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**SQUARE DEAL EXPLOSIVE SOURCE (SUS)  
PROPAGATION MEASUREMENTS (U)**

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19 July 1976

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- (U) Below are listed some of the persons and organizations who contributed to the acquisition and analysis of the data reported here. The planning and execution of the overall exercise involved a far larger group who are mentioned in Refs. 1-4.

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### ACODAC and ANB Operations

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### MABS II Operations and Signal Processing

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### SURVEY Array Operations and Signal Processing

Western Electric Company

### SUS Deployment

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USNS KINGSPORT (T-AG 164)  
RFA OLMEDA (A 124)

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## I. INTRODUCTION

### 1. Background

#### a. SQUARE DEAL

(U) The SQUARE DEAL Exercise was conducted 15 July to 15 September 1973. Involved were research vessels, plus aircraft, for acoustic source deployment and surveillance of surface shipping. The exercise area, and the separate Phases, I, II, and III, of the exercise are indicated in fig. I-1. More detailed maps are provided in the following chapters dealing with individual phases. The exercise was devoted to acquiring environmental, ambient noise, and acoustic propagation information. The acoustic sources for the propagation measurements included explosives (SUS and SCARF charges), PAR guns, and towed cw sources. This report deals with the acoustic propagation from the explosive SUS charges.

(U) The SUS data were acquired at approximately 12 receiver locations; some locations were occupied at two separate times. There were approximately 50 SUS source events in which the charges were deployed from ships or aircraft. These source tracks were along great circle arcs of lengths from 100 nm to 2000 nm. The source spacings ranged from 0.25 nm for only two short runs to approximately 5.0 nm for aircraft runs; on the major ship tracks, sources at both 91 m and 18 m depth were spaced 1.0 nm apart. For each source explosion, receivers at 2 to 6 locations recorded the resulting signal. Many of these recordings have been analyzed to determine the propagation loss in frequency bands, and it is these analyses which are reported here. Most of the recordings are available for additional determinations of propagation loss and for more detailed research on different features of propagation in the area.

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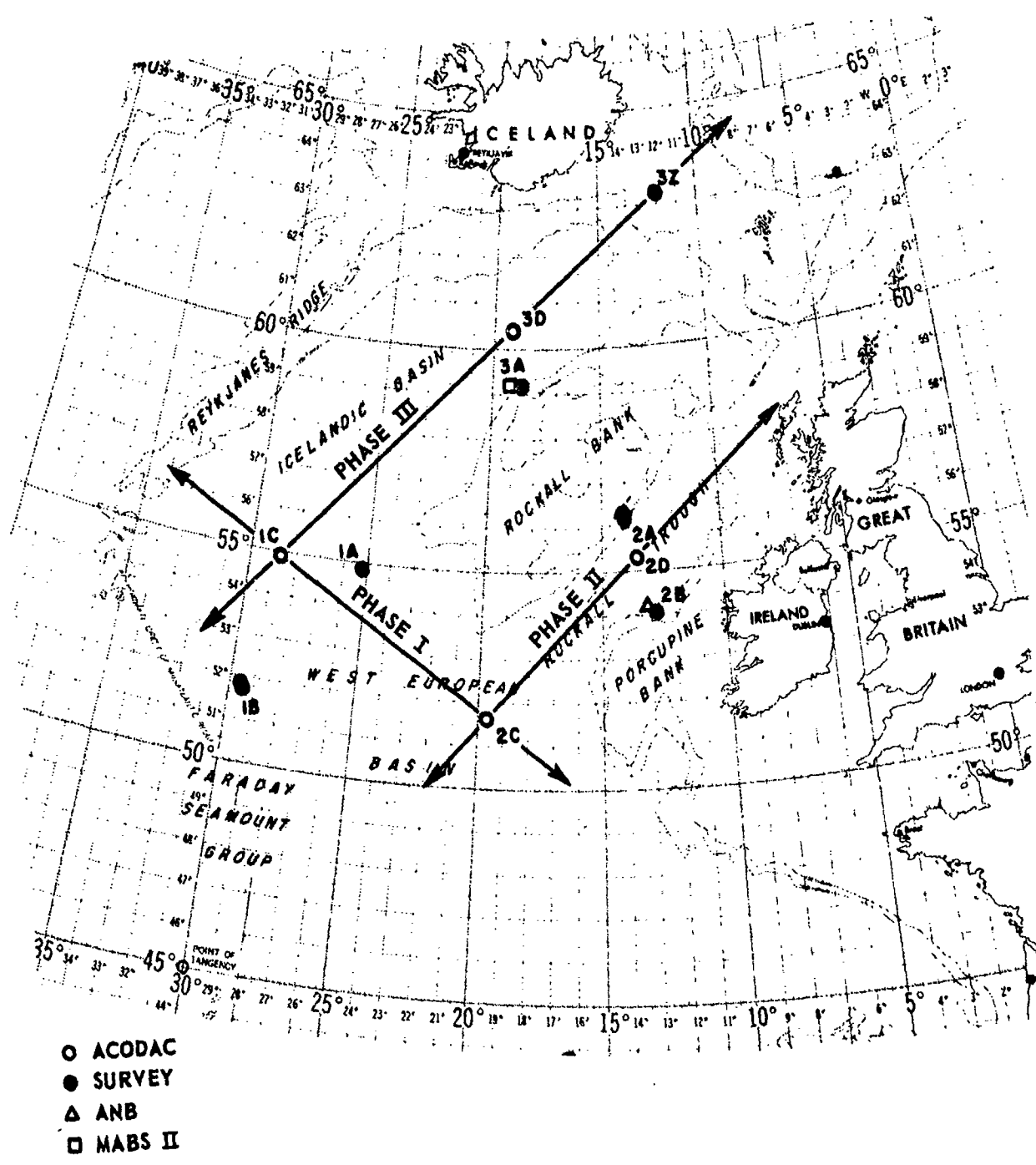


FIGURE I-1  
SQUARE DEAL EXERCISE AREA AND RECORDING SITES (U)

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AS-76-942  
SKM - DR  
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(U) In accordance with the data analysis planning, propagation loss measurements from the SUS recordings have been forwarded to users. This reporting was in the form of computer generated plots and/or digital computer tapes. The scale used most often on the plots was 100 nm/in. abscissa and 10 dB/in. ordinate. Because of the large number of plots which are in this report, the plots included here are reduced in size. The computer retrievable records of propagation loss measurements have been archived and are available to qualified users.

(U) This report has two primary purposes. First, this report provides a survey of the SUS propagation measurements. Second, this report analyzes those features of acoustic propagation in the SQUARE DEAL area that may be discerned from the SUS data and relates these features where possible to known environmental factors. In regard to the first goal, the data presented here do not exhaust the pool of available plots, but rather serve as a guide to the availability and characteristics of the data for particular receiver sites and source runs. In regard to the second goal, the best assessment of the acoustics of the area cannot be made from the SUS propagation loss measurements alone: there is very little SUS data within 100 to 200 nm of the receivers (see section I.1.c), and the SUS runs with a high density of shots were only along the axes of the three major troughs or basins. The information contained in the reports discussed below is needed to form a more complete picture of the area's acoustics.

## b. Related Reports

(U) Details of the planning, the objectives, and the participants in the exercise may be found in Ref. 1 (SQUARE DEAL Exercise Plan). A postexercise survey of the data actually acquired, and selection and scheduling for the analysis of some of the recordings is given in Refs. 2 and 3 (Data Analysis Plan). Details of the recording devices and the signal processing systems employed are found in Refs. 1 and 3. A summary of the exercise operation, and some preliminary environmental and acoustic data are given by Ref. 4 (Synopsis Report).



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- (U) A quality assessment effort was undertaken to verify the quality of the SUS processing; the results of this study are reported in Ref. 5 (Diagnostic Plan). There, it was determined that, with responsible care, the error introduced in the propagation loss measurement by the playback and analysis of the recorded signals is 1.0 dB or less. It should be noted that Ref. 4 mentioned an uncertainty at that time as to the reliability of the ACODAC processing. Reference 5 concluded that the ACODAC processing was of good quality. In addition to the quality assessment, Ref. 5 provided an analysis of the acoustical properties of the ocean bottom in the vicinity of SITES 1C and 1A (Fig. II-1 of the present report).
- (U) There are several reports dealing with specific aspects of the SQUARE DEAL exercise which were prepared by single organizations, but which had received inputs of processed data from several facilities; this report is one of that series. The cw propagation loss report, Ref. 6, should be read with the present report to obtain a more complete picture of acoustic propagation in the area. The environmental oceanographic measurements are reported and analyzed in Ref. 7, whereas the measurements of ambient noise and noise directionality are analyzed in Ref. 8. A study of the SQUARE DEAL area based on theoretical acoustic propagation models, and a comparison of the models with measured data, is given in Ref. 9. Reference 10 is one report of the British activity during SQUARE DEAL.
- (U) An acoustic survey of the SQUARE DEAL area, based upon contributions from the organizations which analyzed the individual aspects of the environment, the acoustic measurements, and the modeling, is provided by Ref. 11 (Environmental Acoustic Summary).
- (U) The question of the determination of the best source levels to use for the SUS sources arose during the analysis of SQUARE DEAL data. As noted in the following subsection, two sets of source level estimates were used to reduce the data reported in the current report. Reference 12 surveys the problem, which came into focus when a comparatively recently acquired set of measurements of source levels differed significantly from previous

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(U) estimates. However, as reported in Ref. 13, this disparity has in large part been explained (as far as most of the frequencies considered in the present report are concerned) by the discovery of a 3 dB error in the more recent measurements.

## c. Sources, Receivers, Data Processing

(U) During each of the three phases of the SQUARE DEAL exercise, propagation loss to various receivers from 1.8 lb SUS explosive sources was measured. The two source depths used are 18 m and 91 m (nominal depth of detonation). These sources were deployed from a ship traveling on a primary source track along the main axis of a trough or basin; additional SUS deployment tracks, radial to one of the receiver sites, were flown by aircraft during each phase.

(U) Receivers included acoustic data capsules (ACODAC), SURVEY arrays, ambient noise buoys (ANB), and moored acoustic buoy systems (MABS II); specifications for these systems are given in Ref. 3. The location of individual receivers and source tracks are described separately for each phase of the exercise in the respective chapters, and shown in Figs. II-1, III-1, and IV-1. Fig. I-1 shows the locations on a large scale map. The ACODAC receivers were located in the center of troughs or basins, on the primary (ship) source track, with at least 400 m of depth excess at the site (though some hydrophones were below the critical depth). Most of the SURVEY, ANB, and MABS sites were atop or on the slopes of ridges or banks surrounding the troughs and basins, but were usually within 20 nm of the open water where there was depth excess.

(U) The signal processing of the SUS propagation loss data reported here was performed by several organizations. As a minor, though visible, consequence, there are several plotting formats for the propagation loss data in this report. More detailed descriptions of the data signal processing are found in Ref. 3 (Vol. II, Data Analysis Plan). Some features of the different systems are given below. Except for the SURVEY

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- (U) data processed on board the receiving ships, all processing was done in a laboratory using magnetic tape recordings.
- (U) The ACODAC data were processed at the Applied Research Laboratories of The University of Texas at Austin (ARL). The ARL system employs digital conversion of the ACODAC recordings (300 Hz bandwidth), followed by computerized techniques for detection and spectral analysis of the shot signals. The length of the transformed (FFT) signal segment was up to 6.83 sec; the actual shot length was determined by a computer algorithm. If shot lengths exceeded 6.83 sec, successive spectra were accumulated. The amount of energy in frequency bands was determined by summing the power spectra over suitable windows.
- (U) Propagation loss for the ACODAC data was determined in one octave bands at 12.5, 25, and 50 Hz and in one-third octave bands at 12.5, 25, 50, 100, 158, 200, and 250 Hz. The 12.5 Hz band data are of questionable value because of calibration and system bandwidth problems. However, the measurements in all of the above bands are archived. In accordance with the data analysis plan (Ref. 2), plots of propagation loss at 25 Hz (one octave), 50 Hz (one octave), and 158 Hz were prepared and forwarded to users. From that body of plots the data presented in the current report was selected.
- (U) The source levels of the SUS sources which were used to reduce the ACODAC data are those determined by Gaspin and Shuler (Ref. 14); these levels are given here in Table I-1. A discussion of these source levels is given in Refs. 12 and 13, which were mentioned in section I.1.b, above. The source levels of Table I-1 were used to process the ANB and MABS II data also.
- (U) The ANB data were processed at Naval Research Laboratory, Washington, D.C. (NRL). The NRL system employs digital conversion of the ANB recordings, followed by FFT conversion of the signal in 1.0 sec blocks. Upon detection, successive spectrum blocks (the number depending upon signal duration) are accumulated. The ANB data were reduced to propagation loss

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(U)

TABLE I-1

SUS SOURCE LEVELS FOR ACODAC, ANB, AND MABS II PROCESSING

Frequency	18 m SUS	91 m SUS
<u>One-Third Octave Bands</u>		
25 Hz	60.0 dB	60.7 dB
50	54.9	55.7
100	53.7	53.3
160	50.3	51.5
250	48.6	49.1
<u>One Octave Bands</u>		
25 Hz	58.6 dB	59.9 dB
50	55.8	55.6

Levels are dB//1 erg/cm<sup>2</sup>/Hz at 1 ya. (Ref. 14)

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- (U) in one octave bands at 25 and 50 Hz, and one-third octave bands at 100, 160, and 256 Hz. The source levels used for the processing are given in Table I-1.
- (U) The MABS II data were processed by the Naval Underwater Systems Center, New London, Connecticut (NUSC). In this system, the MABS II recordings were reproduced into a bank of analog filters which performed the spectral analysis function; the outputs of the filters were then converted to digital form and the signal energy was determined. The MABS II data were reduced to propagation loss in one octave bands at 25 Hz and 50 Hz and in one-third octave bands at 160 Hz. The source levels used are given in Table I-1.
- (U) Most of the SURVEY data were processed on board the receiving platforms by Western Electric Company, Winston-Salem, North Carolina (WECO); this system operated on-line, as the signals were received. In the WECO system, the signal is played through an analog filter bank, then through analog squaring and integrating circuitry. The outputs of the integrations are recorded on moving-pen strip chart recorders and are also monitored by an onboard computer which measures the signal energy in each analysis band. Some of the SURVEY data were subsequently reprocessed (from analog recordings) and/or reformatted at NRL.
- (U) The frequency bands and the source levels used to analyze the SURVEY data differ from those used for the other systems. On board USNS ALBERT J. MYER (T-ARC 6) the analysis was in one-quarter octave bands at 50, 100, and 141 Hz. On board USNS NEPTUNE (T-ARC 2) the analysis was in one-quarter octave bands at either the same three frequencies, or at 50, 141, and 300 Hz.
- (U) Source levels which were used to reduce the SURVEY array data to propagation loss are given by Table I-2, which is from Table V-4 of Ref. 4. As may be seen, the levels in Table I-2 are lower than those of Table I-1. However, the SURVEY propagation loss plots were made at sea and, except

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(U)

TABLE I-2  
SUS SOURCE LEVELS FOR SURVEY PROCESSING

Frequency	18 m SUS	91 m SUS
<u>One-Third Octave Bands</u>		
50 Hz	53.0 dB	52.1 dB
100	50.2	49.4
200	48.8	48.2

(Table V-4 of Ref. 4)

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(U) for the data from Site 3Z, have not been replotted. On the plots of SURVEY data, a correction factor for the propagation loss is indicated. These factors are given in Table I-3; they equal the difference between the standard levels used for SQUARE DEAL (Ref. 14) and the levels used for the SURVEY propagation loss plots (Refs. 4, 12, 13).

(U) During the period in which the signal processing was performed, an effort was initiated to verify the accuracy of, and the intercomparability of, the laboratory processing systems at ARL, NRL, NUSC, WHOI, and WECCO. A principal component of this work was the processing of the same tape recorded signals at the different facilities. The results of that effort are reported in Ref. 5. In general, the intercomparison showed that the propagation loss measured for tape recorded shots at the different facilities varied by  $\pm 1.0$  dB or less on a shot-by-shot basis.

(U) The problem of system overloading was particularly severe on the ACODAC data; to a lesser extent, overloading was a problem in the ANB data. The overloading occurs when the peak level of the incoming signals exceeds the dynamic range of the tape recorder; in the ACODACs, this condition caused the data signal to be momentarily switched off and error tones to be recorded for 1 sec. Overloads obscured most of the ACODAC data out to a range of 150 to 200 nm, and the ANB data out to approximately 100 nm to 200 nm. The problem was more frequent for the 91 m shots than for the 18 m shots. As explained below, detected shots which cause overloads are indicated by a special symbol on plots of propagation loss. A consequence of the overloading problem is that there is no propagation loss data from the ANB or ACODAC systems except from ranges 100 nm or more from the systems.

## 2. Report Outline

(U) Following this introduction, the three principal phases of the exercise are discussed in separate chapters (II, III, IV). For each phase, an area description and details of the exercise such as receiver locations and source tracks are described first. Then the propagation features observed

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(U)

TABLE I-3

VALUES TO ADD TO SURVEY PROPAGATION LOSS PLOTS  
FOR CONFORMITY TO STANDARD SOURCE LEVELS (Ref. 14)

Frequency	18 m SUS	91 m SUS
50 Hz	+2 dB	+4 dB (a)
100	+4	+4 (a)
141	+3	+3 (b)
300	+3	+3 (b)

(a) difference between values from Tables I-1 and I-2.

(b) estimate based upon Ref. 13.



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- (U) for the principal (chip) source track are described for each receiver site and these observations are compared between sites. Observations based on other source runs are then described and further intercomparisons are made. Following the description of observations for the individual phases, intercomparisons between Phases I and II, and between Phases I and III are given in chapter V.
- (U) In section I.3, a summary description, based on information from all of the phases, is given for the propagation loss dependence on range, source depth, receiver depth, frequency, topography.

## 3. Summary of Propagation Effects

- (U) In the following chapters, attention is given to the dependence of propagation loss on range, bottom interaction, source depth, receiver depth, and frequency. Usually, these effects are interrelated. For one example, the difference between the loss from 18 m and 91 m shots at the same range is usually very frequency dependent. As another example, the dependencies of propagation upon source depth, receiver depth, and frequency may have one typical character for sources detonated in deep water where there is depth excess, but the dependencies change if the sources are deployed in a bottom limited situation.

### a. Range, General

- (U) In this report the term open channel, or deep sound channel, will refer to the situation where there is depth excess at the location of the source and everywhere between the source and receiver (for ACODACs) or almost to the receiver (for SURVEY, MABS, and ANB). As a general rule, approximately 400 m of depth excess is needed for good open channel propagation. The situation where the source is at a position such that there is depth deficiency, or where there is an interval of depth deficiency between the source and receiver, will be referred to as a bottom limited channel.

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- (C) Considering that most of the SQUARE DEAL area is in deep water, the open channel propagation is probably the most important propagation mode. In most of the area, the deep, or major, sound channel axis was at a depth of 800 m to 1200 m; also, a shallow sound channel at 100 m to 200 m was found over much of the area. In general, the propagation loss to receivers above critical depth in the open channel situation was characterized by cylindrical spreading. However, sometimes there was so much change in the sound velocity structure along the propagation path (for example, during Phase III in the Icelandic Basin) that the propagation loss was increased in one direction and decreased in the opposite.
- (C) One interesting feature of the SUS propagation loss measurements is that there usually is no strong convergence zone/shadow zone structure evident in the data. Individual propagation loss plots usually show data points to be within  $\pm 3$  dB of an average trend curve.

## b. Bottom Effects

- (U) For the most part, deviations from the general range dependence of propagation loss described above result from topographic effects.
- (C) When the propagation path is bottom limited at the source, two features are observed. First, the received signal is generally attenuated at a rate of 0.1 dB/nm to 0.5 dB/nm as the source ship crosses a ridge or shelf. The rate of attenuation depends upon the exact bathymetry and sound velocity structure as well as upon the other acoustic parameters. Second, when the sources are detonated over the crest of a ridge or rise, a local minimum of propagation loss to a distant receiver is observed. That is, within a range interval of perhaps 20 nm, propagation loss can be as much as 10 dB less than loss from sources at the same range in the absence of the bottom effects. This slope enhancement occurs because sound is reflected from the edge of the rise into the deep sound channel.

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## c. Source Depth

(C) For all phases and source events of SQUARE DEAL, the propagation loss from the 18 m deep sources was greater than the propagation loss from the 91 m sources, and the effect is frequency dependent. From the same range, signals from the 91 m sources are as much as 12 dB stronger than signals from the 18 m sources. Most of the source depth effects can be explained in terms of the Lloyd's Mirror effect, described below.

(U) There is a high bottom loss over most of the area, so that usually only one or two RR or RSR ray arrivals contribute to the received signals. This condition enables sharp "Lloyd's Mirror" or "pressure release" effects to occur. Interference between closely spaced ray pairs causes the received signal spectra to have a modulation of the form  $\sin(f/f_1)$ , where  $f$  is the received frequency and  $f_1$  is determined by the time delay between the ray pairs (Ref. 15). The exact value of  $f_1$  depends upon source depth, receiver depth, and the sound velocity structure. Nominal values for  $f_1$  are 25 Hz for the 91 m sources and 150 Hz for the 18 m sources. Because of the filtering used in processing (one octave at 25 Hz, the one-third octave at other frequencies) the effect upon propagation from the 91 m sources is not striking; however, the 18 m source data clearly show a minimum propagation loss at 158 Hz in most cases.

## d. Receiver Depth

(C) The sites with a variety of receiver depths were those with ACODAC, MABS II, or ANB receiving systems. There, most of the hydrophones are located within the major sound channel, below the upper sound channel axis and above, or within 100 m of, the critical depth, with exceptions of deeper hydrophones at Site 1C during Phase I and Site 2C during Phase II, and a shallow (165 m) receiver at Site 3AA during Phase III. Among the receivers in the sound channel, there was generally little difference in the observed propagation loss. Nominally, to a receiver near critical depth the propagation loss was no more than 3 dB less than the loss to a receiver

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(C) at the deep sound channel axis. Results from the few receivers below critical depth indicate that propagation loss increases rapidly below critical depth. In addition, the signal at these deep receivers seems to be most severely affected by topographic blockage or near-blockage (intervals of no, or very little, depth excess) between the source and receiver. The loss to the shallow receiver at Site 3AA was nominally 3 dB greater than the loss to receivers in the main sound channel. At each site, the same general dependence of propagation loss upon source depth and frequency is observed at all receiver depths.

## e. Frequency

(C) The nominal dependence of propagation loss in an open channel situation upon frequency is a function of source depth, as discussed above. From the 91 m sources, the losses at 25, 50, and 100 Hz are usually within  $\pm 1$  dB of each other; the loss at 200 Hz is approximately 3 dB greater than the loss at 100 Hz.

(C) From the 18 m sources, two types of frequency dependence are observed. When the arrivals contain little bottom reflected energy (because of high bottom loss), the Lloyd's Mirror effect discussed above is dominant, and the greatest loss is at 25 Hz and the minimum loss at 158 Hz may be as much as 10 dB less. When significant bottom reflected energy is present, the Lloyd's Mirror effect is not dominant; this occurs at short (less than 100 nm) ranges and in areas of highly reflecting bottoms. In that case, the loss from the 18 m shots is either frequency independent or increases with frequency.

## 4. Presentation Formats

(U) In the analysis of propagation to individual sites, several types of data displays are used. First, plots of propagation loss versus range for particular source depths and frequency bands to individual hydrophones give an overall view of propagation to each site (for example, Fig. II-3). For

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(U) these figures, the receiver is at zero range; sources generally south or west of the receiver are at negative ranges, and sources north or east of the receiver are at positive range. Each data point is coded in the following manner to provide a measure of the measurement quality and/or measurement problems:

- ×  $S/N > + 3$  dB
- +  $+ 3$  dB  $> S/N > 0$  dB
- $0$  dB  $> S/N > - 3$  dB
- △  $- 3$  dB  $> S/N$
- Overload

The triangle symbol is plotted along the base of the plot to indicate that a shot was detected at that range, but the signal in the frequency band was very weak. The "○" symbol is plotted along the top of the plot to indicate that a shot which overloaded the recording system was detected at that range. At short ranges, where all data was overloaded, the data was often not processed and no symbol will appear.

(U) A second display is that of range averaged propagation loss versus frequency, such as Fig. II-5. This type of display provides a useful summary of the frequency, receiver depth, and source depth dependence of propagation loss in an area. As much as possible, the range intervals over which the averages were made were chosen so that the mean trend of the data changed little over the interval.

(U) Finally, shot-by-shot differences between the loss at the same frequency to different receivers, or between the loss at different frequencies to the same hydrophone, are plotted versus range as in Figs. II-6 and II-7. These displays serve to show the distribution of frequency and depth dependence.

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## II. PHASE I

### 1. Exercise and Area Description

- (U) Phase I of SQUARE DEAL was conducted 1-10 August 1973; the region, the location of the receiver, and the events analyzed here are shown in Fig. II-1. The region is the northwestern portion of the West European Basin, an area partially bounded on three sides by the mid-Atlantic Ridge (composed of the Reykjanes Ridge and the Faraday Seamount Group), the Rockall Bank, and the Porcupine Bank. Throughout this basin there is depth excess, but along the perimeter of the area there is depth deficiency.
- (U) The propagation data were recorded by ACODAC systems at Sites 1C and 2C, and SURVEY arrays at Sites 1A and 1B. Ten explosive source runs were made for propagation studies. USNS WILKES (T-AGS 33) made one SUS run, Event 2a, along the major axis of the basin. The remaining runs were flown by aircraft (see Fig. II-1).
- (U) The sound speed structure within this portion of the West European Basin cannot be described by a single representative sound speed profile; due to the influence of three major water flows, the sound speed profile varies throughout the basin. Figure II-2 illustrates the variation in the structure of the sound speed profiles along the major axis of the basin. Table II-1 gives depths of the hydrophones whose data was processed.
- ### 2. USNS WILKES Source Run, Event 2a
- (U) The major event during Phase I is the SUS run, Event 2a (Fig. II-1), made by USNS WILKES. Figure II-2 illustrates the variations in the sound speed profile and bathymetry along this track; there is depth excess for the entire run. Throughout the southern half of the run the sound speed

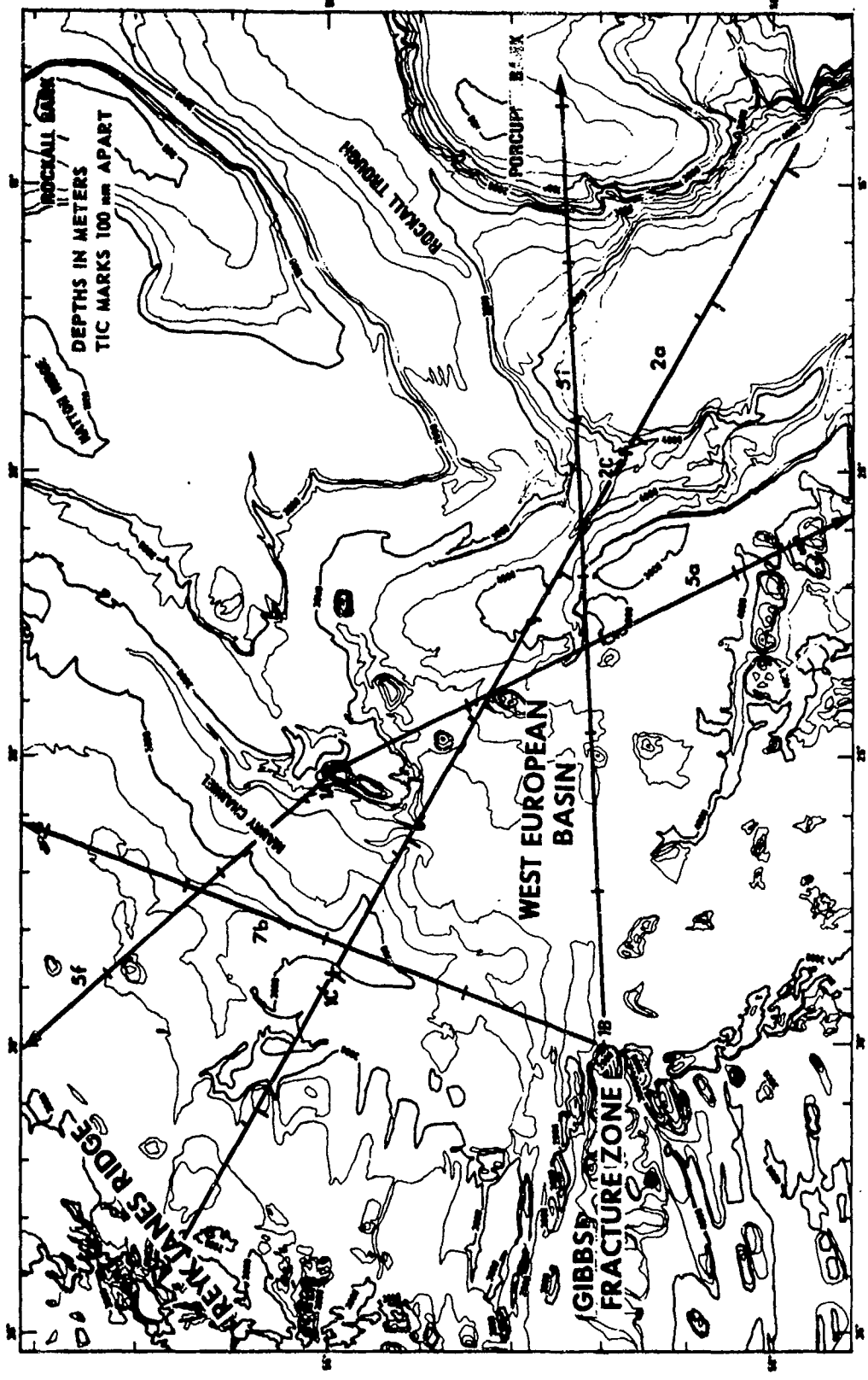


FIGURE II-1  
SUS EVENTS OF PHASE I (U)

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AS-76-598  
5KM · OR  
5 · 10 · 76

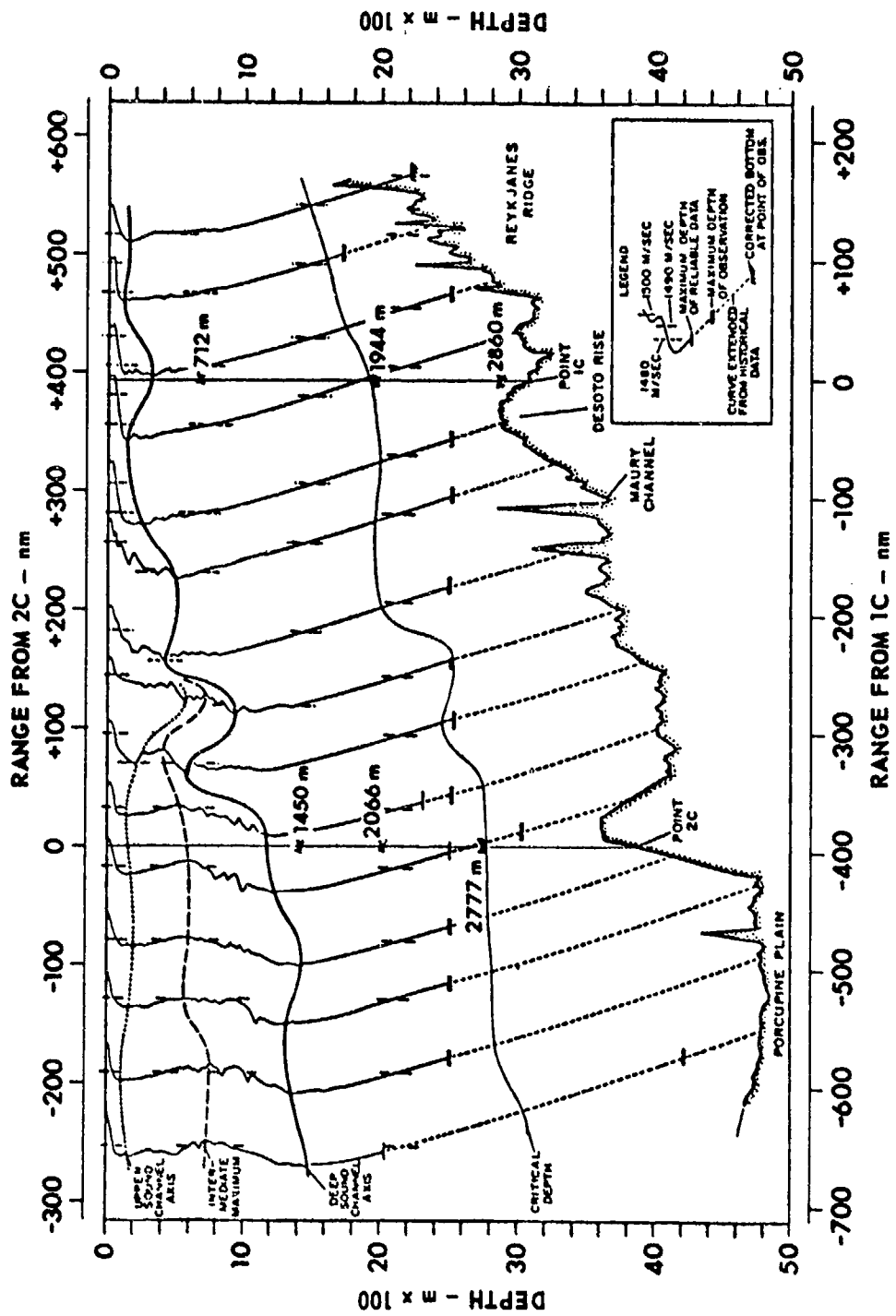


FIGURE II-2  
 SOUND VELOCITY STRUCTURE AND BATHYMETRY  
 IN ROCKALL TROUGH  
 Phase II - Track Along Event 14b

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 AS-76-680  
 SKM - DR  
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(c)

TABLE II-1

REFERENCE LOCATIONS FOR PHASE I (U)  
(From Table III-1 of Ref. 4)

<u>TYPE</u>	<u>SITE</u>	<u>LOCATION</u>	<u>HYDROPHONE DEPTHS - meters</u>	
			<u>m re Profile Features and Bottom</u>	
ACODAC	1C	54°53.3'N 28°50.7'W	712	400 m Below Channel Axis
			1944	Critical Depth
			2860	190 m Off the Bottom
ACODAC	2C	51°29.9'N 19°38.0'W	1450	Deep Sound Channel Axis
			2066	600 m Below Deep Channel Axis
			2777	100 m Above Critical Depth
SURVEY Array	1A	54°52.14'N 25°18.65'W	1802	Critical Depth, Bottom
SURVEY Array	1B	51°49.4'N 29°18.65'W	2038	Critical Depth, Bottom

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(U) profile is characterized by two sound channels; these merge together for the northern half of the run and the profiles have a single sound channel. Data collected by the hydrophones shown in Fig. II-2 have been processed for this run.

a. ACODAC, Site 1C

(U) At Site 1C, the processed data were from hydrophones at depths of 712 m, 1944 m, and 2860 m. These depths correspond to 400 m below the channel axis, the critical depth, and 190 m above the bottom, respectively. The 2860 m receiver is much deeper below critical depth than any other receiver in the SQUARE DEAL Exercise. Also, as shown by Fig. II-2, this receiver depth is slightly below the peak of the DeSoto Rise, which will partially block propagation from sources SE of Site 1C.

(1) Range Dependence

(C) Propagation loss measured at the 1944 m hydrophone is presented in Fig. II-3. Figure II-4 shows the propagation losses from the 91 m sources to the hydrophones at 712 m and 2860 m. Range averaged values of propagation loss are given in Fig. II-5. The data from sources close to the receiver are obscured by system overloading, as indicated by the symbols at the top of the plots of Figs. II-3 and II-4. Beyond 200 nm SE (positive ranges) of the Site 1C, the propagation loss dependence upon range approximates cylindrical spreading. However, the amount of spread in the propagation loss curves, due to convergence zone effects, is greater for the deeper receivers (Fig. II-4). The propagation loss from sources NW of 1C (negative ranges) increases rapidly with range, indicating bottom limited propagation as the track approaches the Reykjanes Ridge.

(2) Source Depth Dependence

(C) Comparison of propagation losses from sources detonated at depths of 91 m and 18 m consistently exhibit more loss for the 18 m sources.

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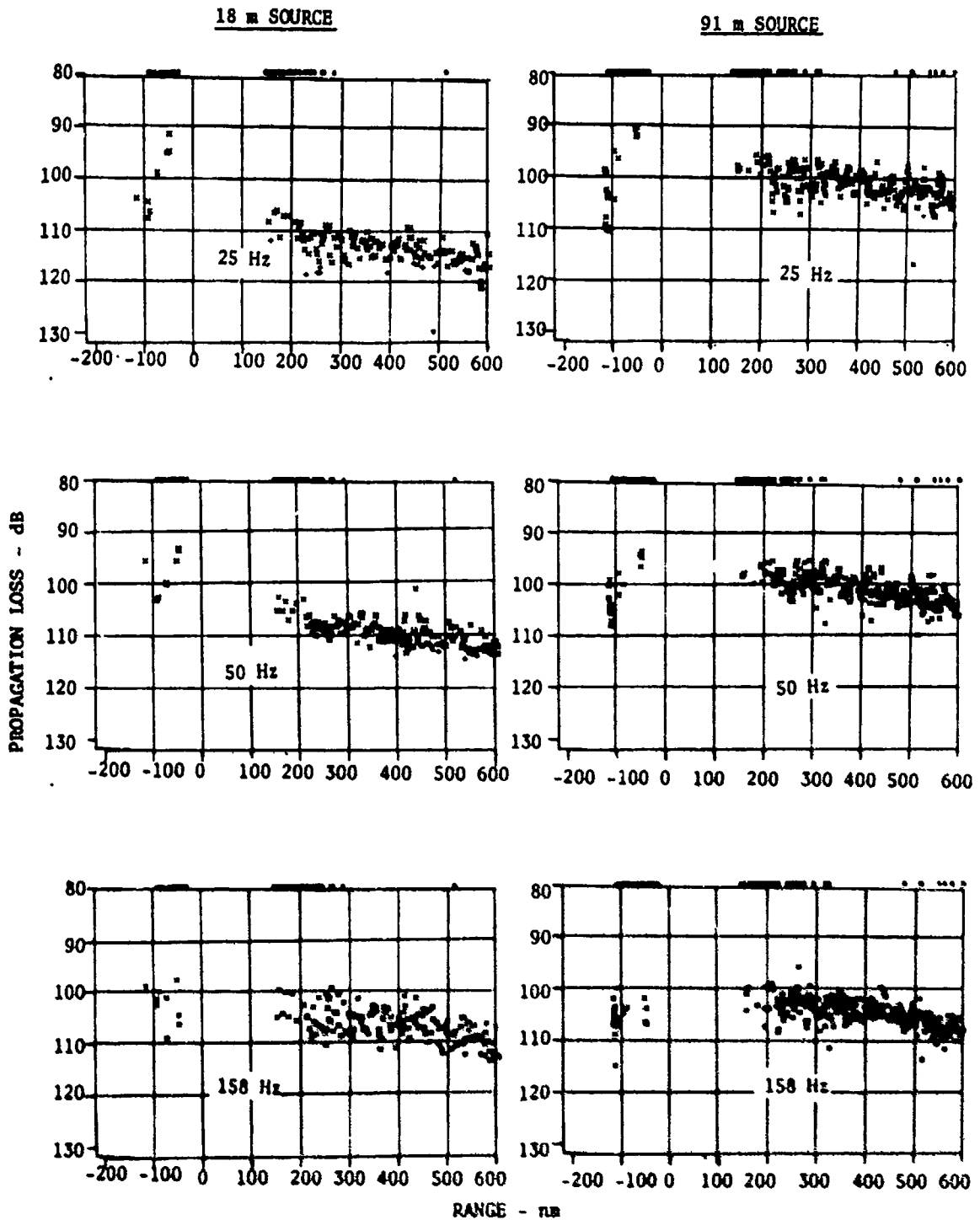


FIGURE II-3  
PROPAGATION LOSS - SITE 1C, EVENT 2a  
1944 m Receiver  
Two Source Depths  
25, 50, and 158 Hz

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SEM

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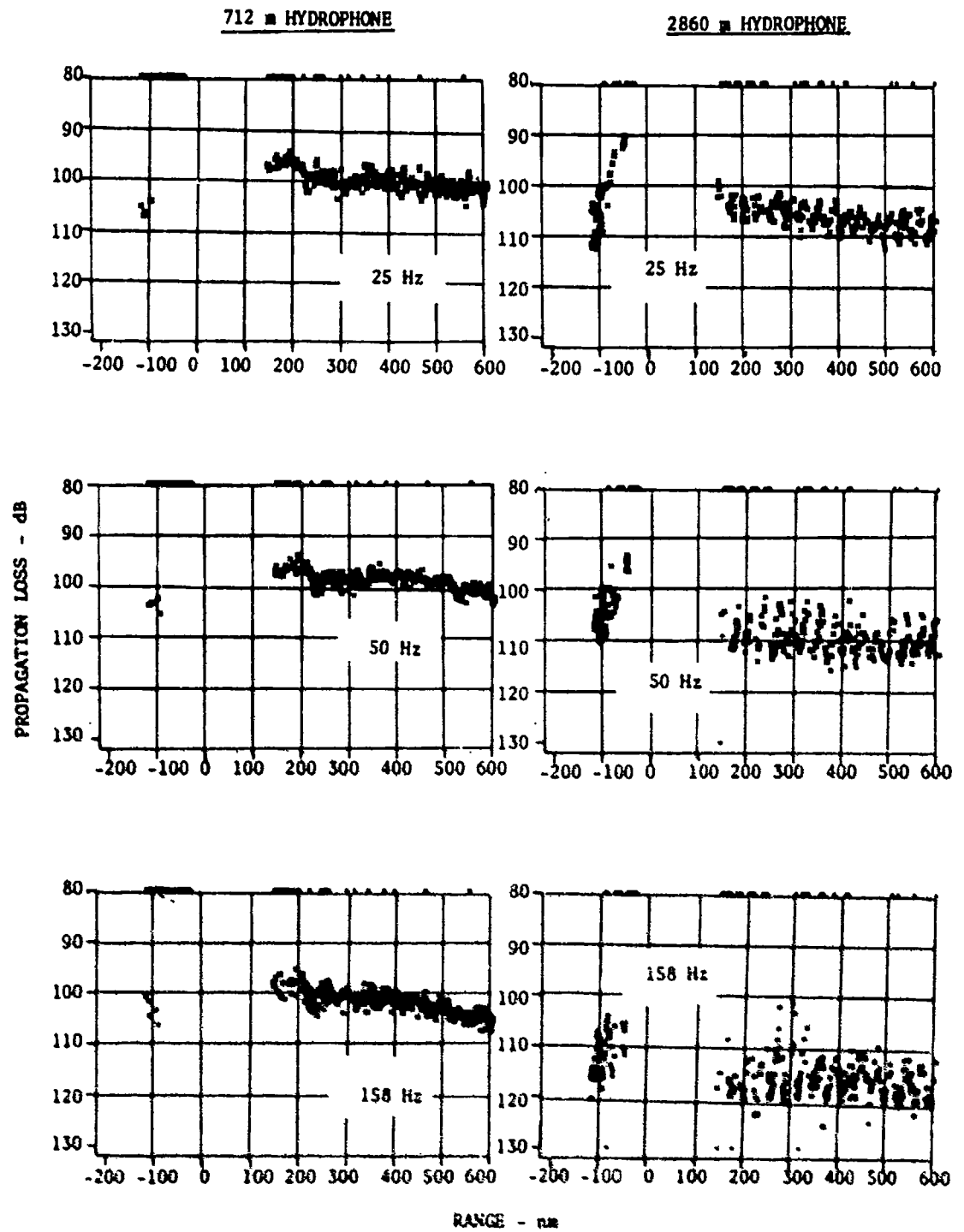


FIGURE 11-4  
PROPAGATION LOSS - SITE 1C, EVENT 2a  
712 m, 2860 m Receivers  
91 m Source  
25, 50, and 158 Hz

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SKM

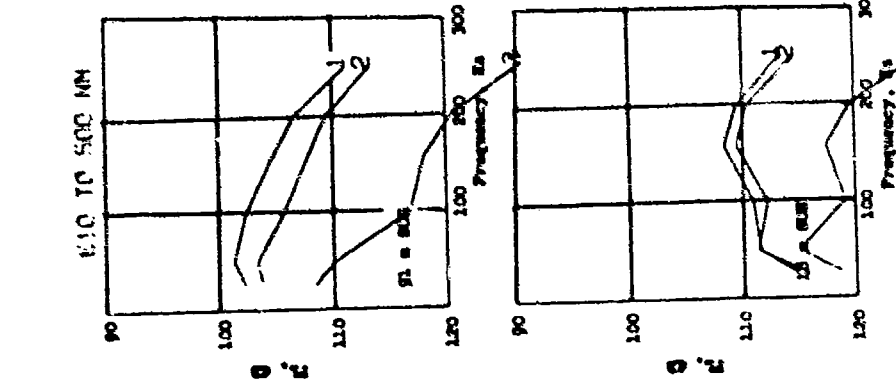
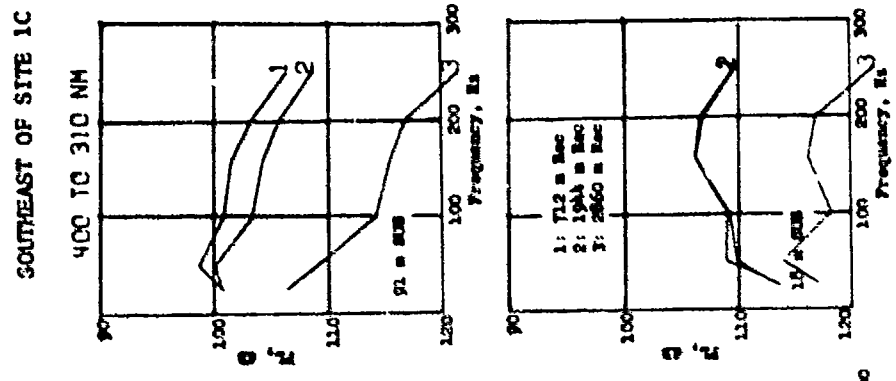
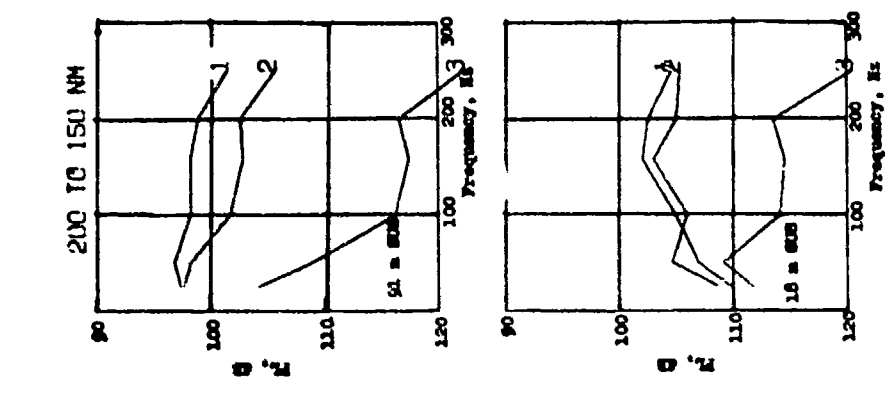
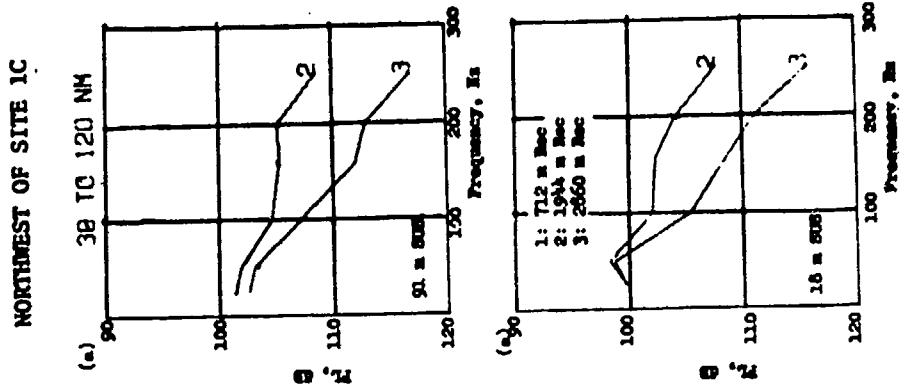


FIGURE 11-5  
 RANGE AVERAGED PL versus FREQUENCY - SITE 2C, EVENT 2a  
 712 m, 1944 m, 2860 m Receivers  
 Two Source Depths

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 SKM

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- (C) This may be seen in the range averaged data of Fig. II-5. The difference is greater than 10 dB at the low frequencies and decreases as the frequency increases; at 250 Hz, the difference is less than 3 dB.

