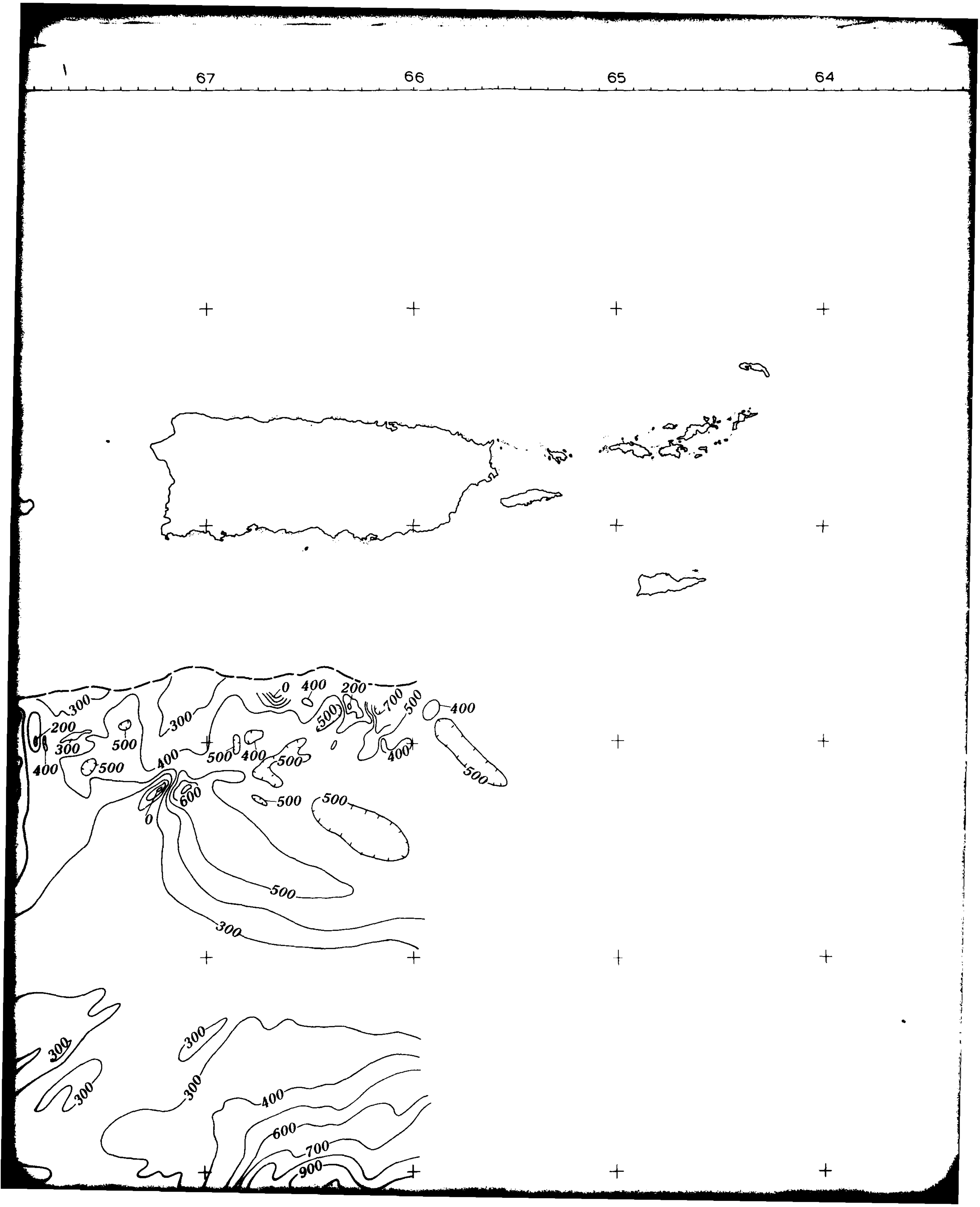
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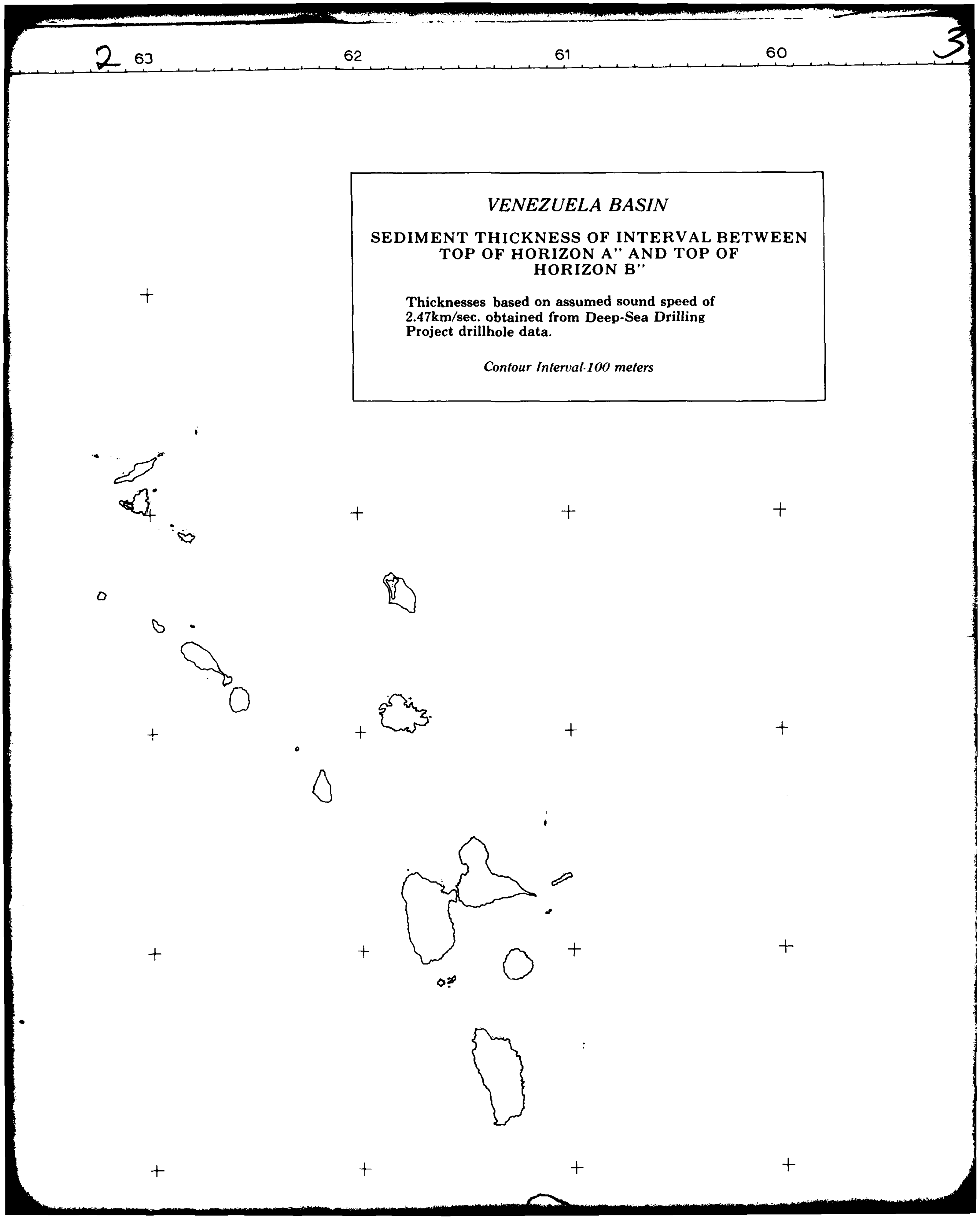
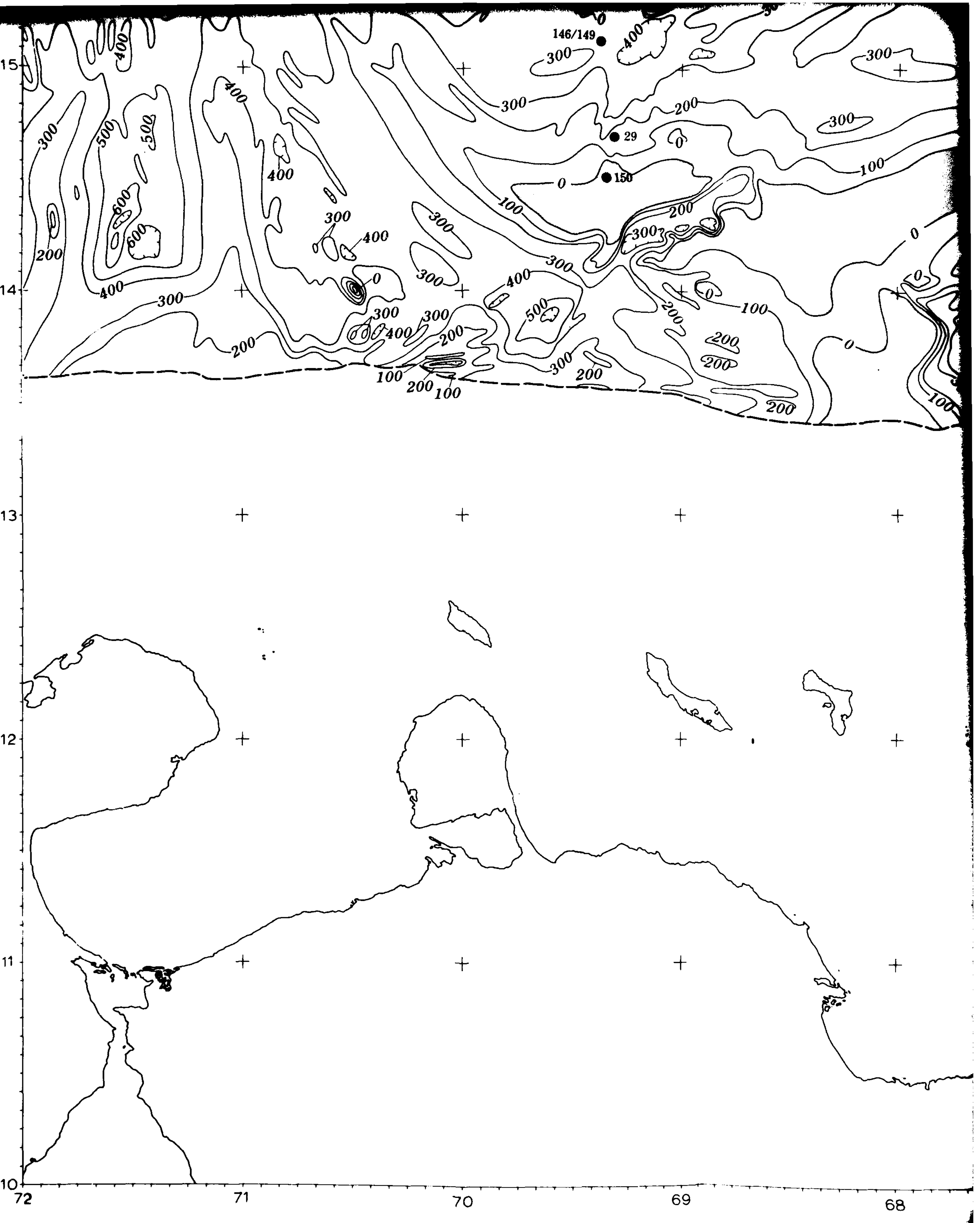


VENEZUELA BASIN

SEDIMENT THICKNESS OF INTERVAL BETWEEN TOP OF HORIZON A" AND TOP OF HORIZON B"

Thicknesses based on assumed sound speed of 2.47km/sec. obtained from Deep-Sea Drilling Project drillhole data.

Contour Interval-100 meters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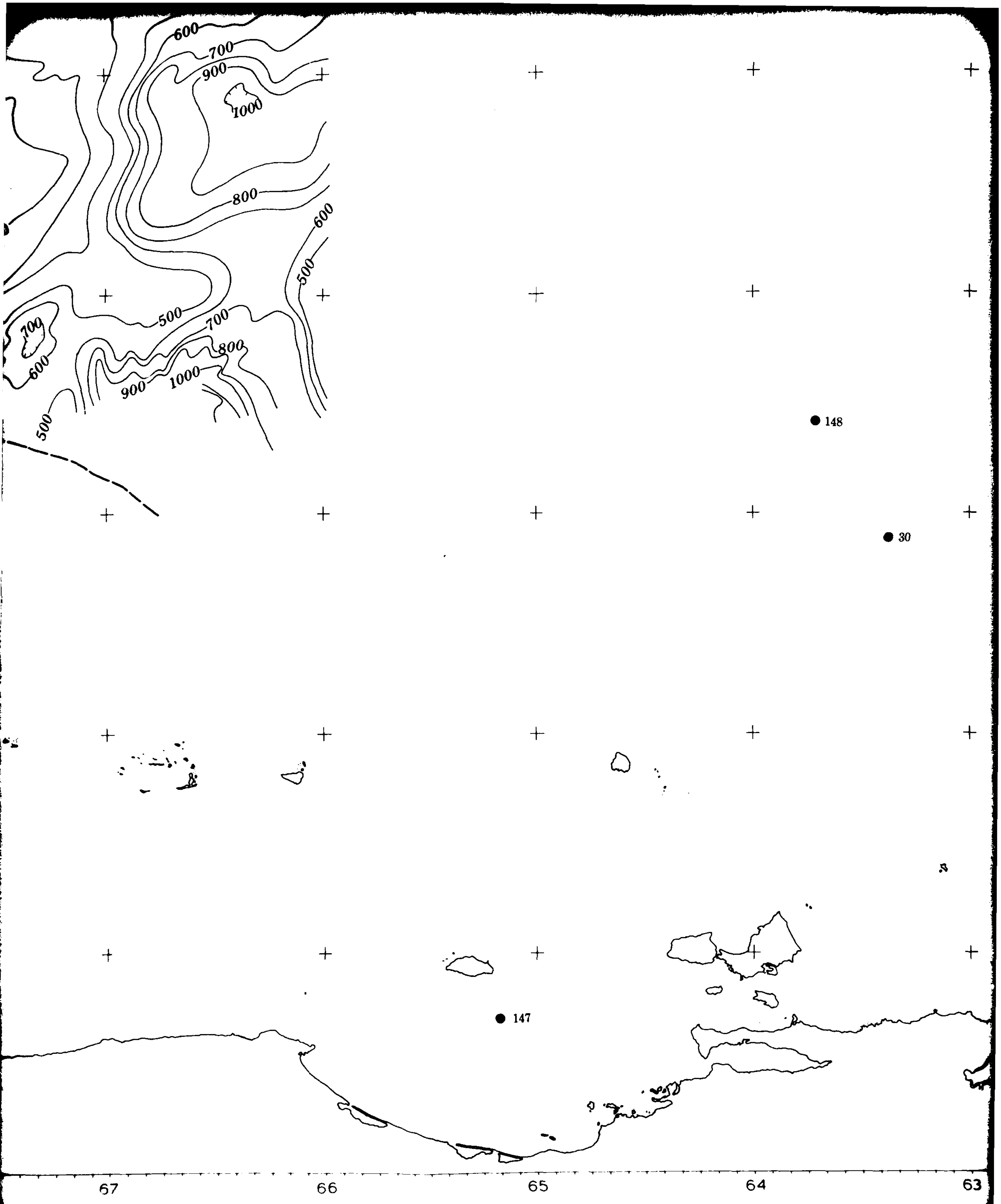
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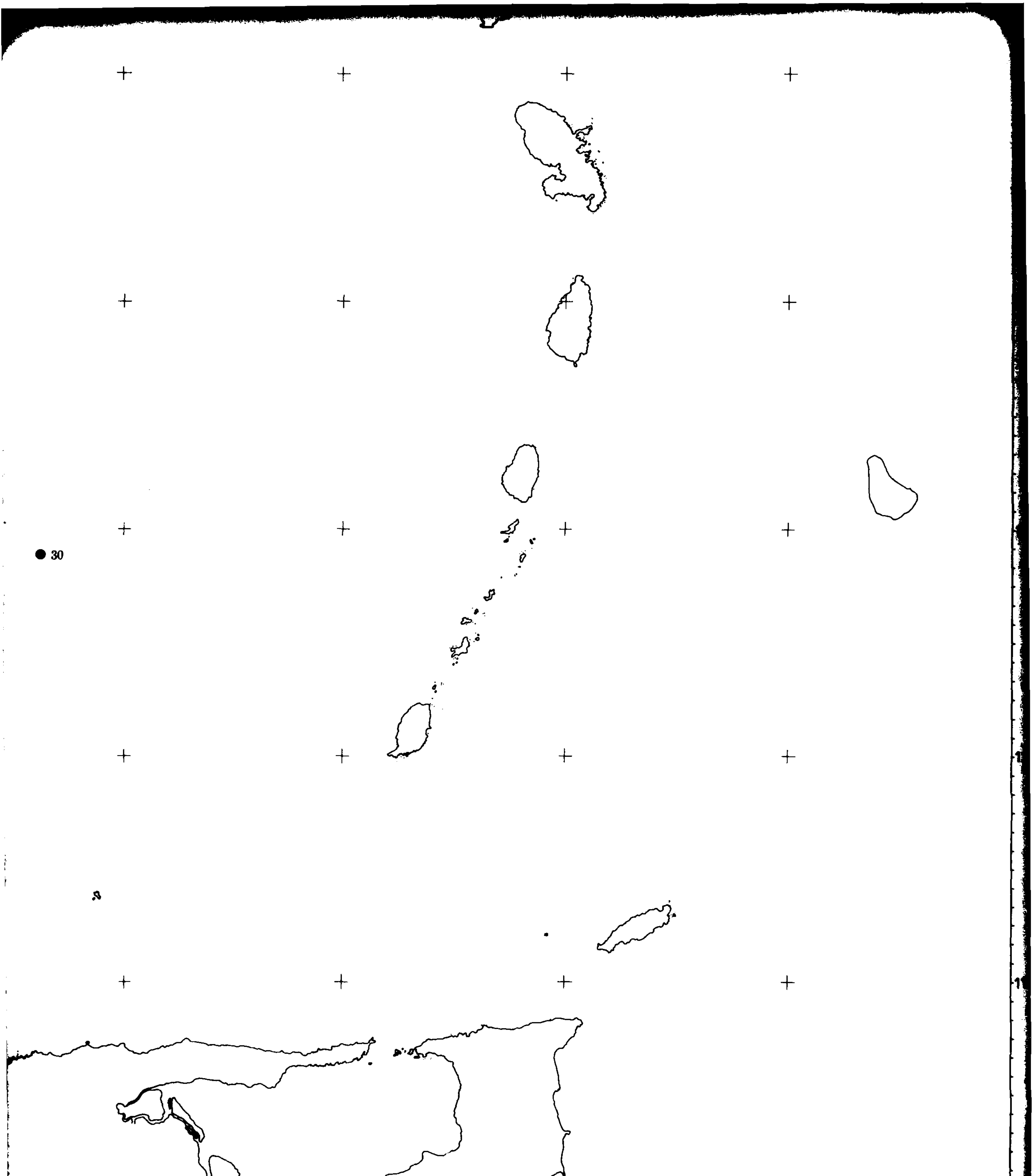
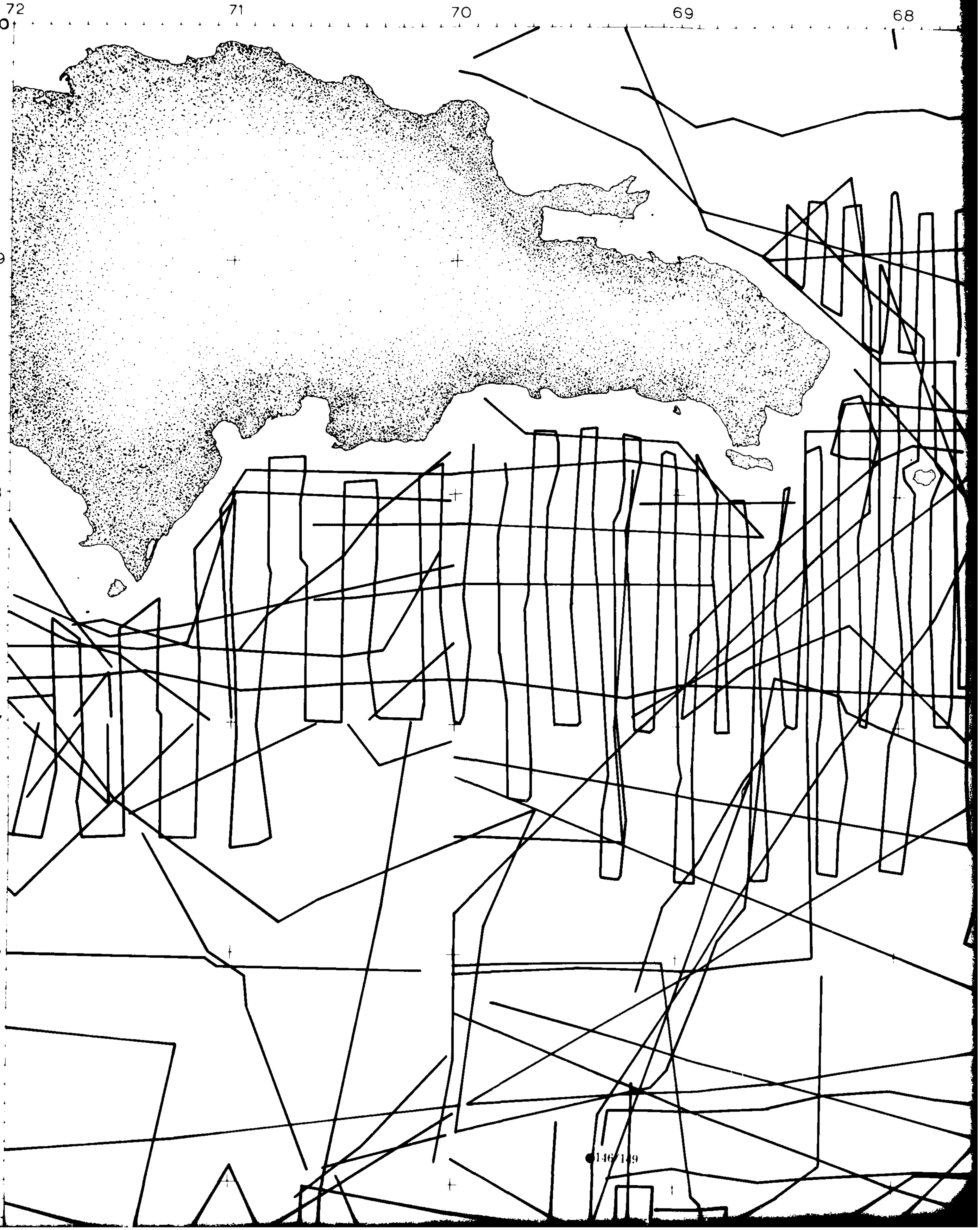


