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SOUND VELOCITY AND BOTTOM CHARACTERISTICS FOR LRAPP ATLANTIC AREAS I, II, AND III(U)

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ABSTRACT (U)

Inventories and summaries of sound velocity, bathymetry, and bottom characteristics have been compiled for three areas in the North Atlantic Ocean between 15° and 65° N latitude and east of 50° to 65° W longitude. The following information is contained in this report: seasonal inventories of sound velocity profiles extending deeper than deep axial depth, charts of the seasonal extent and average axial depth of the upper sound channel, charts of the annual 'strength' of the upper sound channel; charts of the annual extent and average depth of the subsurface sound velocity maximum, annual contour charts of deep axial depth; charts showing bathymetry shoaler than critical depth for summer and winter; an index of the best available bathymetric contour charts; inventories of surficial bottom sediment samples; charts of surficial bottom sediment analysis by grain size classes; an inventory of bottom cores; and a partial inventory of continuous seismic profiles. In addition, a brief analysis is given of water masses that effect sound velocity structures.

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This report has been reviewed and approved for release as a
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Director

Undersea Surveillance Oceanographic Project

DATE: 15 June 1971

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INTRODUCTION

U By a Memorandum for Undersea Surveillance Oceanographic Center dated 6 July 1970, ONR Code 102-OS requested that data inventories and summaries of sound velocity, bathymetry, and bottom characteristics be provided for three priority areas in the North Atlantic Ocean (see Figure 1). NAVOCEANO letter ser 3768 of 4 August 1970 stated that the following information would be provided:

- Sound velocity profile inventories per one-degree square per standard three-month season
- Areal contours of the deep sound channel axis on an annual basis
- Areal contours of the upper sound channel axis and depth of the subsurface sound velocity maximum on a seasonal and/or annual basis along with an indication of the "strength" of the upper sound channel
- Charts showing the height and extent of bottom features shoaler than critical depth for summer and winter
- Index charts showing the most accurate available bathymetric charts and their compilation dates
- Charts showing the distribution of surficial sediments classified by principle grain size constituents
- Charts showing a partial inventory of bottom cores.

In addition, a partial inventory of continuous seismic profiles is included.

(U) Information on the parameters cited above has been organized in three sections, each corresponding to one of the three priority areas shown on Figure 1. In order to maintain a page size presentation, the three areas have been broken into a total of eight subareas. Figure designations are consistent according to the following system:

- Roman numerals designate the priority area (e.g., I, II, or III)
- Arabic numerals designate the parameter within each priority area (e.g., the number of winter oceanographic observations per one-degree square deeper than deep axial depth is Figure I-2, II-2, or III-2)

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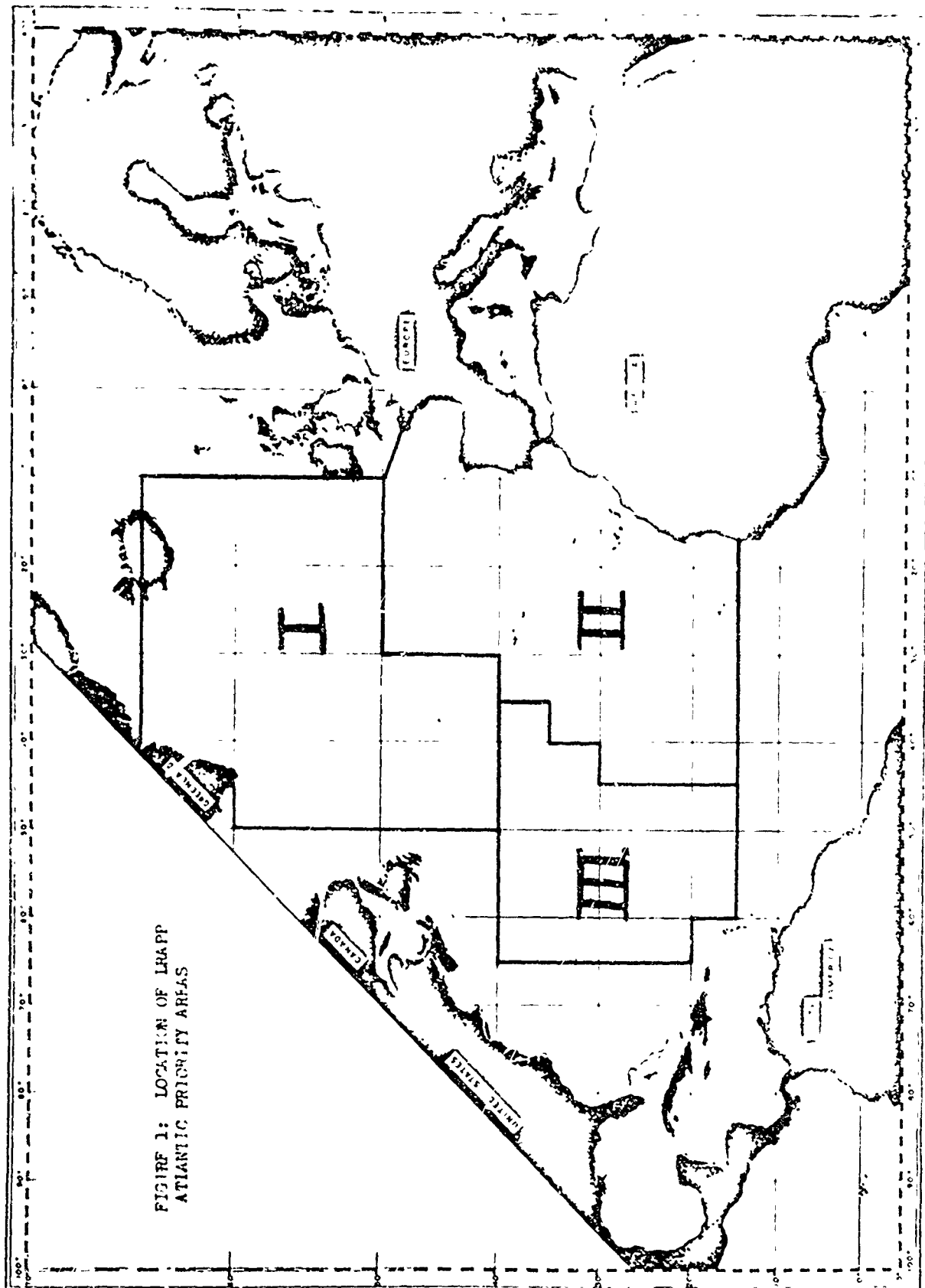


FIGURE 1: LOCATION OF LRAPP
ATLANTIC PRIORITY AREAS

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- Letters designate subareas within priority areas (e.g., Figures I-2A, I-2B, and I-2C).

(U) The locations of these subareas are shown on Figures I-1, II-1, and III-1. For purposes of this report, deep axial depth is defined as the deepest sound velocity minimum (usually absolute minimum). Critical depth is defined as that depth where the sound velocity is equal to the maximum sound velocity found at the surface or in the surface mixed layer.

SOUND VELOCITY PROFILE INVENTORIES

(U) Figures I-2A through I-5C, II-2A through II-5C, and III-2A through III-5B show the number of existing sound velocity observations per one-degree square for the four standard seasons of winter (January through March), spring (April through June), summer (July through September), and autumn (October through December). All observations shown on these figures extend deeper than the deep sound channel (see Figures I-12, II-12, and III-12). The four standard seasons were chosen since the area includes tropical to subarctic conditions. These figures are based upon the following data sources:

- National Oceanographic Data Center (NODC) seasonal sound velocity summaries containing all Nansen cast data extending deeper than 50 meters processed as of the dates shown on Figure 2
- Sound velocimeter and Nansen cast data from the following NAVOCEANO Marine Geophysical Survey (MGS) Atlantic Task Areas:
 - Alpine Area SF (NAVOCEANO, Dec 1966)
 - Alpine Area ST (NAVOCEANO, Aug 1968)
 - Alpine Area I (NAVOCEANO, Sep 1966a and Feb 1967a)
 - Texas Instruments (TI) Area 2 (NAVOCEANO, Feb 1968)
 - TI Area 3 (NAVOCEANO, May 1968)
 - TI Area 5 (NAVOCEANO, Feb 1967b and Jun 1967)
 - TI Area 7/4 (NAVOCEANO, May 1969)
- Sound velocimeter data, furnished by Woods Hole Oceanographic Institution, from the following cruises:
 - R/V ATLANTIS Cruise No. 282, Jul 1962
 - R/V ATLANTIS II Cruise No. 11, Jun 1964

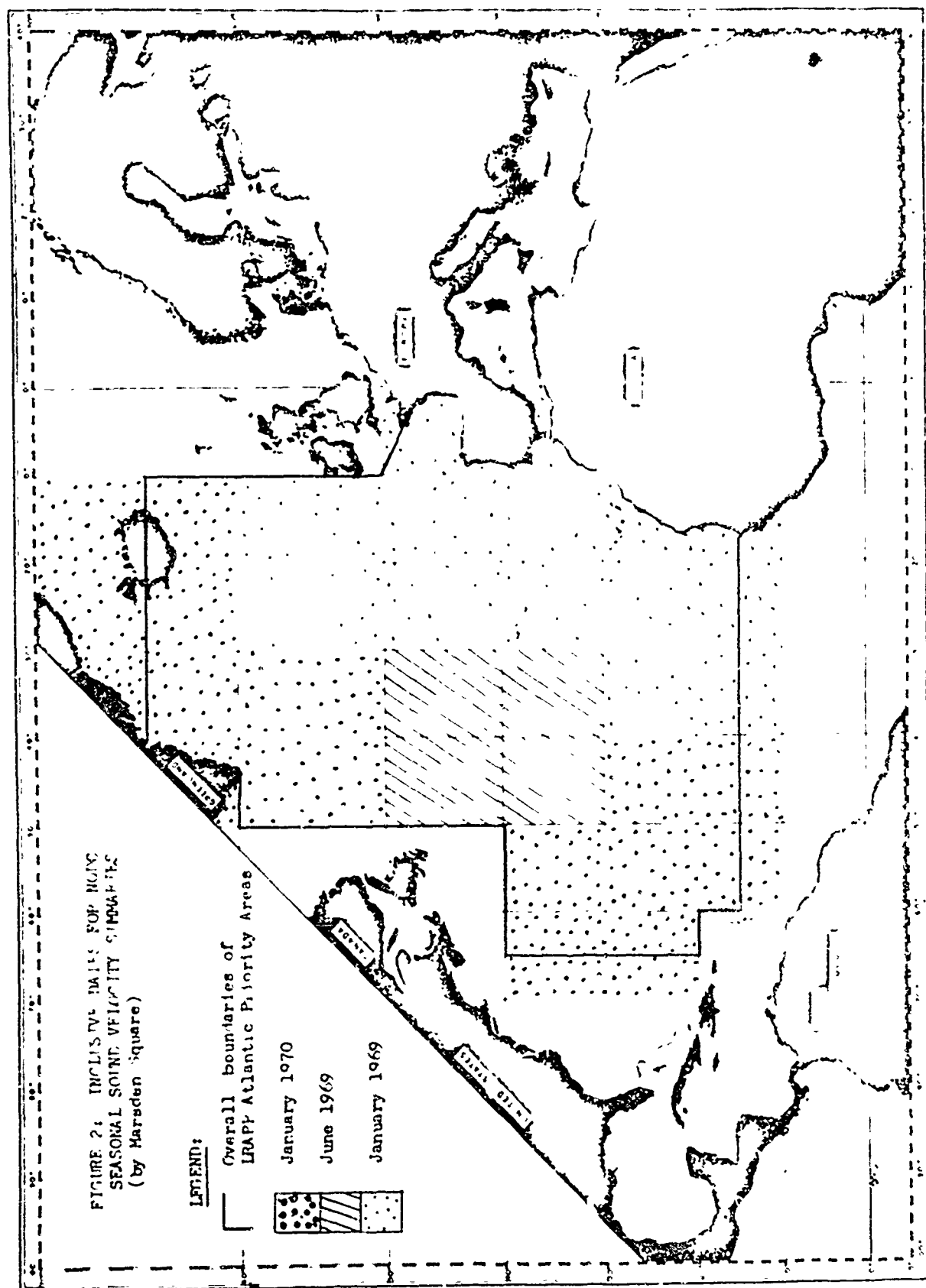


FIGURE 2

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- R/V ATLANTIS II Cruise No. 22, Jul-Aug 1966 (Beckerle, Oct 1968)
- R/V CHAIN Cruise No. 82, Aug-Sep 1968 (Katz, Jun 1969)
- R/V CHAIN Cruise No. 89, Mar 1969 (LaCasce, et al., Jun 1969)
- Sound velocimeter data taken by Lamont-Doherty Geological Observatory during Nov-Dec 1963, Apr-May 1964, and Jun-Jul 1965 (Piip, Jan 1966, Jun 1967, and Apr 1968, respectively)
- Sound velocimeter data taken by the USNS KANE during Jun-Jul 1970 as part of Phase I of the Northeast Atlantic Basin (NEAB) surveys (courtesy of C. Ostericher, Deep Ocean Surveys Division, NAVOCEANO)
- All available Nansen cast and salinity-temperature-depth (STD) recorder data taken as part of the Barbados Oceanographic and Meteorological Experiment (BOMEX) by the following ships:
 - USCGSS OCEANOGRAPHER, USCGC RAINIER, and USCGC (Environmental Science Services Administration, Dec 1969)
 - USNS GILLIS and R/V ADVANCE II (courtesy of P. Mazeika, NAVOCEANO BOMEX Coordinator)
- Additional Nansen cast and STD data taken in support of the International Ice Patrol by the following ships:
 - USCGC EVERGREEN, Apr-Jul 1966 (Wolford, Jun 1966)
 - USCGC EDISTO, Sep-Oct 1967 (Codispoti and Kravitz, May 1968)
 - USCGC WESTWIND, Sep-Oct 1969 (Bunce, Apr 1970)
- Additional Nansen cast data taken in support of the International Commission for the Northwest Atlantic Fisheries (ICNAF) in 1963 as follow:
 - at OCEAN WEATHER STATION POLAR FRONT I and II (same as OWS ALFA), Jun-Jul
 - by RS THALASSA, Apr
 - by CV AEGIR, May
 - by RS ACADEMICIAN KNIPOVITCH, Jun
 - by USCGC EVERGREEN, Jul
 - by R/V EXPLORER, Jul

(published by ICNAF, 1968)

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- Additional Canadian Nansen cast data taken by the following ships:
 - CSS HUDSON, Mar-Jul 1966 (Canadian Oceanographic Data Centre (CODC), 1969a)
 - CSS BAFFIN, Apr-May 1966 (CODC, 1969b)
 - CSS HUDSON, Jan-Mar 1967 (CODC, 1969c)
- Fleet Numerical Weather Central (Monterey) expendable bathythermograph (XBT) data processed as of 1 June 1970
- Additional XBT, sound velocimeter, and Nansen cast data taken as part of the first Northeast Atlantic (NEAT I) experiment during Sep-Oct 1969 by the USNS GIBBS, R/V CHAIN and ACS ST. MARGARETS (courtesy of Acoustics Division, NRL)
- Additional XBT data taken by the USNS GIBBS during May-Jun 1969 and Apr 1970 (courtesy of H. Fleming and G. Shaffer, Acoustics Division, NRL).

In addition, all available Nansen cast and sound velocimeter data taken by Project CAESAR in the North Atlantic Ocean between 1954 and 1967 (indexed by Bunce, Aug 1969) and by the NAVOCEANO Ocean Survey Program (OSP) are included in these figures. Nansen cast and STD data were converted into sound velocity profiles using the equation of Wilson (1960). Various XBT data were converted into sound velocity profiles using the equation of Wilson and historical salinity correction factors.

UPPER SOUND CHANNEL

(U) Figures I-6 through I-9, Figures II-6 through II-9, and Figures III-6 through III-9 show the areal extent and average axial depth of the upper sound channel for each of the four standard seasons. In constructing these figures, seasonal upper axial depths were compiled by one-degree square and averaged on a two-degree square (i.e., four one-degree squares) basis. Two-degree square averages then were contoured on an areal basis. Regions where an upper sound channel is present more than 80% of the time, 20-80% of the time, and less than 20% of the time are indicated on each figure. For purposes of the following discussion, the first case above will be referred to as a permanent upper sound channel, the second as transitory. In the third case, an upper sound channel effectively is absent.

(U) During winter, a permanent upper sound channel is present only east of about 20° W longitude between Cape Finisterre and the Canary Islands (see

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Figure II-6). A transitory upper sound channel surrounds this region north to about 49° N latitude and west to the Azores Islands. A transitory upper sound channel also is present during winter in a small area east of Grand Banks (see Figure I-6) and throughout the Sargasso Sea (see Figure III-6). In the Canary and Iberian Basins, upper axial depths range from approximately 300 meters near Cape Finisterre to greater than 900 meters north of the Canary Islands. South of the Canary Islands, the upper axial depths decrease. Axial depths in the Sargasso Sea and off Grand Banks range between 100 and 300 meters during winter, and are considerably shallower than those in the Canary Basin. This situation prevails during all seasons.

(U) During spring, there is a permanent upper sound channel east of about 20°W longitude between the Canary Islands and Iceland (see Figures I-7 and II-7) and in a small area east of Bermuda (see Figure III-7). However, during spring there are transitory upper sound channels north of about 25° N latitude except over the Mid-Atlantic Ridge and in the Labrador Basin. In the Canary and Iberian Basins, upper axial depths range from less than 300 meters off Cape Finisterre to greater than 900 meters in the vicinity of the Canary Islands. Throughout the remainder of the three areas, upper axial depths range between 100 and 200 meters.

(U) During summer, there is a permanent upper sound channel east of about 20° W longitude between the Canary Islands and Iceland, throughout the basin south of Iceland, and across the Reykjanes Ridge into the central Labrador Basin (see Figures I-8 and II-8). There is also a permanent upper sound channel in the Sargasso Sea (see Figure III-8). The summer extent of the transitory upper sound channel is similar to that during spring, with two exceptions: transitory upper sound channels are present farther to the west in the Labrador Basin during summer but are absent over larger sections of the Mid-Atlantic Ridge north of the Azores Islands. Upper axial depths in the Canary and Iberian Basins are approximately the same during spring and summer (300-900 meters). However, throughout Areas I and III summer axial depths range between 150 and 200 meters; while in Area II, upper axial depths are greater than 200 meters.

(U) During autumn, a permanent upper sound channel is present east of about 20° W longitude between the Canary Islands and the Faeroe Plateau (see Figures I-9 and II-9) and in a local area east and south of Bermuda (see Figure III-9). The extent of transitory upper sound channel is similar during spring and autumn. Upper axial depths in the Canary and Iberian Basins are similar to those during spring and summer. However, in the region north of Cape Finisterre and east of the Mid-Atlantic Ridge, autumn axial depths average about 200 meters (the deepest during the year). In the Sargasso Sea, autumn axial depths also are approximately 50 meters deeper than during summer. In the western

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half of Area I, autumn data are either insufficient to evaluate or insufficient to contour. However, axial depths probably are somewhat deeper during autumn than summer in this region.

(U) The causes of an upper sound channel east of the Mid-Atlantic Ridge have been described by Fenner and Bacon (Dec 1969). Briefly, south of about 43° N latitude (Cape Finisterre), an upper sound channel is formed by the interaction of relatively warm, saline Mediterranean Intermediate Water (MIW) with colder, more dilute North Atlantic Central Water (NACW) carried by an extension of the North Atlantic Current. In this case, upper axial depths coincide with the bottom of the NACW layer. North of about 50° N latitude, an upper sound channel is formed by warming of surface and near-surface layers characterized by permanent or transient positive velocity gradients during winter. In this case, upper axial depths correspond roughly with the maximum depth of summer warming. However, in cases where the maximum depth of summer warming exceeded the maximum depth of winter cooling, an upper sound channel was not found (e.g., south of the Canary Islands and over the Mid-Atlantic Ridge). Between 43° and 50° N latitude, an upper sound channel is formed by warming of surface layers combined with interaction of MIW and NACW. This latter region is characterized by a relatively strong oceanic front from the surface to depths in excess of 1200 meters caused by the interaction of NACW; a cold, dilute flow at depth (Arctic Intermediate Water - AIW); and MIW. Transitory upper sound channels generally were found in regions where various causative forces were attenuated (e.g., regions of MIW dilution, regions where winter cooling is attenuated by warm surface currents, etc.).

(U) West of the Mid-Atlantic Ridge (western half of Area I and Area III), upper sound channels apparently are caused by spring, summer, and autumn warming of the surface and near-surface layers. Such a hypothesis explains the lack of a widespread upper sound channel during winter throughout Area I and the greater extent of a transitory upper sound channel in the Labrador Basin during summer than during spring. Preferential summer warming in the regions influenced by the Irminger Current may explain the permanent upper sound channel west of the Reykjanes Ridge during summer. The localized occurrence of a transitory upper sound channel east of the Grand Banks during winter probably is a result of intensive mixing of waters carried by the North Atlantic and Labrador Currents. In the Sargasso Sea, an upper sound channel was associated with the "18° Water" of Worthington (1959). Somewhat cooler winter conditions near Bermuda and the relative absence of "18° Water" during winter throughout the Sargasso Sea may explain the absence of a permanent upper sound channel during winter in Area III.

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(U) Figures I-10, II-10, and III-10 show the annual average "strength" of the upper sound channel (if present) relative to the subsurface sound velocity maximum. This parameter was compiled by one-degree square and season, averaged by two-degree square on an annual basis, and generalized into seven categories. It is presented by two-degree squares on an annual basis because of the large temporal and spatial variability throughout the three areas. Generally, "A", "B", or "C" values (i.e., 6 to greater than 10 meters/second) indicate the effects of high concentrations of MIW and/or extreme winter cooling followed by intensive summer warming. "D" and "E" values (i.e., 2 to 6 meters/second) generally indicate the effects of intermediate concentrations of MIW and/or average winter cooling and summer warming conditions. "F" and "G" values (0.1 to 2 meters/second) generally are associated with transitory upper sound channels and/or subsurface sound velocity maxima and indicate attenuation of causative forces. The reader is cautioned that two-degree square values of this parameter often mask specific seasonal and areal tendencies.

SUBSURFACE SOUND VELOCITY MAXIMUM

(U) Figures I-11, II-11, and III-11 show the annual areal extent and average axial depth of the subsurface sound velocity maximum. This parameter was compiled by one-degree square and season, averaged by two-degree square on an annual basis, and then contoured on an areal basis. An annual presentation was chosen for this parameter since seasonal two-degree square averages vary by less than 100 meters from comparable annual averages throughout most of the three areas. However, in the vicinity of the Canary Islands, from 43° and 50° N latitude between about 15° and 30° W longitude, on either side of Iceland, and along 40° N latitude between 50° and 65° W longitude there are large seasonal variations in the depth of the subsurface sound velocity maximum. All of these regions roughly correspond to frontal zones either at the surface, at intermediate depths, or both. Regions where a subsurface sound velocity maximum is present greater than 80% of the time, 20-80% of the time, and less than 20% of the time are indicated on each figure. For purposes of the following discussion, the first case above will be referred to as a permanent subsurface sound velocity maximum and the second as a transitory subsurface sound velocity maximum. In the third case, a subsurface sound velocity maximum effectively is absent.

(U) A permanent subsurface sound velocity maximum is present throughout the year east of about 20° W longitude between the Canary Islands and Iceland, throughout the basin south of Iceland, and across the Reykjanes Ridge into the central Labrador Basin (see Figures I-11 and II-11). This areal extent is similar to that of the permanent upper sound channel during summer. There is also a

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permanent subsurface sound velocity maximum in separate regions south and east of the Grand Banks and in the central Sargasso Sea (see Figures I-11 and III-11). Transitory subsurface sound velocity maxima are found throughout all three areas north of about 25° N latitude except over the Mid-Atlantic Ridge, in a region directly off Grand Banks, and in the northern Labrador Basin. The annual average depth of the subsurface sound velocity maximum east of the Mid-Atlantic Ridge decreases to the north from 1300 meters near the Canary Islands to less than 500 meters south of Iceland. West of the Mid-Atlantic Ridge, depths range from less than 200 meters in the north to greater than 400 meters in the central Sargasso Sea.

(U) In the Northeast Atlantic (east of 30° W longitude), subsurface sound velocity maxima are caused solely by MIW south of about 43° N latitude, by winter cooling north of about 50° N latitude, and by a combination of both factors between about 43° and 50° N latitude and in the deep water channel between the Faeroe Plateau and Porcupine Bank (Fenner and Bucca, Dec 1969). In the first region, the depth of this parameter coincided well with the depth of the MIW high salinity core (salinity maximum). In the second region, the depth of the subsurface sound velocity maximum coincided roughly with the maximum depth of winter cooling. In the third region, MIW was found to accentuate the depth of subsurface sound velocity maxima originally formed by winter cooling.

(U) West of 30° W longitude (i.e., in the western half of Area I and in Area III), subsurface sound velocity maxima are considerably shallower than those in the Northeast Atlantic and roughly coincide either with layer depths or the bottom of the "18° Water" layer. Therefore, both the temporal and spatial variability of this parameter are greater west of the Mid-Atlantic Ridge. Despite intensive winter cooling throughout the Labrador Sea (to depths in excess of 500 meters), subsurface sound velocity maxima similar to those north of Porcupine Bank are not present in the western half of Area I. This is largely due to extremely low salinity water carried by the Labrador and West Greenland Currents (less than 34.9 ‰ according to Lee and Ellett, 1967). In this region, winter cooling causes positive velocity gradients throughout the water column (see Figure I-12), and summer warming causes a deep sound channel axis at a depth somewhat below the absolute salinity minimum (often at the surface). Therefore, a subsurface sound velocity maximum is not formed despite intensive winter cooling. The tongue with subsurface sound velocity maxima at greater than 400 meters that lies west of the Reykjanes Ridge at about 60° N latitude is apparently related to higher salinity and warmer waters that are transported by the Irminger Current. This tongue corresponds well with the shape of isohalines and isotherms shown by Wust and Defant (1936) at 400 and 600 meters.

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(U) The Polar Front is shown clearly in the rapid transition of subsurface sound velocity maxima on either side of Iceland. Transitional regions also are found along the northern boundary of Area III (northern wall of Gulf Stream), in the region extending from about 43° to 50° N latitude between about 15° and 30° W longitude (frontal zone caused by interaction of NACW, AIW, and MIW), and in the vicinity of the Canary Islands (region of rapid dilution of MIW). In all these regions of rapid transition, the surface sound velocity maximum tends to merge with either the upper or deep sound channel to form a basically trilinear sound velocity profile.

DEEP SOUND CHANNEL

(U) Figures I-12, II-12, and III-12 show contours of the annual axial depth of the deep sound channel. This parameter was compiled and contoured in a manner similar to that used for the subsurface sound velocity maximum. An annual presentation was chosen for deep axial depth since in any given two-degree square seasonal variations were as great as annual variations. In addition, deep axial depths at any given latitude generally are not directly related to the annual heating and cooling cycle (i.e., deeper values in summer, shallower values in winter). A deep sound channel is found throughout the year in all three areas except in regions off Grand Banks and south and east of Greenland (see Figure I-12). In these two regions, intensive cooling results in positive velocity gradients during the colder months of January through April. During the summer, a deep sound channel is formed in these two regions by warming of the surface and near-surface layers. In a small region off Cape Farvel, positive velocity gradients are present throughout the year.

(U) Annual deep axial depths in the North Atlantic range from greater than 2000 meters off the Iberian coast (see Figure II-12) to less than 100 meters off the Grand Banks and Greenland (see Figure I-12). Two major features are apparent in the overall deep axial depth structure. The first consists of a tongue with anomalously deep values of this parameter that extends west southwest from the Iberian Coast across the North Atlantic to Bermuda. This tongue is bounded by the 1200-meter deep axial depth isoline and its shape corresponds well with the preferential flow of high salinity MIW shown by Worthington (1970). Deep axial depths shoal markedly to the north and south of this tongue. The second major feature consists of a tongue with anomalously shoal values of this parameter that extends along about 55° N latitude from about 40° to about 20° W longitude. This tongue is bounded by the 900-meter deep axial depth isoline and its shape corresponds well with the 35.0 ‰ and less isohalines shown at 400, 600, and 800 meters by Wüst and Defant (1936). The latter tongue corresponds to the flow of low salinity AIW. Deep axial depths tend to deepen to the north and south of 55° N latitude.

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(U) Zones of rapid change in deep axial depth are found to the east and west of Iceland (Polar Front), south and east of Grand Banks (at confluence of the Gulf Stream, North Atlantic Current system and the Labrador Current), and in the vicinity of the Canary Islands (region of rapid dilution of MIW). The extremely broad deep sound channel south of about 30° N latitude in both Areas II and III apparently is a result of diluted concentrations of high salinity MIW (Fenner and Bucca, Dec 1969). However, in the southwest corner of Area III, the width of the channel is constricted by intrusion of low salinity Antarctic Intermediate Water (AAIW) from the south. In the western half of Area I, the sound channel also is narrower because of low salinity AIW.

BATHYMETRY SHOALER THAN CRITICAL DEPTH

(U) Figures I-13, II-13, and III-13 show the amount of bathymetry extending above average critical depth during the composite six-month winter season (Nov-Apr). Figures I-14, II-14, and III-14 show the same parameter for the composite six-month summer season (May-Oct). These composite seasons were chosen because of the lack of data in various regions of the North Atlantic during one or more of the four standard seasons. In addition, six-month depth difference charts show relatively small changes in 500-fathom contours at three-month intervals. In preparation of these figures, critical depths were compiled by one-degree square for each of the two seasons, averaged by two-degree square, and then contoured on an areal basis. Bathymetric charts then were overlayed with the critical depth contours and areas where bathymetry extended above critical depth were outlined. Except in the Northeast Atlantic between 30° and 60° N latitude east of 30° W longitude, bathymetric charts compiled by NAVOCEANO for the National Intelligence Survey (NIS) prior to 1960 were used in constructing these figures. In the Northeast Atlantic, the charts of A. S. Laughton (National Institute of Oceanography, Wormley, England) were used. Critical depth contours are based on NODC serial sound velocity profiles processed as of January 1969, supplemented by sound velocimeter and Nansen cast data from the MGS and CAESAR programs and sound velocimeter data from Woods Hole Oceanographic Institution and Lamont-Doherty Geological observatory.

(U) During both seasons substantial areas of bathymetry shoaler than critical depth are associated with major physiographic features such as the Mid-Atlantic Ridge, the Reykjanes Ridge, the Faeroe Plateau, Porcupine Bank, various seamounts west of Gibraltar, the Canary Rise, the Bermuda Rise, the New England Seamounts, and the Grand Banks. The amount of bathymetry shoaler than critical depth is less during winter than during summer in all cases because of the shallower critical depths during this season. Of particular interest is the lesser amount of bathymetry shoaler than critical depth associated with the

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New England Seamounts, Bermuda Rise, and the intersection of the Reykjanes and Mid-Atlantic Ridges (Gibbs Fracture Zone) during winter (compare Figures I-13 and I-14 and Figures III-13 and III-14).

BATHYMETRIC INDEX CHARTS

(U) Figures I-15, II-15, and III-15 are indices of the best available bathymetric contour charts for the three LRAPP priority areas. Four types of charts were used in compiling these figures:

- NAVOCEANO North Atlantic Regional Charts compiled in 1969
- Charts of A. S. Loughton (National Institute of Oceanography, Wormley, England) compiled in 1966
- NAVOCEANO Bathymetric Contour charts (BC's) contoured in the indicated years
- Charts contoured prior to 1960 as part of the National Intelligence Survey (NIS) program.

Individual, large-scale charts of specific locations or bathymetric features have not been included on these indices.

SURFICIAL BOTTOM SEDIMENTS

Figures I-16, II-16, and III-16 show the location by one-degree square of bottom sediment samples held by NAVOCEANO. These figures reflect the same data distribution shown on Figure V-6 of H.O. Publication No. 700 (NAVOCEANO, 1965). Therefore, the bibliography contained in the above publication also applies to the three figures. There are large variations in the quantity and quality of bottom sediment data throughout the three areas. Only a few shallow nearshore regions have been sampled adequately.

Figures I-17, II-17, and III-17 show the classification of surficial bottom sediments on the basis of principle grain size constituents. These figures were taken directly from Figures V-7 and V-8 of H.O. Publication No. 700 (NAVOCEANO, 1965). Generally, coarser sediments are found over the Mid-Atlantic and Reykjanes Ridges and on the continental shelves. Other regions primarily contain muds, sands, and mud-sands.

BOTTOM CORE INVENTORIES

(U) Figures I-18, II-18, and III-18 show the location by one-degree square of unclassified bottom cores held by NAVOCEANO. A recently updated computer plot of these cores was provided by E. Wilcox, Oceanographic Analysis Division, NAVOCEANO. Cores indexed on these figures vary considerably in length and in type and quality of analysis.

CONTINUOUS SEISMIC PROFILE INVENTORIES

(U) Figures I-19, II-19, and III-19 show a partial inventory of continuous seismic profiles of the subbottom on a one-degree square grid. These figures are based on the following data sources.

- All data collected in the following NAVOCEANO MGS Atlantic Task Areas:
 - Alpine Area SF (NAVOCEANO, Feb 1967c)
 - Alpine Area ST (NAVOCEANO, Aug 1968)
 - Alpine Area I (NAVOCEANO, Sep 1966b)
 - Texas Instruments (TI) Area 2 (NAVOCEANO, Mar 1968)
 - TI Area 3 (NAVOCEANO, Oct 1968)
 - TI Area 5 (NAVOCEANO, Jan 1967)
 - TI Area 7/4 (NAVOCEANO, Apr 1969)
- All data collected on Cruise 9 of the USNS KANE (Lowrie and Escowitz, 1969)
- Data collected by the Woods Hole Oceanographic Institution on the following cruises of the R/V CHAIN:
 - No. 7, 1959 (Dunkle and Hays, May 1966)
 - No. 21, 1961 (Ibid.)
 - No. 34, 1962 (Ibid.)
 - No. 36, 1963 (Ibid.)
 - No. 39, 1963 (Ibid.)
 - No. 43, 1964 (Ibid.)
 - No. 44, 1964 (Ibid.)
 - No. 70 and No. 73, 1967 (Knott, et al., Jul 1968)
 - No. 82, 1968 (Dunkle, Jun 1969)

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- Data collected by the Lamont-Doherty Geological Observatory aboard the R/V VEMA and R/V CONRAD, as contained in the following references:

- Ewing, et al. (1960)
- Wilson (1963)
- Ewing, et al. (1964)
- Jones and Ewing (1969).

Major oceanographic, geological, and geophysical journals and serial publications from major national and international oceanographic institutions and organizations have been searched in preparing these figures. Tracks shown on these figures represent profiles taken with sparker, boomer, and air gun systems.

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LRAPP PRIORITY AREA ONE

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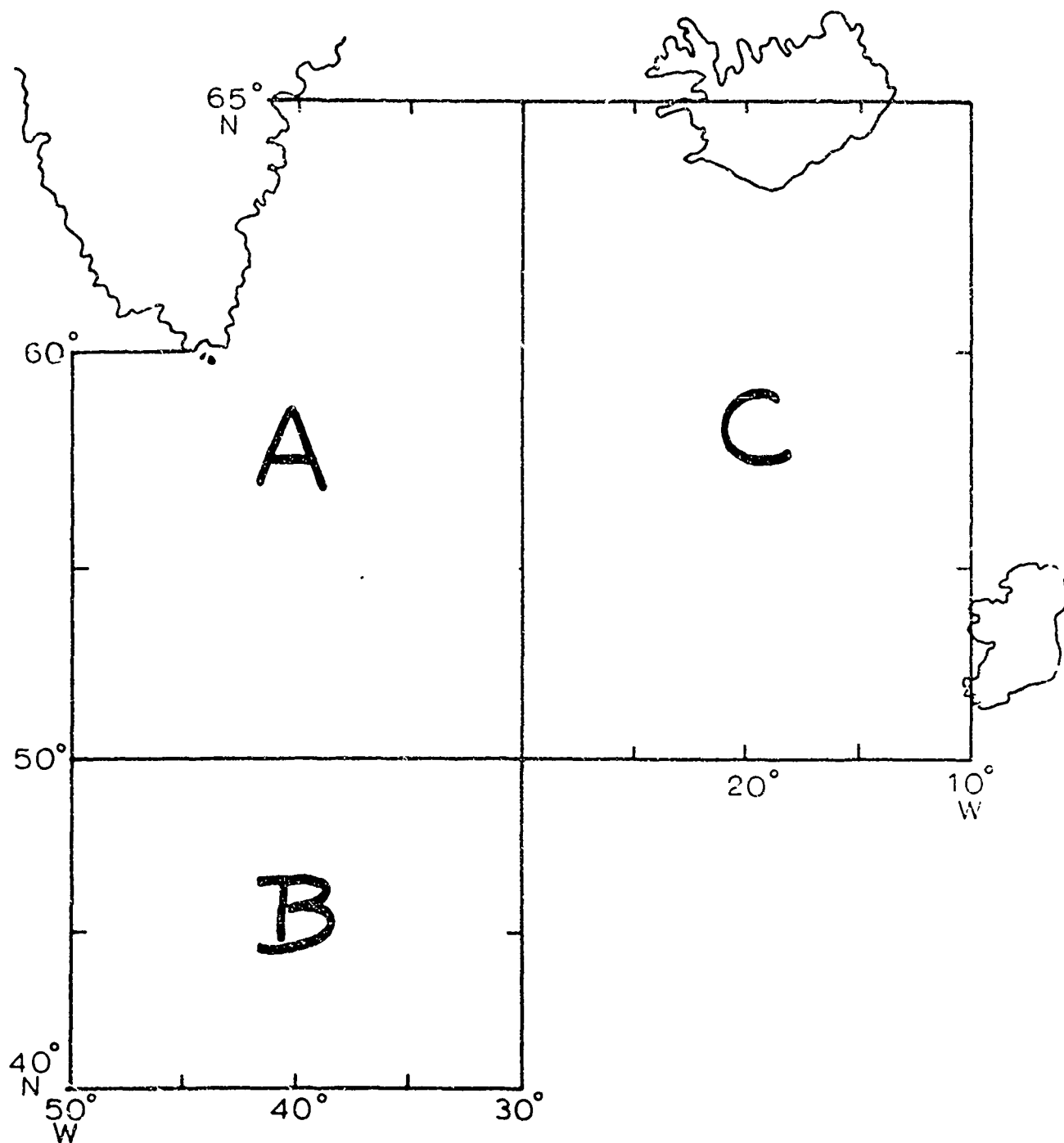


FIGURE L-1: LOCATION OF LAMP ATLANTIC AREA I SURVEYS

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FIGURE I-2A: NUMBER OF WINTER (Jan-Mar) OCEANOGRAPHIC OBSERVATIONS PER ONE-DEGREE SQUARE DEEPER THAN DEEP AXIAL DEPTH