## (3) Receiver Depth Dependence

- (C) At Site 1C, the dependence of propagation loss upon receiver depth is a function of source depth and frequency. This may be seen in the range averaged data of Fig. II-5. The loss to the deepest receiver (2860 m) is approximately 10 dB or more greater than the loss to the other receivers. Comparing the 712 m and 1944 m receivers, the average loss from the 18 m sources is the same at these two depths; from the 91 m sources, there is approximately 3 dB more loss at 1944 m receiver depth. Figure II-6 shows the difference between propagation loss from individual shots to the different receiver depths at 25 Hz.

## (4) Frequency Dependence

- (C) The dependence of propagation loss upon frequency at 1C may be seen in Fig. II-5, and in the plots of differences between propagation loss from individual shots at 158 Hz and 50 Hz, Fig. II-7. From the 91 m sources, the propagation loss increases as frequency increases; there is nominally 4 dB more loss at 158 Hz than at 50 Hz on the two shallower receivers; at the 2860 m receiver, the difference is 8 dB.
- (C) The frequency dependence of the loss from the 18 m sources varies with receiver depth and source location. The frequency dependence of propagation from sources in the open channel region S3 of Site 1C to the receivers above critical depth (Fig. II-5) is typical of such of SQUARE DEAL. That is, there is maximum loss at 25 Hz, and minimum loss at approximately 158 Hz; there is approximately 8 dB more loss at 25 Hz than 158 Hz. This dependence arises from the Lloyd's Mirror effect, discussed in the introduction whereby, if there are no significant bottom reflected arrivals, interference between closely spaced rays from the shallow

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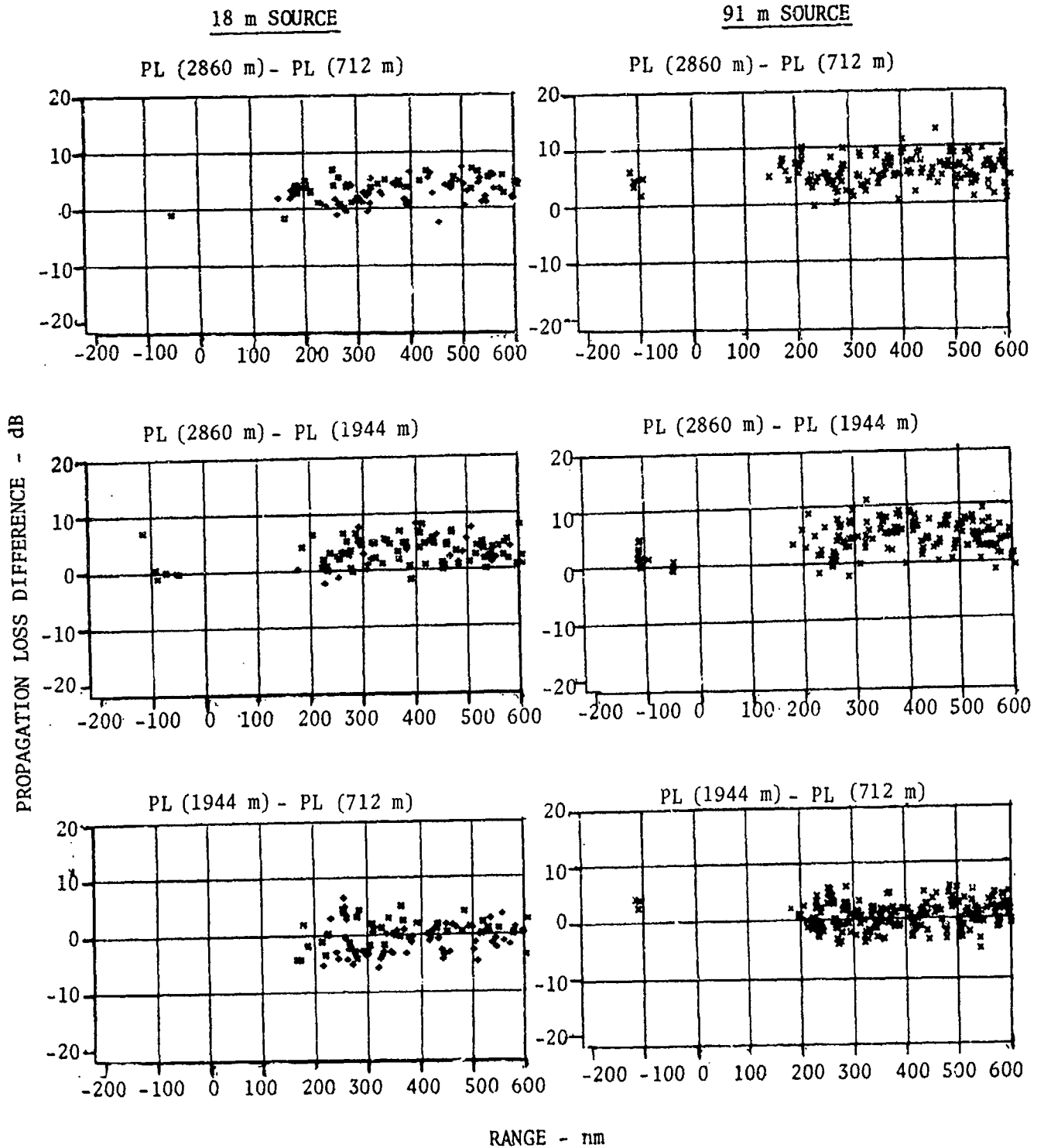
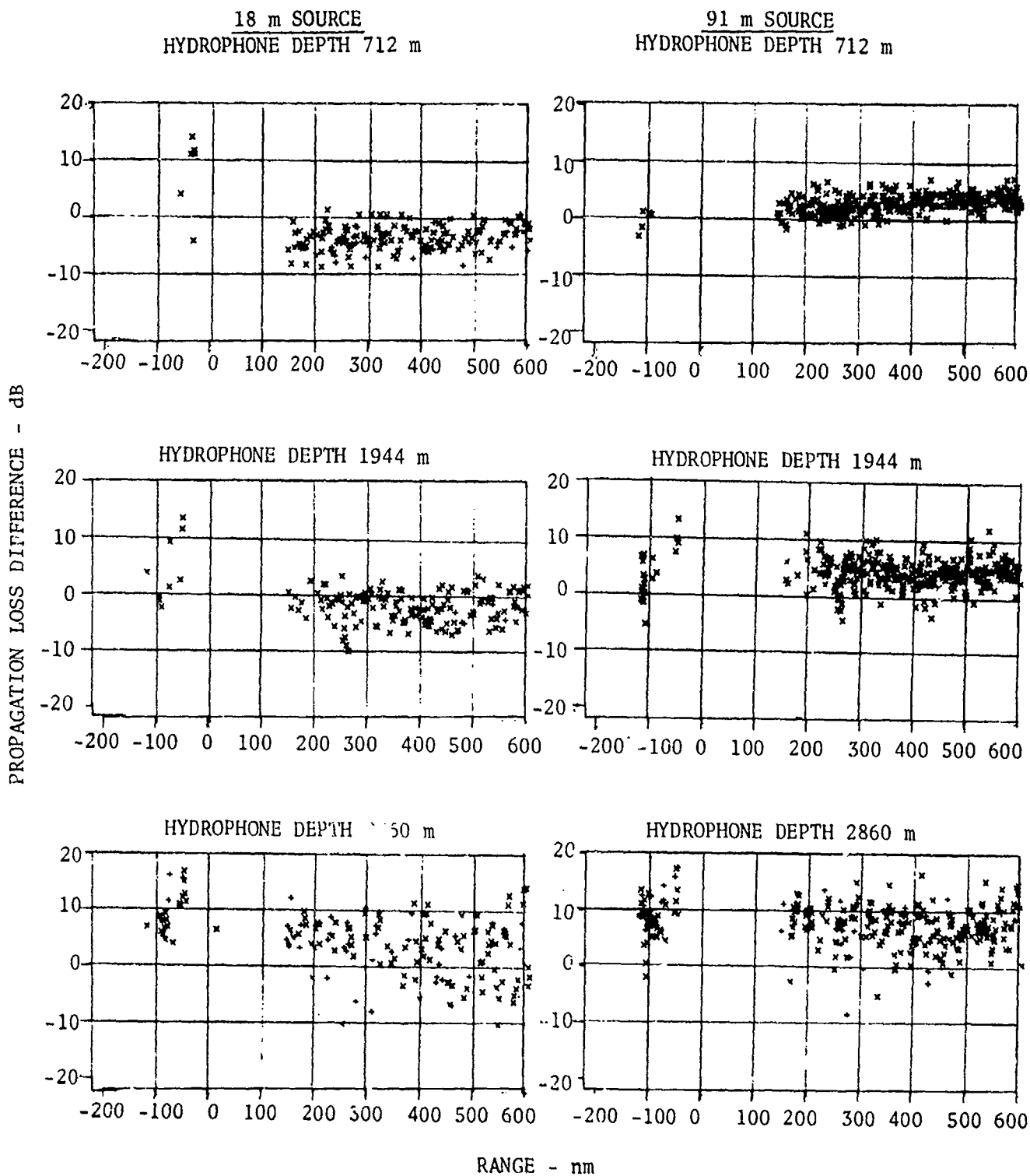


FIGURE II-6  
PROPAGATION LOSS DIFFERENCES - SITE 1C  
Difference Between PL to Receivers  
Two Source Depths  
25 Hz Frequency

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RANGE - nm

FIGURE II-7

PROPAGATION LOSS DIFFERENCES - SITE 1C

Three Receiver Depths

Two Source Depths

Difference Between 158 Hz PL and 50 Hz PL

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SKM



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(C) sources causes the level of the lower frequency components to be reduced. From 18 m sources SE of 1C to the 2860 m receiver, and from NW of Site 1C to all receivers, the Lloyd's Mirror effect is not observed, and propagation loss increases with frequency.

b. ACODAC, Site 2C

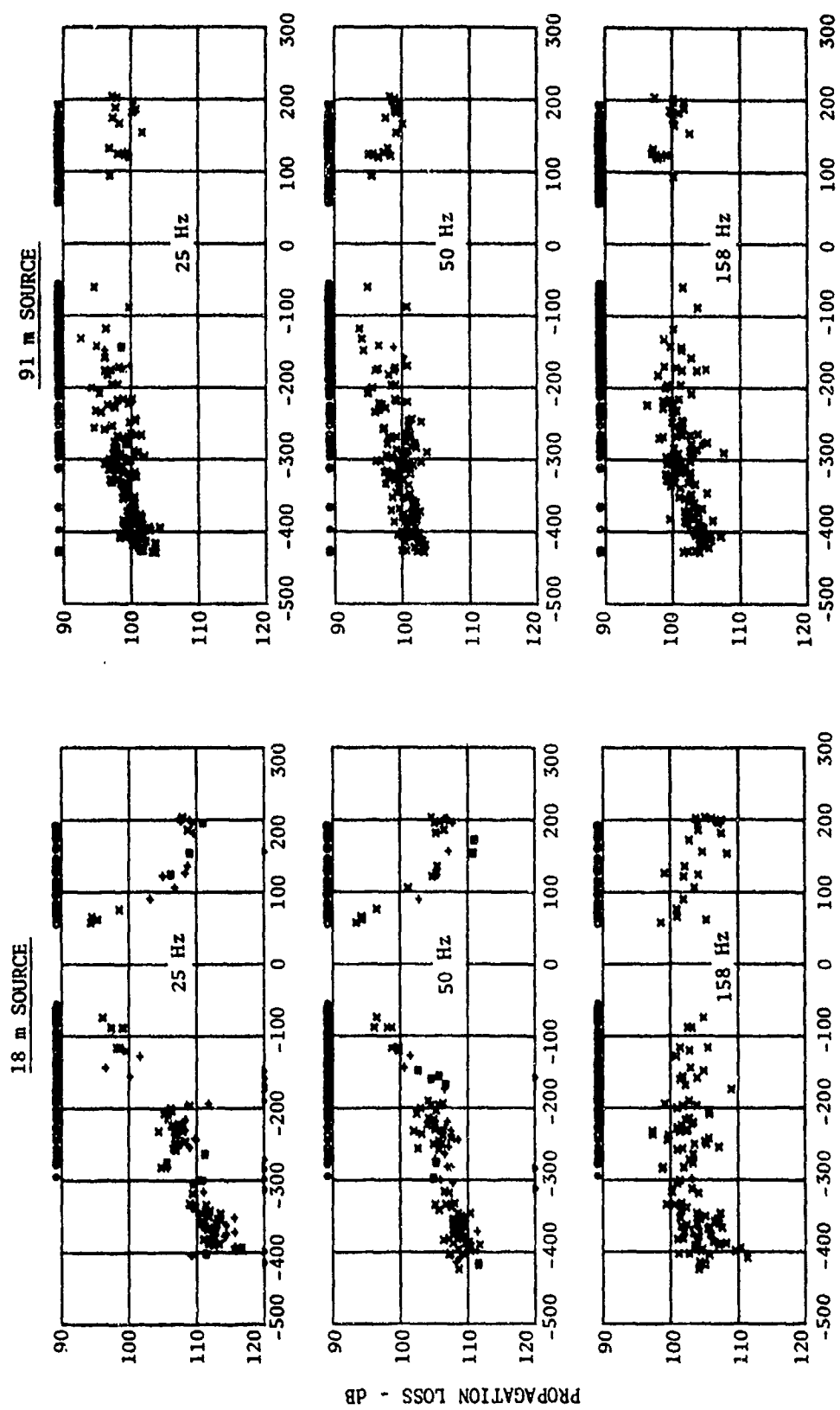
(U) The hydrophones at Site 2C during Phase I whose outputs have been analyzed are at 1450 m, 2066 m, and 2777 m. These depths are the deep sound channel axis, an intermediate depth, and 100 m above the critical depth, as shown in Fig. II-2.

(1) Range Dependence

(C) Propagation losses to the 2066 m depth hydrophone are shown in Fig. II-8; Fig. II-9 shows the propagation loss from the 18 m depth sources to the 1450 m and 2777 m hydrophones. Range averaged values of propagation loss to Site 2C are given in Fig. II-10. The loss from 91 m sources at ranges greater than 150 nm approximates cylindrical spreading. This dependence is also seen for loss from the 18 m sources beyond 150 nm at frequencies above 50 Hz. The loss from the 18 m sources increases at a greater rate below 50 Hz because the Lloyd's Mirror effect is not a dominant factor at close ranges (less than 200 nm) but is at greater ranges (see Fig. II-10); this is probably due to changes in bottom reflectivity along the track.

(2) Source Depth Dependence

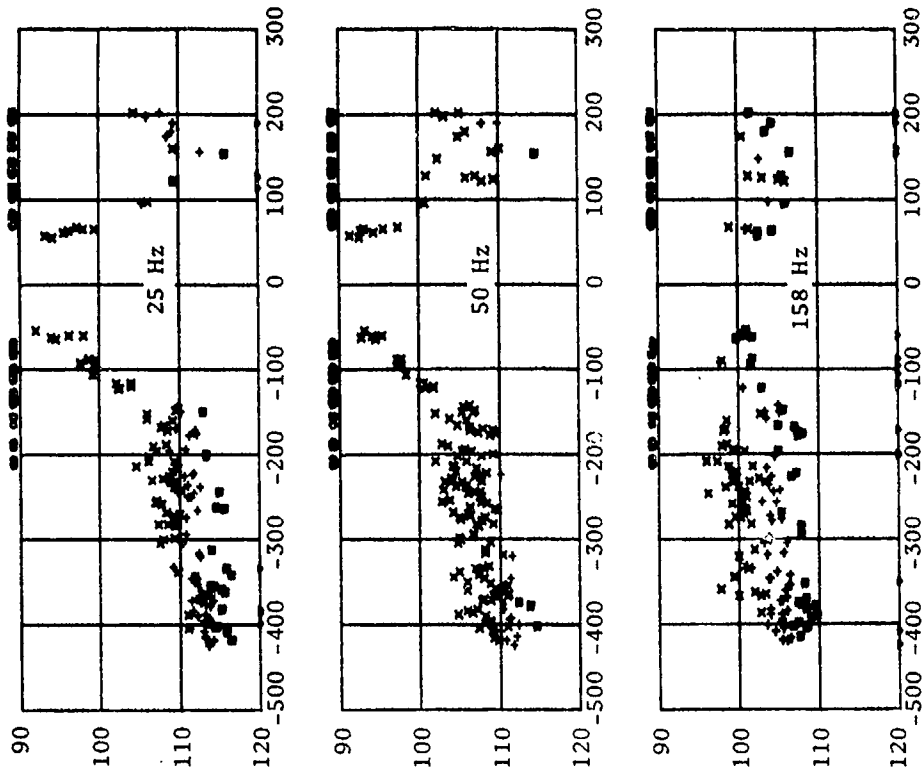
(C) The dependence of propagation loss upon source depth varies with frequency and source location; this may be seen in Fig. II-10. From sources 200 nm or more NW of Site 1C, the loss from the 18 m sources is greater than the loss from the 91 m sources by 8 to 10 dB at 25 Hz and 0 to 3 dB at 158 Hz and above.



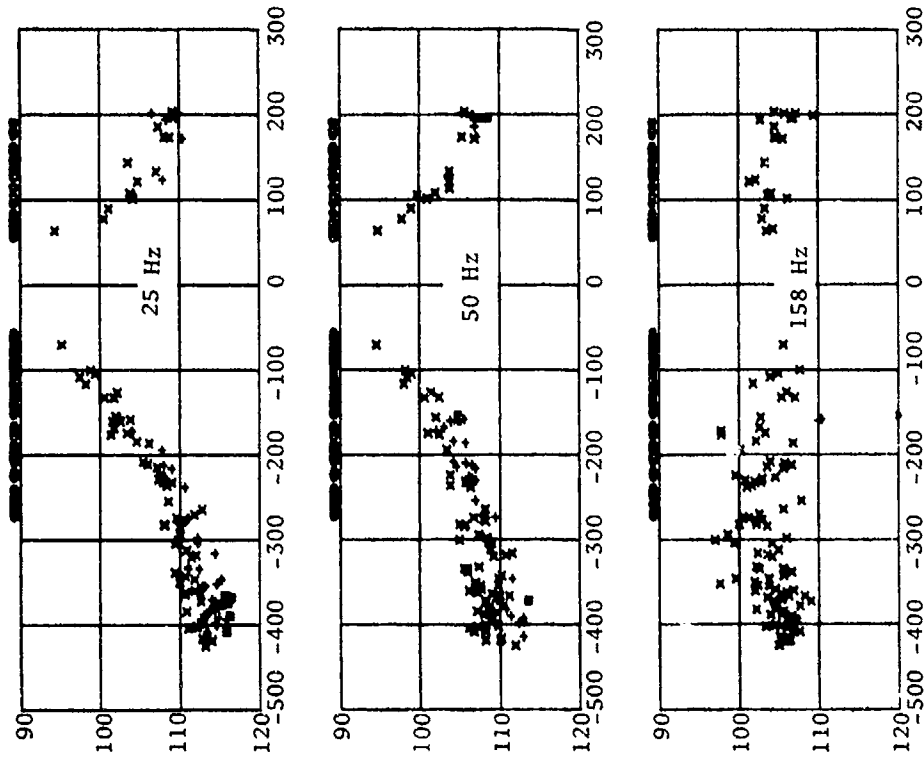
Range nm  
 FIGURE 11-8  
 PROPAGATION LOSS - SITE 2C, EVENT 2a  
 2066 m Receiver  
 Two Source Depths  
 25, 50, and 158 Hz

AS-76-854  
 SKM

HYDROPHONE DEPTH 2777 m



HYDROPHONE DEPTH 1450 m



PROPAGATION LOSS - dB

RANGE - nm

FIGURE II-9  
 PROPAGATION LOSS - SITE 2C, EVENT 2a  
 1450 m, 2777 m Receivers  
 18 m Source Depth  
 25, 50, and 158 Hz

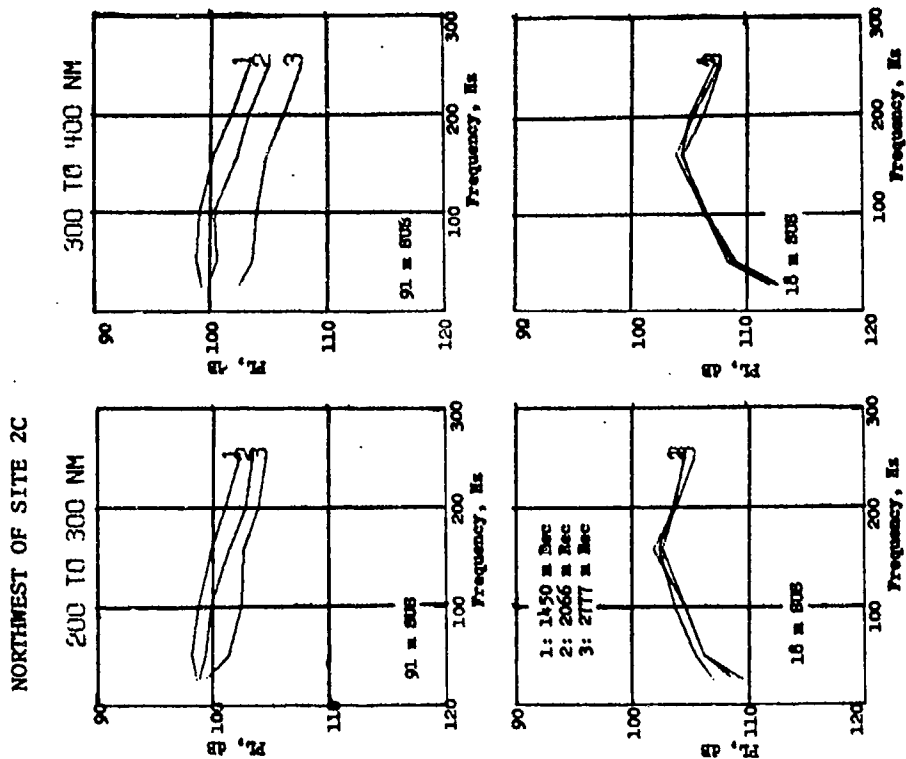
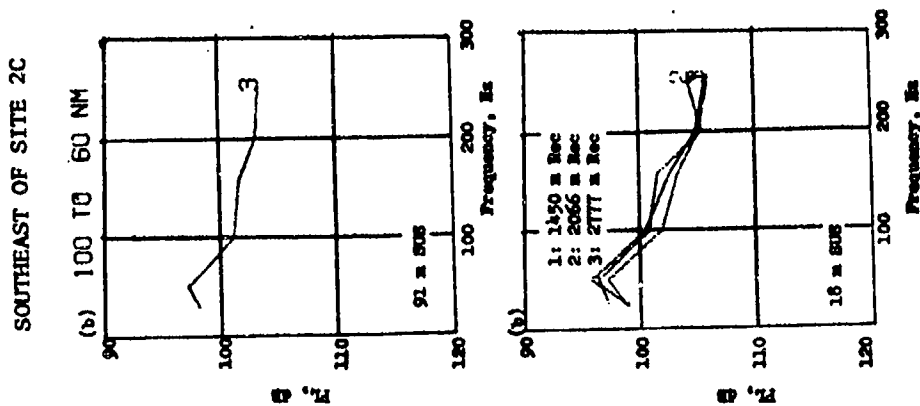


FIGURE II-10  
RANGE AVERAGED PL versus FREQUENCY - SITE 2C, EVENT 2a  
1450 m, 2066 m, 2777 m Receivers  
Two Source Depths

AS-76-856  
SKM

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## (3) Receiver Depth Dependence

- (C) Differences between propagation losses at 50 Hz from individual shots to different hydrophones appear in Fig. II-11; the dependence upon receiver depth is also shown by Fig. II-10. As may be seen, the loss from the 18 m sources shows essentially no trend in the receiver depth dependence. However, the loss from the 91 m sources increases with receiver depth, and the averaged differences show no important frequency dependence; the mean loss from 91 m sources is approximately 4 dB greater at the 2777 m depth than at 1450 m.

## (4) Frequency Dependence

- (C) The frequency dependence of the propagation loss to Site 2C is illustrated by the range averaged data of Fig. II-10, and by the shot-by-shot comparison of Fig. II-12. The frequency dependence of the loss from the 91 m sources is essentially independent of receiver depth or source location; there is approximately 3 dB greater mean loss at 158 Hz than at 50 Hz.

- (C) For the 18 m sources, the frequency dependence varies with source location. From 200 m and beyond, the Lloyd's Mirror effect, evidenced by the minimum loss at 158 Hz (approximately 5 dB less than the loss at 50 Hz), influences the propagation. The 18 m source data available at shorter ranges (most of these shots overloaded the receivers) have a frequency dependence similar to that of the 91 m sources, with loss increasing with frequency.

## c. Comparison of Sites 1C and 2C

- (C) The sound speed profiles in Fig. II-2 show considerable change in structure between Sites 1C and 2C. There is, however, little difference between propagation to receivers at comparable depths at the two sites. Table II-2 presents propagation losses observed at Sites 1C and 2C averaged

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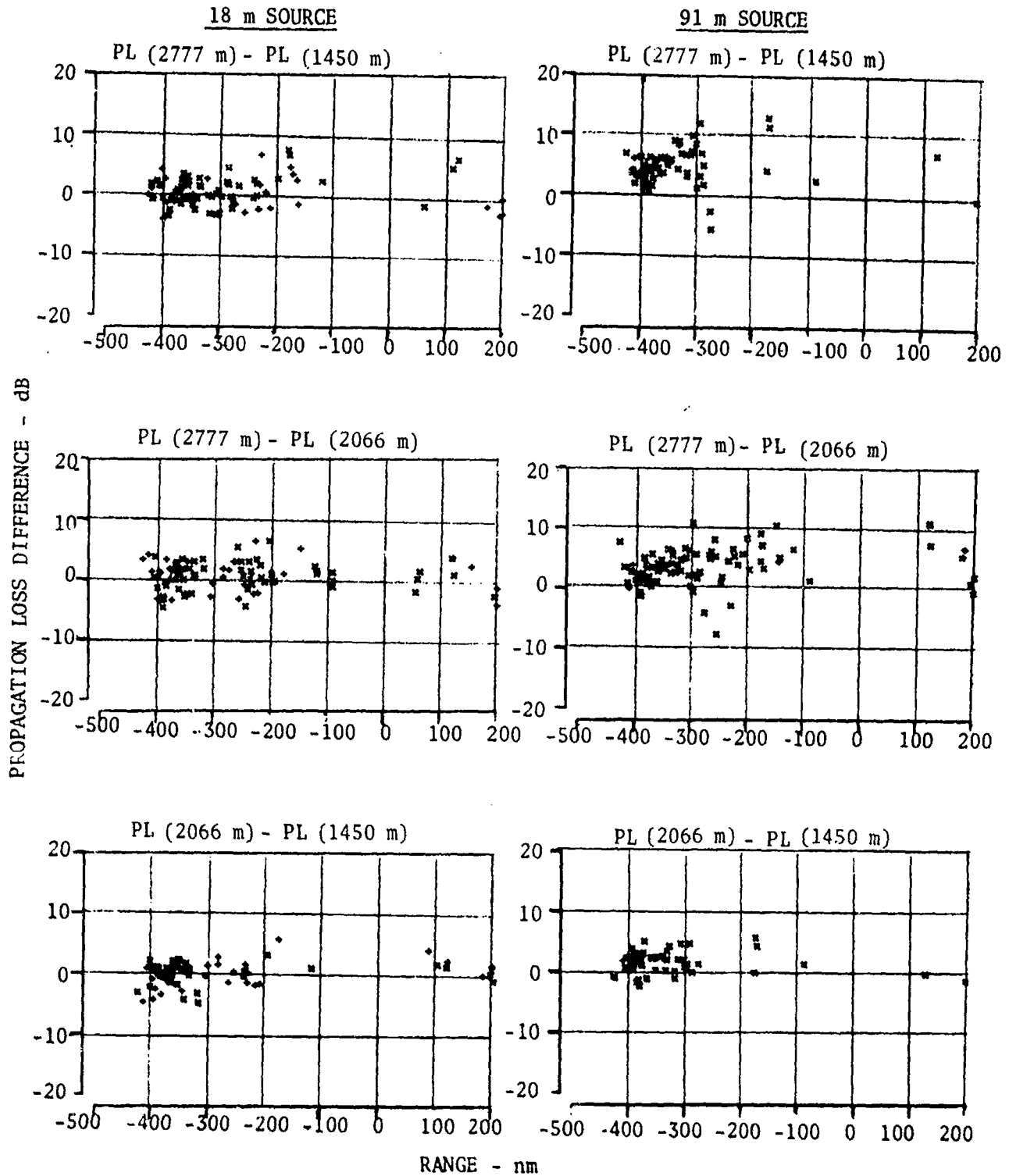


FIGURE II-11  
PROPAGATION LOSS DIFFERENCES - SITE 2C, EVENT 2a  
Difference Between PL to Receivers  
Two Source Depths  
50 Hz Frequency

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18 m SOURCE

91 m SOURCE

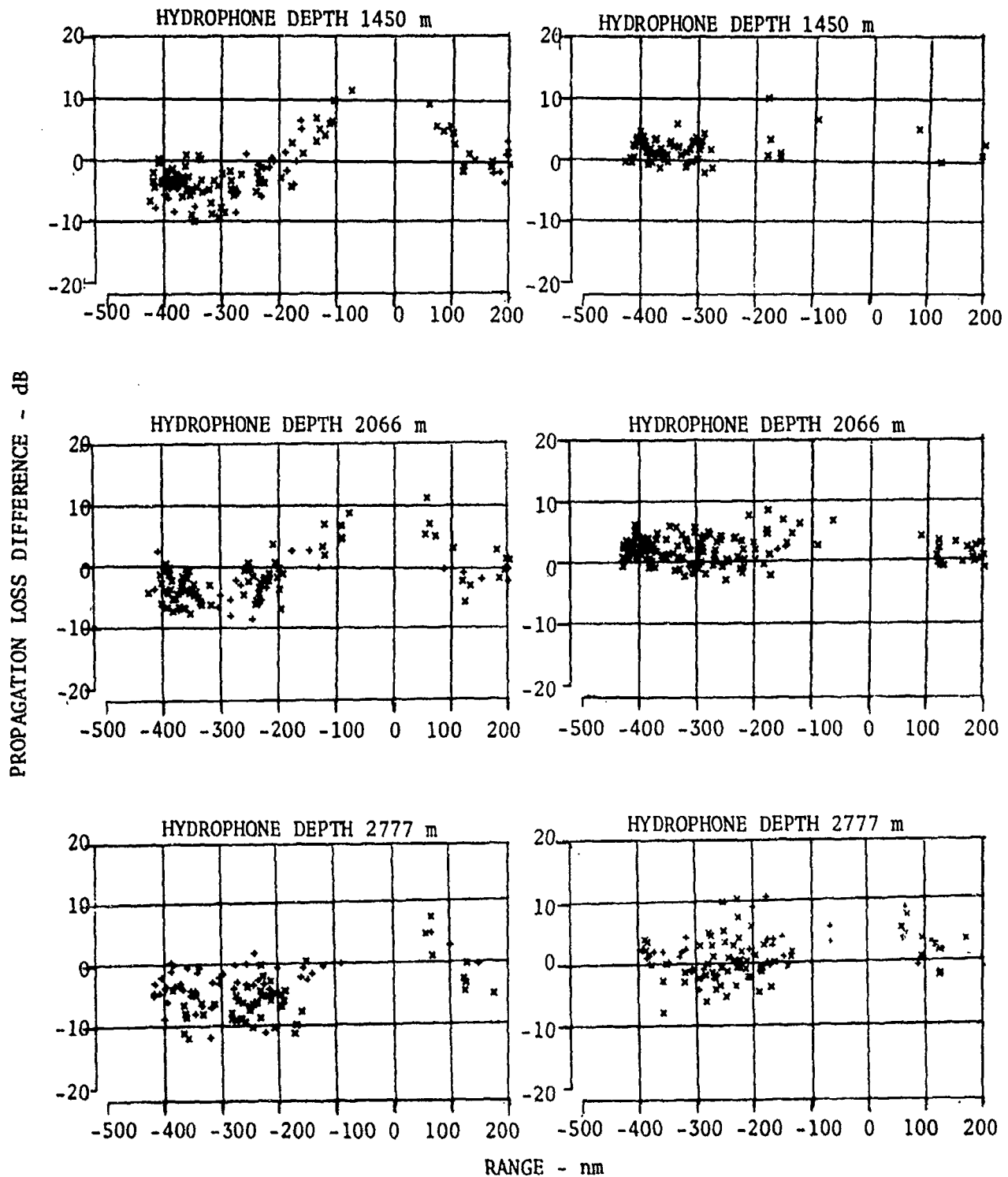


FIGURE II-12  
PROPAGATION LOSS DIFFERENCES - SITE 2C, EVENT 2a  
Three Receiver Depths  
Two Source Depths  
Difference Between 158 Hz PL and 50 Hz PL

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SKM

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(c)

TABLE II-2

COMPARISON BETWEEN PROPAGATION TO SITE 1C AND SITE 2C  
FOR THE RANGE INTERVAL OF 300 nm TO 400 nm (U)

RECEIVER DEPTH/SITE	PROPAGATION LOSS (dB)					
	91 m SOURCE			18 m SOURCE		
	25 Hz	50 Hz	158 Hz	25 Hz	50 Hz	158 Hz
1944 m/1C	101	100	104	116	108	104
2066 m/2C	100	102	102	114	108	106
2860 m/1C	106	109	116	118	114	116
2777 m/2C	102	104	105	114	108	105



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(C) over a range interval of 300 nm through 400 nm; in this interval, the sources are near one site, and propagation is to the other. These data allow comparison between hydrophones at similar depths at the two sites. Remember that the 2860 m depth at Site 1C is far below critical depth, whereas the 2777 m depth is in the sound channel at Site 2C (Fig. II-2).

(C) Considered as a group, the two receivers at Site 2C and the 1944 m receiver at Site 1C have nearly the same average propagation loss (Table II-2). However, the loss to the 2860 m receiver at Site 1C is consistently the greatest in any column; propagation to that receiver is affected by its distance below critical depth, and probably by the DeSoto rise only 30 nm SE of 1C (Fig. II-2).

### 3. Other Source Runs

(U) Nine aircraft SUS runs were flown during Phase I. Events 5a and 5f, radial to Site 1A, and Events 5i and 7b, radial to Site 1B, are shown in Fig. II-1. Propagation loss to the SURVEY arrays at the origins of these runs has been computed.

#### a. SURVEY Array, Site 1A

(C) The receiver at Site 1A is near the bottom above a seamount, at 1802 m depth (slightly above the critical depth); the site is at the NW boundary of the West European Basin (Fig. II-1). Event 5a is a radial run at a bearing of 155° across the deeper part of the Basin; Event 5f is at a bearing of 320°. As may be seen in Fig. II-1, the sources for Event 5f are over shallower water than are those of Event 5a, and propagation to Site 1A is across the NW shoulder of the seamount for Event 5f.

(C) Propagation loss data for these runs are presented in Figs. II-13 and II-14. As discussed in section I.1.c, the correction factors which are given on the plots of the SURVEY data are needed to have the source levels conform to standard values used for the other systems. For both runs, the

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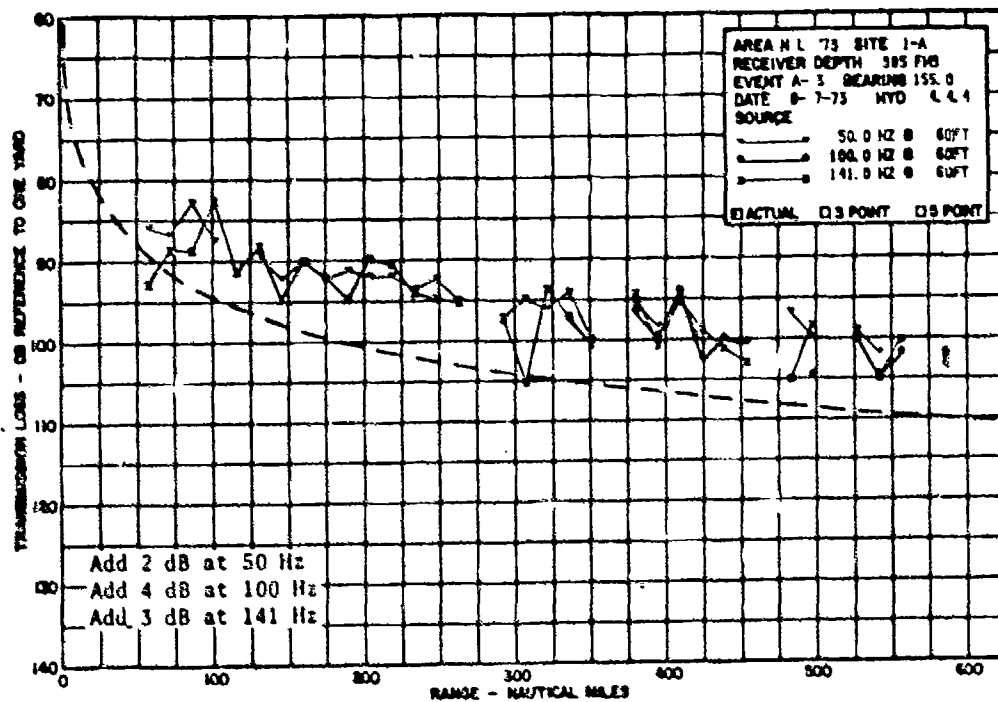
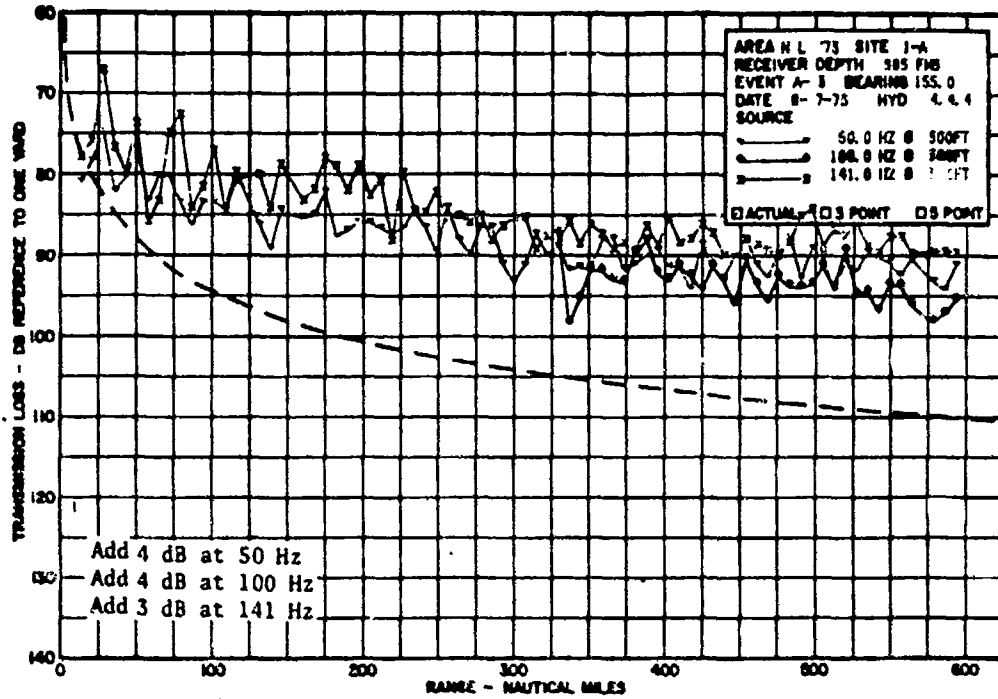


FIGURE II-13  
 PROPAGATION LOSS - SITE 1A, EVENT 5a  
 1802 m Receiver (Bottomed)  
 Two Source Depths  
 50, 100, and 141 Hz

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 SKM

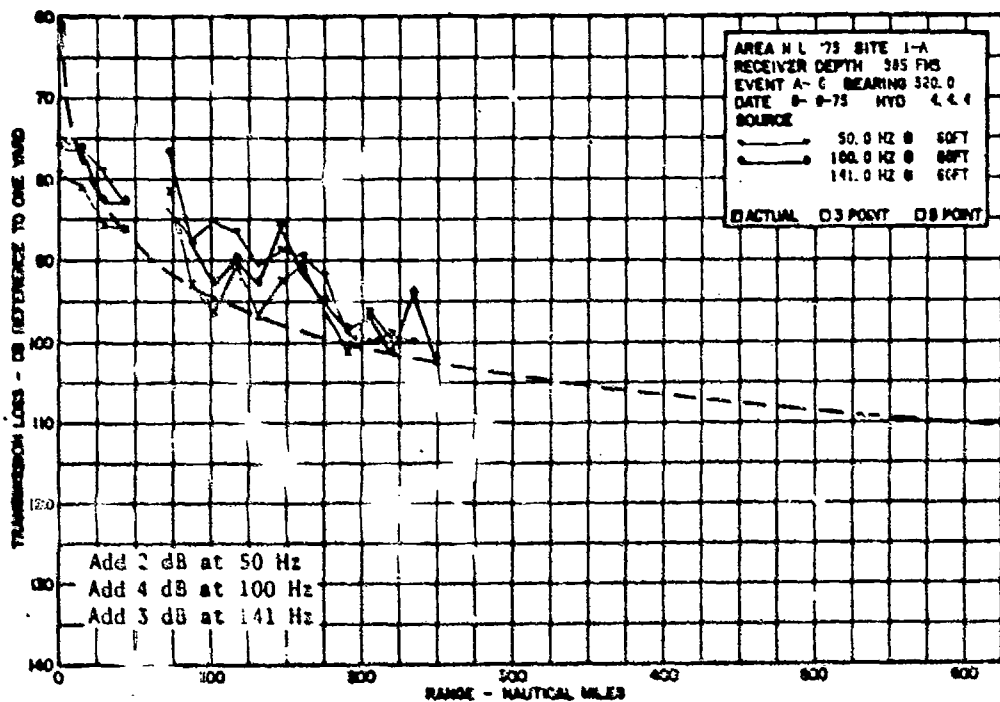
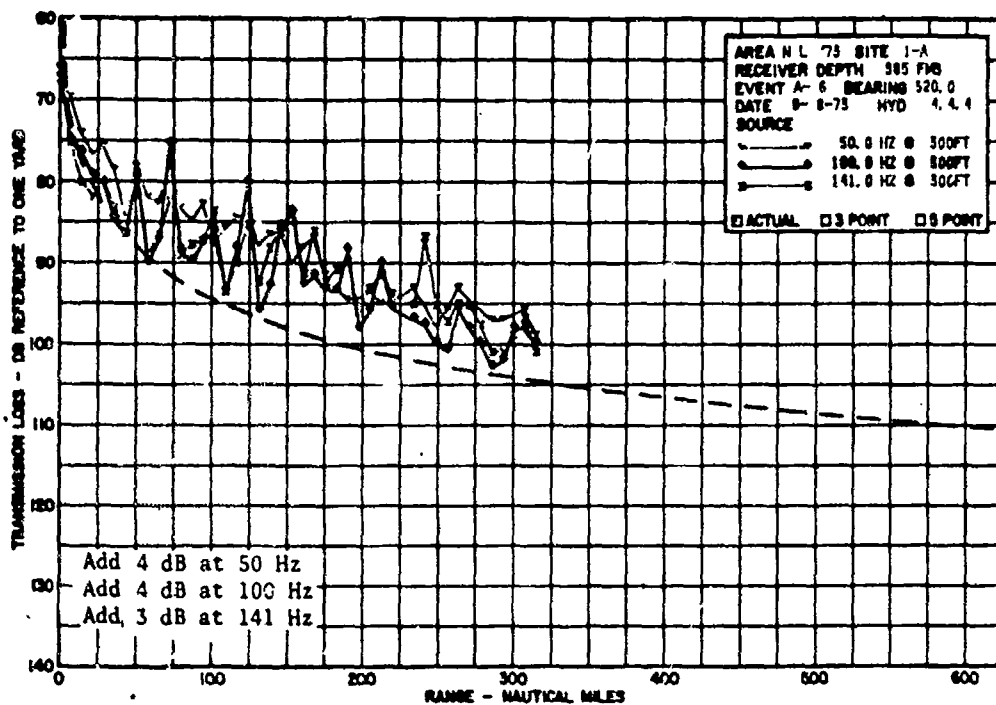


FIGURE II-14  
 PROPAGATION LOSS - SITE 1A, EVENT SF  
 1802 m Receiver (Bottomed)  
 Two Source Depths  
 50, 100, and 141 Hz

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(C) loss from the 18 m shots is approximately 5 dB greater than the loss from the 91 m shots. There is no apparent frequency dependence for the 18 m sources. For the 91 m sources, at the longest ranges of both runs, the greatest loss is at 100 Hz. By comparing Figs. II-13 and II-14, it may be seen that there is greater propagation loss on Event 5f than on 5a. For example, at 200 nm range, the loss on Event 5f is nominally 10 dB greater for the 91 m sources and 6 dB greater for the 18 m sources than the loss on Event 5a. This dependence upon propagation path is what would be expected from the bathymetry of the two paths described in the preceding paragraph.

b. SURVEY Array, Site 1B

(C) The receiver at Site 1B is at a depth of 2039 m, just above critical depth on a seamount along the mid-Atlantic Ridge. Event 7b is a radial run at a bearing of 20°. Fig. II-1 shows this run across the Icelandic Basin; not shown is the portion at the end of the run (approximately 700 nm from Site 1B) where the track passes over the edge of the Reykjanes Ridge. Event 5i is a radial run at a bearing of 87° across the West European Basin; at approximately 530 nm, the depth at the source changes from greater than 3000 m to less than 1000 m as the track crosses Porcupine Bank.