PLATE 7

5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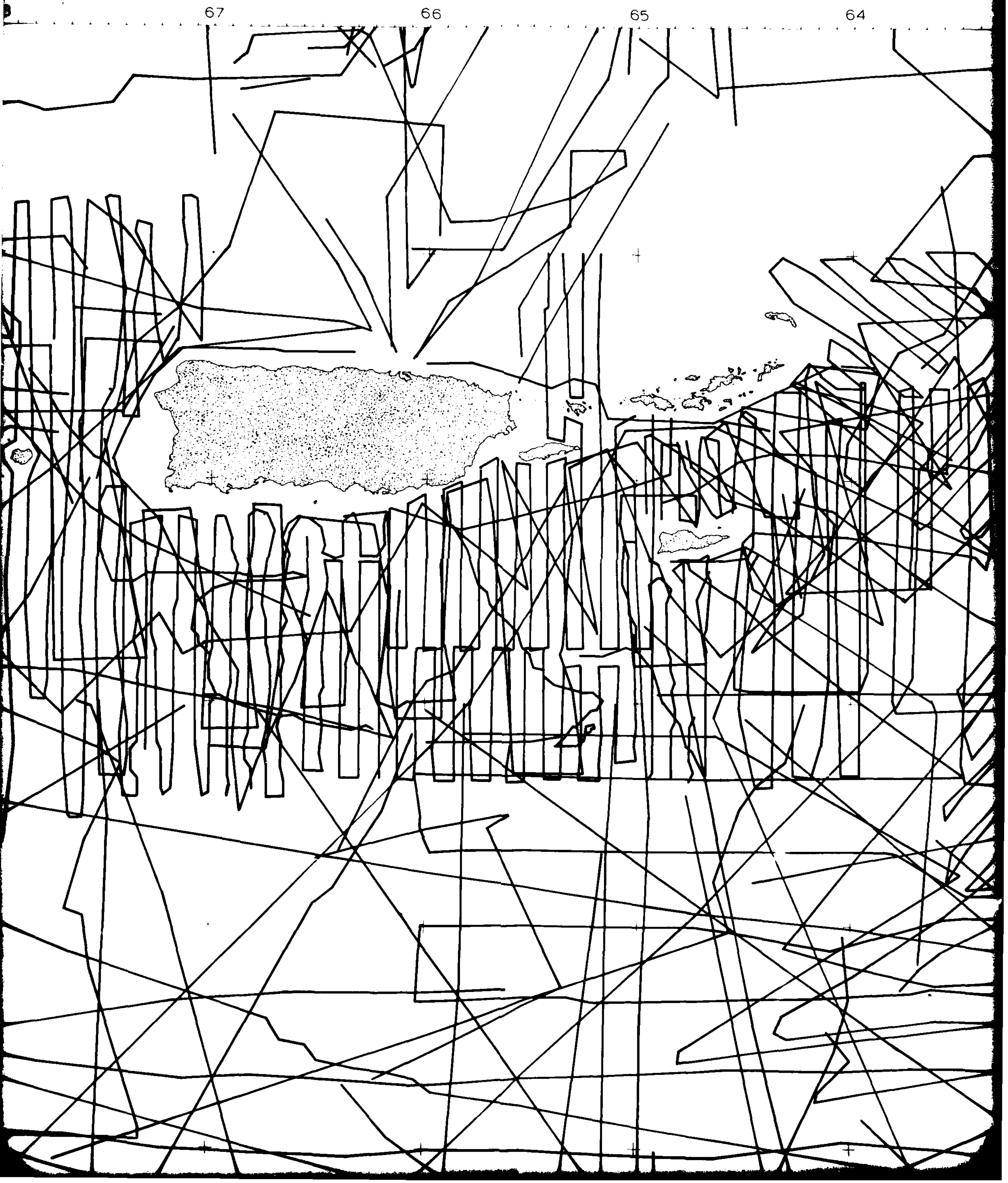
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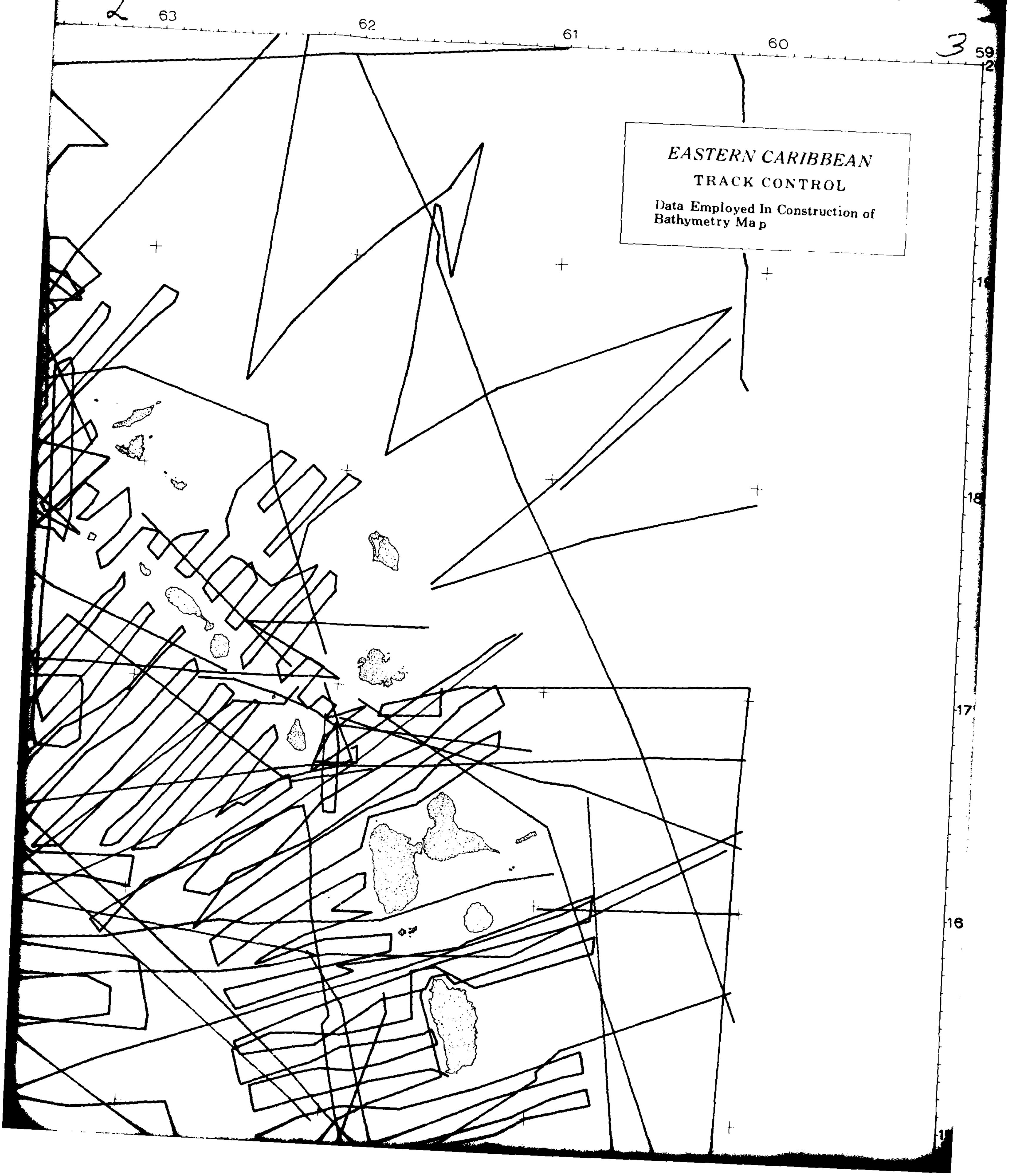
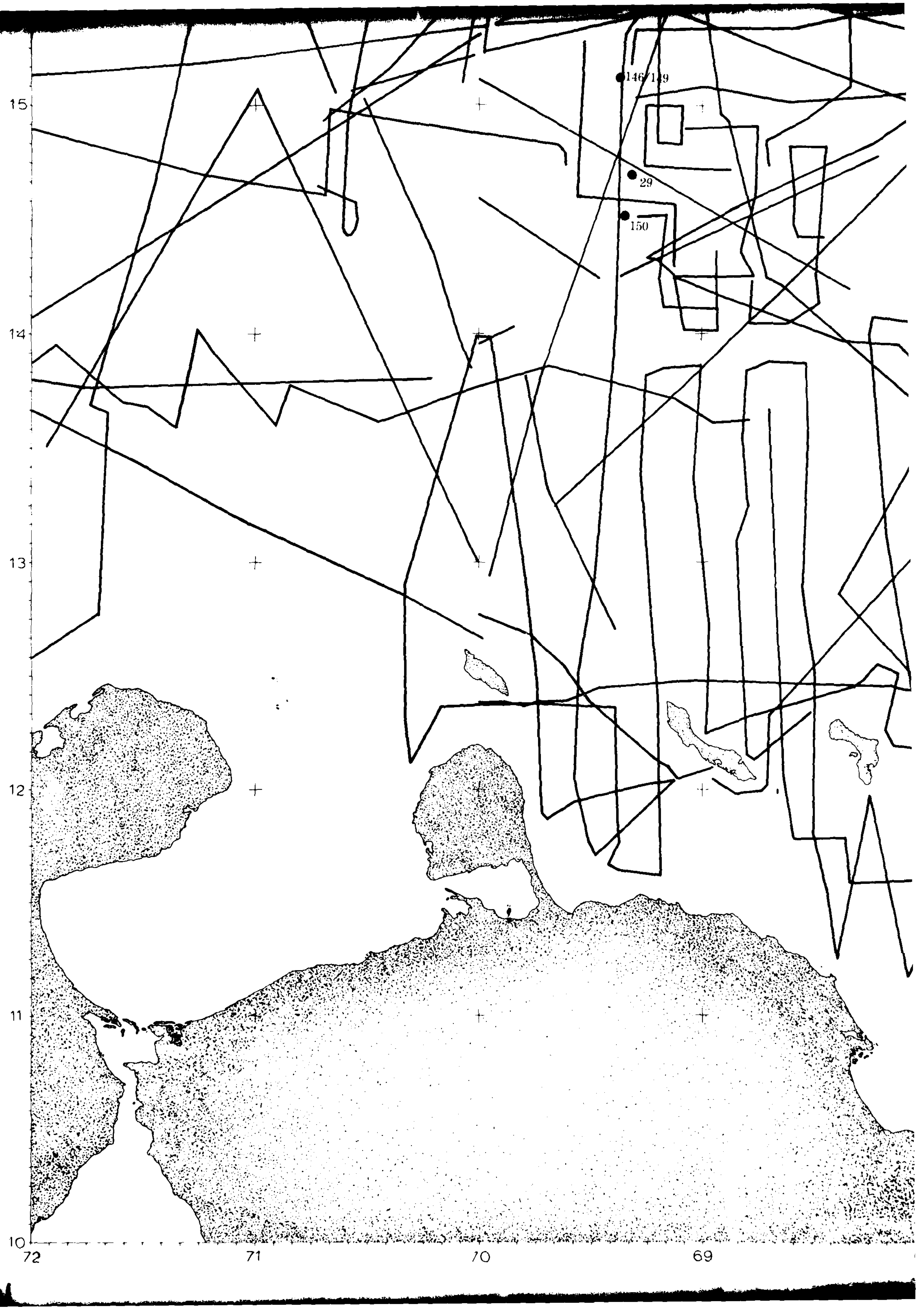


EASTERN CARIBBEAN

TRACK CONTROL

Data Employed In Construction of Bathymetry Map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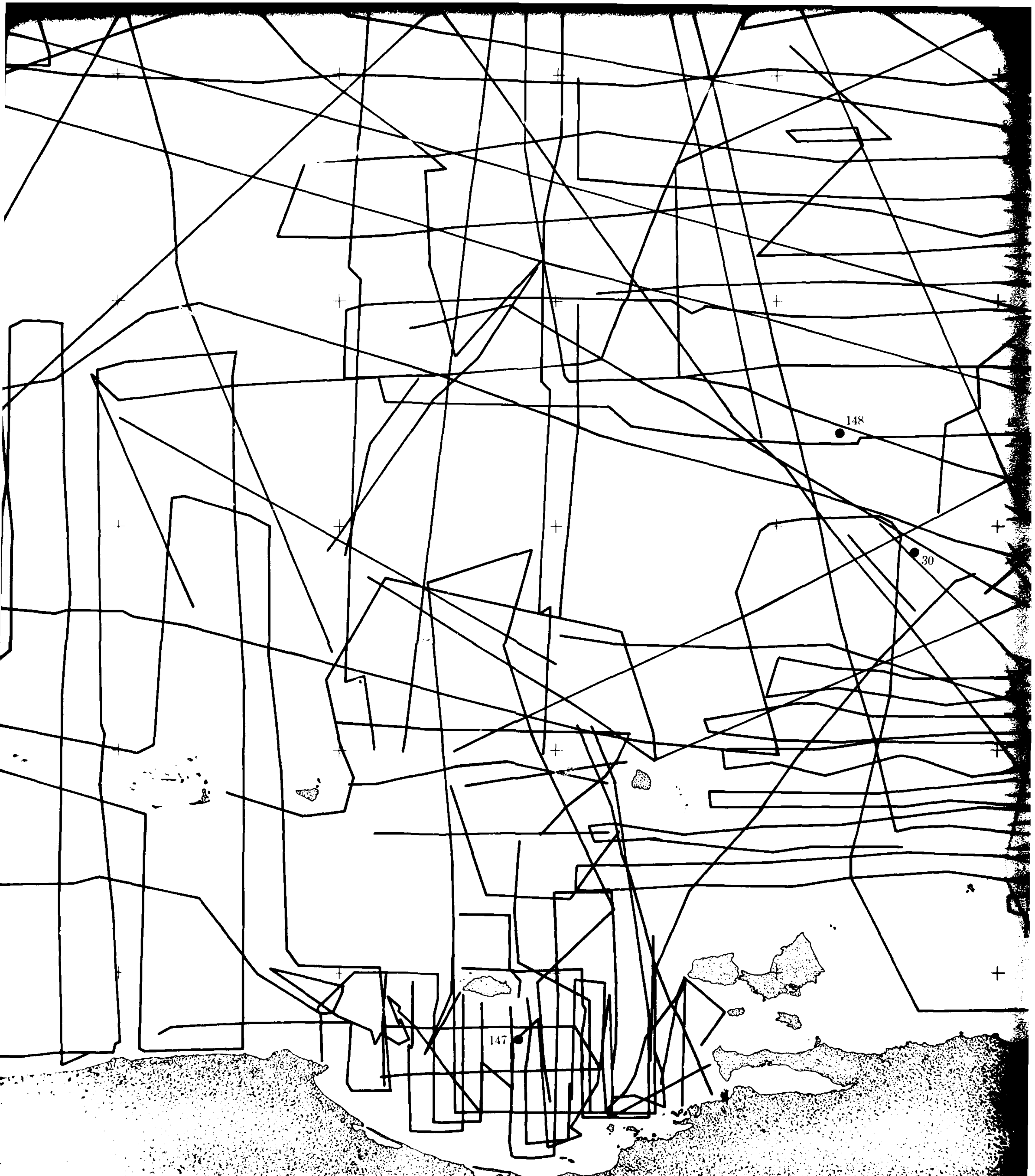
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PLATE 8