60°N
50°W

40°W
65°N

35°

30°W
65°N

60°N
45°W

60°

55°

50°N

FIGURE I-2A

20

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50
N

CONFIDENTIAL

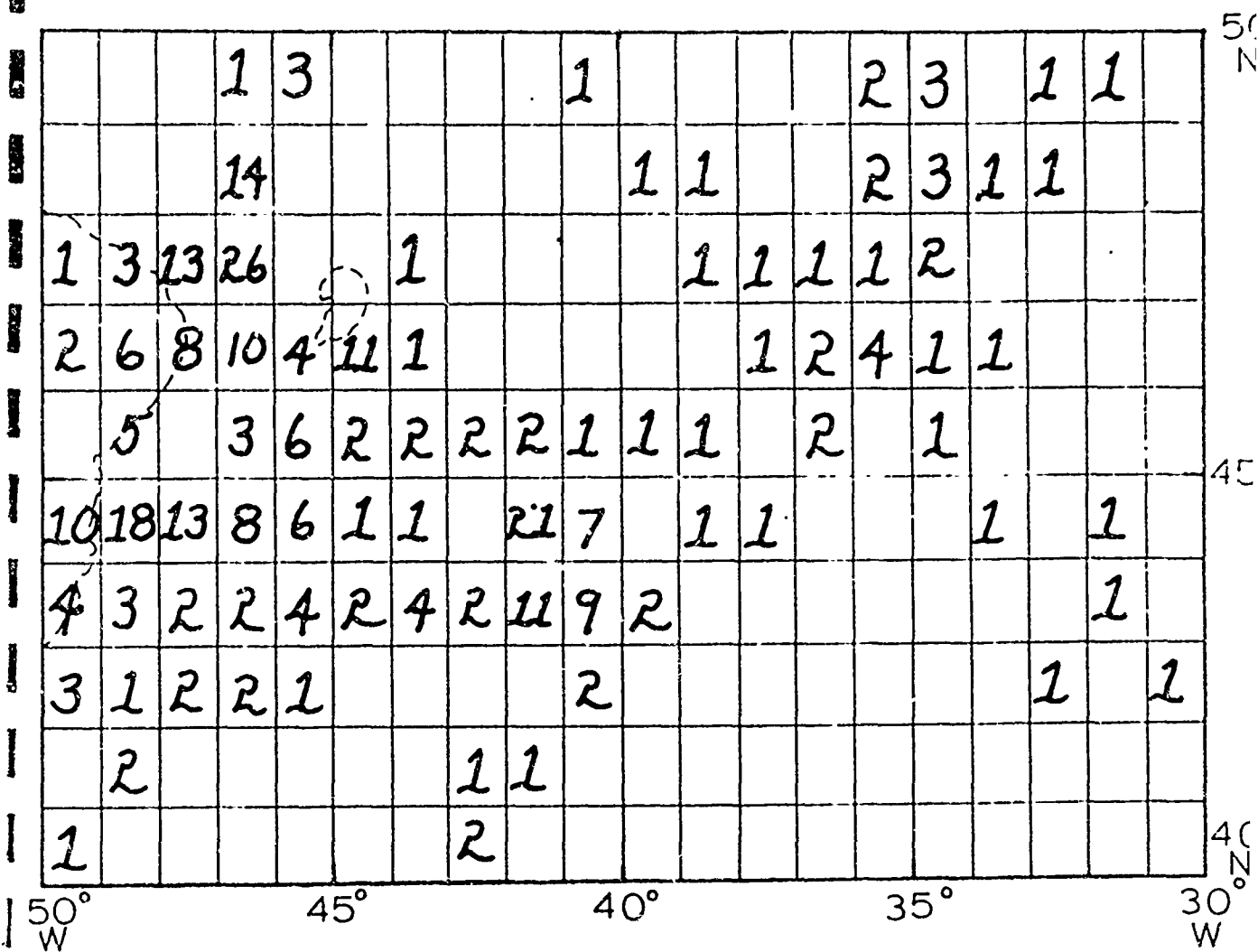


FIGURE I-2B: NUMBER OF WINTER (Jan-Mar) OCEANOGRAPHIC OBSERVATIONS PER ONE-DEGREE SQUARE DEEPER THAN DEEP AXIAL DEPTH



22

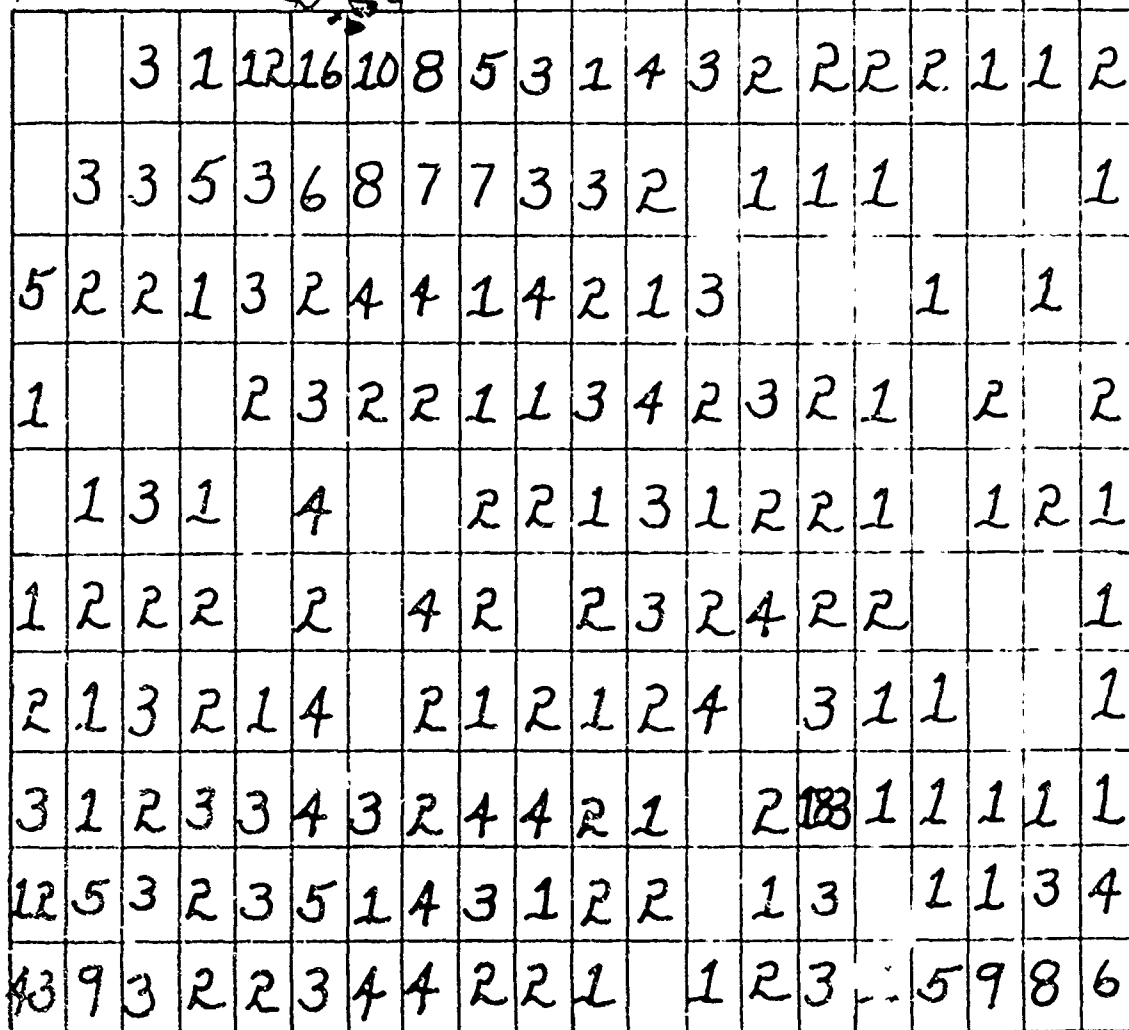
240" W
65° N

35°

30°W
60°N

60°N
50°W

60°N
45°W



60

55

50
N

CONFIDENTIAL

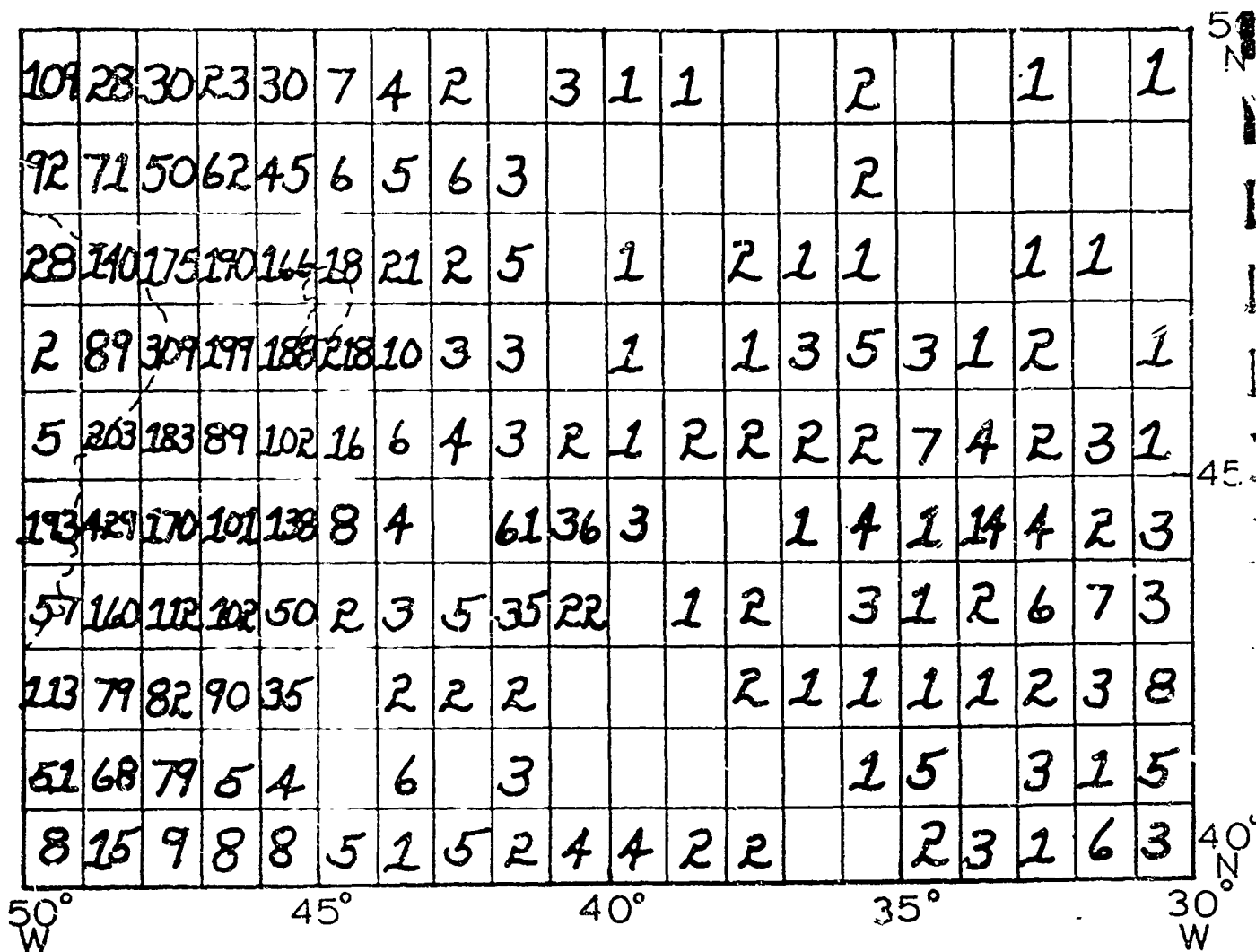


FIGURE I-3B: NUMBER OF SPRING (Apr-Jun) OCEANOGRAPHIC OBSERVATIONS PER ONE-DEGREE SQUARE DEEPER THAN DEEP AXIAL DEPTH

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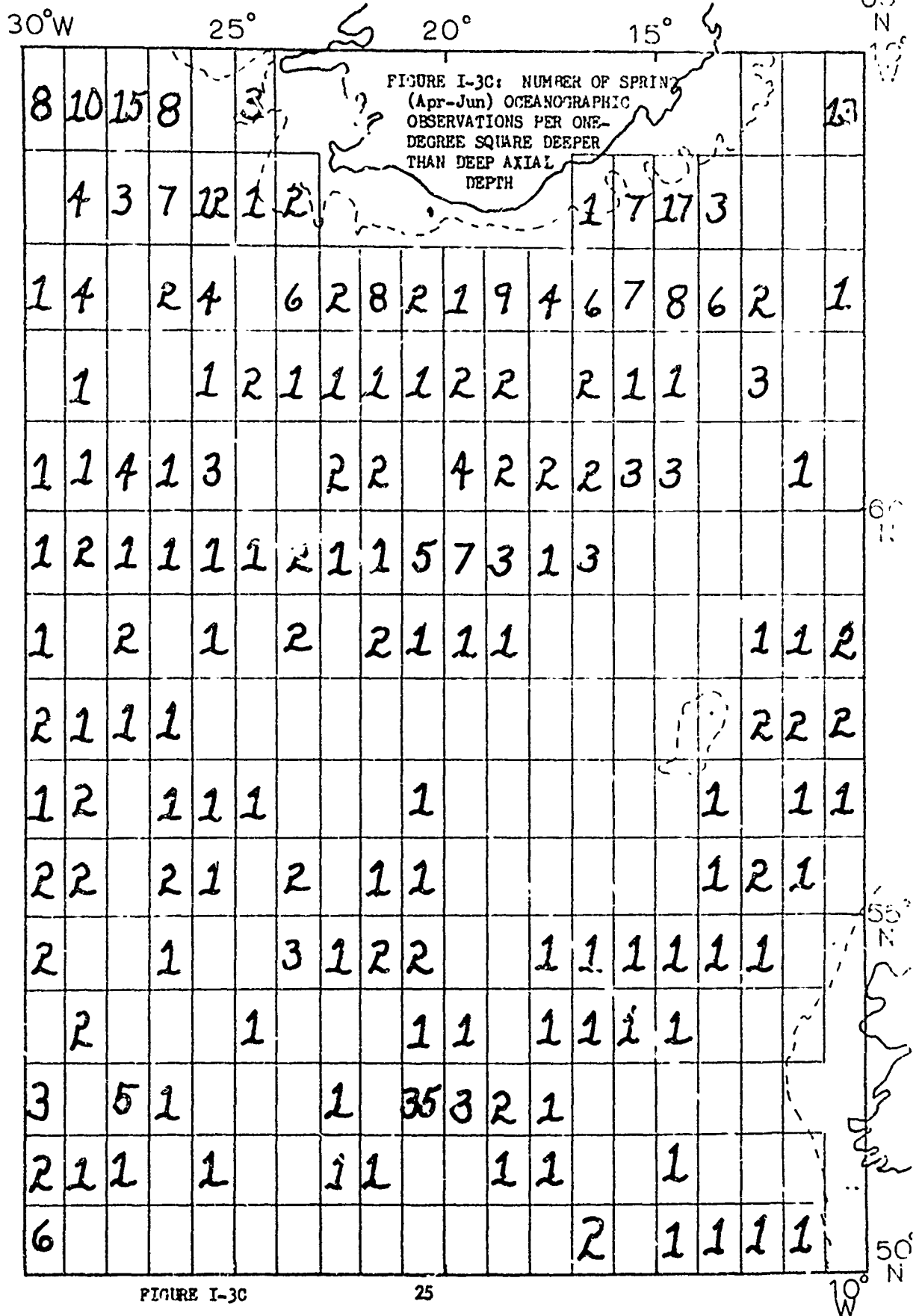


FIGURE I-3C

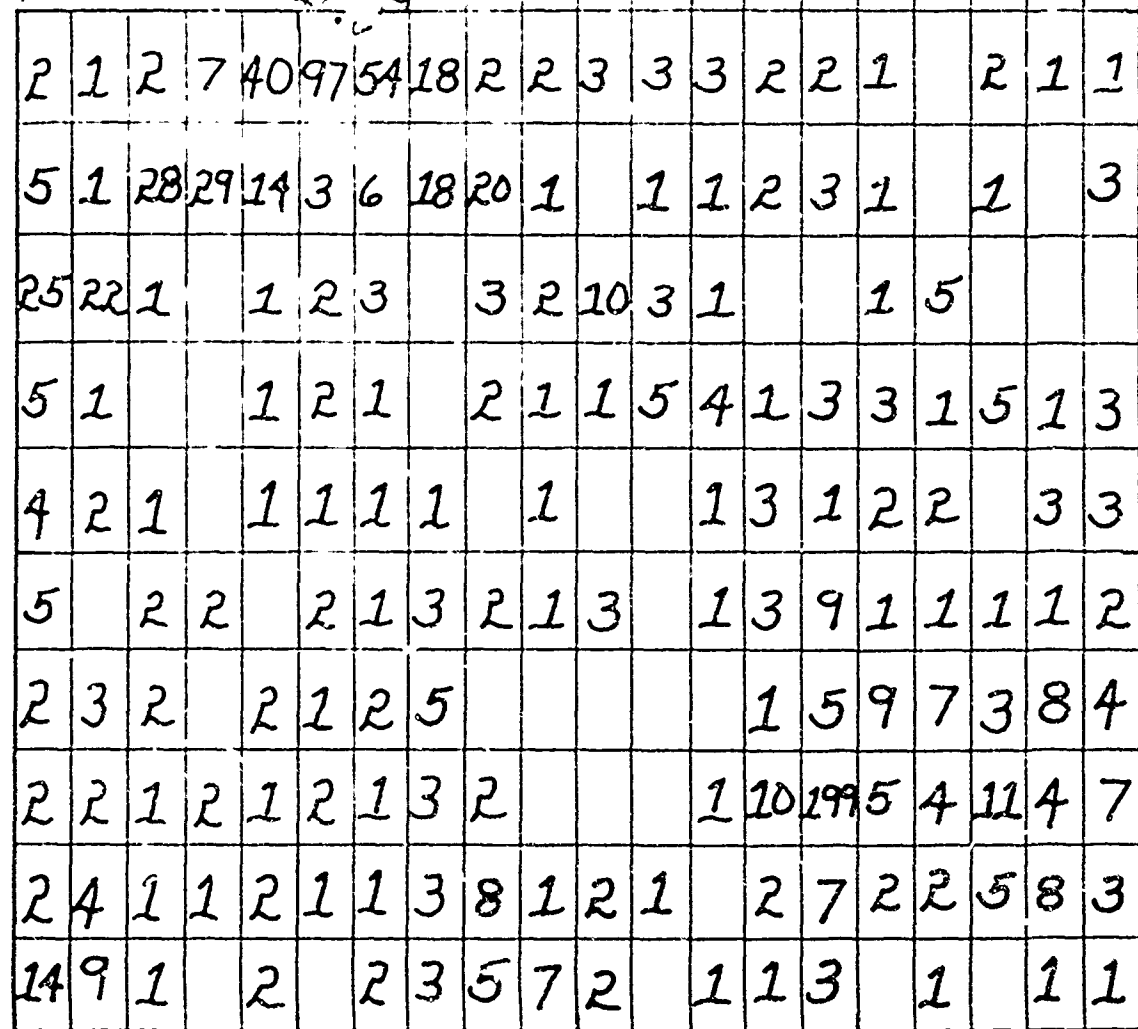
25

710:26 0193

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30°W
65°
N

60°N
50°W



CONFIDENTIAL

50
N

CONFIDENTIAL

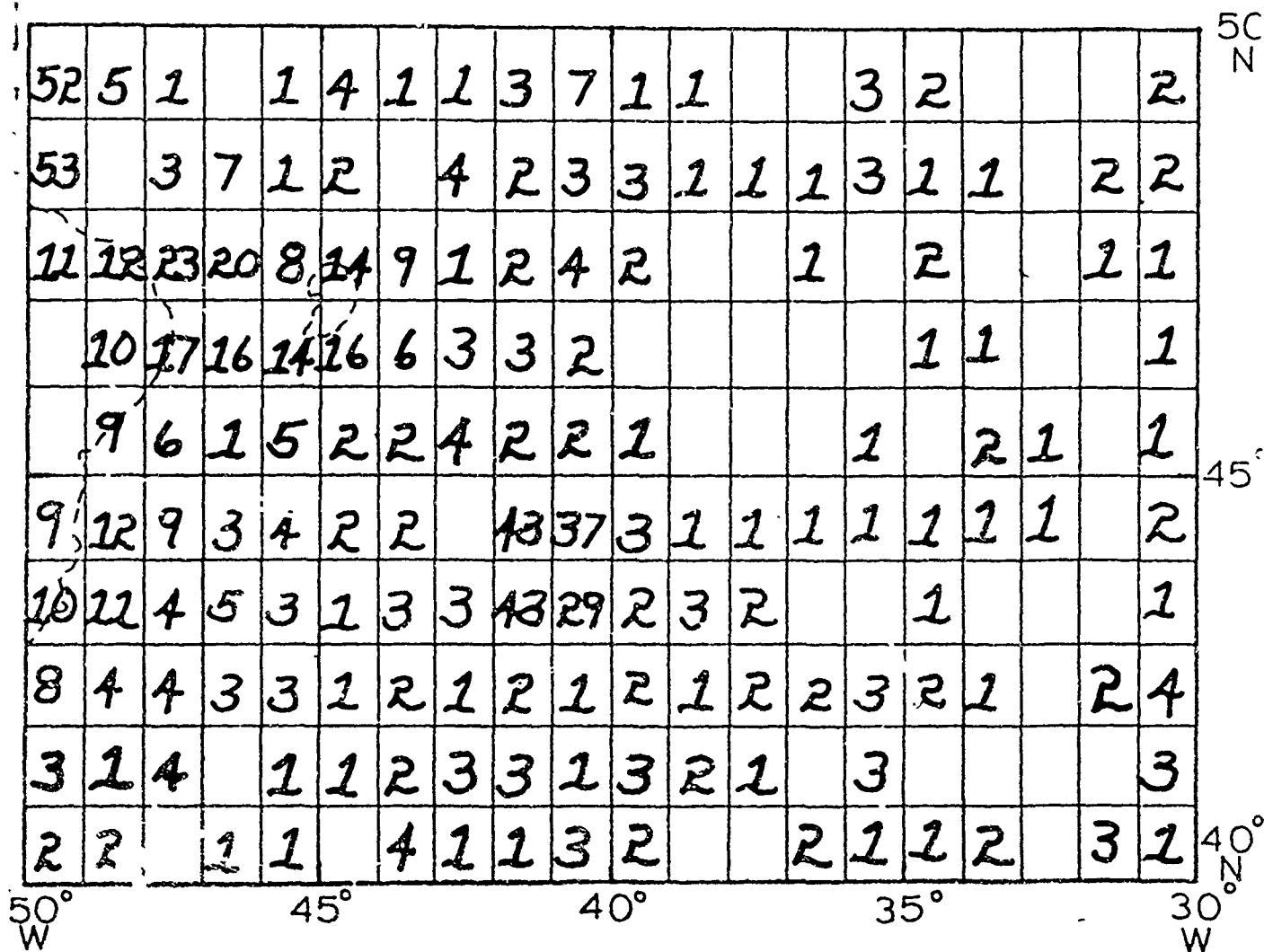
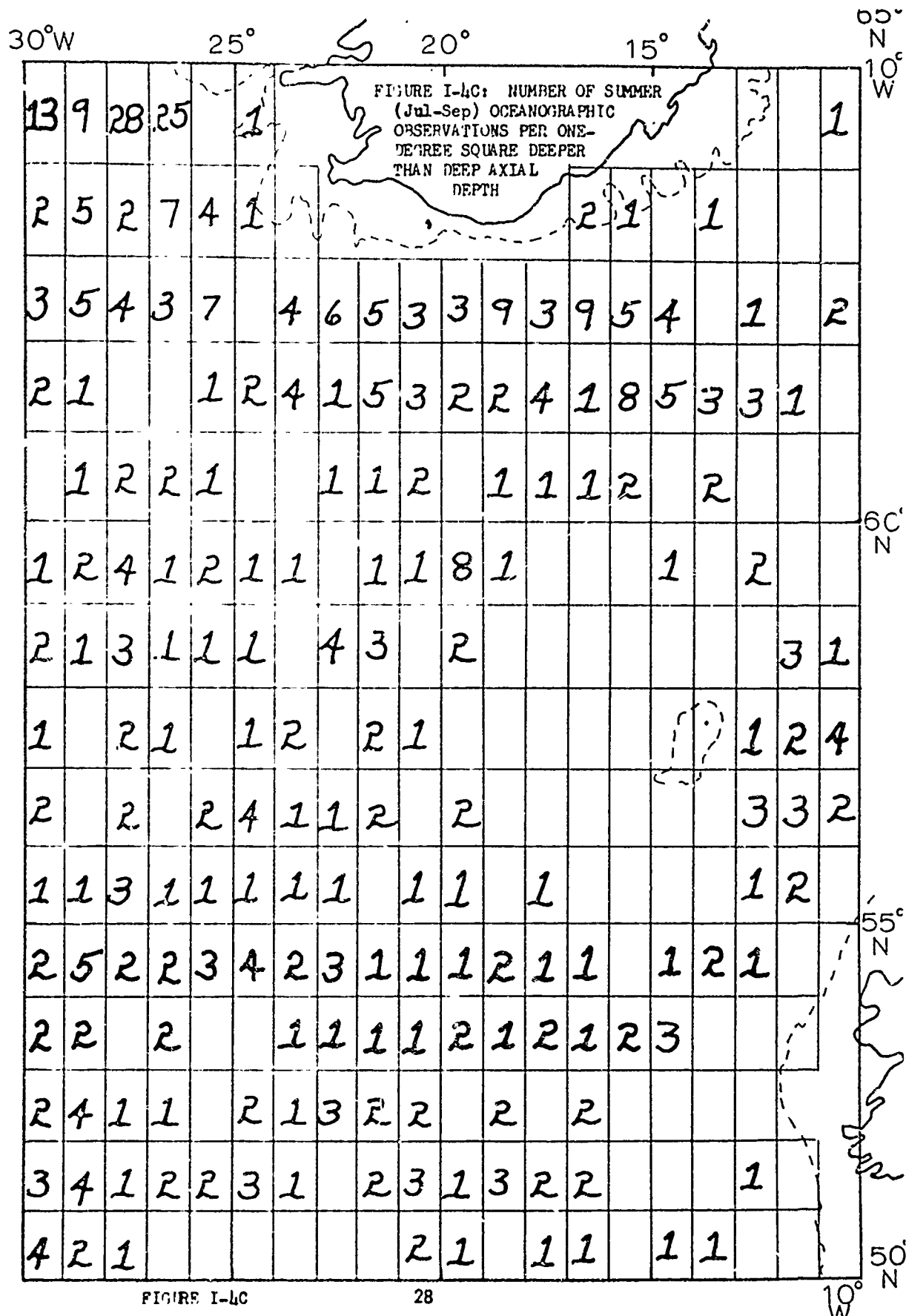


FIGURE I-4B: NUMBER OF SUMMER (Jul-Sep) OCEANOGRAPHIC OBSERVATIONS PER ONE-DEGREE SQUARE DEEPER THAN DEEP WATER DEPTH

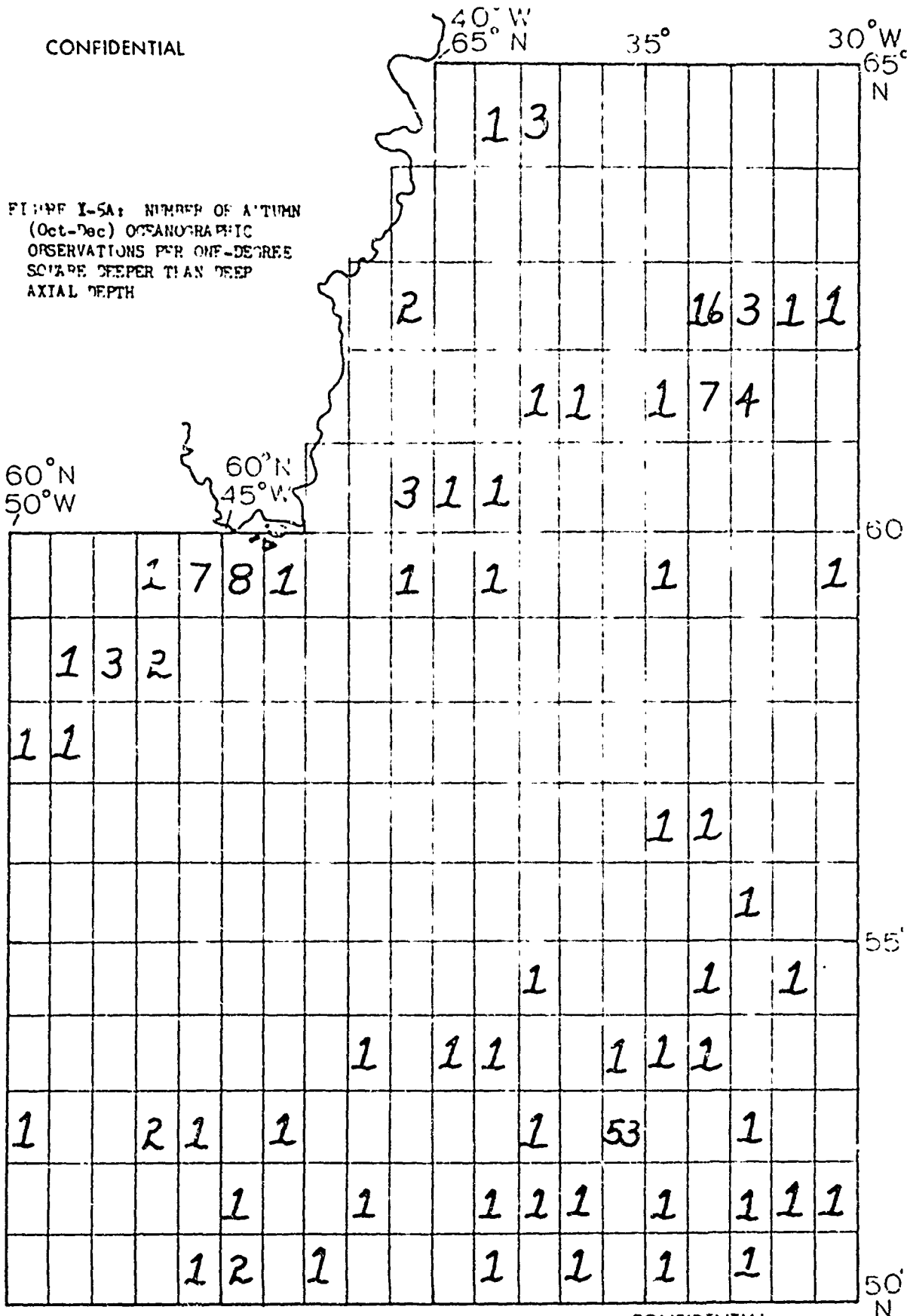
CONFIDENTIAL



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30°W
65°N

FIGURE 1-5A: NUMBER OF AUTUMN
(Oct-Dec) OCEANOGRAPHIC
OBSERVATIONS PER ONE-DEGREE
SQUARE DEEPER THAN DEEP
AXIAL DEPTH



710:26 0193

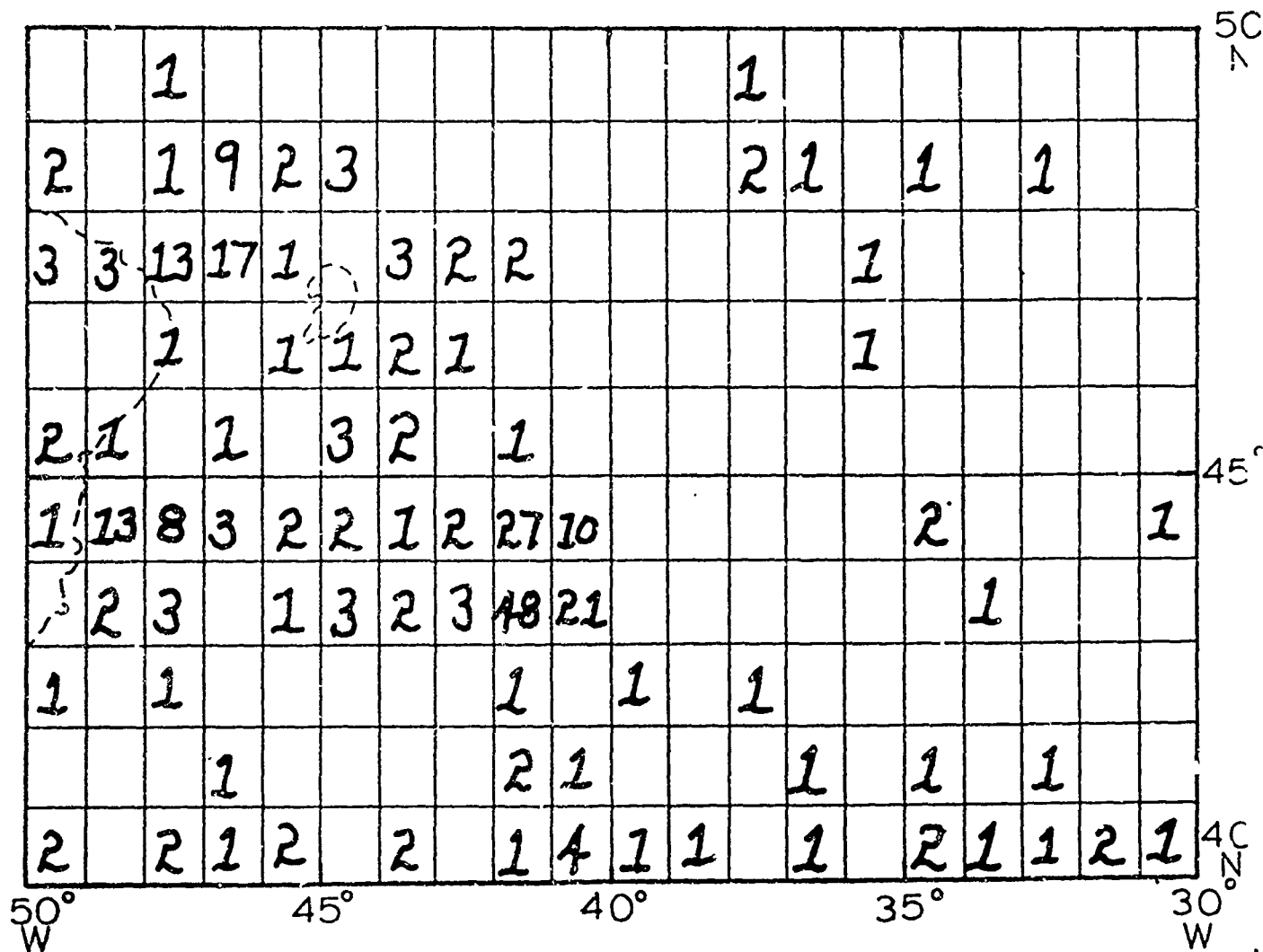


FIGURE I-5B: NUMBER OF AUTUMN (Oct-Dec) OCEANOGRAPHIC OBSERVATIONS PER ONE-DEGREE SQUARE DEEPER THAN DEEP AXIAL DEPTH

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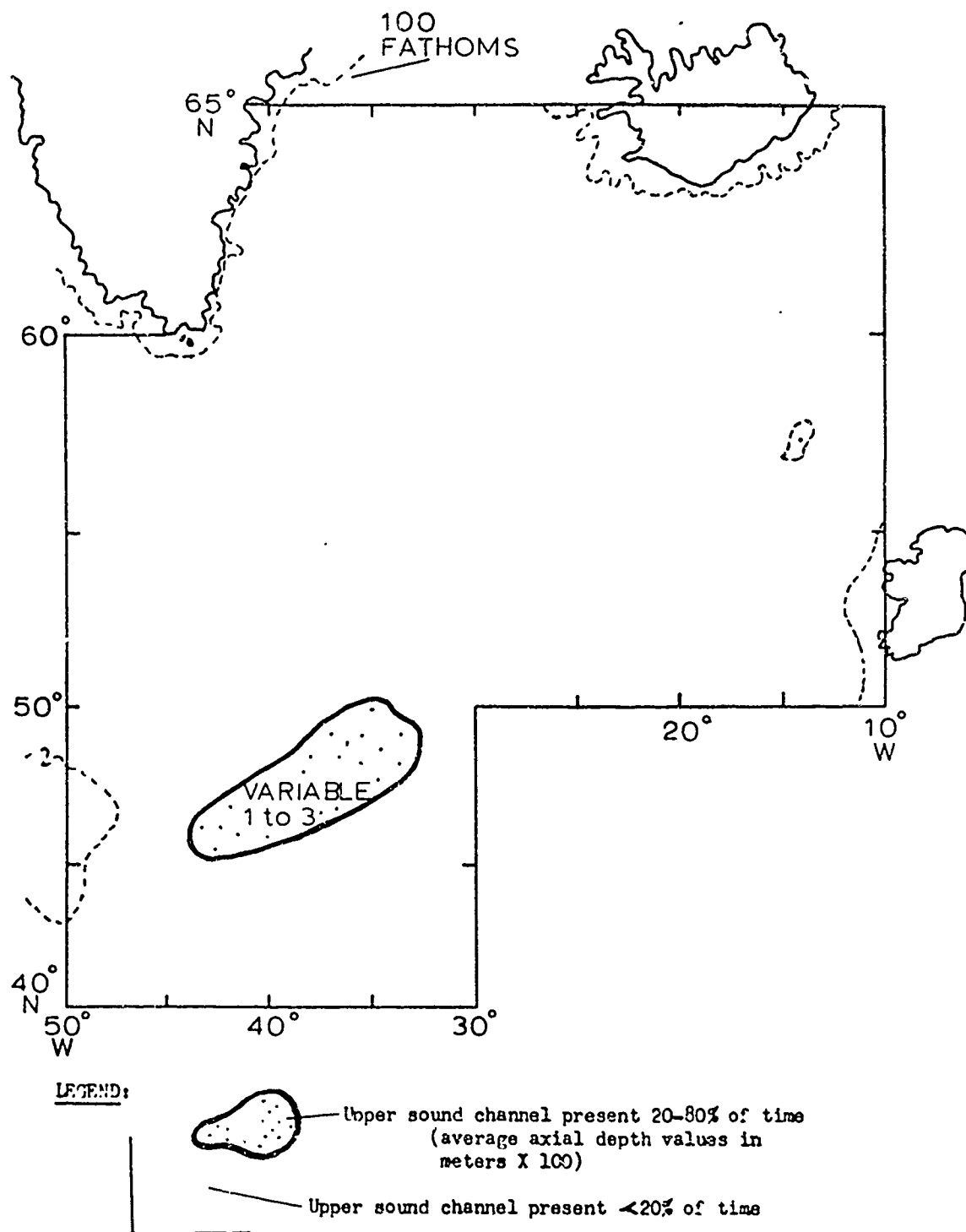


FIGURE I-6: AREAL EXTENT AND AVERAGE AXIAL DEPTH OF
UPPER SOUND CHANNEL FOR WINTER (Jan-Mar)

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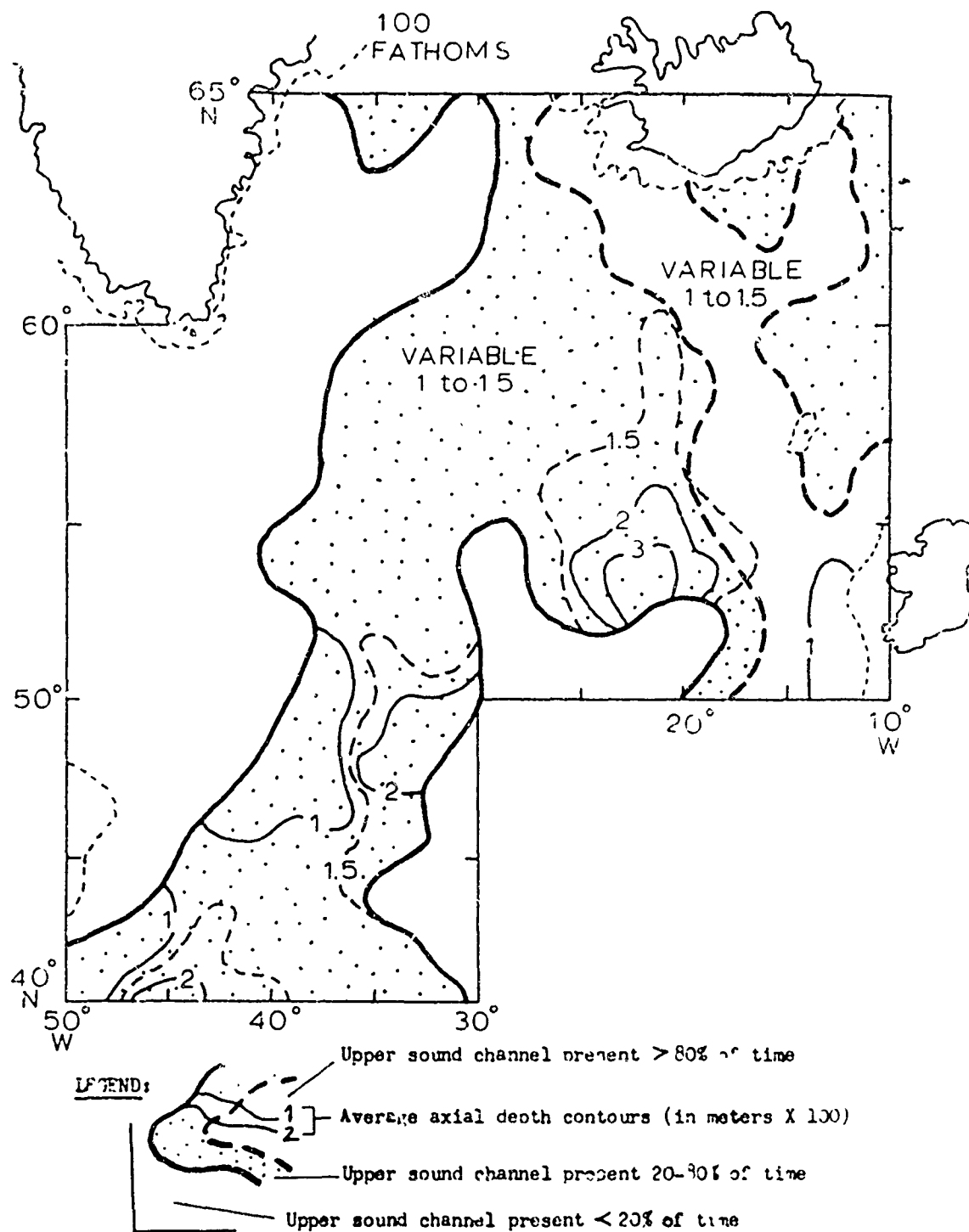


FIGURE I-7: AREAL EXTENT AND AVERAGE AXIAL DEPTH OF UPPER SOUND CHANNEL FOR SPRING (Apr-Jun)

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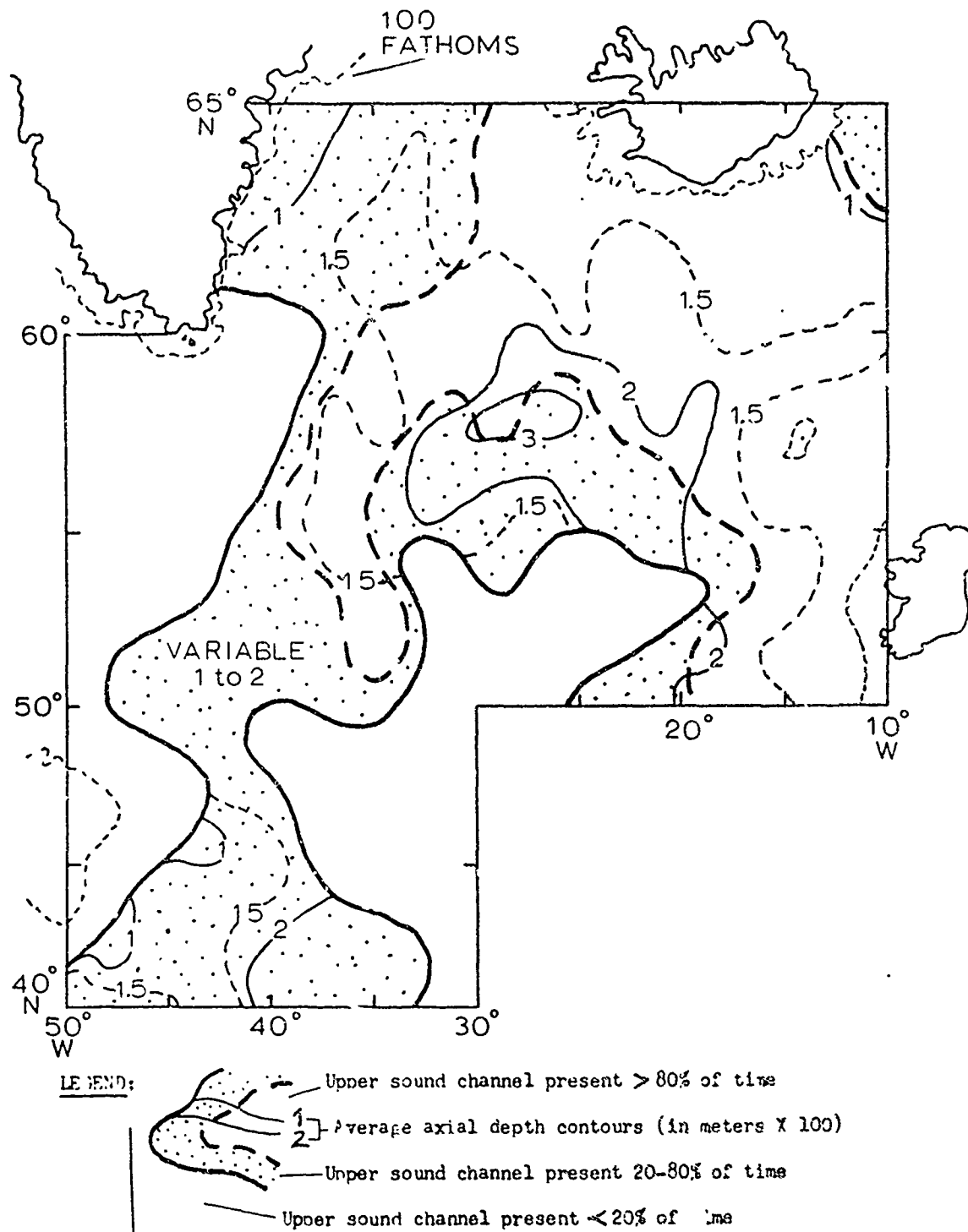


FIGURE I-8: AREAL EXTENT AND AVERAGE AXIAL DEPTH OF UPPER SOUND CHANNEL FOR SUMMER (Jul-Sep)

UNCLASSIFIED

UNCLASSIFIED

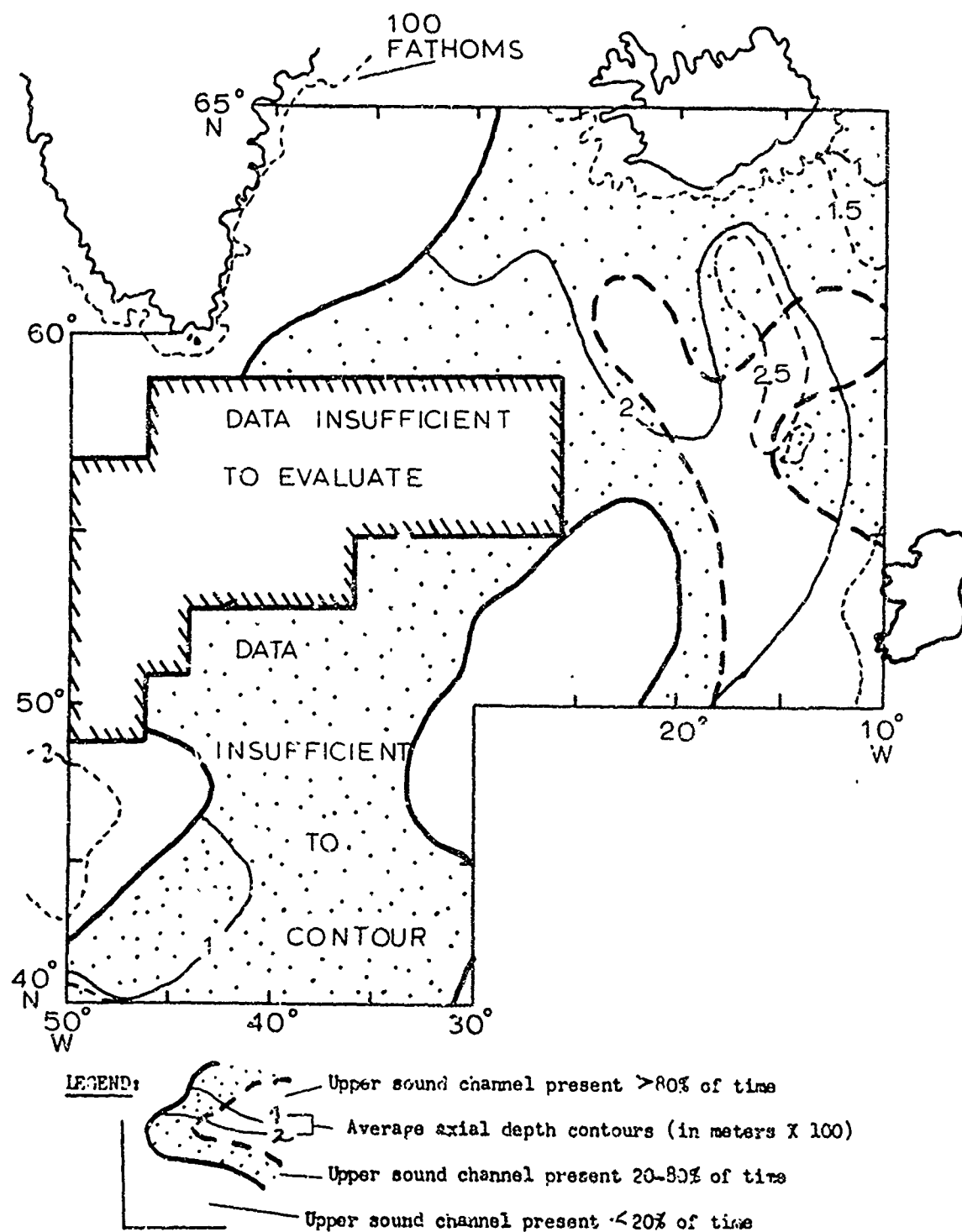


FIGURE I-9: AREAL EXTENT AND AVERAGE AXIAL DEPTH OF UPPER SOUND CHANNEL FOR AUTUMN (Oct-Dec)

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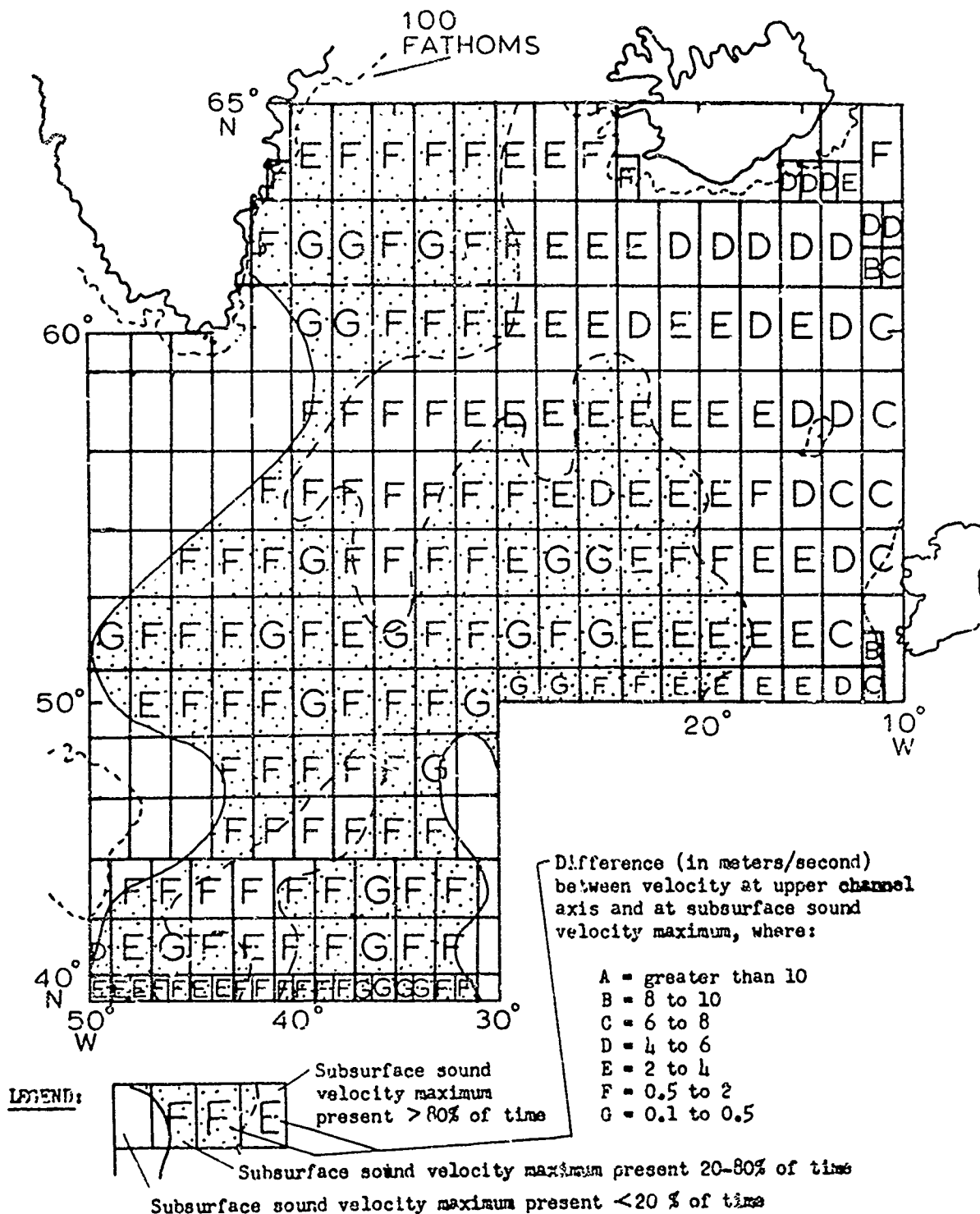