(C) Propagation loss data for these runs are presented in Figs. II-15 and II-16. The range scale of Fig. II-16 differs from that of Figs. II-13, II-14, and II-15; also, the highest frequency shown in Figs. II-15 and II-16 is 300 Hz rather than 141 Hz. The propagation loss curves for the two runs show equivalent levels at the same range, frequency, and source depth. From the 91 m sources, the loss at 50 Hz is approximately the same as the loss at 141 Hz; the loss at 300 Hz is approximately 5 dB more at 400 nm than at the other two frequencies and shows attenuation in addition to spreading loss. From the 18 m sources, the loss at 141 Hz is approximately 3 dB less than the loss at 50 Hz; this is consistent with the Lloyd's Mirror effect.

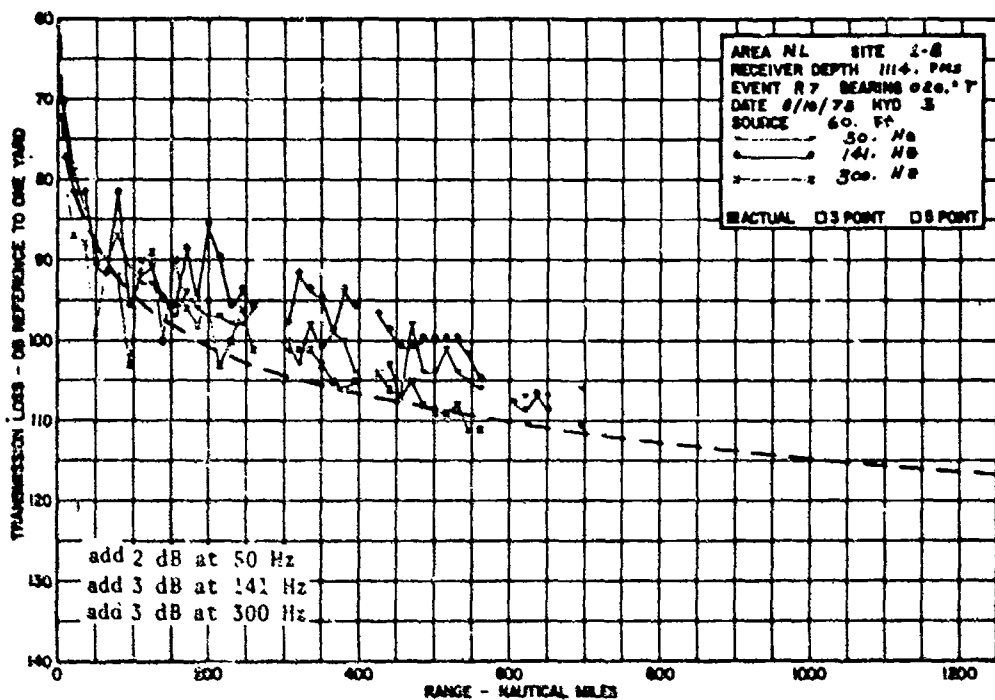
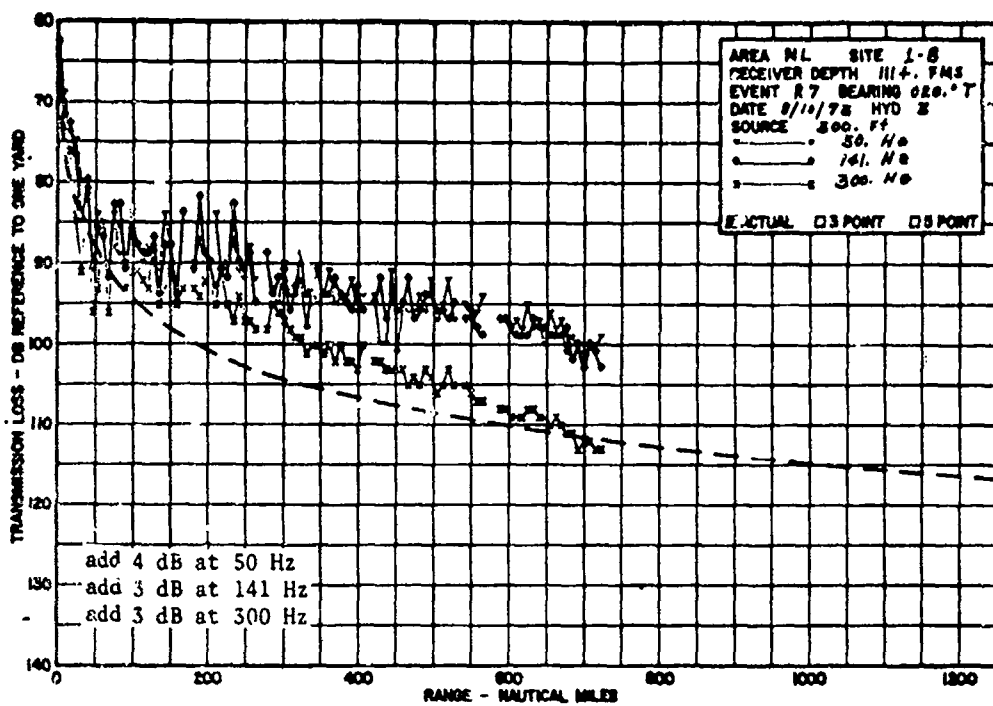


FIGURE II-15  
 PROPAGATION LOSS - SITE 1B, EVENT 7b  
 2038 m Receiver  
 Two Source Depths  
 50, 141, and 300 Hz

AS-76-861  
 SKM

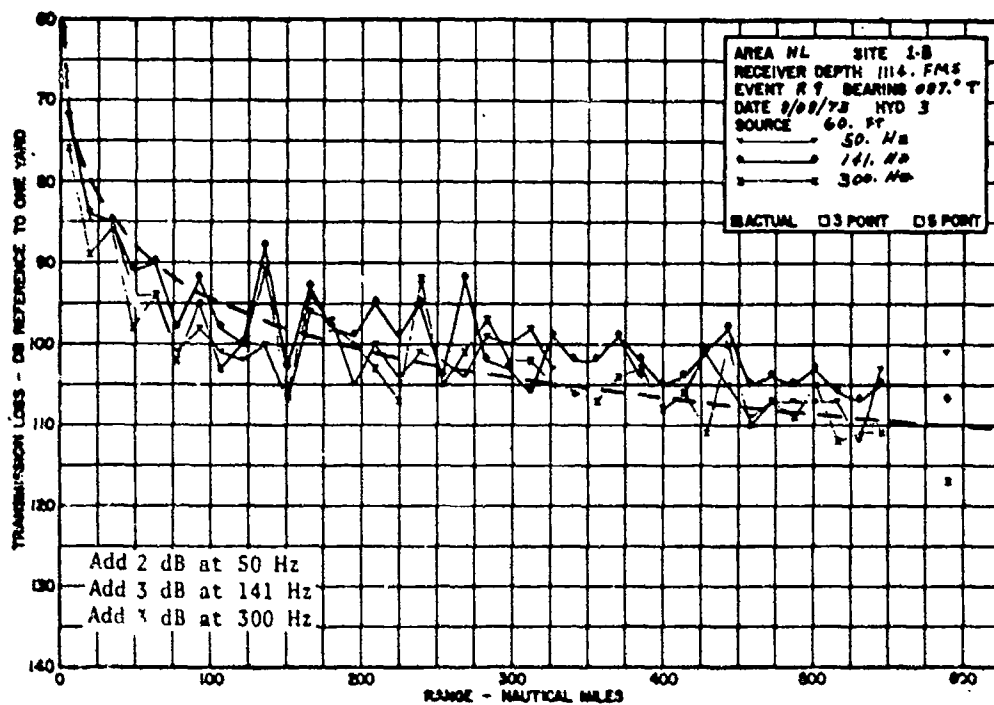
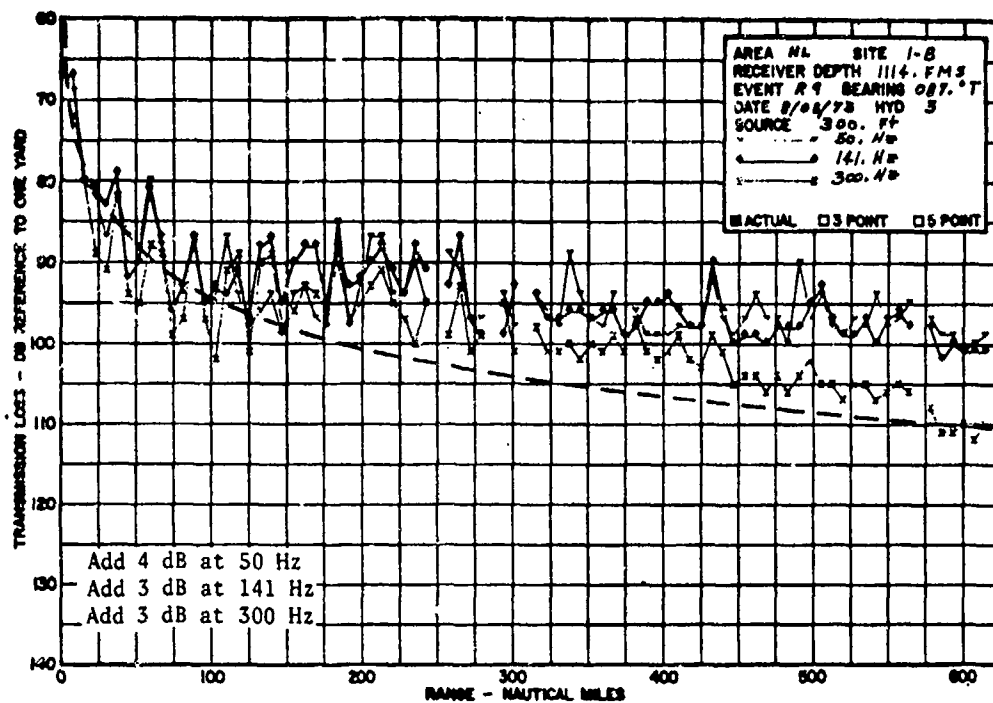


FIGURE II-16  
 PROPAGATION LOSS - SITE 1B, EVENT S1  
 2038 m Receiver  
 Two Source Depths  
 50, 141, and 300 Hz

AS-76-862  
 SKN

(C) Near the end of both runs (675 nm on Event 7b and 575 nm on Event 5i), the loss from the 91 m sources increases approximately 5 dB as the runs pass over shallow water; from these locations, few 18 m shots are detected.

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## III. PHASE II

### 1. Exercise and Area Description

- (U) During Phase II, 15-25 August 1973, SUS sources were deployed by RFA OLMEDA (A 124) on a track along the Rockall Trough and by aircraft along 13 tracks radial to Site 2B. Three of the source runs have been selected for analysis. These three runs, shown in Fig. III-1, are the RFA OLMEDA run along the Rockall Trough, Event 14b, and two of the aircraft runs, Events 12k and 12m.
- (U) Propagation loss to four sites is available for Phase II. The systems at these locations, shown in Fig. III-1, are ACODACS at Sites 2C and 2D, an ANB at Site 2BB, and a SURVEY array at Site 2B. In Table III-1, hydrophone depths are related to sound speed profile features and bottom depth for each receiver site.
- (U) Topography and sound speed structure along the track of the RFA OLMEDA source run are related, in Fig. III-2, to the hydrophone depths at Sites 2C and 2D. To better define the topography and sound velocity structure of the Rockall Trough, Fig. III-3 shows a cross section across the trough from Site 2BB to Site 3AB.

### 2. RFA OLMEDA Source Run, Event 14b

- (U) During Event 14b, the RFA OLMEDA deployed SUS charges while traversing 840 nm along the axis of Rockall Trough and the Porcupine Plain (Figs. III-1 and III-2). The signals were received by ACODACS at Sites 2C and 2D, which are on the source track in deep water in the central part of the trough. Signals from the hydrophones shown in Table III-1 at each ACODAC site were analyzed. These data are used to examine propagation in the Rockall Trough, discussed below. Also examined are data from a SURVEY array at

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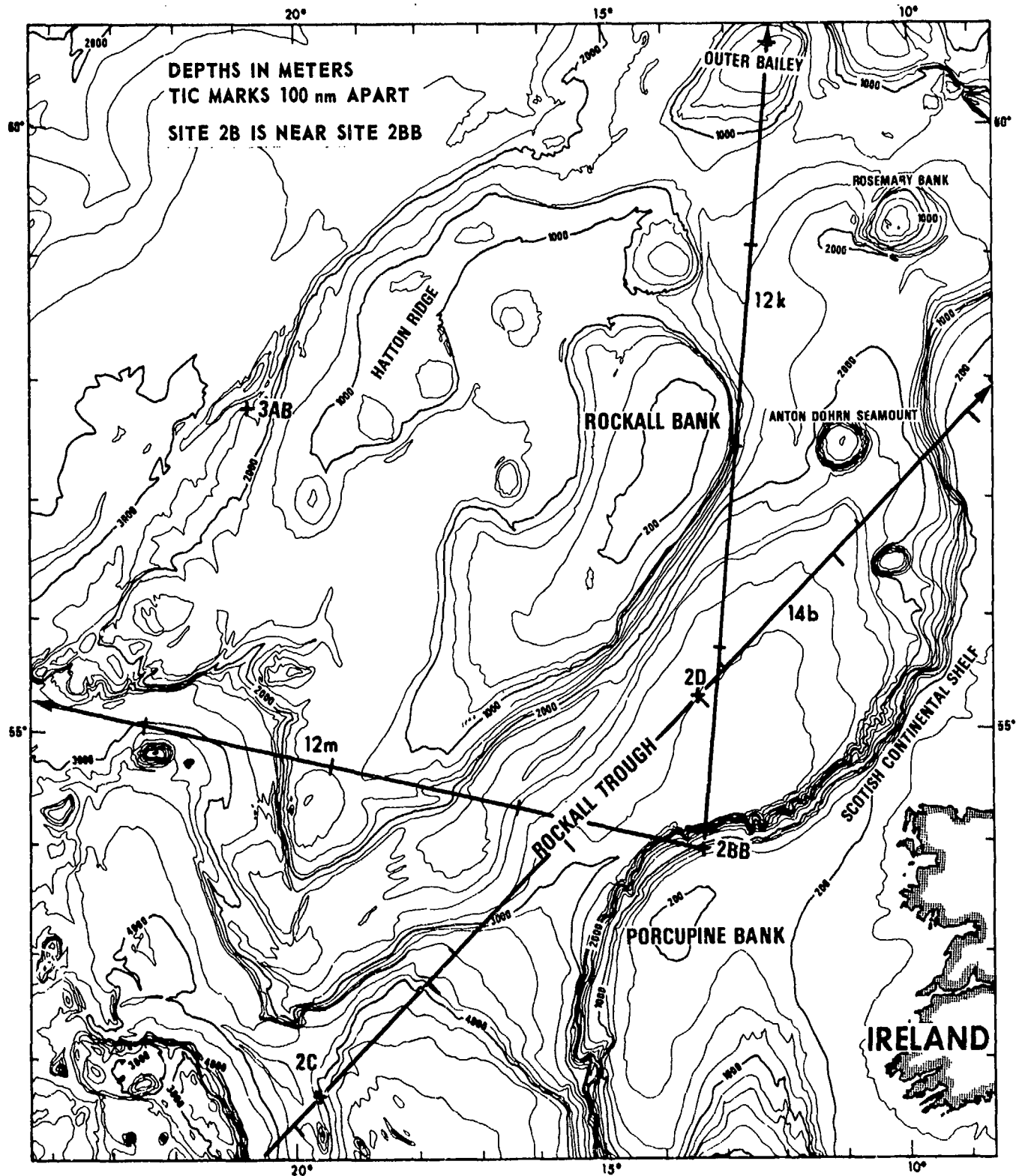


FIGURE III - 1  
SUS EVENTS OF PHASE II (U)

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AS-76-599  
SKM - DR  
5 - 10 - 76

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(C)

TABLE III-1

REFERENCE LOCATIONS FOR PHASE II (U)  
(From Table III-1 of Ref. 4)

RECEIVER DATA			
TYPE	SITE	LOCATION	HYDROPHONE DEPTHS - meters
ACODAC	2C	51°30.1'N	398 250 below upper axis 200 above int. maximum
			1009 400 below int. maximum 200 above deep axis
		19°37.2'W	1376 175 below deep axis 1375 above critical depth
			1834 635 below deep axis 1085 above critical depth
		2445 1250 below deep axis 300 above critical	
		3147 400 below critical 650 above bottom	
ACODAC	2D	55°12.2'N	585 410 below upper axis 365 above int. maximum
			715 540 below upper axis 235 above int. maximum
		13°33.1'W	1810 310 below deep axis 590 above critical
			2467 70 below critical 330 above bottom
SURVEY Array	2B	54°08.78'N 13°05.33'W	1728 on the bottom (480 m below lower axis)
ANB	2BB	54°00.8'N	300 120 below upper axis 555 above bottom
		12°56.0'W	610 430 below upper axis 245 above bottom

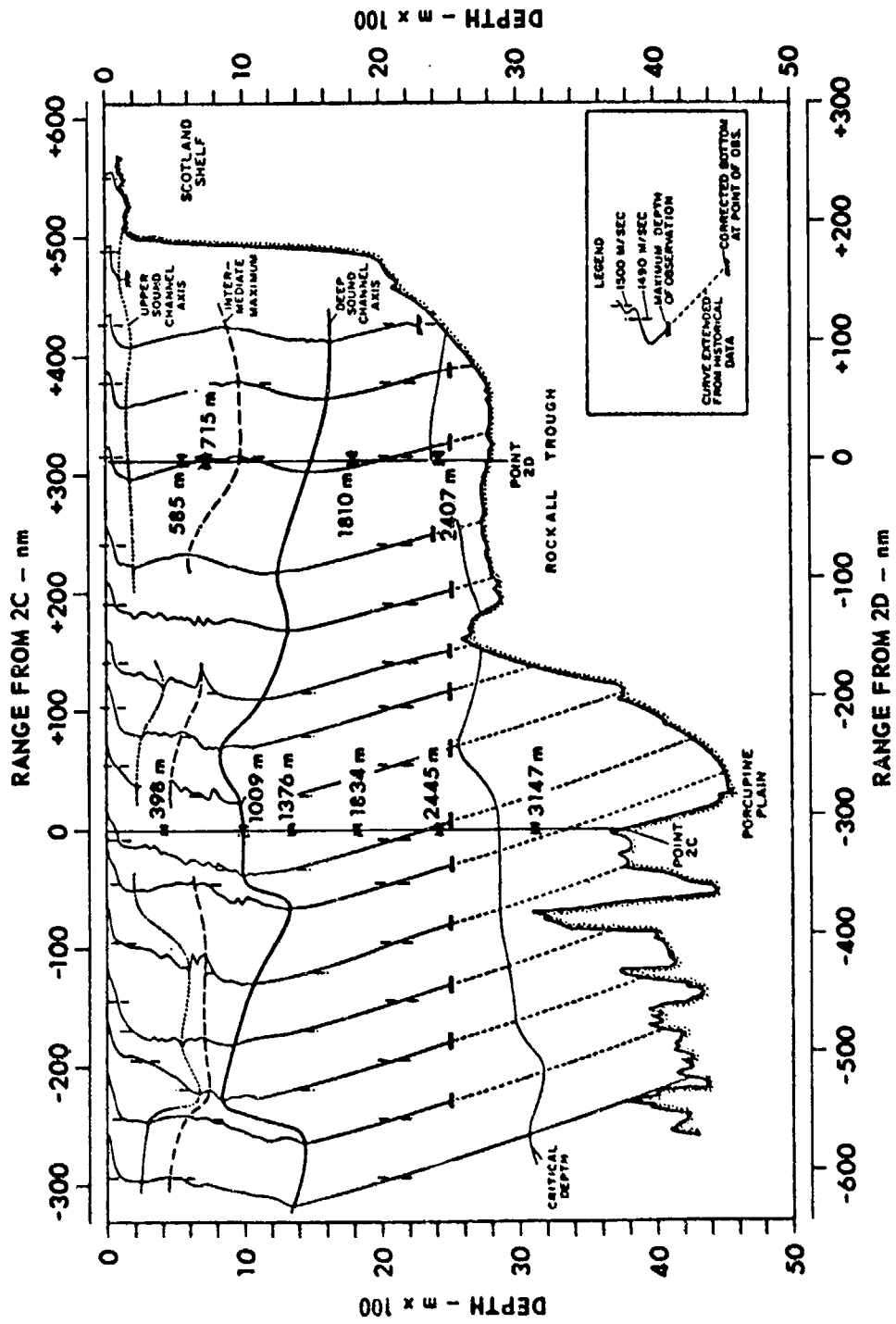


FIGURE III-2  
 SOUND VELOCITY STRUCTURE AND BATHYMETRY  
 IN WEST EUROPEAN BASIN  
 Phase I - Track Along Event 2a

ARL - UT  
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 SKM - DR  
 6-17-76

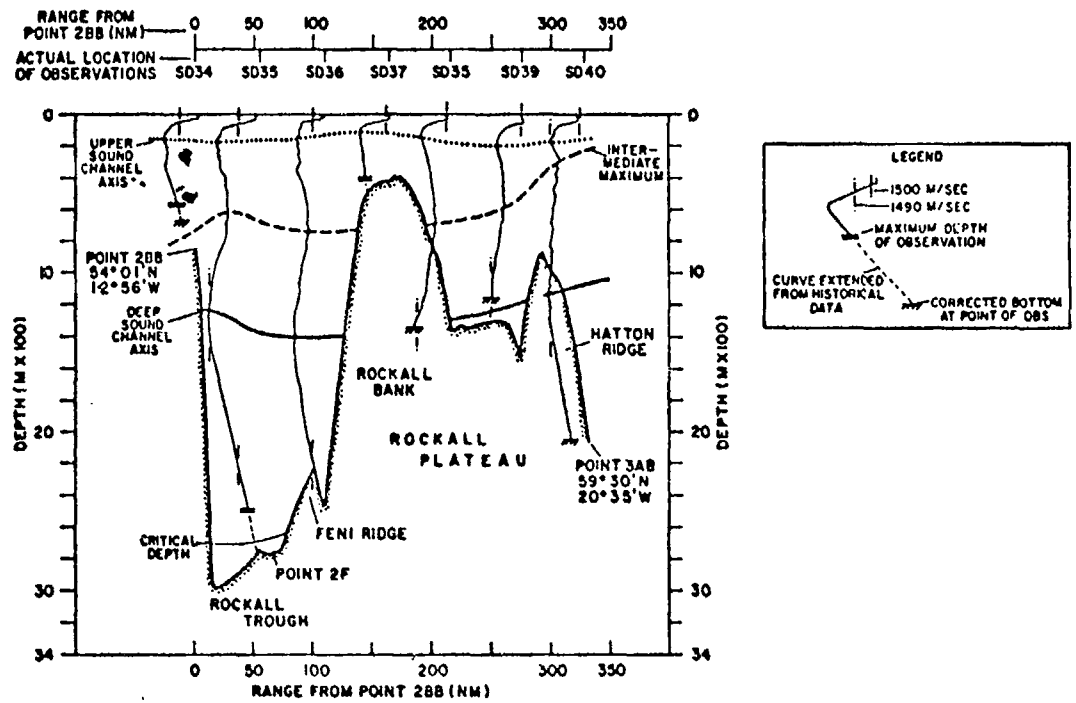


FIGURE III-3  
 SVP AND BATHYMETRY ALONG TRACK FROM 2BB TO 3AB

(U) Site 2B on the sloping rise up to Porcupine Bank (Figs. III-1, III-3) and from an ANB at Site 2BB on the Porcupine Bank.

(C) By comparing Figs. III-2 and II-2, it may be seen that the propagation path in Event 14b is much more bottom limited than the path in Event 2a (Section II). Also, approximately 160 nm NE of Site 2C, there is an interval over which there is depth deficiency; to the NE of that blockage, there is only 400 m, or less, of depth excess. Approximately 7 nm SW of Site 2C, there is a point at which the depth excess is only 200 m. These variations of bathymetry along Event 14b influence the level of the propagation loss, and also can affect the frequency, source depth, and receiver depth dependences.

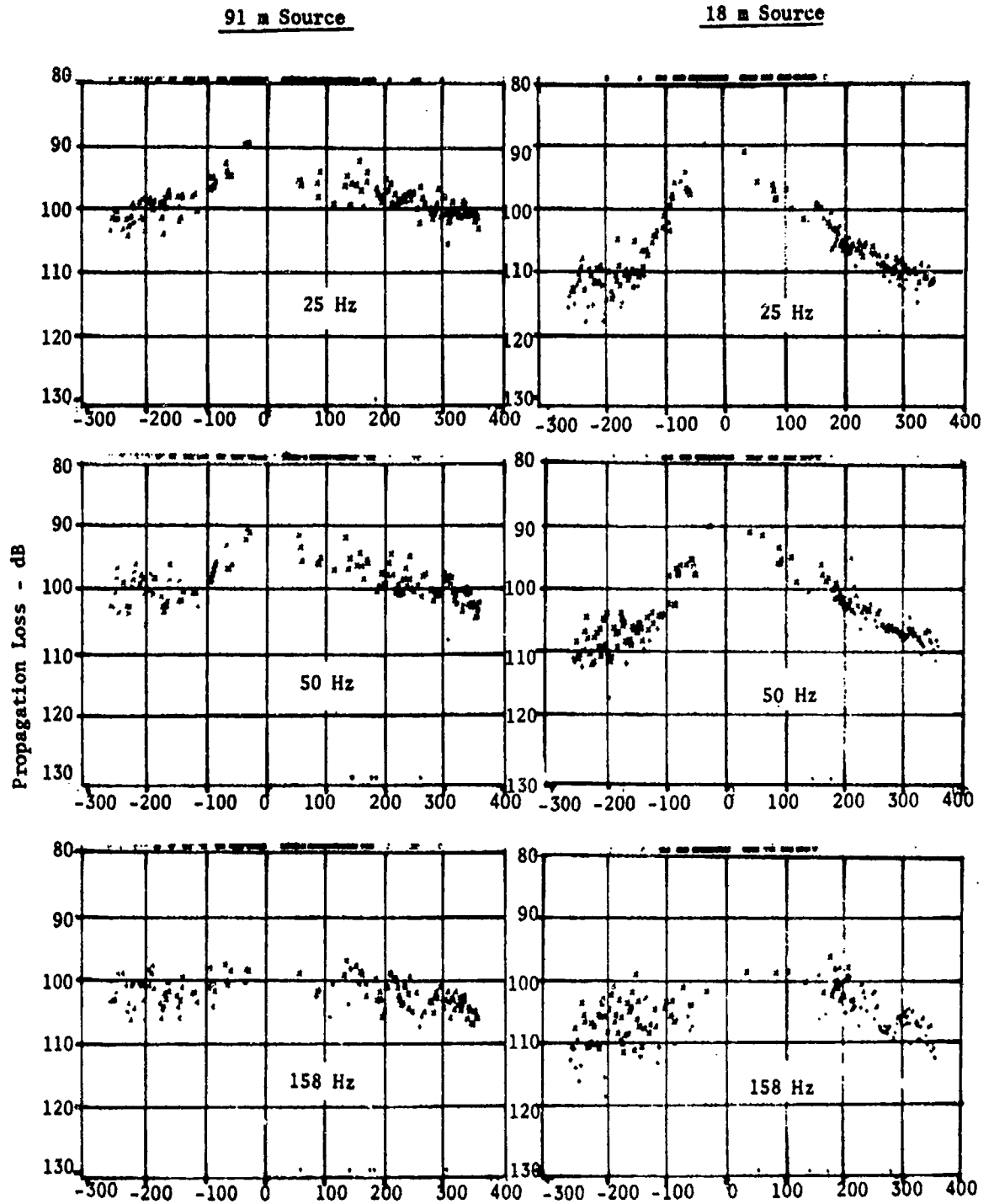
a. ACODAC, Site 2C

(U) The receiver depths at Site 2C are shown in Table III-1. One hydrophone, at 3147 m, is well below the critical depth. Propagation loss from both source depths to the 2445 m receiver is shown in Fig. III-4; loss from the 18 m source at 25 Hz to all receivers is shown in Fig. III-5. Range averaged propagation loss versus frequency to all receivers is given by Figs. III-6.

(1) Range Dependence

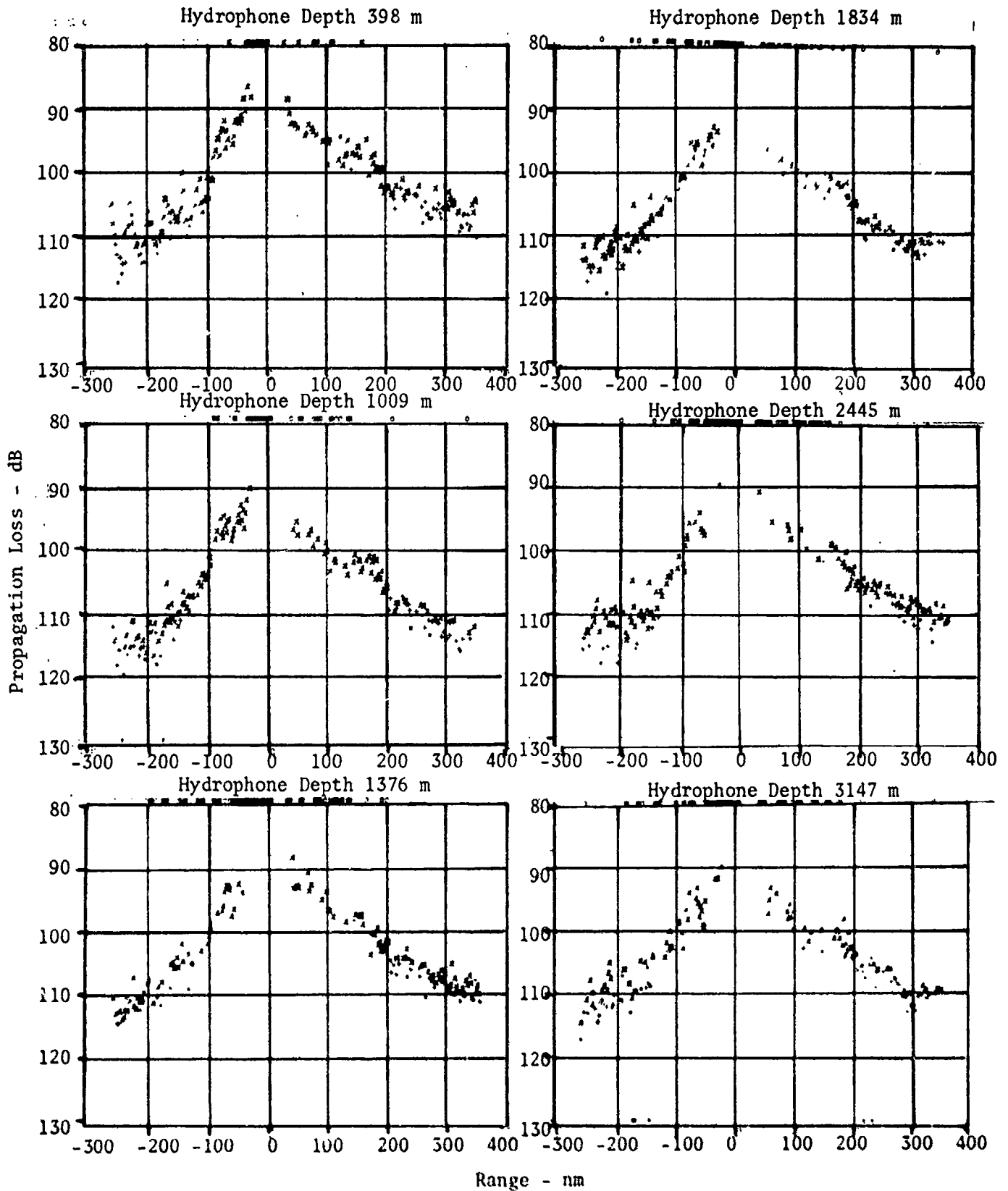
(C) Several features of the propagation to this site are illustrated in Figs. III-4 and III-5. Average propagation loss increases regularly with range both NE and SW of Site 2C. From 18 m depth source, the rate of propagation loss increase is greater from sources SW of the site than from sources NE of the site so that, at 300 nm range, the propagation loss is from 5 to 10 dB higher from sources to the SW. This may be related to the shallower upper channel axis depth NE of Site 2C, which would allow better coupling from the shallow sources. The rate of increase of loss with range is more symmetrical for the 91 m source depth. In general, at this site, the rate of increase of loss with range from the

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Range - nm  
FIGURE III-4  
PROPAGATION LOSS - SITE 2C, EVENT 14b  
2445 m Receiver  
Two Source Depths  
25, 50, and 158 Hz

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SKM



Range - nm  
FIGURE III-5  
PROPAGATION LOSS - SITE 2C, EVENT 14b  
Six Receiver Depths  
18 m Source  
25 Hz Frequency

AS-76-865  
SKM

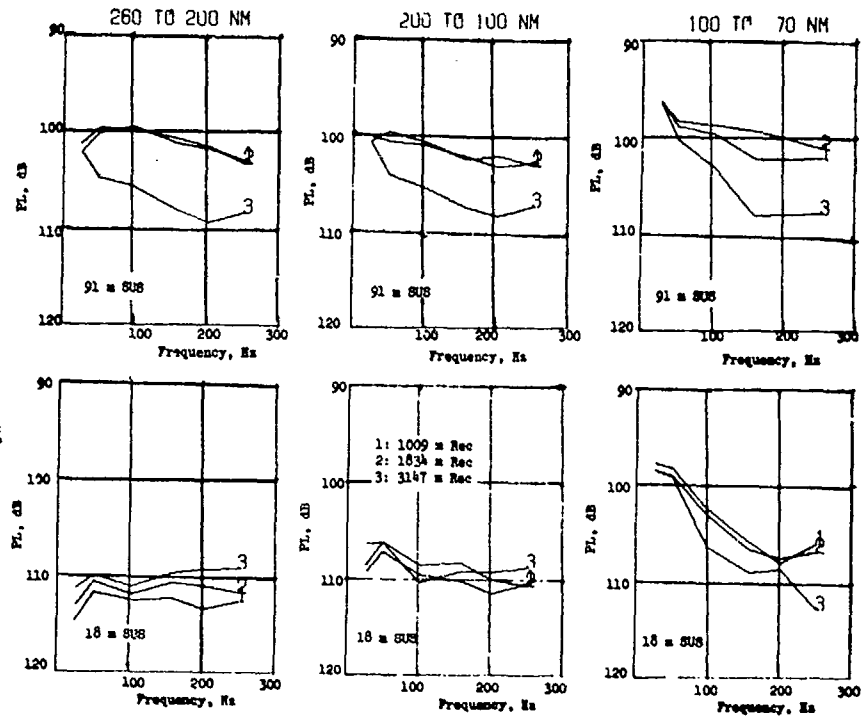


FIGURE III-6a

RANGE AVERAGED PL versus FREQUENCY - SITE 2C, EVENT 14b

Sources Southwest of Site 2C  
 1009 m, 1834 m, 3147 m Receivers  
 Two Source Depths

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 SKM



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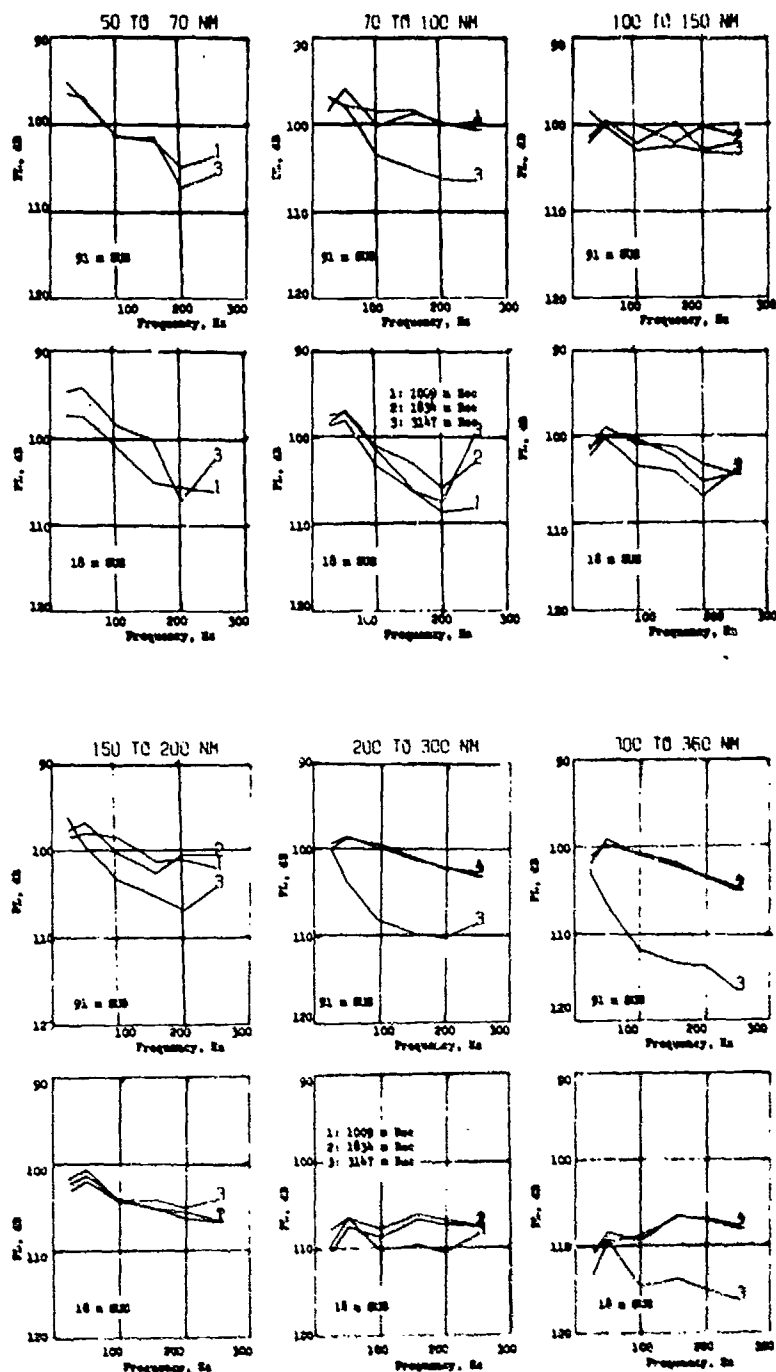


FIGURE III-6b

RANGE AVERAGED PL versus FREQUENCY - SITE 2C, EVENT 14b

Sources Northeast of Site 2C  
 1009 m, 1834 m, 3147 m Receivers  
 Two Source Depths

AS-76-867  
 SKM

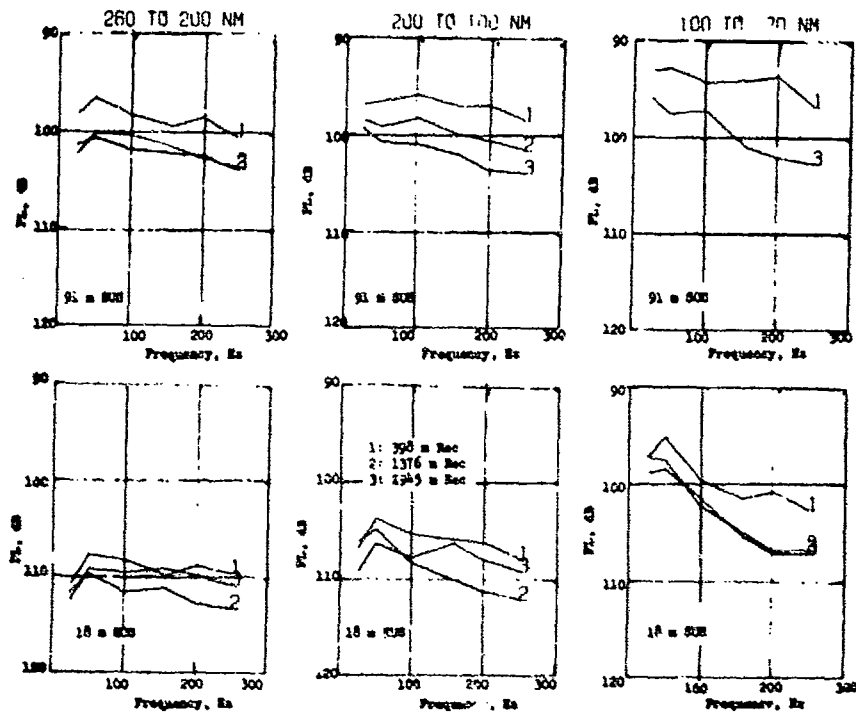


FIGURE III-6c

RANGE AVERAGED PL versus FREQUENCY - SITE 2C, EVENT 14b

Sources Southwest of Site 2C  
 398 m, 1376 m, 2445 m Receivers  
 Two Source Depths

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 SKM

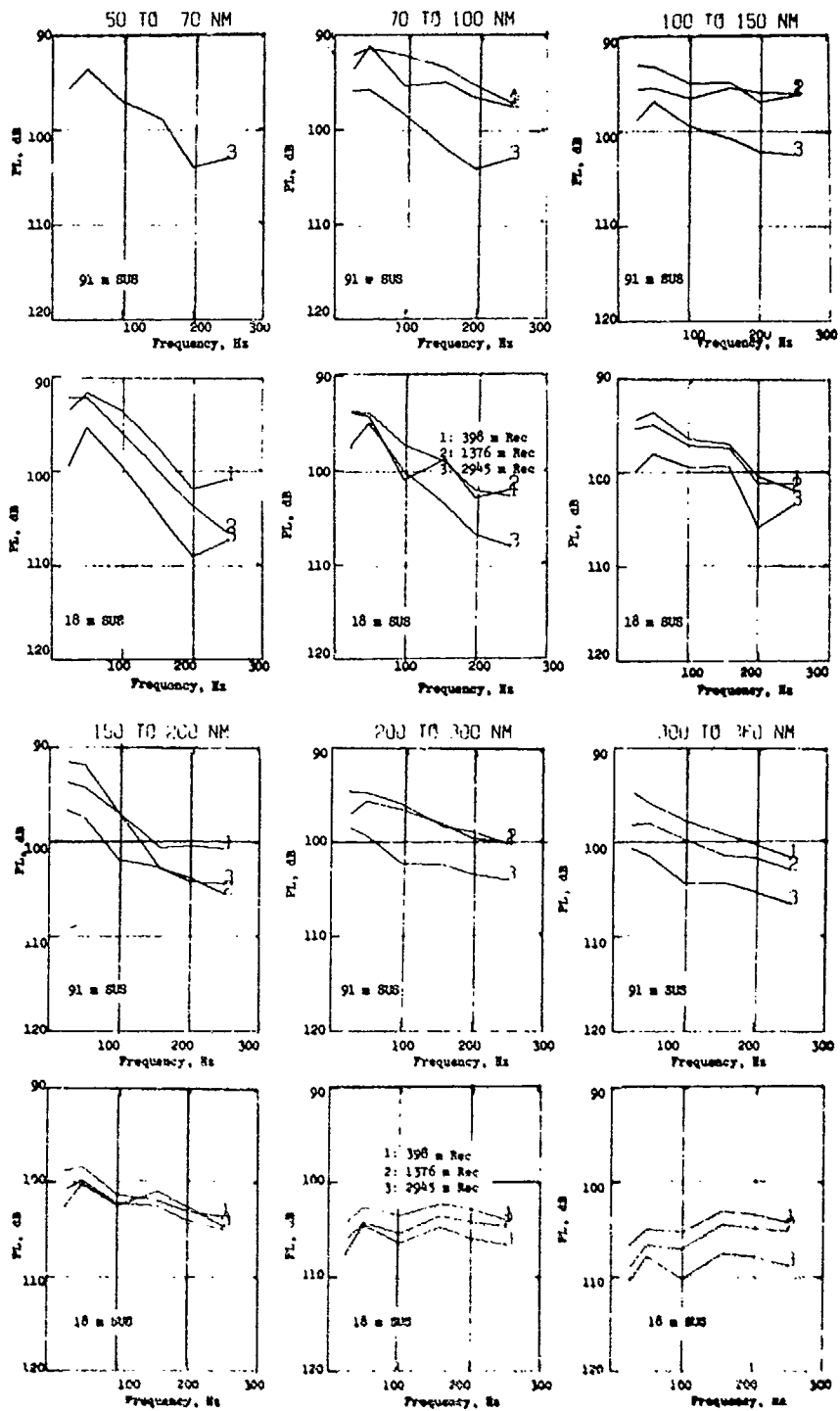


FIGURE III-6d

RANGE AVERAGED PL versus FREQUENCY - SITE 2C, EVENT 14b

Sources Northeast of Site 2C  
 398 m, 1376 m, 2445 m Receivers  
 Two Source Depths

(C) 18 m sources is greater than from the 91 m sources. This source depth effect is most evident at 25 Hz and least evident at 158 Hz.