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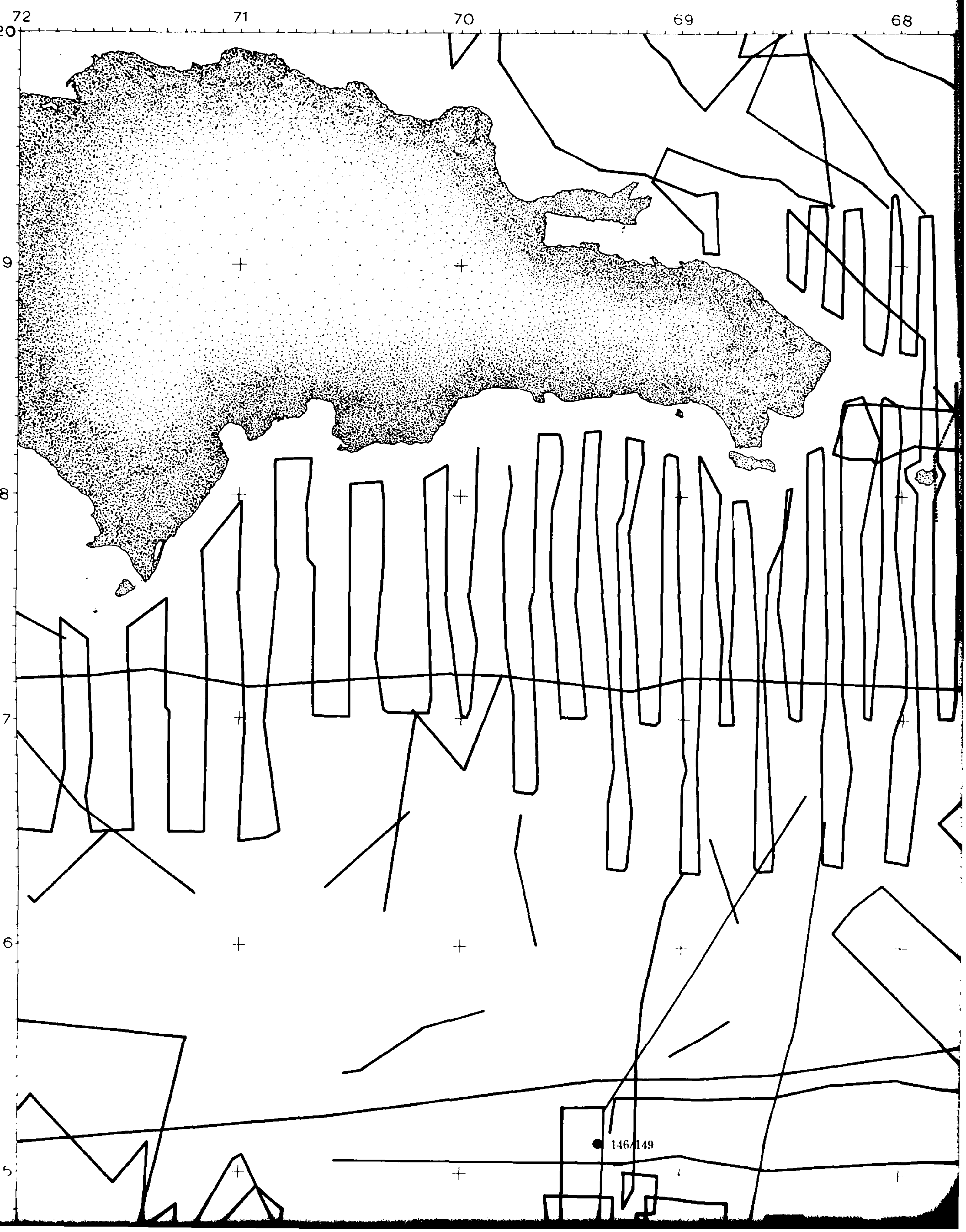

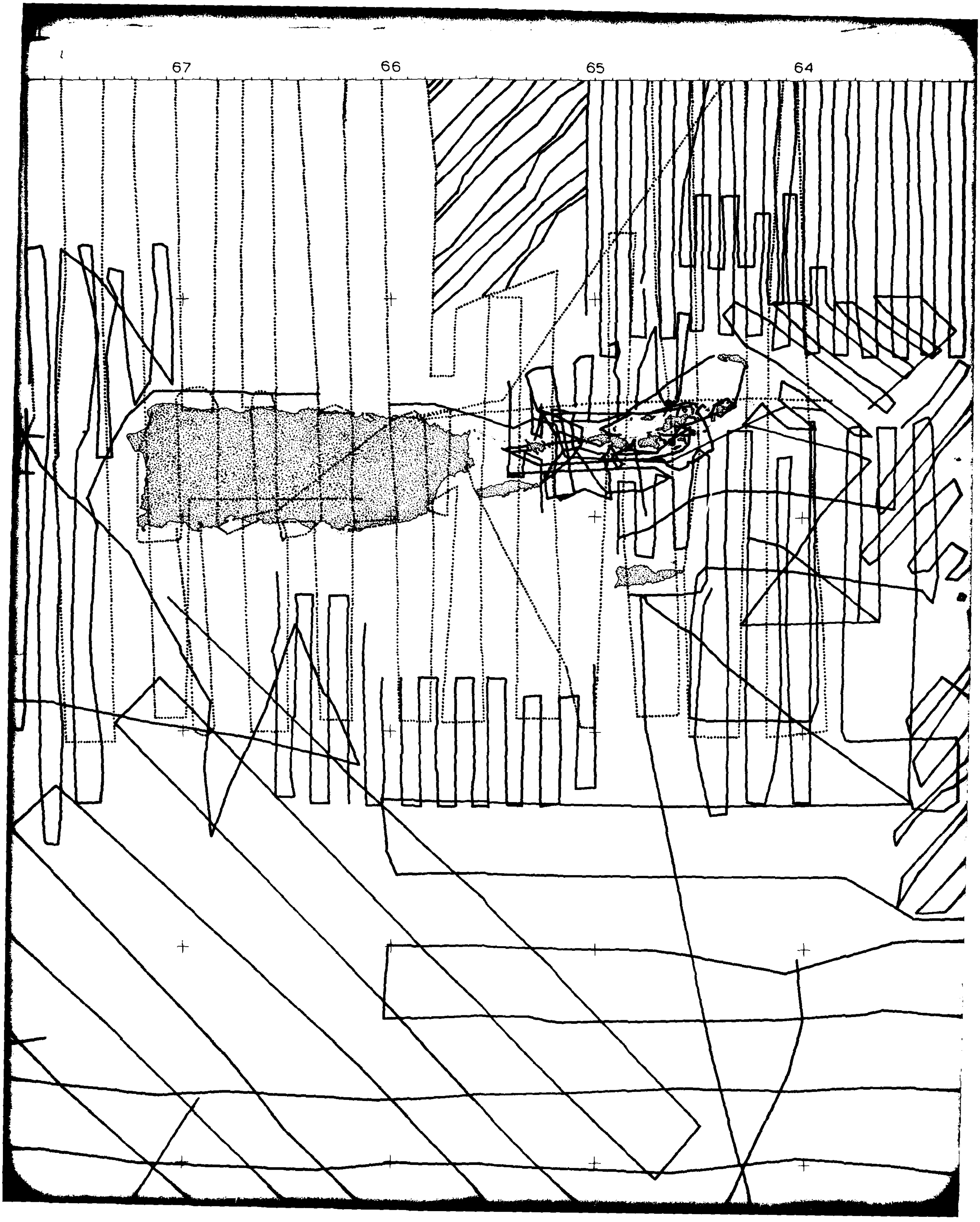
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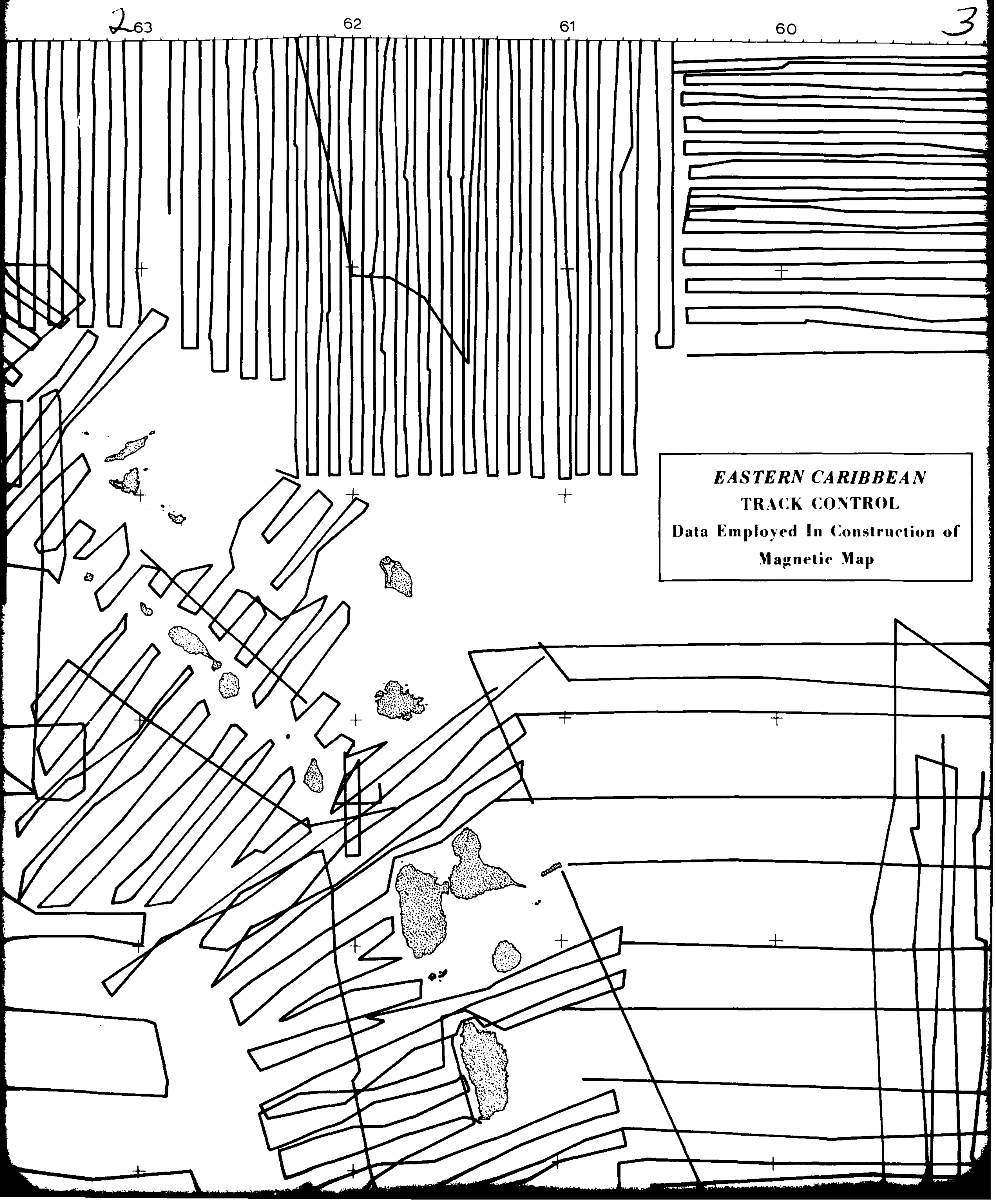
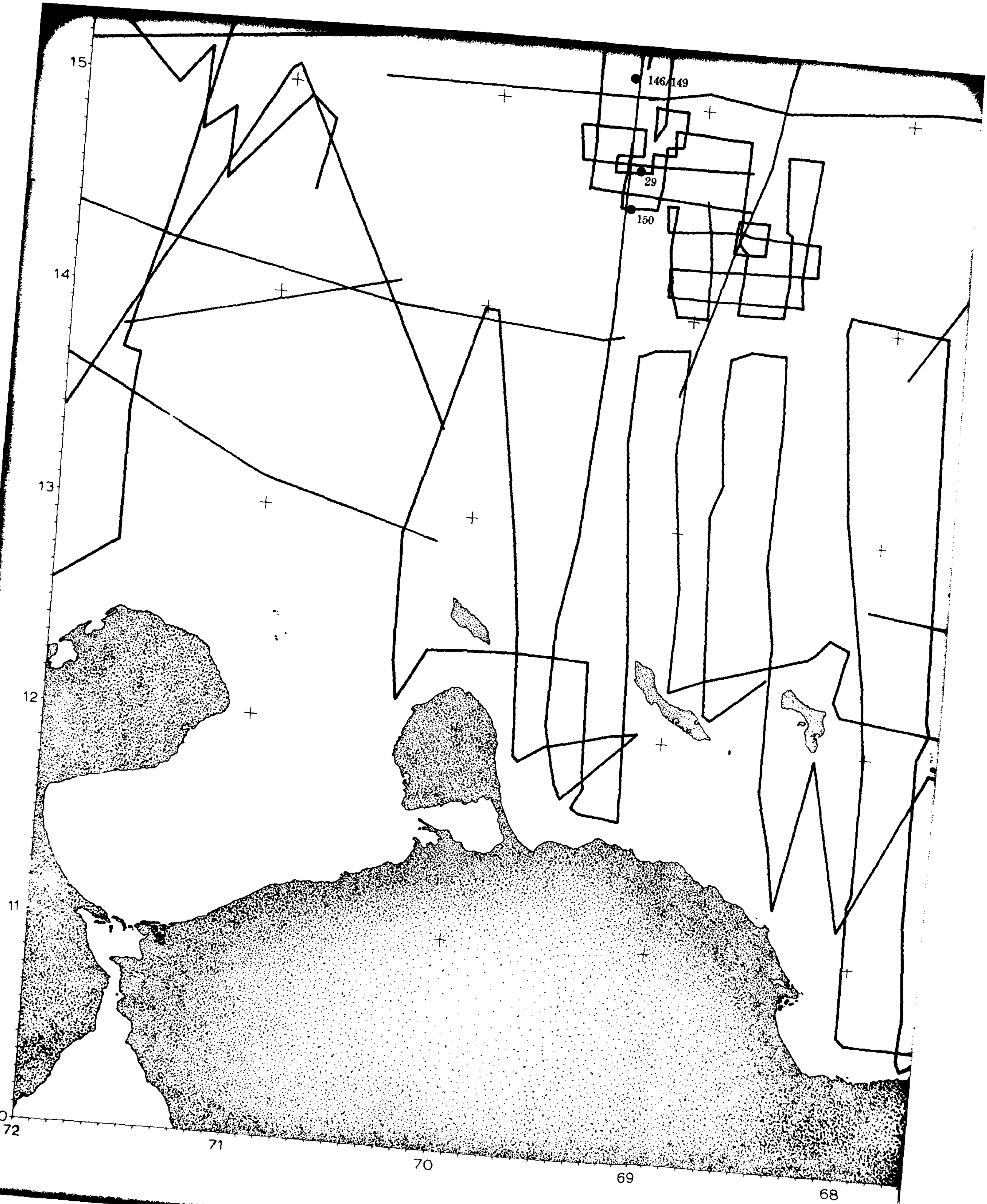