FIGURE I-10: ANNUAL AVERAGE "STRENGTH" OF UPPER SOUND CHANNEL (if present) RELATIVE TO SURFACE SOUND VELOCITY MAXIMUM

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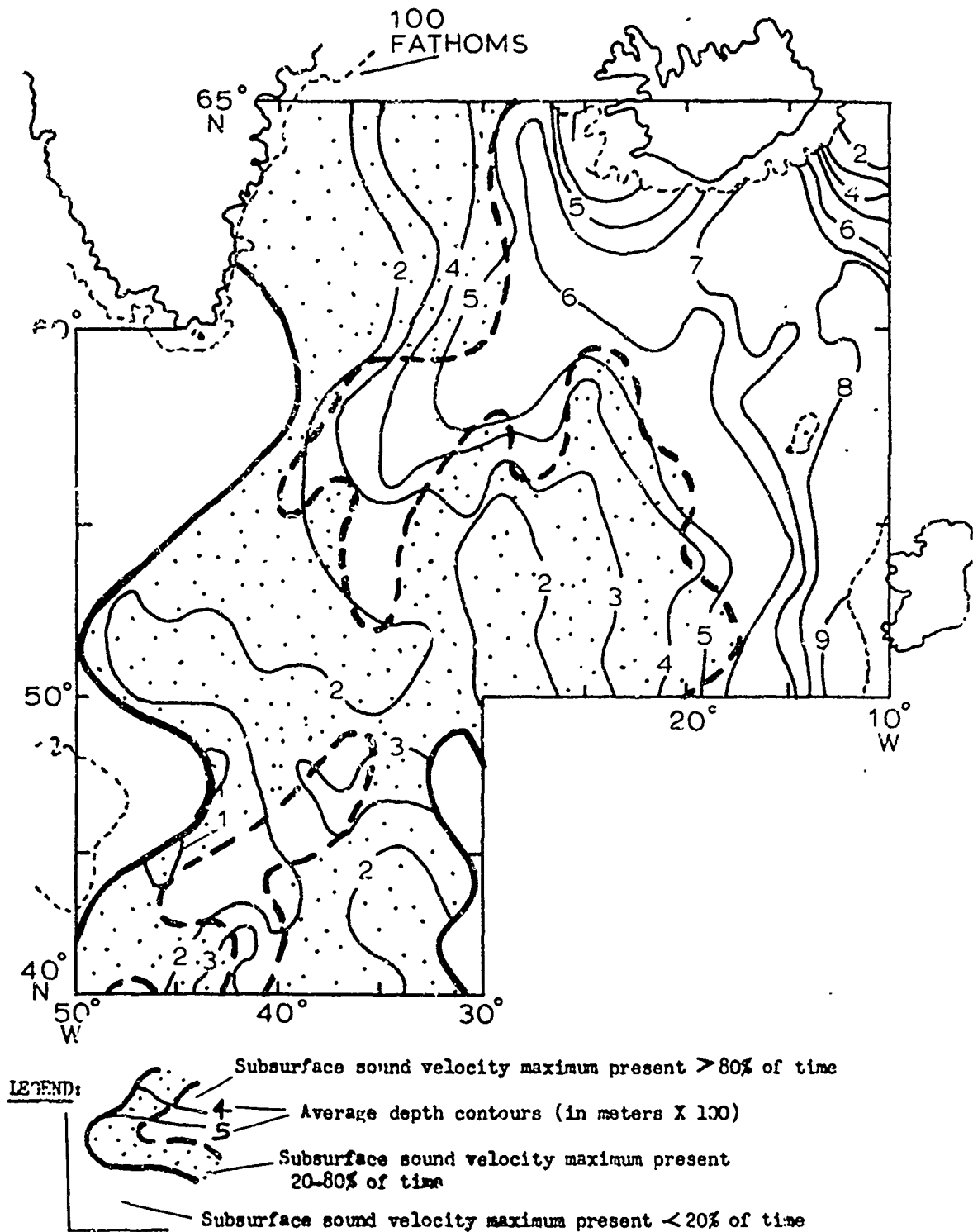


FIGURE I-11: ANNUAL AREAL EXTENT AND AVERAGE AXIAL DEPTH OF SUBSURFACE SOUND VELOCITY MAXIMUM

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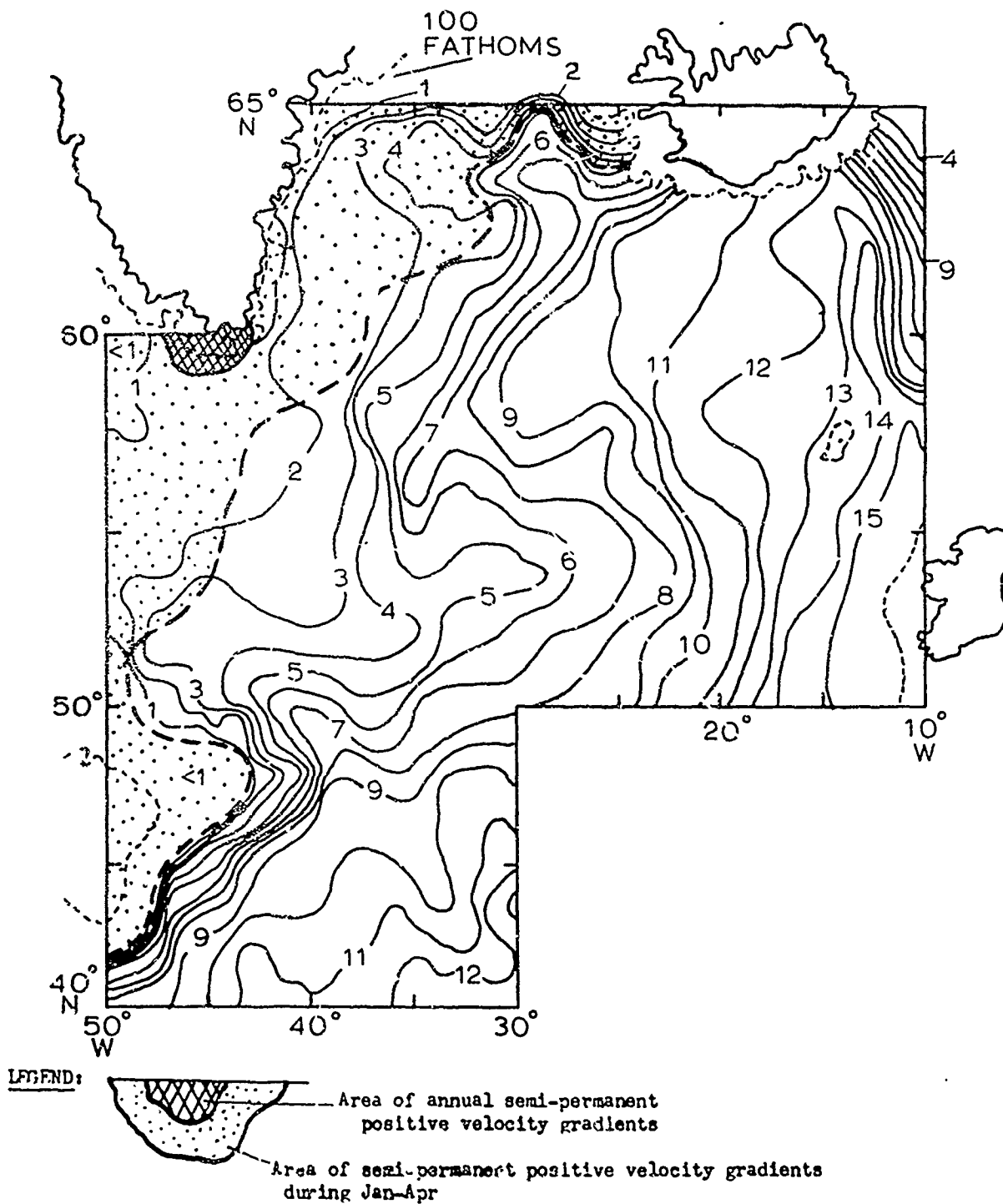


FIGURE L-12: ANNUAL AVERAGE DEPTH OF DEEP SOUND CHANNEL AXIS
(in meters X 100)

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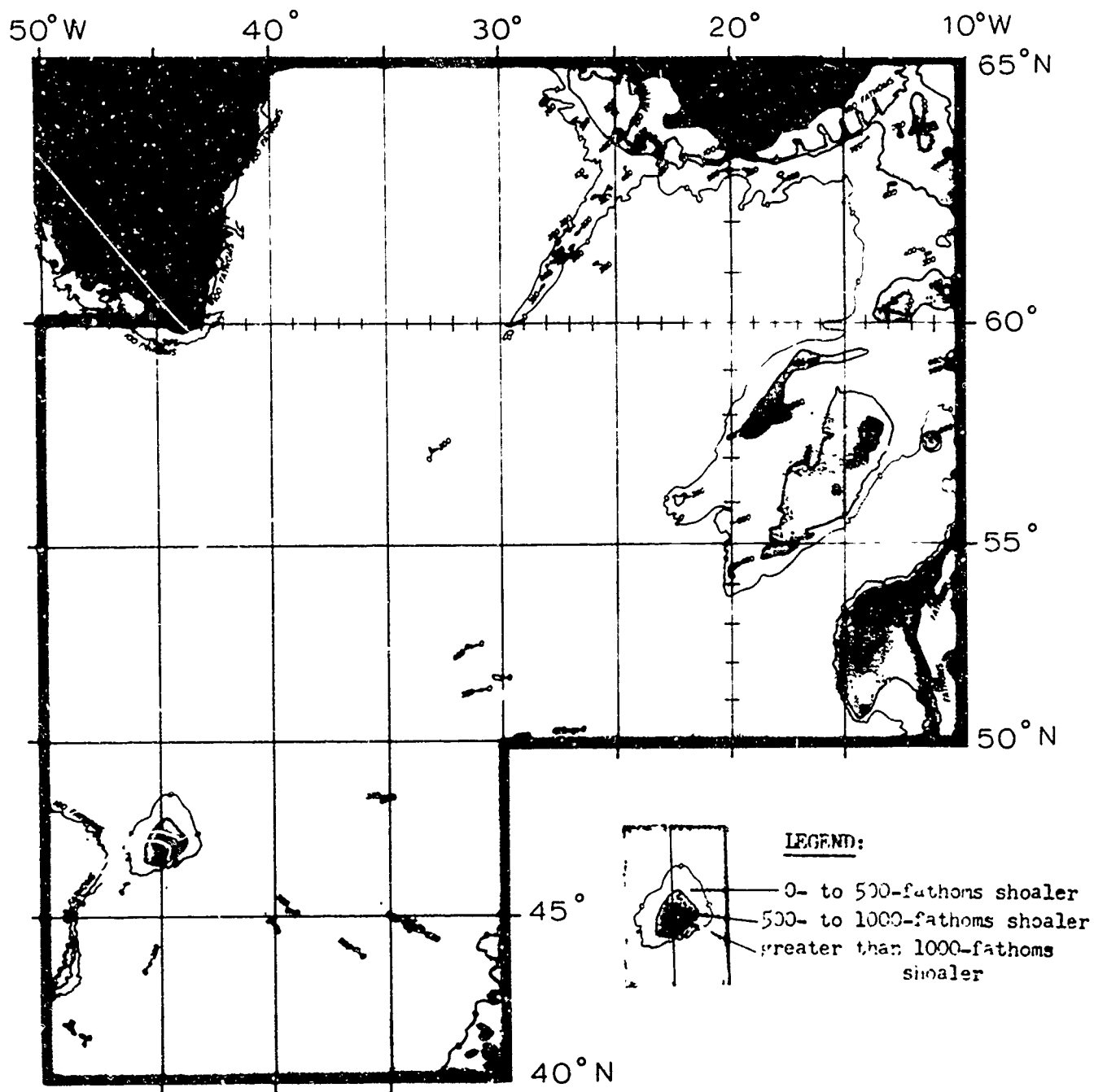


FIGURE I-13: BATHYMETRY SHOALER THAN AVERAGE CRITICAL DEPTH
FOR WINTER (Nov-Apr)
(Contour interval = 500 fathoms)

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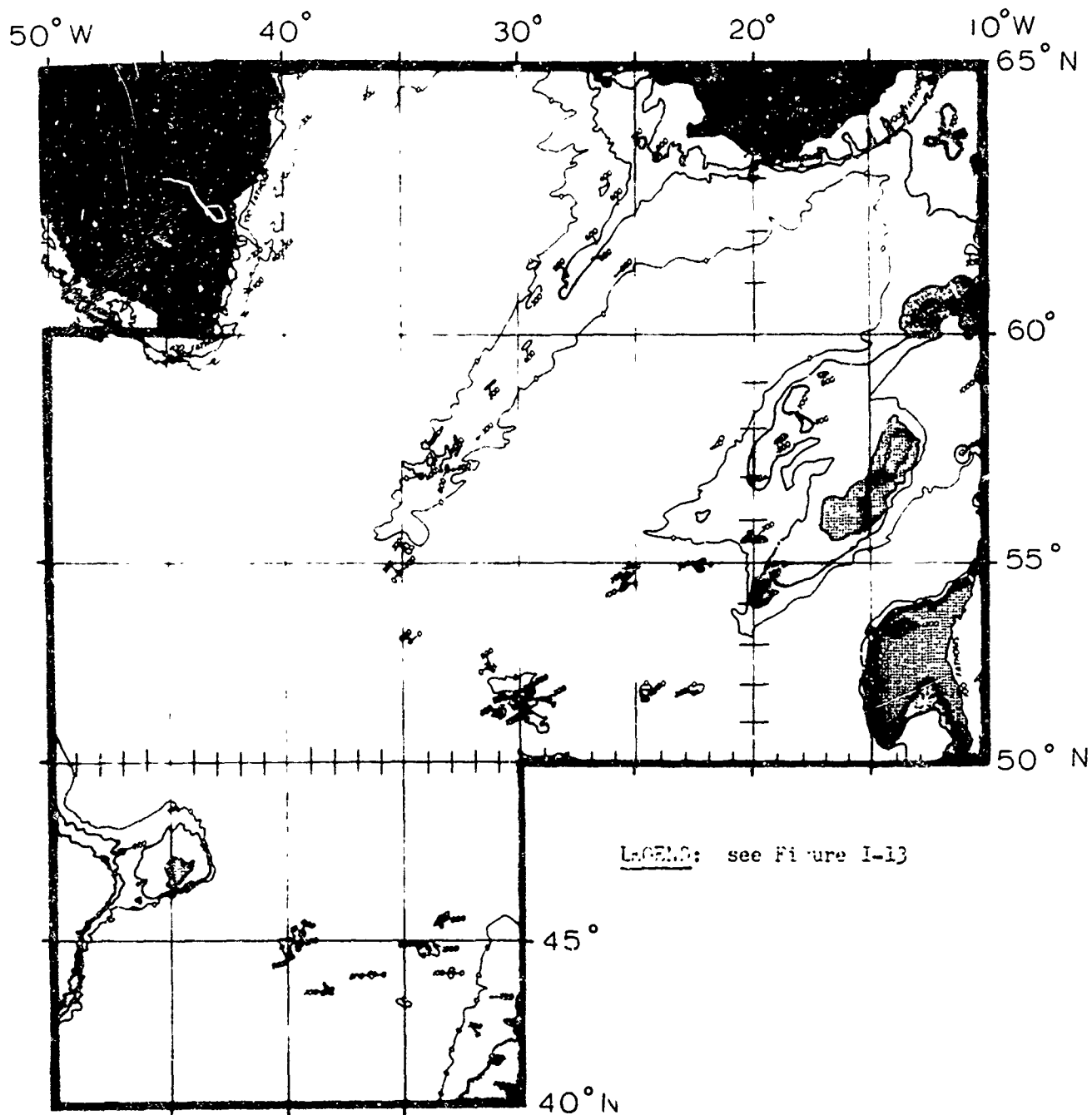


FIGURE I-14: BATHYMETRY SHOALER THAN AVERAGE CRITICAL DEPTH
FOR SUMMER (May-Oct)
(Contour interval = 500 fathoms)

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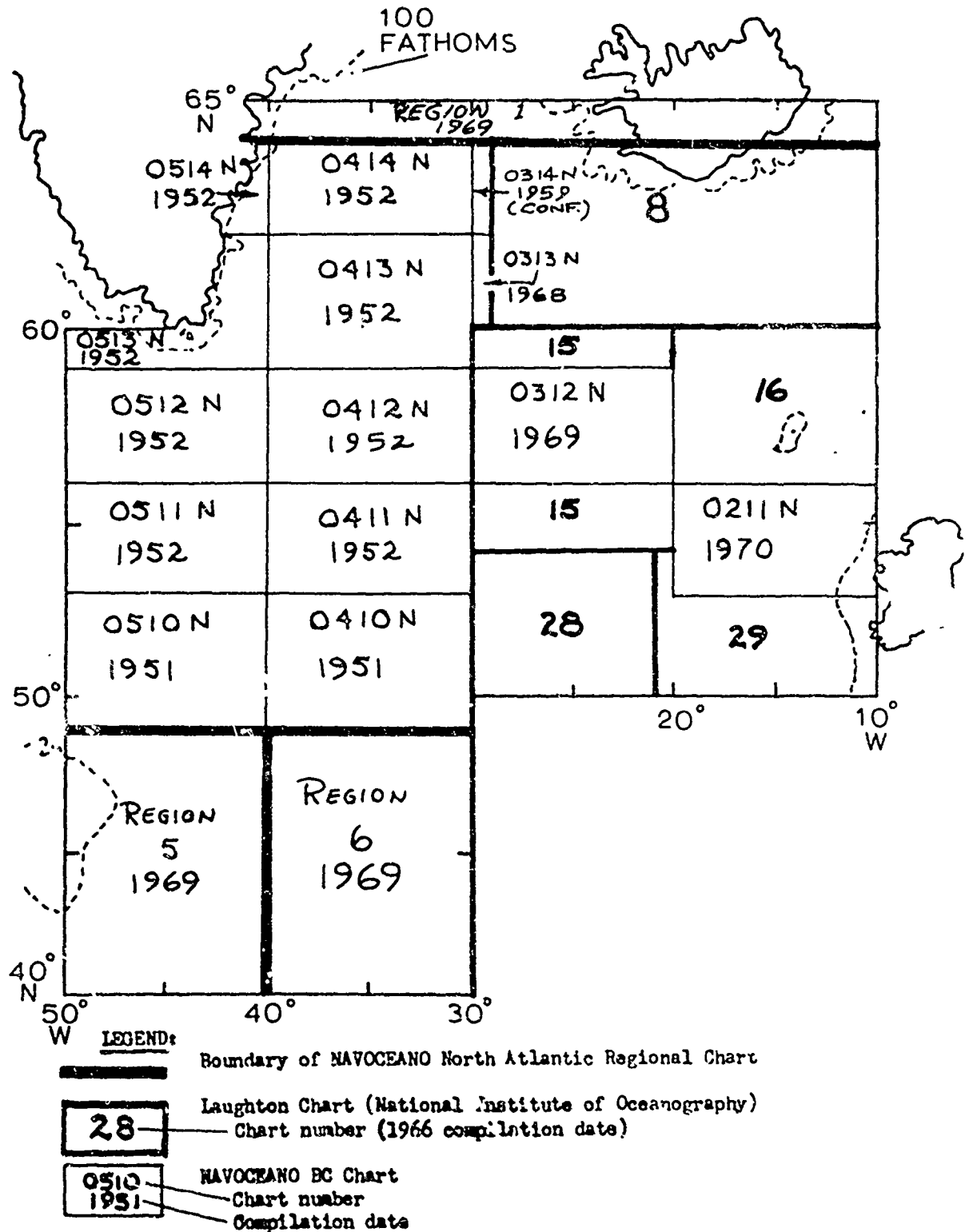


FIGURE 1-15: INDEX OF BEST EXISTING BATHYMETRIC CHARTS

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FIGURE I-16A: NUMBER OF
BOTTOM SEDIMENT SAMPLES PER
ONE-DEGREE SQUARE

LEGEND:

$\frac{1}{3}$ — Number of surface
sediment samples from
cores

Number of surface sediment
samples from snappers,
grabs, etc.

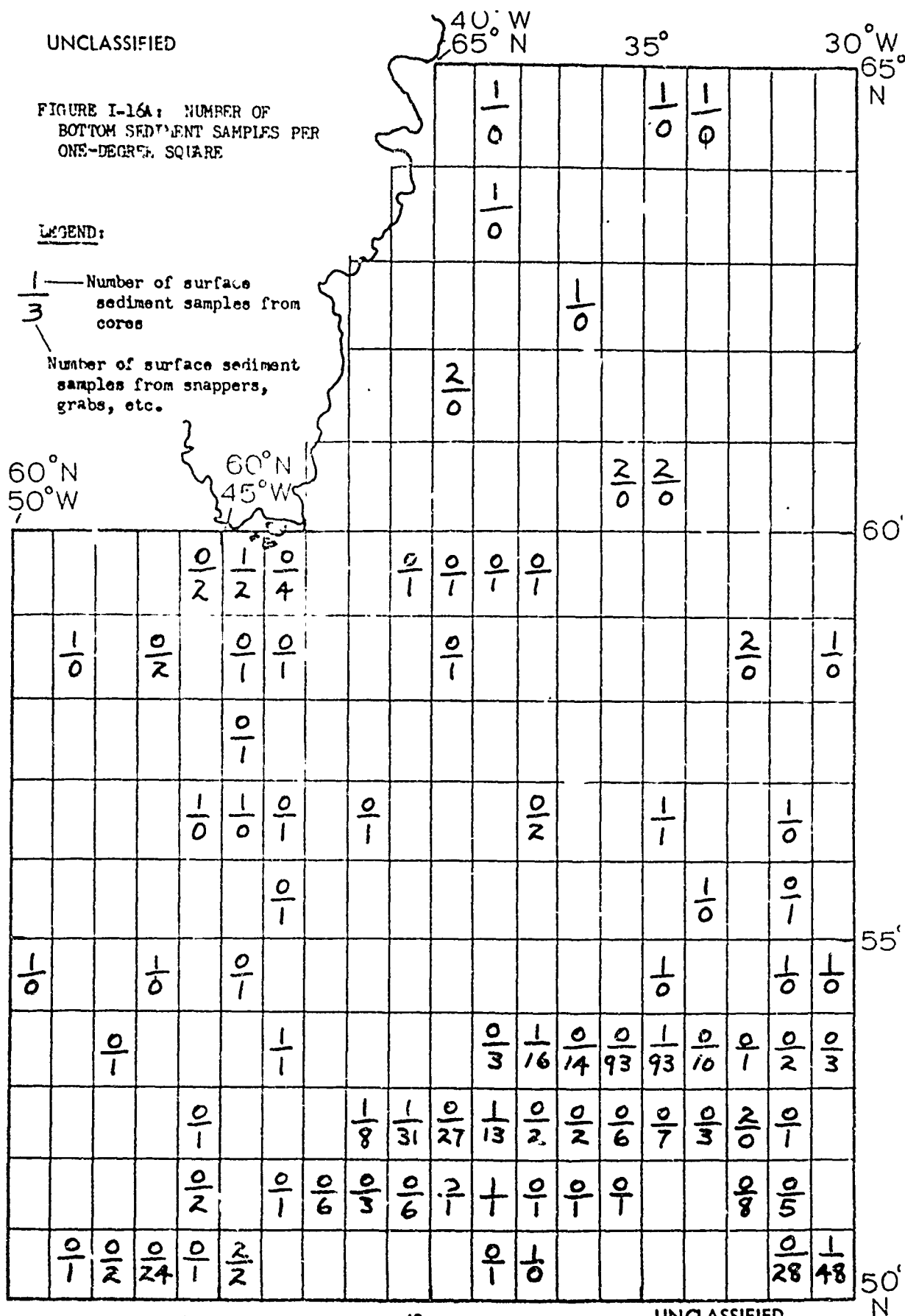


FIGURE I-16A

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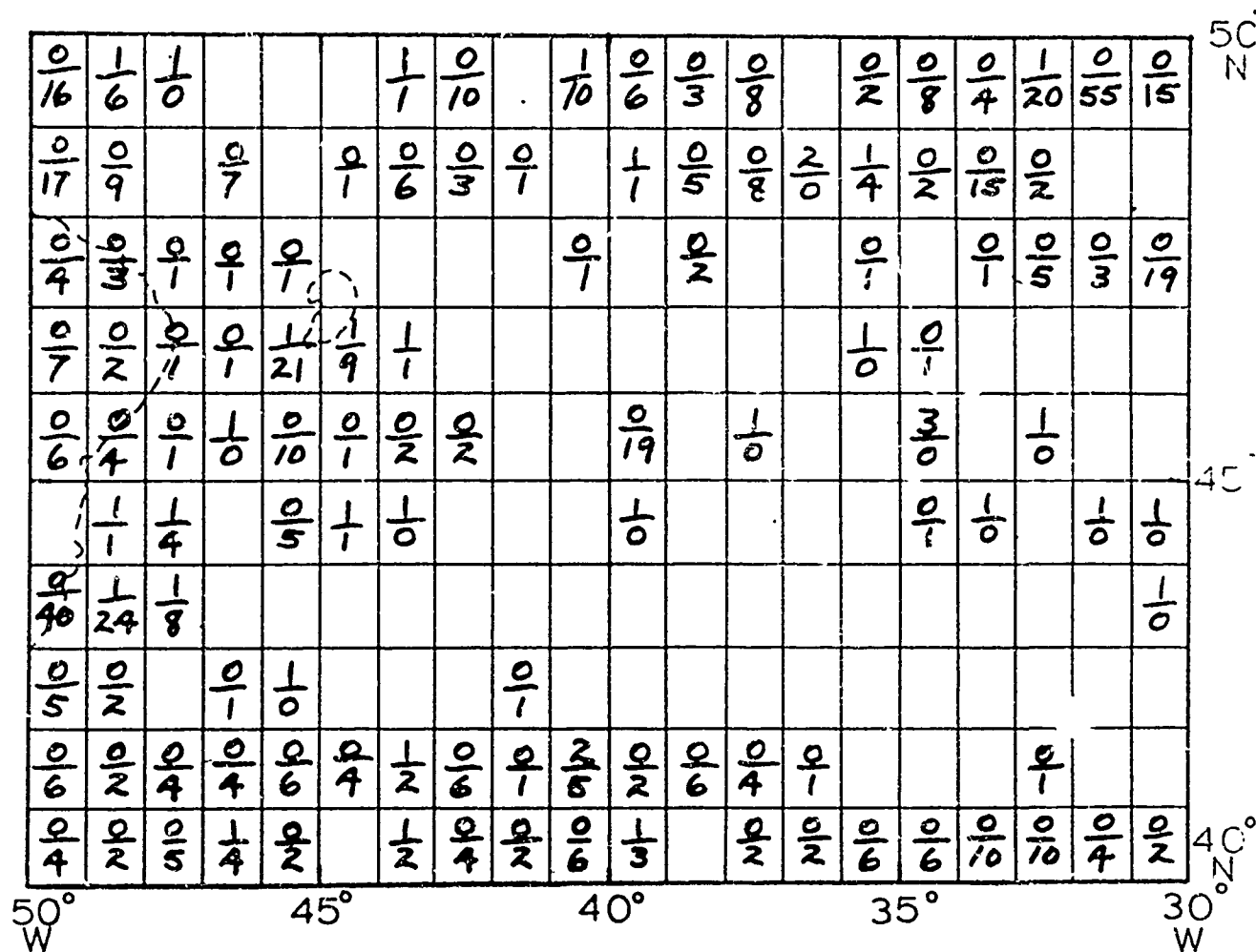


FIGURE I-16B: NUMBER OF BOTTOM SEDIMENT SAMPLES
PER ONE-DEGREE SQUARE

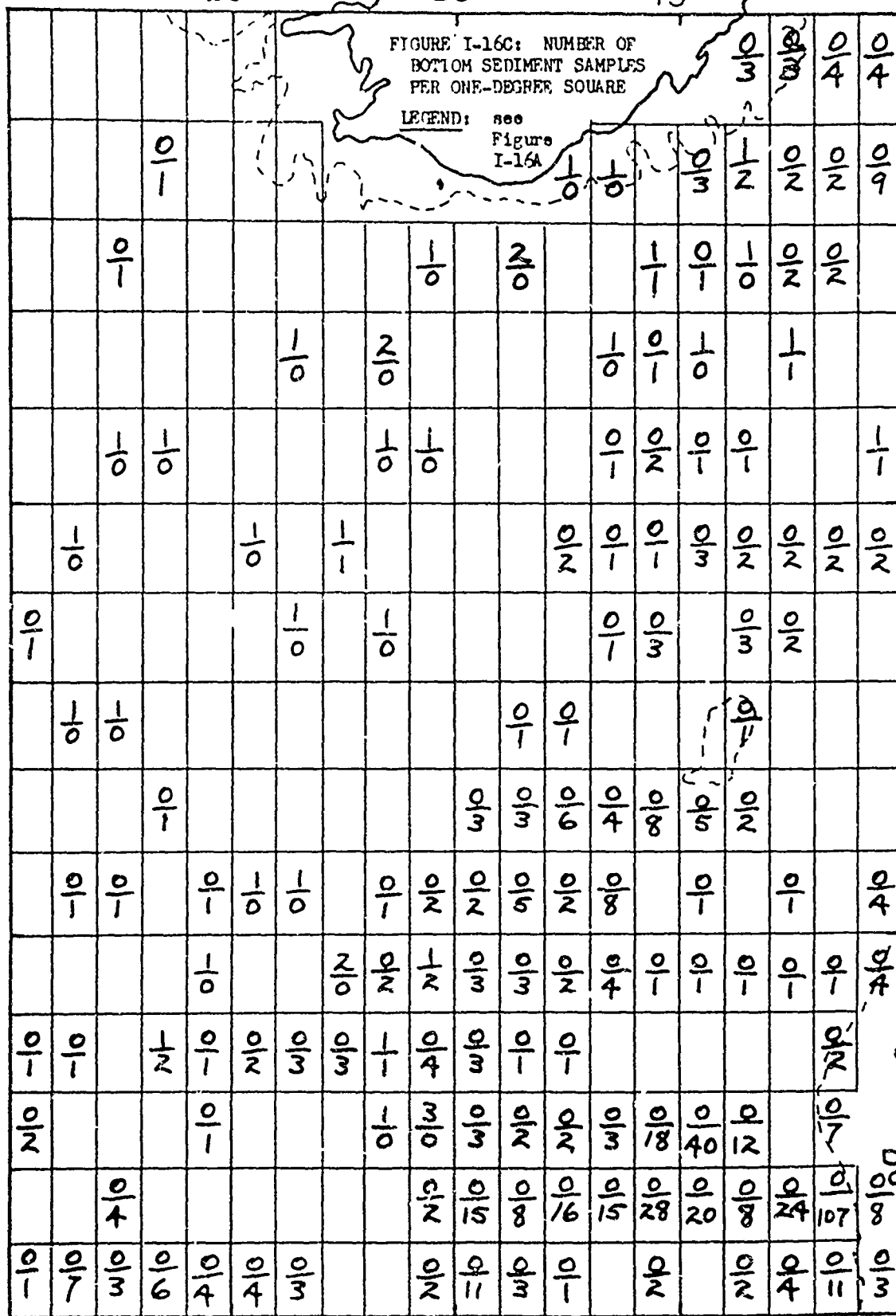
LEGEND: see Figure I-16A

25°

20°

15°

65°
N
10°
W



450°
N

55°
N

50
N

FIGURE I-16C

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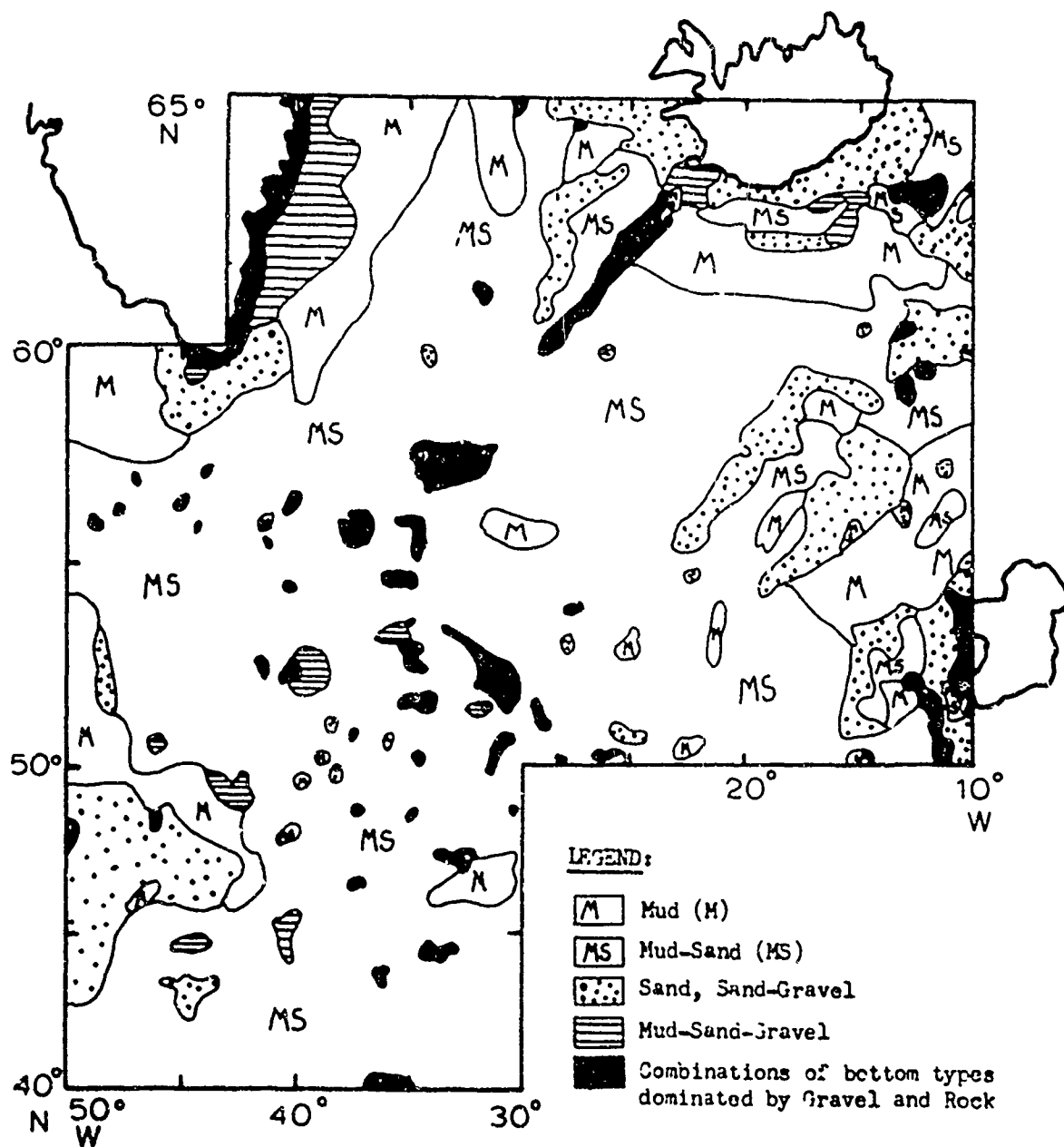


FIGURE I-17: DISTRIBUTION OF SURFICIAL BOTTOM SEDIMENTS

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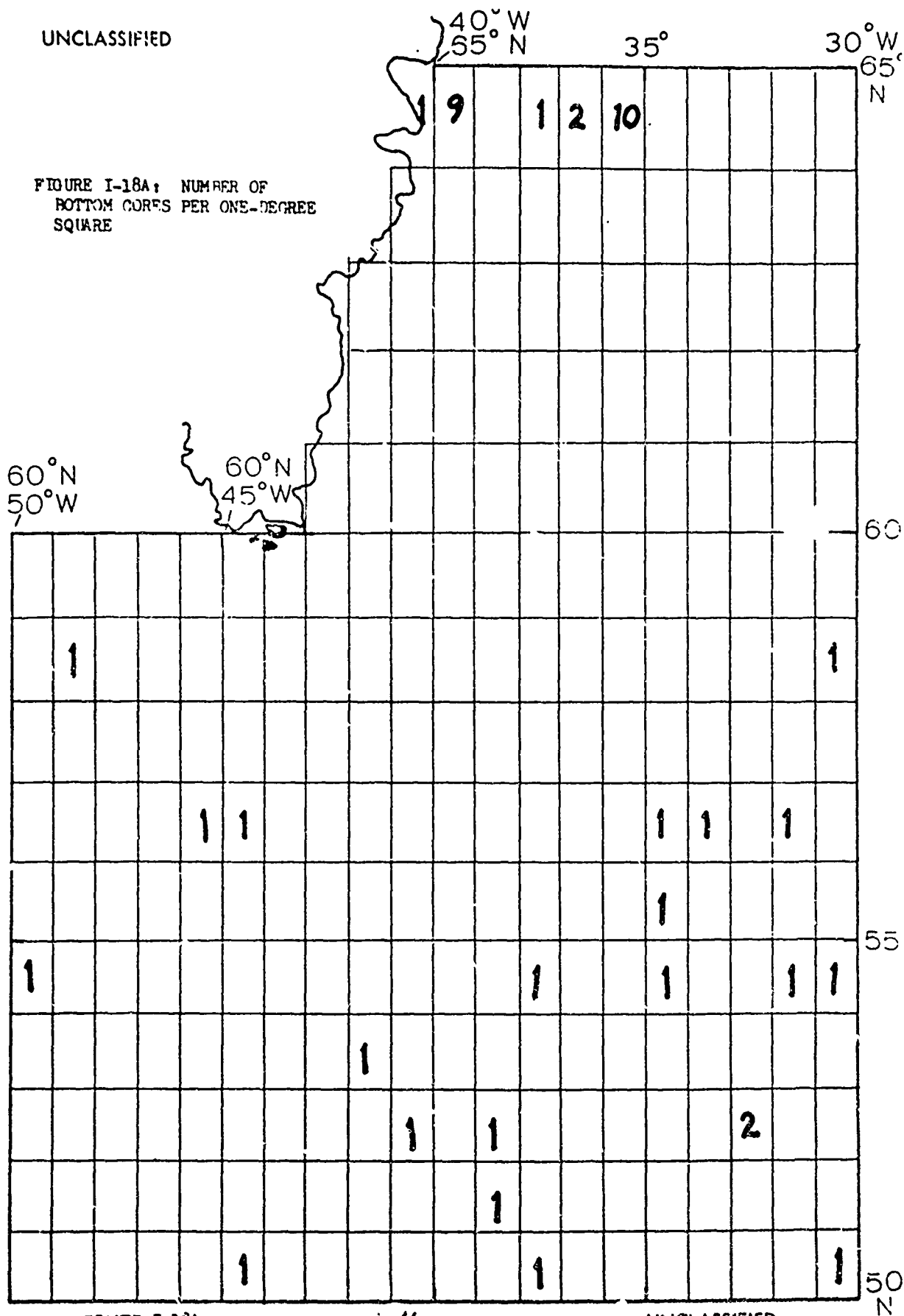


FIGURE I-18A: NUMBER OF
BOTTOM CORES PER ONE-DEGREE
SQUARE

FIGURE I-18A

46

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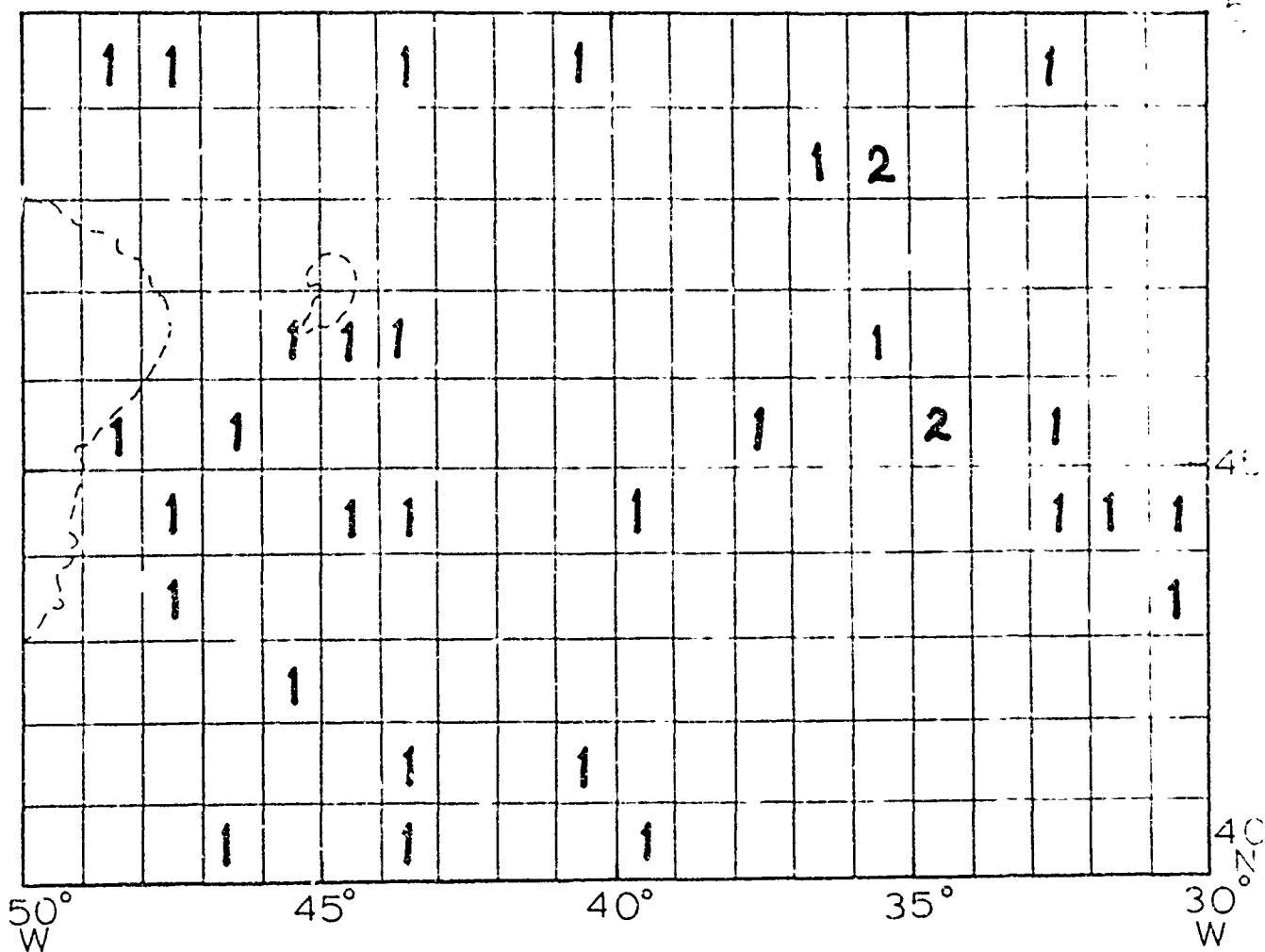


FIGURE I-18B: NUMBER OF BOTTOM CORES PER ONE-DEGREE SQUARE

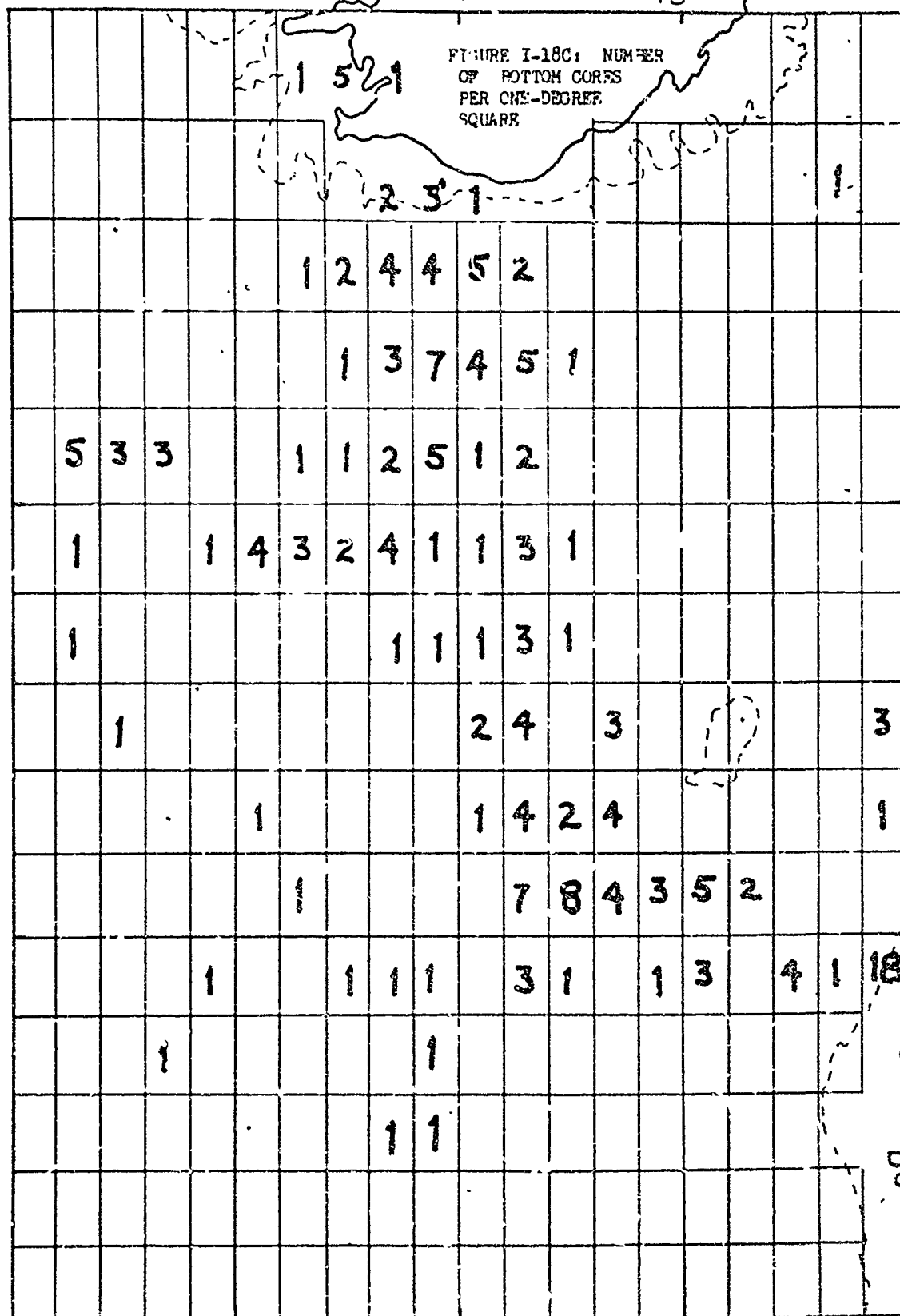
30°W

25°.