(2) Source Depth Dependence

(C) Propagation loss averaged over range intervals is shown in Fig. III-6. These show that the loss from the 91 m sources is less than from the 18 m sources. Details of the source depth dependence vary with source location in the following manner. From the SW, there is 8 dB to 10 dB more loss from the 91 m sources at all frequencies, whereas from the NW the mean difference is approximately 5 dB at 158 Hz and 10 dB at 25 Hz.

(3) Receiver Depth Dependence

(C) Receiver depth dependence is shown by the data in Figs. III-5 and III-6. The maximum difference between propagation loss to the different receiver depths is 12 dB, and is usually less than 10 dB. To the five shallowest hydrophones (398 m to 2445 m), the variation is generally less than 5 dB. As may be seen from Fig. III-6, the loss to the deepest hydrophone (3147) is generally greater than the loss to the other receivers; this effect is greater at higher frequencies (with less than 1 dB difference among the hydrophone depths at 25 Hz) and for the 91 m sources.

(4) Frequency Dependence

(C) Frequency dependence at Site 2C is interrelated with source depth and range dependence. As shown in Fig. III-6, from the deep sources, the propagation loss increases with frequency. From ranges less than 200 miles, Fig. III-6 shows that, on the average, the loss also increases with frequency for the 18 m sources. For longer ranges, the frequency dependence for the 18 m sources shows the influence of the Lloyd's Mirror effect, with a minimum loss at 158 Hz. This range variable frequency dependence is further illustrated in Fig. III-7, which shows the difference between propagation loss at different frequencies from individual shots.

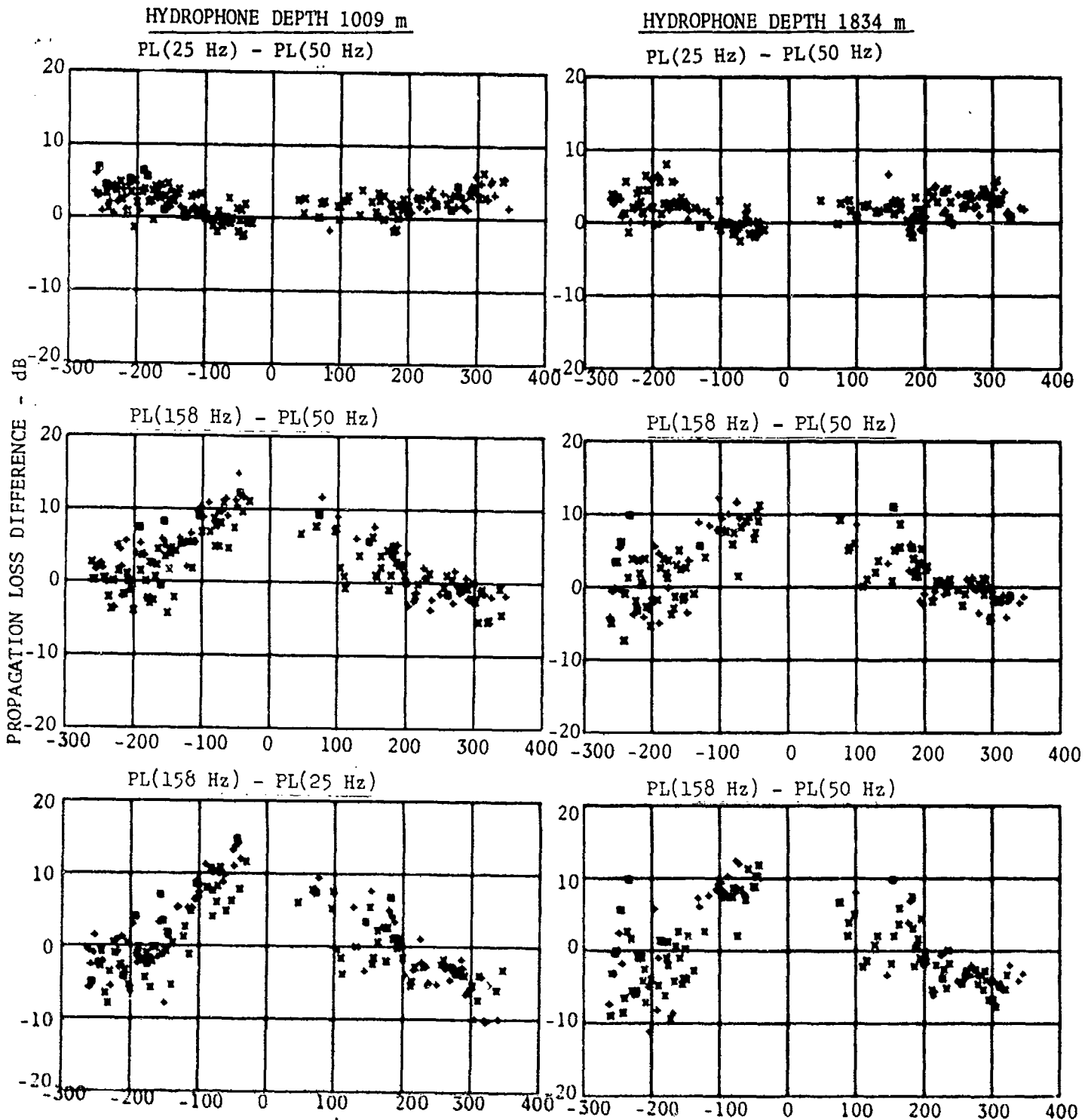


FIGURE III-7  
PROPAGATION LOSS DIFFERENCES - SITE 2C, EVENT 14b  
1009 m and 1834 m Receivers  
18 m Source Depth  
Differences Among PL at 25, 50, and 158 Hz

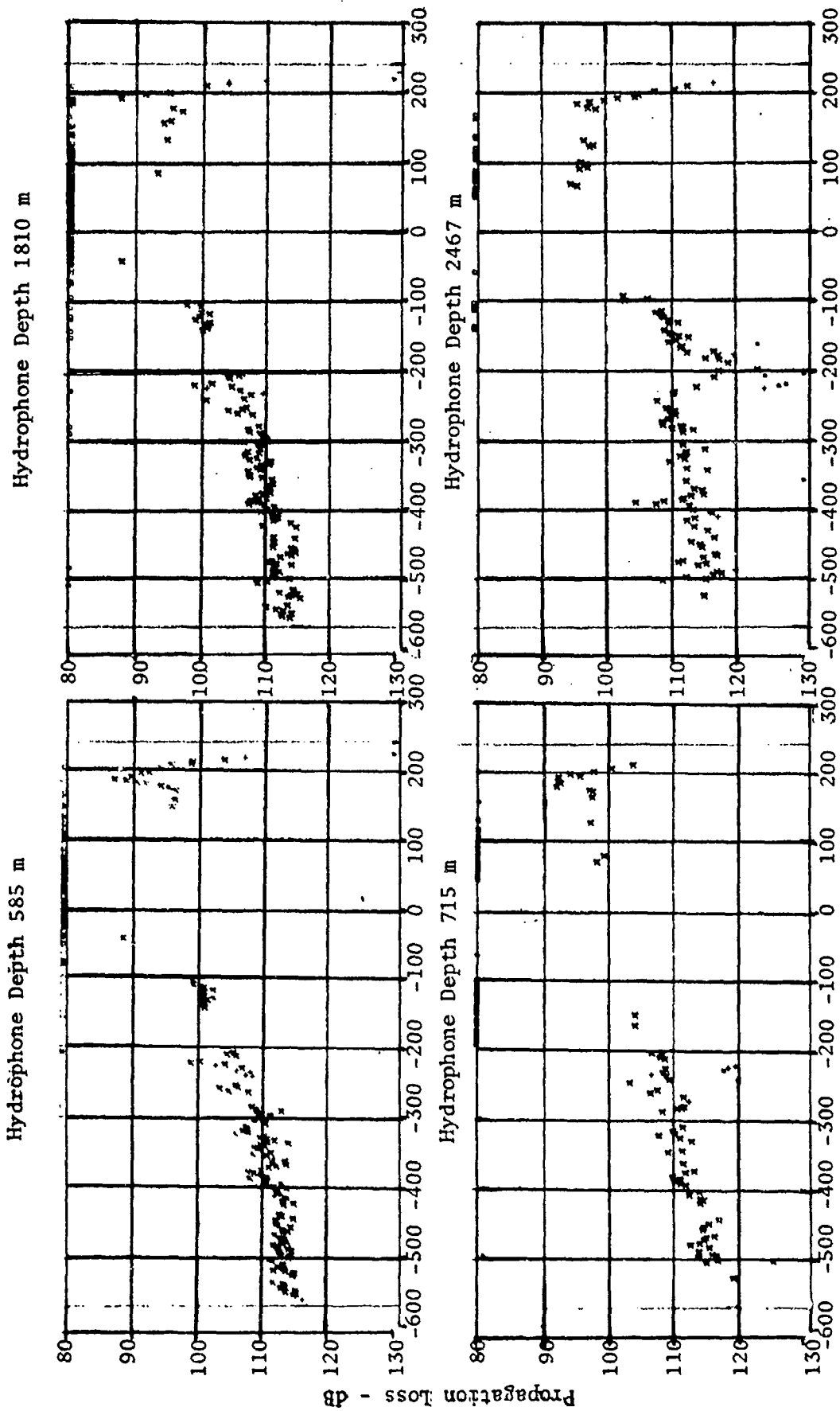
b. ACODAC, Site 2D

(U) The data analyzed from Site 2D were from hydrophones at 585 m and 715 m depth, both of which are between the upper sound channel axis and the intermediate maximum; at 1810 m, which is 310 m below the deep sound channel axis; and at 2467 m, just 70 m below critical depth but only 330 m above the bottom. Propagation loss at 50 Hz from the 18 m sources to these receivers is shown in Fig. III-8; range averaged propagation loss versus frequency is shown in Fig. III-9.

(1) Range Dependence

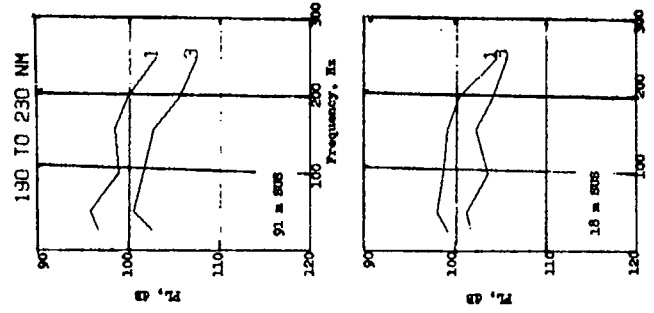
(C) Several features of the propagation to Site 2D are shown by the data in Fig. III-8. The short range data are obscured by overloads; however, there is an obvious asymmetry between the loss from sources NE and SW of the site. This asymmetry is related in the following paragraphs to topography and to the sound speed profile shown in Fig. III-2.

(C) Consider first propagation from sources SW of the site. As shown in Fig. III-8, propagation at 50 Hz from the 18 m source depth to the deepest (2467 m) receiver exhibits a very rapid increase in loss with range out to about 200 nm, and then a recovery to lower loss at about 250 nm, beyond which the loss increases only gradually with range. Though less pronounced, a similar behavior is suggested by the data for the 1810 m receiver. For these two receiver depths, this same behavior is shown by the data for the 91 m source depth and for frequencies of 25 and 158 Hz. Propagation to these deep receivers is apparently being strongly influenced by bathymetry. As shown in Fig. III-2, SW of the site bottom depth is only about 2800 m out to about 175 nm, and beyond increases to an average value larger than 4000 m for ranges greater than 225 nm. At 150 nm SW of Site 2D, there is no depth excess. This topographic influence west of Site 2D is much less of a factor in propagation to the two shallowest hydrophones, especially to the one in the upper sound channel at 585 m.



Range - nm  
 FIGURE III-8  
 PROPAGATION LOSS - SITE 2D, EVENT 14b  
 Four Receiver Depths  
 18 m Source Depth  
 50 Hz

NORTHEAST OF SITE 2D



SOUTHWEST OF SITE 2D

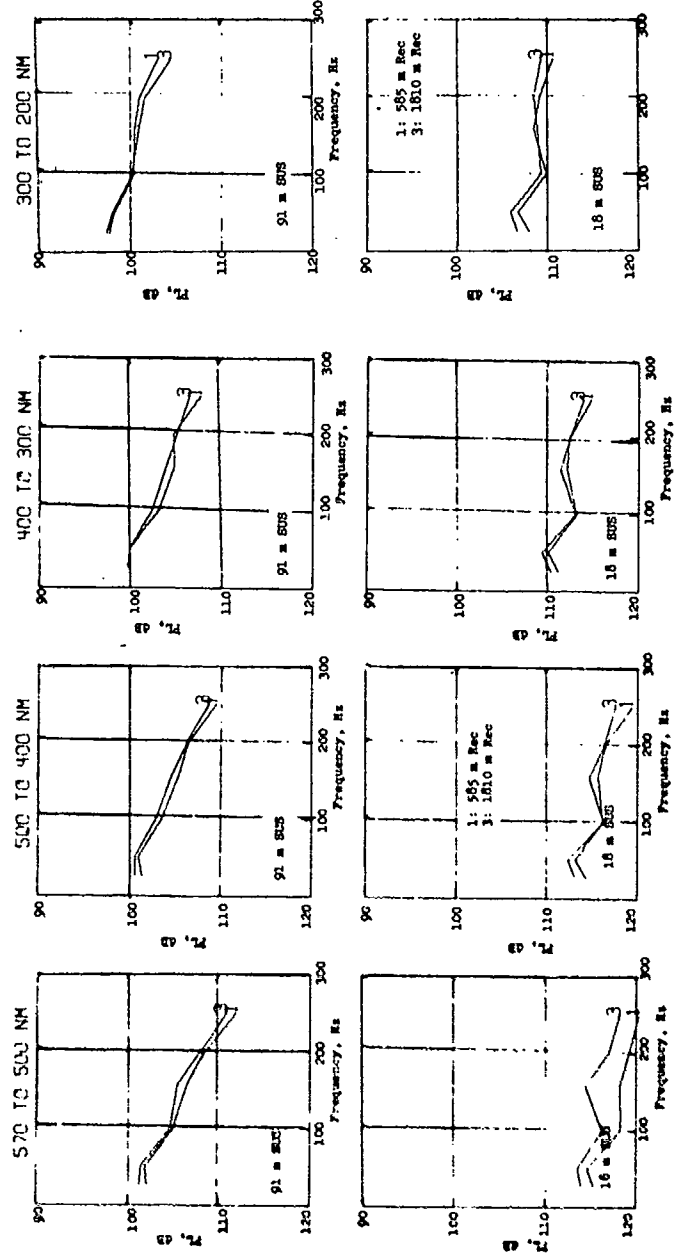


FIGURE III-9a

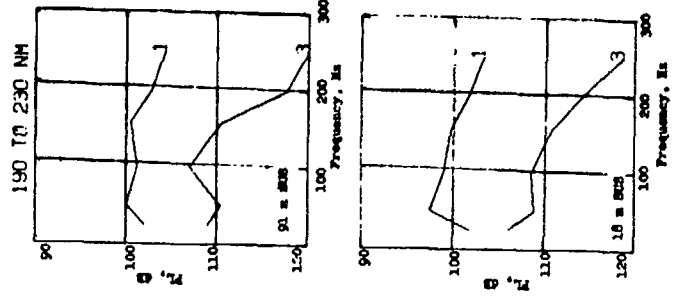
RANGE AVERAGED PL vs FREQUENCY - SITE 2D, EVENT 14b

585 m, 1810 m Receivers

Two Source Depths



NORTHEAST OF SITE 2D



SOUTHWEST OF SITE 2D

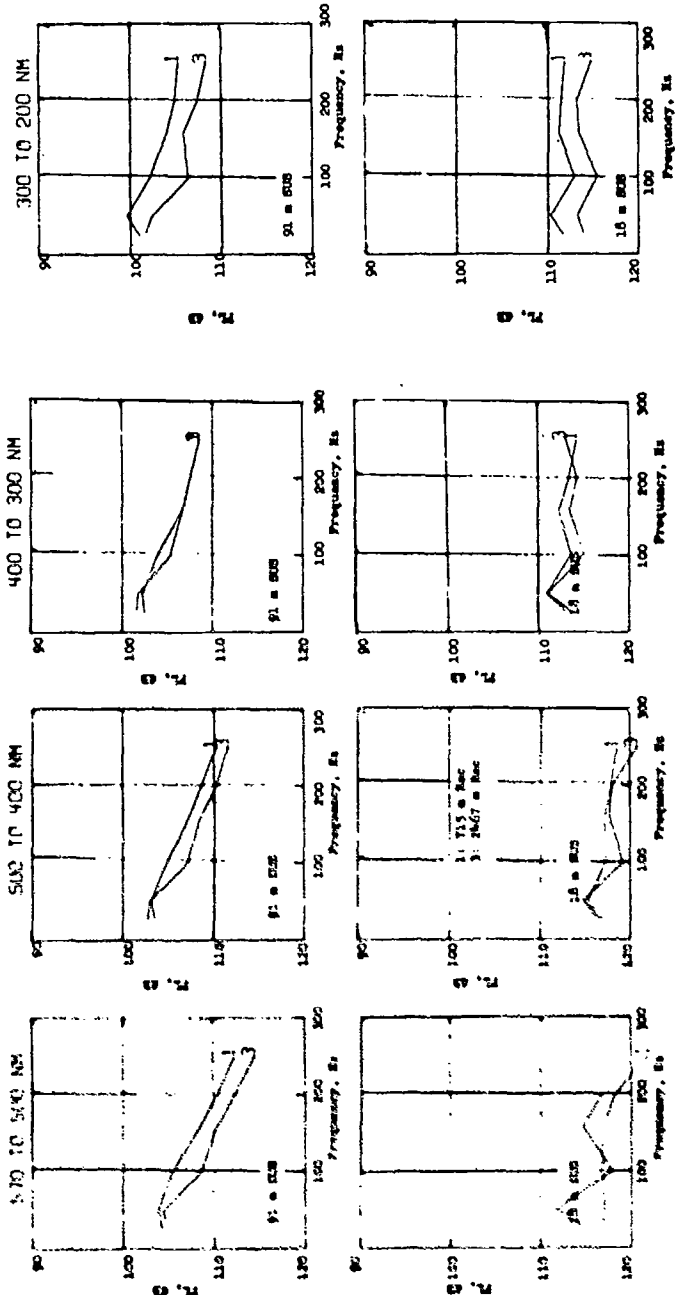


FIGURE III-9b  
 RANGE AVERAGED PL vs FREQUENCY - SITE 2D, EVENT 14b  
 715 m, 2467 m Receivers  
 Two Source Depths

(C) With sources NE of the site, an even stronger topographic influence is exhibited. As shown in Fig. III-2, the depth becomes gradually shallower NE of Site 2D, reaching 2000 m at 180 nm. The very steep rise up to the 150 m Scotland Shelf depth then occurs over an interval of less than 10 nm. A slope enhancement (reduced loss) of up to 10 dB is shown at 190 nm range for all receiver depths (Fig. III-8). As RFA OLMEDA moves over the shallow Scotland Shelf, a rapid increase of loss with range is observed at all receiver depths at Site 2D. These same general features are exhibited by the data at 25 and 158 Hz and also for the 91 m source depth at all three frequencies.

(2) Source Depth Dependence

(C) As was seen at Site 2C, the data at Site 2D indicate a more rapid increase of loss with range from the 18 m sources than from the 91 m sources. Although the loss for the two source depths is of similar magnitude at short ranges, the higher rate of increase with range results in as much as 15 dB higher loss from the 18 m sources at 550 nm range SW. This source depth dependence is further illustrated by the range averaged data shown in Fig. III-9.

(3) Receiver Depth Dependence

(C) Receiver depth dependence is also shown by Fig. III-9. As previously described, the deepest (2467 m) hydrophone exhibits a high loss for ranges less than about 250 nm. Beyond 300 nm range, maximum difference between loss to the different receiver depths is on the order of 5 dB with minimum loss being shown by the two hydrophones which were closest in depth to the two sound channel axes (i.e., the hydrophones at 585 m and 1810 m depth).

(4) Frequency Dependence

- (C) Figure III-9 shows that, at Site 2D, the frequency dependence of the propagation loss from the shallow sources is markedly different from what is seen in most of SQUARE DEAL. There is a minimum in propagation loss at 25 Hz or 50 Hz for both source depths. That is, the Lloyd's Mirror effect does not dominate propagation from the 18 m sources; this is evidence that bottom reflected components constitute a significant portion of the arriving signals. From the 18 m sources, the loss at 200 Hz is approximately 3 dB higher than the loss at 25 Hz. From the 91 m sources, the 200 Hz loss is 6 to 10 dB higher than the 25 Hz loss.

c. SURVEY Array, Site 2B

- (U) At this site, near Site 2BB of Fig. III-1, on the sloping side of Porcupine Bank at the edge of Rockall Trough, the hydrophone is on the bottom at 1728 m depth. The RFA OLMEDA source run (Event 14b) is not radial to Site 2B, but passes within 65 nm of this site.

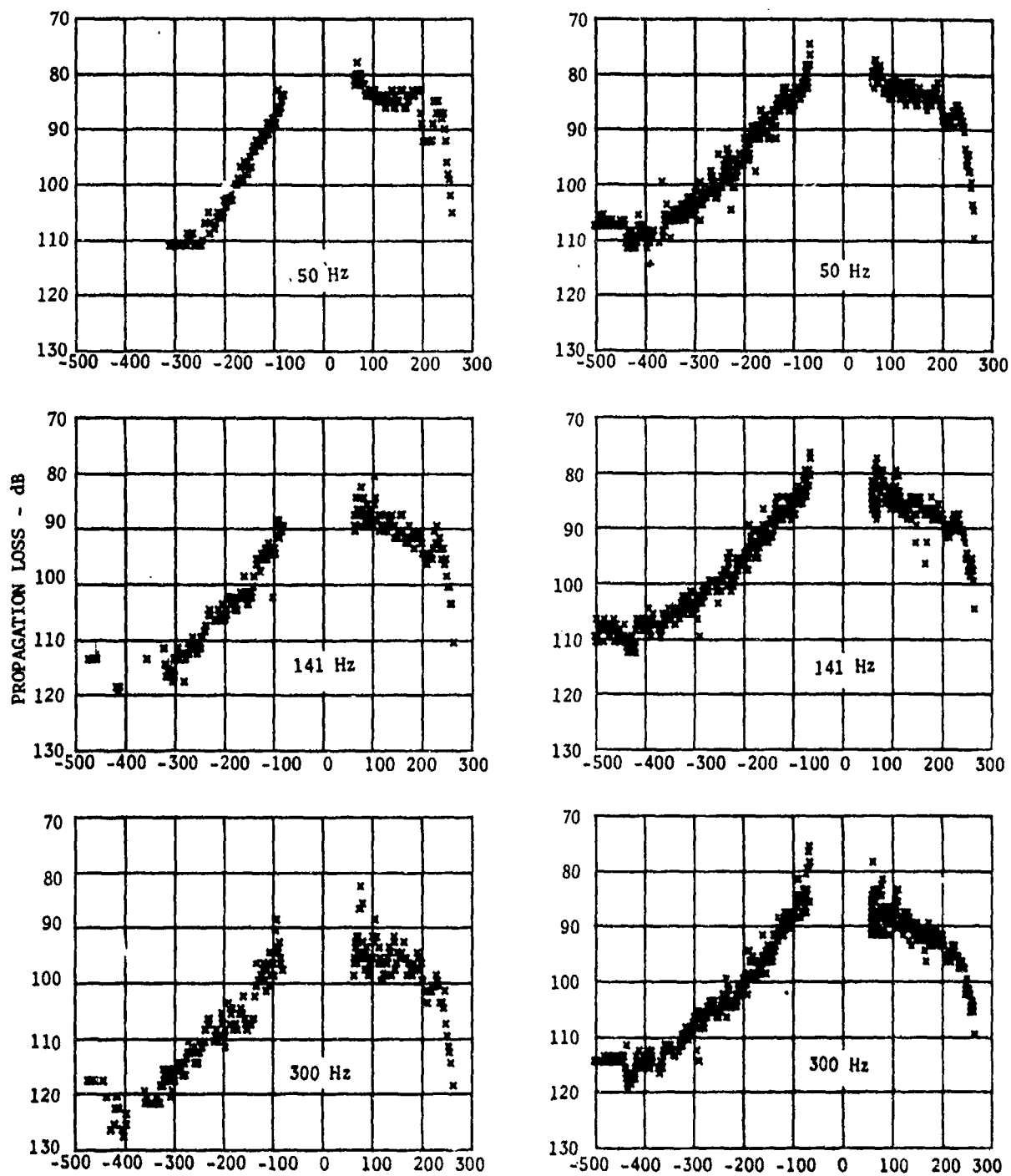
(1) Range Dependence

- (C) In Fig. III-10, propagation loss to Site 2B for Event 14b is shown for source depths of 18 and 91 m at frequencies of 50, 141, and 300 Hz. The loss increases with range much faster from sources SW of Site 2B than it does from sources NE of the site; at 150 nm, the loss from the SW is nominally 10 dB greater than the loss from the NE. This is because the path to Site 2B from sources to the SW is bottom limited across the shoulder of Porcupine Bank, as may be seen in Fig. III-1. To the NE, the source track passes onto the shallow Scotland Shelf at about 200 nm range and propagation loss rapidly increases with further range increase. There is some slope enhancement seen at approximately 230 nm range.

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18 m SOURCE

91 m SOURCE



RANGE - nm  
FIGURE III-10  
PROPAGATION LOSS - SITE 2B, EVENT 14b  
1728 m Receiver  
Two Source Depths  
50, 141, and 300 Hz

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SKM

(2) Source Depth Dependence

- (C) The propagation loss from the 18 m sources is greater than the loss from the 91 m sources, with the difference depending upon source location. From the SW of Site 2B, the difference is approximately 5 to 10 dB, while from the NE the difference is approximately 0 dB at 50 Hz and 3 dB at 141 and 300 Hz.

(3) Frequency Dependence

- (C) These data exhibit an increase of loss with frequency for both source depths similar to that seen at Site 2D.

d. ANB, Site 2BB

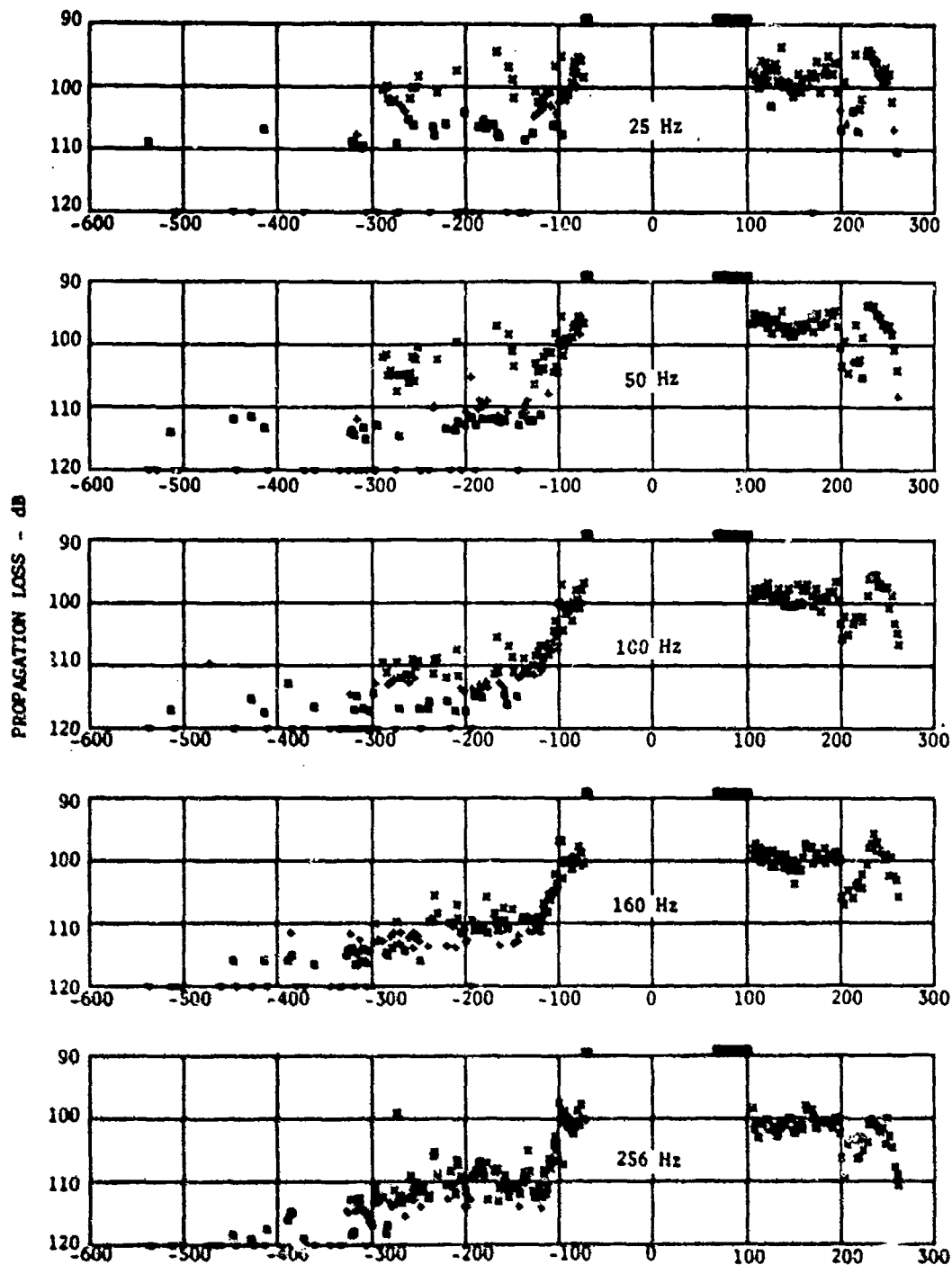
- (U) This ANB system is located in 855 m of water on the Porcupine Bank (Figs. III-1 and III-3). Hydrophone depths are 300 m and 610 m. The site is at the top of a steeply sloping bottom which rises out of the Rockall Trough (the location of the RFA OLMEDA source run). Water depth at the site is less than the deep sound channel axis depth in the nearby Rockall Trough (Fig. III-3) and is almost as shallow as the intermediate maximum in the sound speed profile.

(1) Range Dependence

- (U) Propagation loss for RFA OLMEDA source run to the 300 m receiver is shown in Figs. III-11a and III-11b, and to the 610 m receiver in Figs. III-12a and III-12b. The source run is nonradial to Site 2BB and the range of closest approach is 65 nm.
- (C) In agreement with the data from the SURVEY array at Site 2B, the ANB (Site 2BB) data exhibit a much more rapid increase of propagation loss with range for sources SW of the site than for sources NE of the site. From the 18 m sources, the difference is approximately 10 dB at 150 nm

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18 m SOURCE

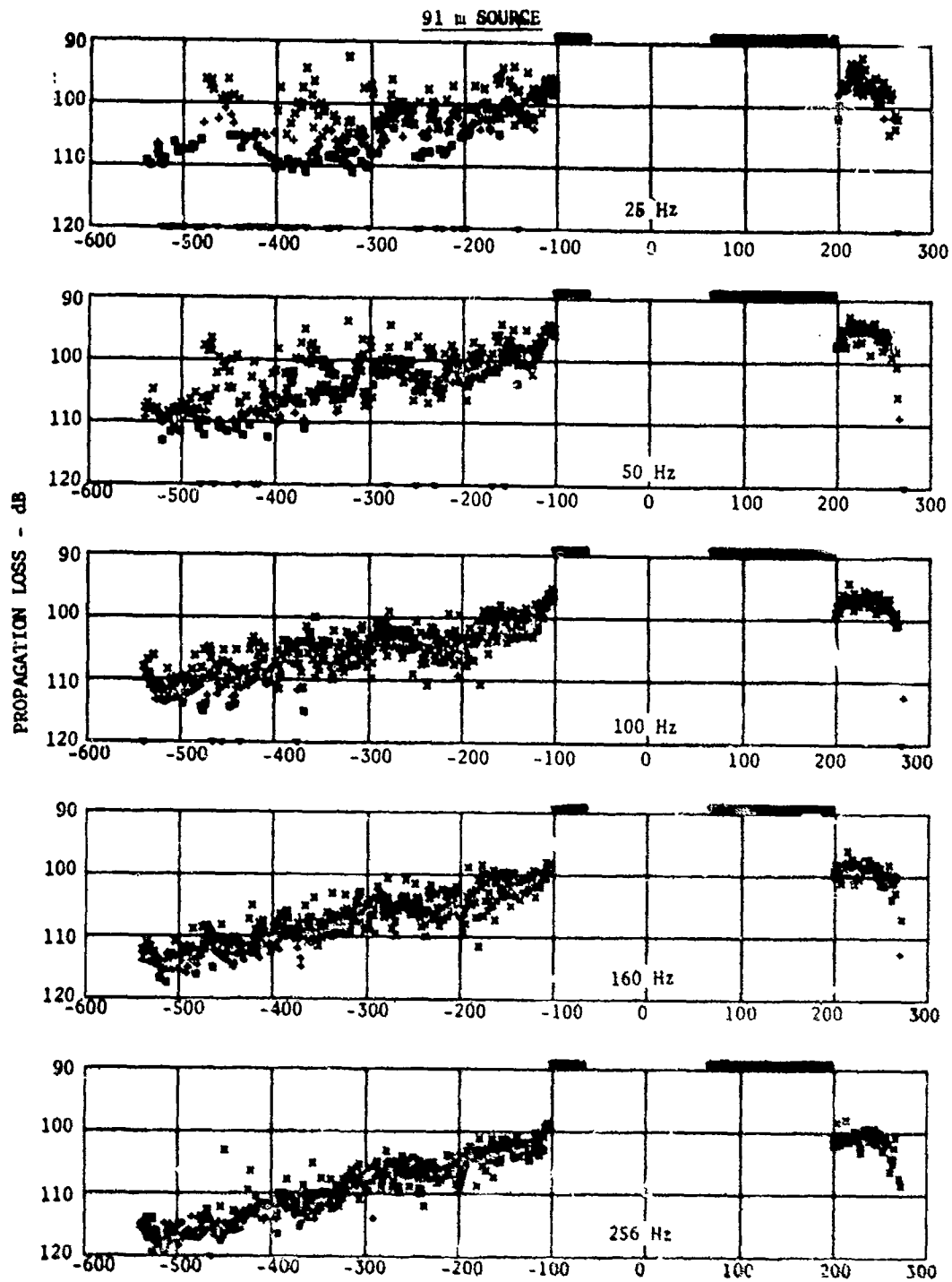


RANGE - nm  
FIGURE 111-11a  
PROPAGATION LOSS - SITE 288, EVENT 14b  
300 m Receiver  
18 m Source  
25, 50, 100, 160, and 256 Hz

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S104

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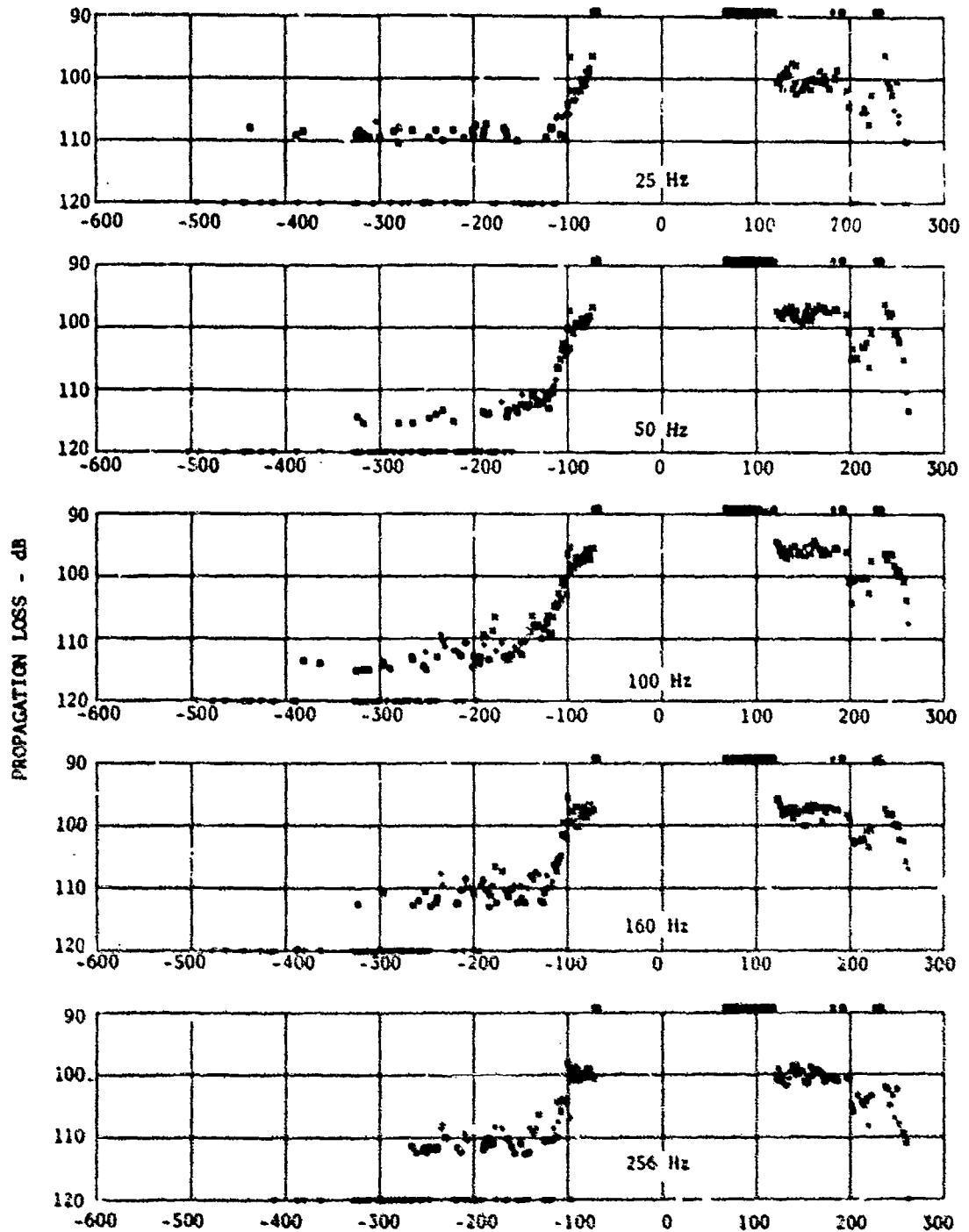
AS-76-876  
SAX

66

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# UNCLASSIFIED

18 m SOURCE



RANGE - m

FIGURE III-12a

PROPAGATION LOSS - SITE 288, EVENT 14b

610 m Receiver

18 m Source

25, 50, 100, 160, and 256 Hz

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SKM

# UNCLASSIFIED



# UNCLASSIFIED

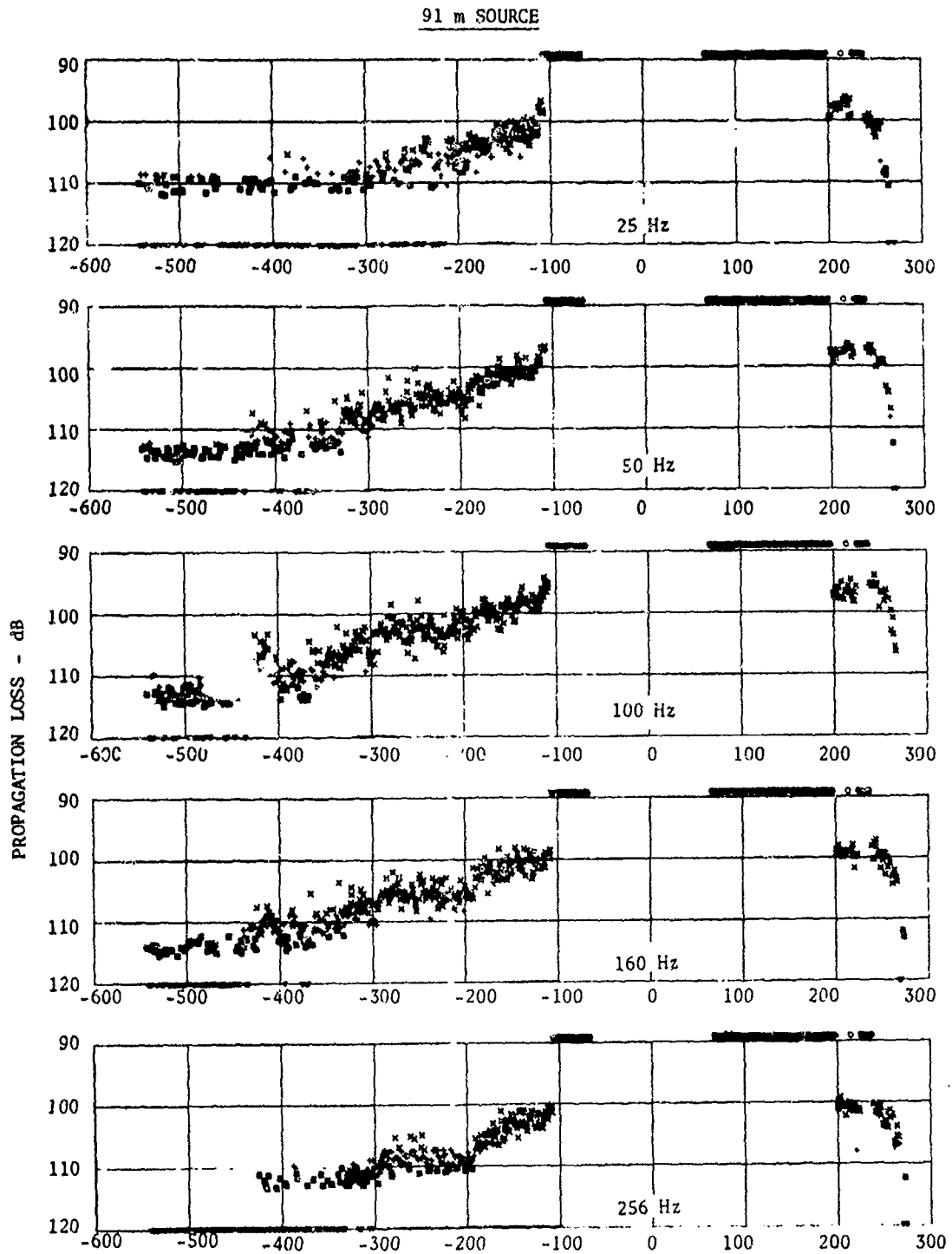


FIGURE III-12b  
PROPAGATION LOSS - SITE 2BB, EVENT 14b  
610 m Receiver  
91 m Source  
25, 50, 100, 160, and 256 Hz

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(C) range; overloading obscures the effect for the 91 m sources. At the higher frequencies, slope enhancement, similar to that previously noted for Sites 2B and 2D is evident for sources at a range of about 225 nm NE of the receiver.

(C) Propagation from sources SW of Site 2BB is partially blocked by Porcupine Bank; the effect of the blockage varies with source and receiver depth, and frequency. From 91 m sources in this region, propagation loss at 25 and 50 Hz to the 300 m receiver is 6 to 10 dB less than the loss to the 600 m receiver (the 300 m data also show much more scatter). At the higher frequencies, there is little difference between the receiver depths. (The 18 m shots are weakly detected from sources in this area.)

## (2) Source Depth Dependence

(C) At all frequencies, the loss at a given range is greater from the 18 m sources than from the 91 m sources. The low signal-to-noise ratio for the 18 m shots makes the difference difficult to estimate (Figs. II-11 and II-12); nominally, the difference is 10 dB at 50 and 100 Hz, and 6 dB at the other frequencies.

## (3) Receiver Depth Dependence

(C) Very little receiver depth dependence is shown for sources NE of the site (compare Figs. III-11 and III-12). However, the 600 m receiver depth shows much higher losses than the 300 m receiver depth for sources to the SW, as noted.