EASTERN CARIBBEAN

TRACK CONTROL

Data Employed In Construction of Magnetic Map



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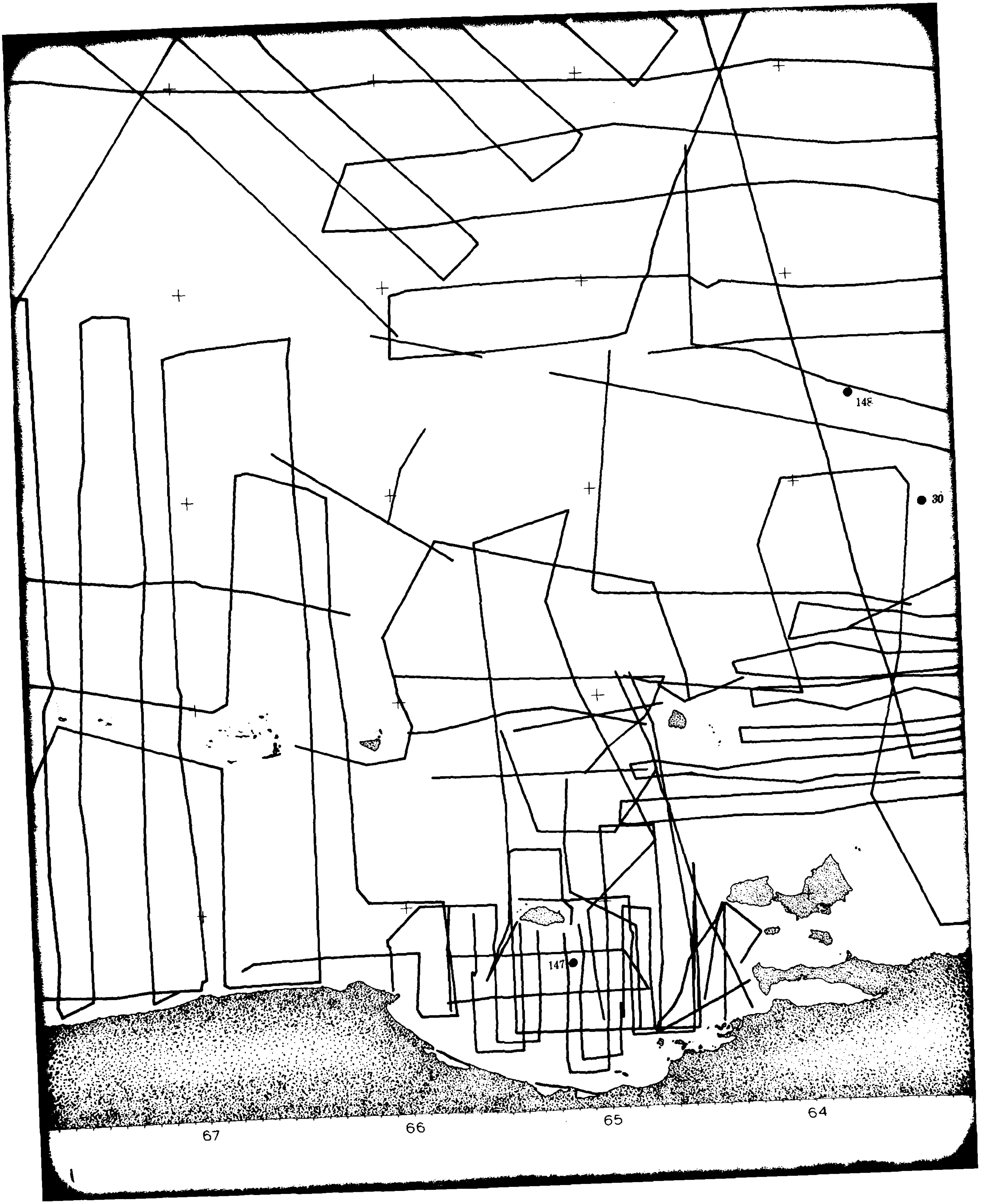
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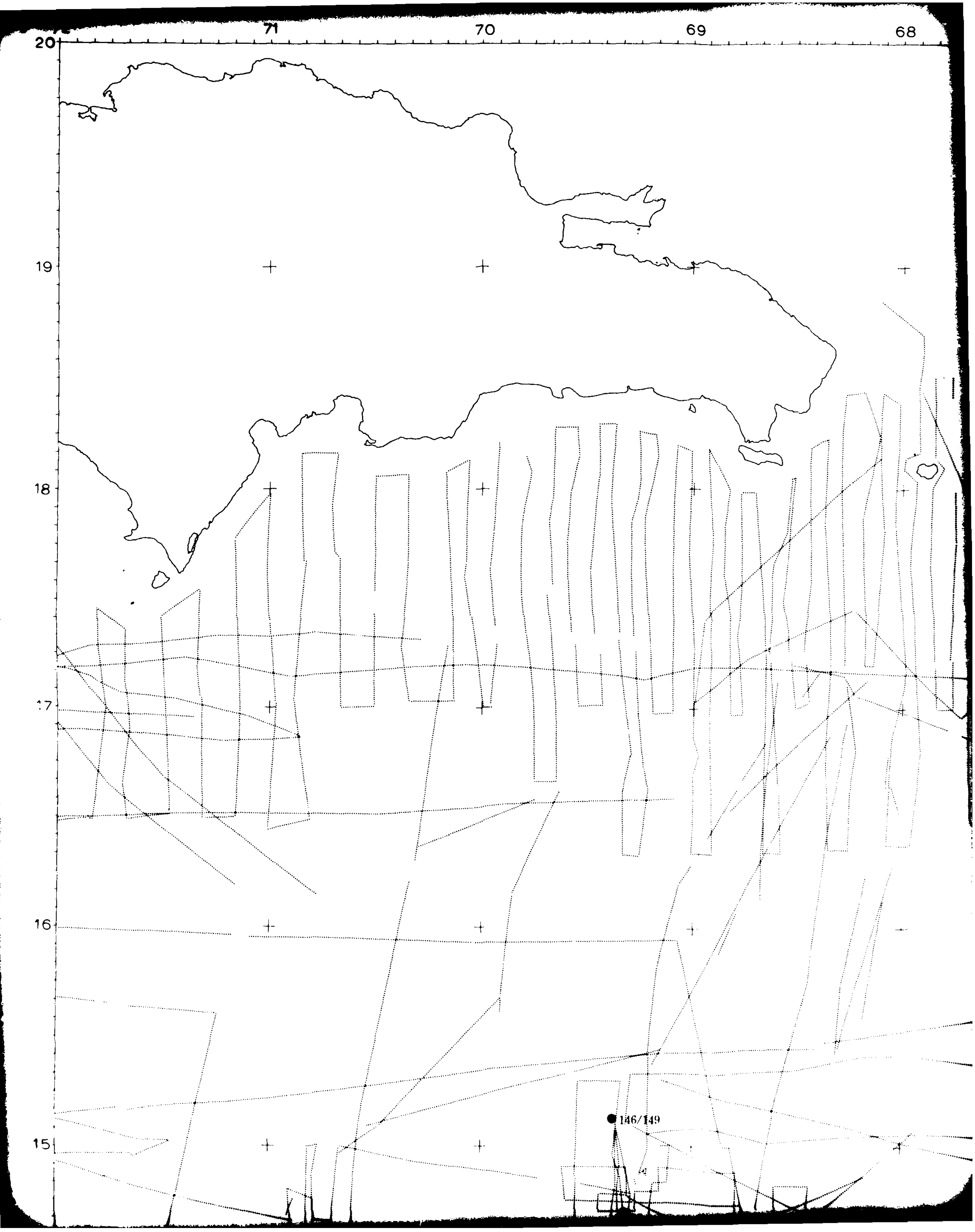
PLATE 9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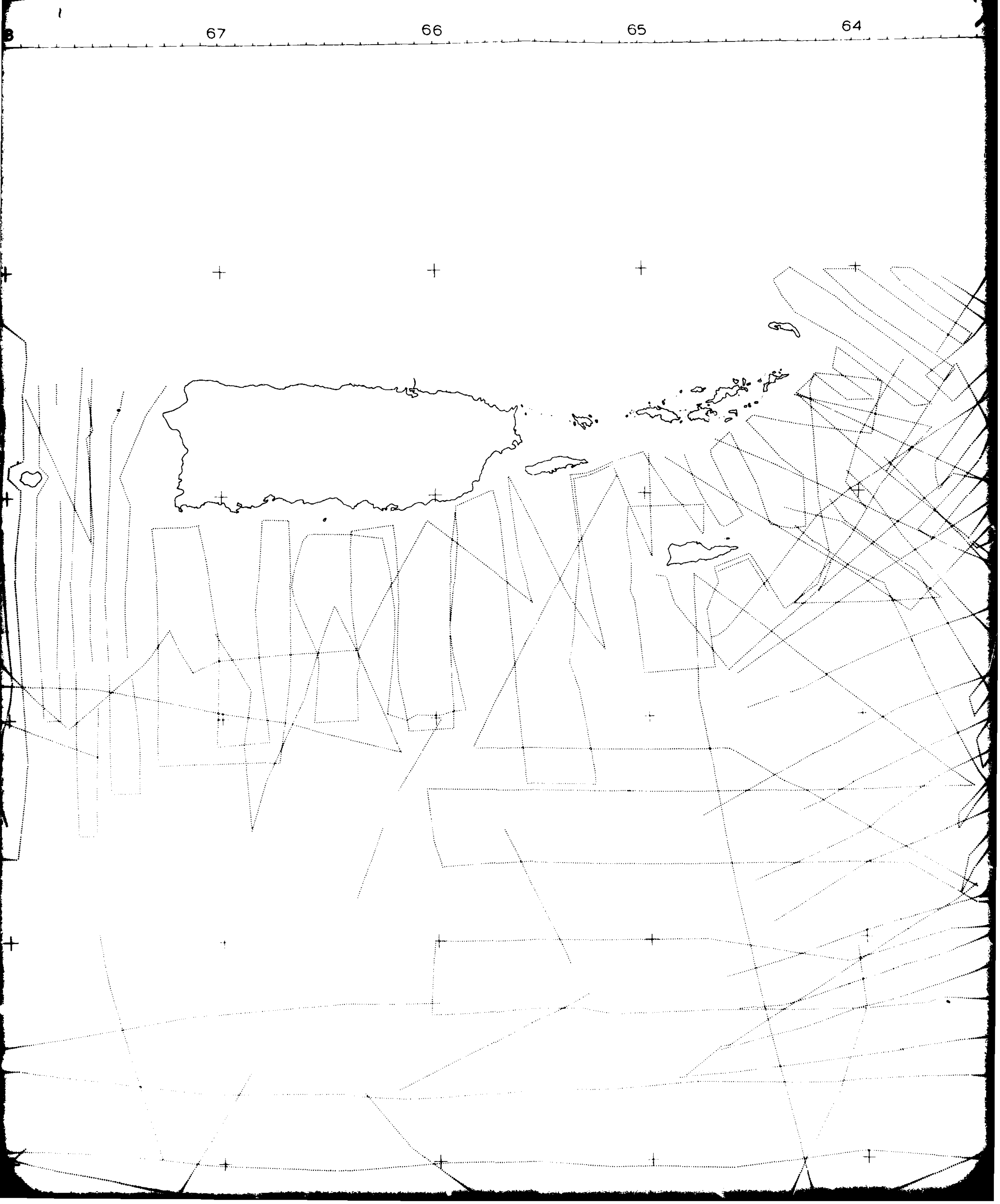
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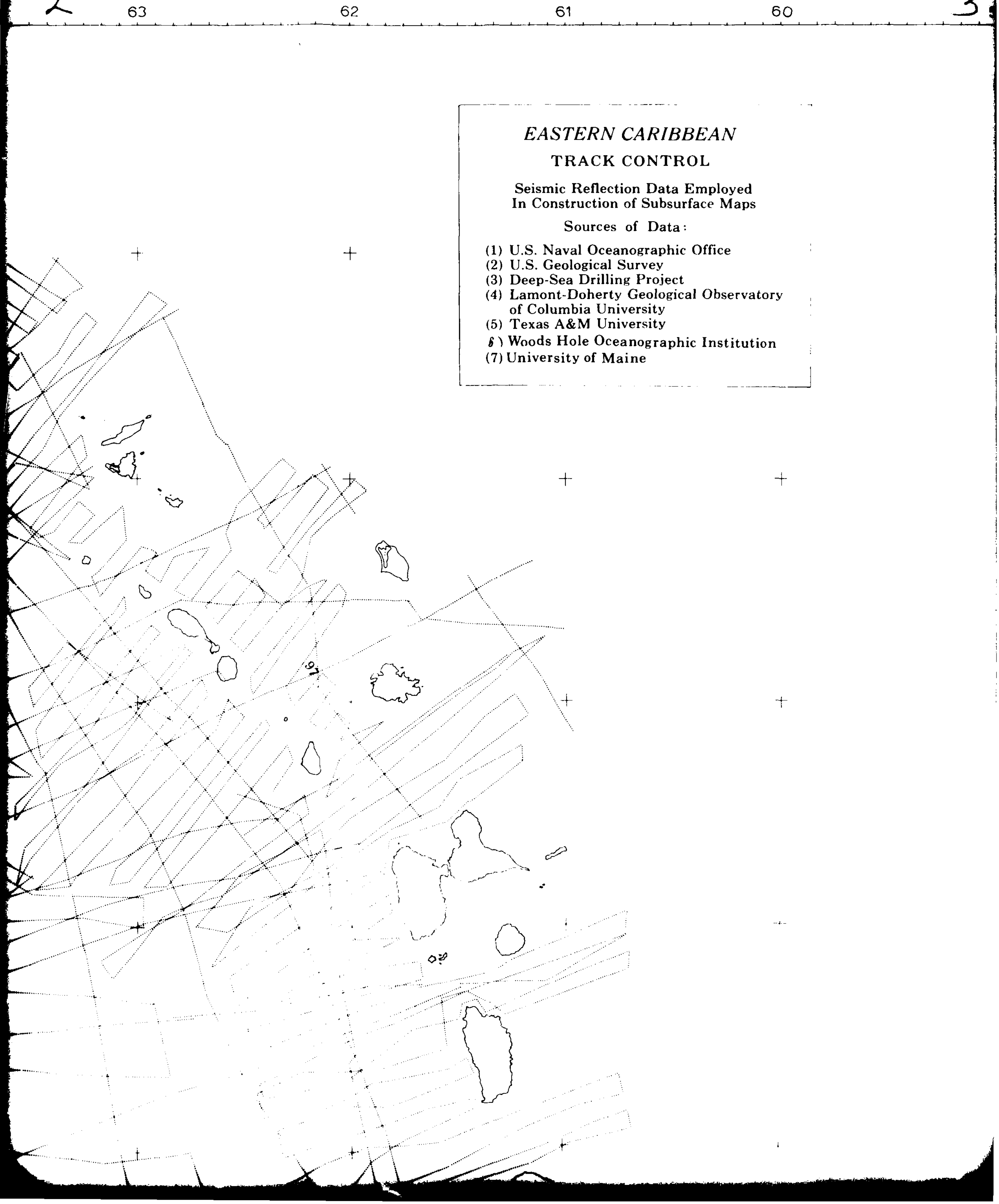


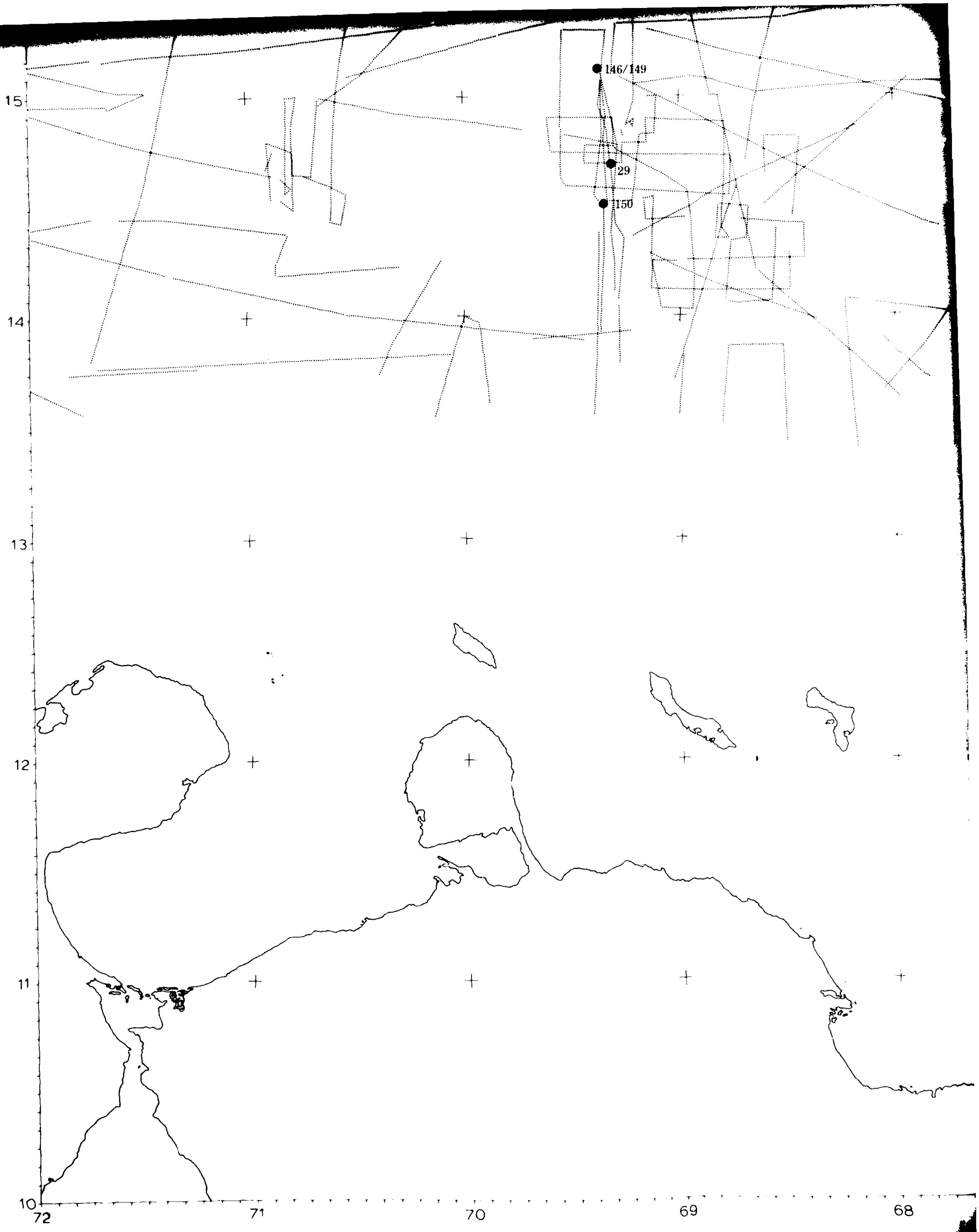
EASTERN CARIBBEAN

TRACK CONTROL

Seismic Reflection Data Employed
In Construction of Subsurface Maps

Sources of Data:

(1) U.S. Naval Oceanographic Office
(2) U.S. Geological Survey
(3) Deep-Sea Drilling Project
(4) Lamont-Doherty Geological Observatory of Columbia University
(5) Texas A&M University
(6) Woods Hole Oceanographic Institution
(7) University of Maine