20°

15°

65°
N
1° C°
W



60°
N

55°
N

50
N

48

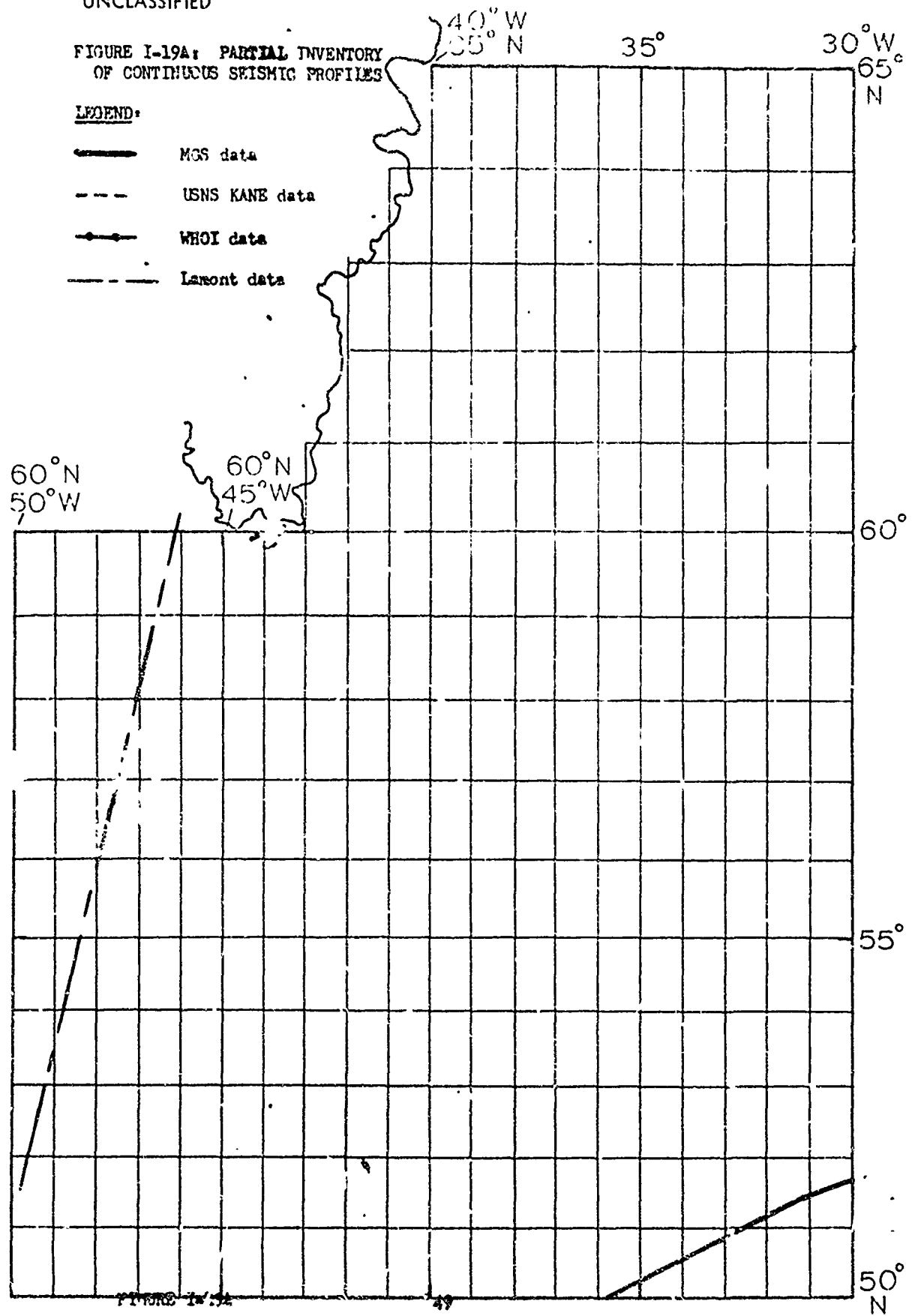
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FIGURE I-19A: PARTIAL INVENTORY
OF CONTINUOUS SEISMIC PROFILES

LEGEND:

- MCS data
- - - USNS KANE data
- WHOI data
- - - Lamont data



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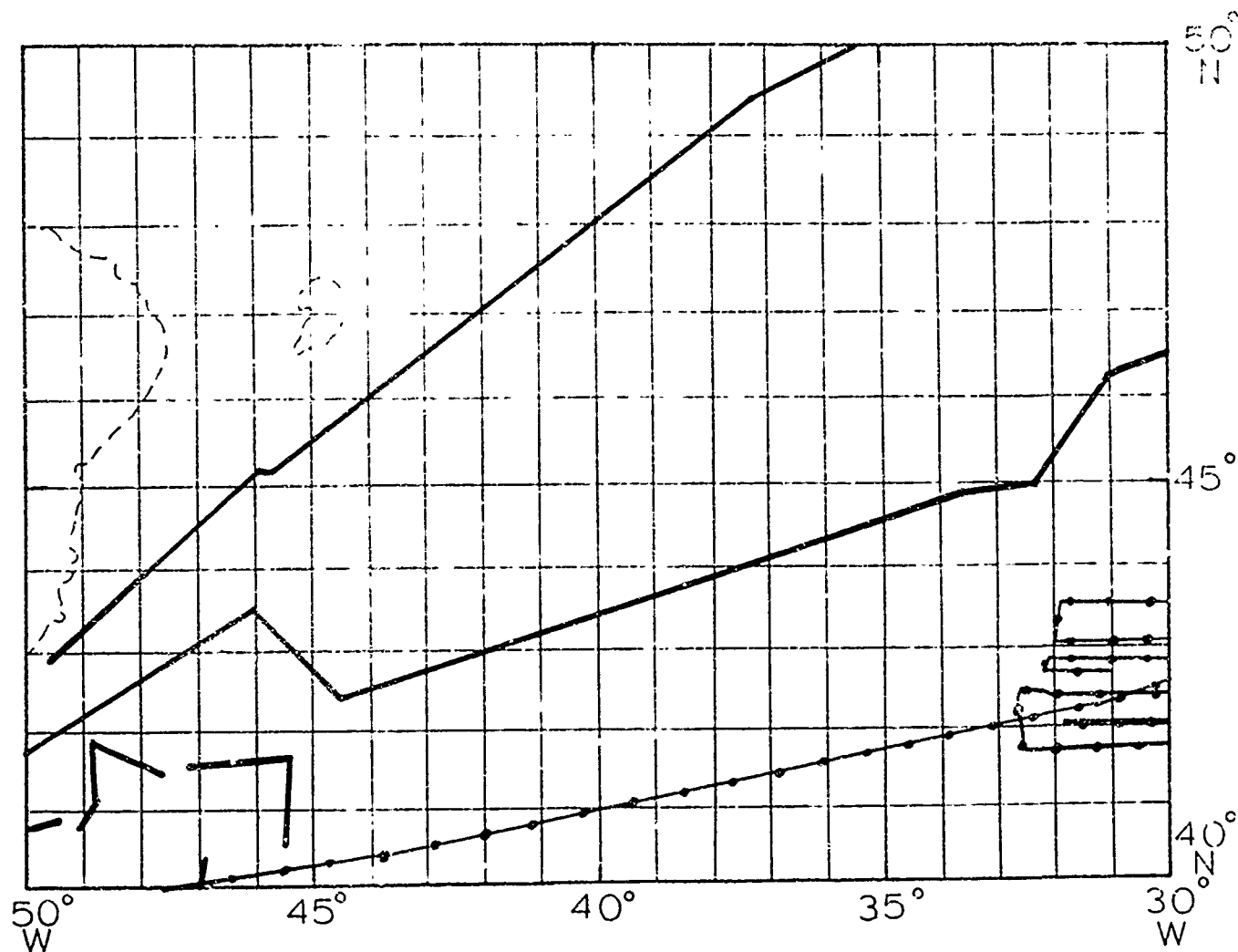
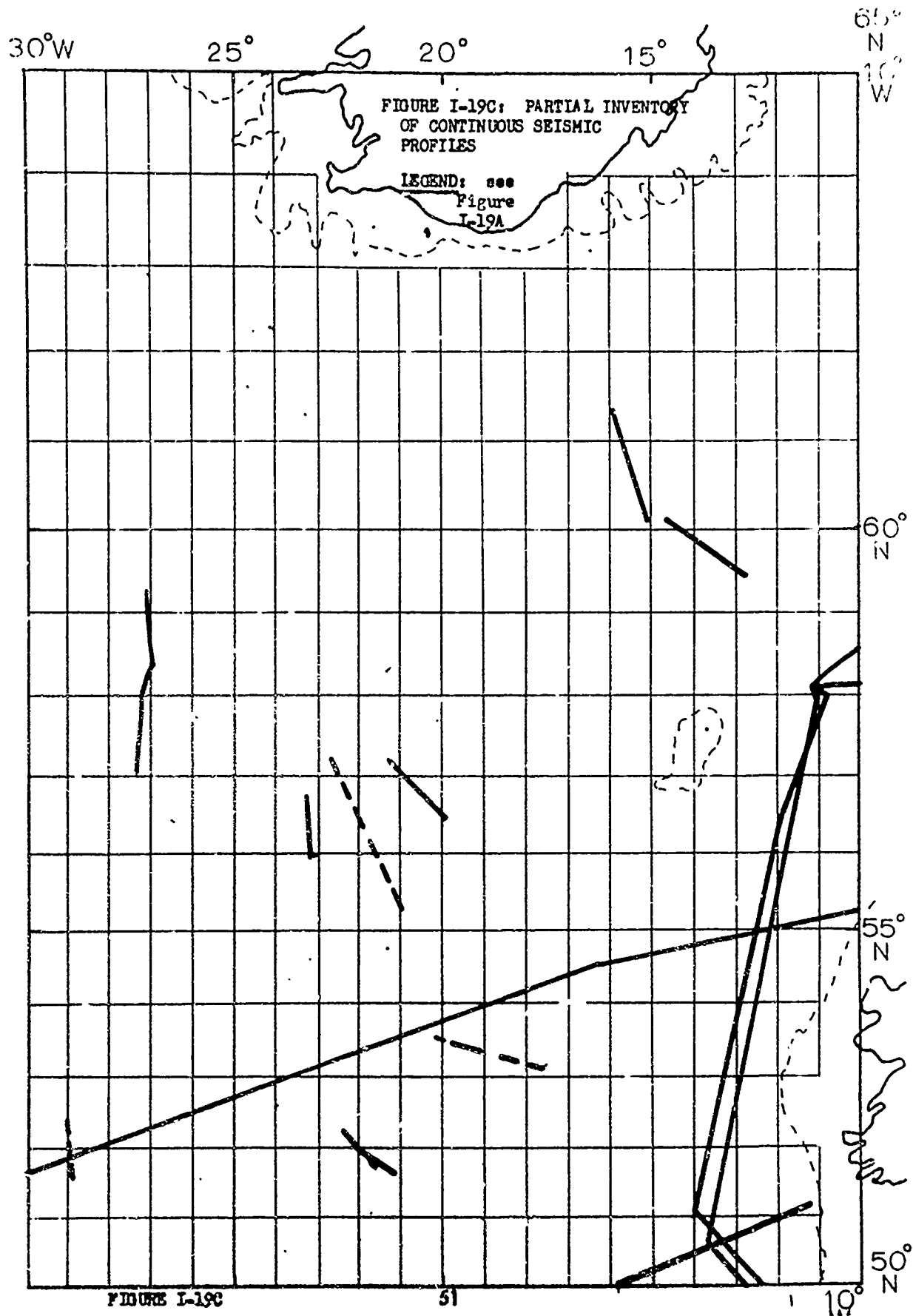


FIGURE I-19B: PARTIAL INVENTORY OF CONTINUOUS SEISMIC PROFILES

LEGEND: see Figure I-19A

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LRAPP PRIORITY AREA TWO

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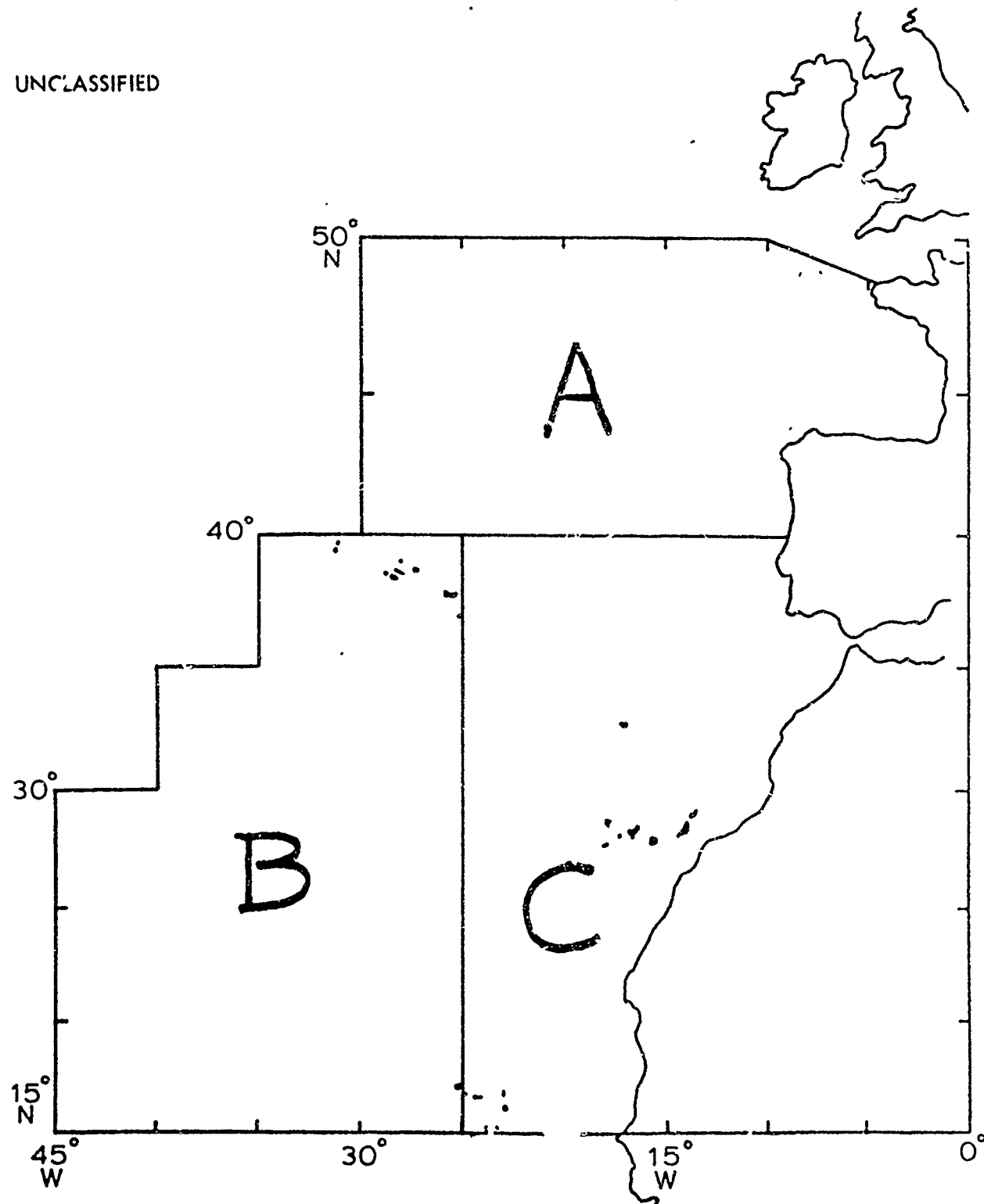


FIGURE II-1: LOCATION OF LRAPP ATLANTIC AREA II SUBAREAS

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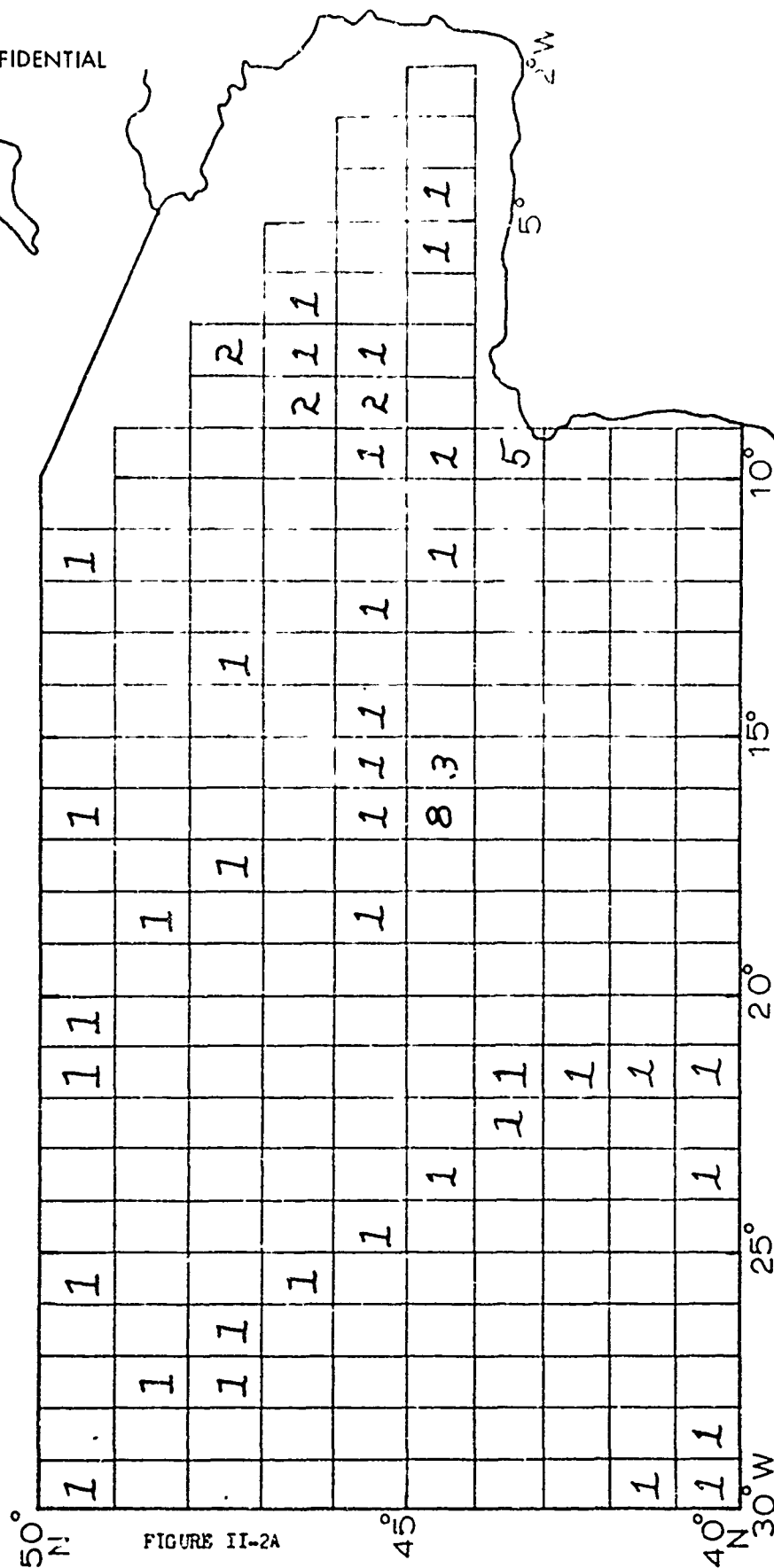
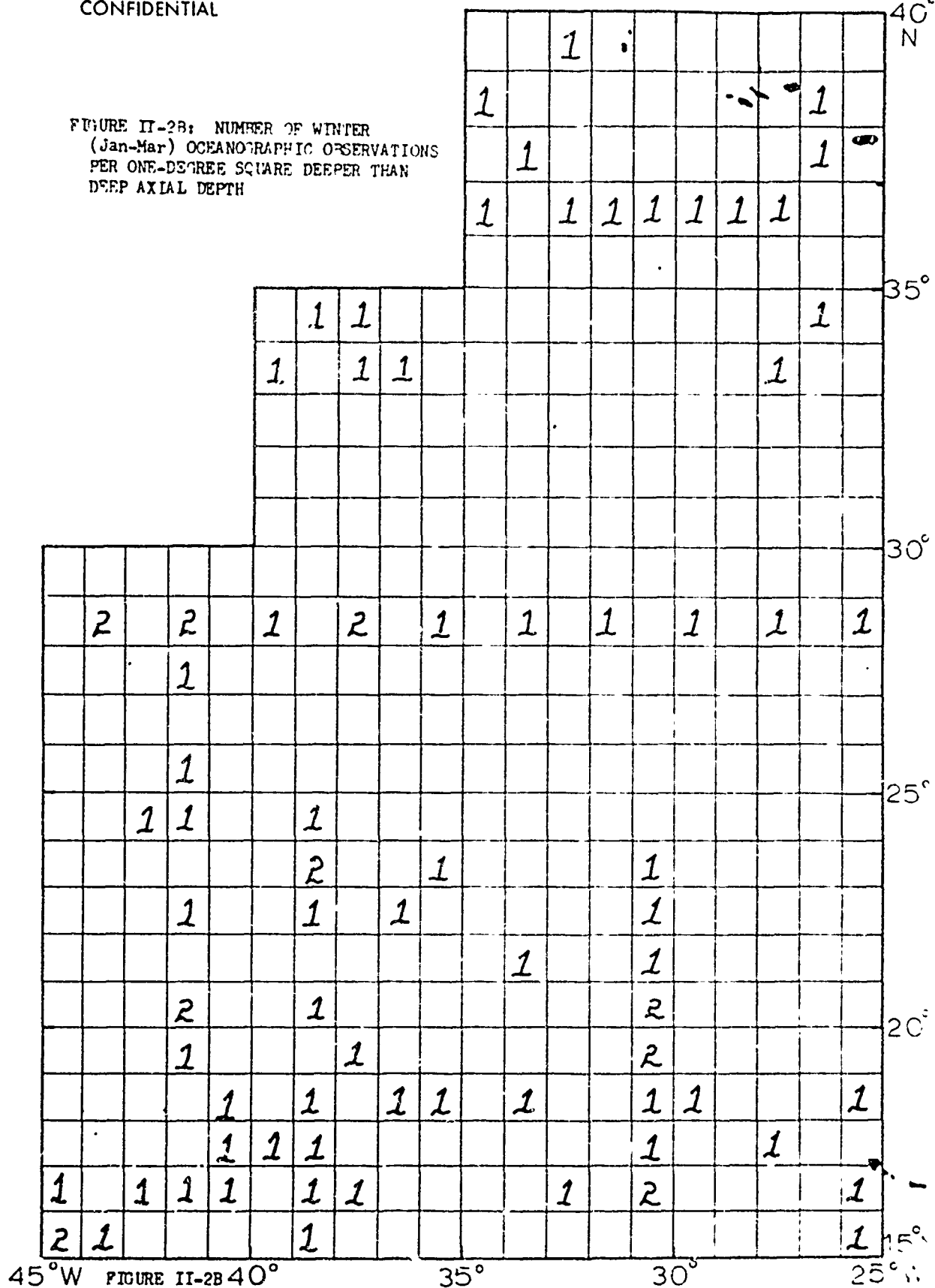


FIGURE II-2A

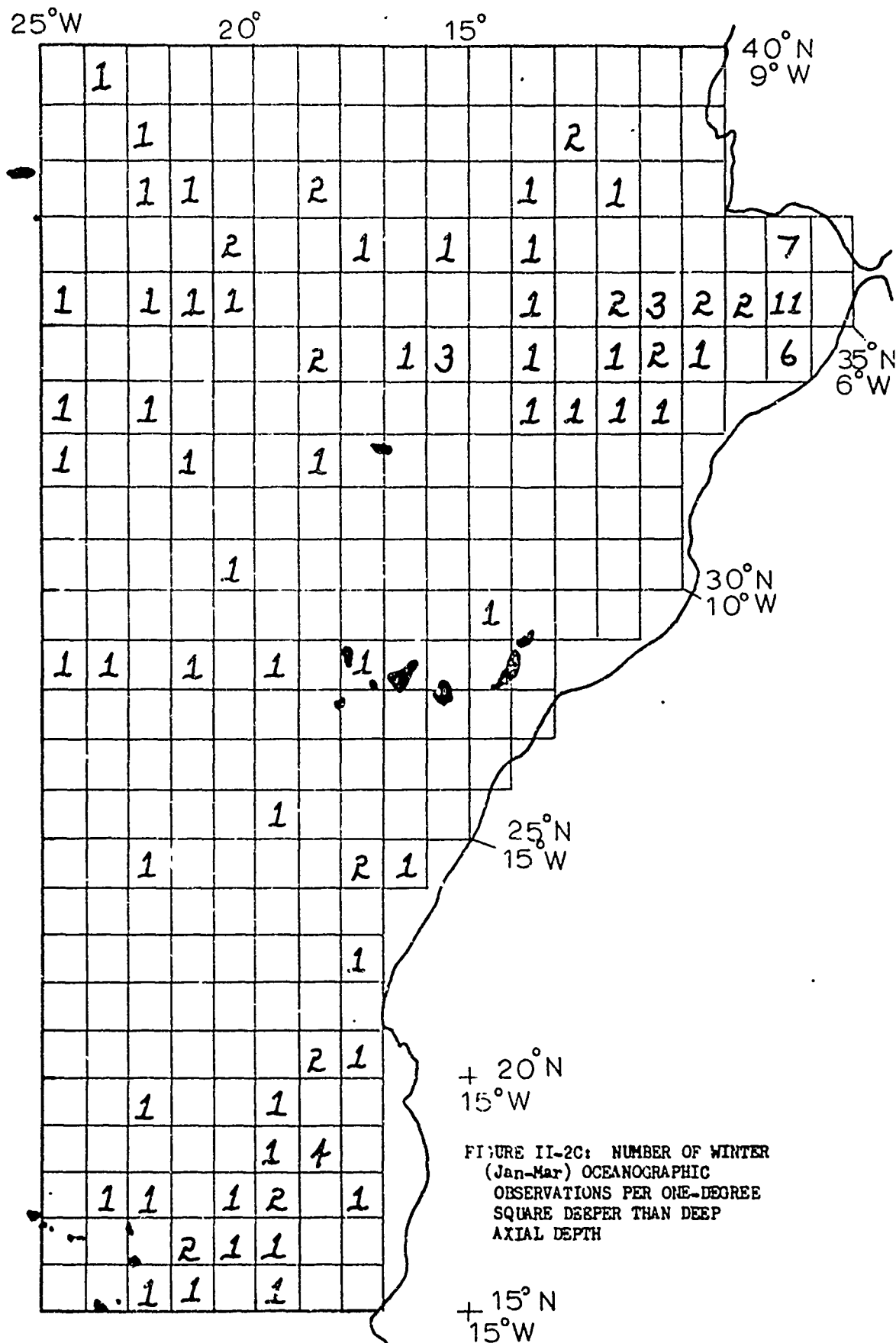
FIGURE II-2A: NUMBER OF WINTER (Jan-Mar) OCEANOGRAPHIC OBSERVATIONS PER ONE-DEGREE SQUARE PER TIME DEPTH

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FIGURE II-2B: NUMBER OF WINTER
(Jan-Mar) OCEANOGRAPHIC OBSERVATIONS
PER ONE-DEGREE SQUARE DEEPER THAN
DEEP AXIAL DEPTH



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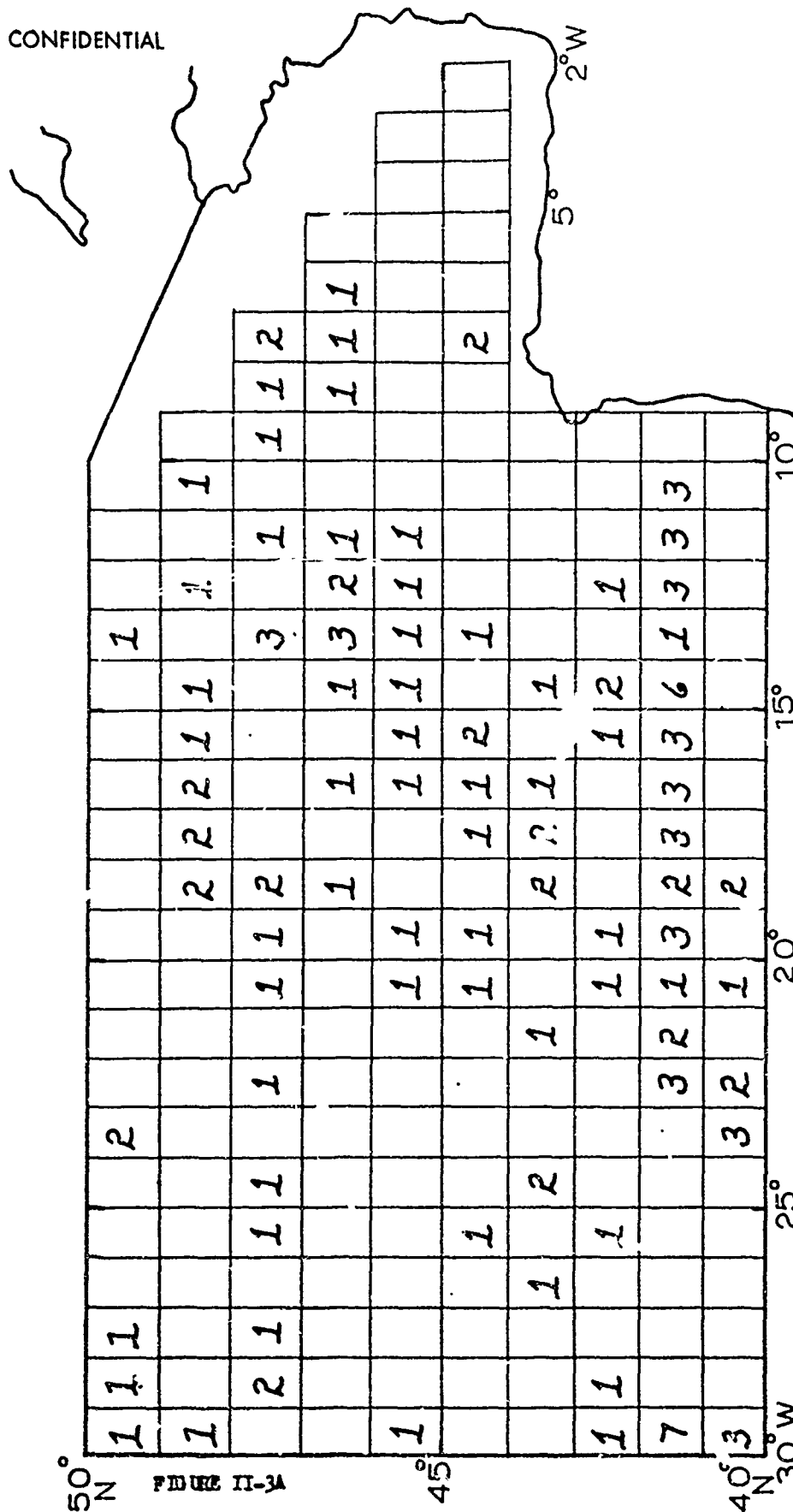
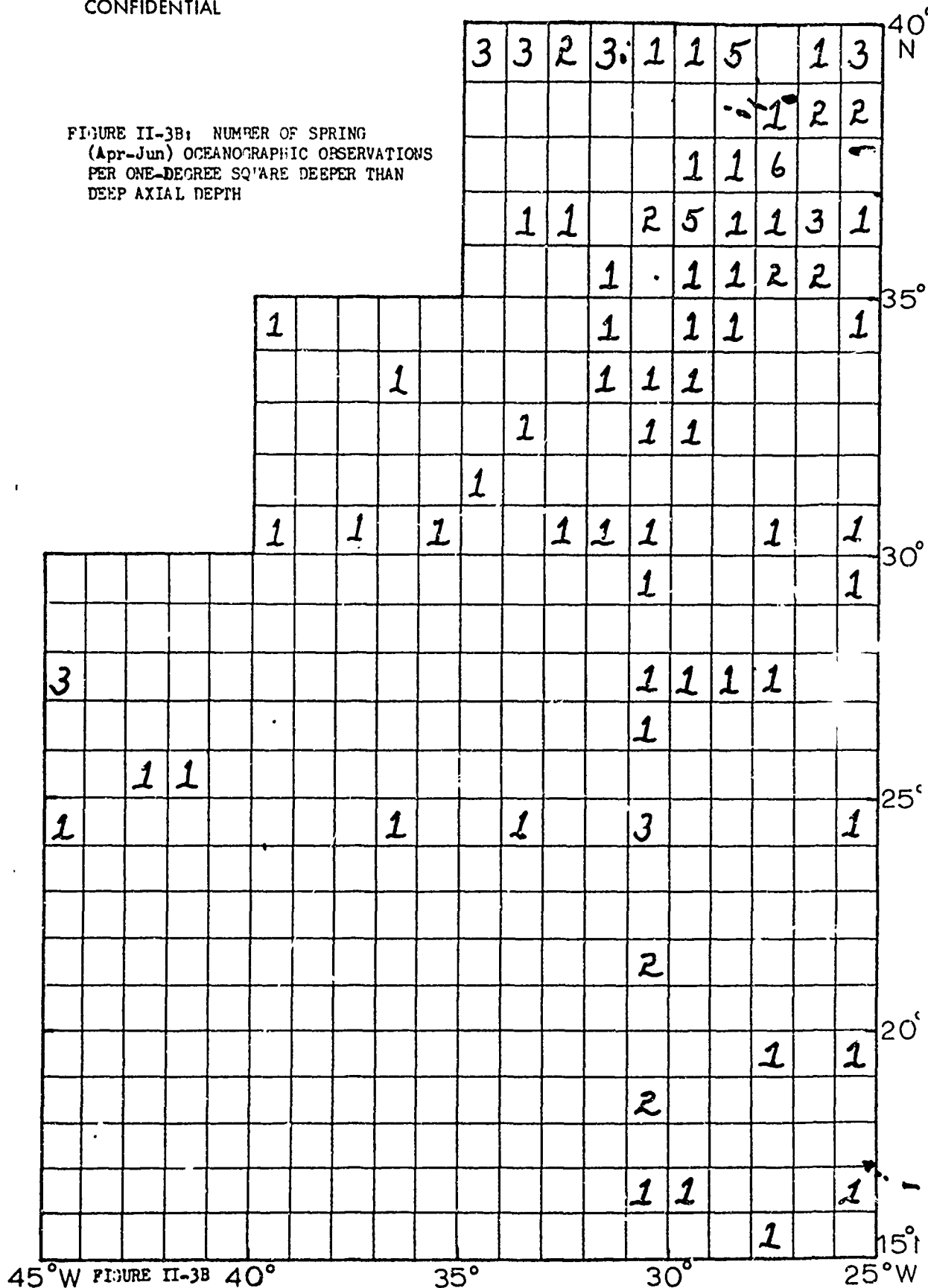


FIGURE II-3A: NUMBER OF SPRING (Apr-Jun) OCEANOGRAPHIC OBSERVATIONS PER ONE-DEGREE SQUARE DEEPER THAN DEEP AXIAL DEPTH

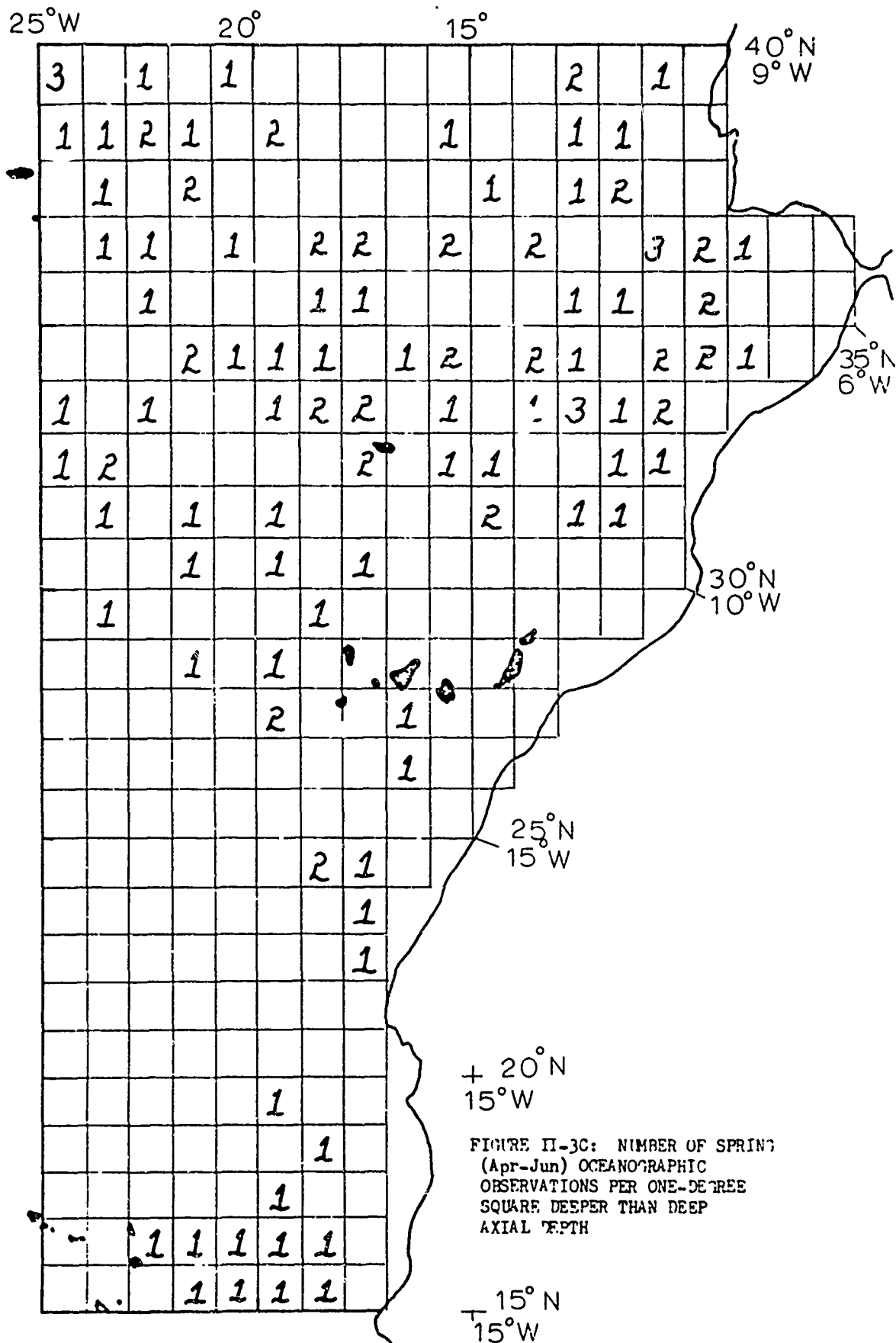
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FIGURE II-3B: NUMBER OF SPRING
(Apr-Jun) OCEANOGRAPHIC OBSERVATIONS
PER ONE-DEGREE SQUARE DEEPER THAN
DEEP AXIAL DEPTH



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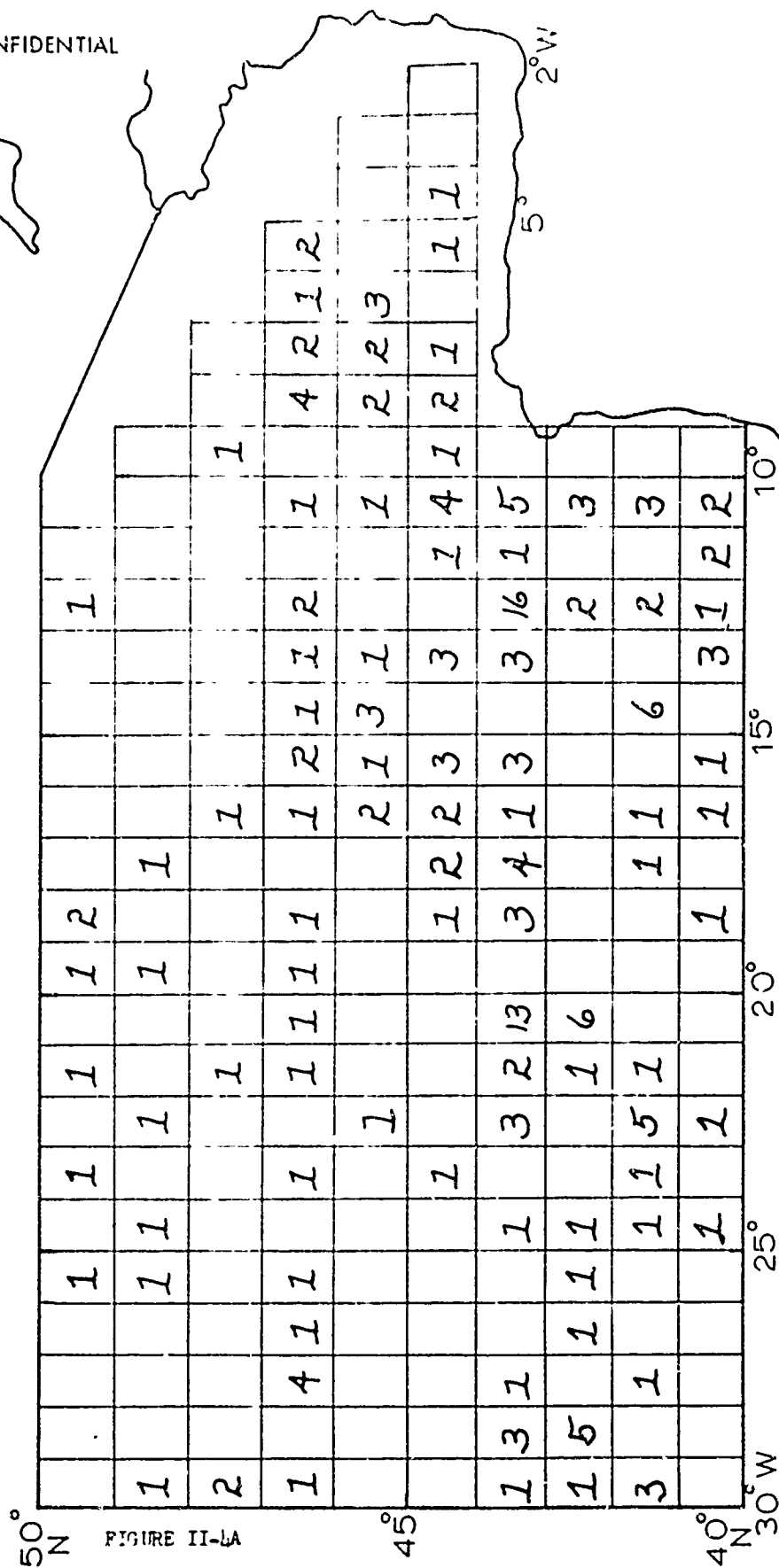
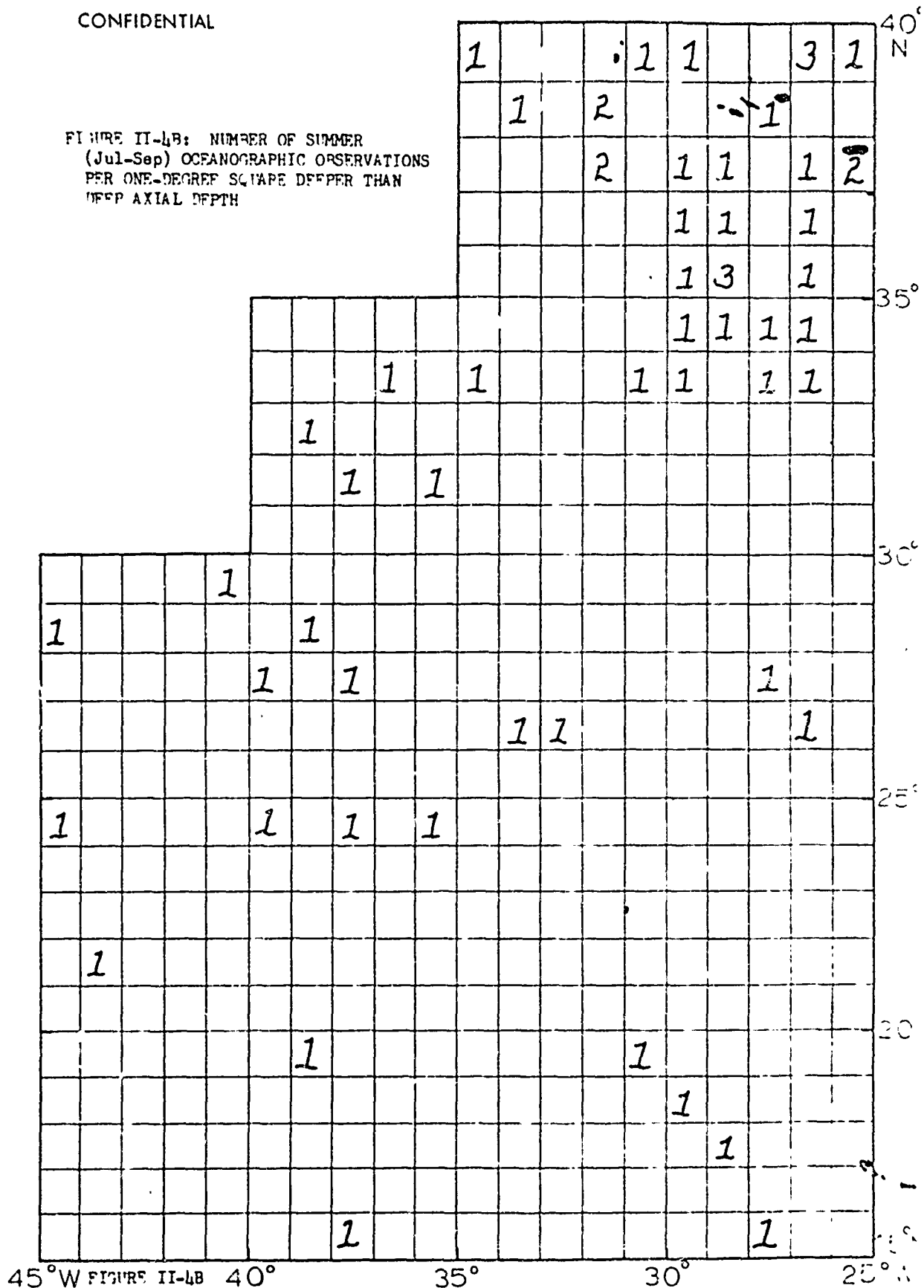


FIGURE II-1A

FIGURE II-1A: NUMBER OF SUMMER (Jul-Sep) OCEANOGRAPHIC OBSERVATIONS PER ONE-DEGREE SQUARE DEEPER THAN DEEP AXIAL DEPTH

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FIGURE II-4B: NUMBER OF SUMMER
(Jul-Sep) OCEANOGRAPHIC OBSERVATIONS
PER ONE-DEGREE SQUARE DEEPER THAN
DEEP AXIAL DEPTH