## e. Comparison of Receiver Sites

(C) For the ACODACs at both Sites 2C and 2D, data are available for one hydrophone near 1800 m depth and another near 2450 m depth. The range between Sites 2C and 2D is approximately 300 nm. From both the 18 m

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(C) and 91 m sources located between the two sites, the propagation losses seen at the 1800 m receivers over the 300 nm range interval are essentially the same at both sites. However, to the near 2450 m depth receiver, the loss is about 10 dB greater at Site 2D than at Site 2C for ranges out to 200 nm; the levels are about the same at 300 nm. This is an effect of the topography described above for the deeper receivers at Site 2D (Section III-2b).

### 3. Aircraft Source Run, Event 12m

(U) This run is radial to Site 2B at a bearing of  $282^\circ$ ; the track crosses the RFA OLMEDA (Event 14b) track at a range of about 100 nm from Site 2B (see Fig. III-1). Sources were deployed at ranges out to 450 nm from Site 2B. This track passes over the SW edge of Rockall Bank; approximately 160 nm from Site 2B, depth excess (approximately 2500 m) is lost.

#### a. SURVEY Array, Site 2B

(C) As shown by Fig. III-13, propagation loss from the 91 m sources increased with range to a measured value at Site 2B of approximately 85 dB at 160 nm. Beyond that range the rate of increase in the propagation loss is greater and the data also shows more scatter. From the 18 m sources, the loss is approximately 3 dB greater than the 91 m loss at ranges less than 160 nm, and 10 dB or more greater (when shots are detectable) at the longer ranges.

(C) The frequency dependence of these data is shown by Fig. III-14; except in one range interval, propagation loss increases with increasing frequency for both source depths. The exception is the 125 to 300 nm range interval over which the deep source data sometimes show the same loss at 50 and 141 Hz and sometimes show higher loss at 50 Hz (decreasing loss with frequency between 50 and 141 Hz).

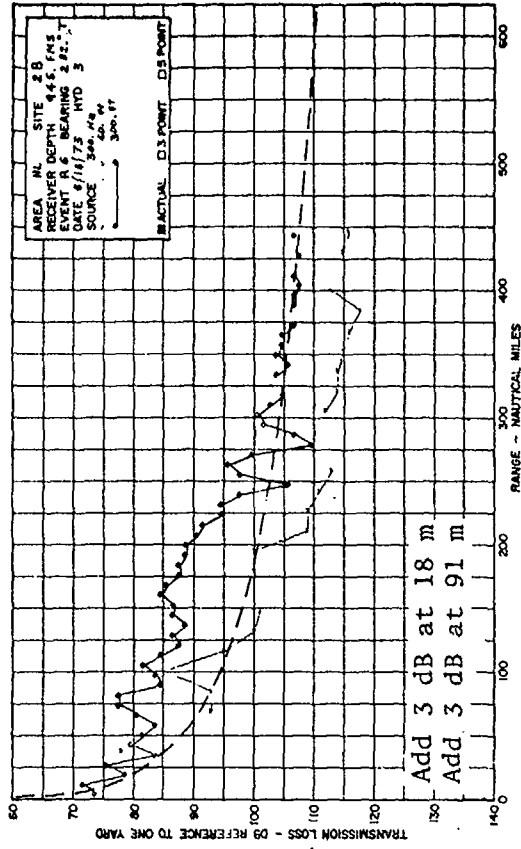
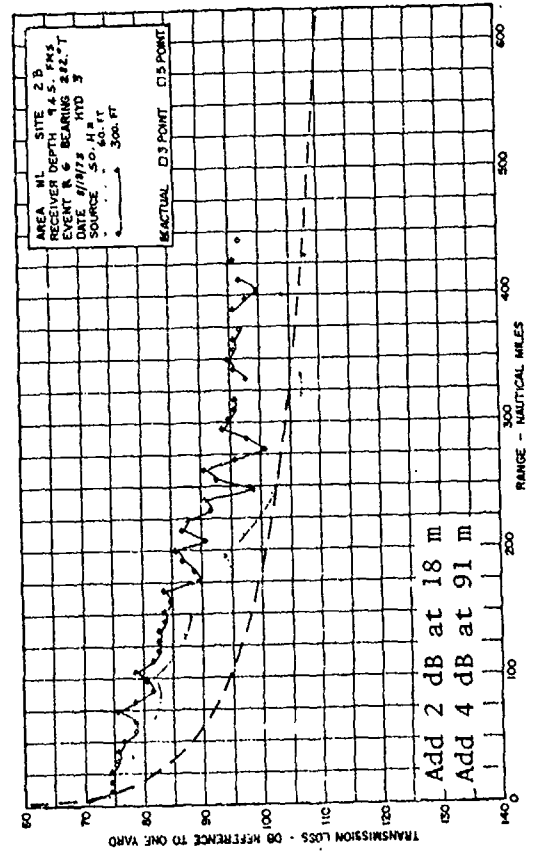
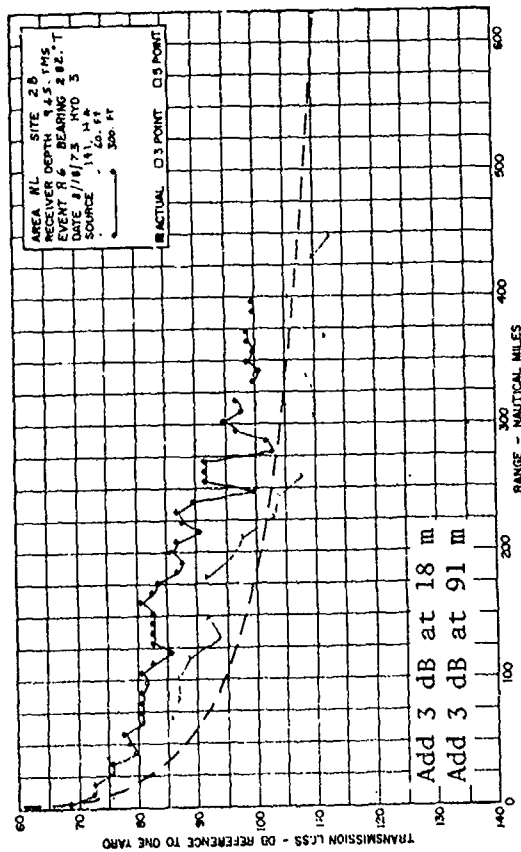


FIGURE III-13

PROPAGATION LOSS - SITE 2B, EVENT 12m  
 1800 m Receiver  
 Two Source Depths (Each Plot)  
 50, 141, and 300 Hz



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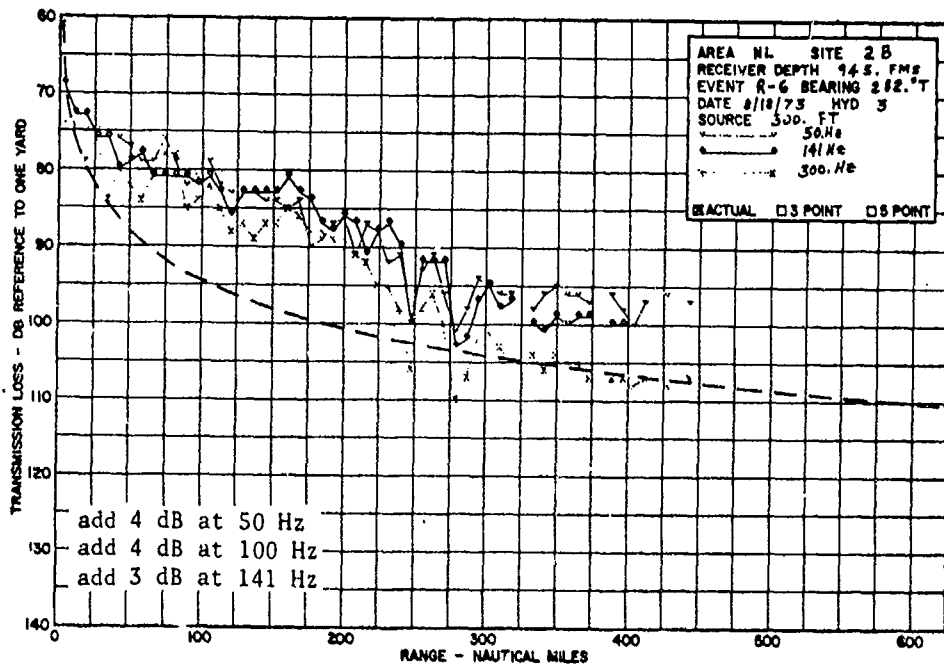
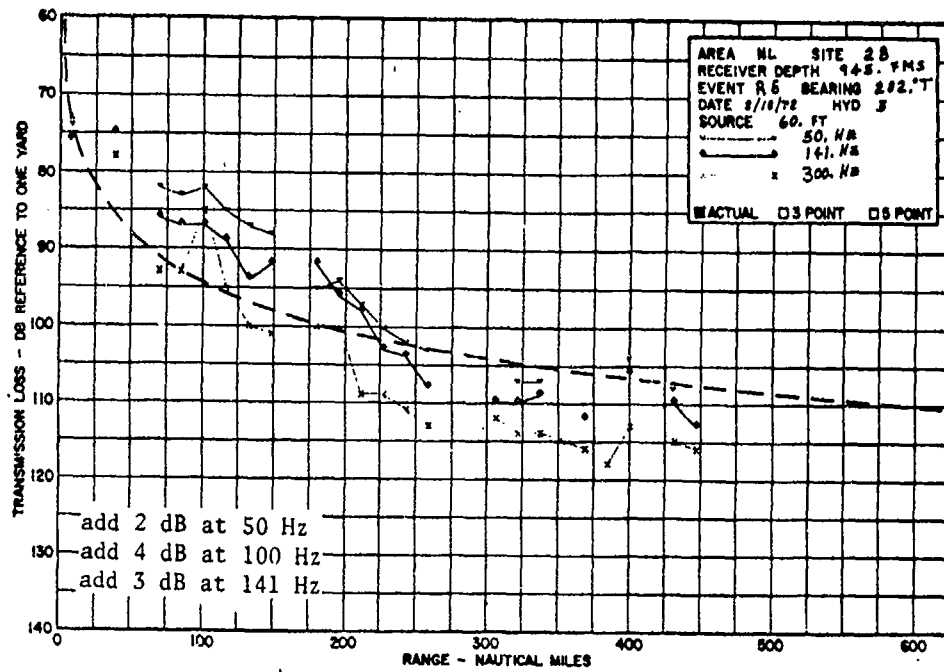


FIGURE III-14

PROPAGATION LOSS - SITE 2B, EVENT 12m

1800 m Receiver  
 Two Source Depths  
 50, 141, and 300 Hz

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## b. ANB, Site 2BB

- (C) As shown by Figs. III-15 and III-16, the shots during Event 12b were poorly detected at this site, especially the 18 m shots. From the 91 m sources, at ranges less than approximately 200 nm, the propagation loss is 95 dB at 100 Hz and less, and 100 dB at 160 and 256 Hz. These values are representative for both receiver depths. Beyond that range the propagation loss increases, say, 3 dB at the lower frequencies and 6 to 10 dB at the higher frequencies. These values for propagation loss are approximately 10 dB greater than those reported for Site 2B (Figs. III-13 and III-14).

## c. ACODAC, Site 2D

- (C) At this site, almost all of the signals from the 18 m sources were not detectable; from the 91 m sources, the signals overloaded the ACODAC out to a range of approximately 200 nm, beyond which depth excess at the source was lost (Figs. III-17 and III-18). The effect of the loss of depth excess is seen at a shorter range on the 2467 m receiver, which is below critical depth (Fig. III-17). The nominal value of 105 dB loss at 200 nm is closer to the 100 dB measured at Site 2BB than to the 90 dB reported at the same range at Site 2B. It is notable that beyond 200 nm the propagation loss in most of the plots of Figs. III-17 and III-18 increases at a nominal rate of 10 dB/100 nm, a much greater increase than was seen at Sites 2B and 2BB. This is probably attributable to there being a longer path across the shallow SW end of Rockall Bank to Site 2D than to Sites 2B and 2BB, as may be seen from Fig. III-1.

## 4. Aircraft Source Run, Event 12k

- (U) This run is radial to Site 2B at a bearing of 5°; sources were deployed out to 550 nm range. Once over Rockall Trough, there is open channel propagation out to 150 nm, beyond which the depth decreases over Rockall Bank (Fig. III-1).

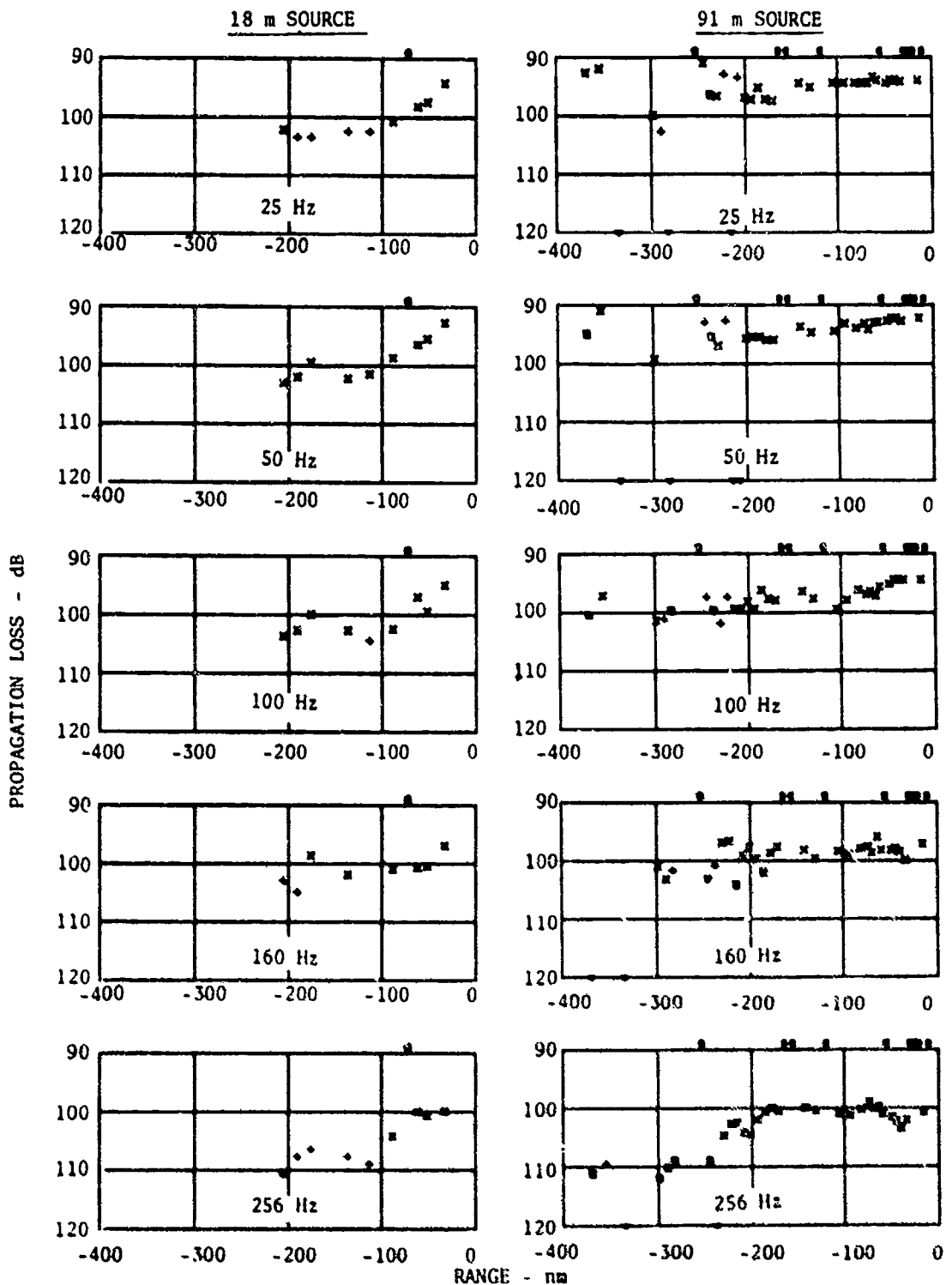
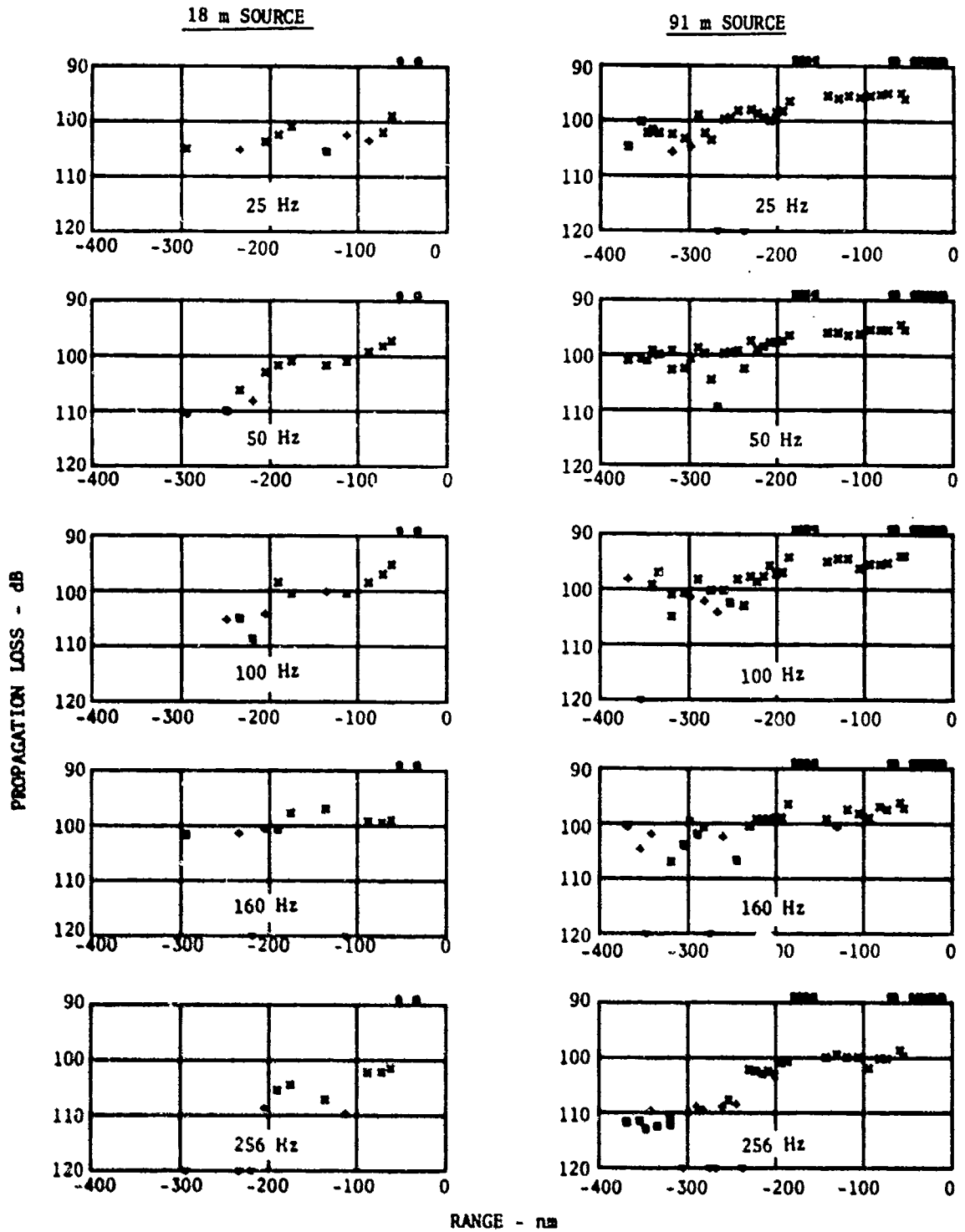


FIGURE III-15  
PROPAGATION LOSS - SITE 28B, EVENT 12m  
300 m Receiver  
Two Source Depths  
25, 50, 100, 160, and 256 Hz

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SKM

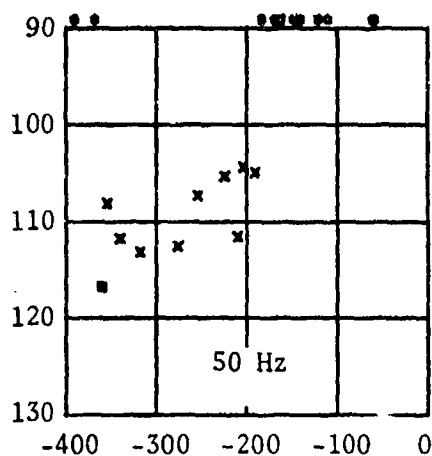


RANGE - nm  
FIGURE III-16  
PROPAGATION LOSS - SITE 2BB, EVENT 12m  
610 m Receiver  
Two Source Depths  
25, 50, 100, and 256 Hz

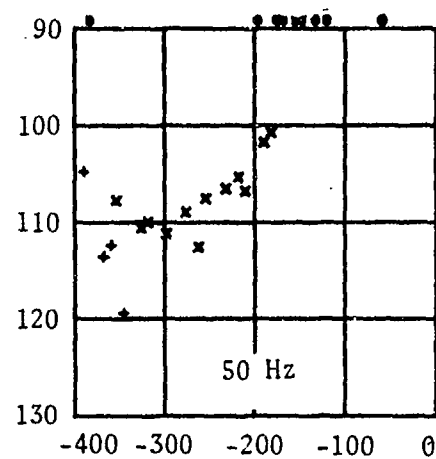
AS-76-882  
SKM



HYDROPHONE DEPTH 585 m

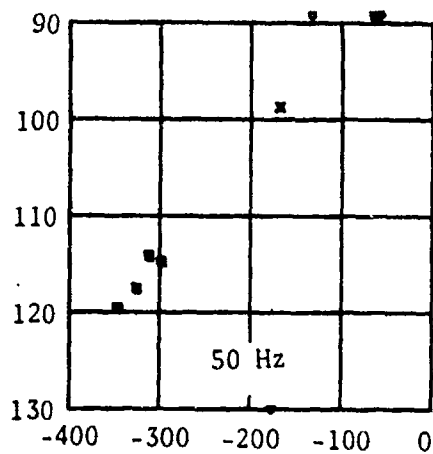


HYDROPHONE DEPTH 1810 m

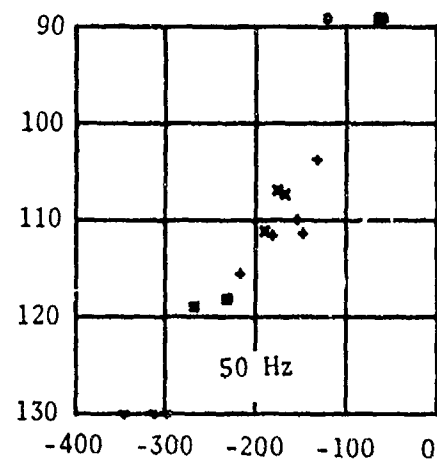


PROPAGATION LOSS - dB

HYDROPHONE DEPTH 715 m

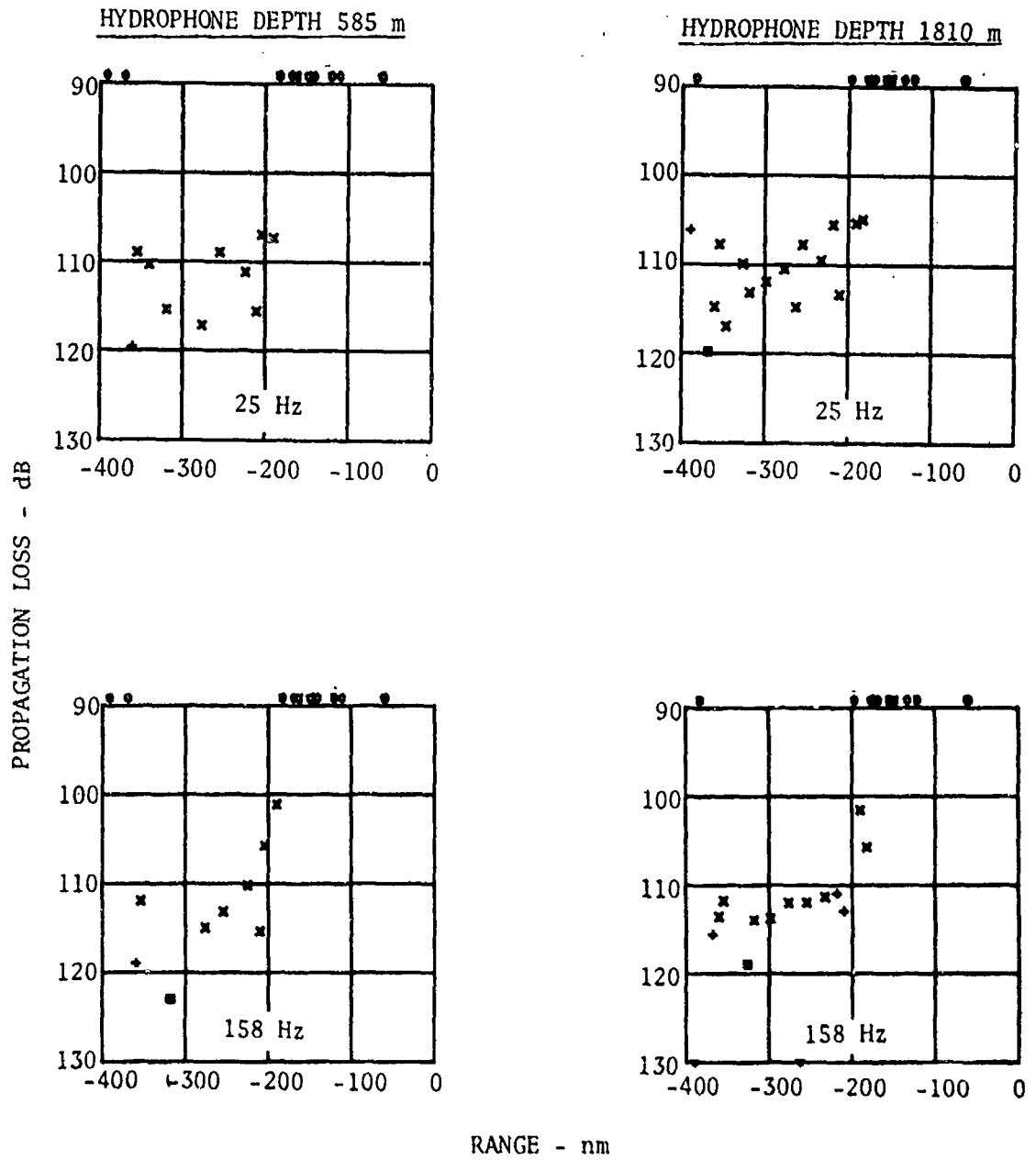


HYDROPHONE DEPTH 2467 m



RANGE - nm

FIGURE III-17  
PROPAGATION LOSS - SITE 2D, EVENT 12m  
Four Receiver Depths  
91 m Source  
50 Hz



RANGE - nm  
 FIGURE III-18  
 PROPAGATION LOSS - SITE 2D, EVENT 12m  
 585 m and 1810 m Receivers  
 91 m Source  
 25 Hz and 158 Hz

a. SURVEY Array, Site 2B

- (c) The propagation loss measured at Site 2B is shown in Figs. III-19 and III-20. The loss along this track is similar to what was shown for Event 12m. For example, from the 91 m sources, propagation loss is approximately 85 dB at 200 nm range, and then, as the sources move into the shallower water, the loss increases to approximately 95 to 100 dB at 400 nm. The loss from the 18 m sources is approximately 5 dB greater than the loss from the 91 m sources at ranges greater than 200 nm (Fig. III-19). For both source depths, the loss increases with frequency (Fig. III-20).

b. ANB, Site 2BB

- (c) The propagation loss to Site 2BB is shown in Figs. III-21 and III-22. Most of the received signals overloaded the system out to 200 nm for the 300 m receiver or 150 nm for the 610 m receiver. As the sources move across the shallow water, the increase in propagation loss is greater at the higher frequencies and from the shallower sources. Many more shots were detected at the 610 m receiver than at the 300 m receiver (because of a higher noise level at 300 m), but propagation loss values at the two receiver depths are approximately equal.

c. ACODAC, Site 2D

- (c) Essentially no data are available for the 18 m source depth because of low signal-to-noise ratio. Better propagation from the sources at 91 m results in data such as shown in Fig. III-23 for 50 Hz propagation loss to receivers at depths of 585 m, 715 m, 1810 m, and 2467 m. The data in Fig. III-23 illustrate both the range and receiver depth dependence. Out to 200 nm range, loss increases faster with range to the deepest hydrophone (2467 m) so that, at 400 nm range, the loss at 2467 m is about 10 dB higher than that observed at the other three hydrophones. The loss from the 91 m sources is essentially the same at 25 and 50 Hz, and 3 to 5 dB higher at 158 Hz than at 50 Hz.

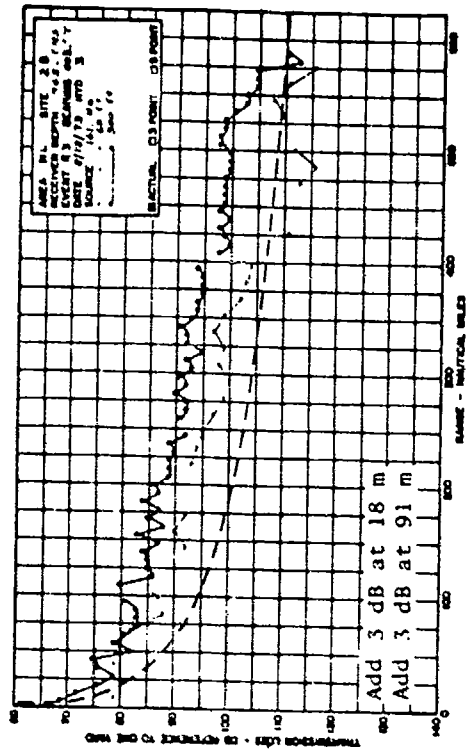
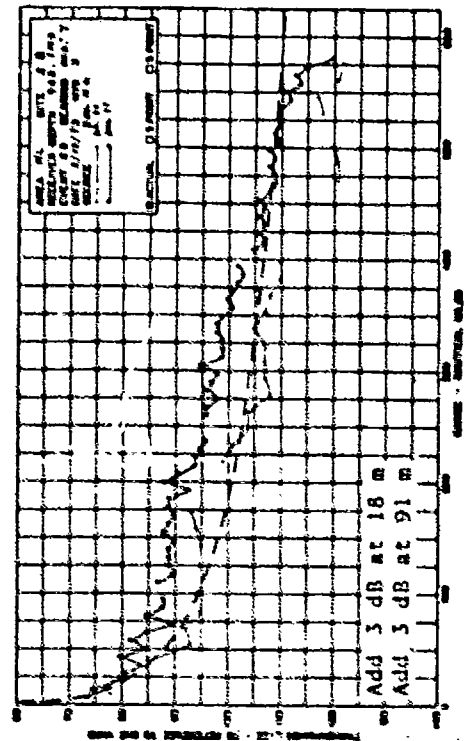
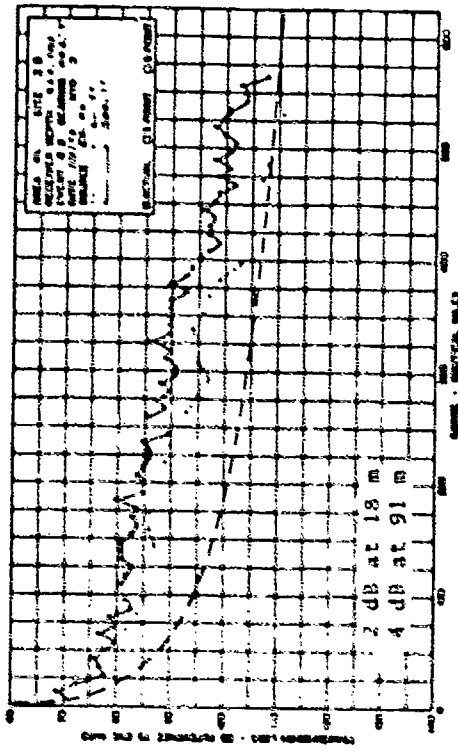


FIGURE III-19  
 PROPAGATION LOSS - SITE 2B, EVENT 12k  
 1728 m Receiver  
 Two Source Depths  
 50, 141, and 300 Hz



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 SEN

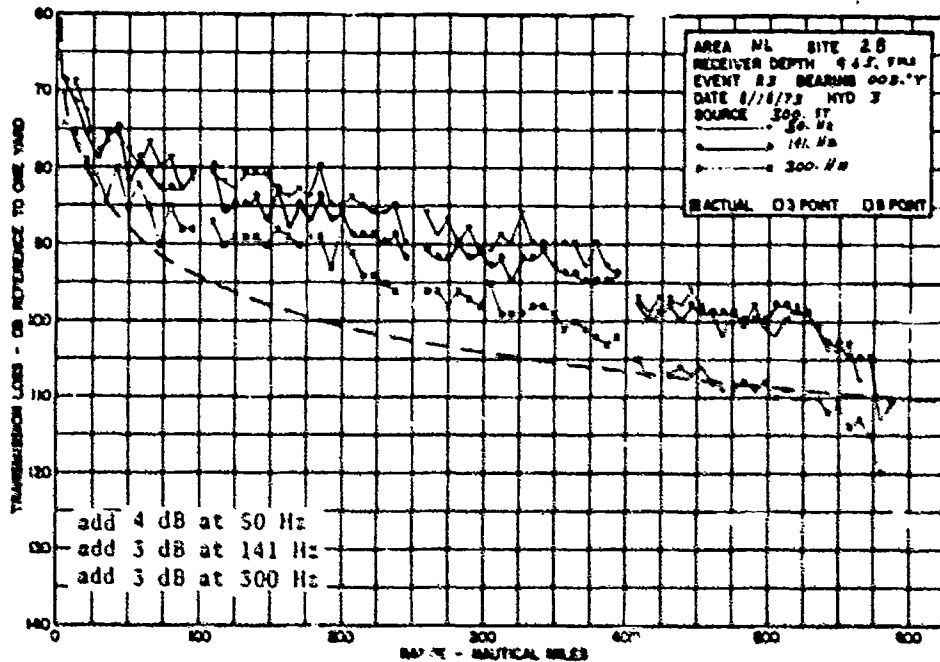
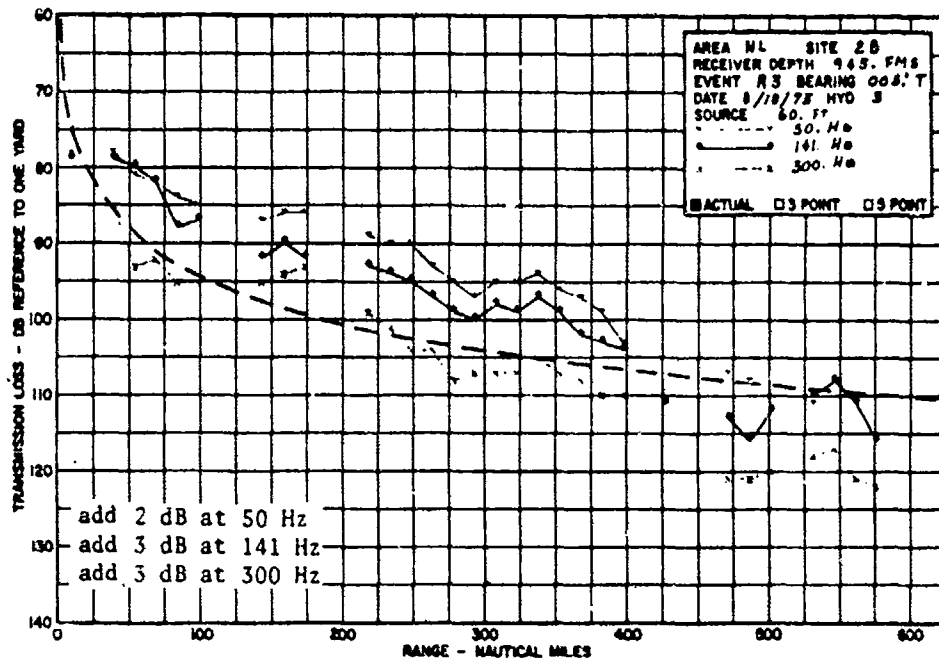


FIGURE III-20

PROPAGATION LOSS - SITE 28, EVENT 12k

1728 m Receiver  
Two Source Depths  
50, 141, and 300 Hz

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SKN

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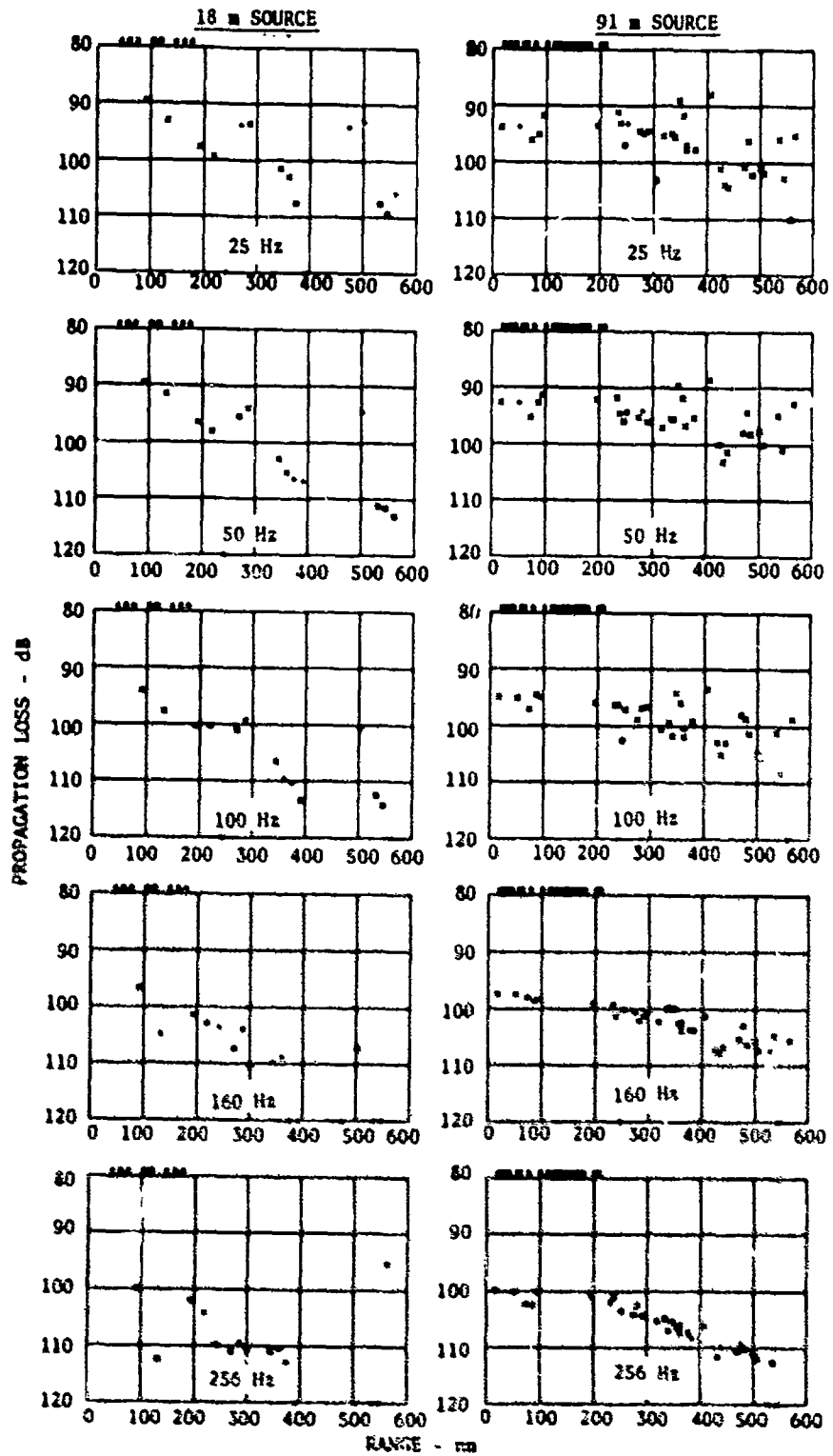


FIGURE III-21  
PROPAGATION LOSS - SITE 25B, EVENT 12E  
300 m Receiver Two Source Depths 25, 50, 160, and 256 Hz AS-76-887  
543

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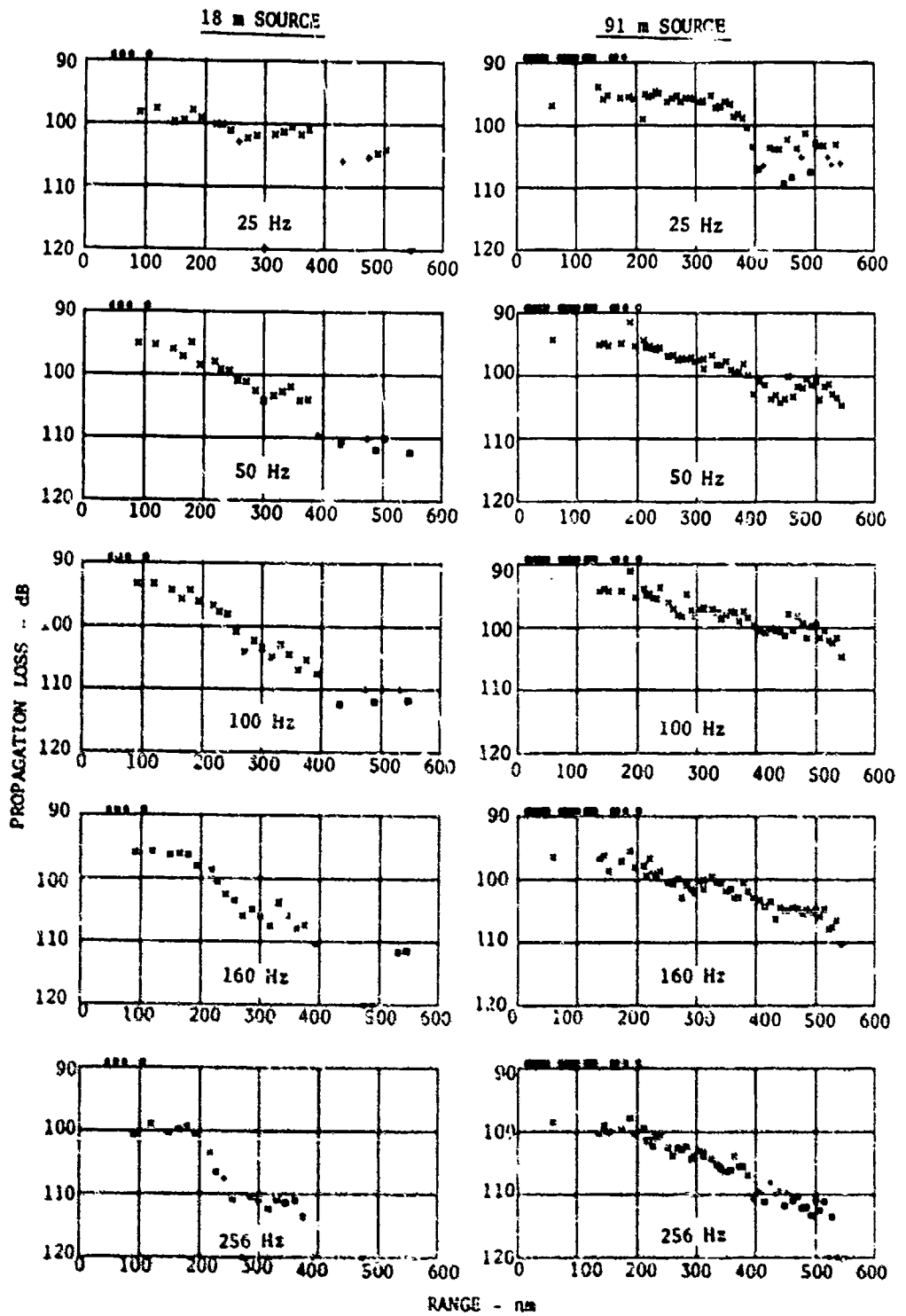
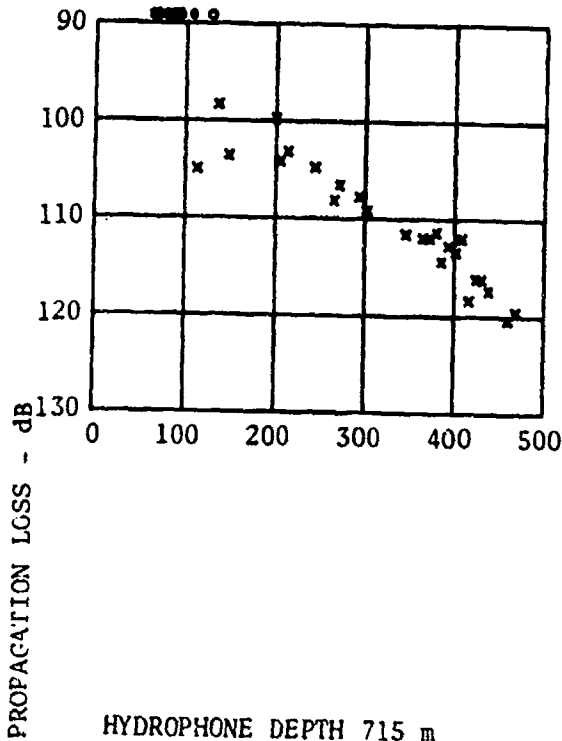


FIGURE 111-22  
PROPAGATION LOSS - SITE 28B, EVENT 12k  
610 m Receiver  
Two Source Depths  
25, 50, 100, 160, and 256 Hz

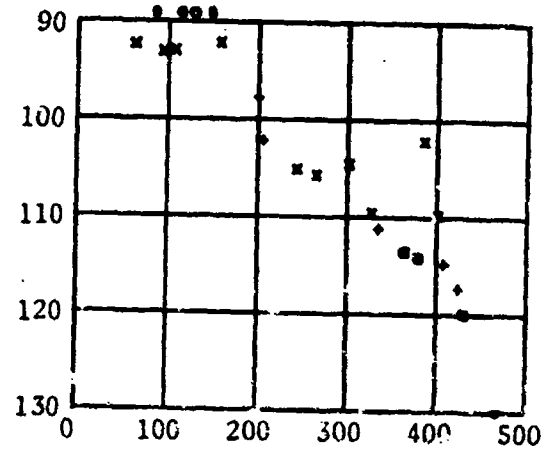
AS-76-889  
S1M

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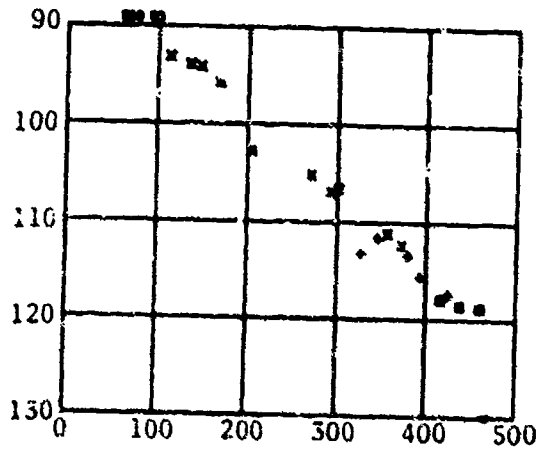
HYDROPHONE DEPTH 585 m



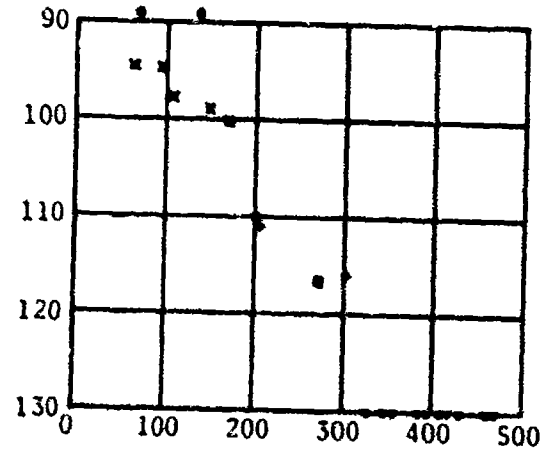
HYDROPHONE DEPTH 1810 m



HYDROPHONE DEPTH 715 m



HYDROPHONE DEPTH 2467 m



RANGE - nm  
FIGURE III-25  
PROPAGATION LOSS - SITE 2D, EVENT 12k  
Four Receiver Depths  
91 m Source  
50 Hz



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IV. PHASE III

1. Exercise and Area Description

(U) Phase III of SQUARE DEAL was conducted during September 1973. The locations of the receivers and the event discussed here are shown in Fig. IV-1. The Icelandic Basin, the area of Phase III, is bounded to the northwest by Reykjanes Ridge and to the southeast by Rockall Bank. The receivers deployed for Phase III were ACODACs at Sites 1C and 3D, SURVEY arrays at Sites 3A and 3Z, and the MABS II at Site 3AA. Information regarding hydrophone depths, etc., for all processed data is given in Table IV-1. The major source event of this phase was Event 22a during which RFA OLMEDA began at point 3ZZ in the Norwegian Sea, proceeded along the Great Circle through Sites 3D and 1C, and completed the SUS event at point 3F, west of the mid-Atlantic ridge. For a second series of source events, aircraft deployed SUS charges along paths radial to Site 3A, including one path across Rockall Bank.