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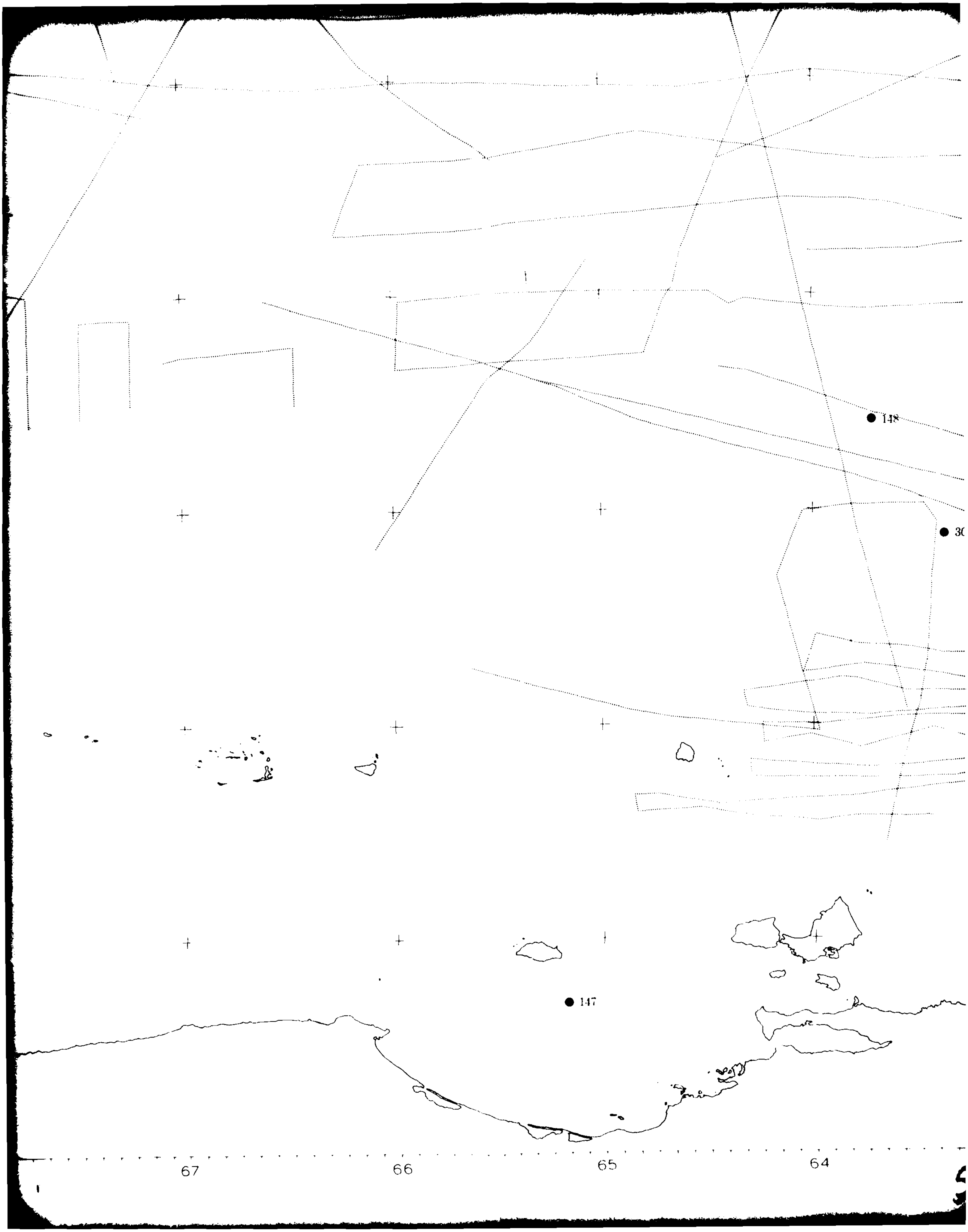
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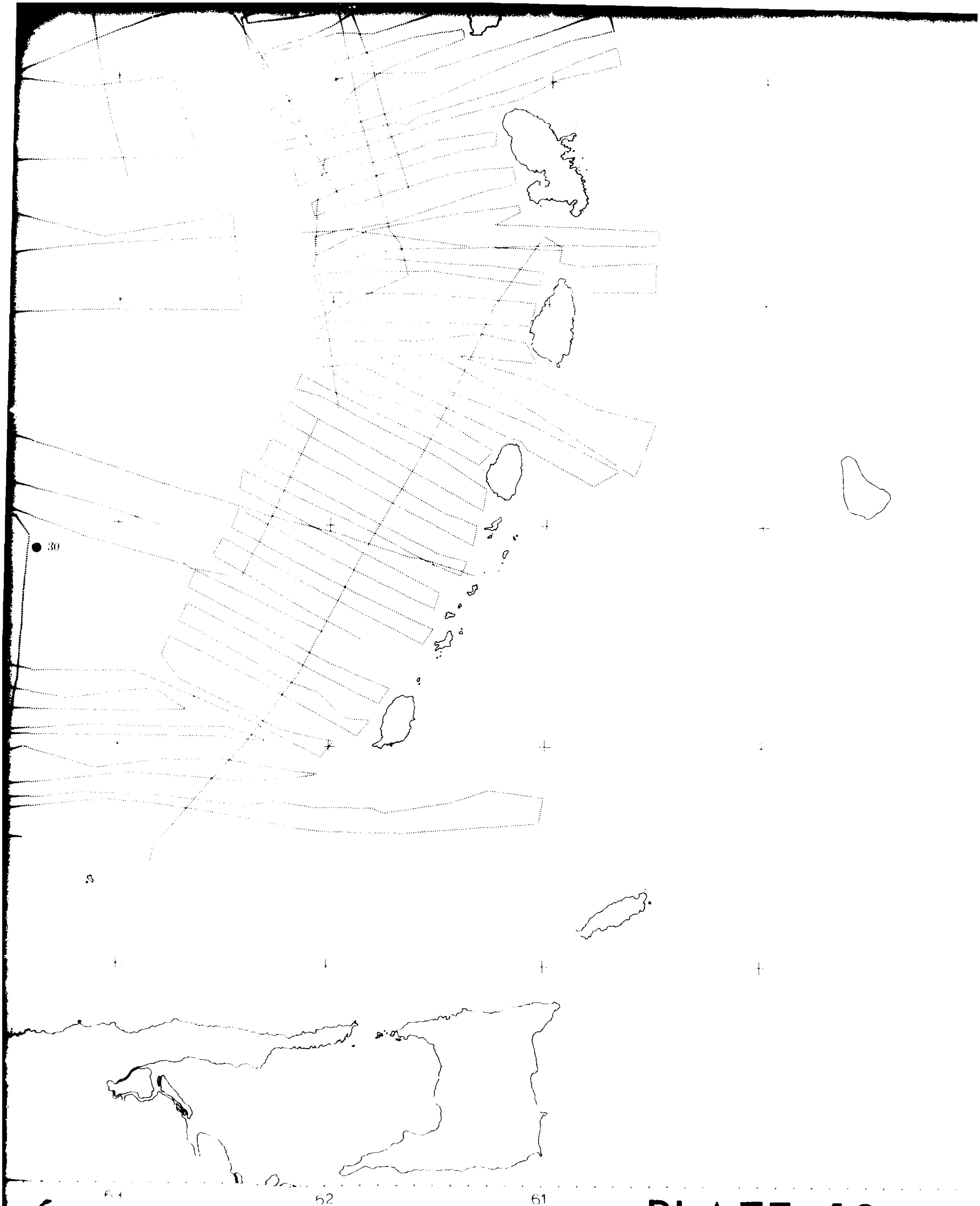

PLATE 10

AD-A085 888   NAVAL OCEANOGRAPHIC OFFICE NSTL STATION MS   F/G 8/10
REGIONAL GEOLOGICAL/GEOPHYSICAL STUDY OF THE CARIBBEAN SEA (NAV--ETC(U)
AUG 76   J E MATTHEWS, T L HOLCOMBE
UNCLASSIFIED   NOO-RP-3   NL

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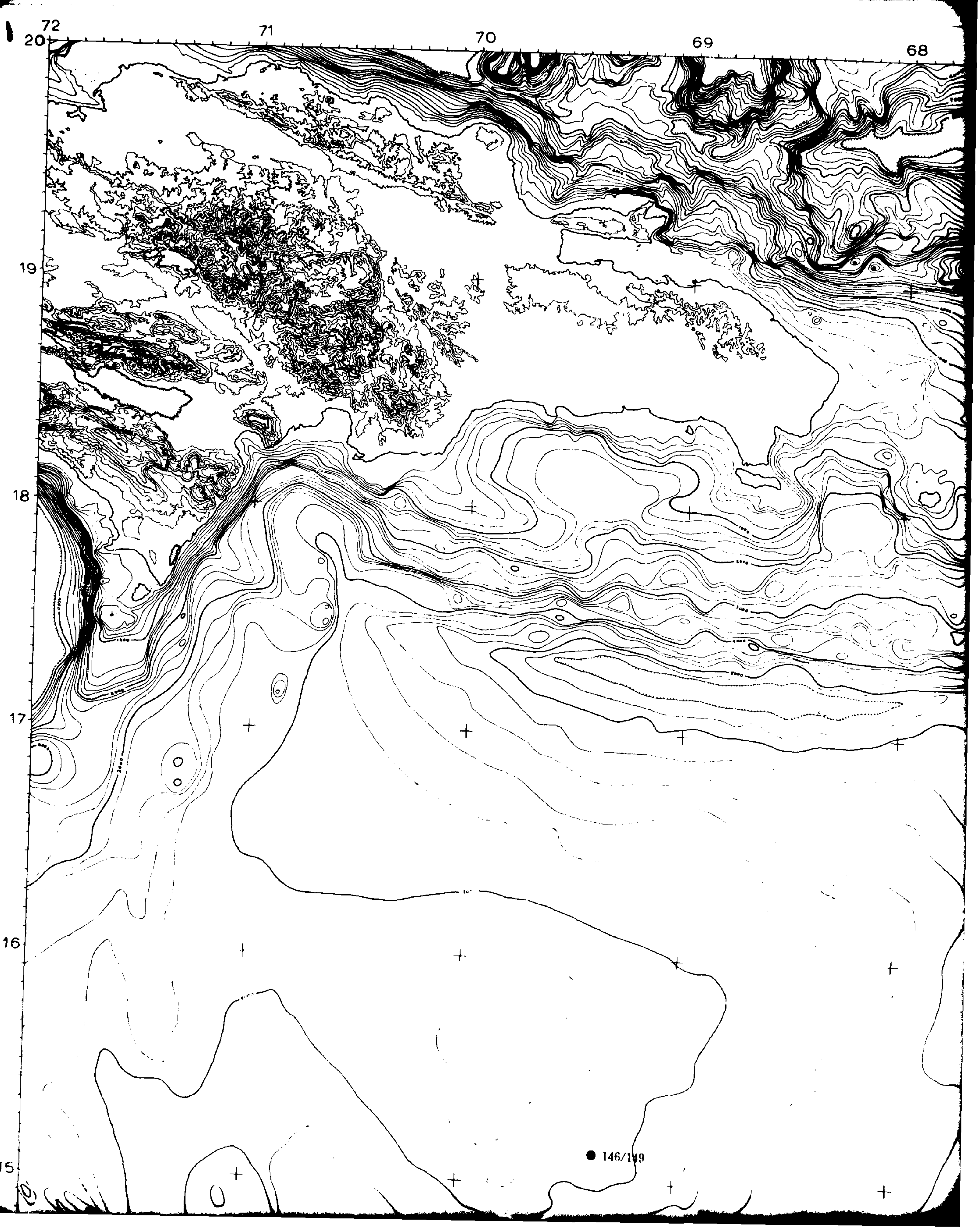
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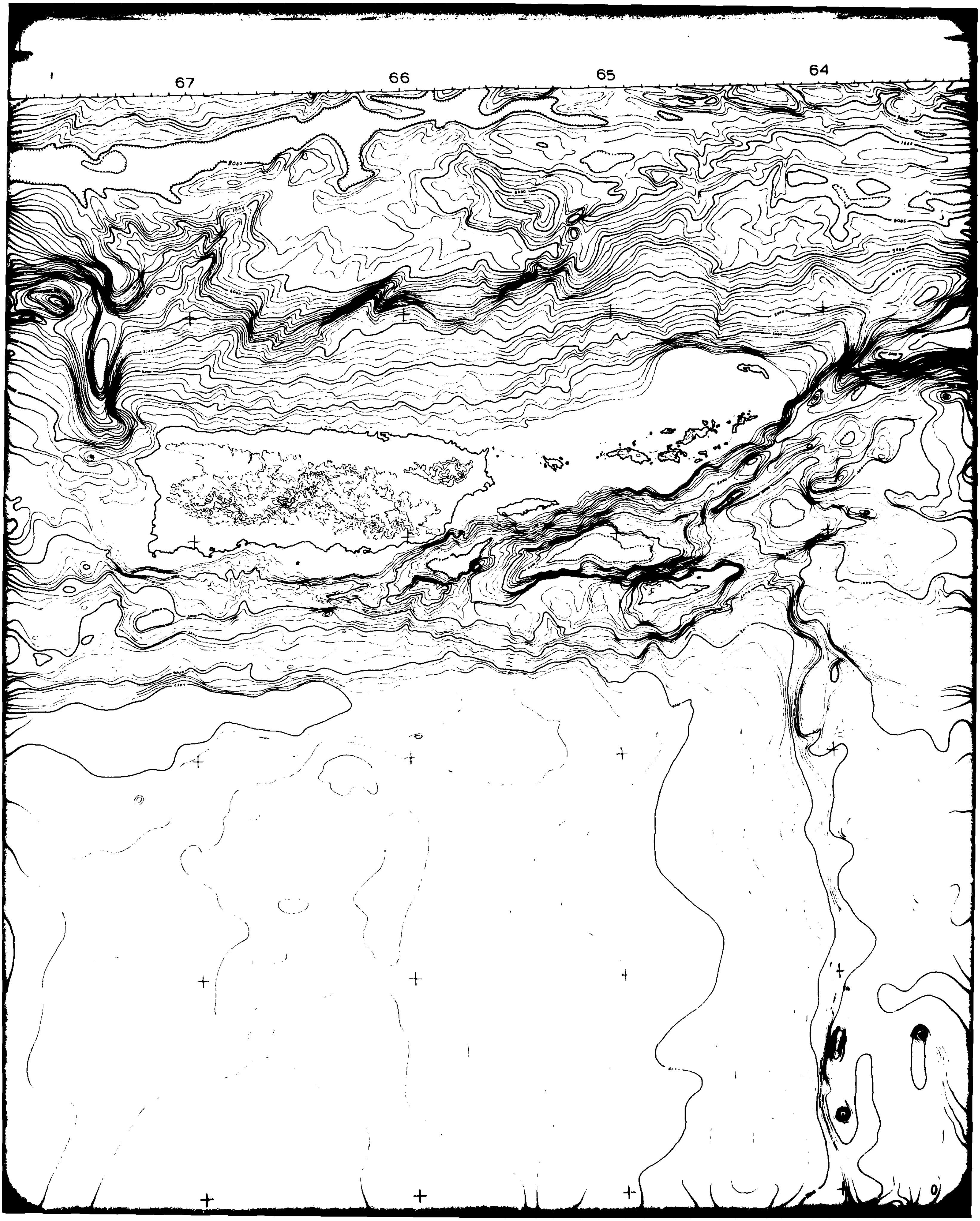
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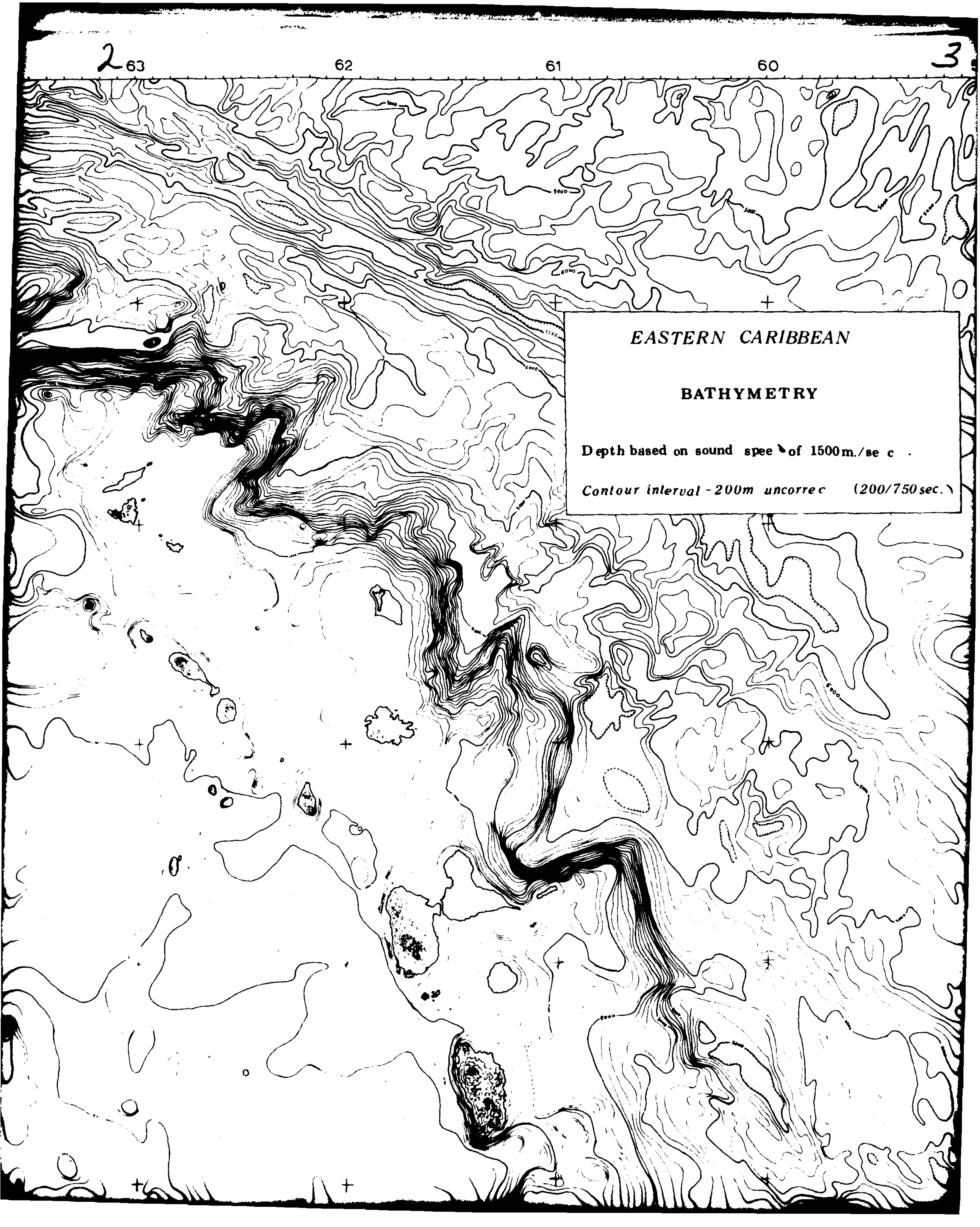
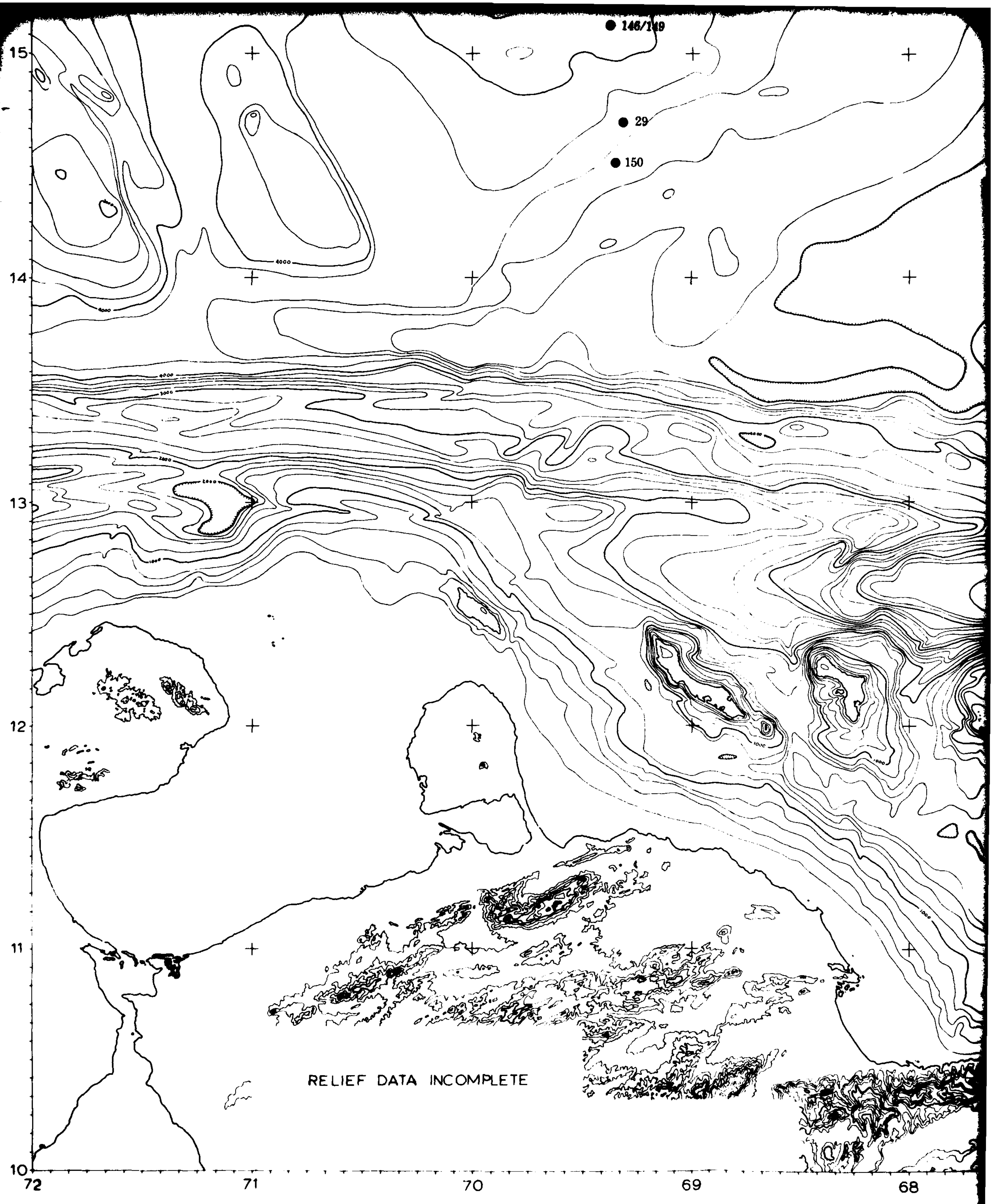