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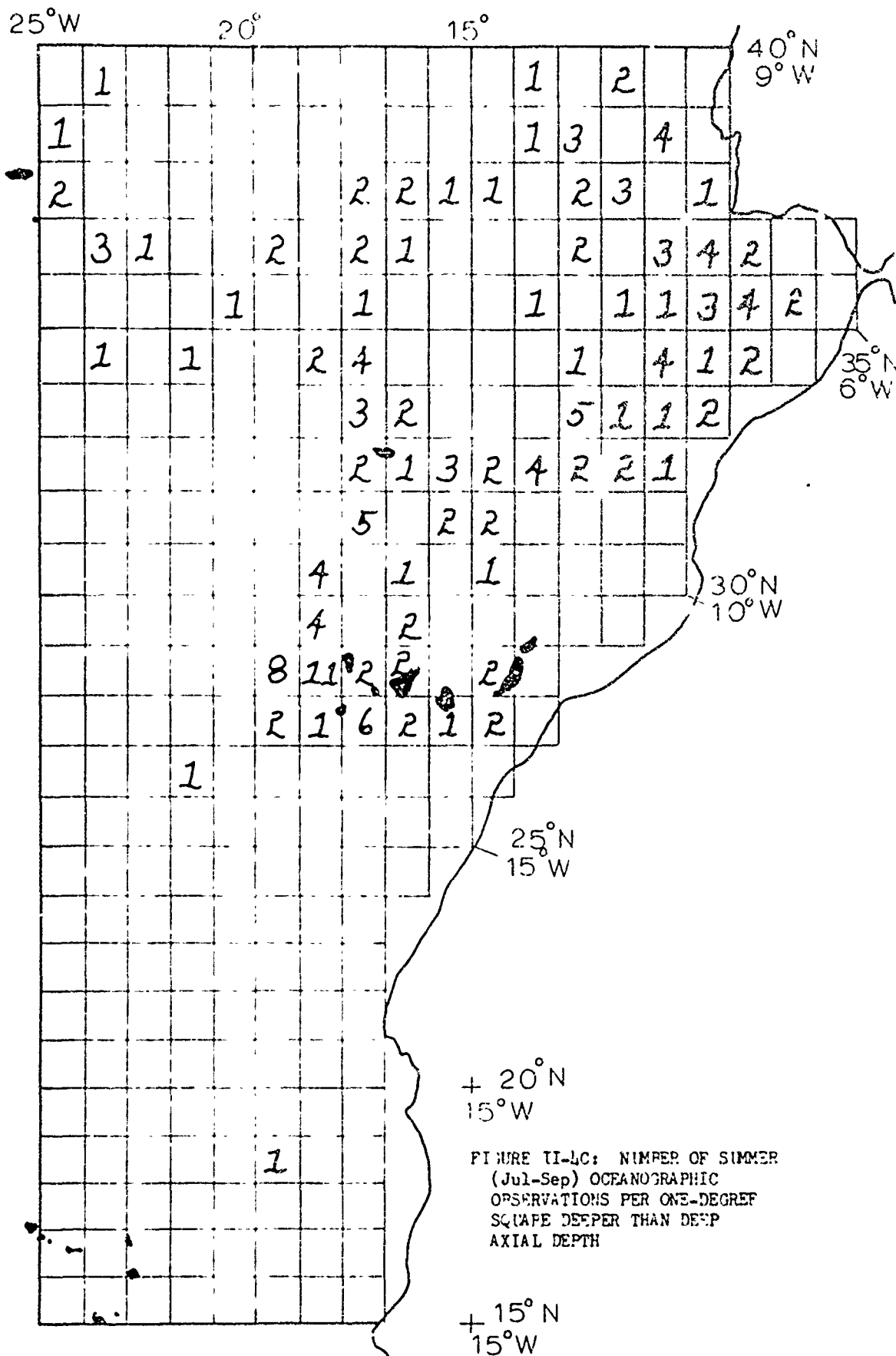


FIGURE II-4C: NUMBER OF SUMMER (Jul-Sep) OCEANOGRAPHIC OBSERVATIONS PER ONE-DEGREE SQUARE DEEPER THAN DEEP AXIAL DEPTH

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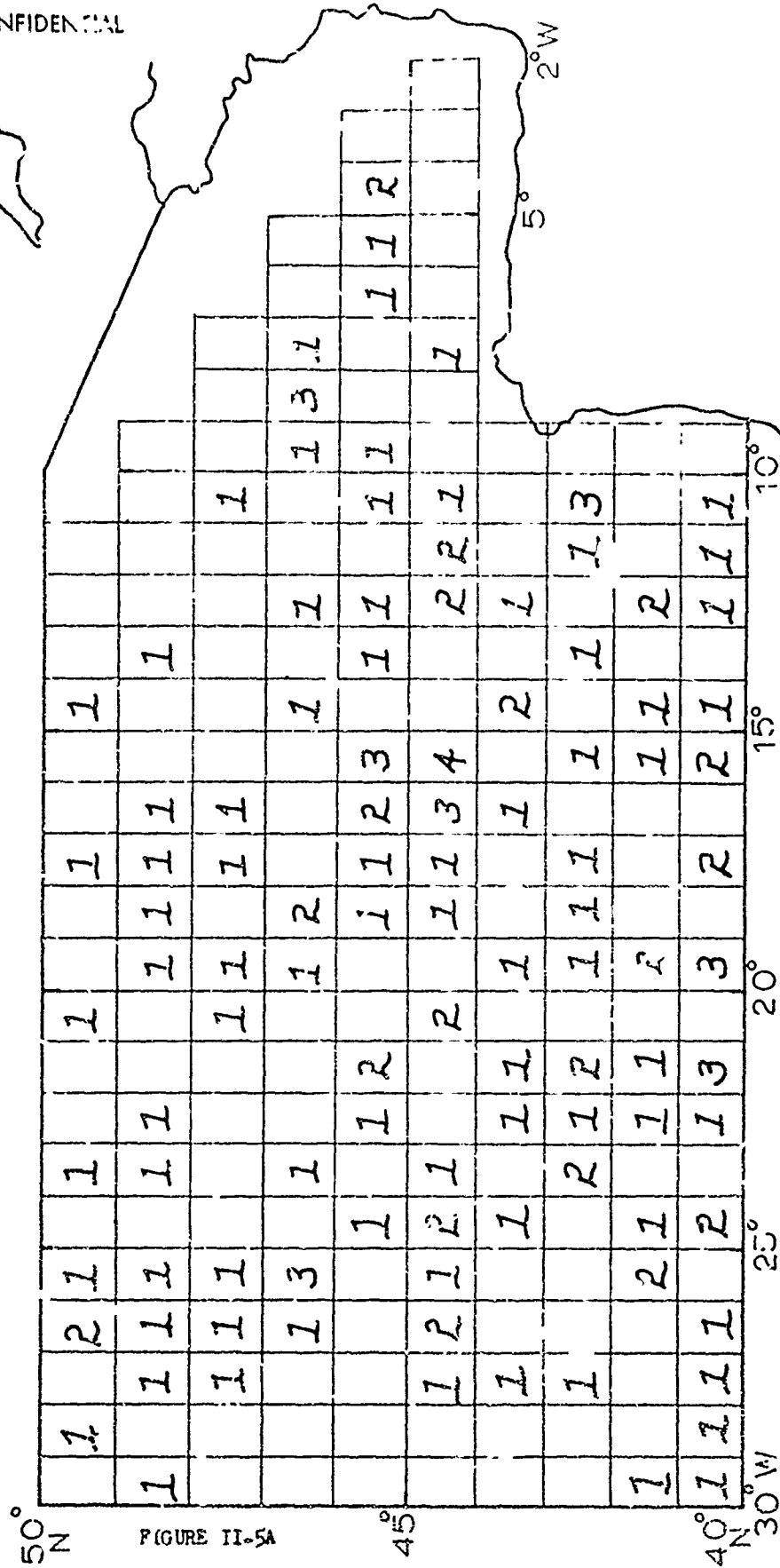


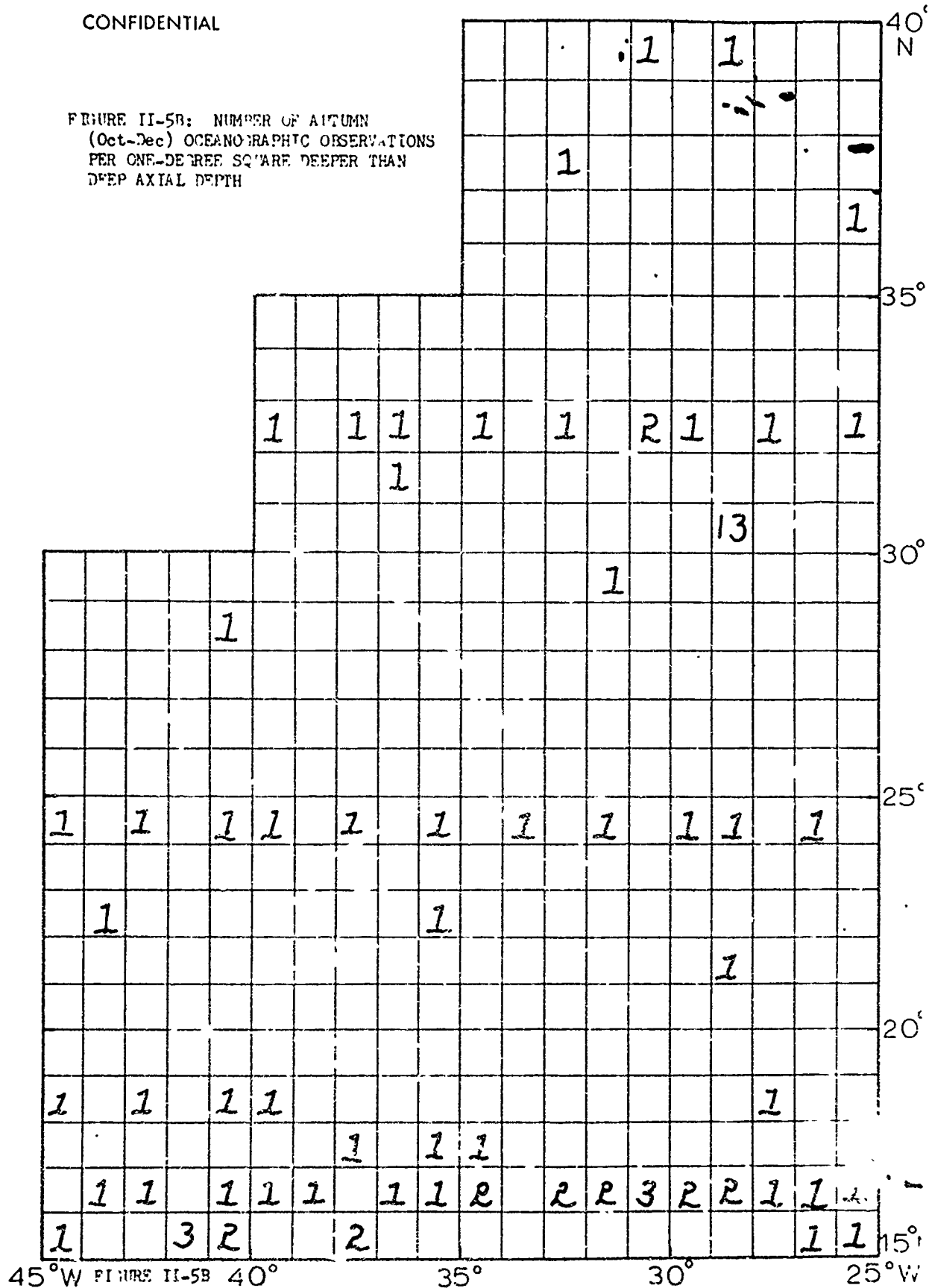
FIGURE II-5A

FIGURE II-5A: NUMBER OF AUTUMN (Oct-Dec) OCEANOGRAPHIC OBSERVATIONS PER ONE-DEGREE SQUARE DEEPER THAN DEEP AXIAL DEPTH

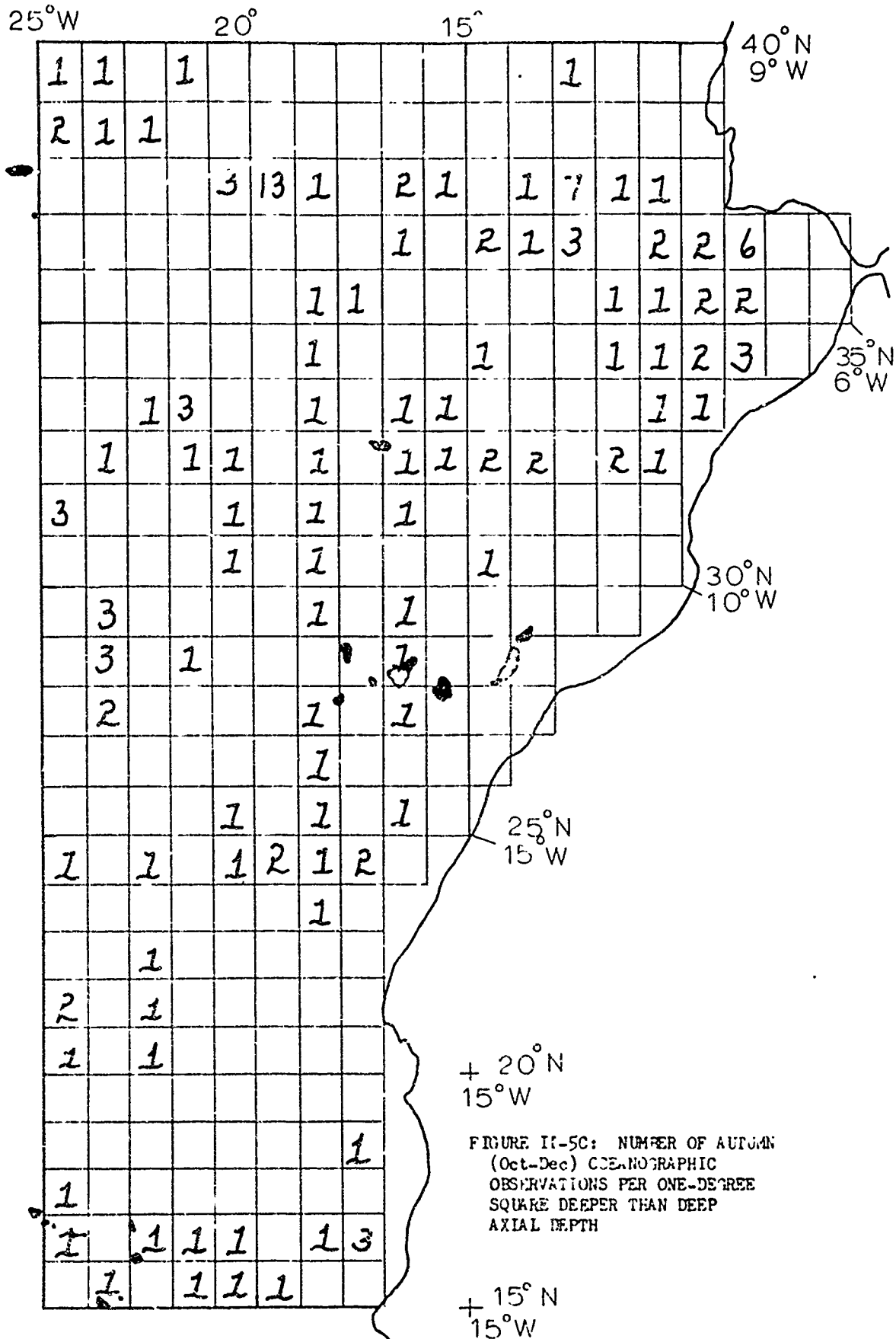
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FIGURE II-5B: NUMBER OF AUTUMN
(Oct-Dec) OCEANOGRAPHIC OBSERVATIONS
PER ONE-DEGREE SQUARE DEEPER THAN
DEEP AXIAL DEPTH



CONFIDENTIAL



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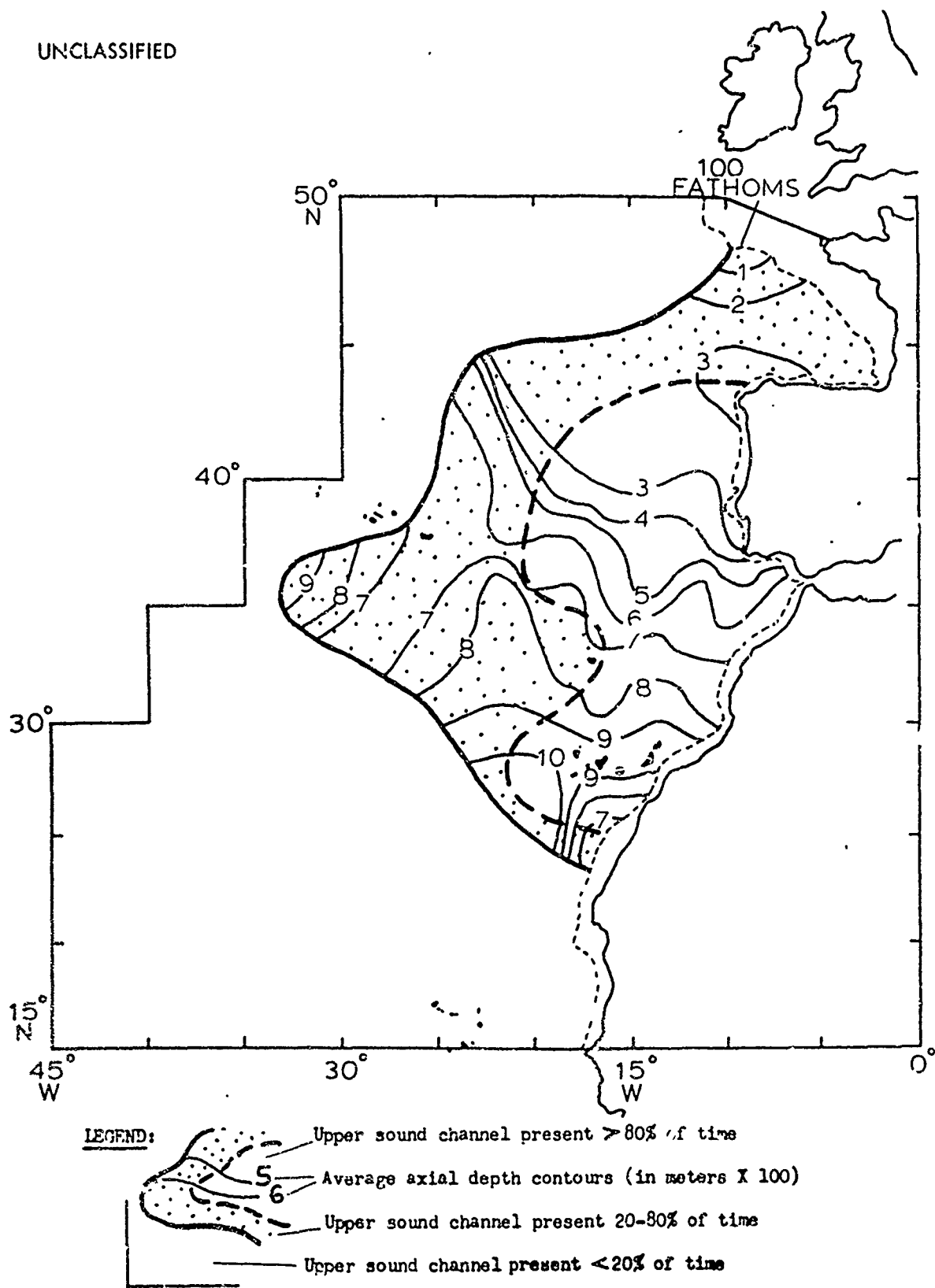


FIGURE II-6: AREAL EXTENT AND AVERAGE AXIAL DEPTH OF UPPER SOUND CHANNEL FOR WINTER (Jan-Mar)

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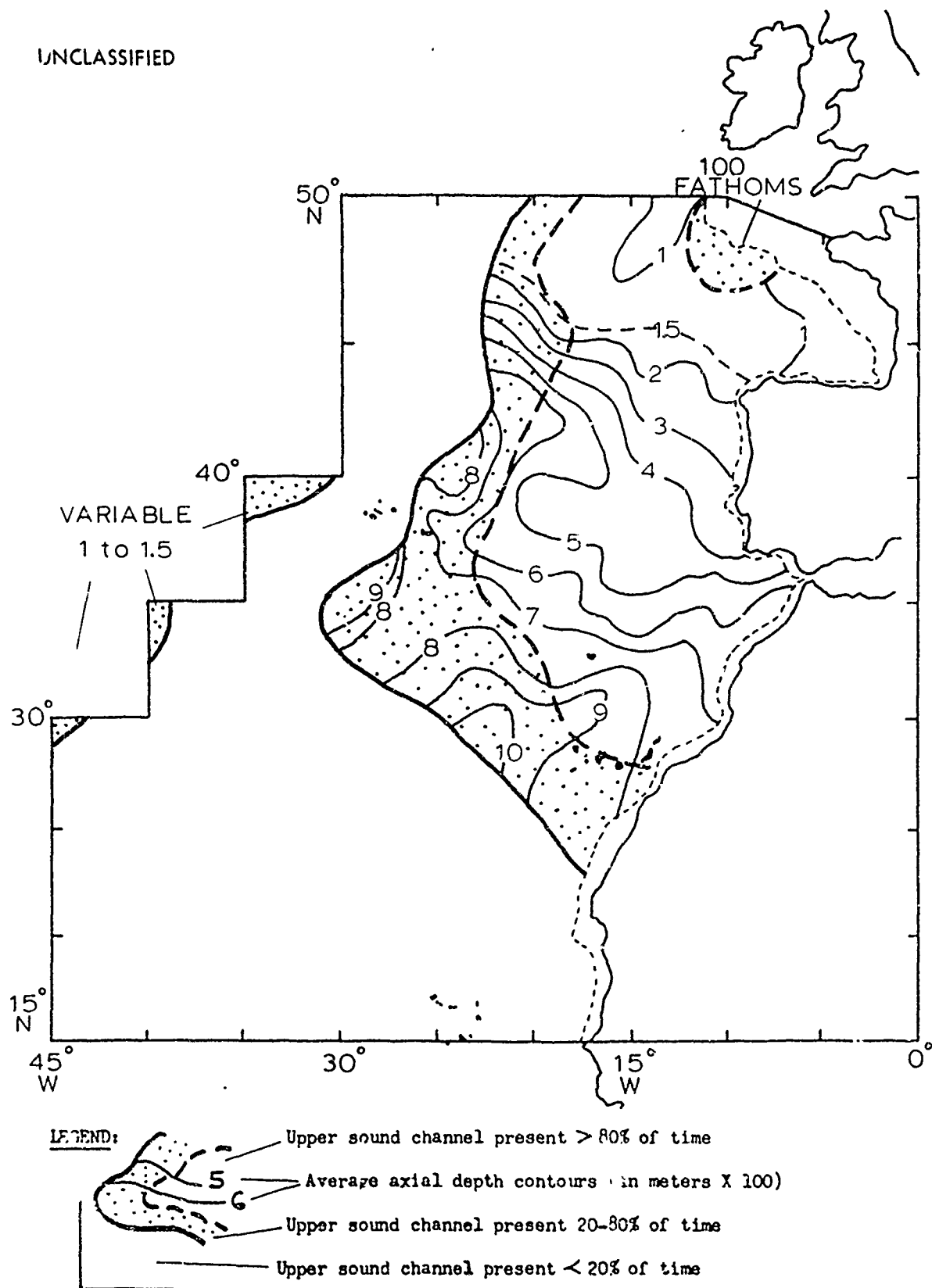


FIGURE II-7: AREAL EXTENT AND AVERAGE AXIAL DEPTH OF UPPER SOUND CHANNEL FOR SPRING (Apr-Jun)

UNCLASSIFIED

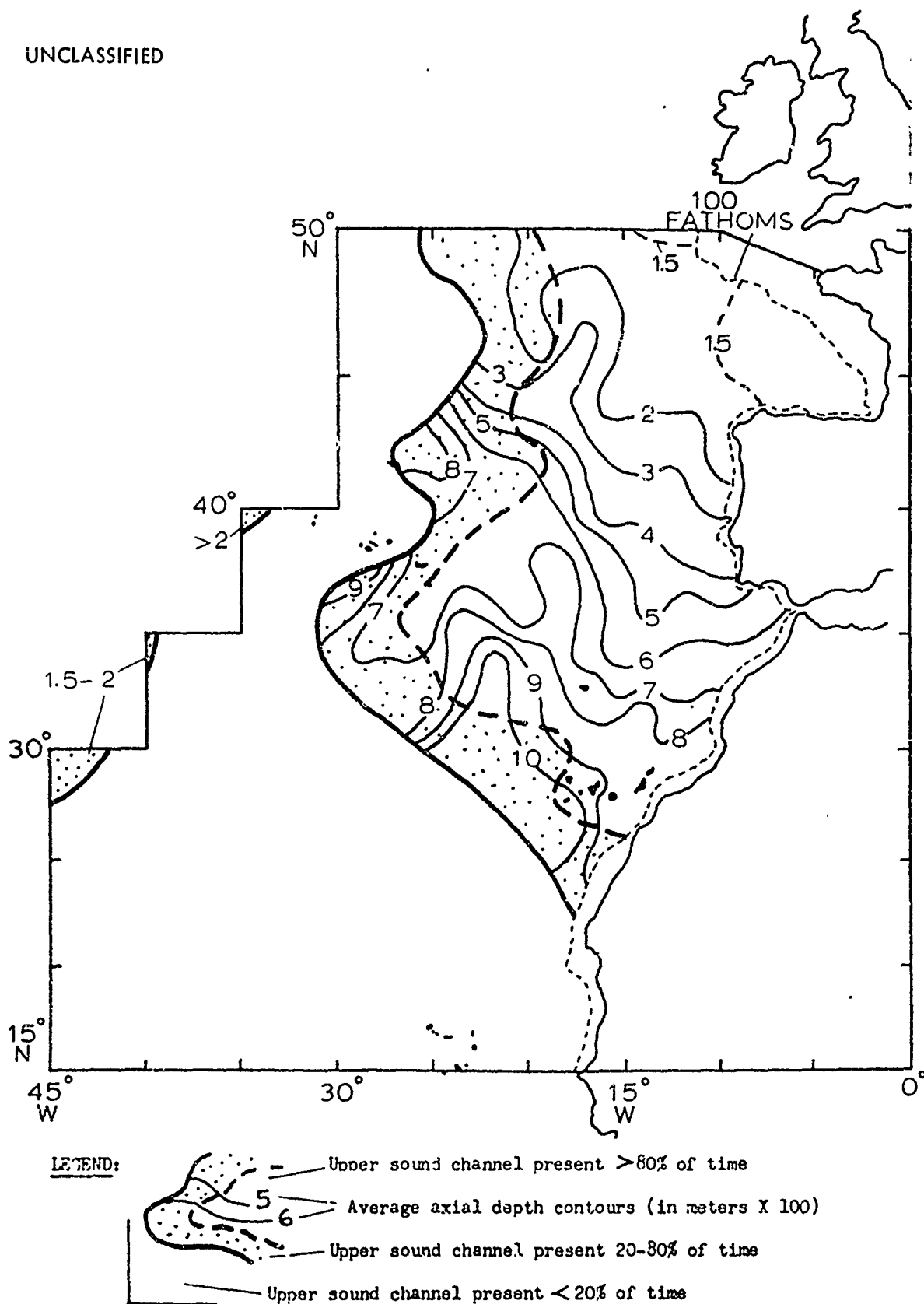


FIGURE II-8: AREAL EXTENT AND AVERAGE AXIAL DEPTH OF UPPER SOUND CHANNEL FOR SUMMER (Jul-Sep)

UNCLASSIFIED

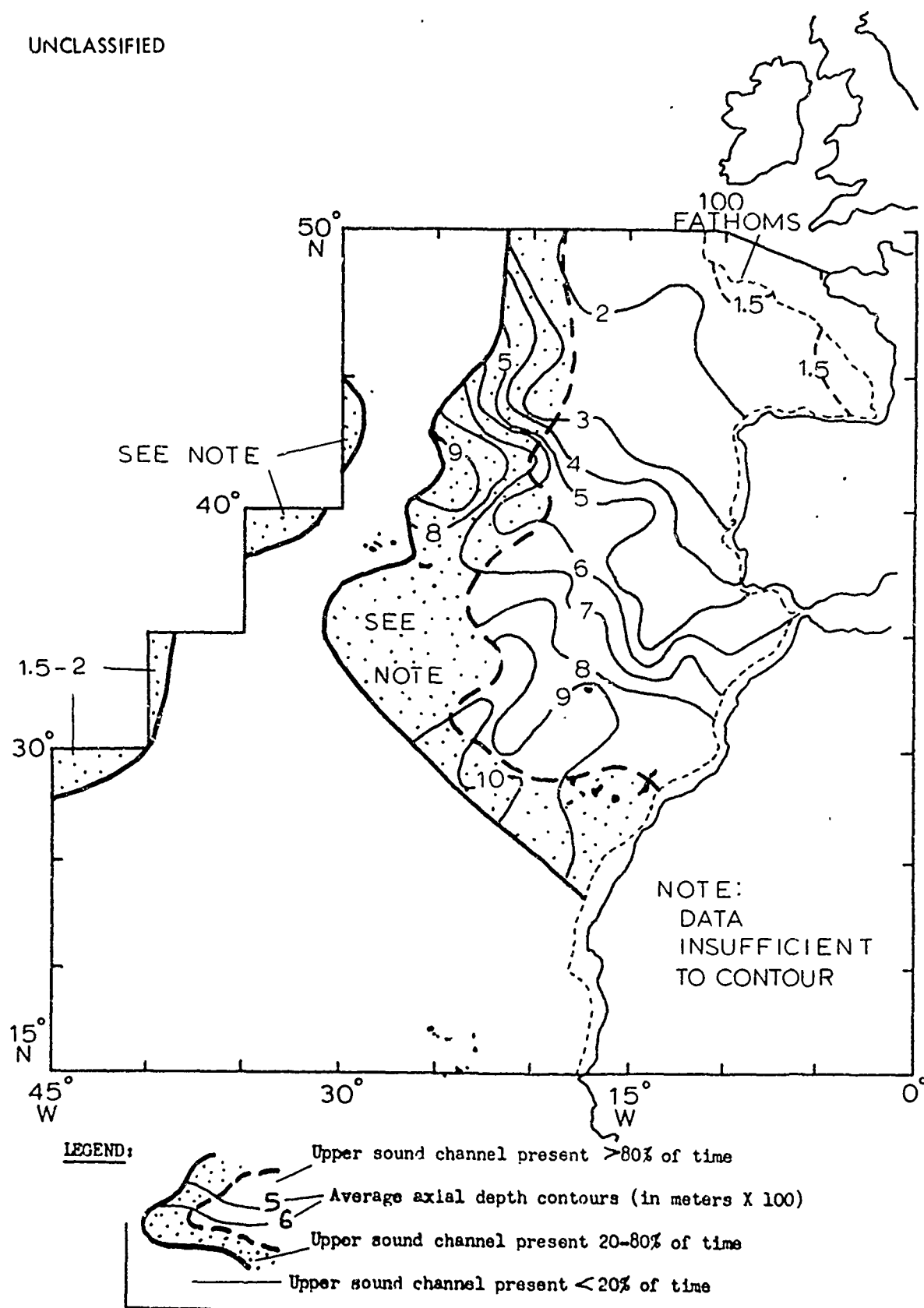


FIGURE II-9: AREAL EXTENT AND AVERAGE AXIAL DEPTH OF UPPER SOUND CHANNEL FOR AUTUMN (Oct-Dec)

UNCLASSIFIED

NOTE:

Letters represent difference (in meters/second) between velocity at upper sound channel axis and at subsurface sound velocity maximum, where:

- A = greater than 10
- B = 8 to 10
- C = 6 to 8
- D = 4 to 6
- E = 2 to 4
- F = 0.5 to 2
- G = 0.1 to 0.5

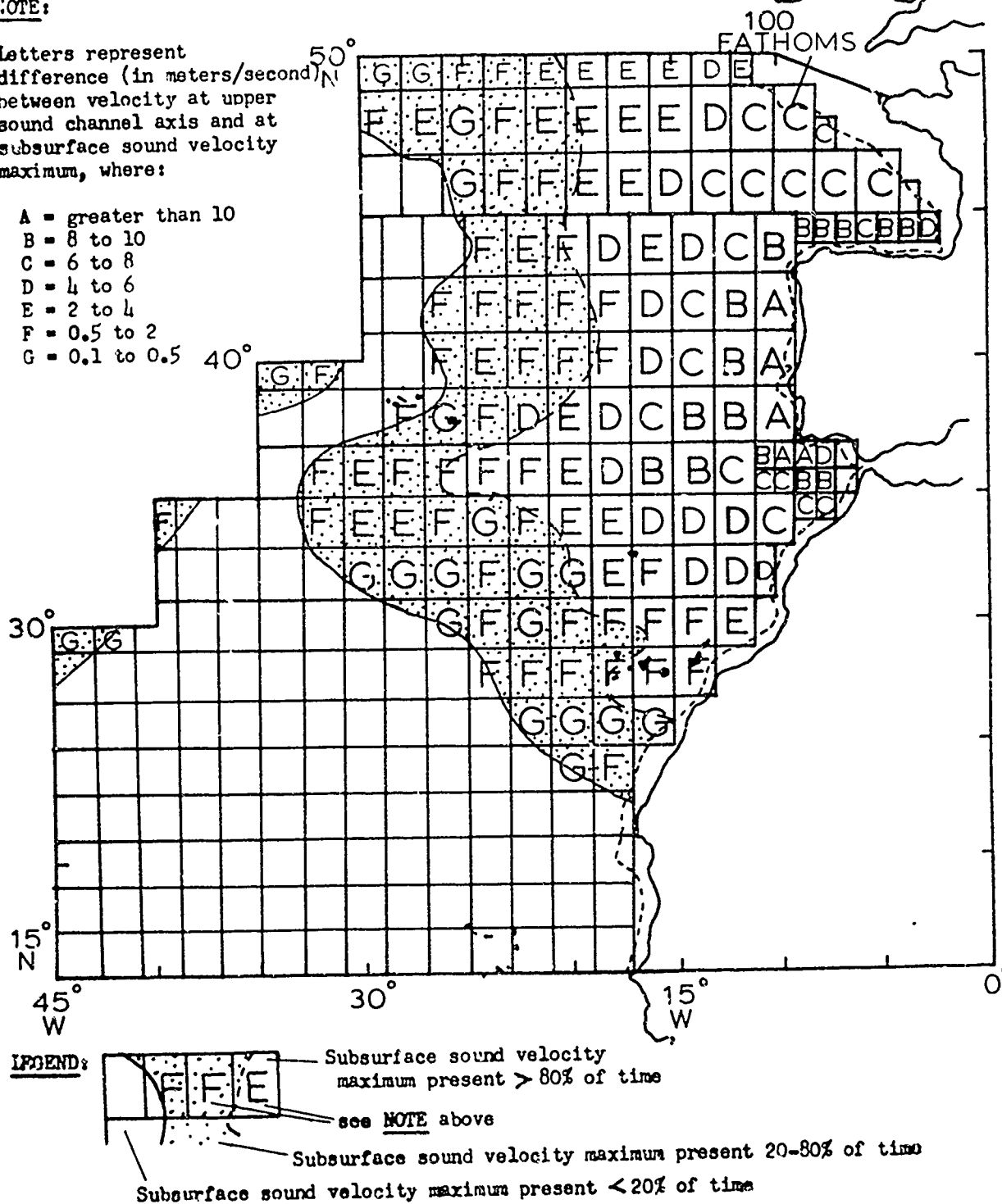


FIGURE II-10: ANNUAL AVERAGE "STRENGTH" OF UPPER SOUND CHANNEL (if present) RELATIVE TO SUBSURFACE SOUND VELOCITY MAXIMUM

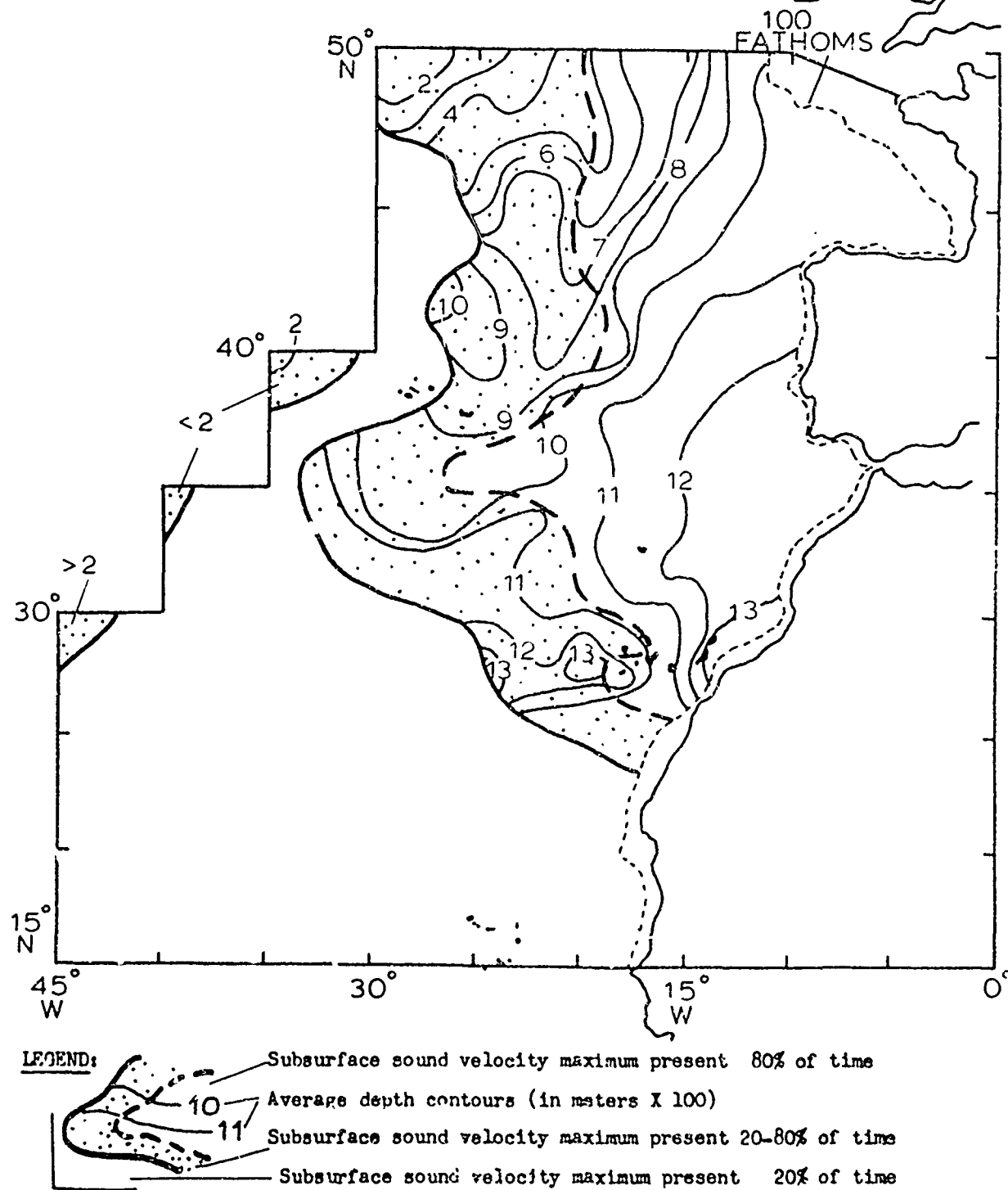


FIGURE II-11: ANNUAL AREAL EXTENT AND AVERAGE AXIAL DEPTH OF SUBSURFACE SOUND VELOCITY MAXIMUM

UNCLASSIFIED

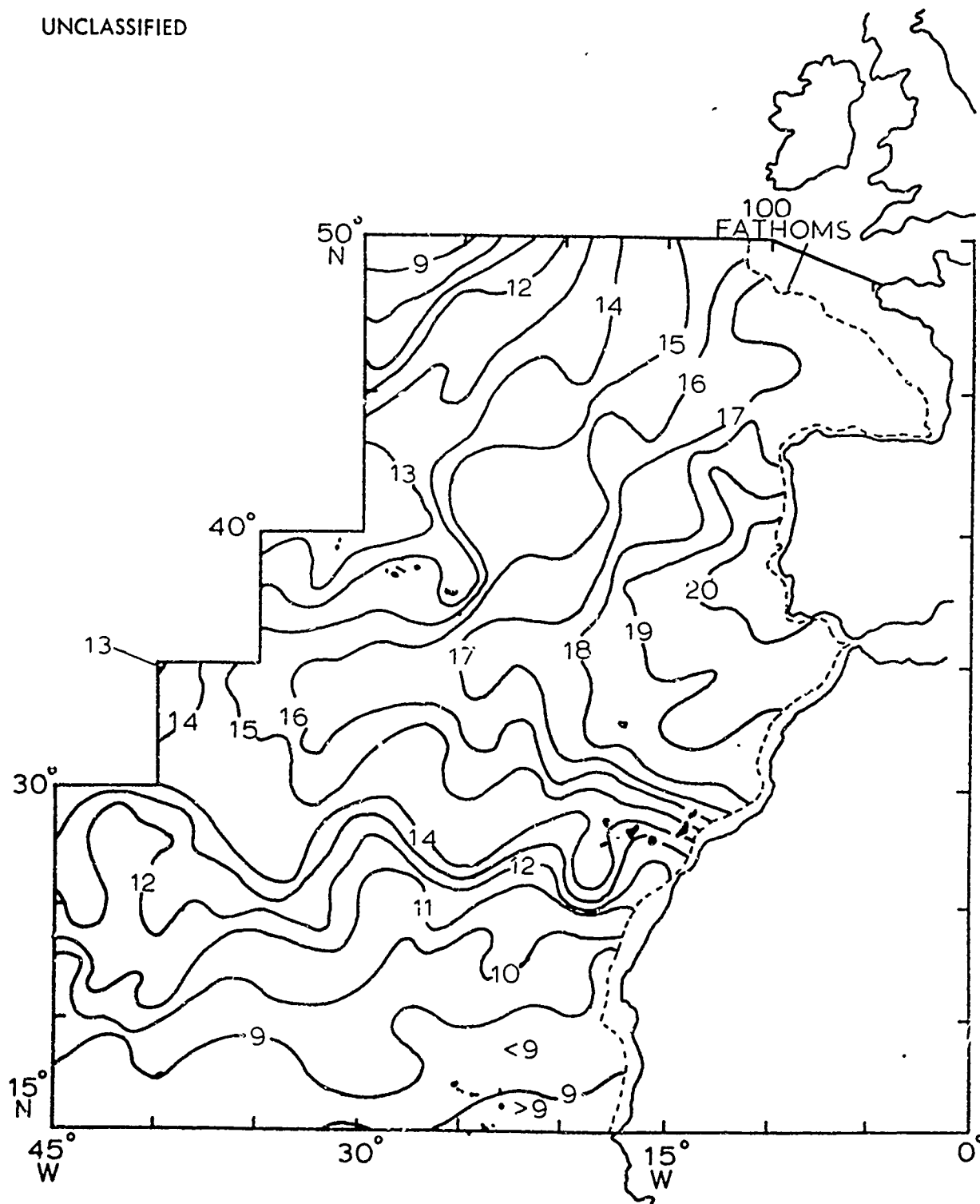
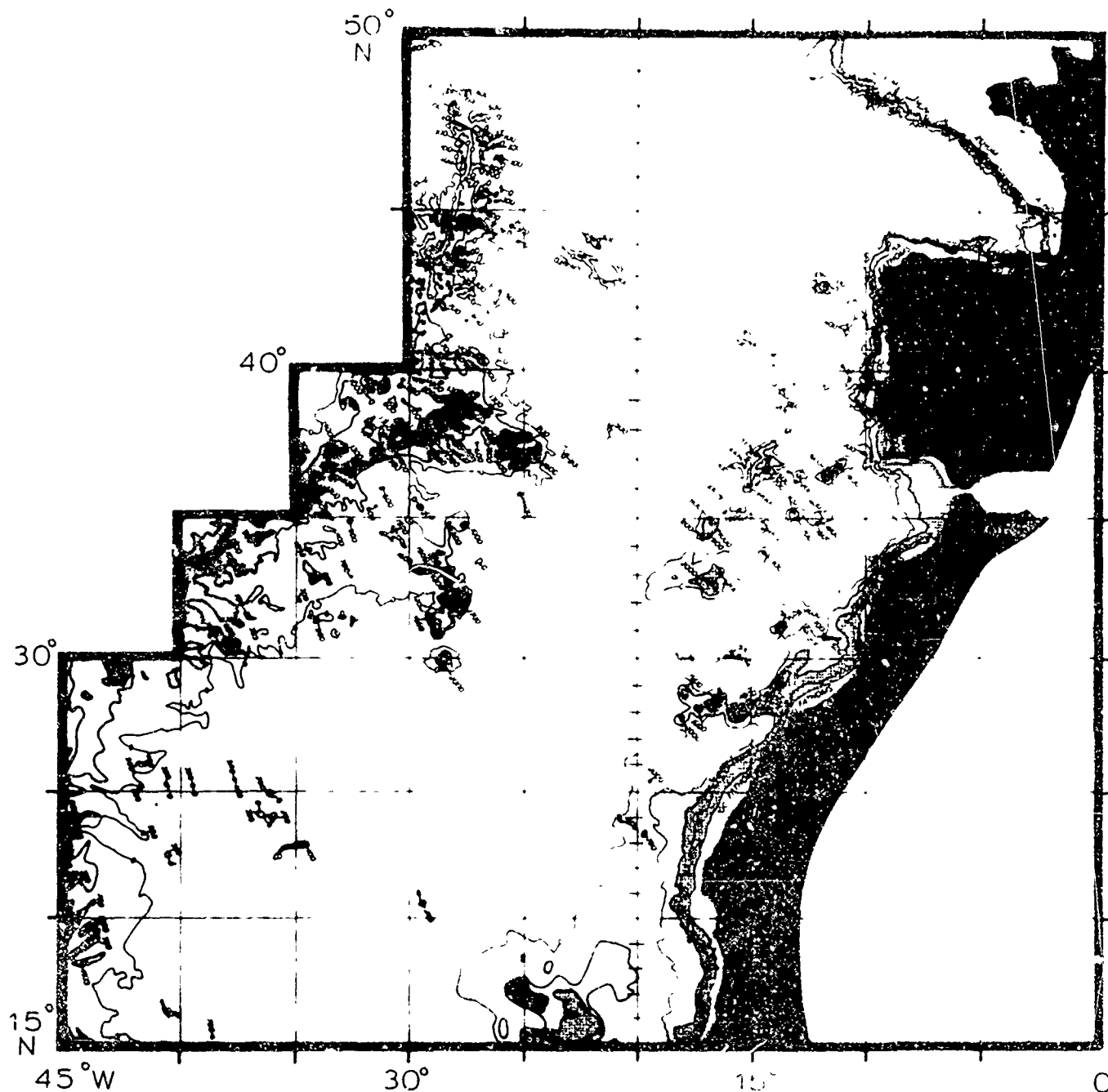