2. RFA OLMEDA Source Run, Event 22a

(U) The long RFA OLMEDA SUS run was on 7-10 September 1973. The sensors along the track whose recordings have been processed are shown in Fig. IV-2, along with the bathymetry and sound velocity structure. The Faeroe-Iceland ridge and the Gibbs Fracture Zone in the mid-Atlantic ridge are two obvious geographic influences upon propagation. The sound velocity structure shows considerable change along the track and is particularly asymmetric about Site 1C. From 200 nm NE of Site 1C to Site 3Z there is an upper sound channel with axis at approximately 100 m depth; there is no depth excess along this same interval.

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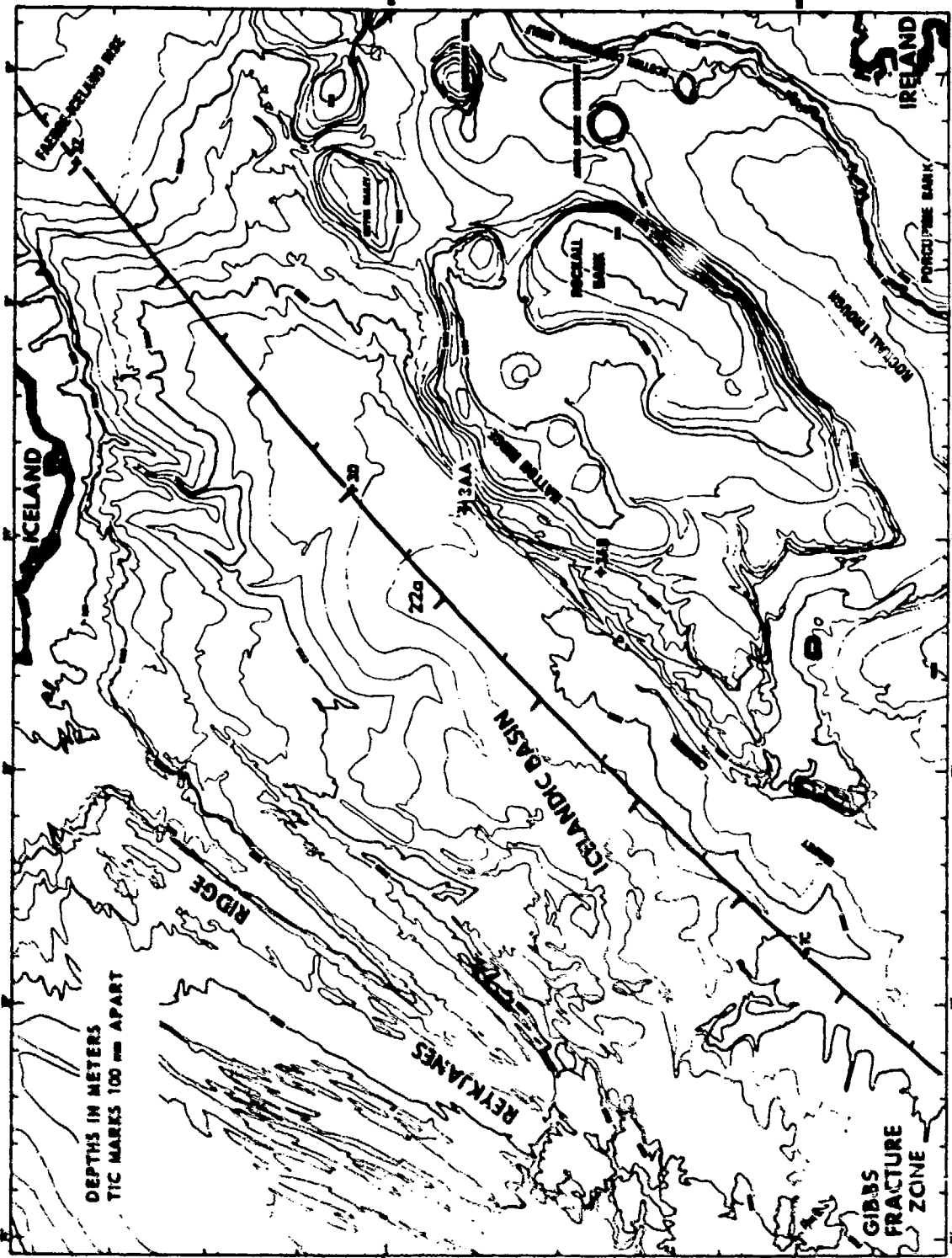


FIGURE IV - 1  
SUS EVENTS OF PHASE III (U)

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AS - 76 - 600  
SKM - DR  
3 - 10 - 76

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(c)

TABLE IV-1

REFERENCE LOCATIONS FOR PHASE III (U)  
(From Table III-1 of Ref. 4)

TYPE	SITE	LOCATION	HYDROPHONE DEPTHS - meters
ACODAC	3D	60°24.9'N 19°04.0'W	406 Near upper sound channel axis
			1078 Near deep sound channel axis
			1812 100 m above critical depth
ACODAC	1C	54°52.4'N 28°49.2'W	606 250 m below sound channel axis
			895 550 m below sound channel axis
			1960 100 m below critical depth
SURVEY	3Z	63°09.83'N 12°00.34'W	426 Bottom, near crest of Faeroe-Iceland Ridge. Sound velocity minimum at bottom.
MABS II	3AA	59°07.7'N 19°14.2'W	165
			966
			1454
			2155
SURVEY	3A	59°07.67'N 18°38.85'W	
	3ZZ	64°28'N 07°40'W	
	3F	51°05.8'N 33°35.9'W	

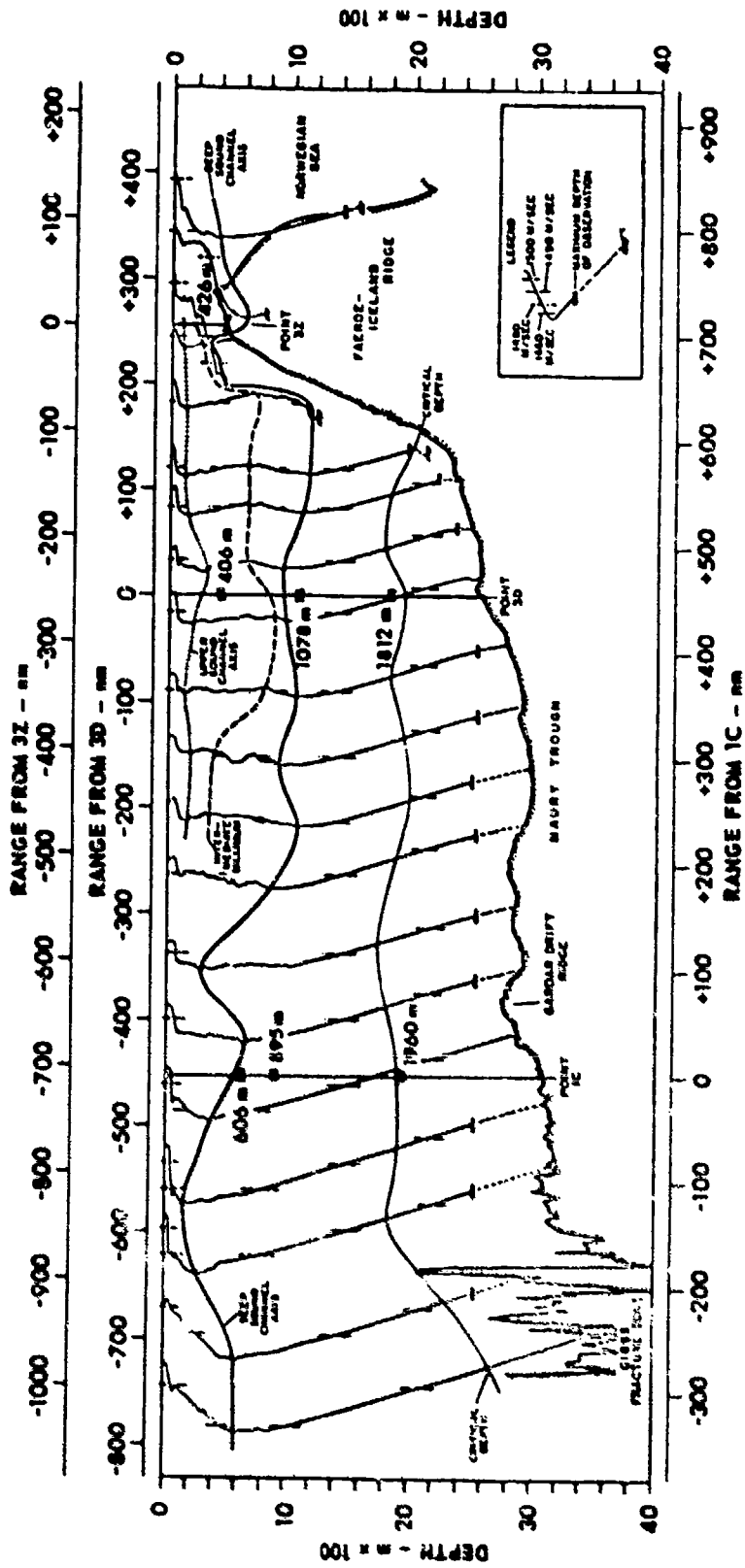


FIGURE IV-2  
 SOUND VELOCITY STRUCTURE AND BATHYMETRY IN ICELANDIC BASIN  
 PHASE III - TRACK ALONG EVENT 22g

ARL - UT  
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 SKM - DR  
 6-17-76

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## a. ACODAC, Site 3D

(U) The processed hydrophones at Site 3D are at 406 m, near the upper sound channel axis, at 1078 m, near the deep sound channel axis, and at 1812 m approximately 100 m above the critical depth. Figure IV-3 shows propagation to the 1078 m receiver from both 18 m and 91 m sources whereas Fig. IV-4 shows propagation loss from only the 91 m sources to the 406 m and 1812 m receivers. Range averaged propagation loss to the three receiver depths in selected range intervals is shown in Fig. IV-5.

### (1) Range Dependence

(C) Overloading of the received shots within  $\pm 200$  nm of Site 3D limits discussion of the range dependence of propagation loss to longer ranges. In the open channel region SW of Site 3D, between 200 nm and 600 nm, the range dependence of propagation loss shows approximately cylindrical spreading at 158 Hz and above. At the lower frequencies, the loss is almost independent of range over this interval. Indeed, Figs. IV-4 and IV-5 show propagation loss to the deep receiver even decreasing slightly with range at the lower frequencies.

### (2) Bottom Effects

(C) NE of Site 3D, most of the shots cause overloads out to 180 nm, where depth excess is lost across the Faeroe-Iceland Ridge. For shots between that point and Site 3Z, the 1812 m receiver shows 10 to 15 dB increase in loss; an effect of this magnitude is probably masked by overloading at the other hydrophones. When the source shots are near point Site 3Z, the 50 Hz data show a local minimum in propagation loss due to edge enhancement. Starting at 650 nm SW of Site 3D at the western end of the Event 22a source run, the Gibbs Fracture Zone (in the mid-Atlantic Ridge) causes a 10 to 15 dB increase in loss from the 91 m sources as RFA OLMEDA traverses the zone; few of the 18 m shots were detectable in that region. At 700 nm SW of Site 3D, which is beyond the short interval

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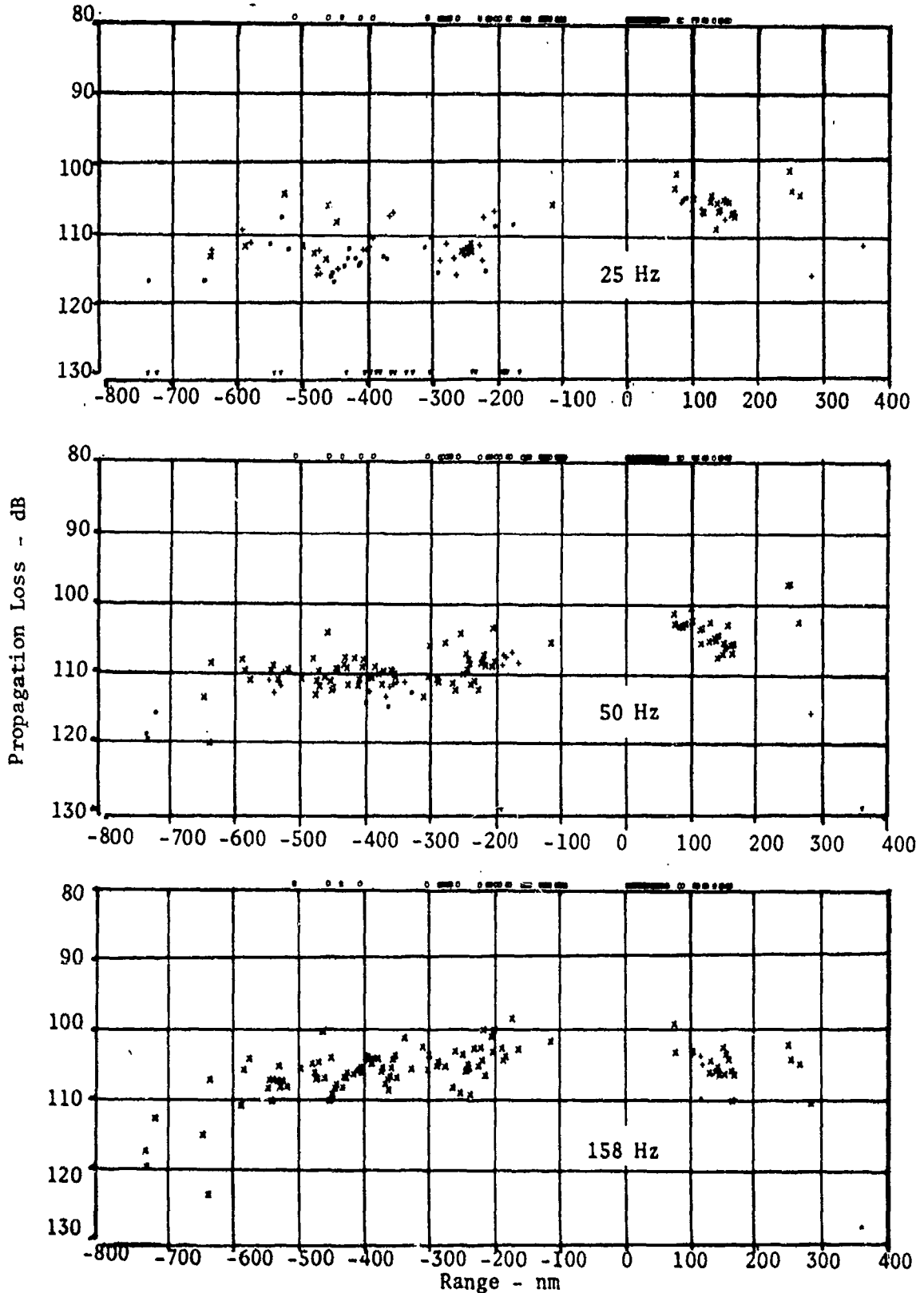


FIGURE IV-3a  
PROPAGATION LOSS - SITE 3D, EVENT 22a  
1078 m Receiver  
18 m Source  
25, 50, and 158 Hz

90

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SKM

# UNCLASSIFIED

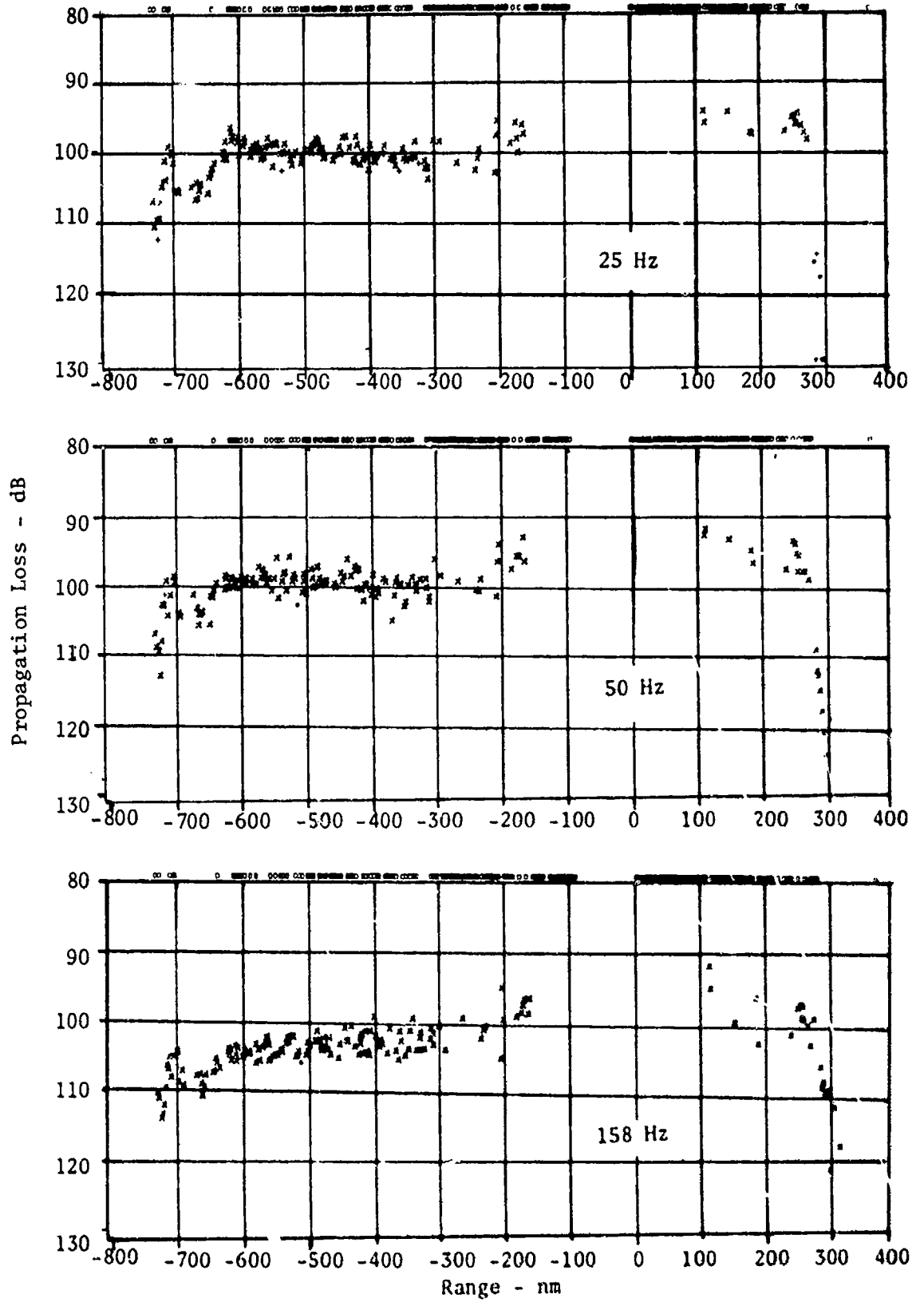


FIGURE IV - 3b

PROPAGATION LOSS - SITE 3D, EVENT 22a

1078 m Receiver

91 m Source

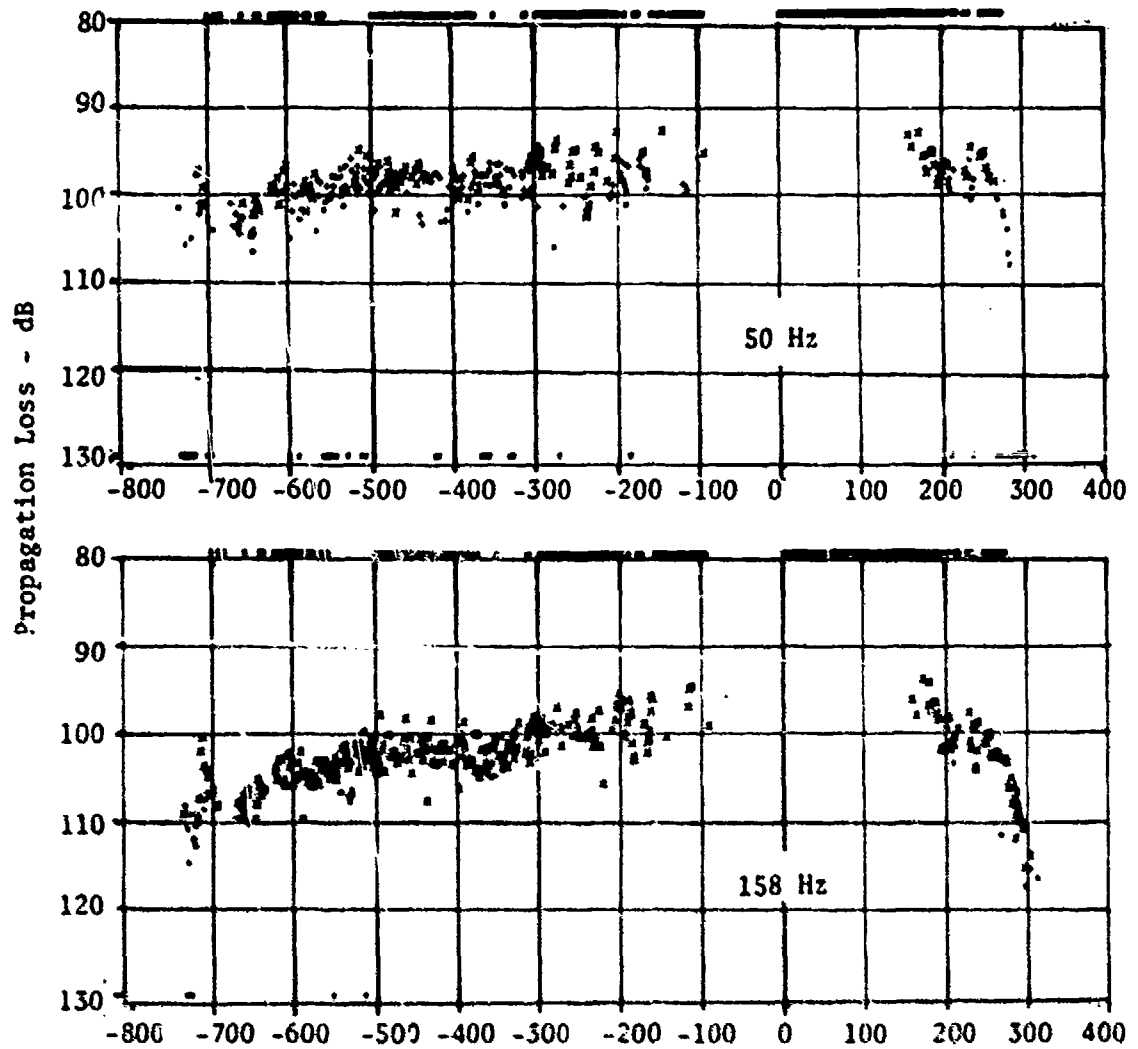
25, 50, and 158 Hz

91

AS-76-891  
SKM

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Range - nm  
FIGURE IV-4a  
PROPAGATION LOSS - SITE 3D, EVENT 22a  
496 m Receiver  
91 m Source  
50 Hz and 158 Hz

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1812 m Hydrophone

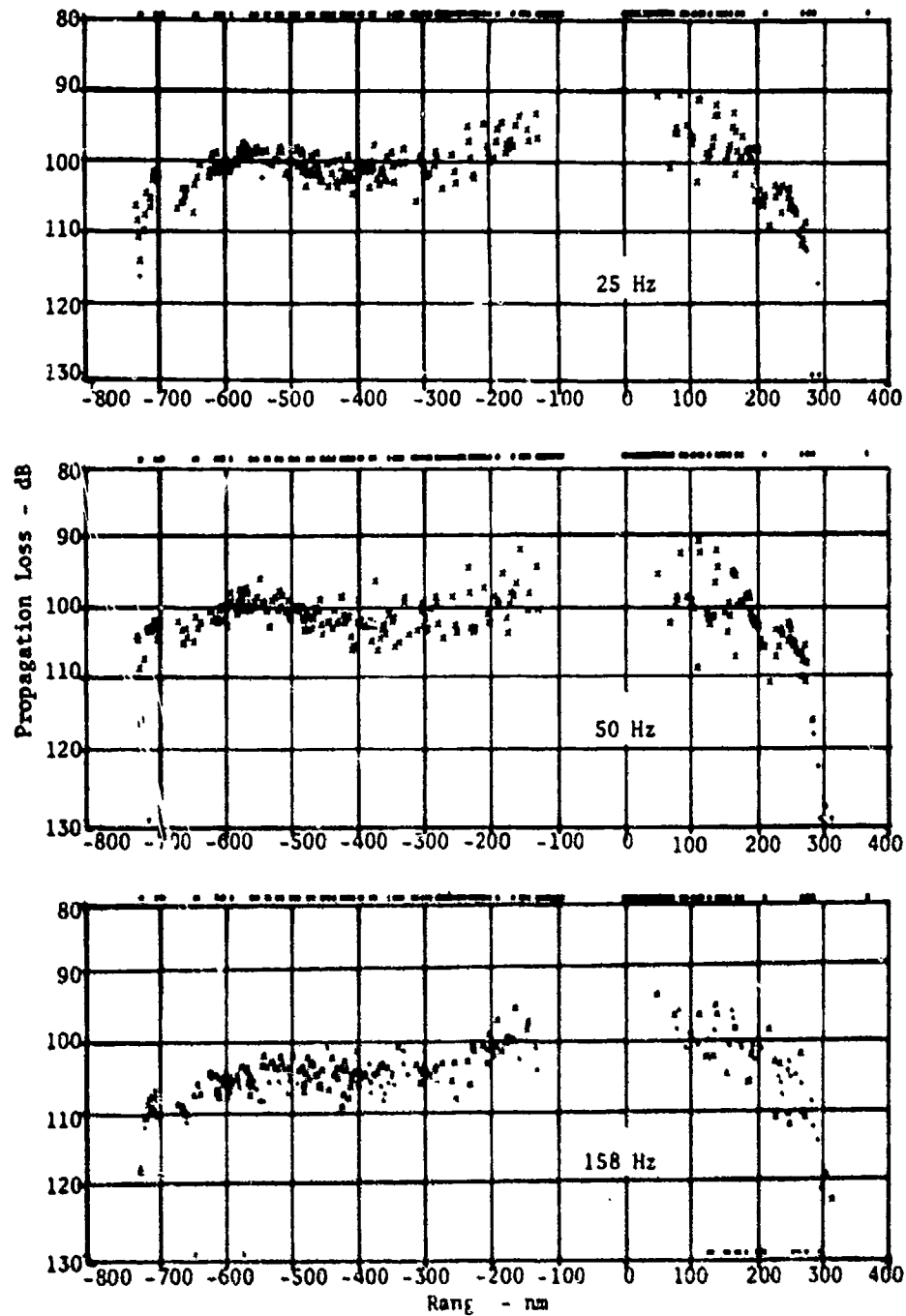


FIGURE IV-4b  
PROPAGATION LOSS - SITE 3D, EVENT 22a  
1812 m Receiver  
91 m Source  
25, 50, and 158 Hz

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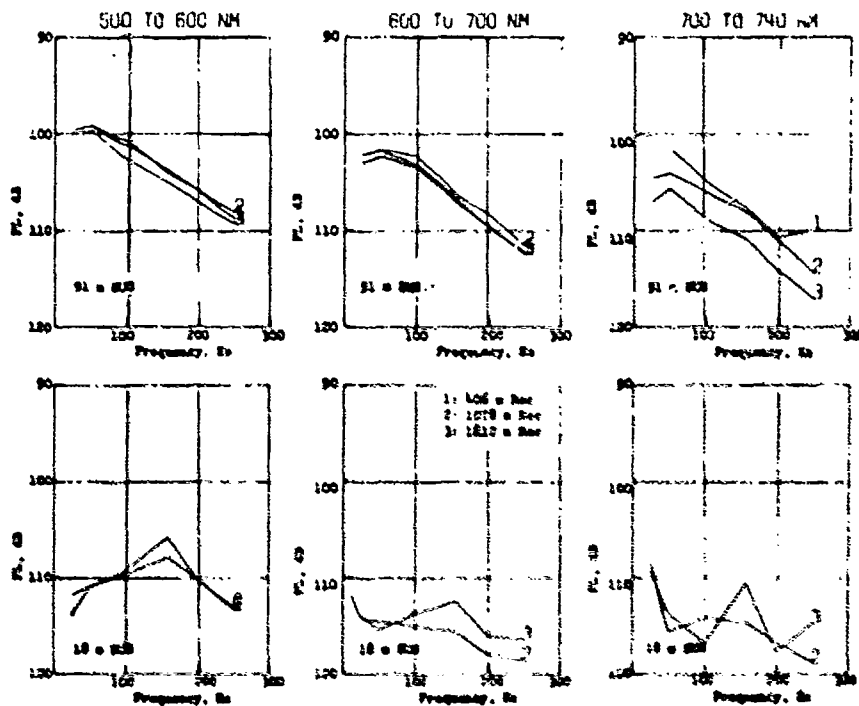
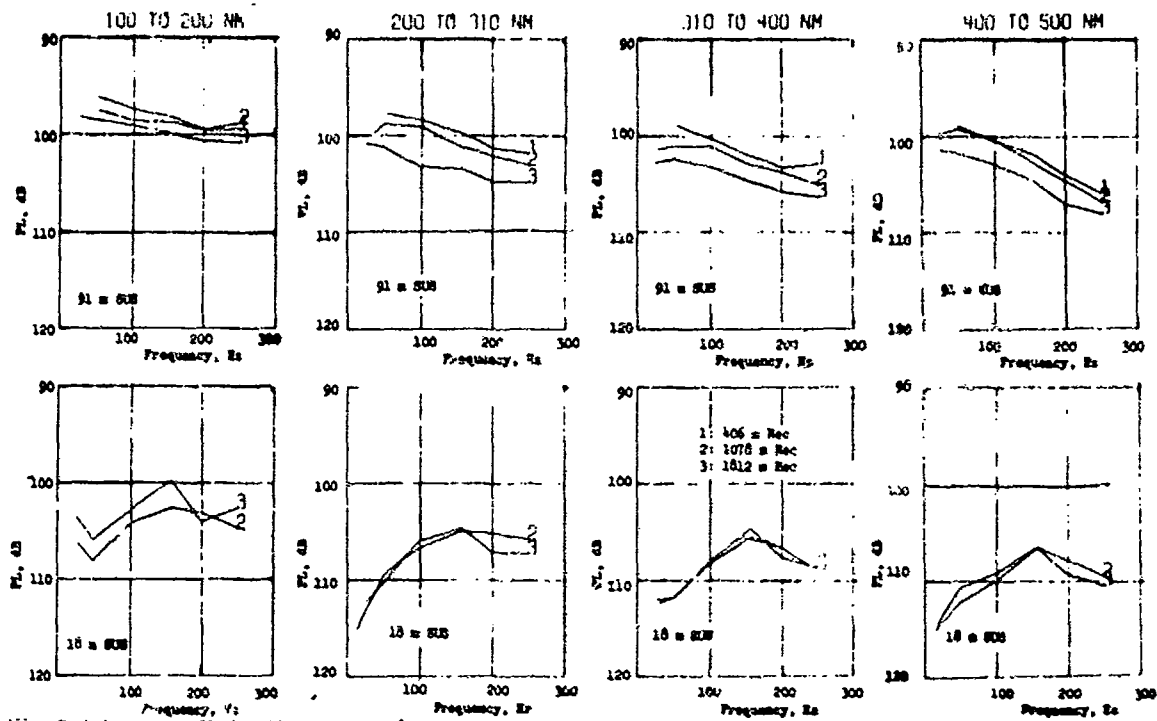


FIGURE IV-5a

RANGE AVERAGED PL versus FREQUENCY - SITE 30, EVENT 22a

Sources Southwest of Site 30  
 406 m, 1078 m, 1812 m Receivers  
 Two Source Depths

gh

AS-76-894  
 SKM

# UNCLASSIFIED

# UNCLASSIFIED

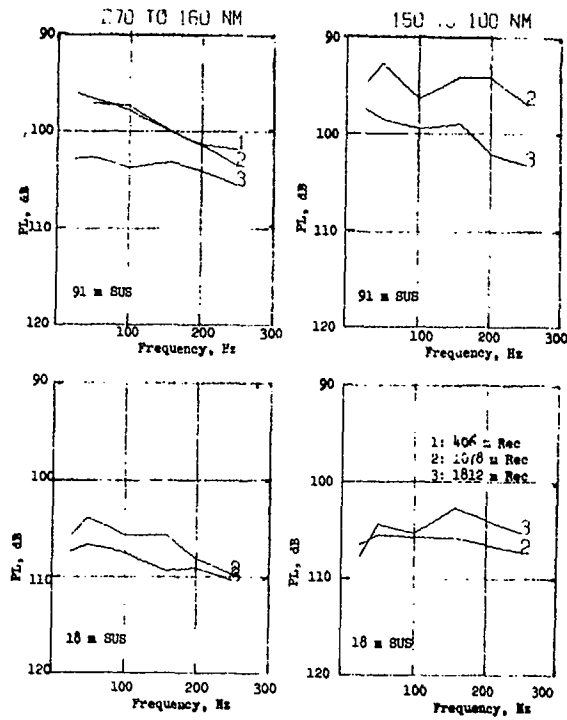


FIGURE IV-5b

RANGE AVERAGED PL versus FREQUENCY - SITE 3D, EVENT 22a

Sources Northeast of Site 3D  
406 m, 1078 m, 1812 m Receivers  
Two Source Depths

AS-76-895  
SKM

# CONFIDENTIAL

- (C) of depth deficiency shown in Fig. IV-2, there is evidence of edge enhancement causing propagation loss to be 5 dB less than the values for sources at nearby ranges at all frequencies.

## (3) Source Depth

- (C) The difference between the propagation loss from the two source depths over the open channel is similar to that of the rest of SQUARE DEAL: 5 dB more loss from the 18 m source at 158 Hz and 10 to 12 dB more at 25 Hz and 50 Hz; this difference is shown clearly in Fig. IV-5.

## (4) Receiver Depth

- (C) The dependence of propagation loss upon receiver depth at Site 3D is shown in the depth difference plots of Fig. IV-6; in addition, Fig. IV-5 also reveals the receiver depth dependencies. The 406 m and 1078 m receivers are at the two sound channel axes; as may be seen, there is effectively no difference between propagation loss to these receivers from the 91 m shots. (Cable strumming makes the 18 m shots undetectable at the 406 m receiver.) In the open channel regions, the loss from the 91 m sources to the 1812 m receiver is on the average 2 to 3 dB greater than the loss to the shallow receivers. Similar plots indicate that the propagation loss from the 18 m sources is independent of receiver depth.

## (5) Frequency Dependence

- (C) Figure IV-7 gives frequency difference plots comparing 158 Hz and 50 Hz propagation loss on a shot-by-shot basis; Fig. IV-5 shows the frequency dependence on a range averaged basis.
- (C) During most of Event 22a, propagation loss from the 91 m sources increases with increasing frequency; for example, the loss at 158 Hz is nominally 4 dB greater than the loss at 50 Hz.

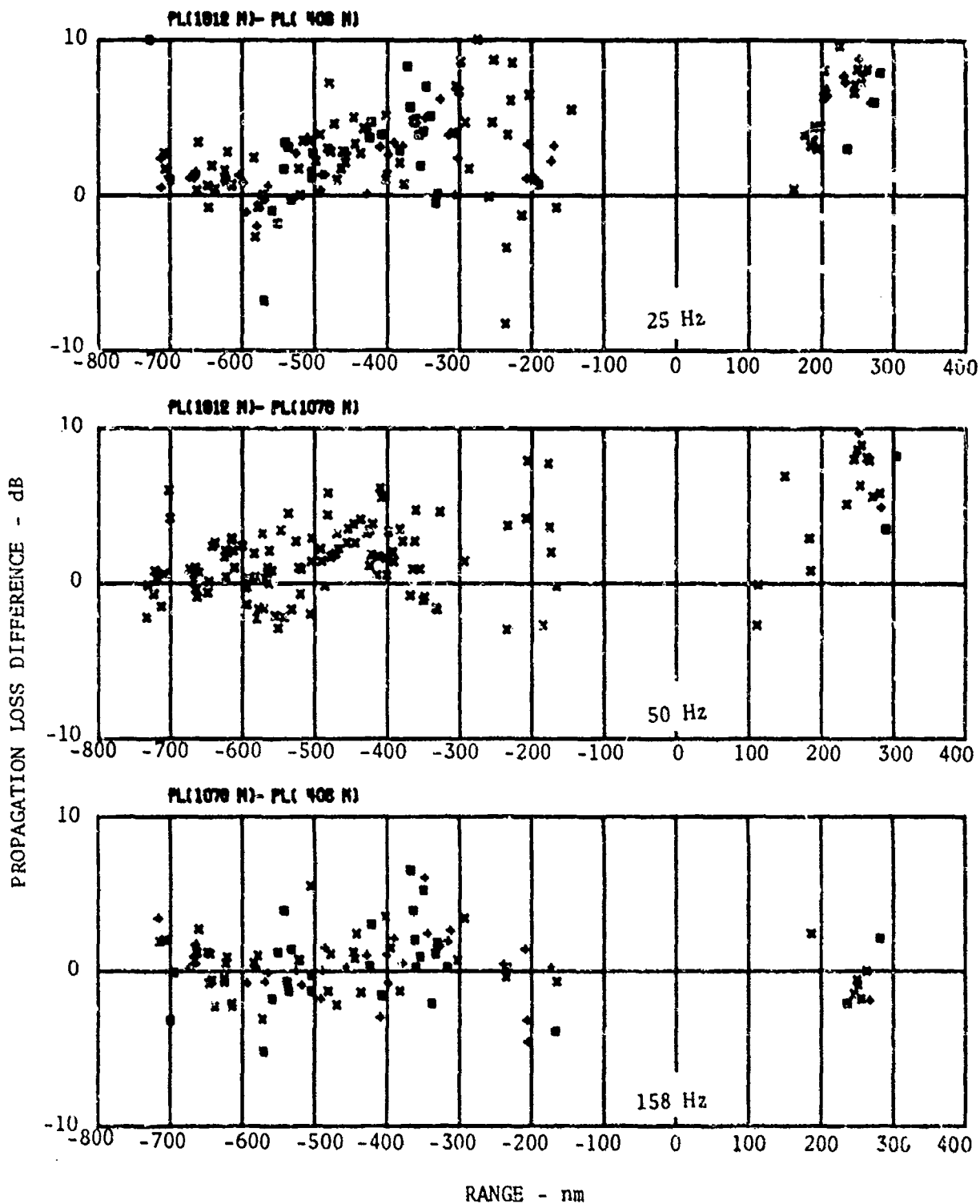


FIGURE IV-6a  
PROPAGATION LOSS DIFFERENCES - SITE 3D, EVENT 22a  
Differences Among PL to Receivers  
91 m Source  
50 Hz

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199.5 Hz

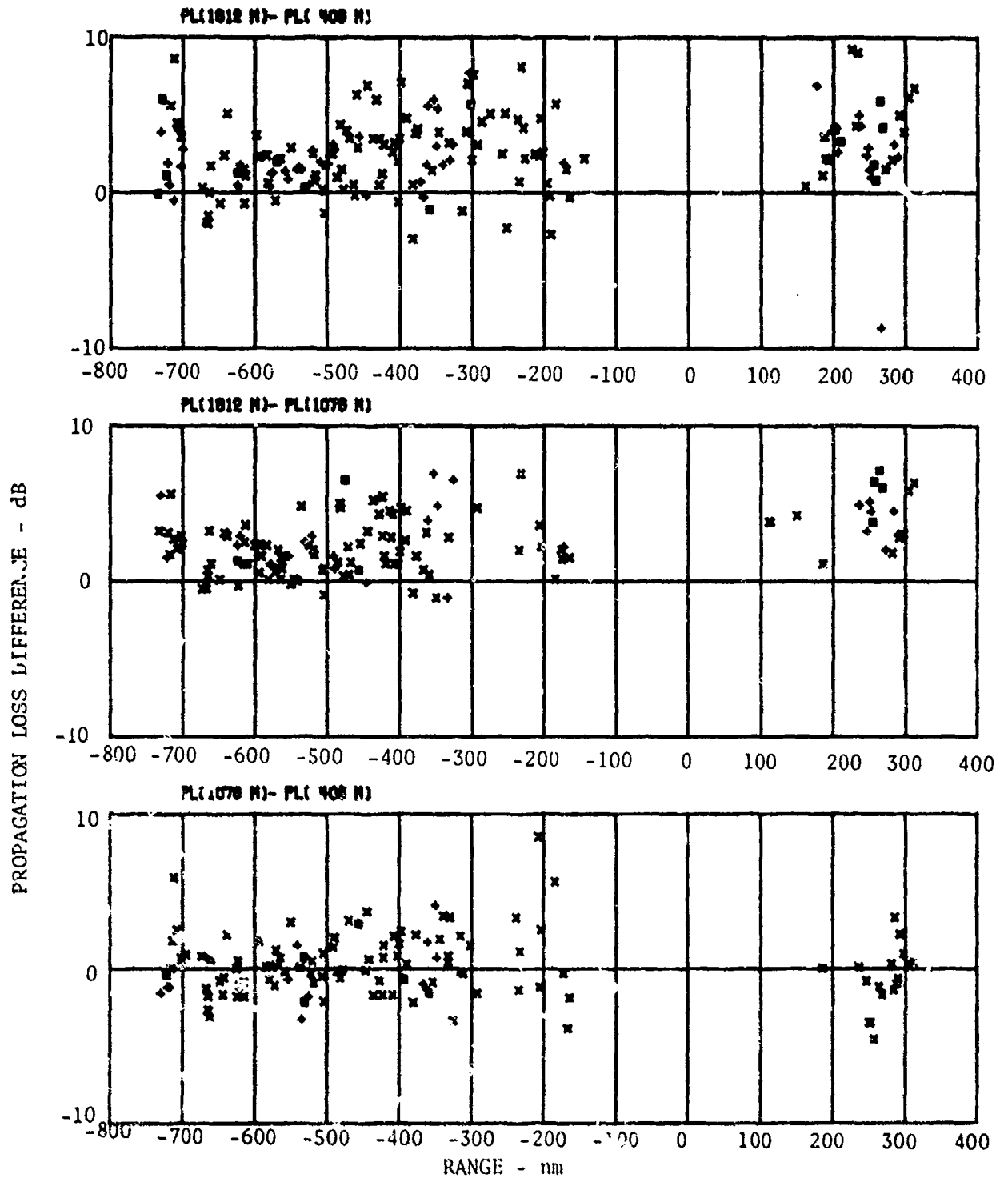


FIGURE IV-6b  
PROPAGATION LOSS DIFFERENCES - SITE 3D, EVENT 22a  
Difference: Among PL to Receivers  
91 m Source  
200 Hz