EASTERN CARIBBEAN

BATHYMETRY

Depth based on sound speed of 1500m./sec.

Contour interval - 200m uncorrec (200/750 sec.)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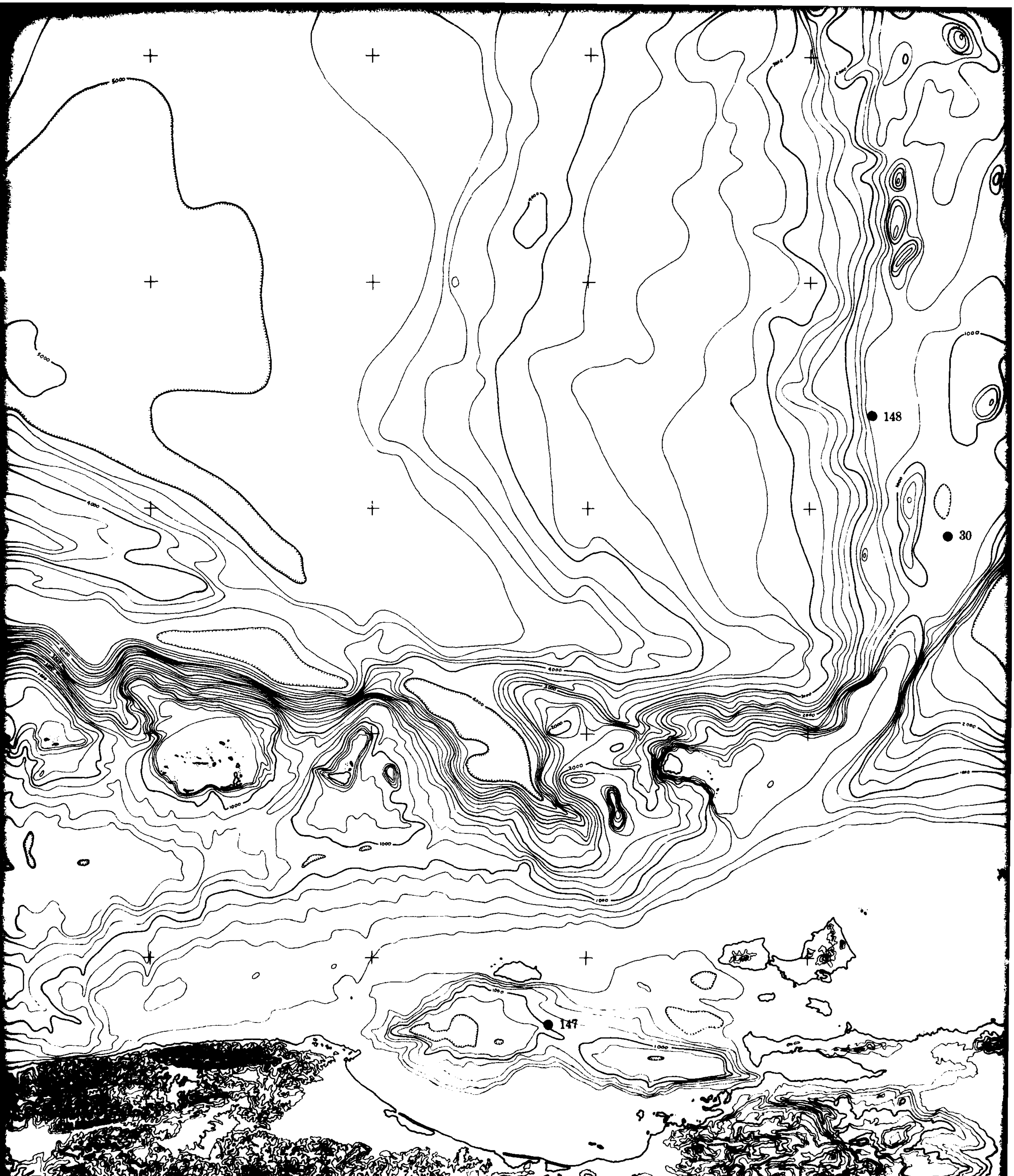
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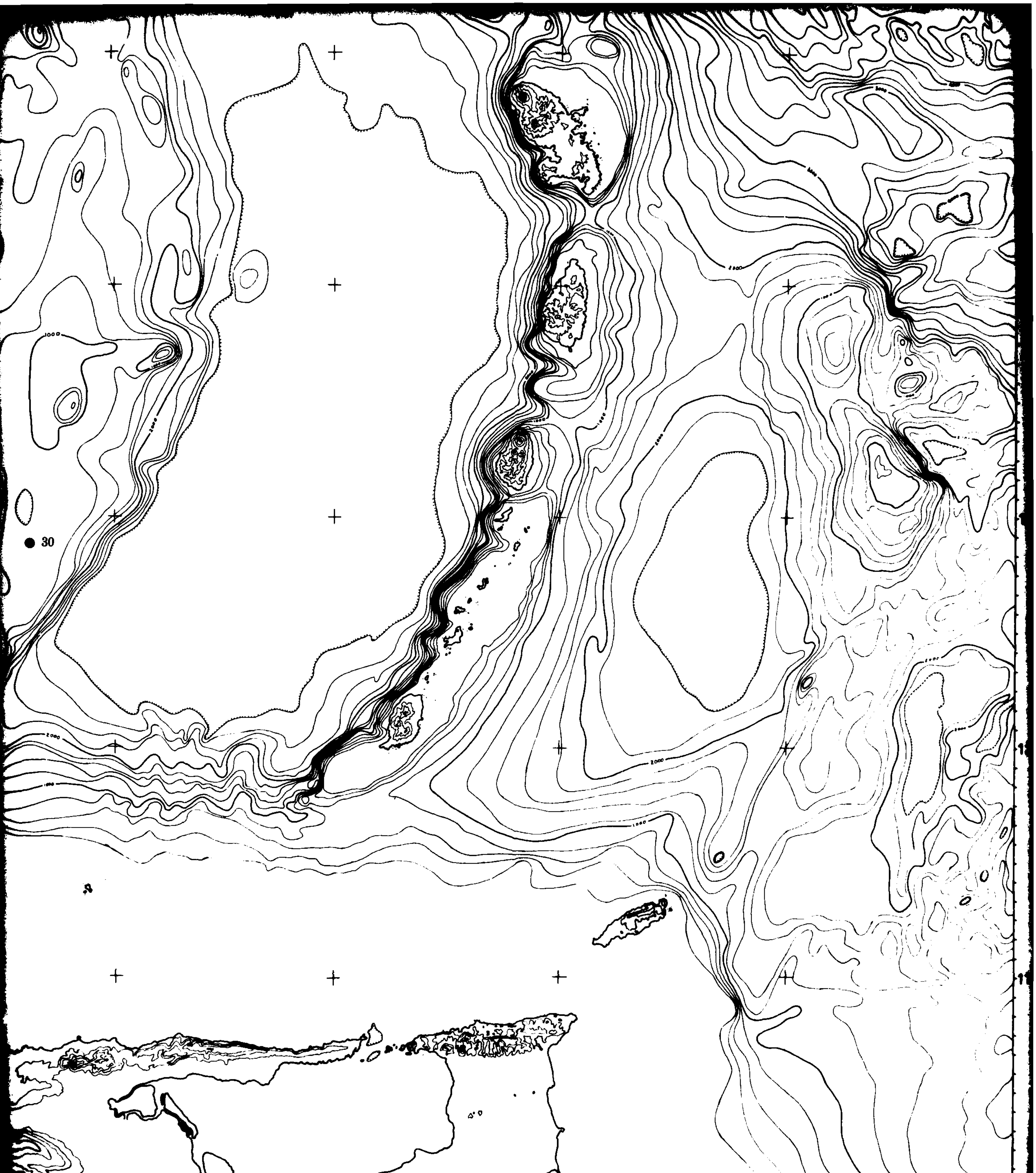
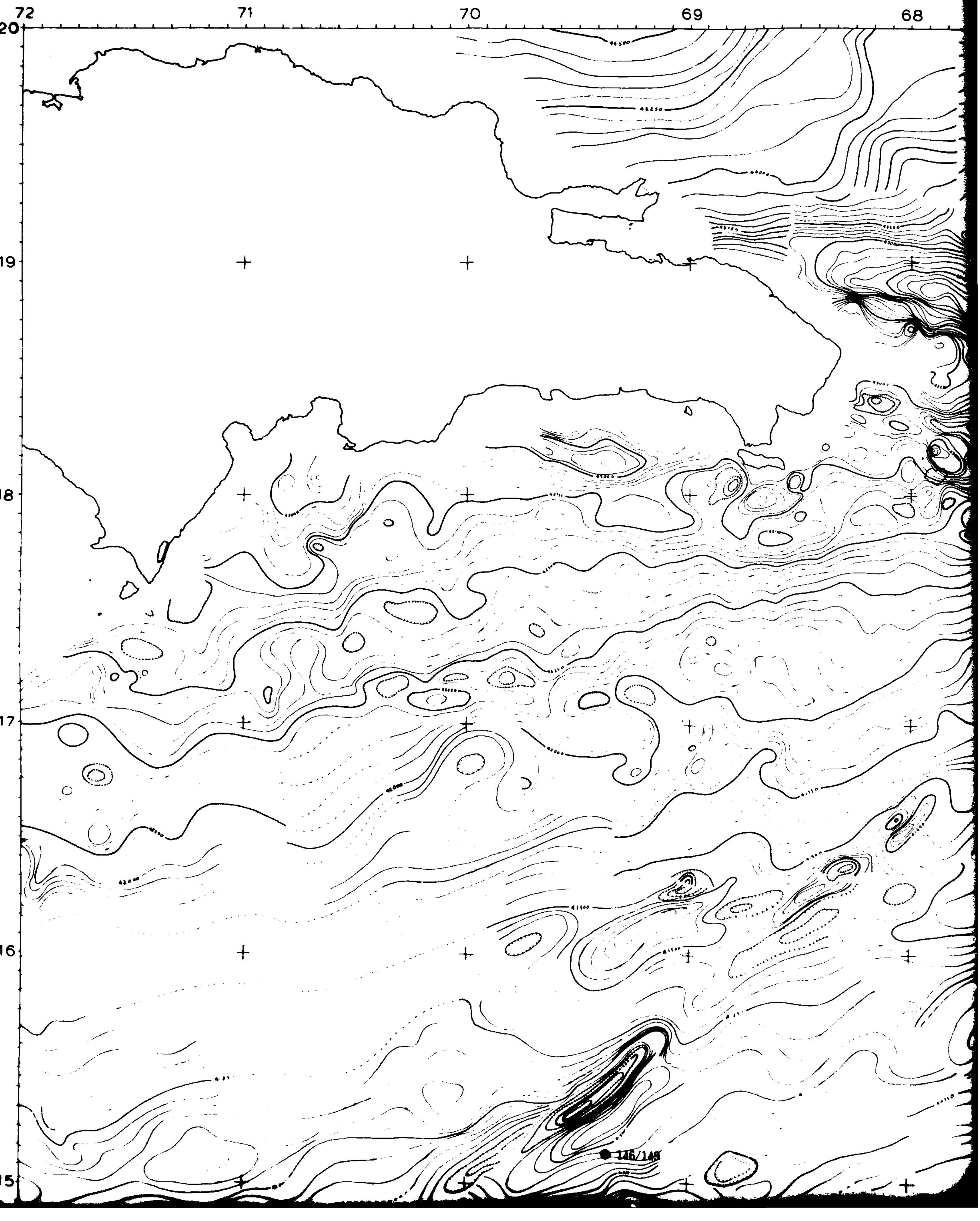