FIGURE II-12: ANNUAL AVERAGE DEPTH OF DEEP SOUND CHANNEL AXIS
(in meters X 100)

UNCLASSIFIED



LEGEND: see Figure I-13

FIGURE II-13: BATHYMETRY SHOALER THAN AVERAGE CRITICAL DEPTH
FOR WINTER (Nov-Apr)
(Contour interval = 500 fathoms)



LEGEND: see Figure II-13

FIGURE II-14: BATHYMETRY OF DEEPER THAN AVERAGE CRITICAL DEPTH
FOR SUMMER (May-Oct)
(Contour interval = 500 fathoms)

Best Available Copy

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50° N

40°

30°

15° N

45° W

30°

15° W

REGION 5
1969

REGION 6
1969

100 FATHOMS

USOC CHART No. 2

USOC CHART No. 3

28

29

42

43

59

60

79

80

81

103

104

0309 N
1969

0308 N
1969

0406 N
1951

0306 N
1952

0505 N
1966

0405 N
1966

0504 N
1953

0404 N
1953

0304 N
1969

0503 N
1953

0403 N
1952

0305 N
1952

0205 N
1952

Boundary of NAVOCEANO North Atlantic Regional Chart

 — Laurhton Chart (National Institute of Oceanography)
— Chart number (1966 compilation date)

 — NAVOCEANO BC Chart
— Chart number
— Compilation date

 — USOC Charts (pre-1960 compilation)

37

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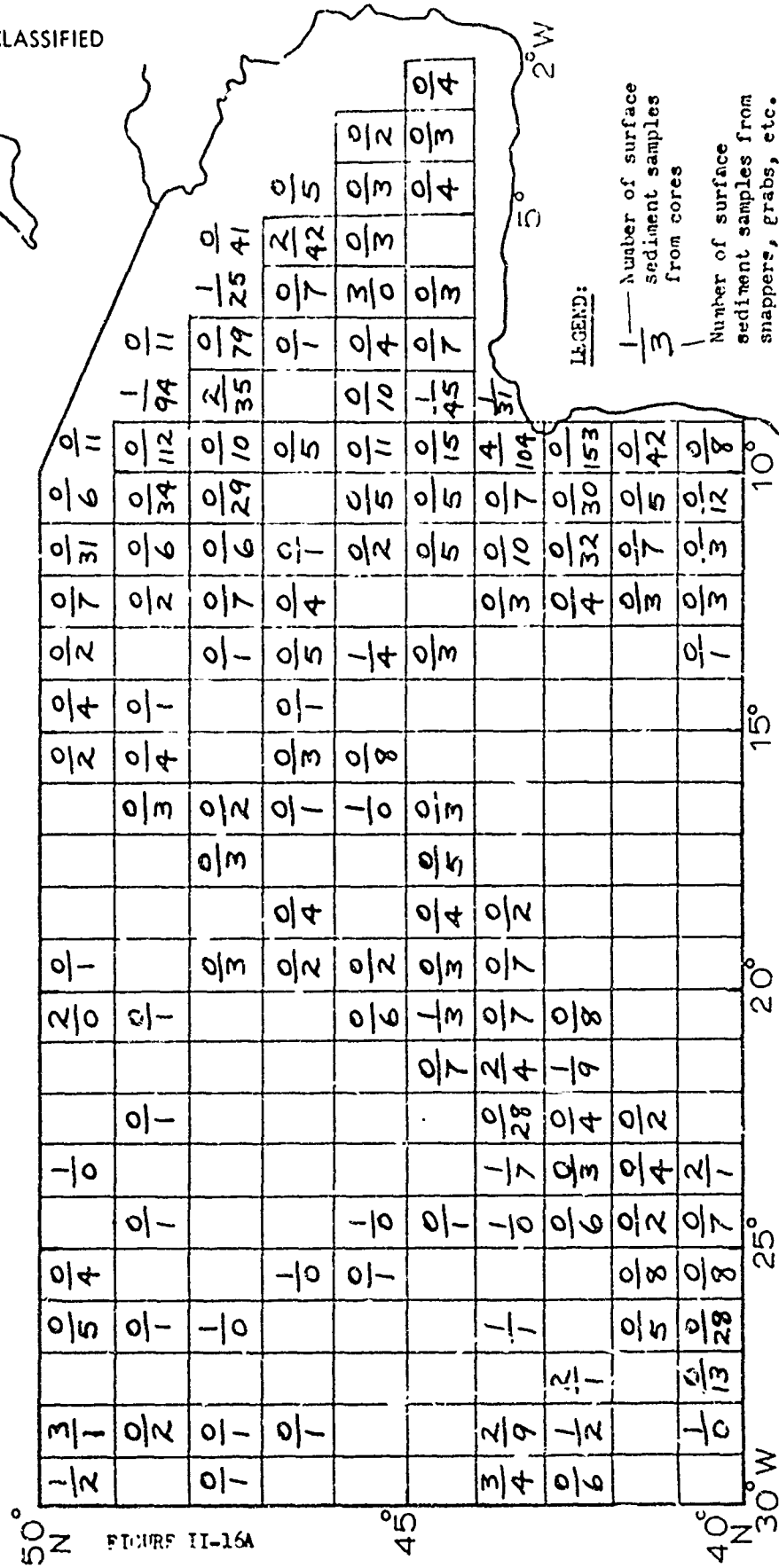


FIGURE II-16a

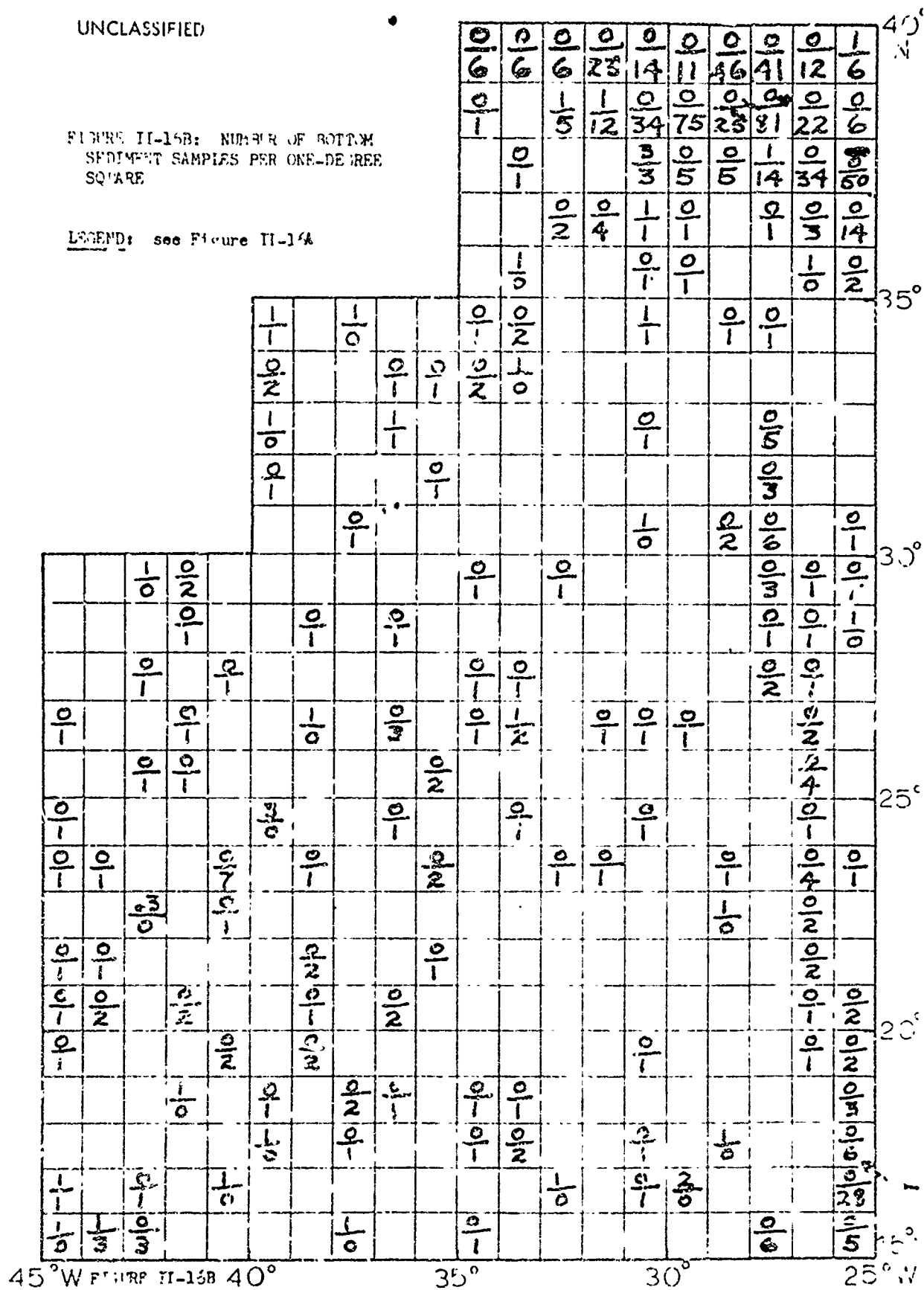
FIGURE II-16a: NUMBER OF BOTTOM SEDIMENT SAMPLES PER ONE-DEGREE SQUARE

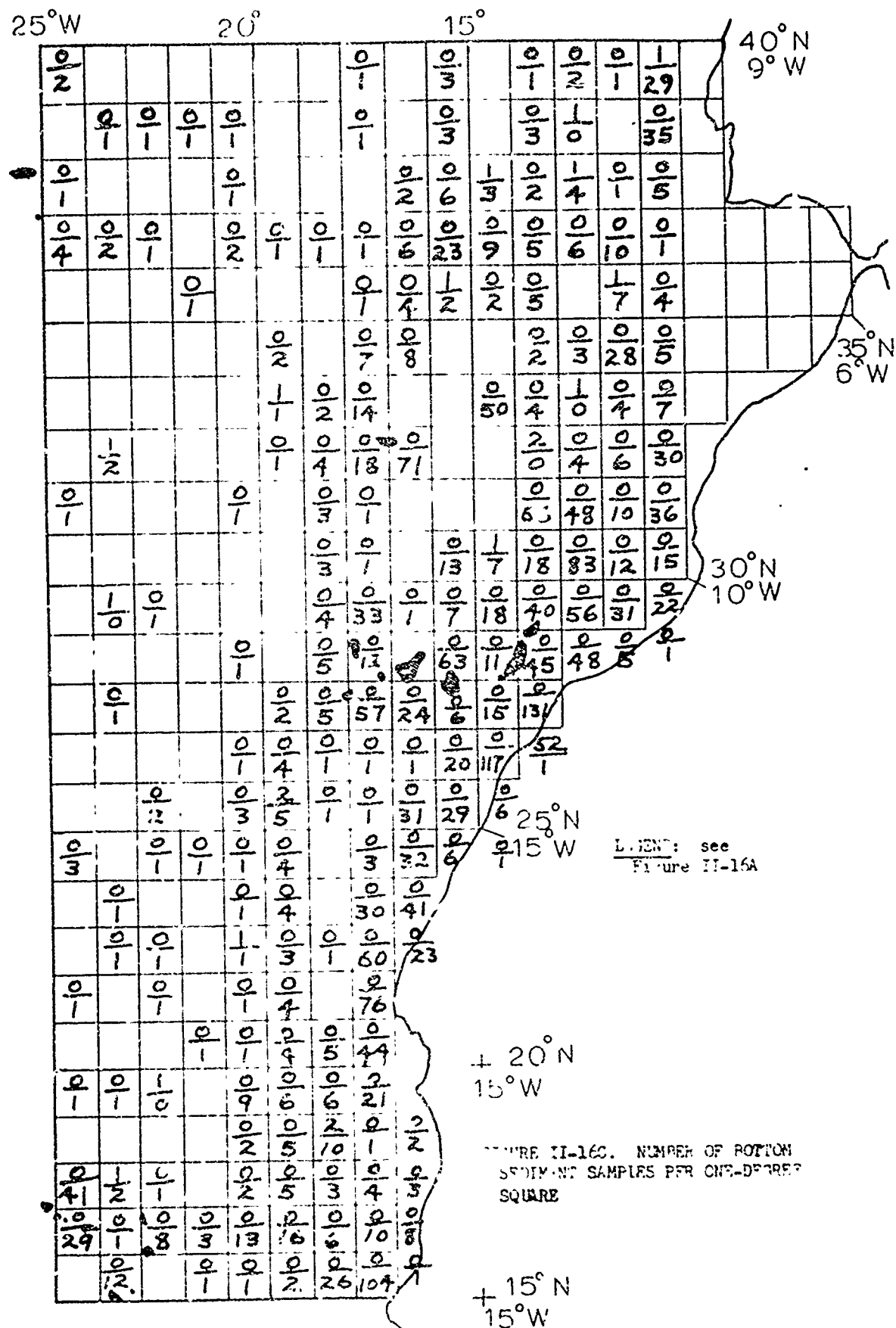
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UNCLASSIFIED

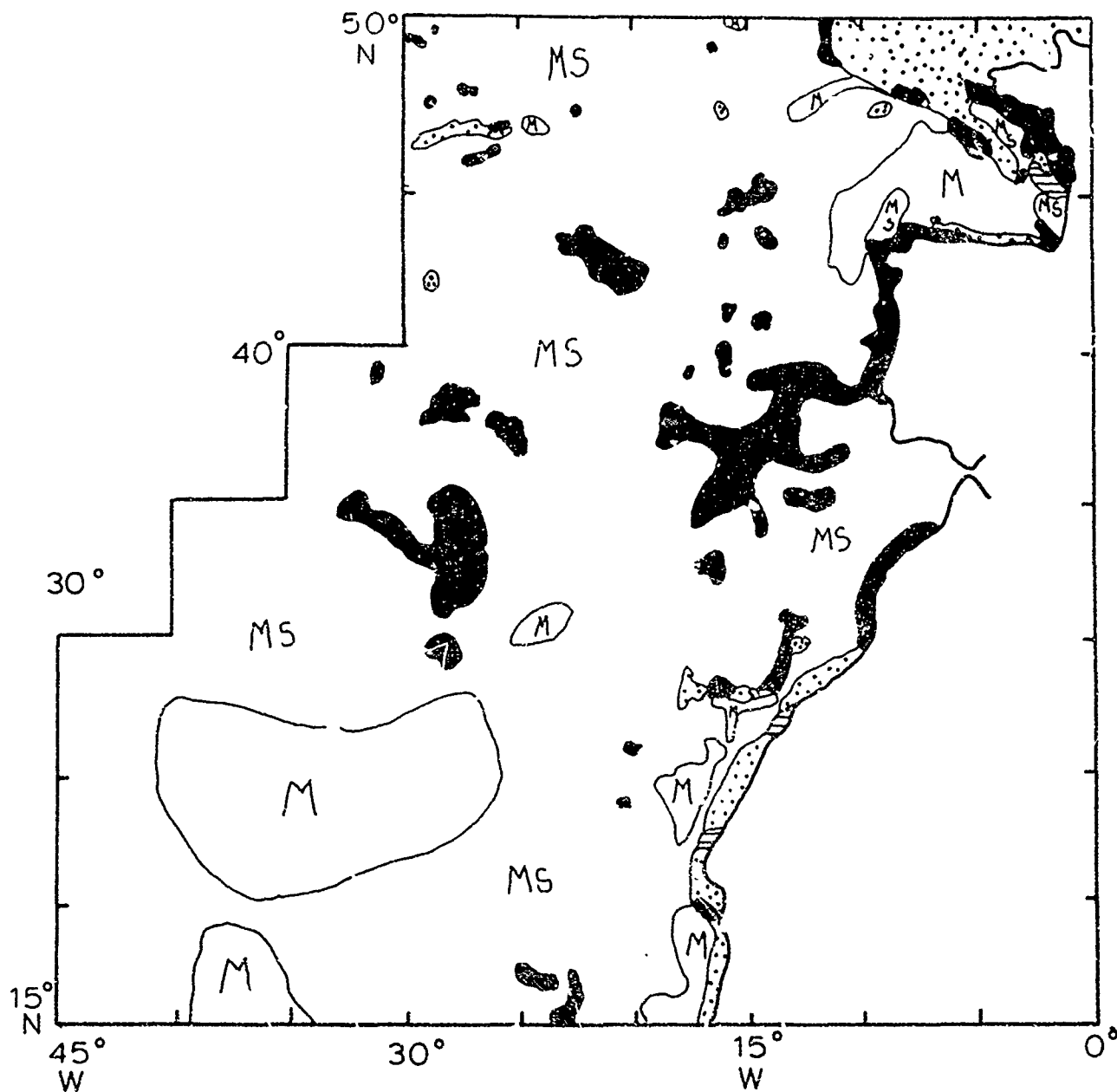
FIGURE II-15B: NUMBER OF BOTTOM
SEDIMENT SAMPLES PER ONE-DEGREE
SQUARE

LEGEND: see Figure II-15A





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LEGEND: see Figure I-17

FIGURE II-17: DISTRIBUTION OF SURFICIAL BOTTOM SEDIMENTS

UNCLASSIFIED

UNCLASSIFIED

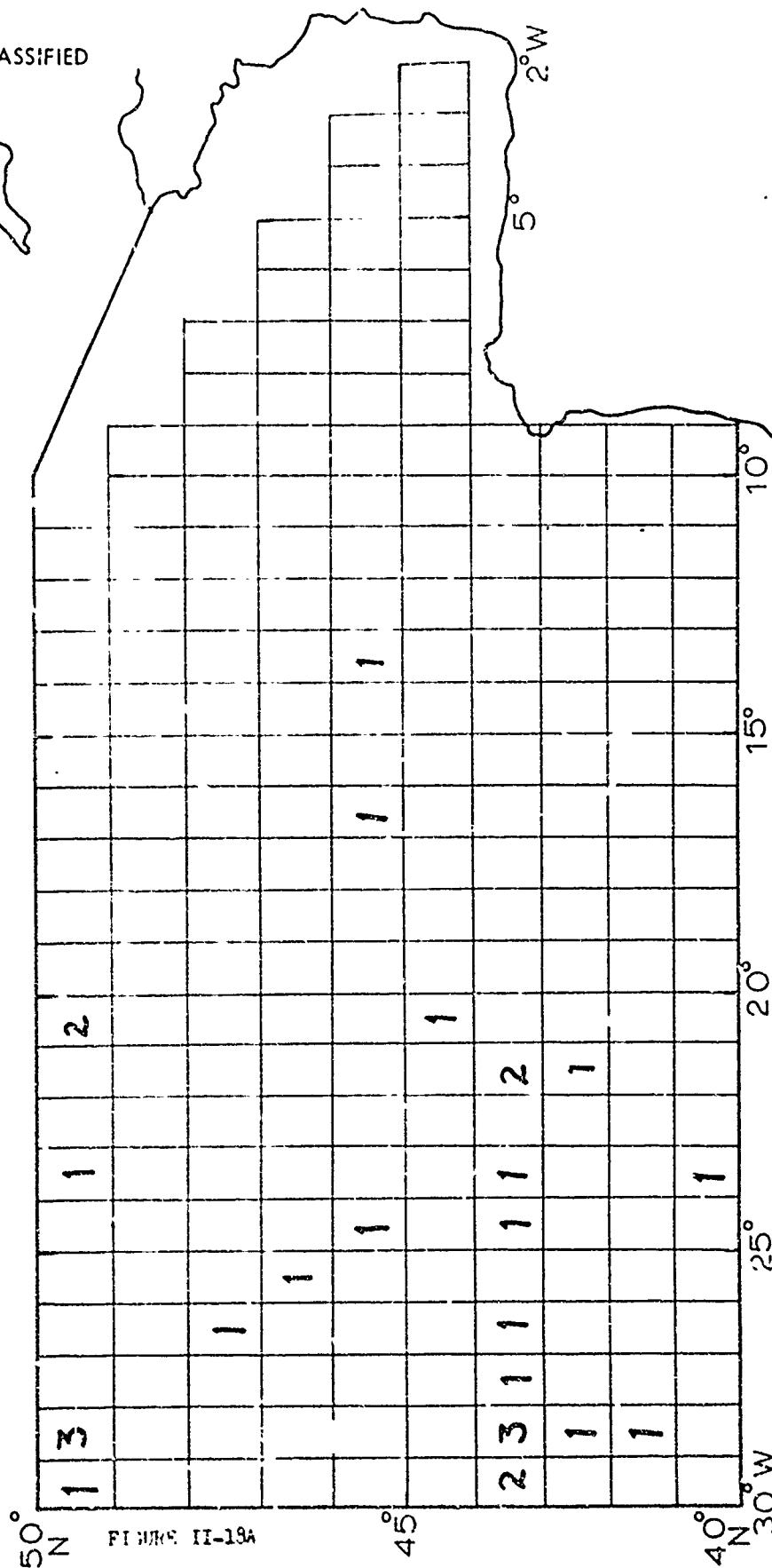


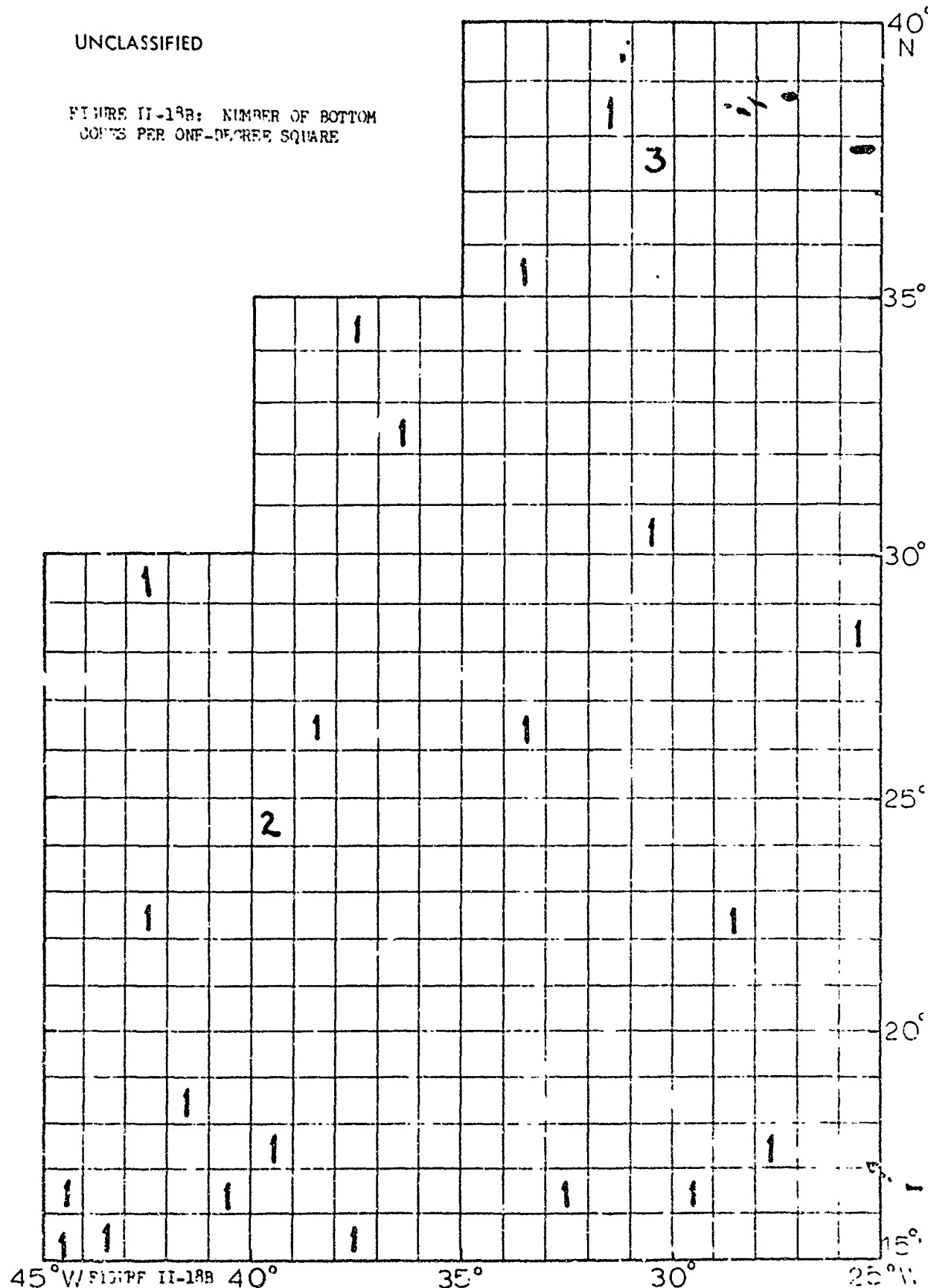
FIGURE II-19a

FIGURE II-19a: NUMBER OF BOTTOM CORES PER ONE-DEGREE SQUARE

UNCLASSIFIED

UNCLASSIFIED

FIGURE II-18B: NUMBER OF BOTTOM
COMES PER ONE-DEGREE SQUARE



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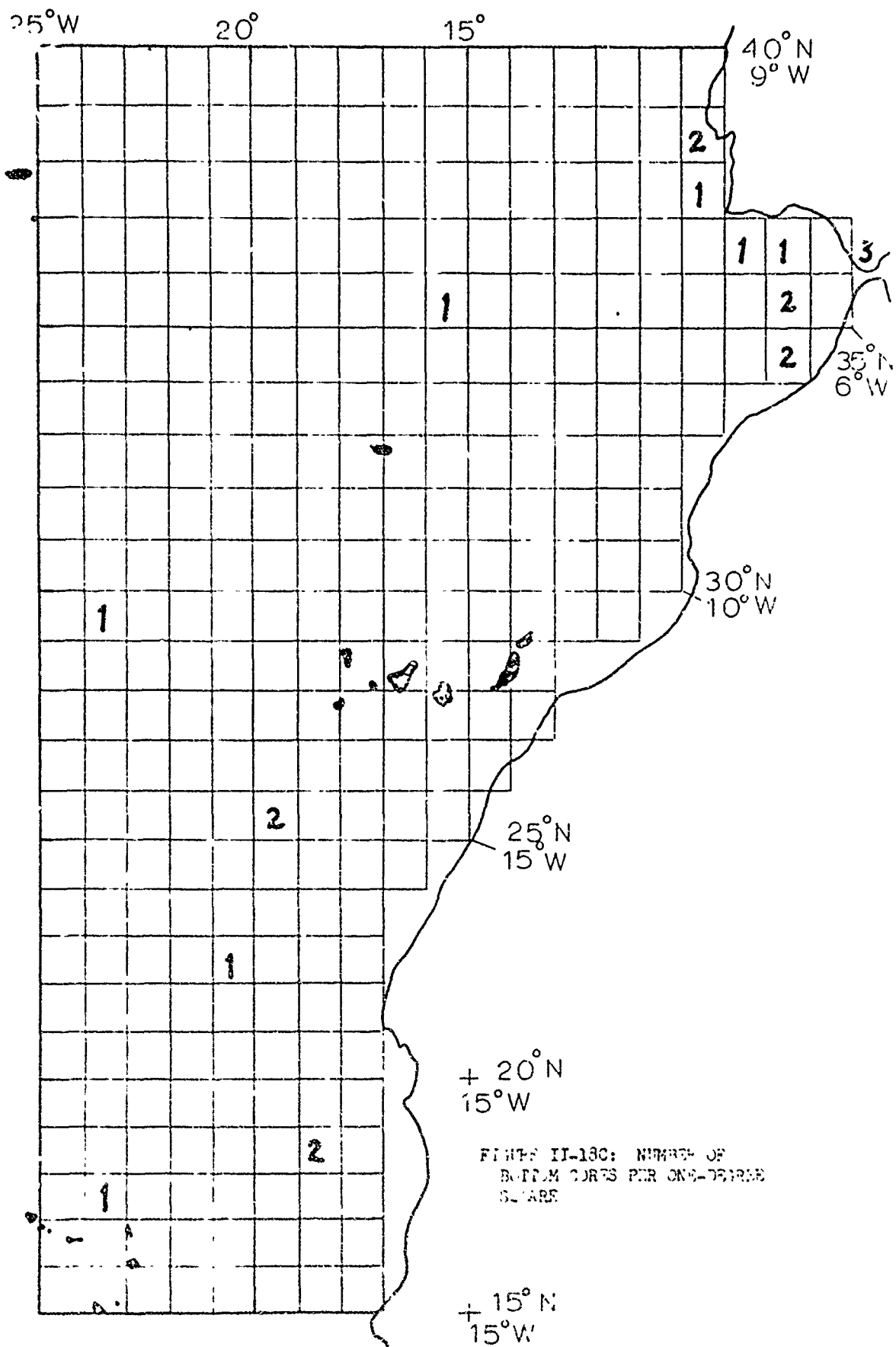


FIGURE II-130: NUMBER OF
BOTTOM CORES PER ONE-DEGREE
SQUARE

UNCLASSIFIED

UNCLASSIFIED

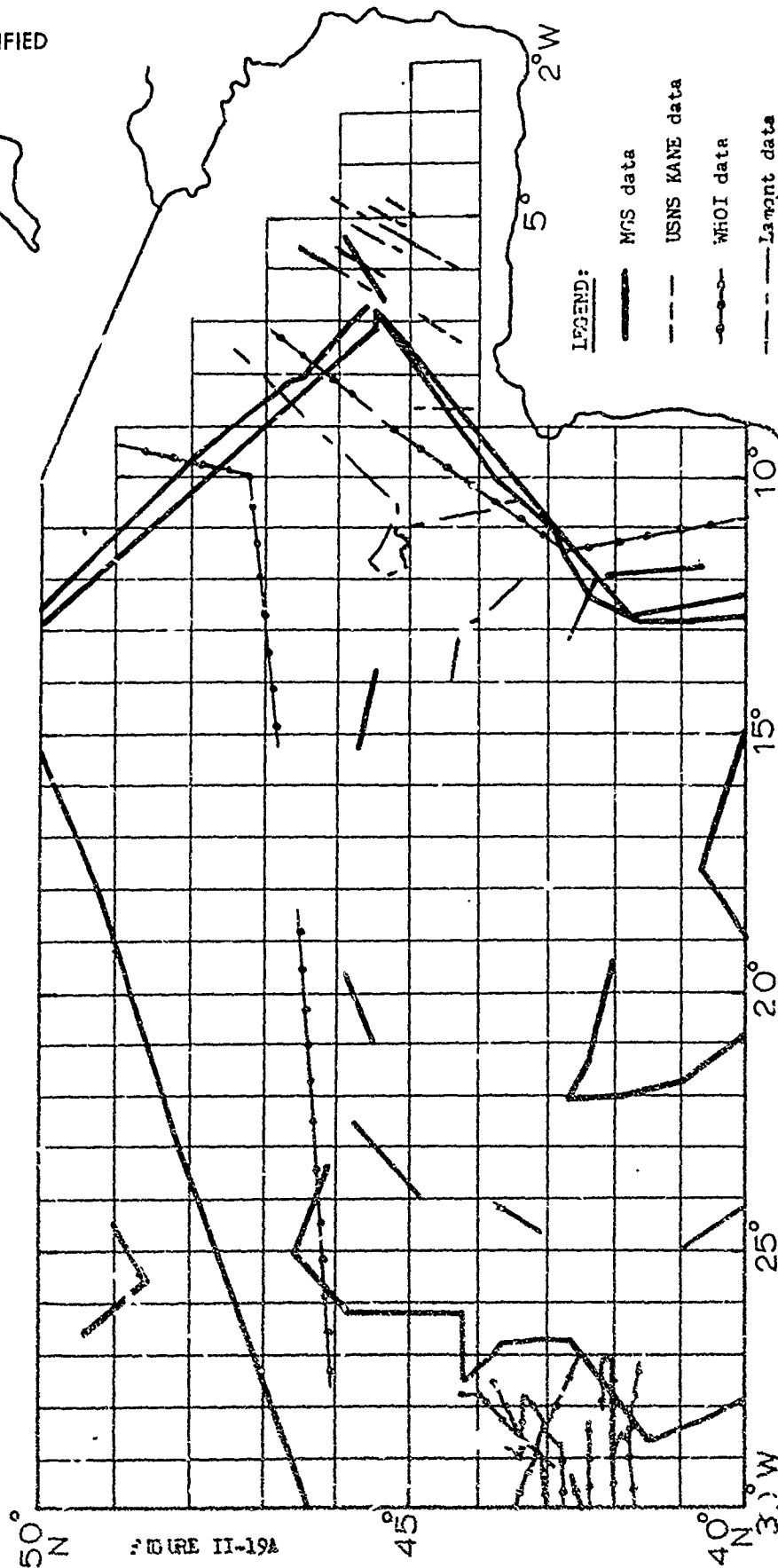
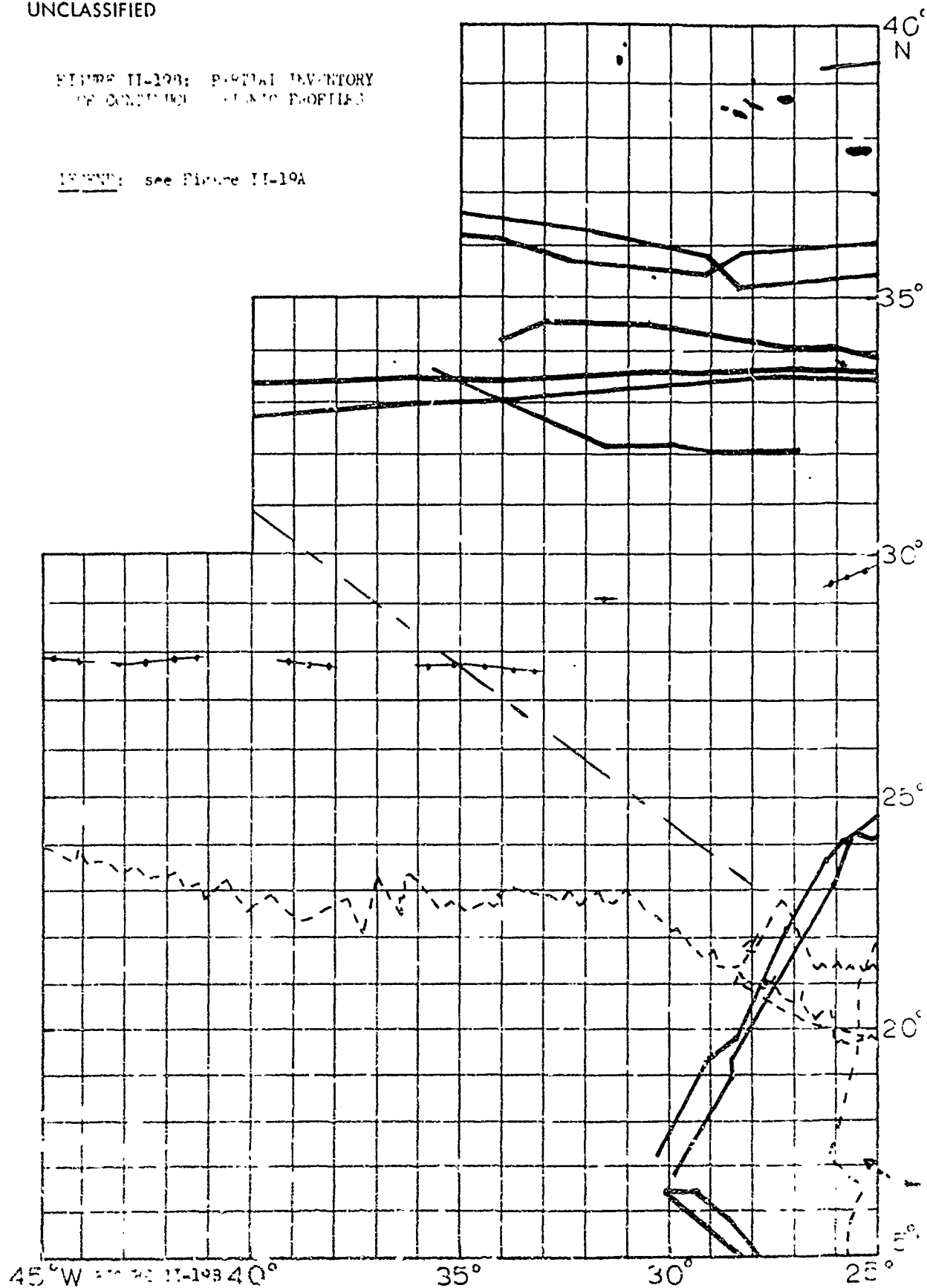


FIGURE II-19A: PARTIAL INVENTORY OF CONTINUOUS SEISMIC PROFILES

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FIGURE II-19B: PARTIAL INVENTORY
OF CONTINUED CLIMATIC PROFILES

REMARK: see Figure II-19A



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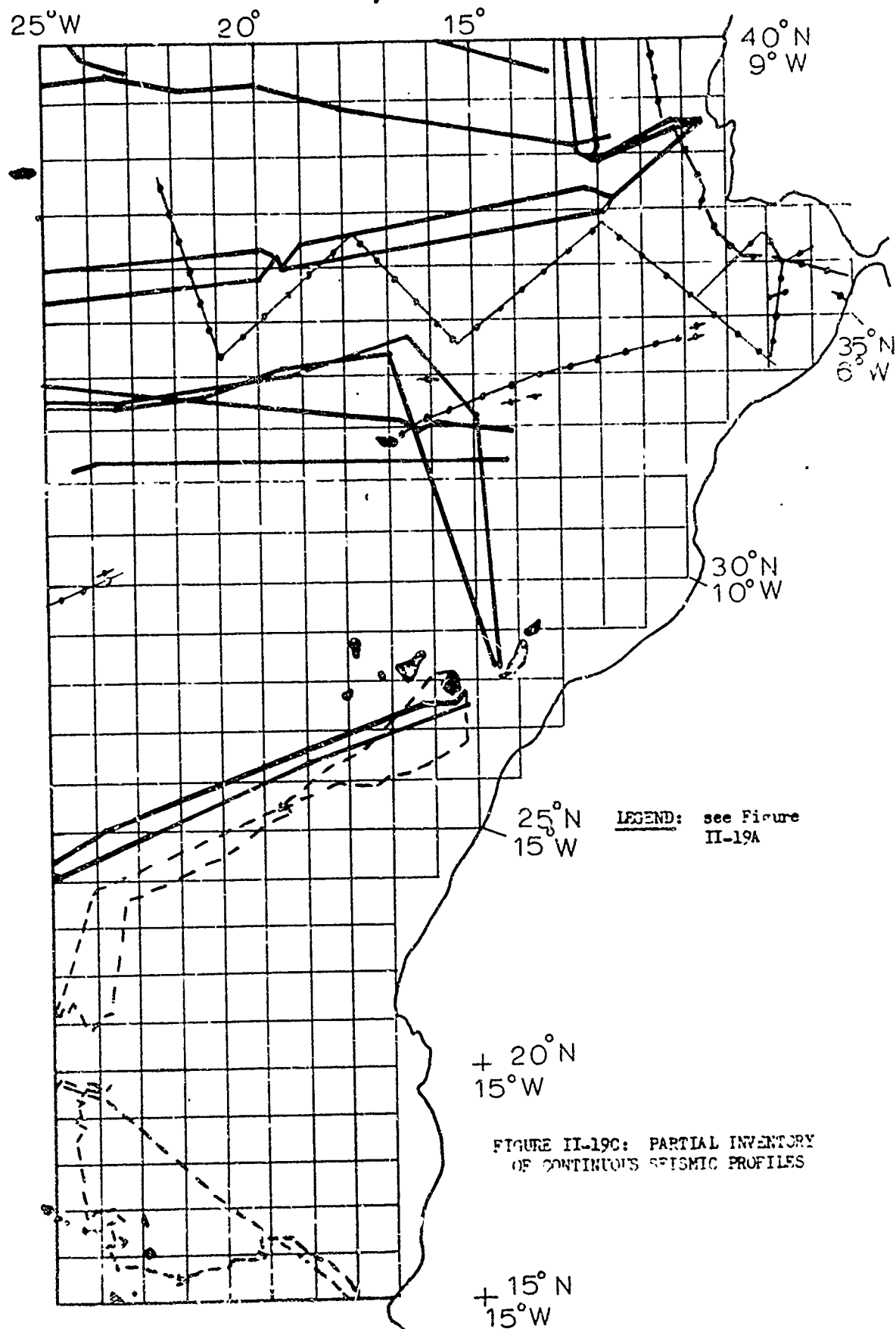


FIGURE II-19C: PARTIAL INVENTORY
OF CONTINUOUS SEISMIC PROFILES

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LRAPP PRIORITY AREA THREE

UNCLASSIFIED

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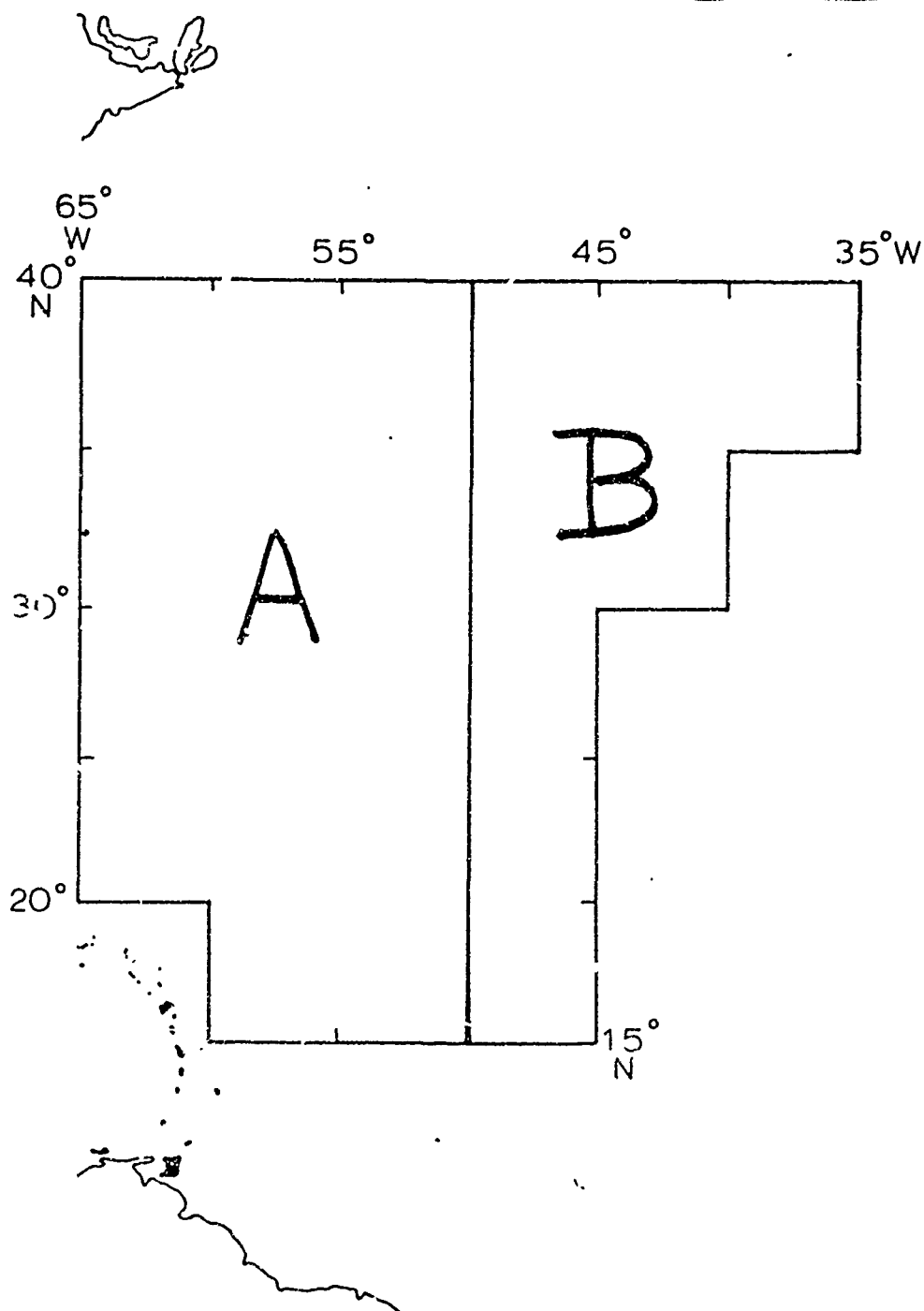


FIGURE III-1: LOCATION OF IRAPP ATLANTIC AREA III SUBAREAS

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65° W

60°

55°

50° W

	2			1													40° N
1	1	2			2												
3	1	2															
6	8	2	3	1													
7	4	2	1	2												1	35°
6	2								1	1		1	1				
9	2	1				1	2	1		1	1						
70	1	2		1													
4	1	1					1		1								
5				2			1										30°
2						1	1	1									
5						1	1	1					1				
3	1						2	1									
2							1	1									
2	1						2				3						25°
	1					1	1				1						
		1				1	1					1					
2	1			1			1				1						
3	2	2	1	1			1										
3	2	5	2			1	1	1				2					20°
						2	1	1	2			1					
						2		2	2			1	1				
						3	1	2	1			1					
						1	2	1	1	1		2					
						1	1	1	1	1		2				1	15°