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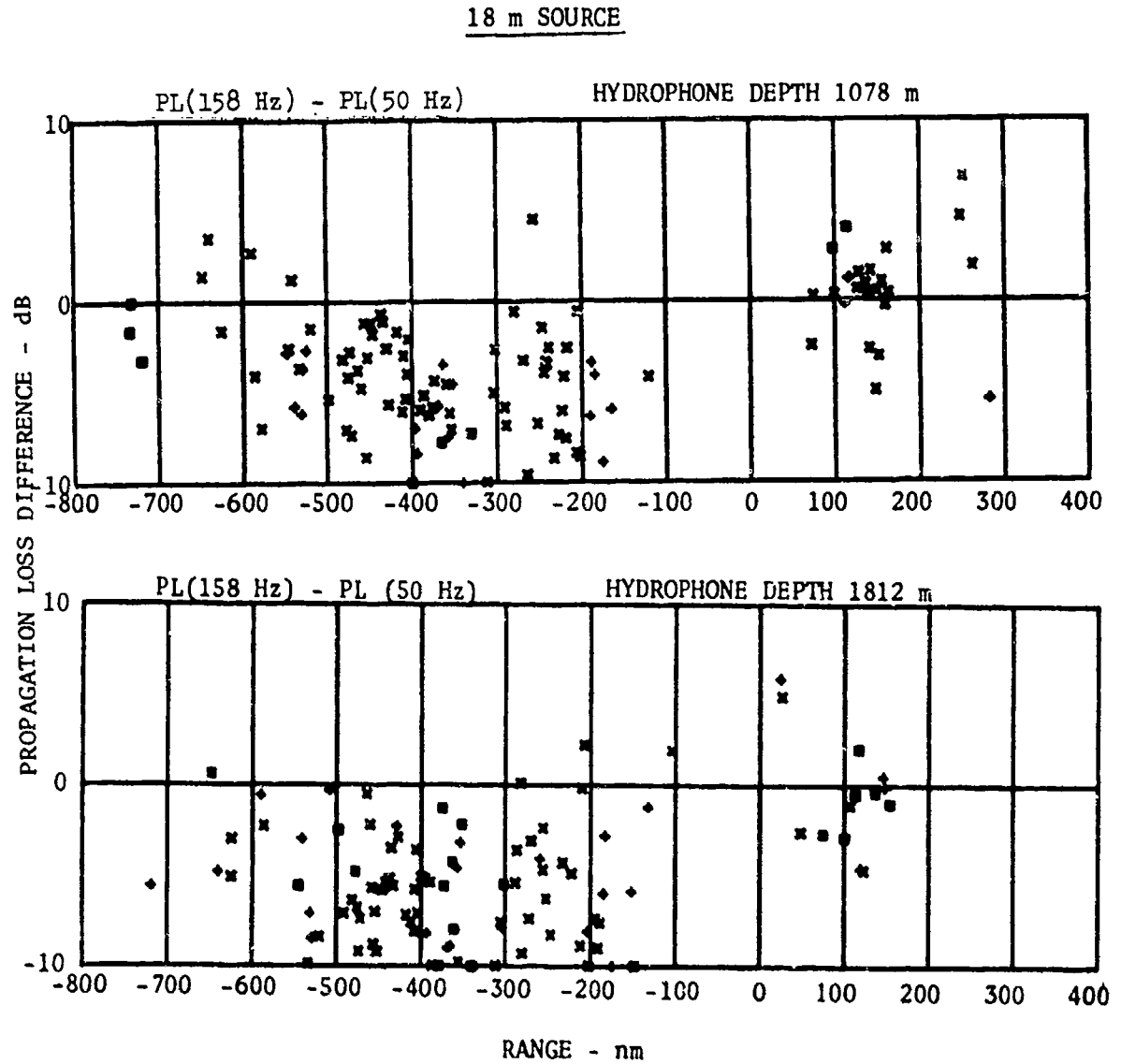
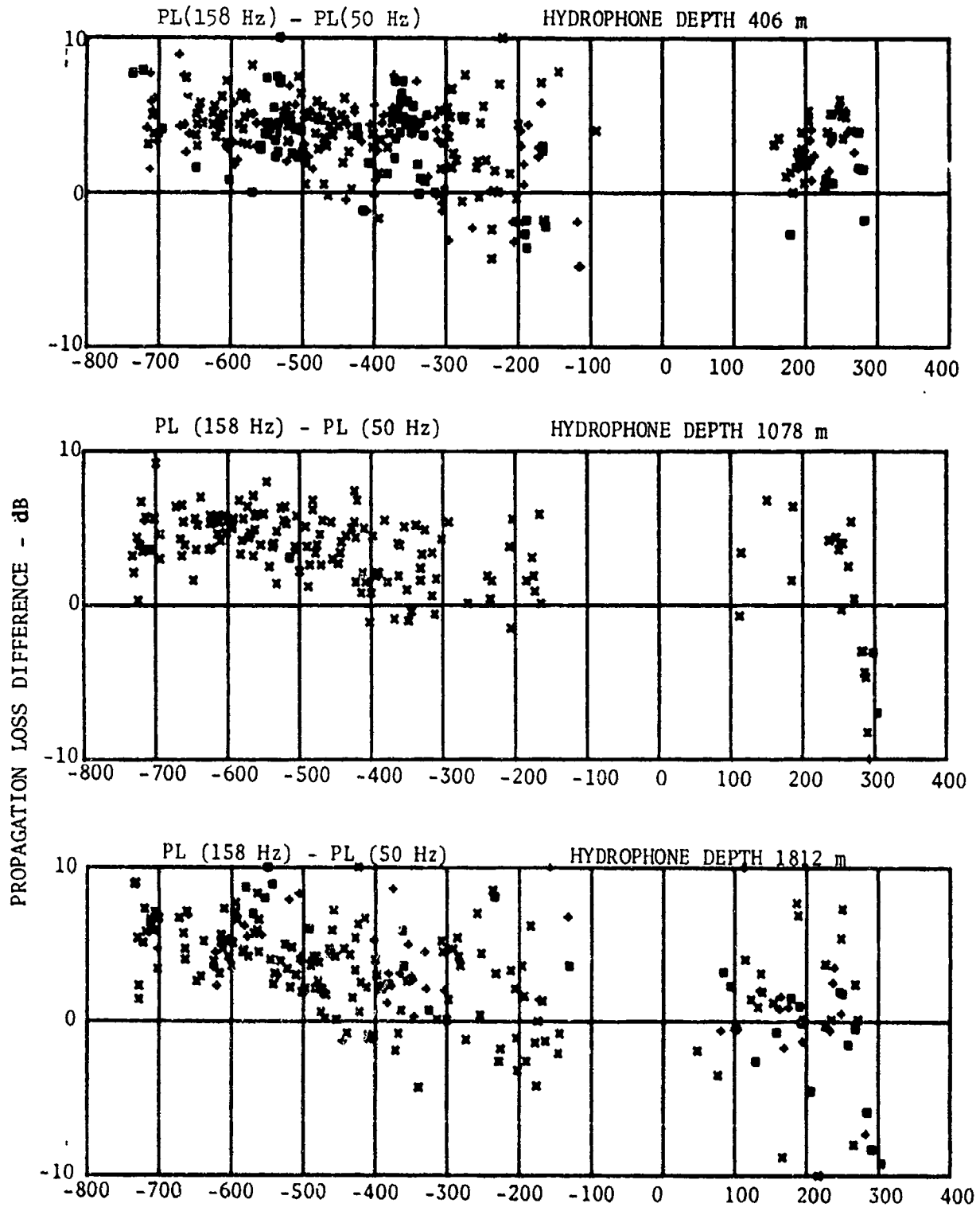


FIGURE IV-7a  
PROPAGATION LOSS DIFFERENCES - SITE 3D, EVENT 22a  
1078 m and 1812 m Receivers  
18 m Source  
Difference Between 158 Hz PL and 50 Hz PL

AS-76-  
SKM

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91 m SOURCE



RANGE - nm

FIGURE IV-7b

PROPAGATION LOSS DIFFERENCES - SITE 3D, EVENT 22a

Three Receivers

91 m Source

Difference Between 158 Hz PL and 50 Hz PL

100

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AS-76-899

SKM



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- (C) Propagation loss from the 18 m sources shows the frequency dependence common to most of SQUARE DEAL. In the open channel SW of Site 3D, Figs. IV-5 and IV-7b show the loss generally decreasing with frequency up to 160 Hz, and then increasing with frequency up to 250 Hz. However, in the high attenuation regions over Faeroe-Iceland Rise and Gibbs Fracture Zone, the loss from the 18 m sources is approximately independent of frequency.

b. ACODAC, Site 1C

- (C) The hydrophones processed at Site 1C for Phase III are at depths of 606 m, approximately 200 m below the sound channel axis; 890 m; and 1960 m, approximately 100 m below critical depth. Propagation loss from sources at each of the two source depths to the 606 m receiver is given in Fig. IV-8, whereas Fig. IV-9 shows the loss to the 890 m receiver and 1960 m receiver from 18 m sources only. The range averaged propagation loss data are shown in Fig. IV-10.

(1) Range Dependence

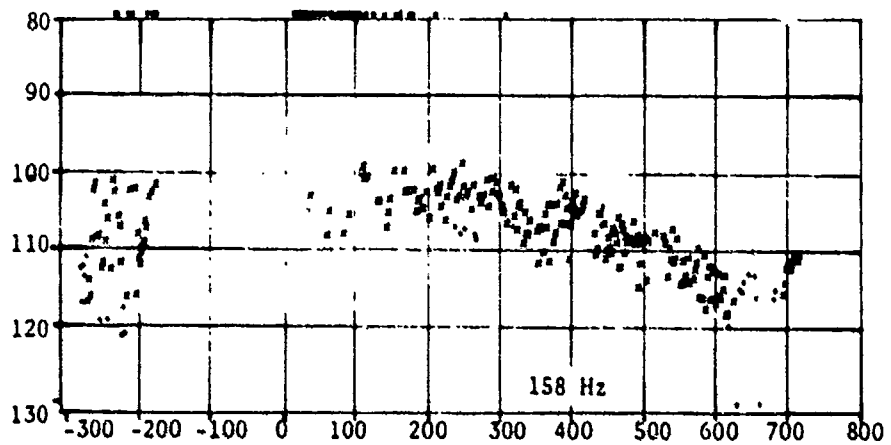
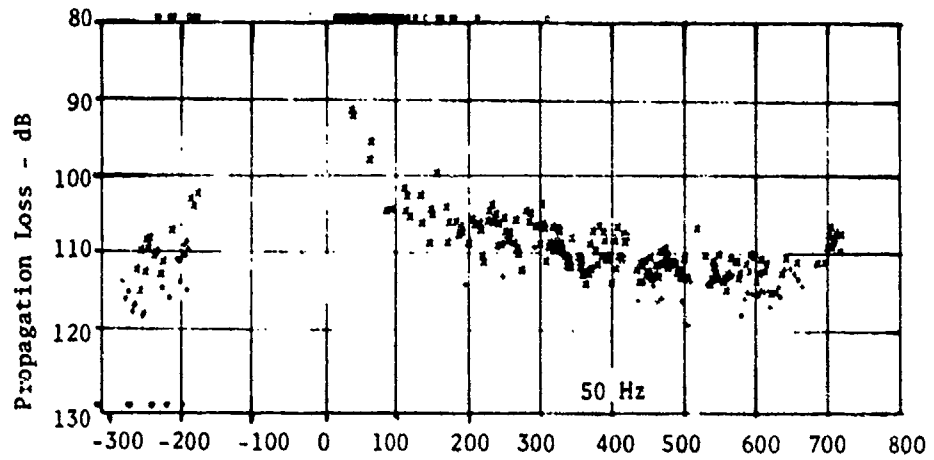
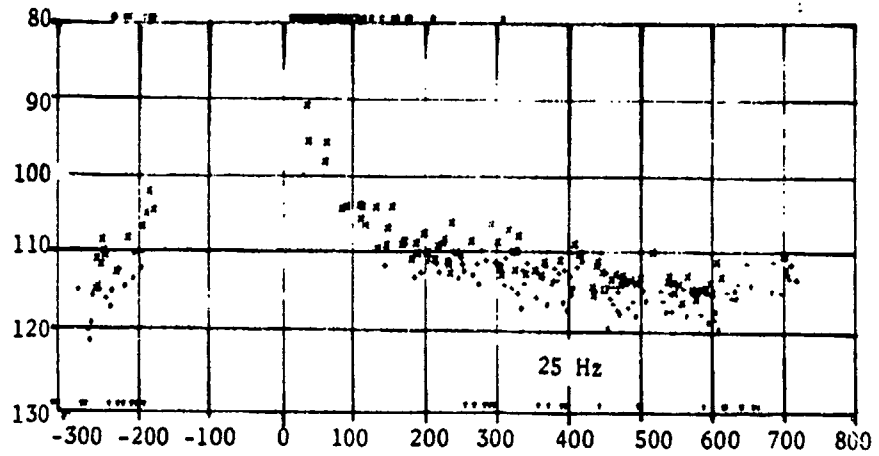
- (C) From sources in the interval 250 nm to 600 nm NE of Site 1C, propagation loss increases at a rate greater than that of cylindrical spreading; this is different from the range dependence seen at Site 3D. For the 91 m sources the propagation loss at 600 nm range is approximately 4 to 6 dB greater than the loss at 300 nm. From the 18 m sources, the loss increases between the same ranges by approximately 5 to 8 dB.

(2) Boundary Effects

- (C) All of the shots SW of Site 1C cause overloading until the Gibbs Fracture Zone is reached at 200 nm range. Between 200 nm and 300 nm SW, propagation loss increases by at least 15 to 20 dB for all frequencies and source depths. At the opposite end of the Event 22a track, the Faeroe-Iceland Ridge influences propagation in two ways. First, there is loss of

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18 m Source



Range - nm

FIGURE IV-8a

PROPAGATION LOSS - SITE 1C, EVENT 22a

606 m Receiver

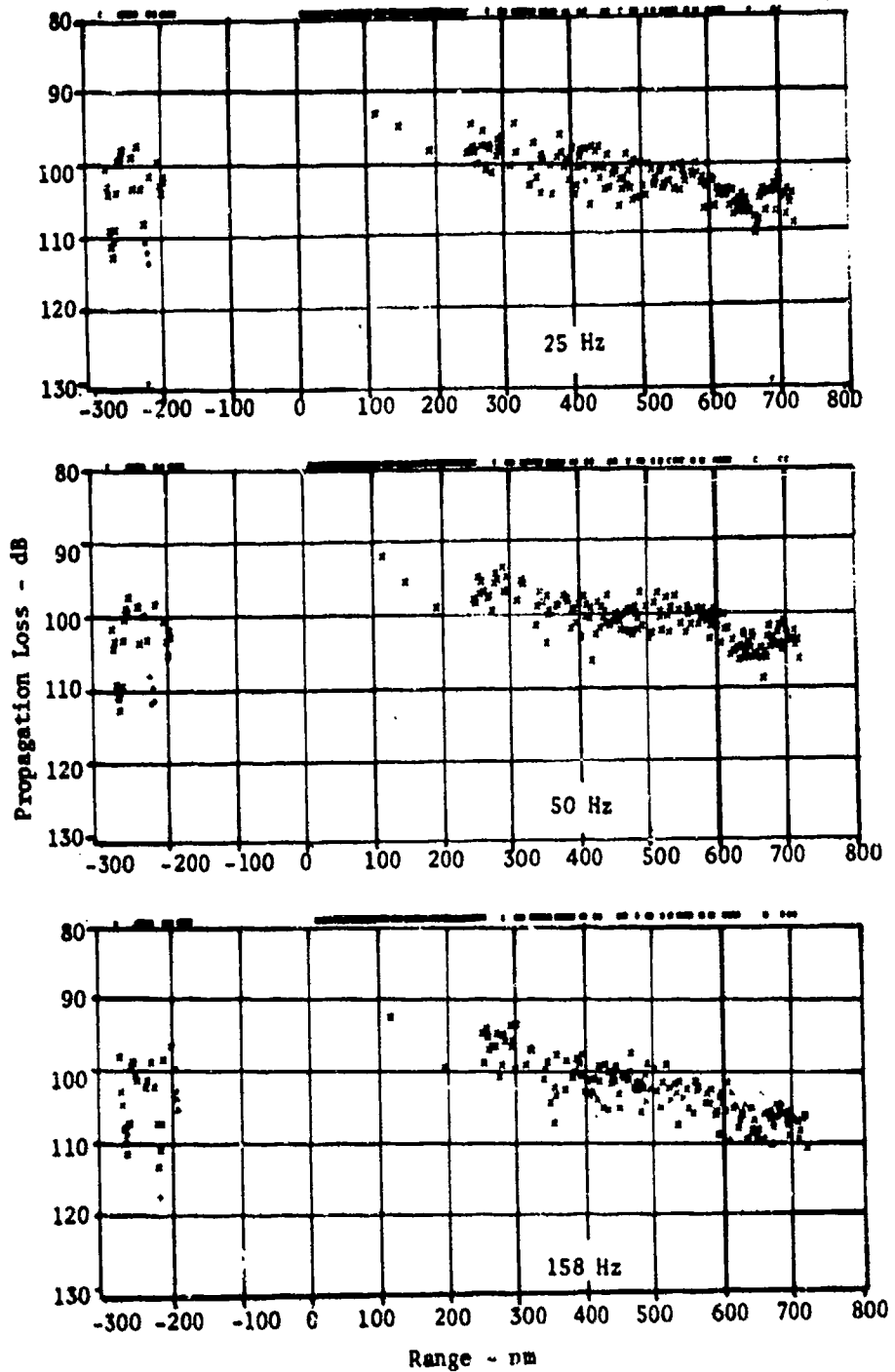
18 m Source

25, 50, and 158 Hz

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SKM

# UNCLASSIFIED

91 m Source



Range - nm

FIGURE IV-8b

PROPAGATION LOSS - SITE 1C, EVENT 22a

606 m Receiver

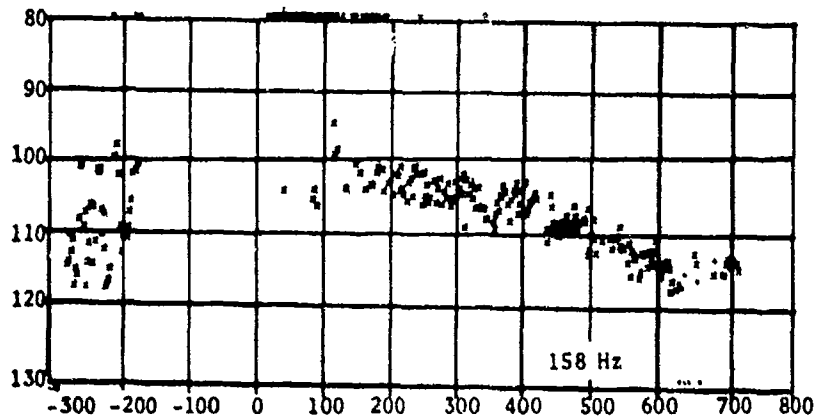
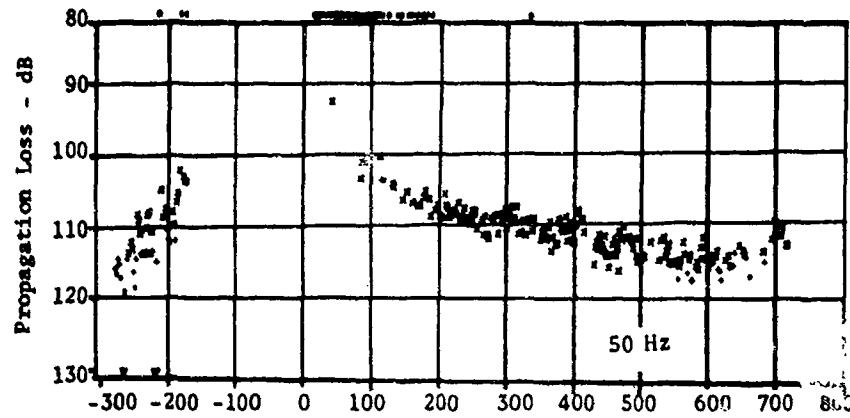
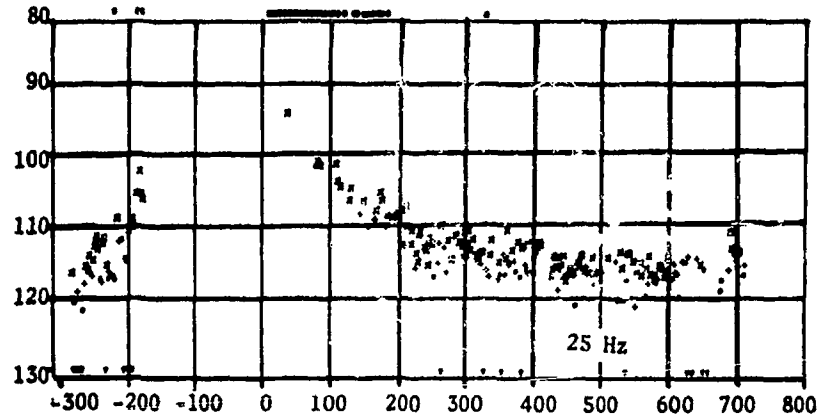
91 m Source

25, 50, and 158 Hz

AS-76-901  
SKM

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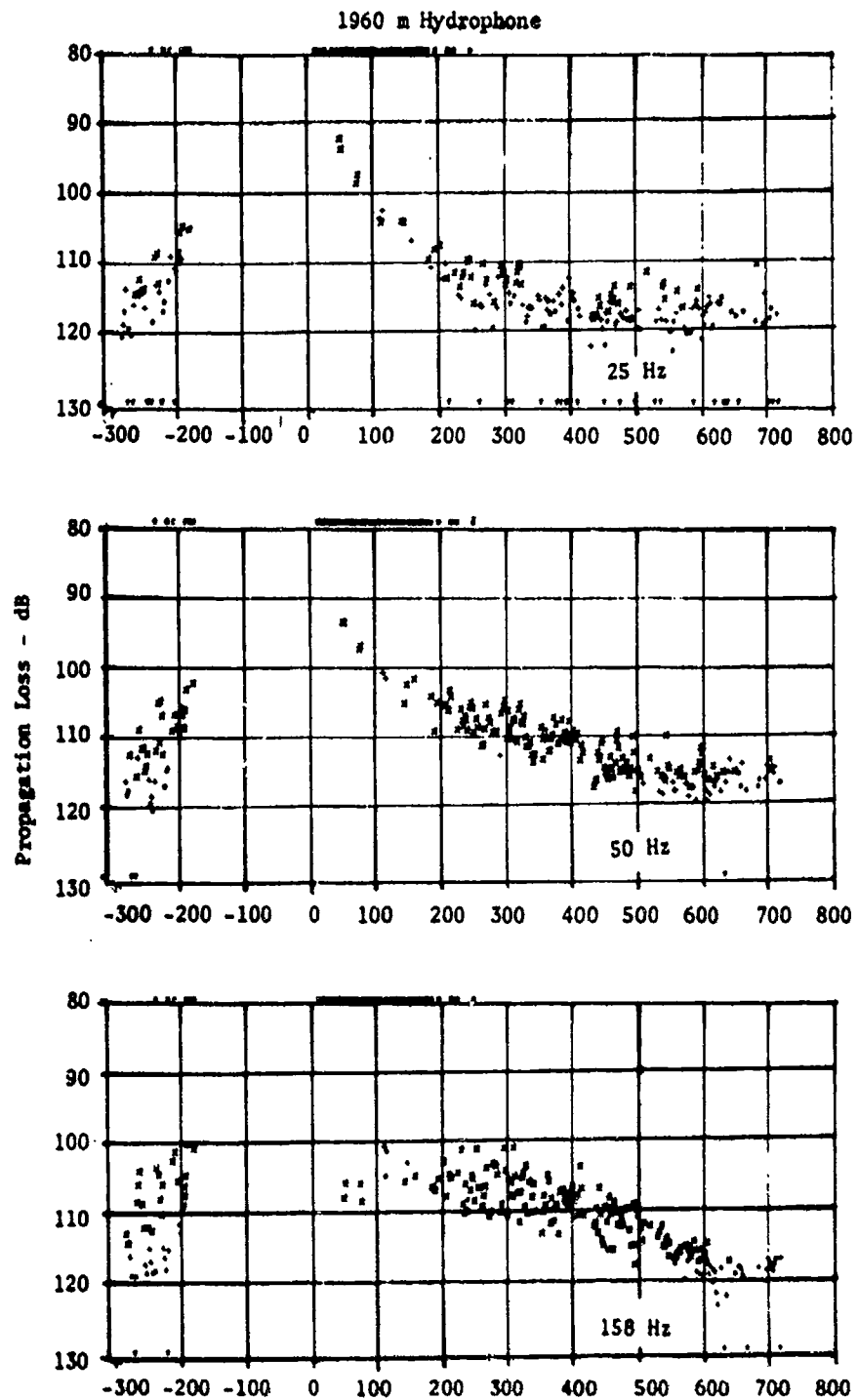
## 890 m Hydrophone



Range - nm  
FIGURE IV-9a  
PROPAGATION LOSS - SITE 1C, EVENT 22a  
890 m Receiver  
18 m Source  
25, 50, and 158 Hz

AS-76-902  
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Range - nm  
FIGURE IV-9b  
PROPAGATION LOSS - SITE 1C, EVENT 22a  
1960 m Receiver  
18 m Source  
25, 50, and 158 Hz

AS-76-903  
SKH

NORTHEAST OF SITE 1C

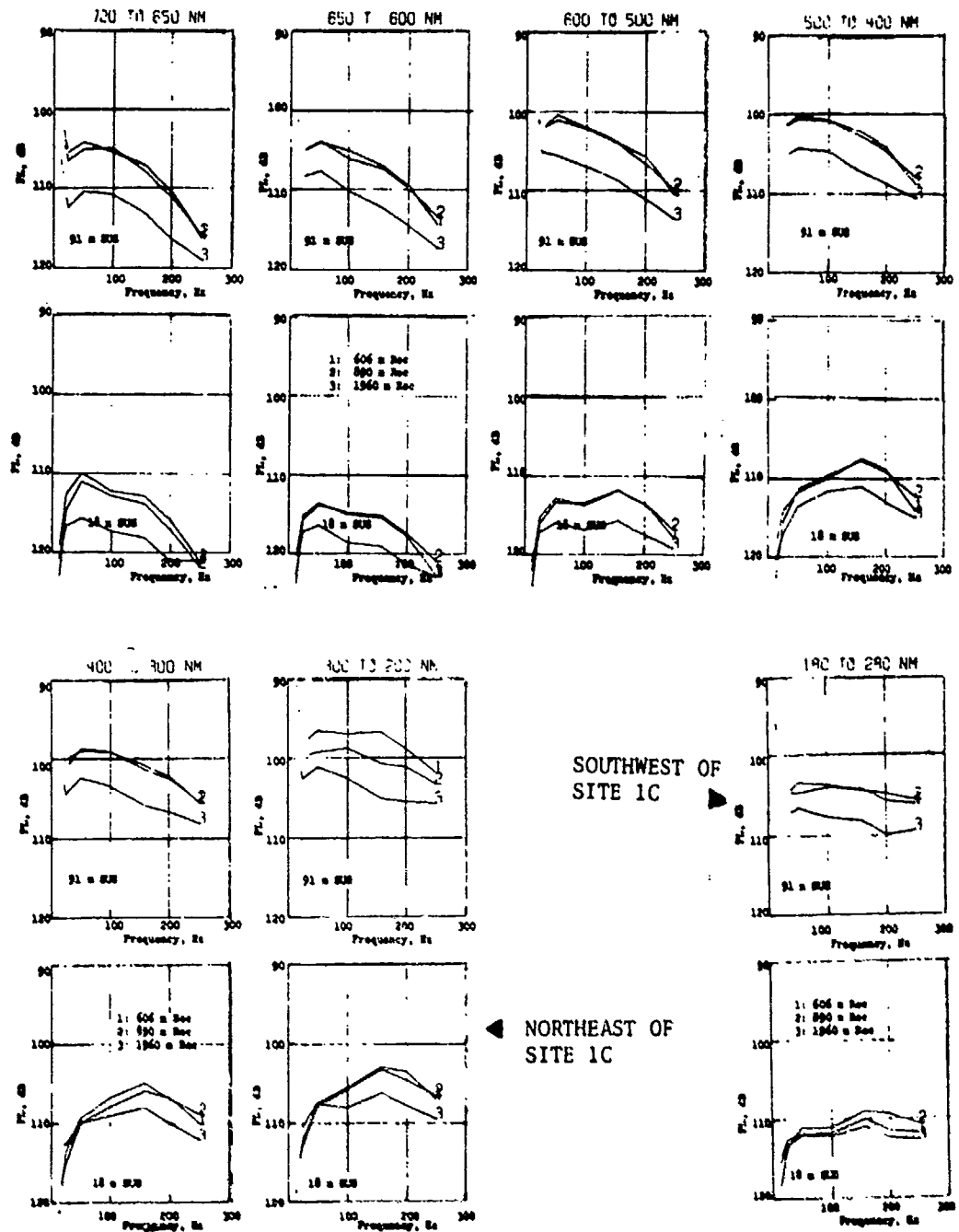


FIGURE IV-10

RANGE AVERAGED PL versus FREQUENCY - SITE 1C, EVENT 22a

606 m, 890 m, 1960 m Receivers  
Two Source Depths

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- (C) depth excess at 600 nm NE of Site 1C, as reflected by the increase in and propagation loss from the 91 m sources of 5 to 6 dB at 25 and 50 Hz. Second, in the shallow water at 700 nm, near point Site 3Z, approximately 5 dB decrease in propagation loss due to edge enhancement is seen at 25 and 50 Hz for the 91 m sources and at 50 and 158 Hz for the 18 m sources.

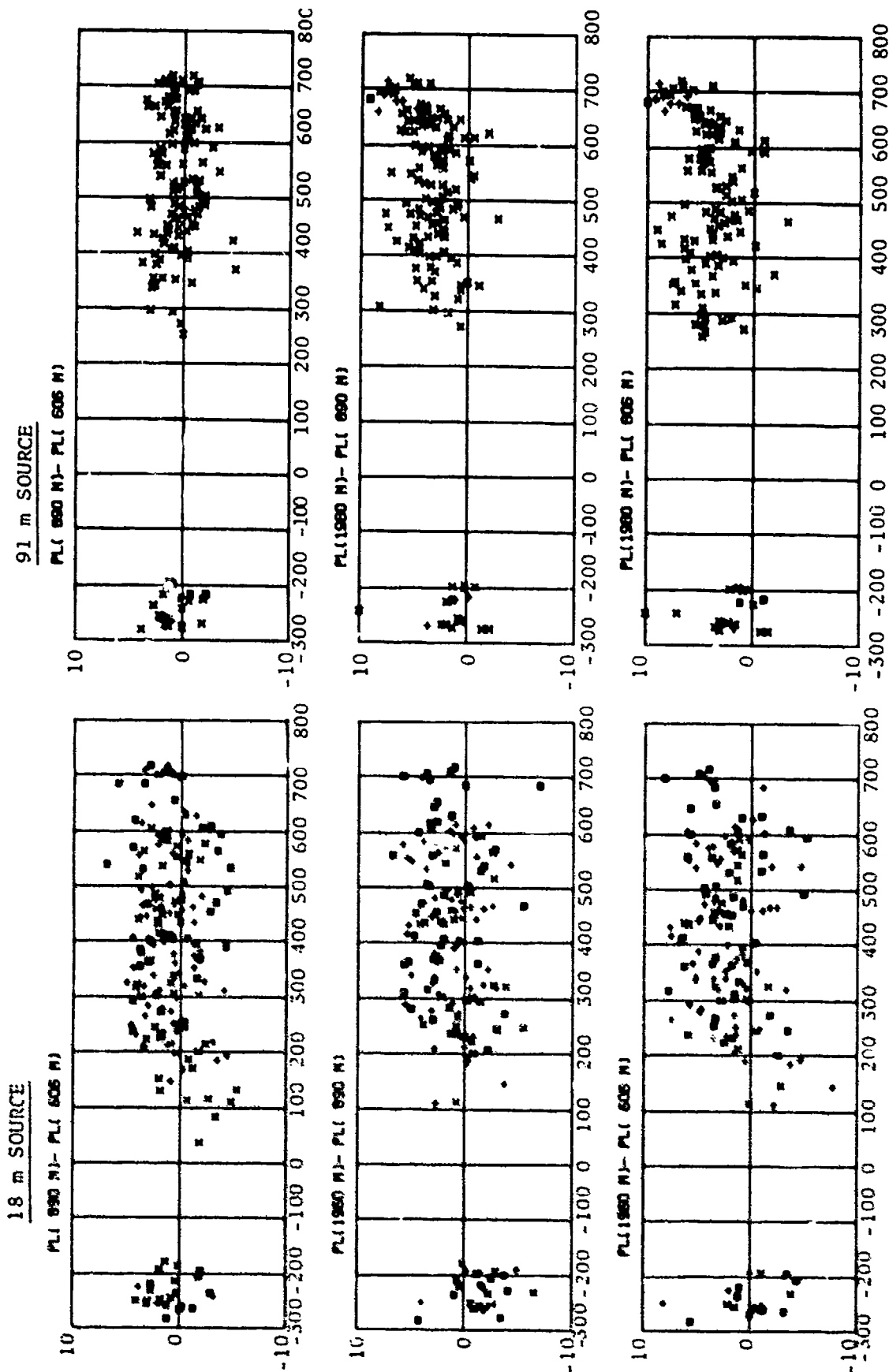
## (3) Receiver Depth Dependence

- (C) Differences between propagation loss to different receivers at Site 1C are given in Fig. IV-11. In general, in the open channel loss is 4 dB to 5 dB greater to the 1960 m receiver (just below critical depth) than to receivers near the axis from 91 m sources at all frequencies. From the 18 m sources, loss to the deep receiver is 1 to 2 dB greater at 25 Hz and 50 Hz and 4 dB greater at 200 Hz. In the high attenuation region over the Gibbs Fracture Zone, the receiver depth dependencies are diminished.

## (4) Frequency Dependence

- (C) The dependence of propagation loss upon frequency at Site 1C is illustrated by Figs. IV-10 and IV-12. From 91 m sources in the open channel NE of Site 1C, the loss at 50 Hz is 2 to 3 dB less than at 25 Hz or at 158 Hz. However, from the 91 m sources in the high attenuation region over the Gibbs Fracture Zone, there is less loss on a shot-by-shot basis (Fig. IV-12) at 158 Hz, than at 50 Hz or 25 Hz; this is similar to the effect of the Faeroe-Iceland Ridge upon the 91 m sources which was seen at Site 2D.
- (C) From the 18 m sources, the frequency dependence is one of decreasing loss with increasing frequency over the open channel region and also over the high attenuation region above the Gibbs Fracture Zone. For example, propagation loss at 50 Hz is 3 dB greater than the loss at 158 Hz. The change in the near surface velocity structure and loss of critical depth which occurs 600 nm NE of Site 1C does cause a change in the frequency

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PROPAGATION LOSS DIFFERENCE - dB

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RANGE - nm  
 FIGURE IV-11a  
 PROPAGATION LOSS DIFFERENCES - SITE 1C, EVENT 22a  
 Differences Among PL to Receivers  
 Two Source Depths  
 25 Hz

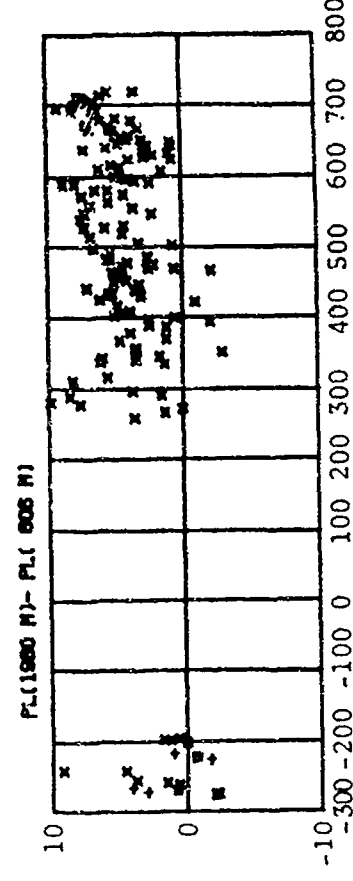
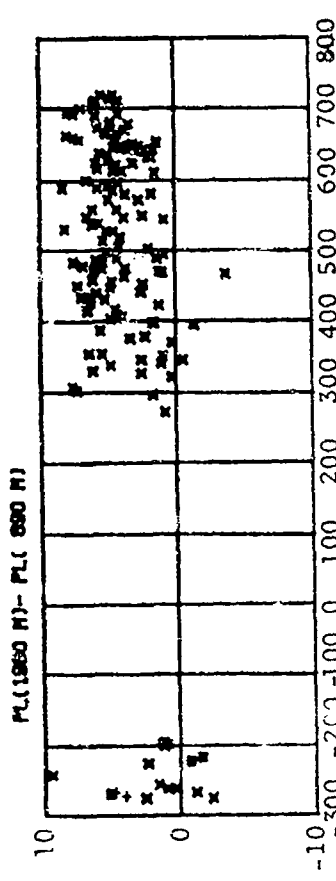
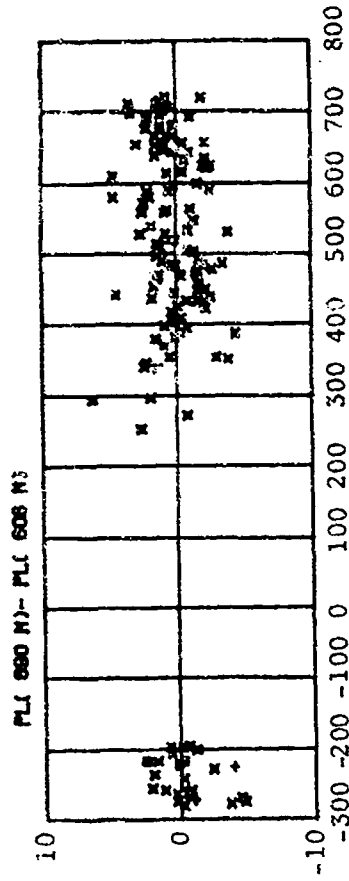
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NYS

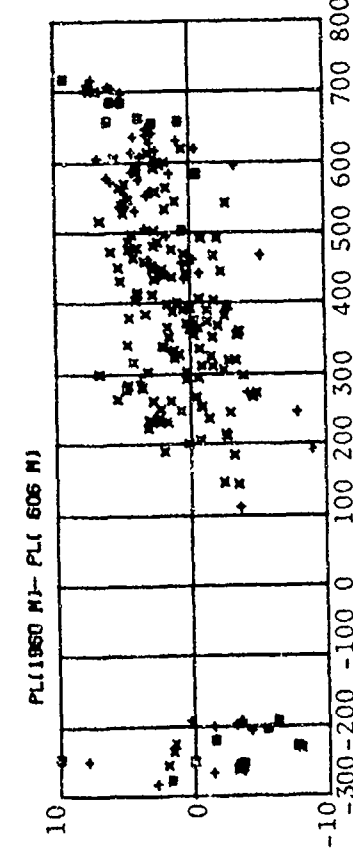
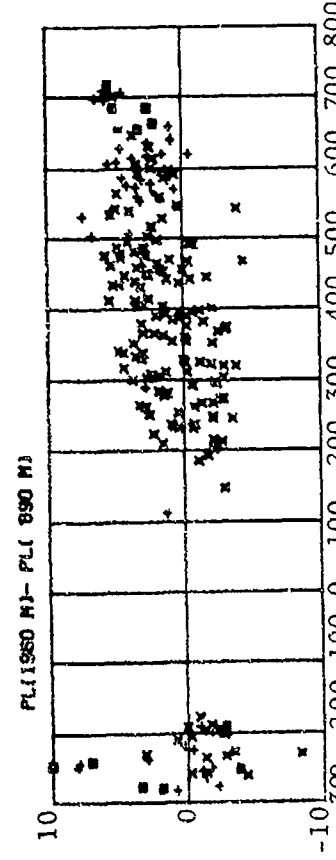
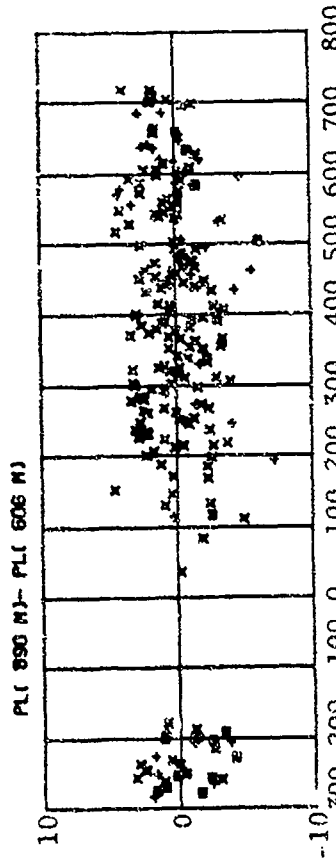


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91 m SOURCE



18 m SOURCE



PROPAGATION LOSS DIFFERENCE - db

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RANGE - nm  
 FIGURE IV-11b  
 PROPAGATION LOSS DIFFERENCES - SITE 1C, EVENT 22a  
 Difference Among PL to Receivers  
 Two Source Depths

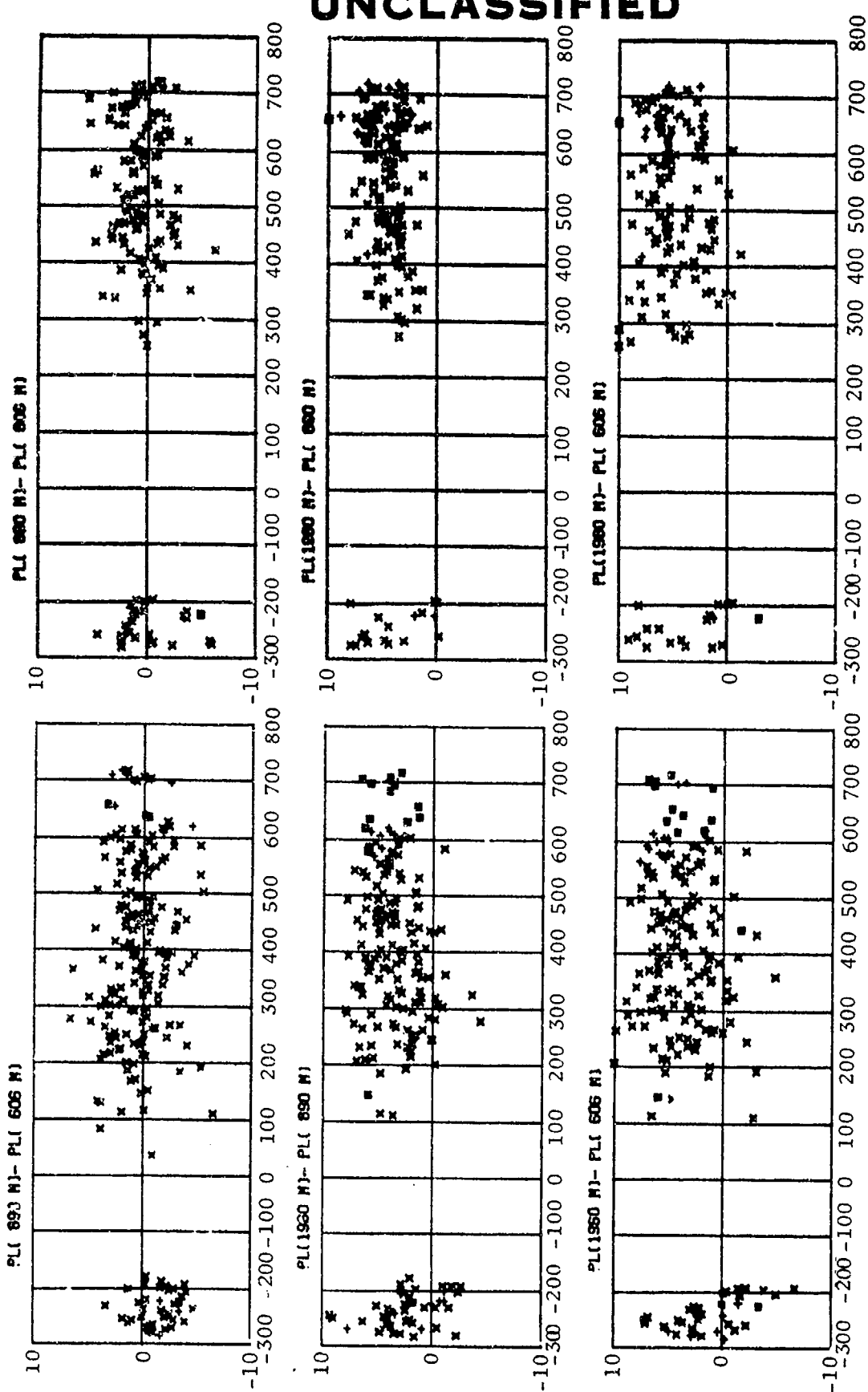
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KMS

SV PLZ

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18 m SOURCE

91 m SOURCE



PROPAGATION LOSS DIFFERENCE - dB

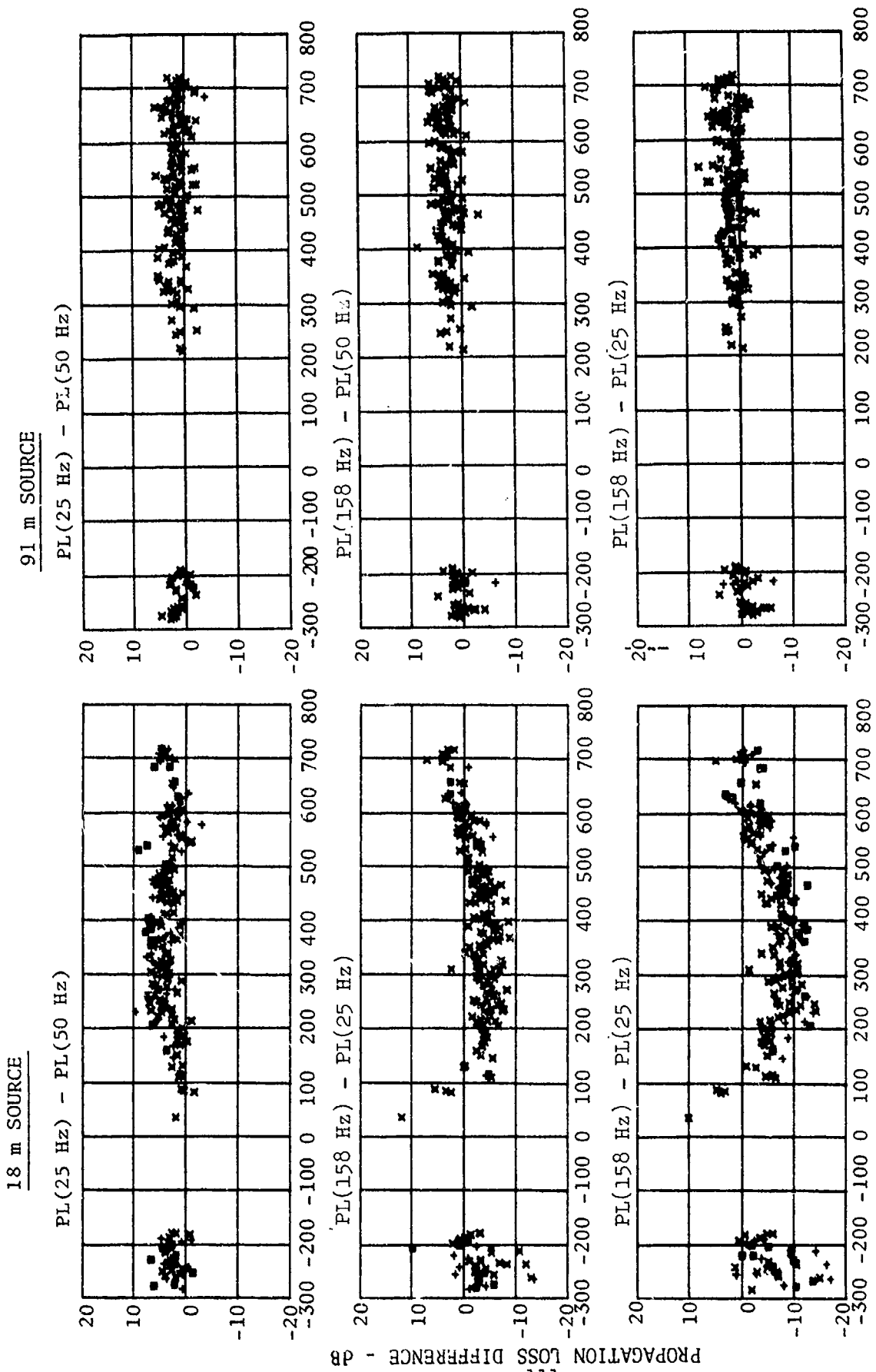
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RANGE - nm  
 FIGURE IV-11c  
 PROPAGATION LOSS DIFFERENCES - SITE 1C, EVENT 22a  
 Difference Among PL to Receivers  
 Two Source Depths  
 200 Hz

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RANGE - nm  
 FIGURE IV-12  
 PROPAGATION LOSS DIFFERENCES - SITE 1C, EVENT 22a  
 850 m Receiver  
 Two Source Depths

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- (C) dependence of the 18 m measurements. Figure IV-12 shows that, beyond 600 nm range, the relative frequency dependence of propagation loss from the 18 m sources is similar to that of the 91 m sources.

c. SURVEY Array, Site 3Z

- (C) The SURVEY array atop Faeroe-Iceland Ridge is located at Site 3Z, on the bottom, in 426 m of water. An SVP taken over Site 3Z is shown in Fig. IV-13; the 1472 m/sec velocity at the bottom is the minimum velocity of the entire area between Site 3Z and Site 1C. Also, recall that propagation loss to the ACODAC receivers from sources near Site 3Z (detonated at 91 m depth) showed a local minimum due to slope enhancement.