PLATE 1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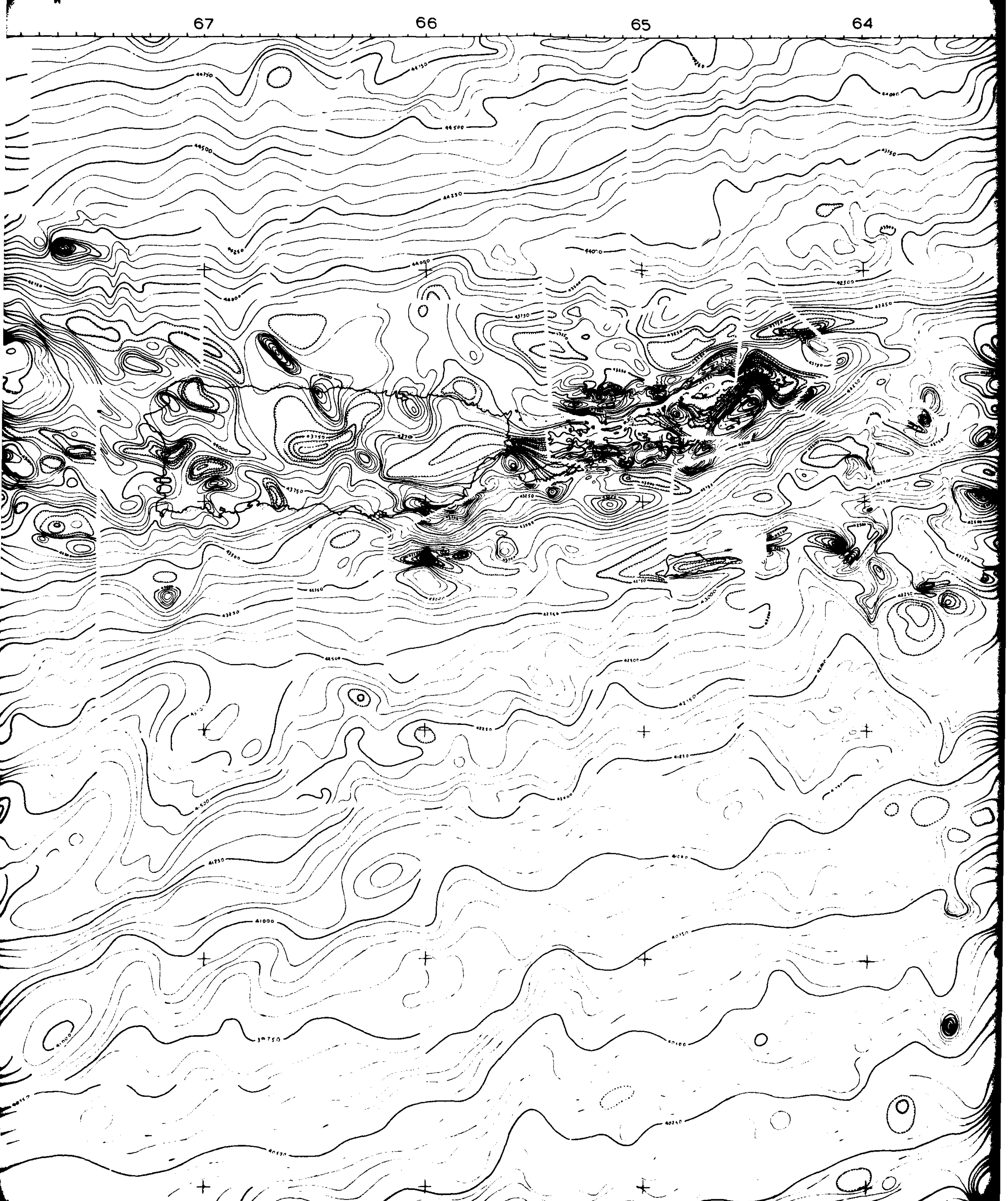
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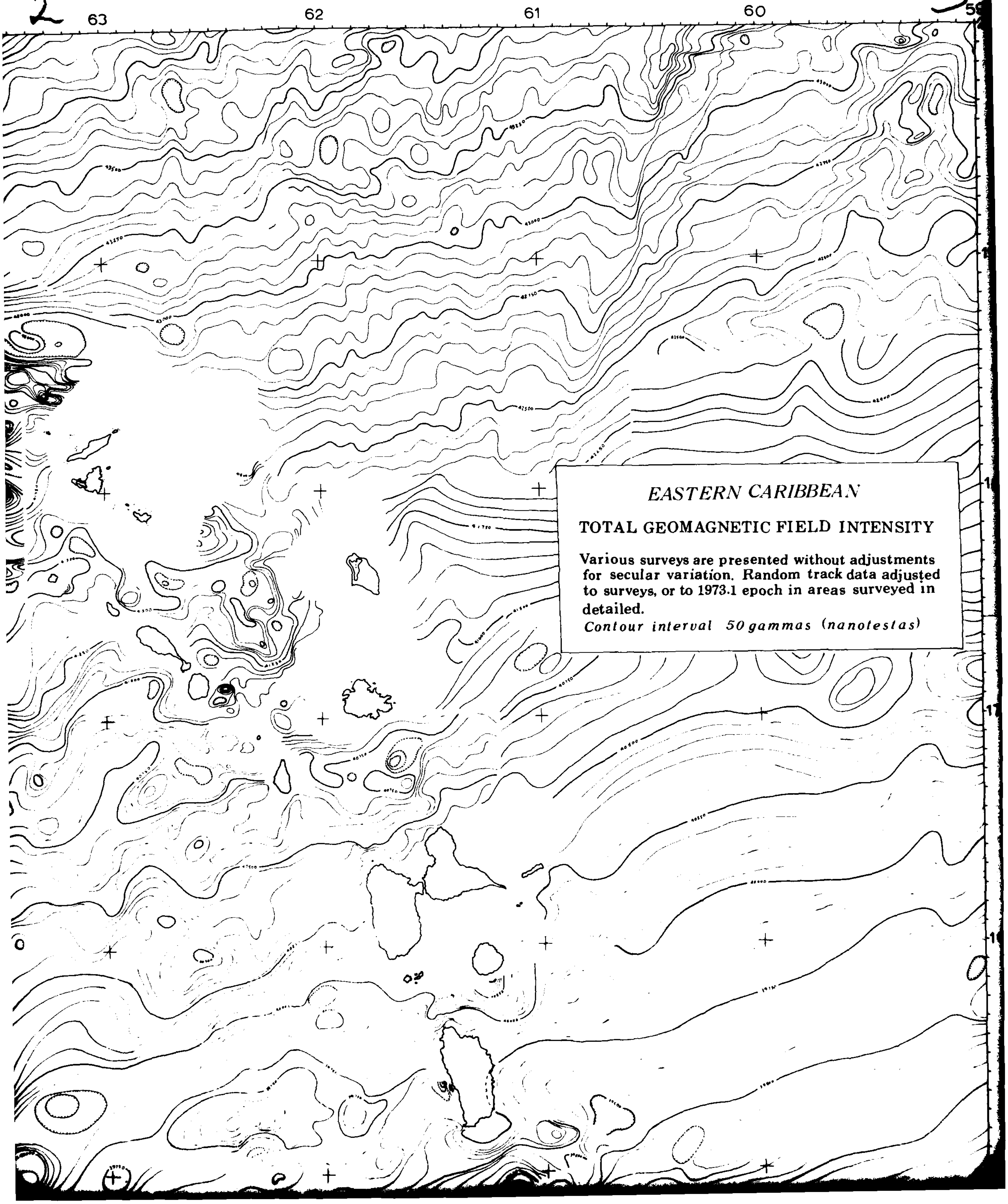
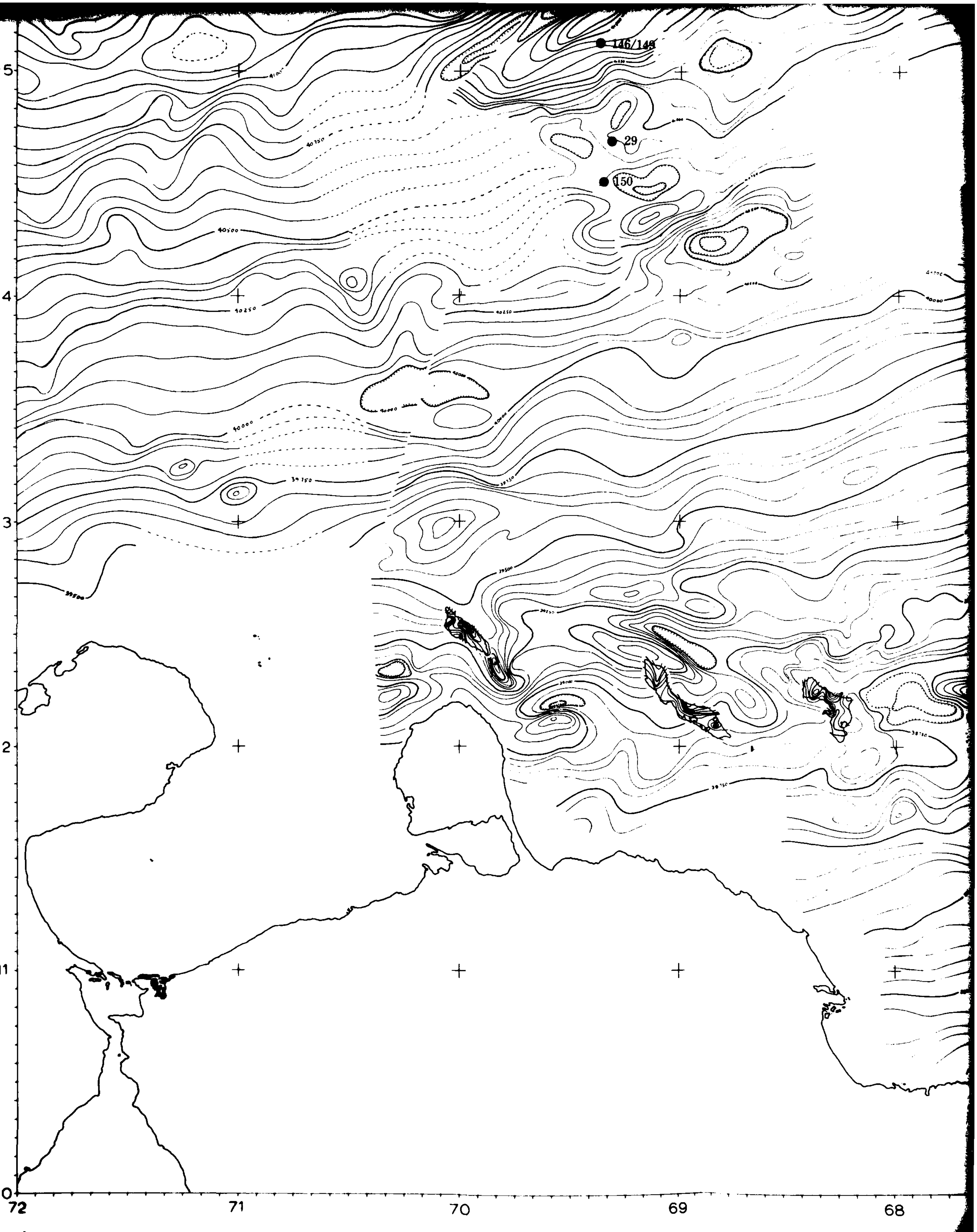


EASTERN CARIBBEAN

TOTAL GEOMAGNETIC FIELD INTENSITY

Various surveys are presented without adjustments for secular variation. Random track data adjusted to surveys, or to 1973.1 epoch in areas surveyed in detailed.

Contour interval 50 gammas (nanotestas)


146/149
29
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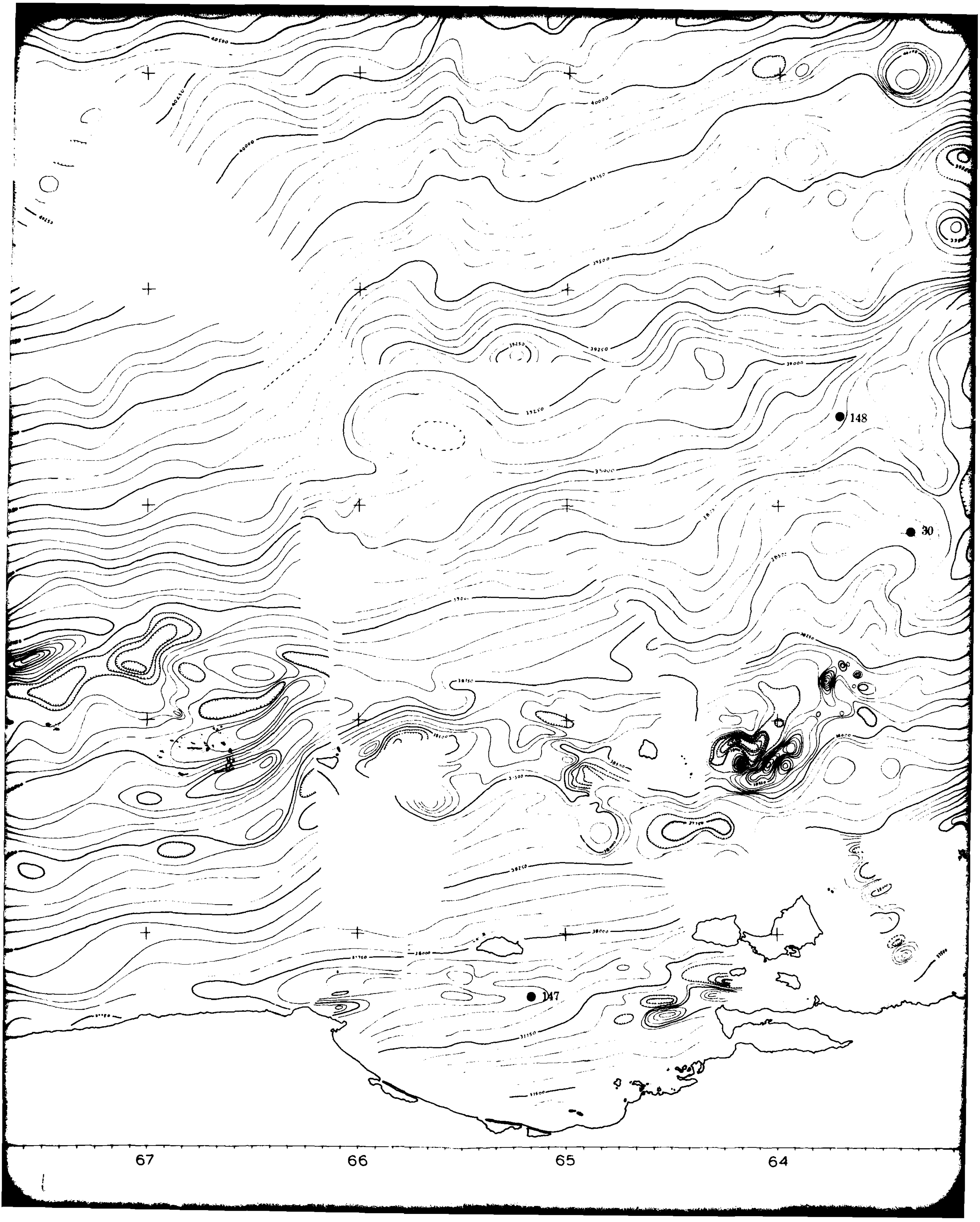
39250
38750

4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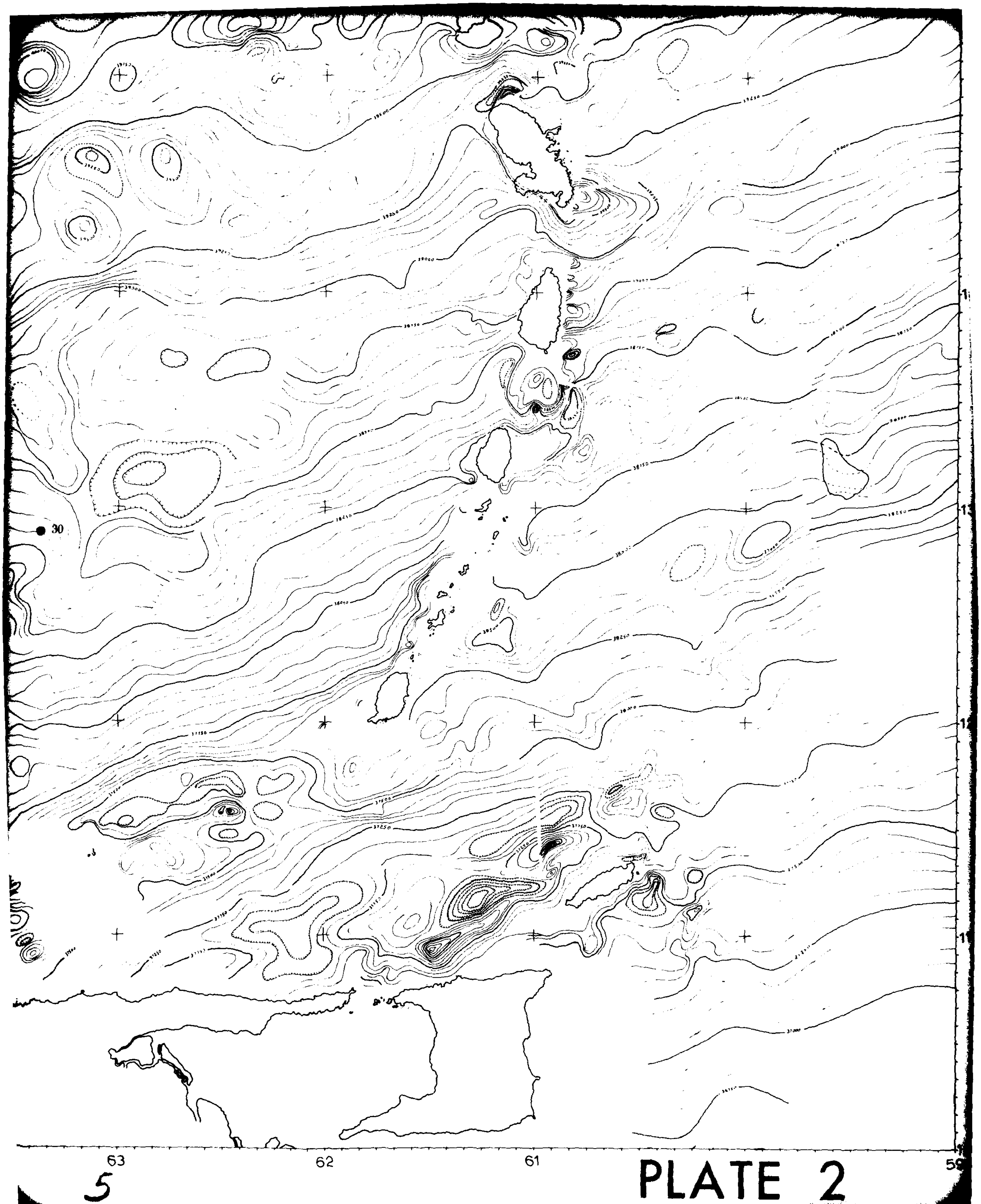