FIGURE III-2A: NUMBER OF
WINTER (Jan-Mar) OCEANOGRAPHIC
OBSERVATIONS PER ONE-DEGREE
SQUARE DEEPER THAN DEEP
AXIAL DEPTH

CONFIDENTIAL

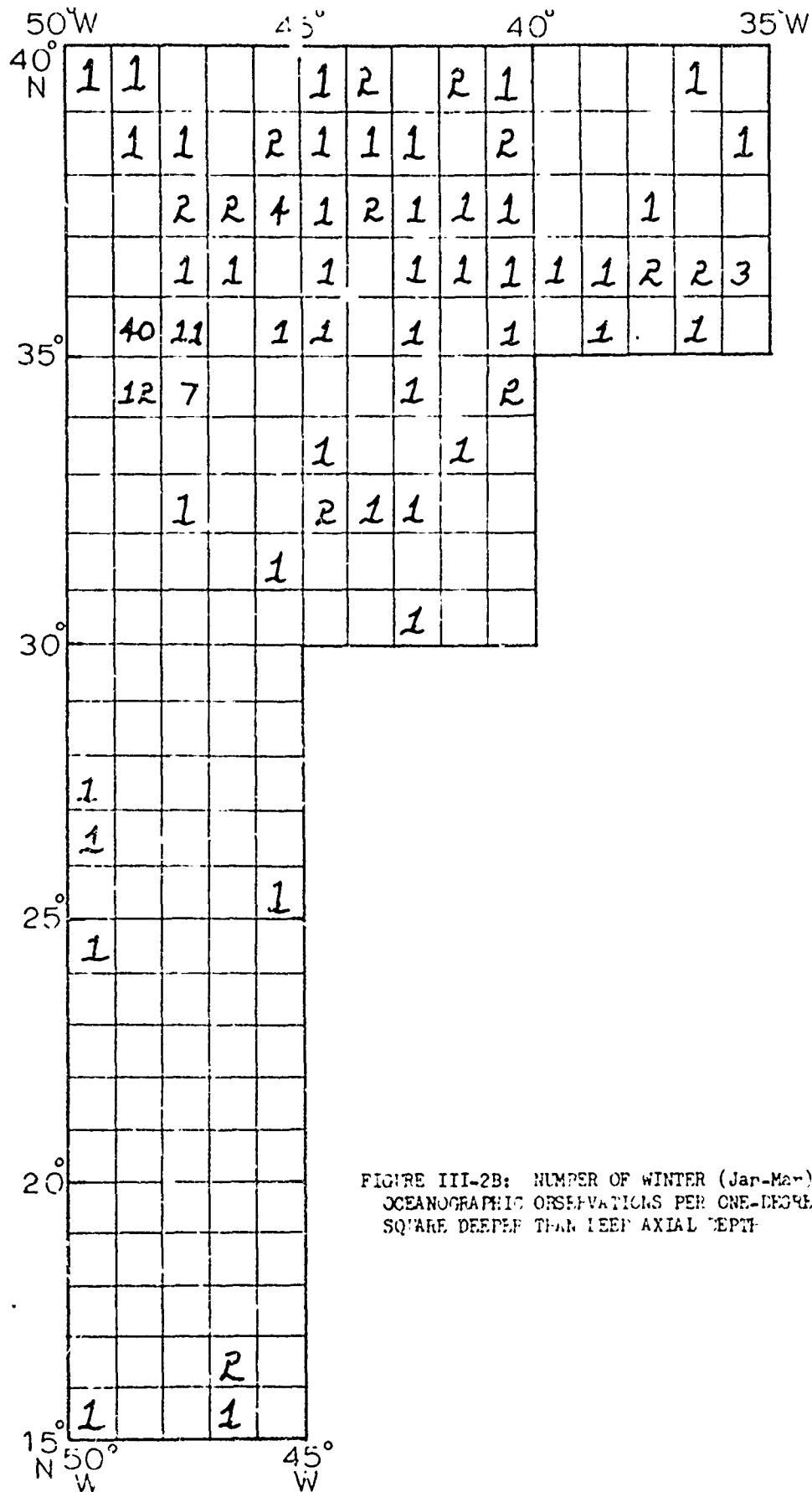


FIGURE III-2B: NUMBER OF WINTER (Jan-Mar)
OCEANOGRAPHIC OBSERVATIONS PER ONE-DEGREE
SQUARE DEEPER THAN 1000 AXIAL DEPTH

CONFIDENTIAL

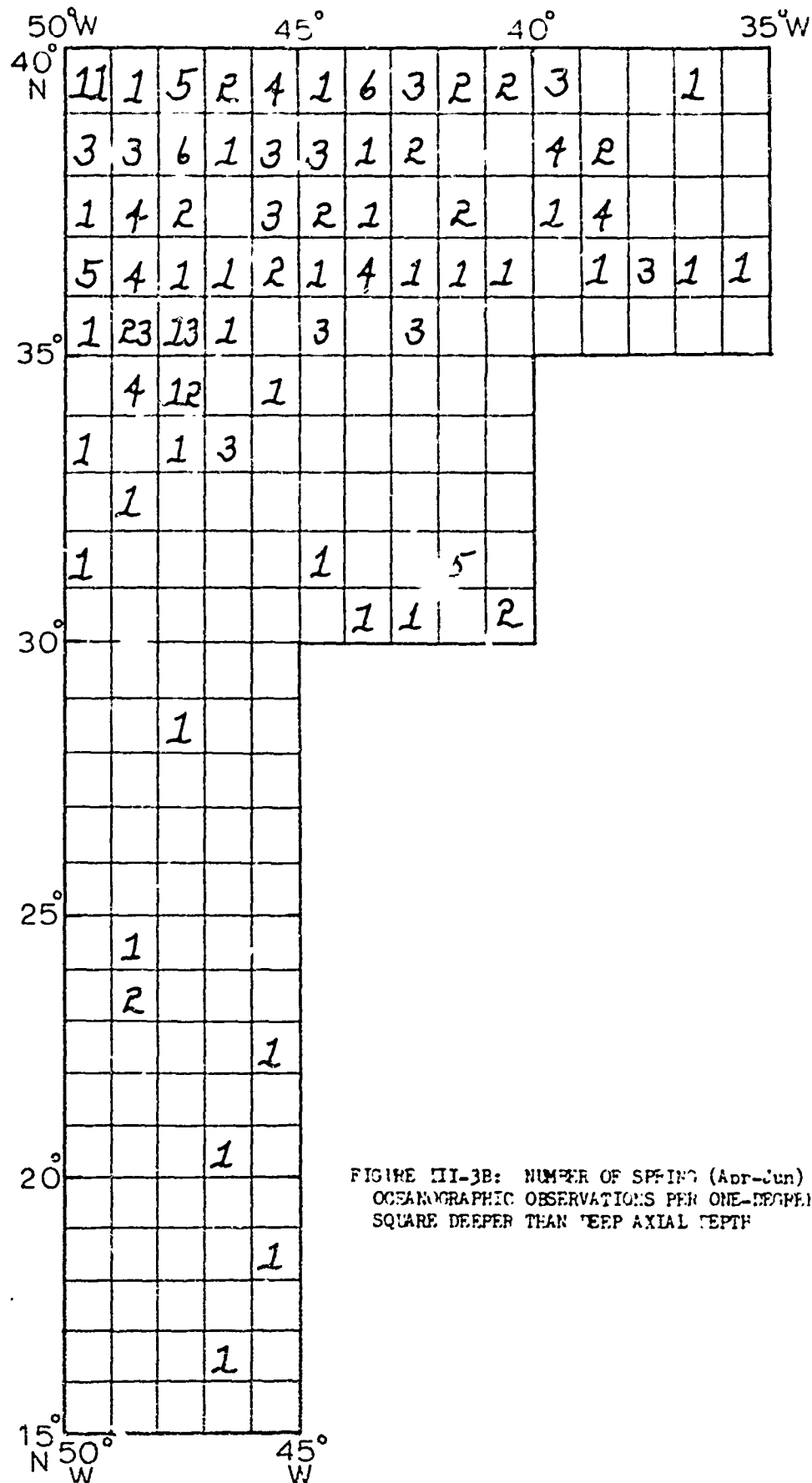
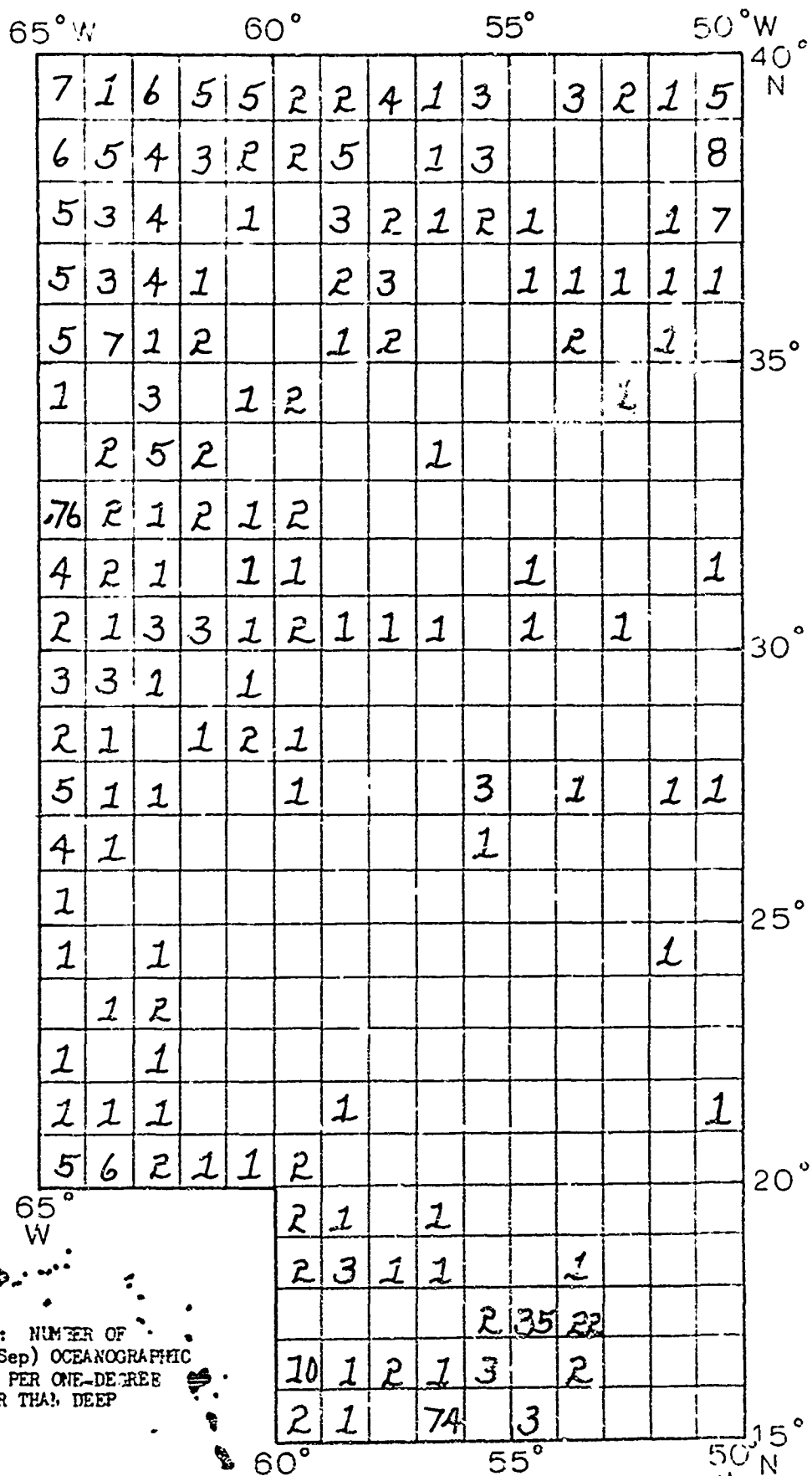


FIGURE III-3B: NUMBER OF SPRING (Apr-Jun)
OCEANOGRAPHIC OBSERVATIONS PER ONE-DEGREE
SQUARE DEEPER THAN 1000 FATHOMS

CONFIDENTIAL



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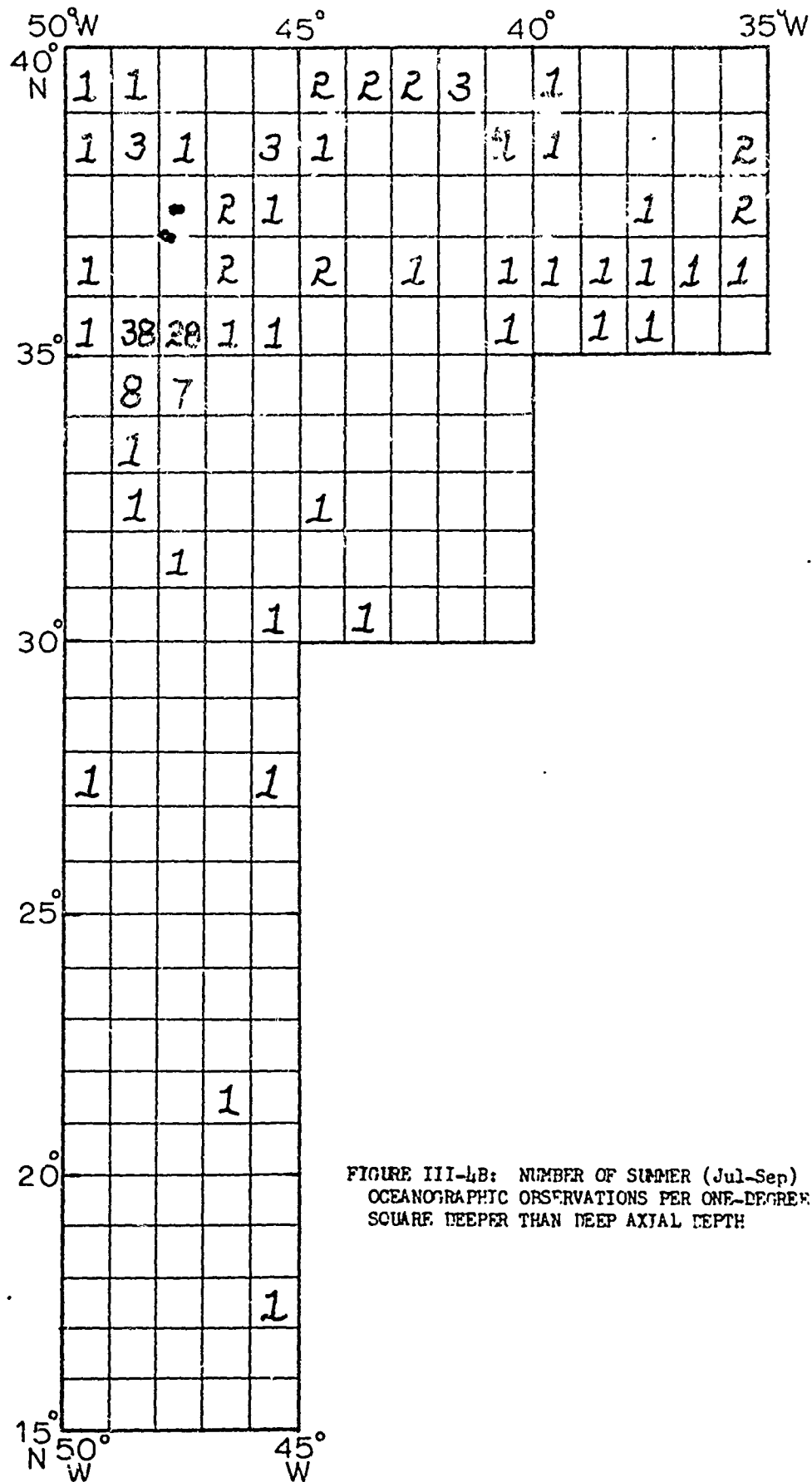


FIGURE III-4B: NUMBER OF SUMMER (Jul-Sep)
OCEANOGRAPHIC OBSERVATIONS PER ONE-DEGREE
SQUARE DEEPER THAN DEEP AXIAL DEPTH

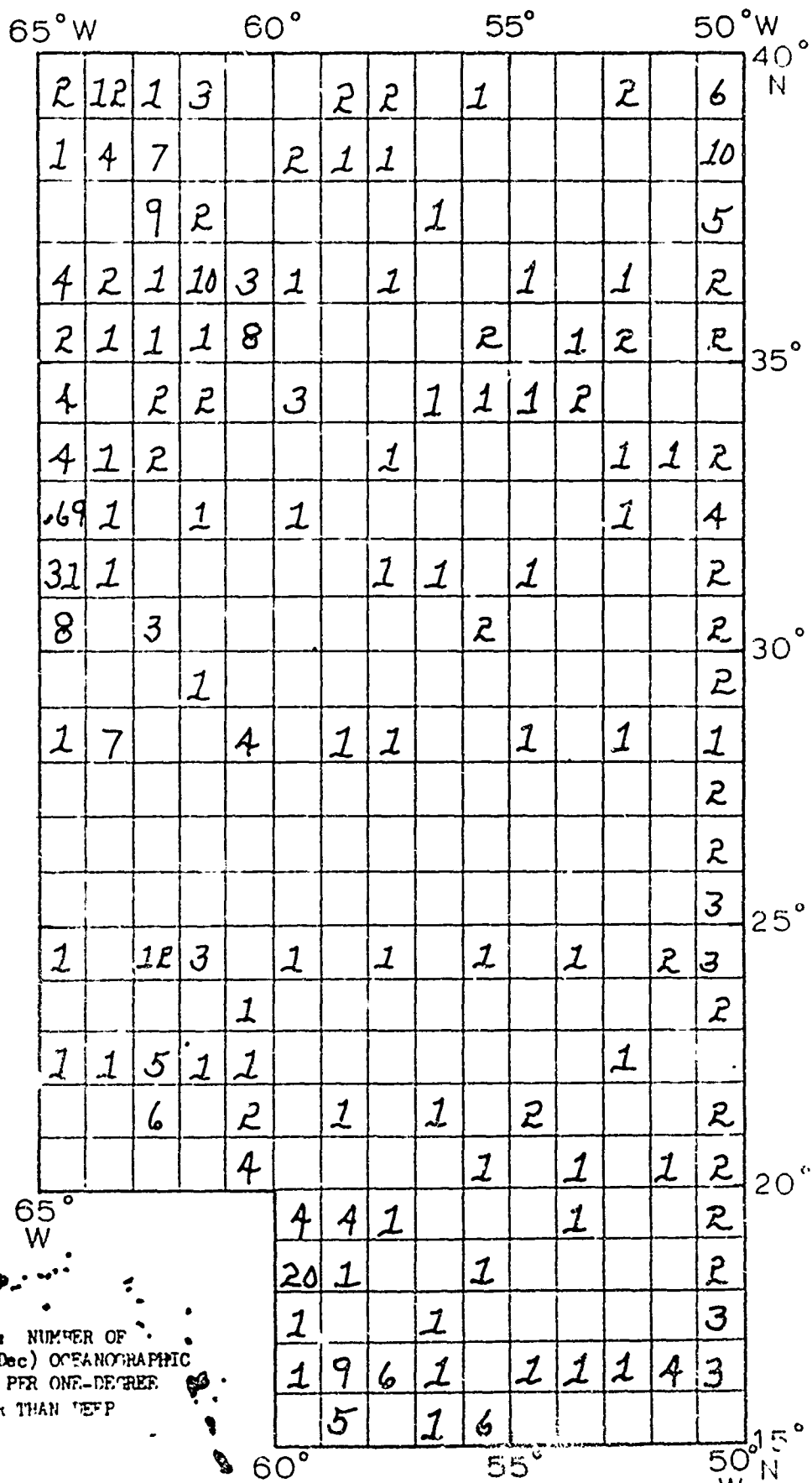


FIGURE III-5A: NUMBER OF
AUTUMN (Oct-Dec) OCEANOGRAPHIC
OBSERVATIONS PER ONE-DEGREE
SQUARE DEEPER THAN 1000
FATHOM DEPTH

CONFIDENTIAL

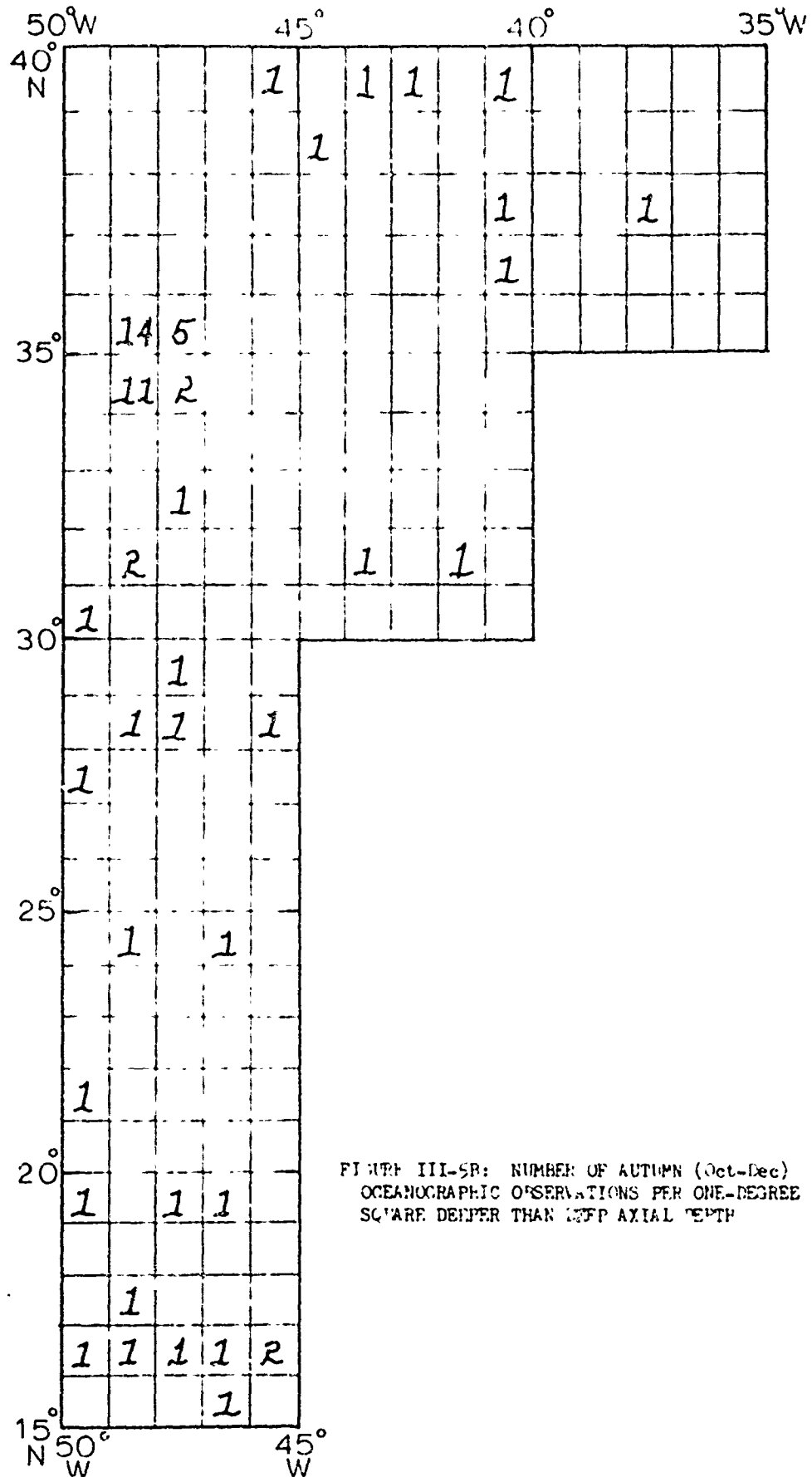


FIGURE III-5B: NUMBER OF AUTUMN (Oct-Dec)
OCEANOGRAPHIC OBSERVATIONS PER ONE-DEGREE
SQUARE DEEPER THAN 1000 AXIAL DEPTH

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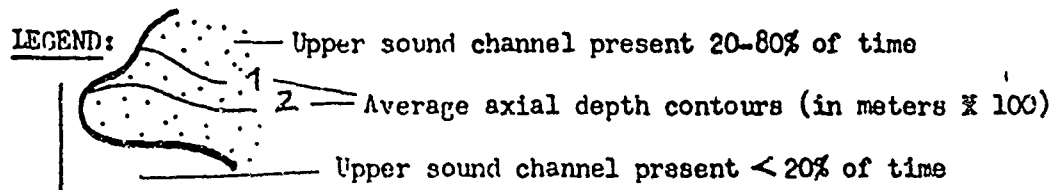
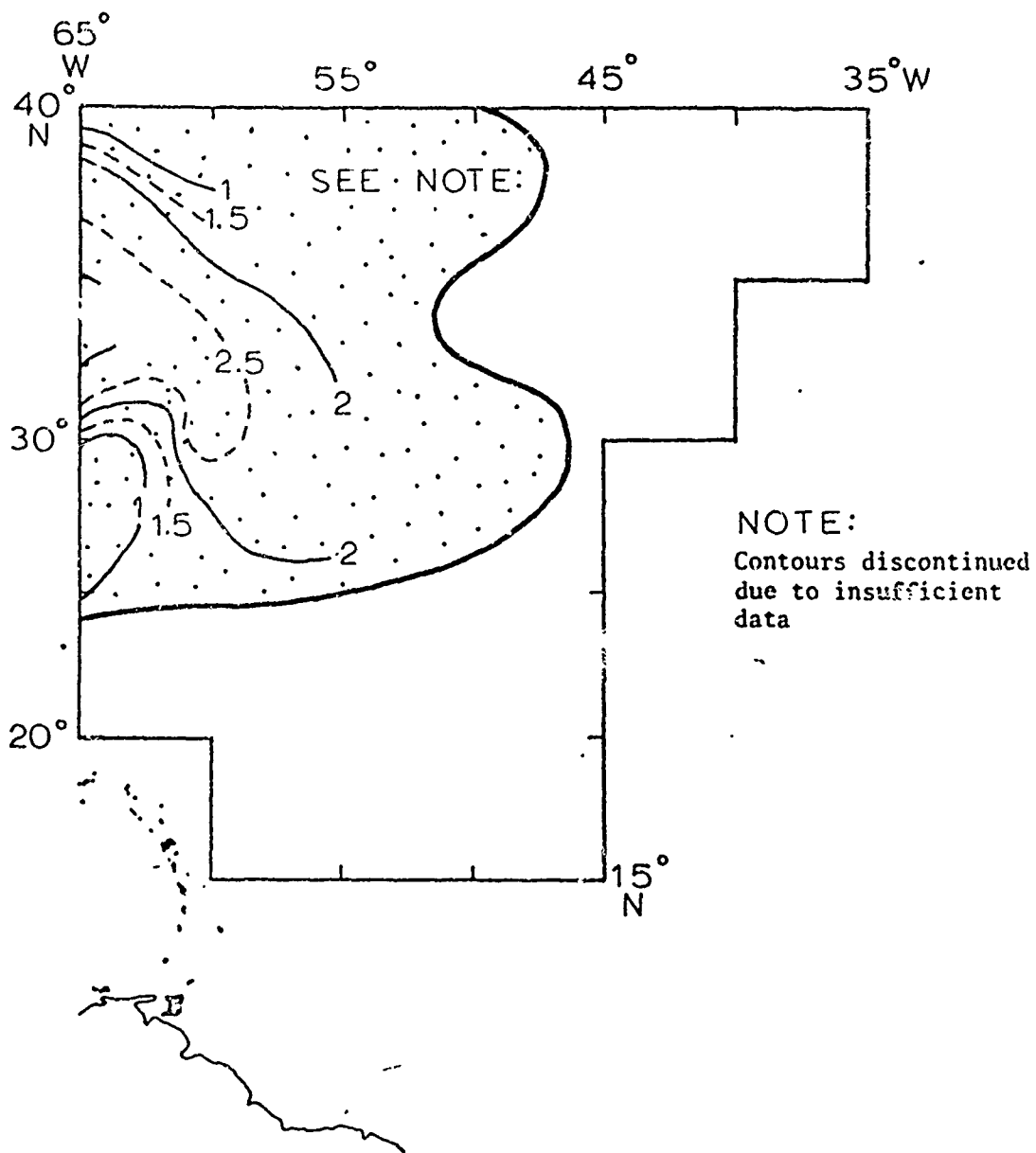


FIGURE III-6: ARFAL EXTENT AND AVERAGE AXIAL DEPTH OF UPPER SOUND CHANNEL FOR WINTER (Jan-Mar)

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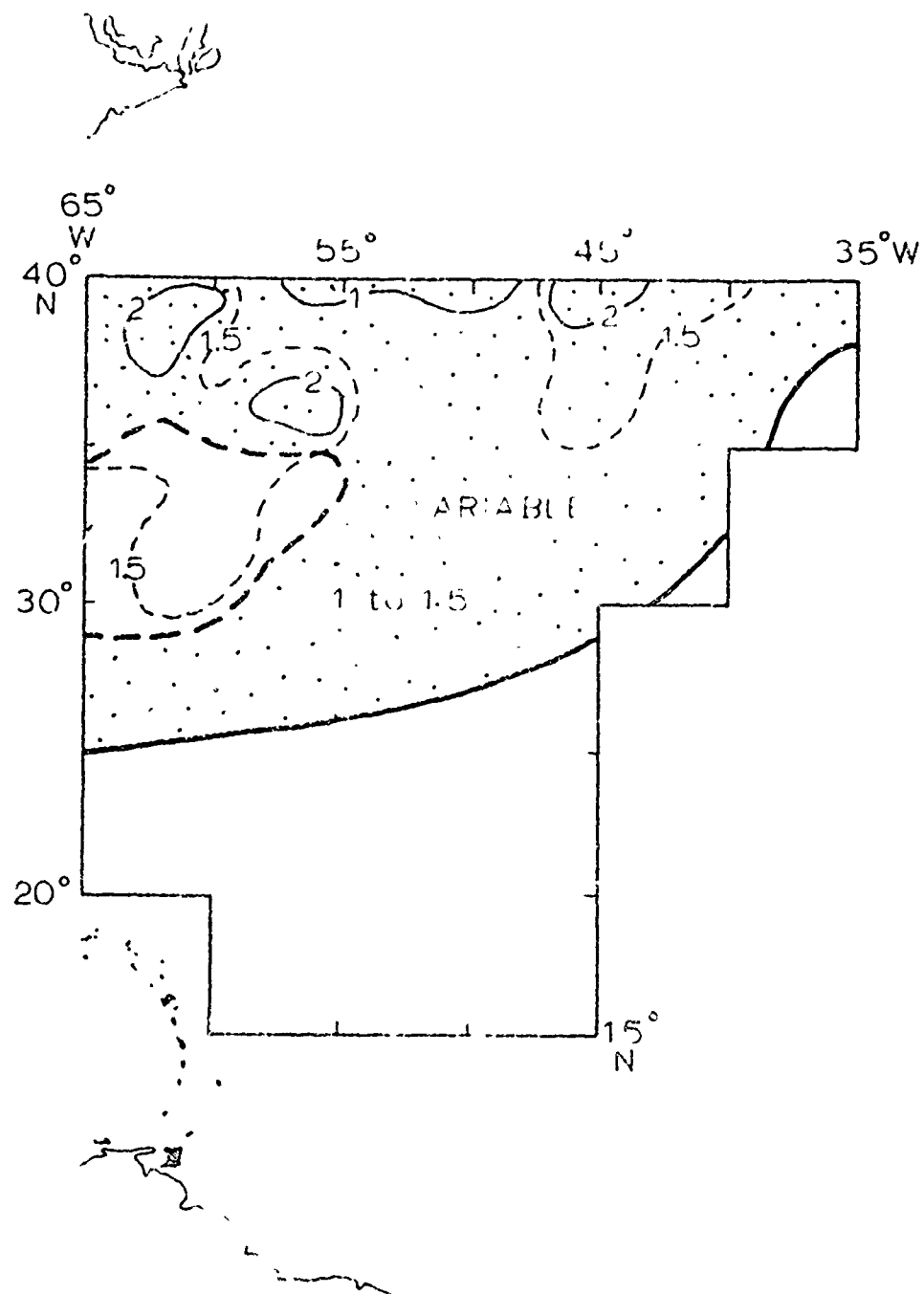
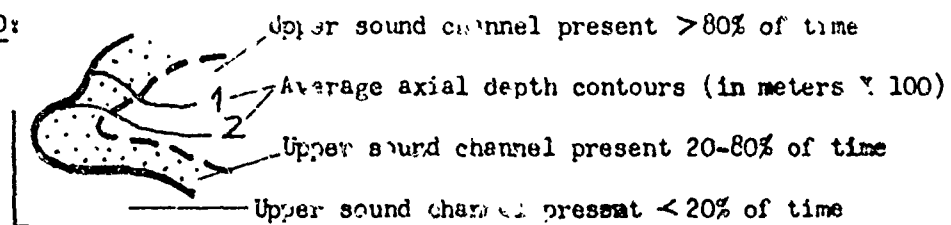
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FIGURE III-7: AREAL EXTENT AND AVERAGE AXIAL DEPTH OF UPPER SOUND CHANNEL FOR SPRING (Apr-Jun)

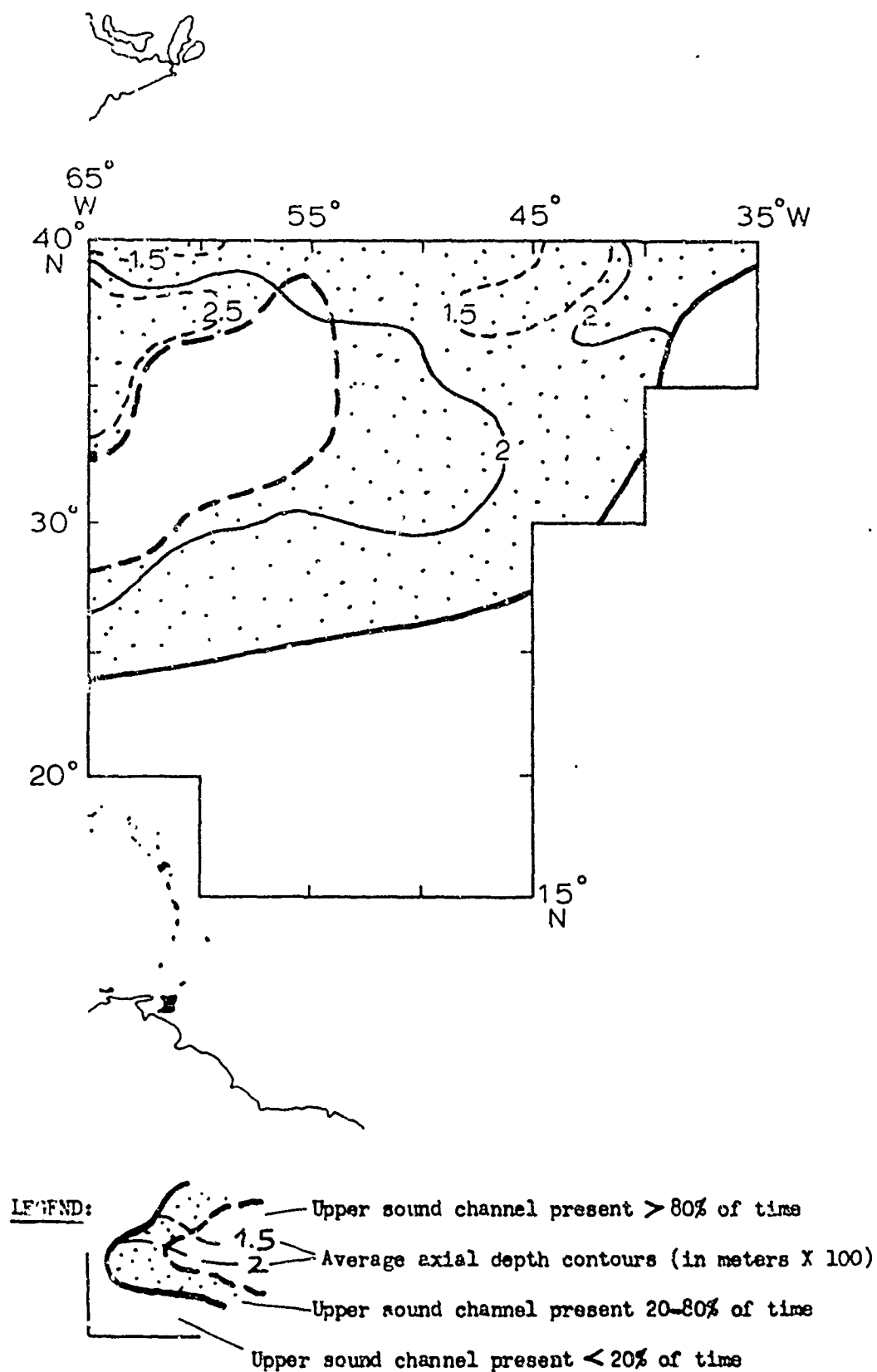


FIGURE III-8: AREAL EXTENT AND AVERAGE AXIAL DEPTH OF UPPER SOUND CHANNEL FOR SUMMER (Jul-Sep)

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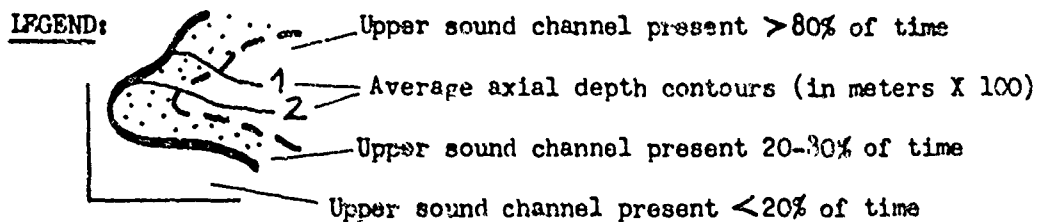
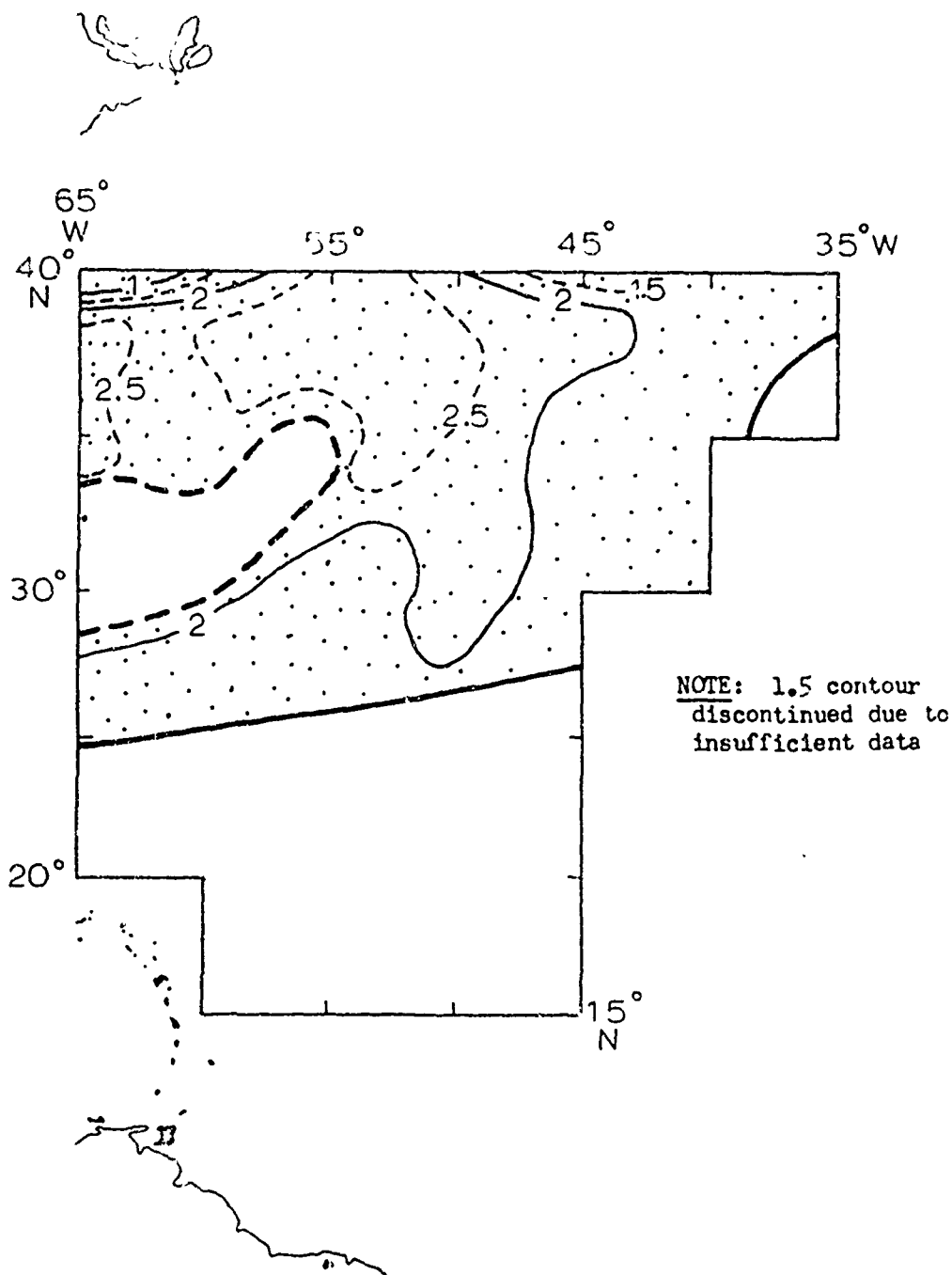


FIGURE III-9: AREAL EXTENT AND AVERAGE AXIAL DEPTH OF UPPER SOUND CHANNEL FOR AUTUMN (Oct-Dec)

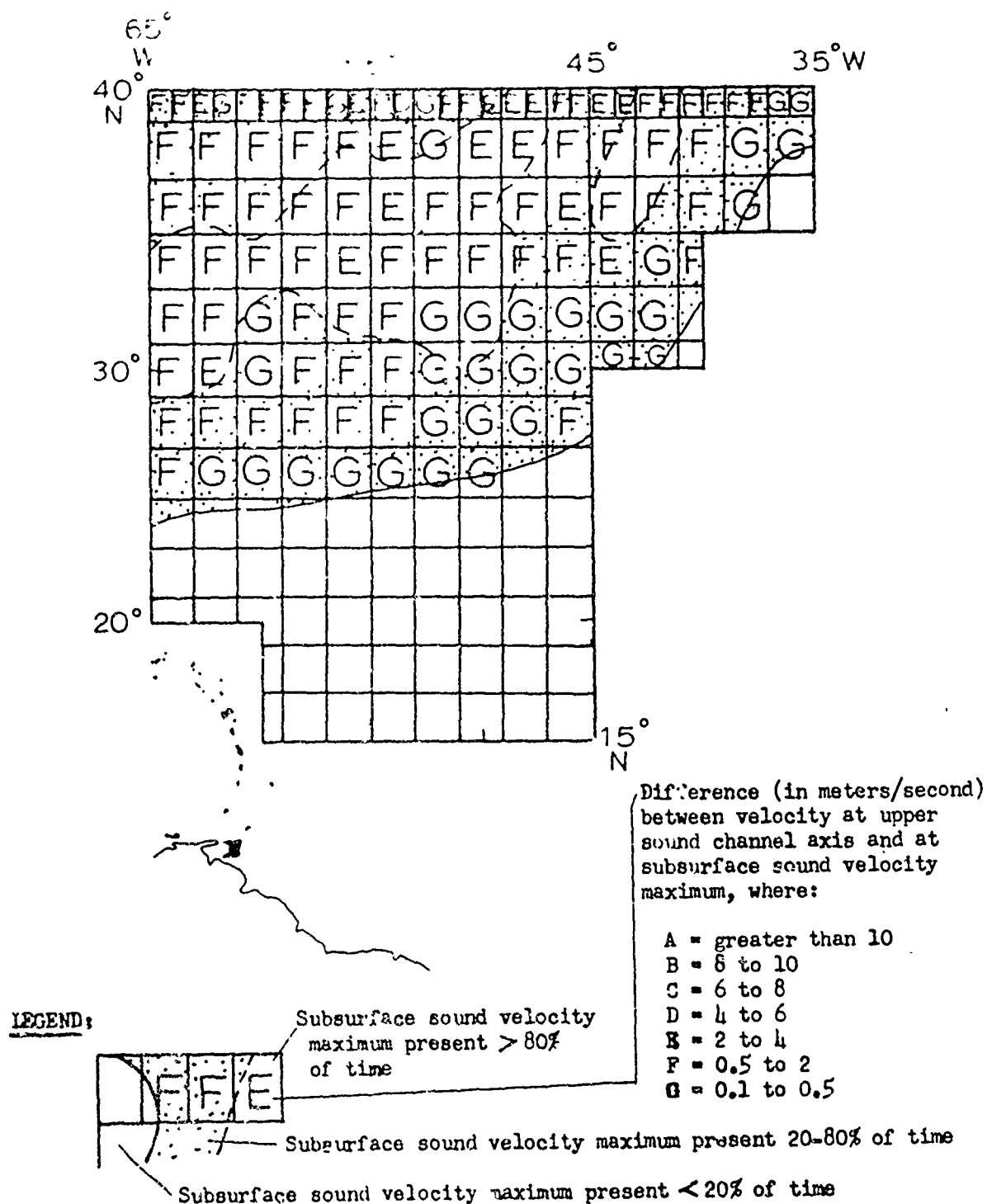


FIGURE III-10: ANNUAL AVERAGE "STRENGTH" OF UPPER SOUND CHANNEL (if present) RELATIVE TO SUBSURFACE SOUND VELOCITY MAXIMUM

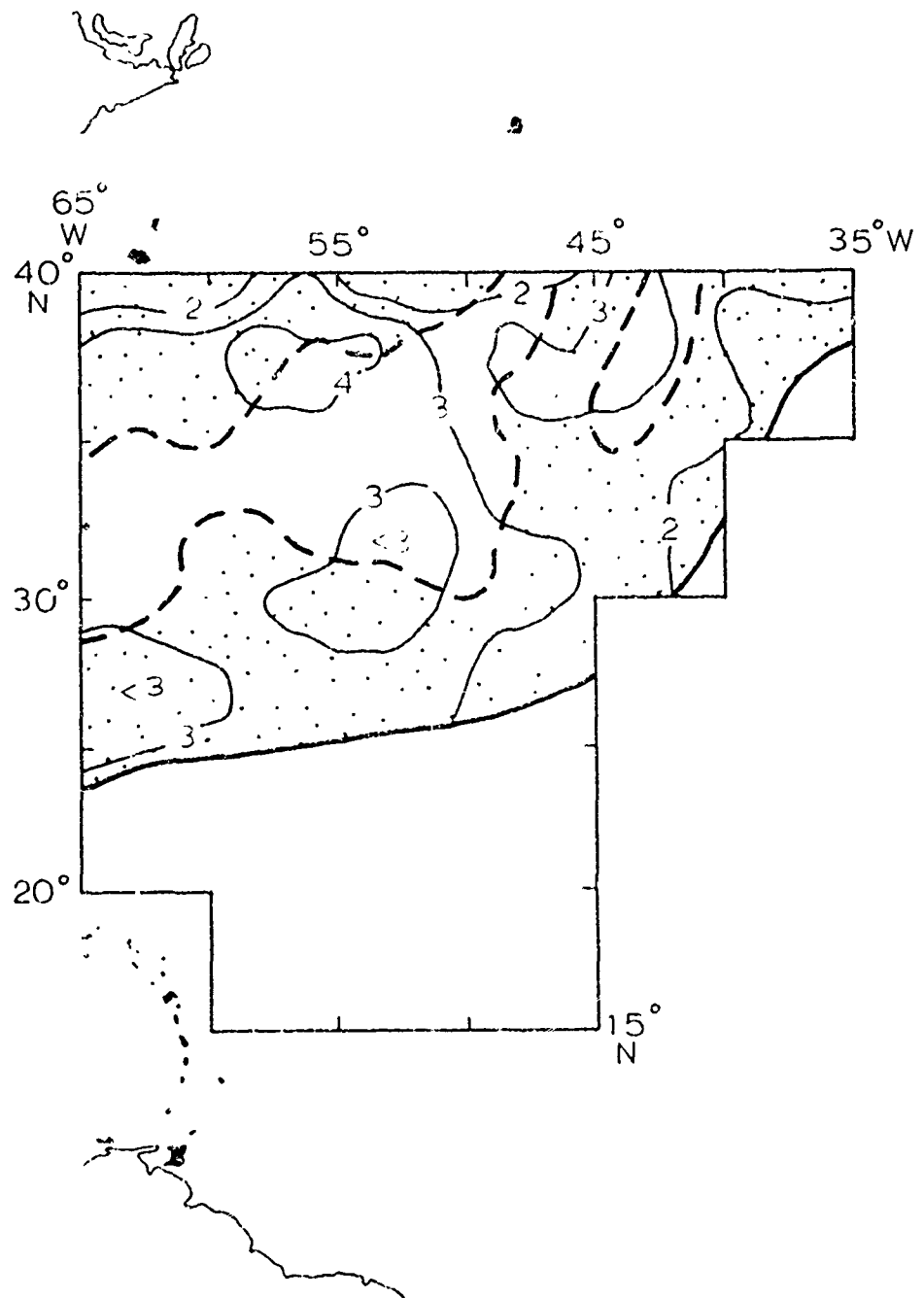
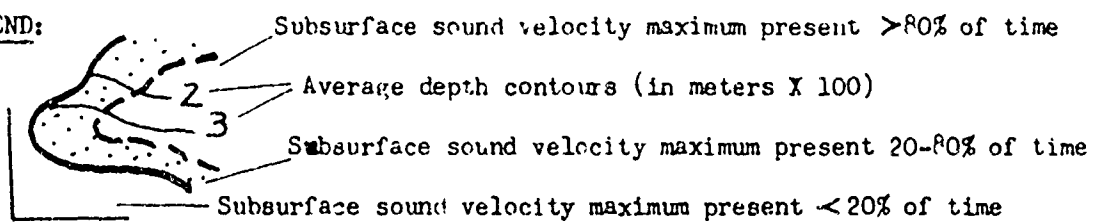
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FIGURE III-11: ANNUAL AREAL EXTENT AND AVERAGE AXIAL DEPTH OF SUBSURFACE SOUND VELOCITY MAXIMUM