- (C) Propagation loss to Site 3Z is shown in Fig. IV-14. The propagation loss curves generally break into three regions. Northeast of Site 3Z, the loss increases very rapidly due to attenuation over the shallow channel. Southwest of Site 3Z, the channel deepens until depth excess is reached approximately 80 nm SW of the receiver; over this interval, propagation loss is characterized by a combination of attenuation and spreading. Beyond 100 nm SW, the propagation loss curves resemble those from the ACODACs at Sites 3D and 1C.

(1) Range Dependence

- (C) There is an open propagation channel from 100 nm to 900 nm SW of Site 3Z. At 50 Hz and 100 Hz, the loss from the 91 m sources increases at a cylindrical spreading rate or less; between 450 nm and 900 nm there is effectively no change in the loss.

(2) Bottom Effects

- (C) Propagation loss from sources NE of Site 3Z to Sites 3D and 1C is high due to attenuation across the Faeroe-Iceland Rise. Figure IV-14 shows a similar high attenuation in shots received at Site 3Z from nearby

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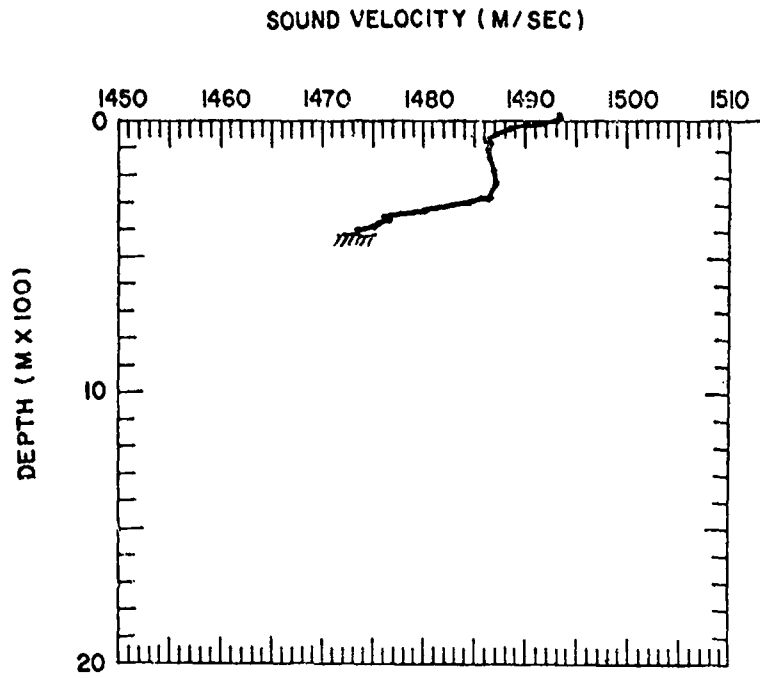


FIGURE IV-13

SOUND VELOCITY PROFILE AT SITE 32

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18 m SOURCE

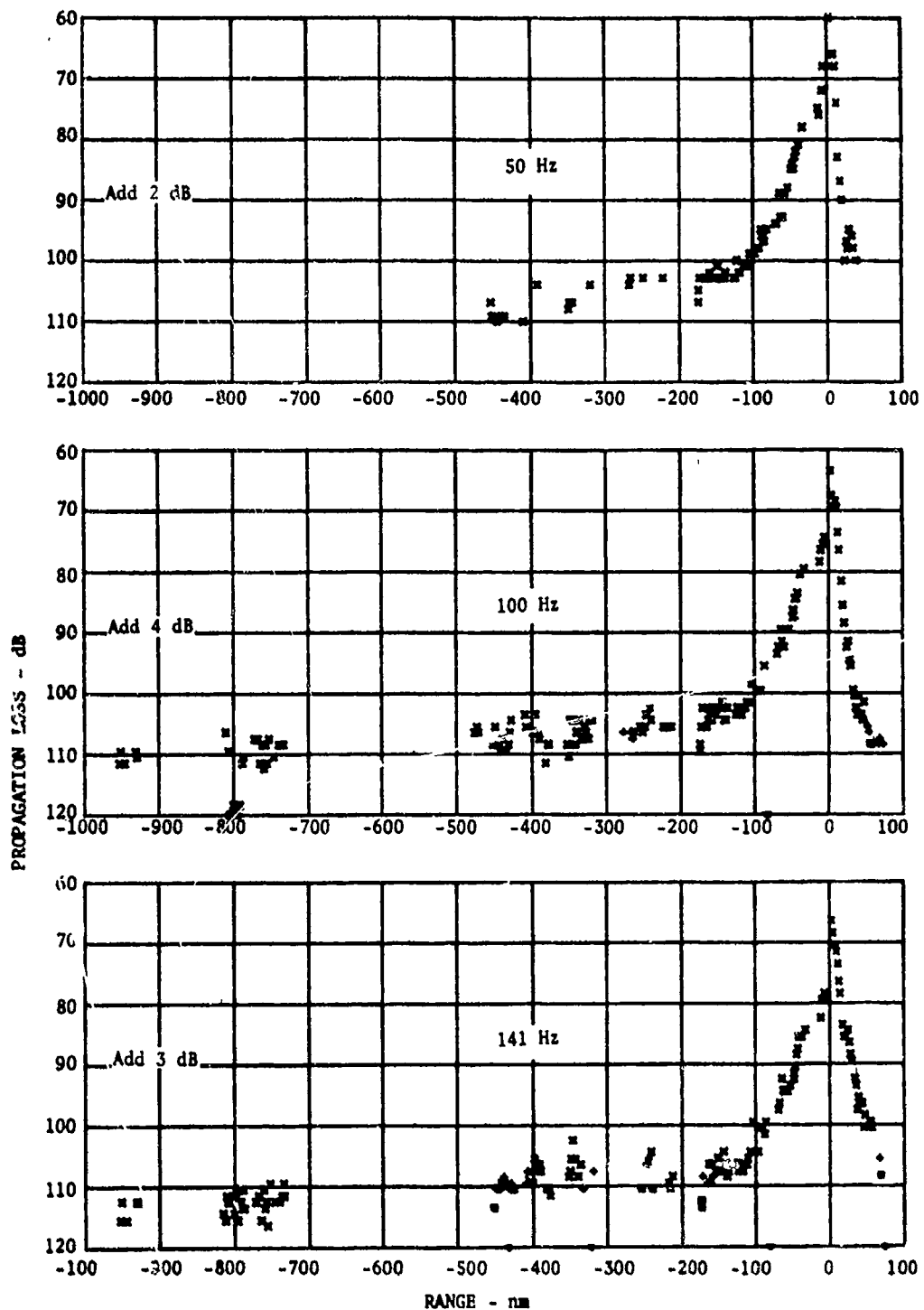


FIGURE IV-14a  
PROPAGATION LOSS - SITE 3Z, EVENT 14b  
426 m Receiver  
18 m Source  
50, 100, and 141 Hz

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## 91 m SOURCE

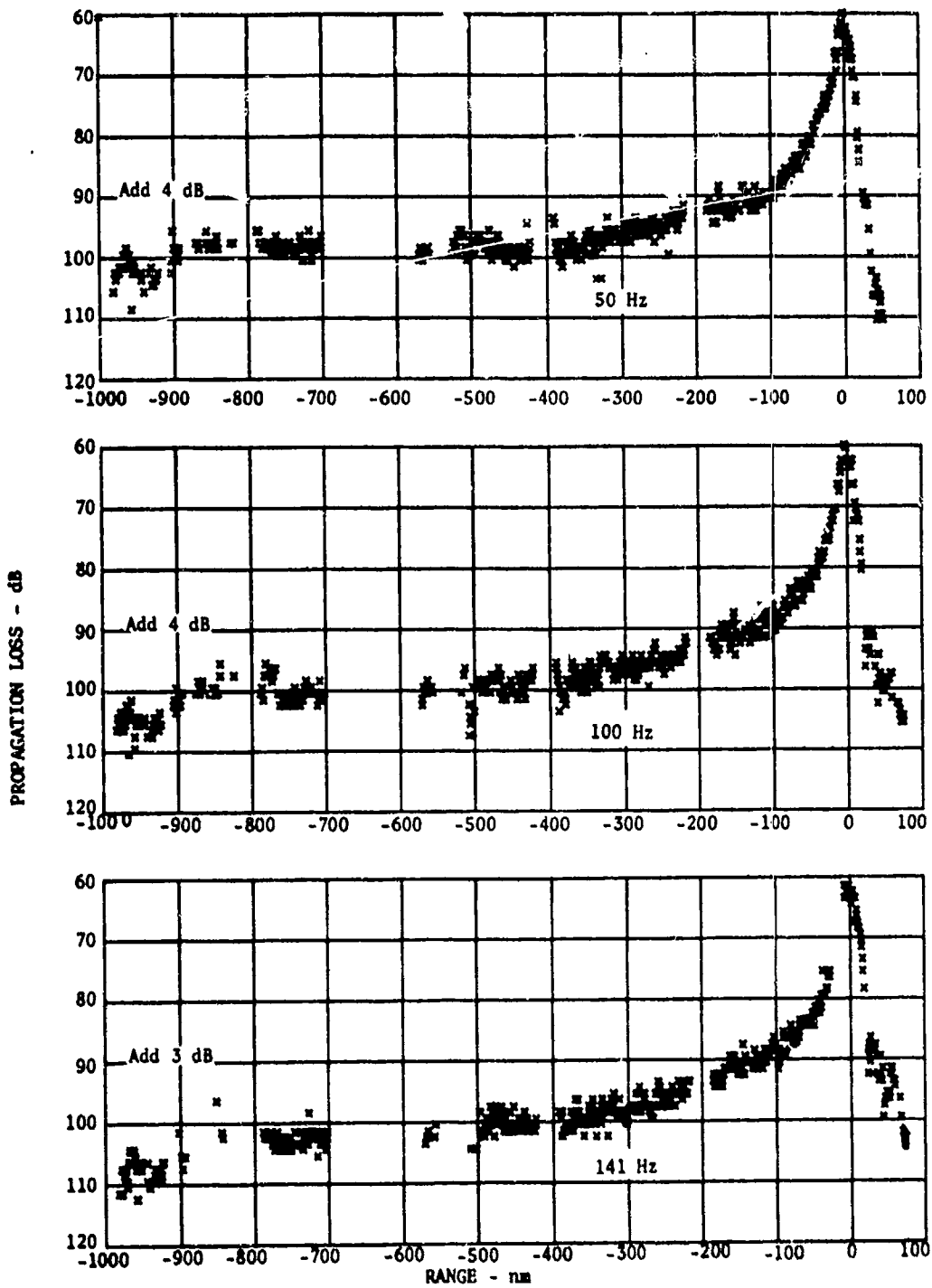


FIGURE IV-14b  
PROPAGATION LOSS - SITE 32, EVENT 14b  
426 m Receiver  
91 m Source  
50, 100, and 141 Hz

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SKM

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(C) sources (within, say,  $\pm 50$  nm). The asymmetry of the bottom depth about Site 3Z is reflected in the propagation measurements. The frequency dependence of the attenuation is similar to that observed at Site 3D. Namely, the attenuation of energy at the lower frequencies across the shallow water is greater than the attenuation at the higher frequencies.

## (3) Source Depth and Frequency Dependence

(C) The source depth dependence is related to source location. Propagation from sources NE of Site 3Z, across shallow water, shows no source depth dependence at any of the frequencies studied. Southwest of Site 3Z, going into deeper water, the difference between propagation loss from the two source depths increases until, near 150 nm SW, the loss is approximately 15 dB greater from the 18 m sources at 100 Hz and 141 Hz. Beyond 250 nm the loss from the 18 m sources is approximately 10 dB greater than the loss from the 91 m sources.

### d. MABS II, Site 3AA

(U) Event 22a was nonradial to Site 3AA; the range to the point of closest approach was 53 nm. Figure IV-15 shows the sound velocity profile at Site 3AA. The outputs of the hydrophones shown in Table IV-1 have been processed. Propagation loss from the 18 m and 91 m sources to the 1454 m receiver are shown in Fig. IV-16. Figure IV-17 presents the loss from the 91 m source to the 165 m and 2155 m receivers.

## (1) Range Dependence

(C) The open sound channel extends approximately 600 nm to the SW and 250 nm to the NE from Site 3AA; propagation loss to each receiver is roughly symmetrical about the CPA (closest point of approach) of 53 nm. Away from the CPA, the loss increases rapidly out to approximately 150 nm range at frequencies of 100 Hz and below; this effect is more noticeable for the 18 m sources. Beyond approximately 150 nm, the loss increases by only 3 dB or less out to 600 nm to the SW, where bathymetric effects are seen.



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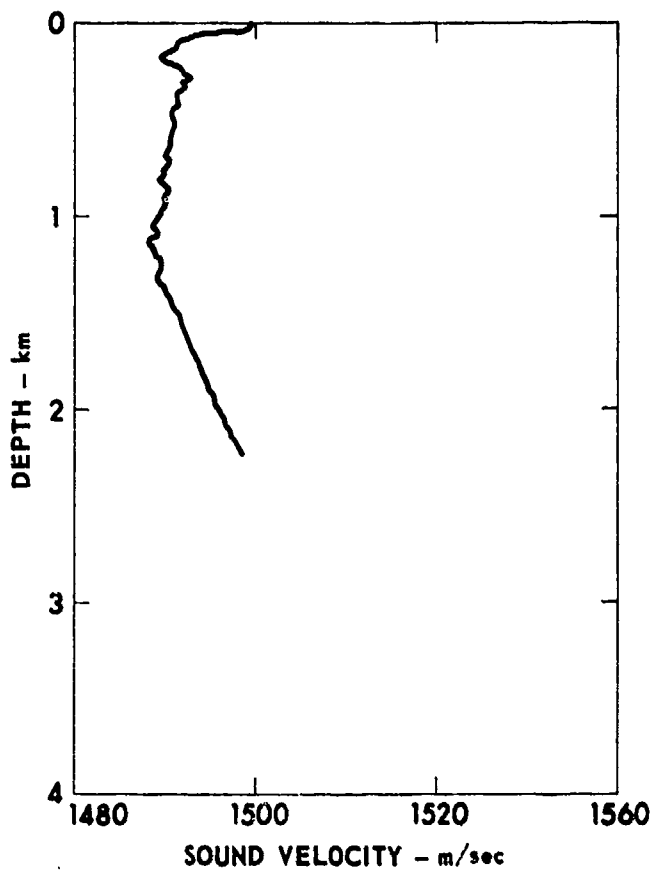


FIGURE IV-15  
SVP AT SITE 3A

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AS-76-932  
SKM - DR  
7-27-76

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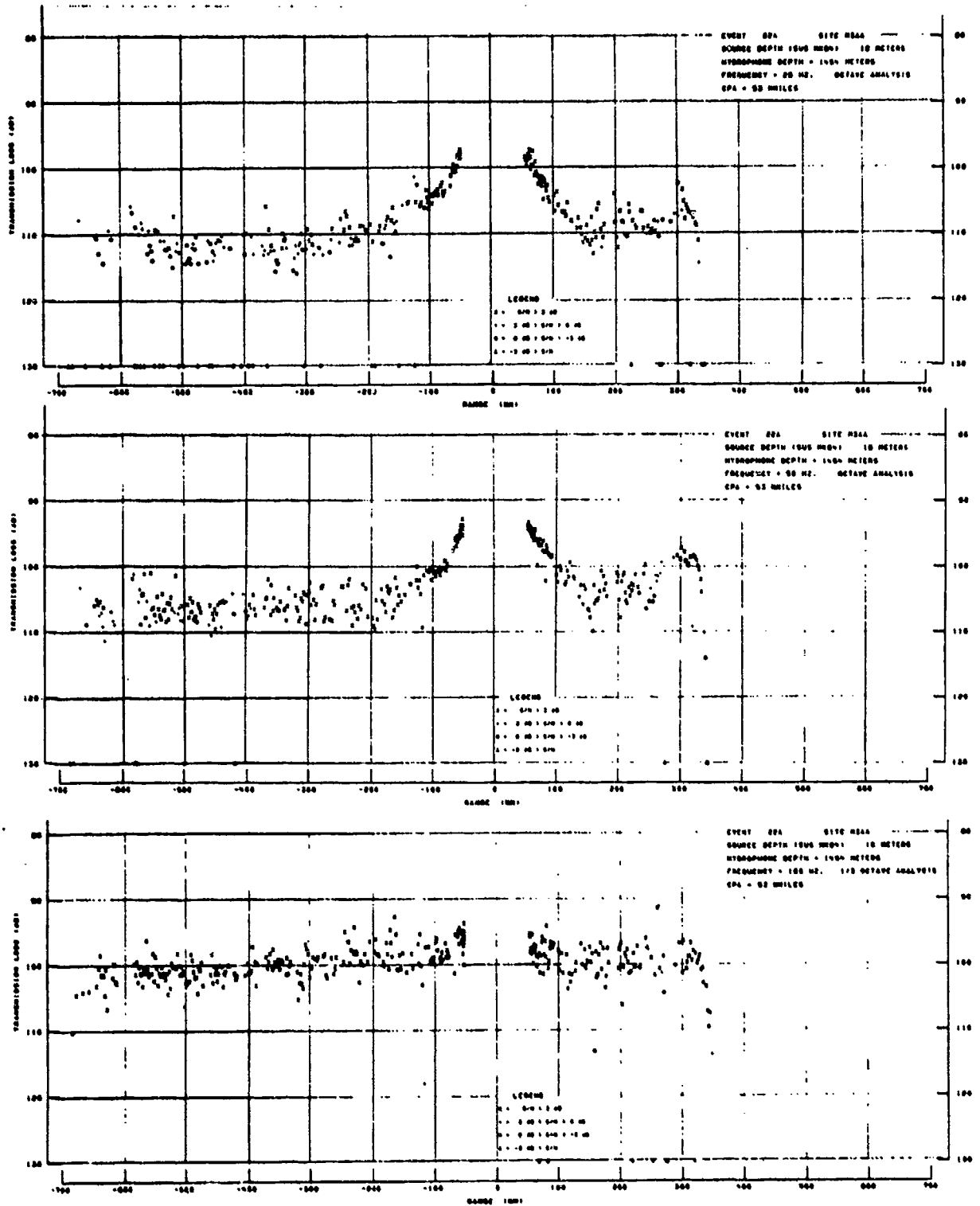


FIGURE IV-16a  
 PROPAGATION LOSS - SITE 3AA, EVENT 14b  
 1454 m Receiver  
 18 m Source  
 25, 50, and 160 Hz

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 SKM

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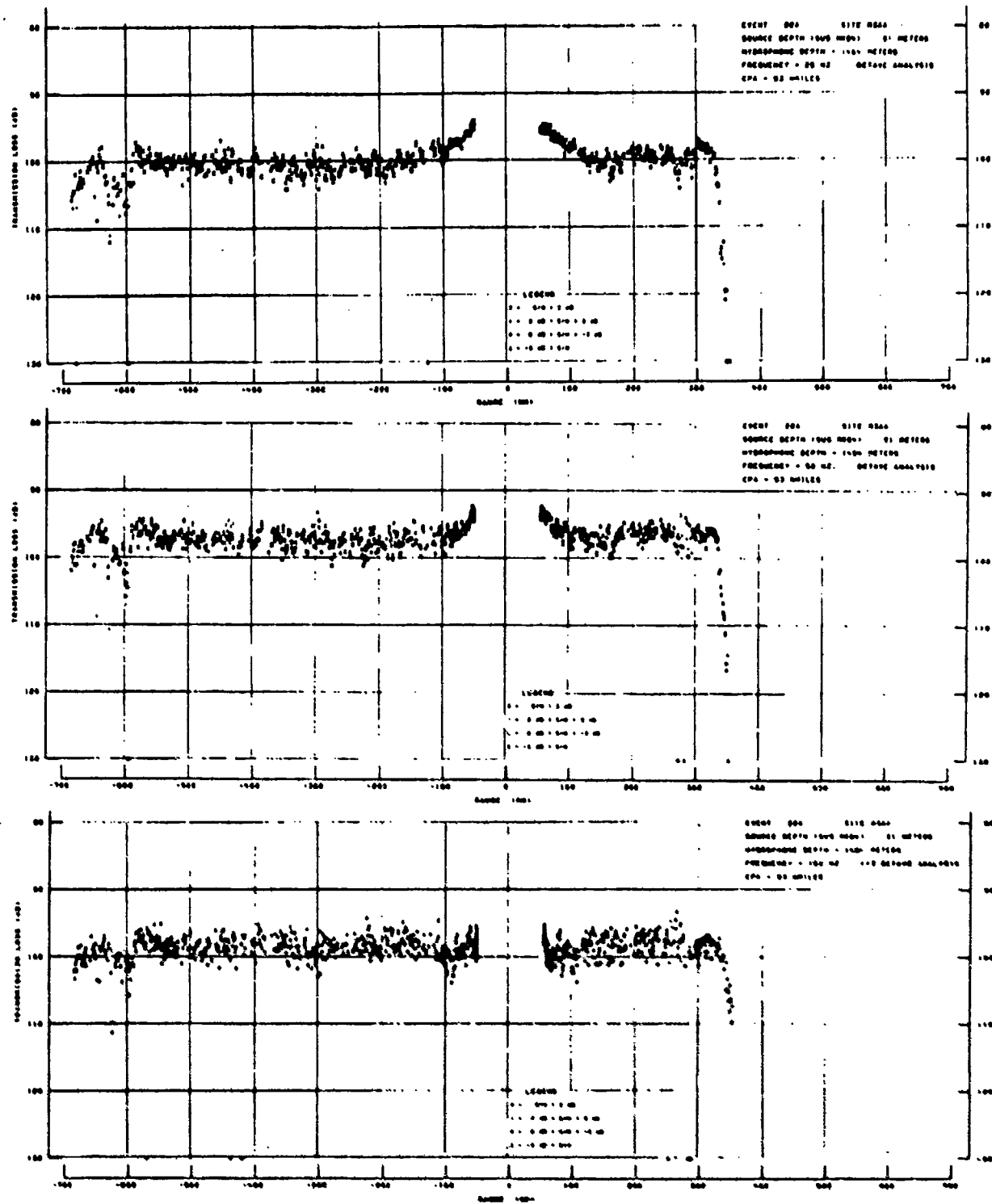


FIGURE IV-16b  
PROPAGATION LOSS - SITE JAA, EVENT 14b  
1454 m Receiver  
91 m Source  
25, 50, and 160 Hz

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SEM

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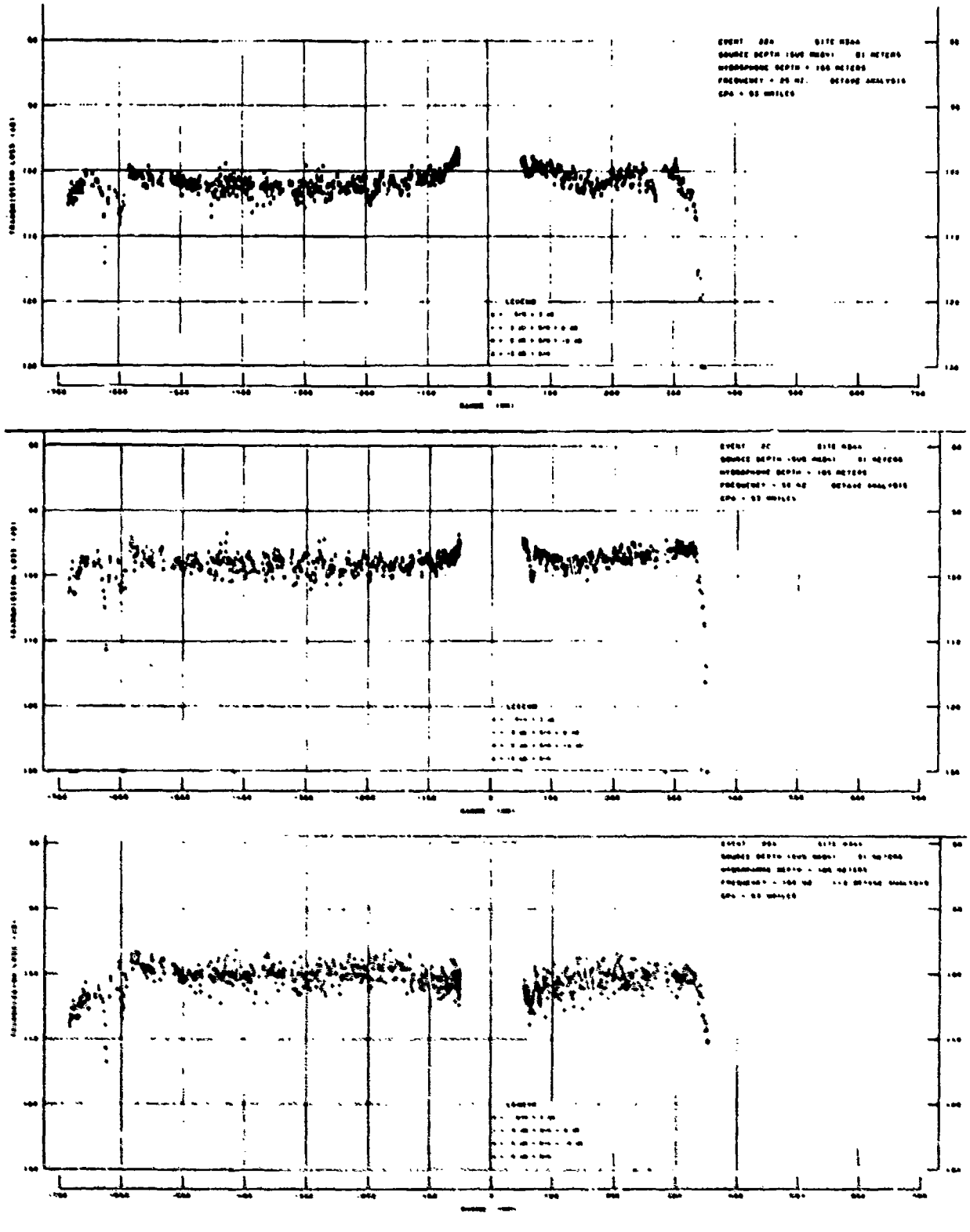


FIGURE IV-17a  
 PROPAGATION LOSS - SITE 3AA, EVENT 14b  
 165 m Receiver  
 91 m Source  
 25, 50, and 160 Hz

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SEM

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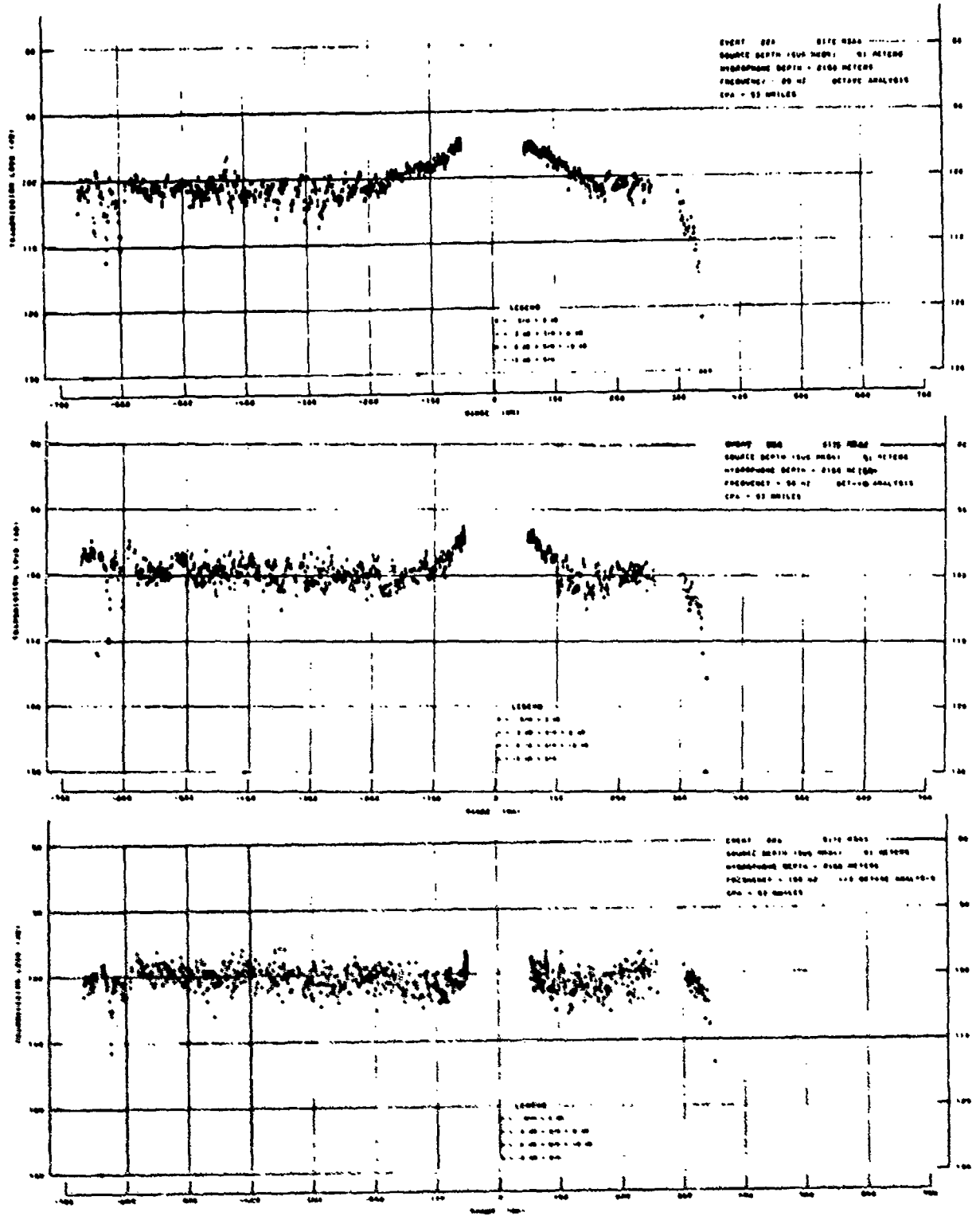


FIGURE IV-17b  
PROPAGATION LOSS - SITE 3AA, EVENT 14b  
2155 m Receiver  
91 m Source  
25, 50, and 160 Hz

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SEM

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## (2) Source Depth Dependence

- (C) The propagation loss from the 18 m source is, in general, greater than the 91 m source propagation loss. At 25 Hz, the 18 m source exhibits 8 to 12 dB more loss. The difference as a function of frequency decreases to approximately 0 dB as the frequency increases to 250 Hz.

## (3) Receiver Depth Dependence

- (C) All of the Site 3AA hydrophones were above critical depth; the propagation loss was less to receivers in the deep sound channel than to the other receivers. The 966 m and the 1454 m receivers showed propagation loss within 0.5 dB of each other. The greatest difference among receiver depths was between loss to these deep sound channel receivers and the 165 m receiver in the shallow sound channel; the loss to the 165 m receiver was up to 3 dB greater.

## (4) Frequency Dependence

- (C) Propagation from the 91 m source to Site 3AA is almost independent of frequency for ranges less than 300 to 400 nm, though the 50 Hz and 100 Hz bands have up to 3 dB less loss than do the other bands. At ranges greater than 400 nm, there is 5 dB less loss at 100 Hz than at 25 Hz; propagation loss then increases above 100 Hz. There is a general increase of 4 dB from the minimum at 100 Hz to the level at 250 Hz.
- (C) Propagation loss from the 18 m source to Site 3AA generally decreases with increasing frequency; the exact nature is range dependent. Out to 200 nm range, there is 5 dB more loss at 25 Hz than at 100 Hz; beyond 300 nm, the difference is 10 dB.

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## (5) Bottom Effects

(C) Beyond 250 nm to the NE of Site 3AA, depth excess and the surface duct are lost as the source passes over the Faeroe-Iceland Rise. Slope enhancement from sources in the range interval of 250 to 300 nm was observed. At frequencies of 100 Hz and less there is a 5 to 8 dB decrease in propagation loss from the 18 m source due to the slope enhancement; above 100 Hz there is no clear edge enhancement for the 18 m sources. The effect upon the propagation from the 91 m sources amounts to only 1 or 2 dB at 25 Hz and 50 Hz.

(C) Beyond the region of slope enhancement, propagation loss increased approximately 10 dB over a 30 nm range.

(C) The source crosses over the Gibbs Fracture Zone at a range of 575 nm. Near this range, the 18 m source is not detected for 30 to 40 nm; at approximately 610 nm, the 18 m source is again detected. The loss from the 18 m source after the recovery is approximately 1 dB greater than before the loss of the signal. Within the range interval of 585 nm to 625 nm the loss from the 91 m source shows a 3 to 5 dB increase; then at a range of approximately 655 nm, loss from the 91 m source is approximately 2 to 3 dB greater than it was before the zone.

### e. Comparison of Propagation to Sites 3D and 1C

(C) Figure IV-2 shows a definite change in the sound velocity structure between Sites 3D and 1C, as is reflected in a slight difference between propagation to the two sites from sources located between them. The range dependence was described in the discussion of each site. Average values of propagation loss over range intervals of 200 to 300 nm and 400 to 500 nm from each site are presented in Table IV-2. Sources in the closer interval are approximately midway between Sites 1C and 3D while those in the farther interval are approximately over the opposite site. At the 200 to 300 nm range, only the shallowest receivers in the 158 Hz band show

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(C)

TABLE IV-2

COMPARISON OF PROPAGATION LOSS TO ACODACS AT SITES 3D AND 1C  
DURING EVENT 22a, 200 TO 300 nm FROM RECEIVERS (U)

(A) 200 to 300 nm Range

	<u>25 Hz</u>	<u>50 Hz</u>	<u>158 Hz</u>
<u>91 m Sources</u>			
1C, 606 m	98 dB	96 dB	97 dB
3D, 406 m	-	98	100
1C, 890 m	100	99	101
3D, 1078 m	100	99	101
1C, 1960 m	102	102	105
3D, 1812 m	101	101	104
<u>18 m Sources</u>			
1C, 606 m	111	108	103
3D, 406 m	-	-	-
1C, 890 m	112	108	104
3D, 1078 m	113	104	105
1C, 1960 m	113	108	106
3D, 1812 m	112	110	104

(B) 400 to 500 nm Range

<u>91 m Sources</u>			
1C, 606 m	102	100	102
3D, 406 m	-	99	102
1C, 890 m	102	100	103
3D, 1078 m	100	99	103
1C, 1960 m	105	104	107
3D, 1812 m	102	102	105
<u>18 m Sources</u>			
1C, 606 m	114	112	108
3D, 406 m	-	-	-
1C, 890 m	116	112	108
3D, 1078 m	114	110	107
1C, 1960 m	117	114	111
3D, 1812 m	114	112	101

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(C) as much as 3 dB difference between sites. At the 400 nm to 500 nm range, the loss from the 91 m sources is 2 to 3 dB greater to Site 1C than to Site 3D on the middle and deepest receivers. This larger difference for the deeper receivers may be partially due to the fact that the 1960 m hydrophone at Site 1C is 100 m below critical depth while the 1812 m hydrophone at Site 3D is 100 m above critical depth.

f. Comparison of Propagation to Sites 3D and 3Z

(C) At Sites 3D and 3Z, propagation from sources at long ranges (greater than 200 nm, say) is characterized by little dependence upon range at 100 Hz and below. Propagation to Sites 3D and 3Z from sources approximately over Site 1C is compared in Table IV-3. For the column headed 150 Hz, 158 Hz is used at Site 3D and 141 Hz at Site 3Z. The range to Site 3D is approximately 450 nm and to Site 3Z, approximately 700 nm. As may be seen, propagation from the 91 m sources to the one receiver at Site 3Z is equivalent to or better than propagation to the two receivers chosen for comparison at Site 3D; in contrast, propagation from the 18 m sources is better to Site 3D than to Site 3Z.

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(c)

TABLE IV-3

COMPARISON OF PROPAGATION LOSS TO ACODAC AT SITE 3D  
AND SURVEY ARRAY AT SITE 3Z DURING EVENT 22a  
SOURCES OVER SITE 1C (U)

	<u>25 Hz</u>	<u>50 Hz</u>	<u>100 Hz</u>	<u>150 Hz</u>
<u>91 m Sources</u>				
3D, 1078 m	100	99	100	103
3Z (bottom)	-	98	100	102
3D, 1812 m	101	102	103	105
<u>18 m Sources</u>				
3D, 1078 m	114	110	109	107
3Z (bottom)	-	-	111	113
3D, 1812 m	114	112	110	107

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## V. COMPARISON OF REGIONS

### 1. Comparison of Phase I and Phase III, Site 1C

- (C) ACODAC systems were located at Site 1C during Event 2a of Phase I and Event 22a of Phase III; Event 2a is a SUS run along the axis of the West European Basin (Fig. II-1) and Event 22a is along the Icelandic Basin (Fig. IV-1). The relative propagation loss from sources in the two basins to Site 1C depends upon source depth, receiver depth, and frequency. Whenever significant differences in the loss from equivalent ranges were observed, there was greater loss from the Icelandic Basin.
- (C) Table V-1 compares range averaged values of propagation loss to receivers near the sound channel axis (712 m for Phase I, 606 m for Phase III) and near critical depth (1444 m for Phase I, 1960 m for Phase III) for two range intervals. There is an open channel for propagation to Site 1C from sources in all four source locations. To receivers at the axis at Site 1C, the mean loss from the 91 m sources in both basins is almost identical. However, to the deeper receivers, the loss from 91 m sources is nominally 2 dB greater for sources in the Icelandic Basin (Event 22a). These comparisons were noted for both range intervals.
- (C) For the 18 m sources the comparison seems to depend upon the range interval. In the 300 to 400 nm interval, the loss from the 18 m sources to hydrophones at the axis are the same from both directions. To the deeper hydrophones, there is approximately 2 dB more loss from sources in the Icelandic Basin. In the 500 to 600 nm interval, the loss from 18 m sources in Event 22a is greater for both receiver depths.

(c) **TABLE V-1**  
**RANGE AVERAGED PROPAGATION LOSS AT SITE 1C FROM EVENTS 2a AND 22a (U)**

EVENT NUMBER	RECEIVER DEPTH	SOURCE DEPTH	Propagation Loss in the Range Interval 300 to 400 nm			Propagation Loss in the Range Interval 500 to 600 nm				
			25 Hz	50 Hz	158 Hz	250 Hz	25 Hz	50 Hz	158 Hz	250 Hz
			2a	712	18	114	109	105	108	115
22a	606		113	110	106	110	115	113	112	118
2a	1944		113	108	105	107	116	111	109.6	115
22a	1960		115	110	108	112	117	116	115.7	119
2a	712	91	100	99	101	105	102	101	105	111
22a	606		100	99	101	106	102	101	104	110
2a	1944		101	99	103	106	104	103	108	113
22a	1960		104	102	106	108	105	101	109	113

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## 2. Comparison of Phase I and Phase II, Site 2C

- (C) There were ACODAC systems at Site 2C during Event 2a of Phase I and Event 14b of Phase II. Event 2a was along the major axis of the West European Basin (Fig. II-1). In the range interval of 200 to 300 nm west of Site 2C the sound speed profile changed from one with a double minimum to one with a single minimum. There was a depth excess along the entire source track. Event 14b was down the Rockall Trough (Fig. III-1). The sound speed profiles along this source track were characterized by a double minimum. At a range of approximately 200 nm NE of Site 2C there was a loss of depth excess for a short range interval (Fig. III-2).
- (C) Table V-2 presents range averaged propagation loss for selected receivers at Site 2C for Events 2a and 14b. For both range intervals, the 91 m source propagation loss was 1 to 2 dB more from the West European Basin than from the Rockall Trough. From the 18 m sources at low frequencies (25 Hz and 50 Hz), there was as much as 3 dB more loss to the SW (Event 2a) than to the NE (Event 14b). At the higher frequencies for the 18 m source, however, there was 1 to 2 dB more loss from the NE than from the SW. This behavior for the 18 m sources is due to the fact that the Lloyd's Mirror effect was prominent during Event 2a, but was much less significant during Event 14b.

(c) TABLE V-2  
RANGE AVERAGED PROPAGATION LOSS AT SITE 2C FROM EVENTS 2a AND 14b (U)

EVENT NUMBER	RECEIVER DEPTH	SOURCE DEPTH	Propagation Loss in the Range Interval 200 to 300 mm					Propagation Loss in the Range Interval 300 to 400 mm								
			25 Hz	50 Hz	100 Hz	158 Hz	200 Hz	250 Hz	25 Hz	50 Hz	100 Hz	158 Hz	200 Hz	250 Hz		
2a 14b	1450	18	111	106	105	102	104	104	104	104	104	104	104	104	105	107
	1376		109	103	106	104	104	105	105	106	107	104	105	105	105	105
2a 14b	2777		111	105	105	102	104	105	105	105	105	105	106	106	106	108
	2445		110	104	106	105	106	107	107	107	110	108	108	108	108	109
2a 14b	1450	91	98	99	99	100	101	102	102	102	102	102	102	102	102	104
	1376		97	96	97	98	100	100	100	100	100	100	100	100	102	103
2a 14b	2777		100	102	103	103	104	105	105	105	105	105	106	106	106	108
	2445		99	100	102	102	103	103	104	104	104	104	104	104	104	105

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