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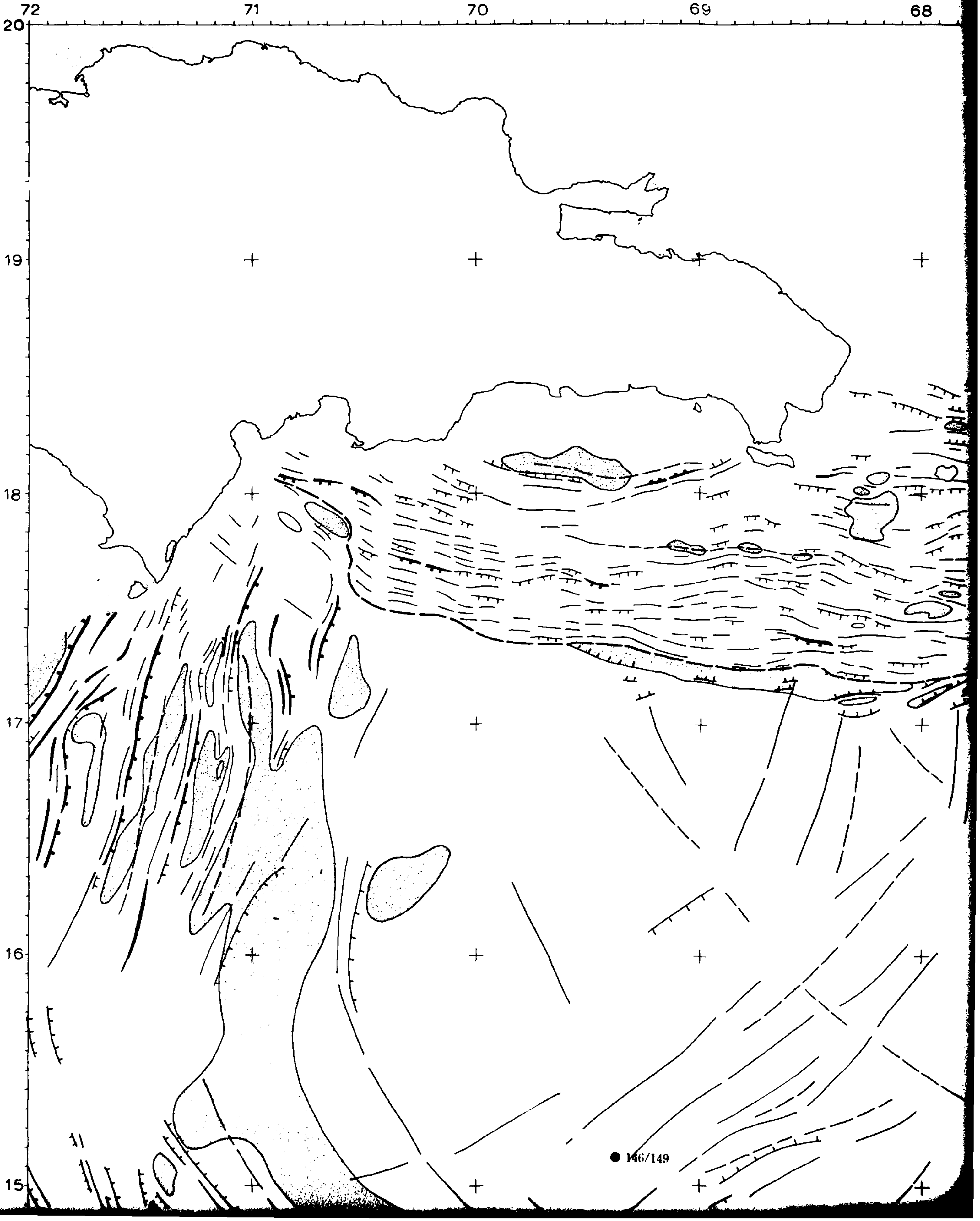
PLATE 2


72
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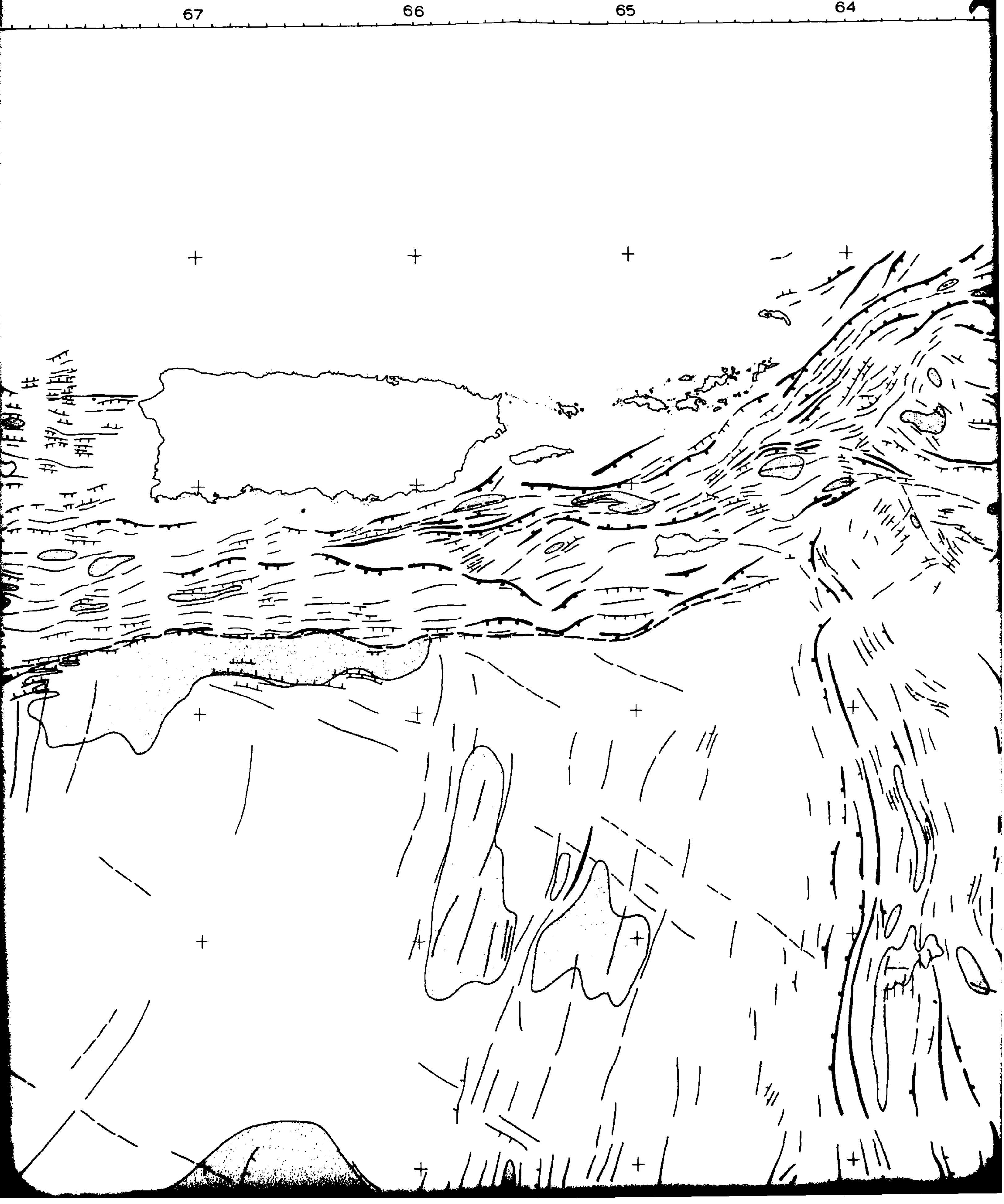
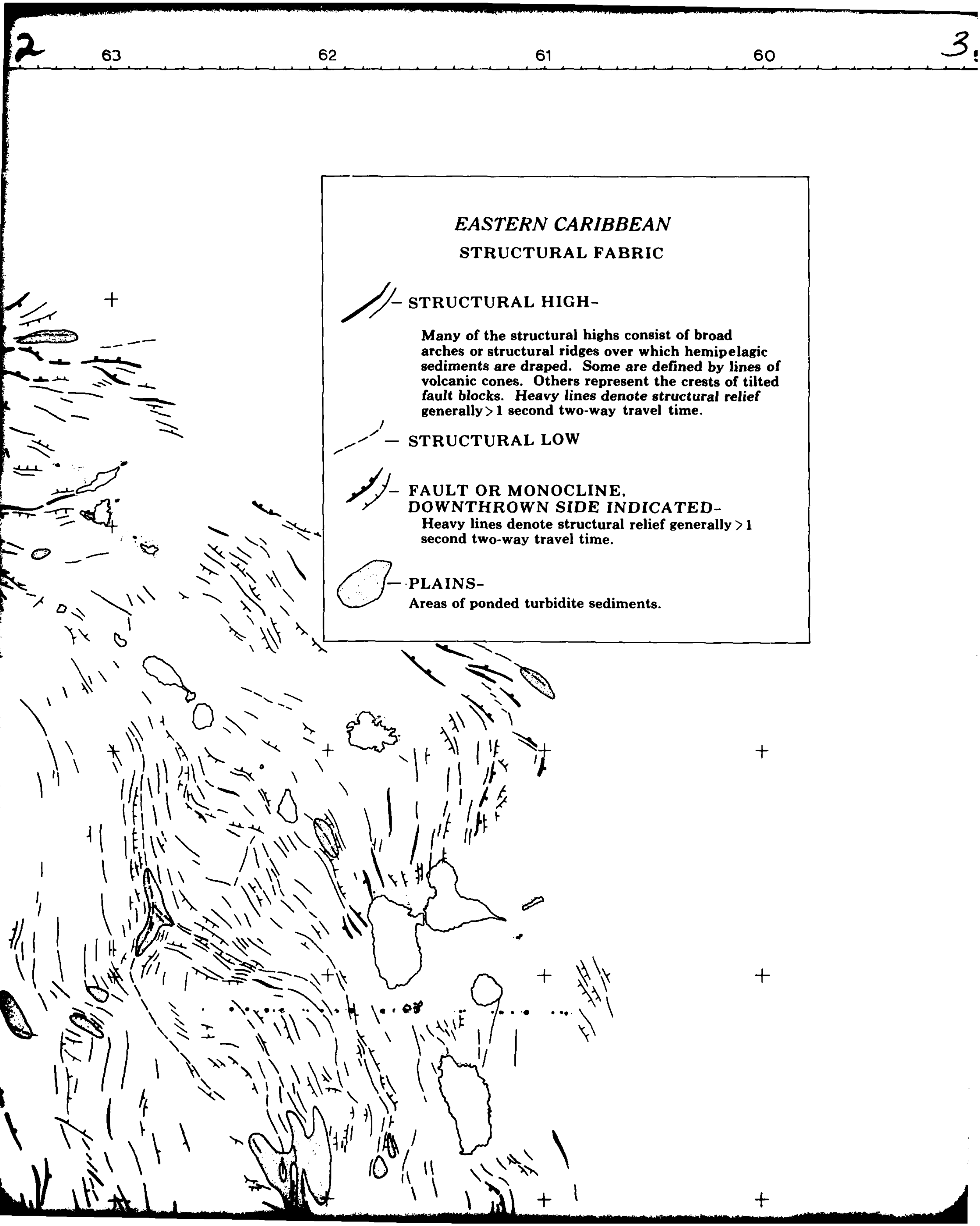




EASTERN CARIBBEAN

STRUCTURAL FABRIC

— STRUCTURAL HIGH-

Many of the structural highs consist of broad arches or structural ridges over which hemipelagic sediments are draped. Some are defined by lines of volcanic cones. Others represent the crests of tilted fault blocks. *Heavy lines denote structural relief* generally > 1 second two-way travel time.

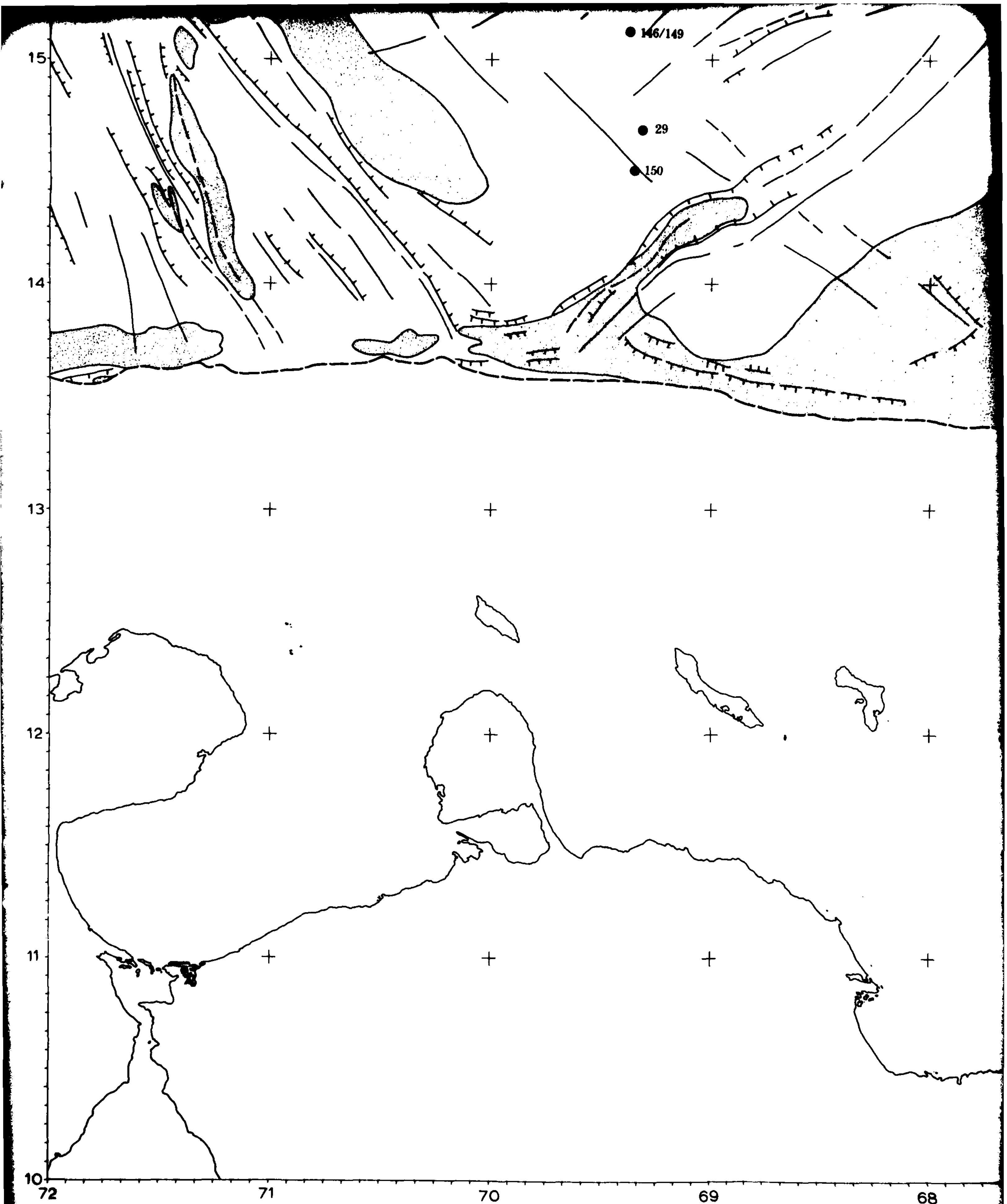
— STRUCTURAL LOW

— FAULT OR MONOCLINE, DOWNTHROWN SIDE INDICATED-

Heavy lines denote structural relief generally > 1 second two-way travel time.

— PLAINS-

Areas of ponded turbidite sediments.



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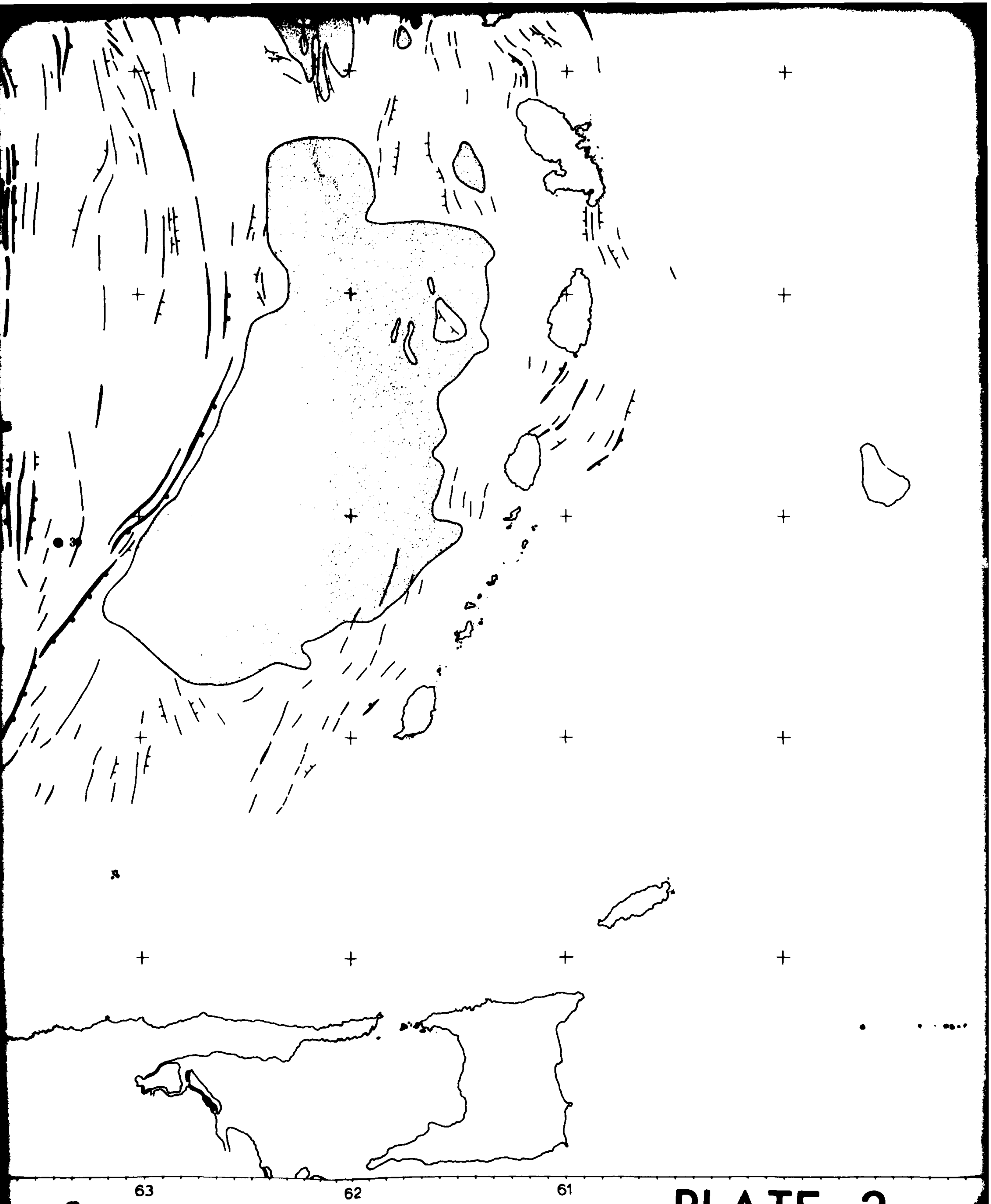

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PLATE 3