UNCLASSIFIED

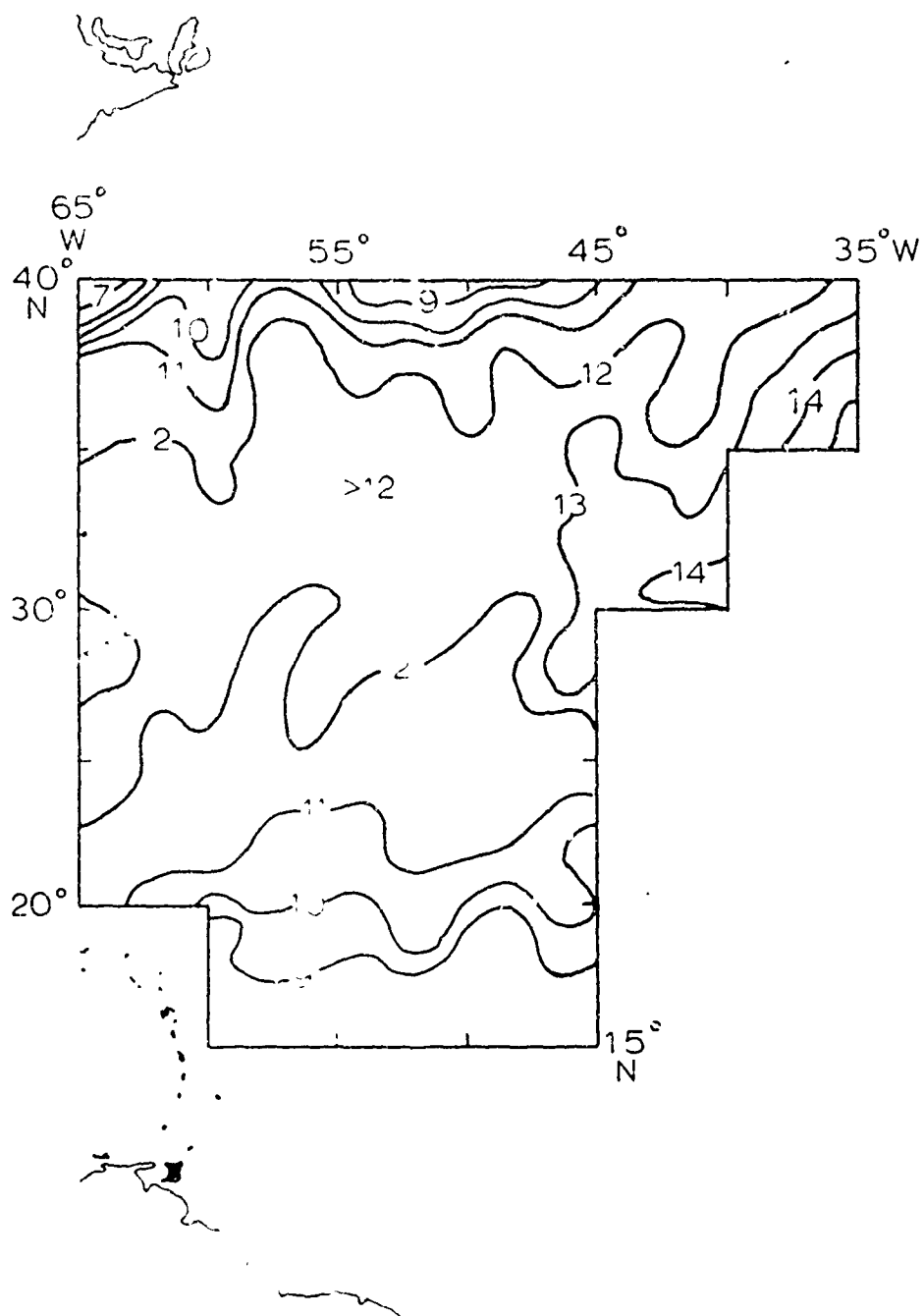


FIGURE III-12: ANNUAL AVERAGE DEPTH OF DEEP SOUND CHANNEL AXIS
(in meters X 100)

UNCLASSIFIED

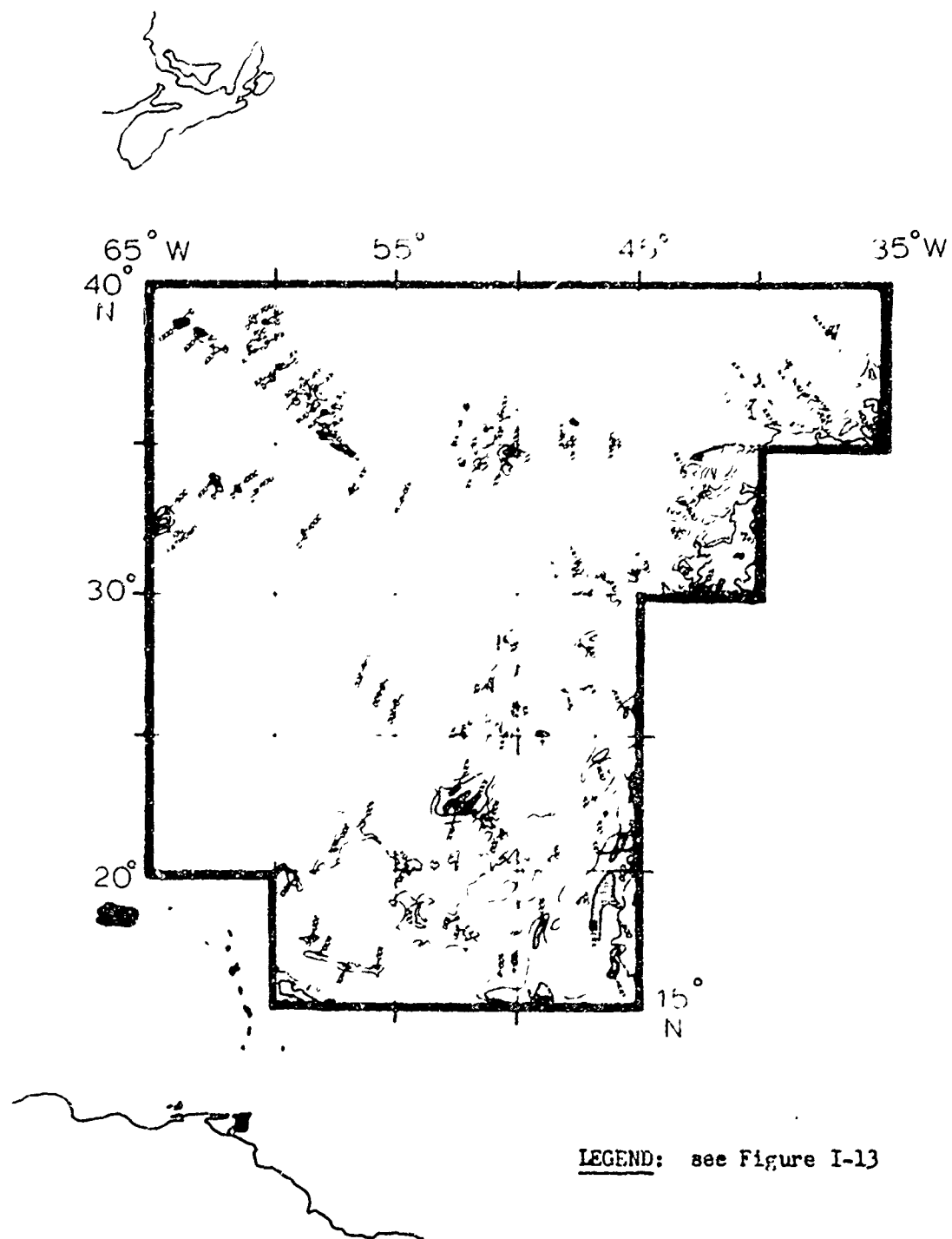


FIGURE III-13: BATHYMETRY SHOALER THAN AVERAGE CRITICAL DEPTH
FOR WINTER (Nov-Apr)
(Contour interval = 500 fathoms)

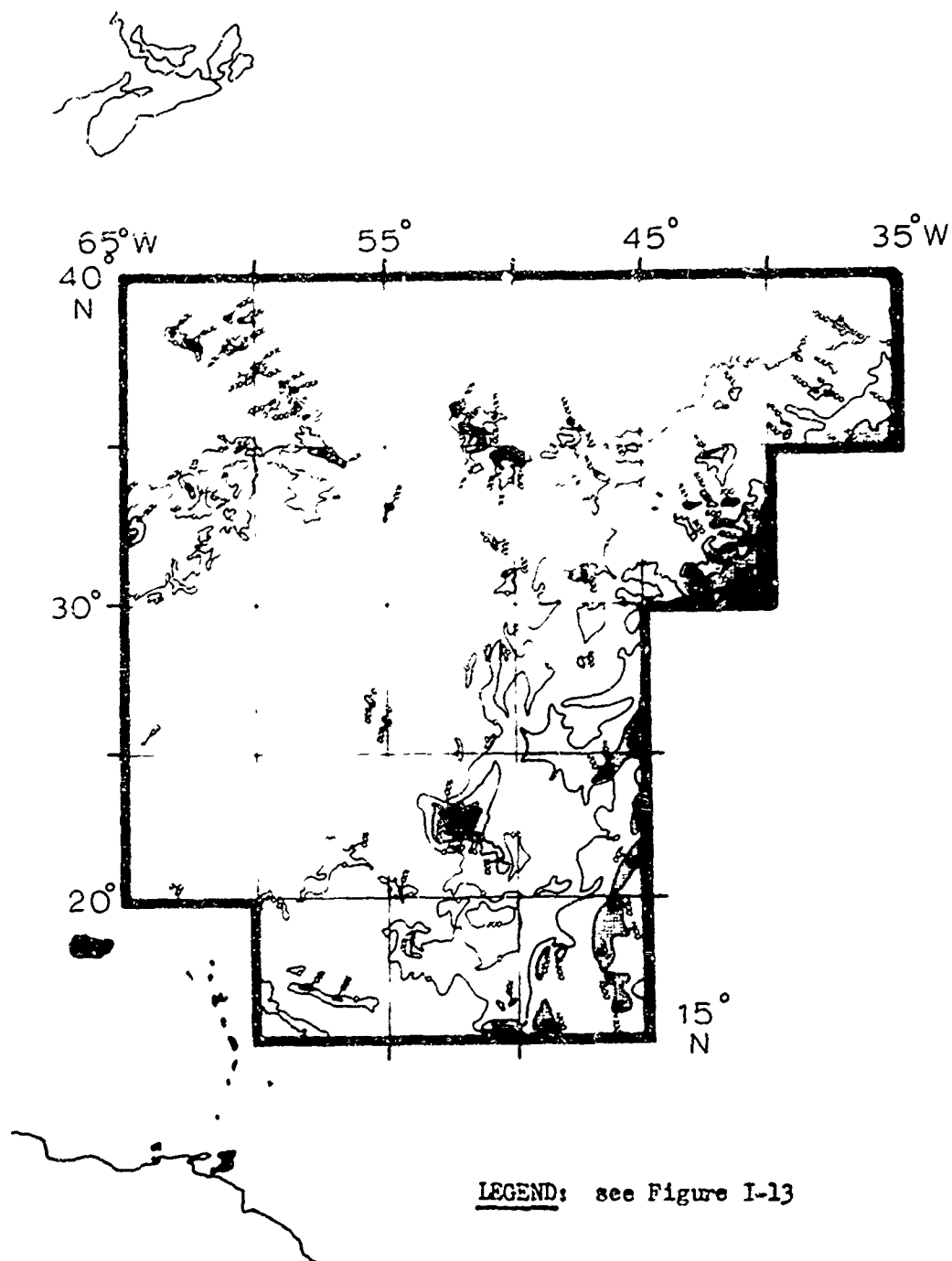
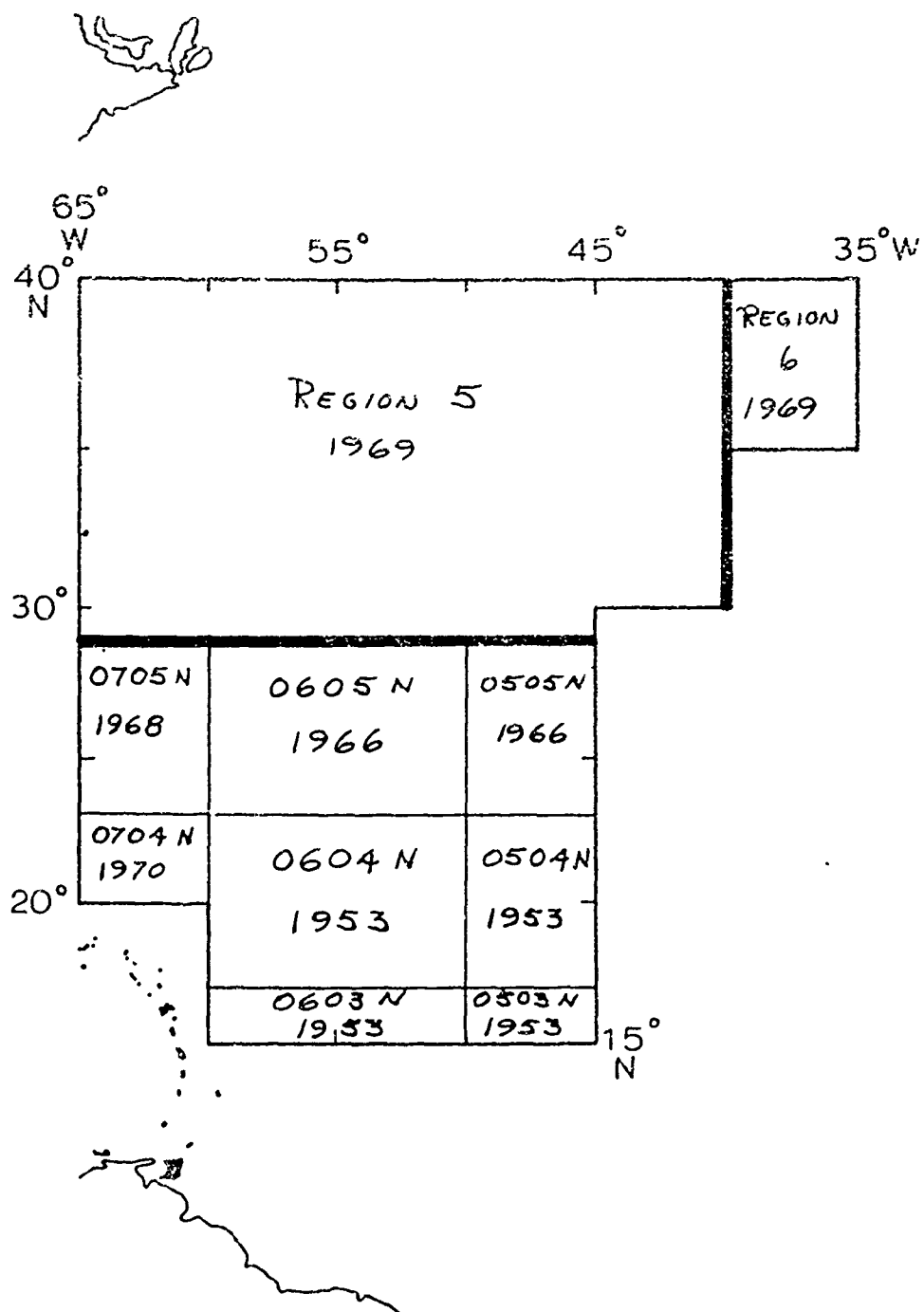


FIGURE III-14: BATHYMETRY SHOALER THAN AVERAGE CRITICAL DEPTH
FOR SUMMER (May-Nov)
(Contour interval = 500 fathoms)

LEGEND:

 Boundary of NAVOCEANO North Atlantic Regional Chart

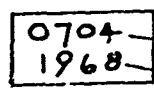
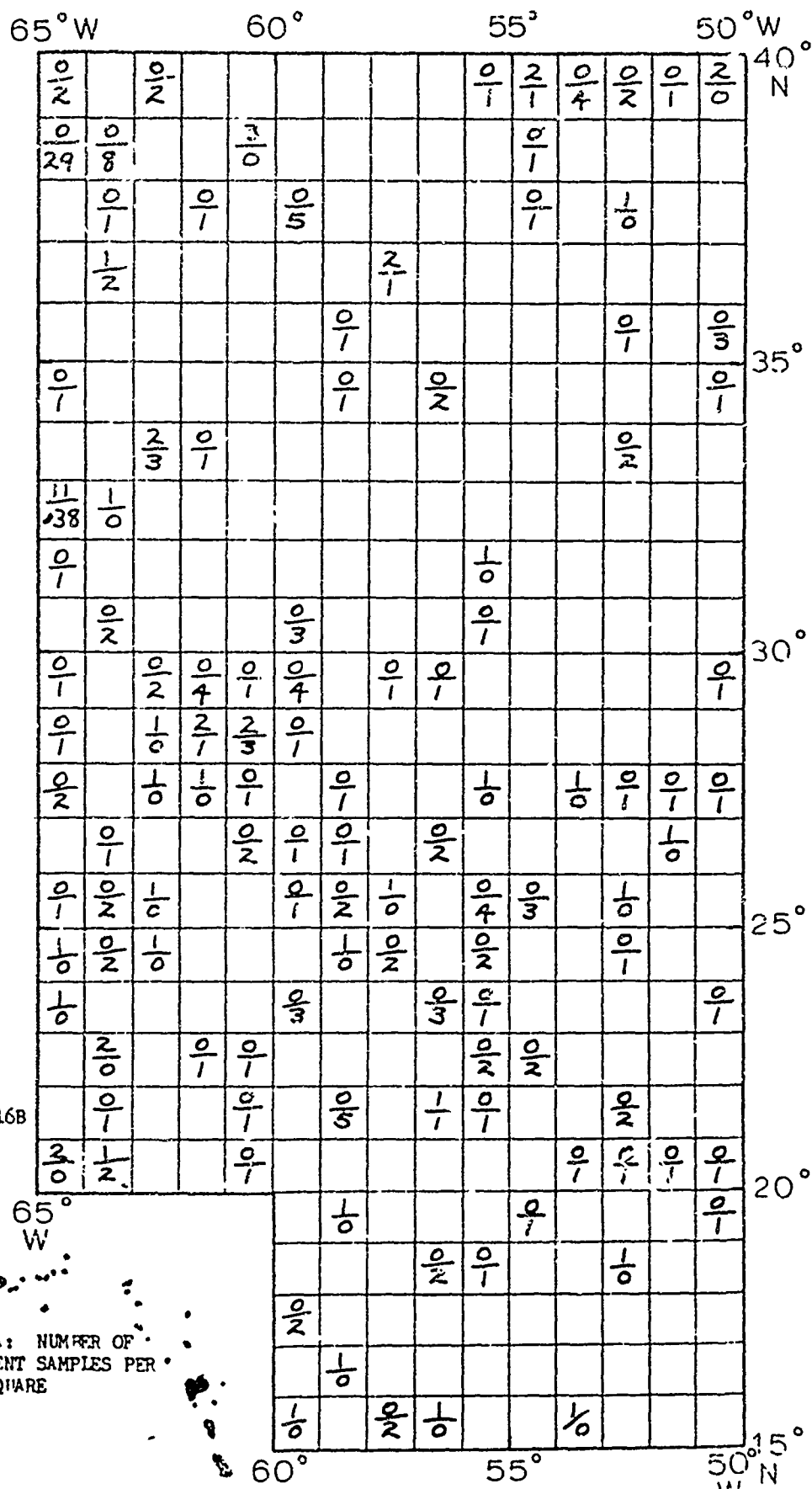
 NAVOCEANO BC Chart
 Chart number
 Compilation date

FIGURE III-15: INDEX OF BEST EXISTING BATHYMETRIC CHARTS

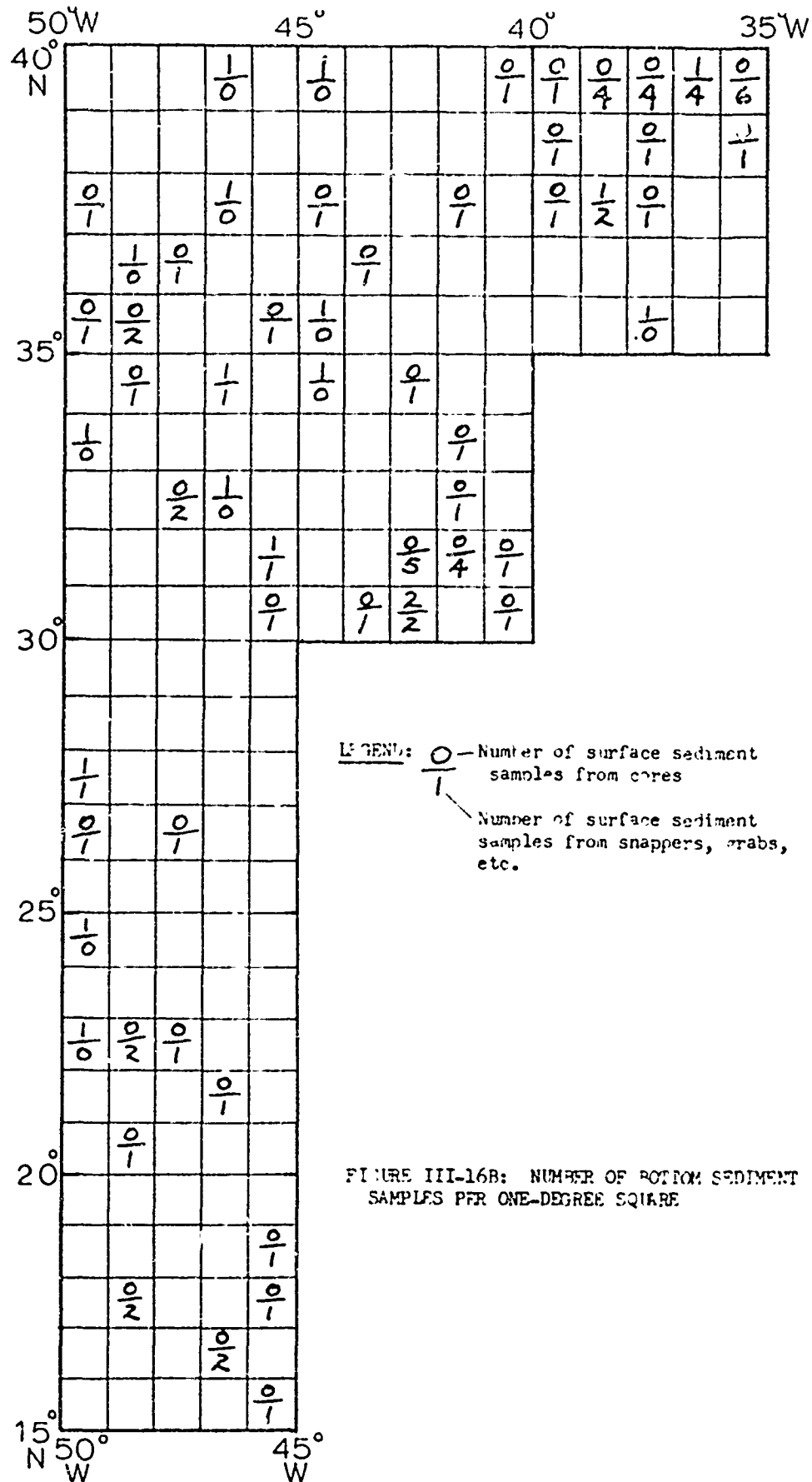
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LEGEND: see
Figure III-16B

FIGURE III-16A: NUMBER OF
BOTTOM SEDIMENT SAMPLES PER
ONE-DEGREE SQUARE

UNCLASSIFIED



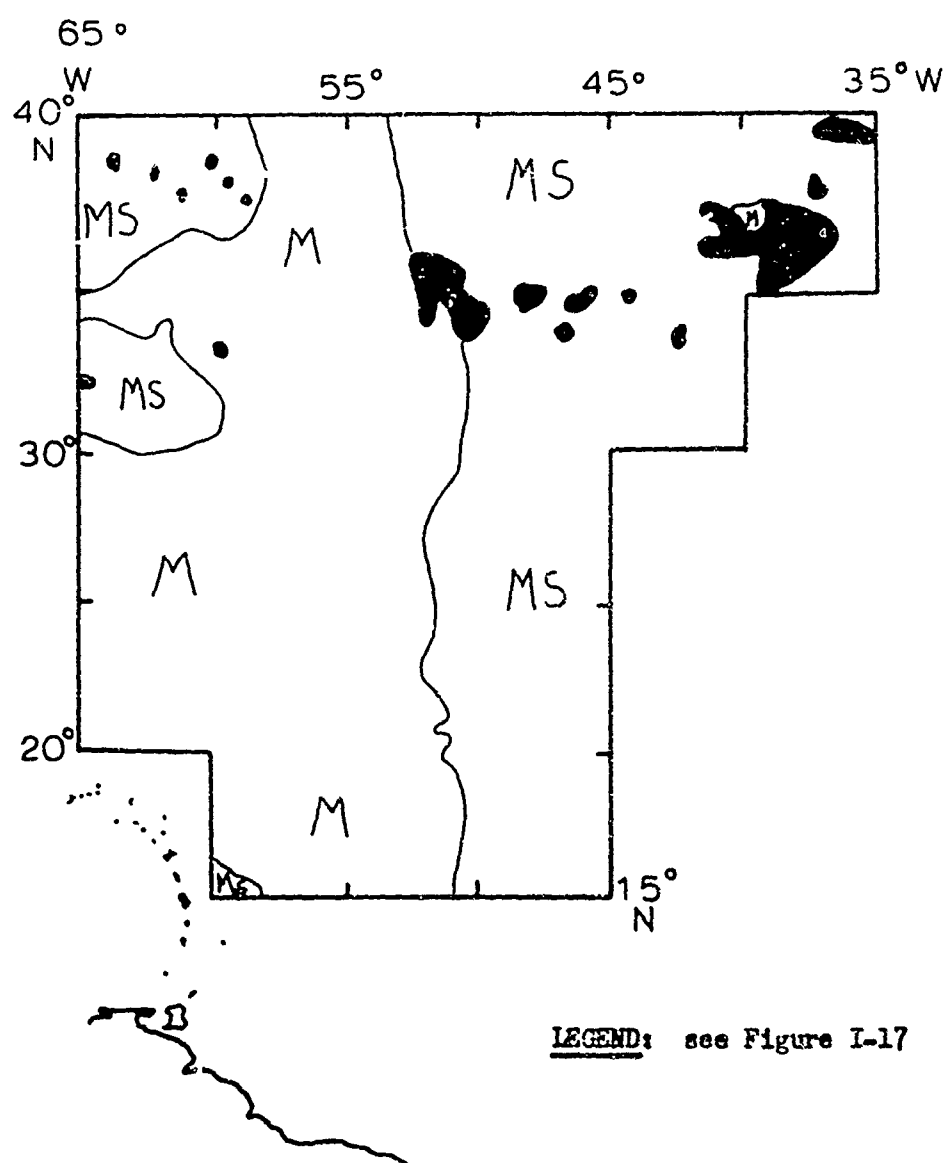


FIGURE III-17: DISTRIBUTION OF SURFICIAL BOTTOM SEDIMENTS

UNCLASSIFIED

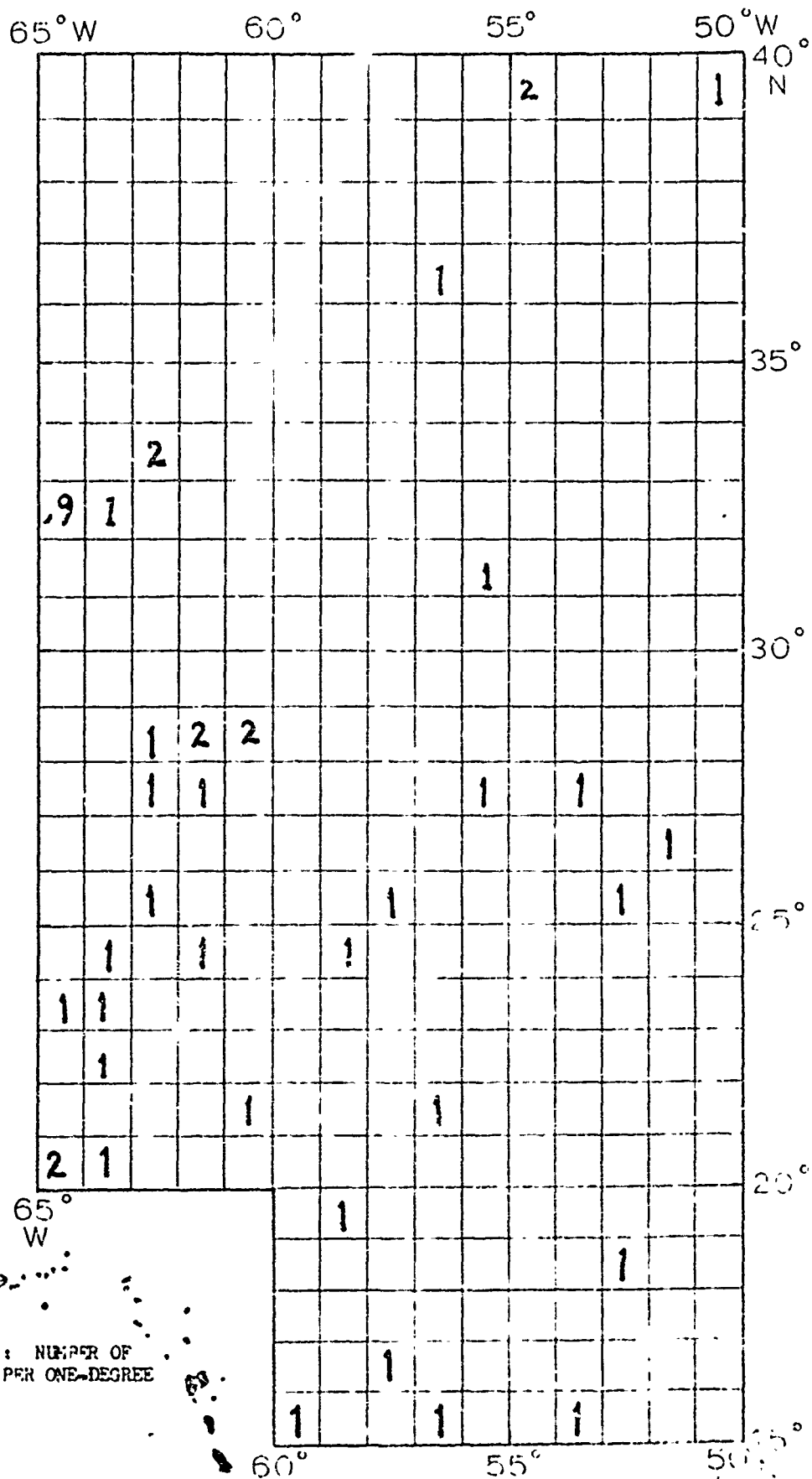


FIGURE III-18A: NUMBER OF
BOTTOM CORES PER ONE-DEGREE
SQUARE

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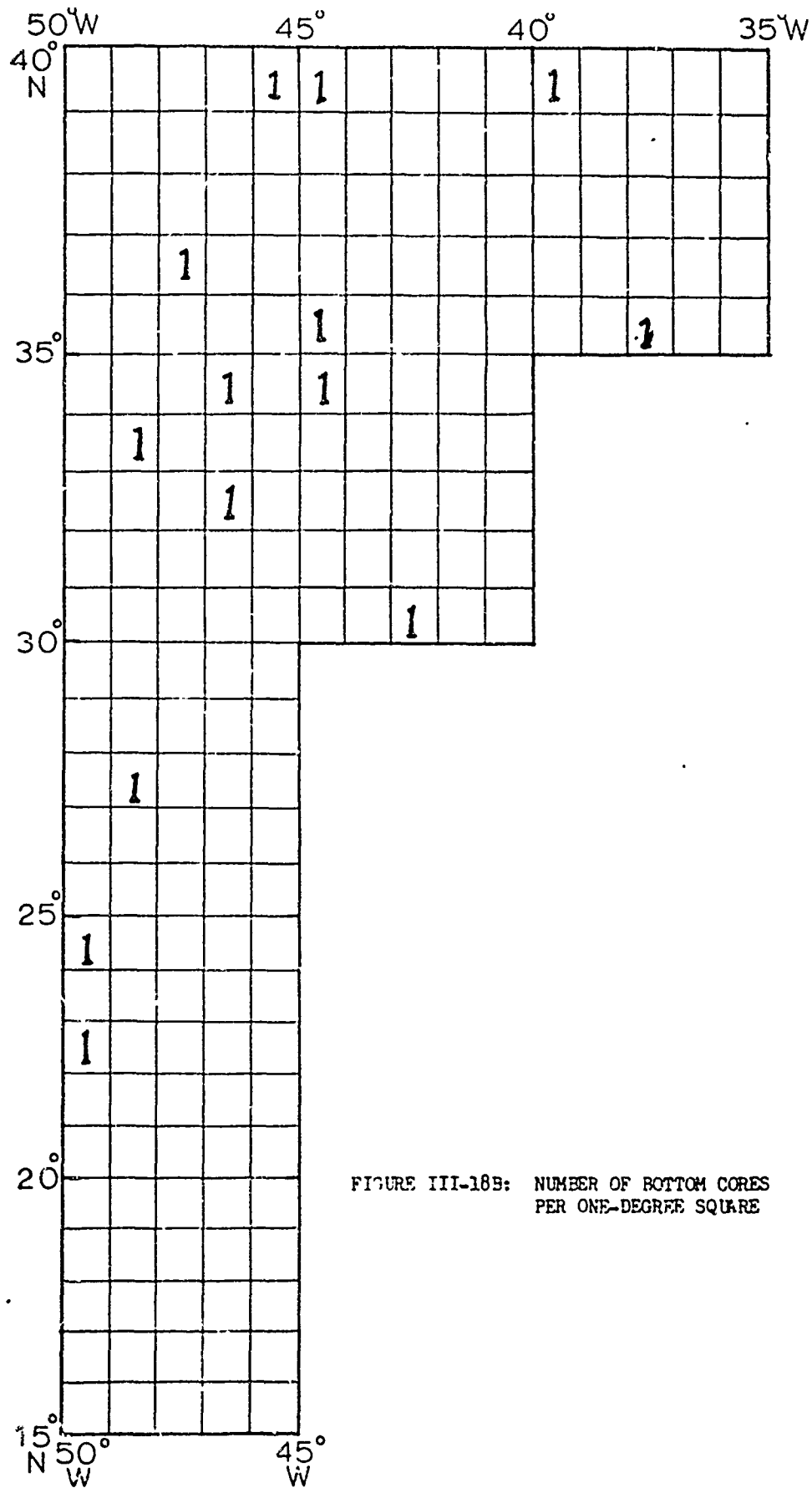
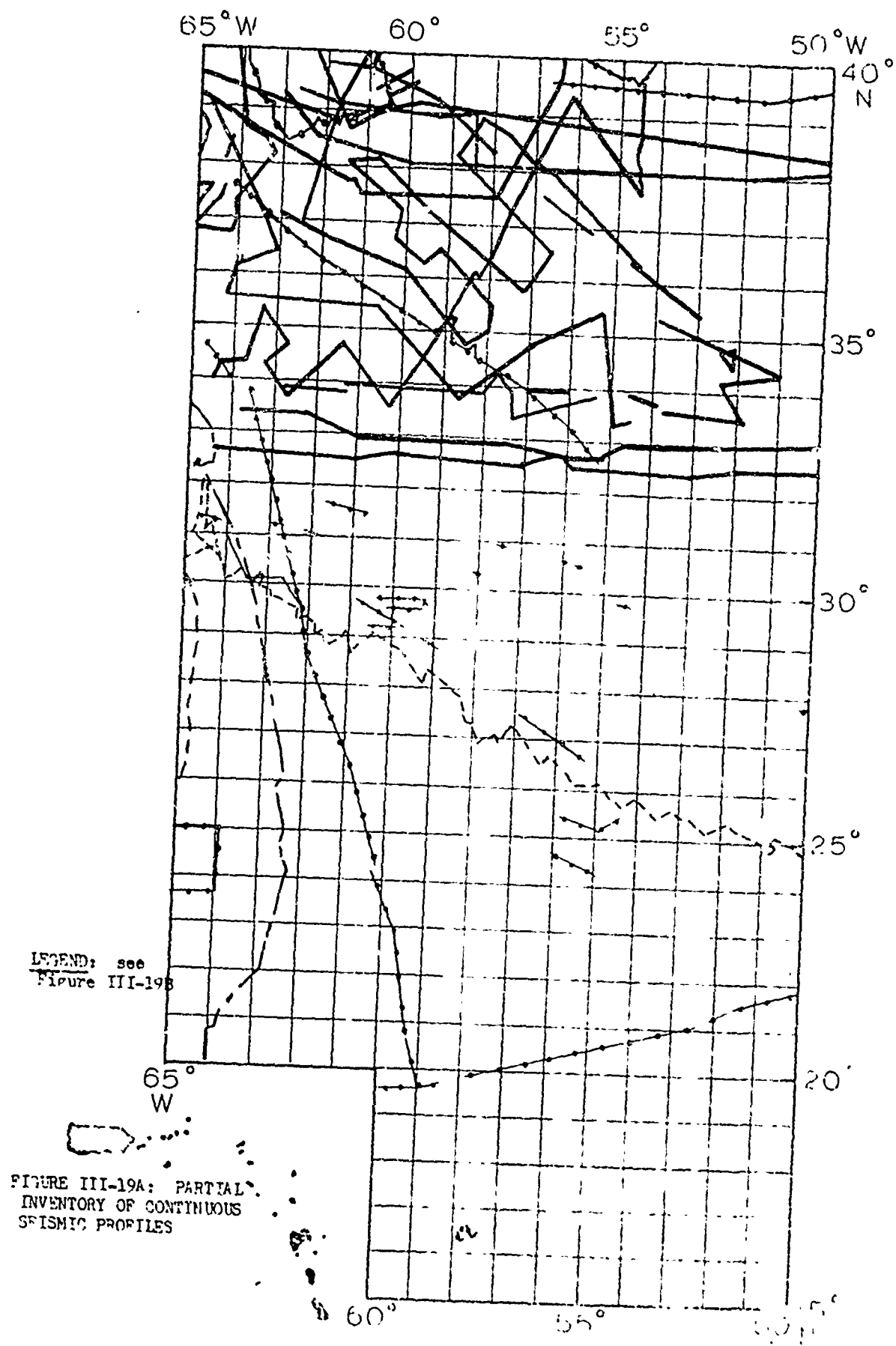


FIGURE III-18B: NUMBER OF BOTTOM CORES
PER ONE-DEGREE SQUARE

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UNCLASSIFIED



UNCLASSIFIED

UNCLASSIFIED

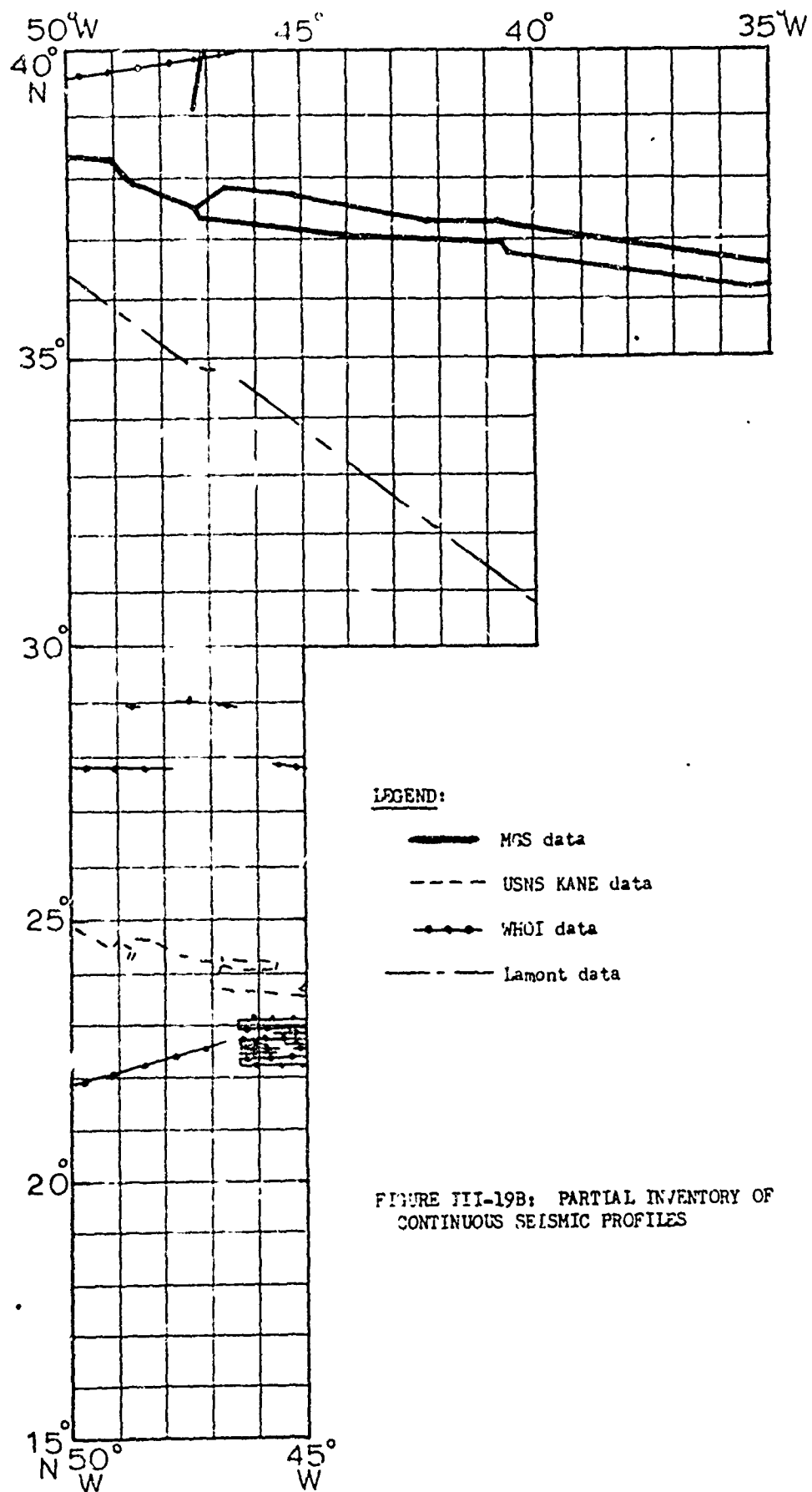


FIGURE III-19B: PARTIAL INVENTORY OF
CONTINUOUS SEISMIC PROFILES

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- , Apr 1970, Oceanographic cruise summary. Baffin Bay - Davis Strait - Labrador Sea, October 1969: U. S. Naval Oceanographic Office no. 70-16.
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- , 1969b, Grand Banks to the Azores and Scotian Shelf - April 12 to May 5, 1966: 1969 Data Record Series, Rept. no. 2, CODC Reference 10-66-002.
- , 1969c, East Greenland, Denmark Strait, and Irminger Sea - January 16 to April 5, 1967: 1969 Data Record Series, Rept. no. 4, CODC Reference no. 10-67-001.
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- LaCasce, E. O., Jr., Wooding, C. M., and Beckerle, J. C., Jun 1969, Sound velocity characteristics in the Sargasso Sea based on observations on cruise 89 of the R/V CHAIN: Woods Hole Oceanographic Inst. Reference no. 69-38 (unpublished manuscript).

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Lowrie, A. and Escowitz, E., editors, 1969, KANE 9: Global Ocean Floor Analysis and Research Data Series, v. 1, U. S. Naval Oceanographic Office Publication, U. S. Govt. Printing Office, Washington, D. C.

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13. ABSTRACT (U) Inventories and summaries of sound velocity, bathymetry, and bottom characteristics have been compiled for three areas in the North Atlantic Ocean between 15° and 65° N latitude and east of 50° to 65° W longitude. The following information is contained in this report: seasonal inventories of sound velocity profiles extending deeper than deep axial depth, charts of the seasonal extent and average axial depth of the upper sound channel, charts of the annual "strength" of the upper sound channel, charts of the annual extent and average depth of the subsurface sound velocity maximum, annual contour charts of deep axial depth, charts showing bathymetry shoaler than critical depth for summer and winter, an index of the best available bathymetric contour charts, inventories of surficial bottom sediment samples, charts of surficial bottom sediment analysis by grain size classes, an inventory of bottom cores, and a partial inventory of continuous seismic profiles. In addition, a brief analysis is given of water masses that effect sound velocity structures.			

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