DIGITAL DEEP-SEA SOUNDING LIBRARY

DESCRIPTION AND INDEX LIST

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ABSTRACT

Automated access to a worldwide coverage of over 1 000 000 deep sea soundings is provided by a new digital data library. The deep sea soundings recorded on available master plotting sheets of the major maritime nations have been incorporated in this new facility.

The methods used in evaluating, digitizing, and processing the data are described in detail. The data are maintained in full both on magnetic tape and on over 60 000 frames of microfilm. The four master library lists are described and sample pages reproduced. The locations of all recorded sound profiles are presented in 708 computer generated index maps.

The data in the library will now be put to use in the solution of numerical problems of both global and regional character. Some of the applications in which this library will be employed include the determination of an average ocean depth model for numerical computations of global geophysical character (such as needed, for example, in the study of ocean tides, the propagation of tsunamis, in geodesy in general, and in the spherical harmonic analysis of earth topography), quantitative textural analysis of topography (slopes, wave lengths, amplitudes), and detailed hypsometric studies.

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Automated access to a worldwide coverage of deep sea soundings is needed for many geophysical, geological and cartographical applications. It is the purpose of this paper to give a general account of the data incorporated in a recently established digital data library, to outline the methods used in digitizing, processing, and evaluating this data, and to indicate some of the applications in which this library will be employed.

Deep-sea soundings were first obtained by hemp and later by wire line, but since the 1920's virtually all have been obtained by echo timing methods. The echo times collected in the data libraries of the U.S. Naval Oceanographic Office, the Woods Hole Oceanographic Institution, the Scripps Institution of Oceanography, the Lamont Geological Observatory and other oceanographic institutes are recorded in units of 1/400 sec. This unit is known as the standard unit (t_e), or the nominal fathom. The echo times shown on plotting sheets maintained by the British Commonwealth hydrographic departments are indicated in approximate fathoms and include a correction for the vertical velocity of sound. Such corrections are made according to a standard table, and may be as large as 300 fathoms. The resulting velocity corrected depths are not strictly true, due to imperfections in the tables, seasonal variations and other factors.

In addition to these two general procedures, individual institutions or individual workers throughout the world have introduced other units of echo time equal to 1/420, 1/750, and 1/725 sec., and have adopted tables other than the standard one to obtain " corrected depths ". Since all echo soundings are measurements of time, one must have accurate information concerning the units and corrections applied and the type, scale, and ultimate accuracy of the recorder used, in order to combine soundings obtained from various sources.

The standard deep-sea plotting sheets use a Mercator grid at either 4 inches or 8 inches to 1° longitude. Other scales and even other projections are employed by various institutions. Since a great variety of units and scales are employed, the compilation of soundings accumulated from various sources has required the expenditure of much effort. The recent significant increase in deep-sea survey and exploration and the installation of digital acquisition systems on survey ships obviously require the use of more efficient automated methods of data processing the correction in order to combine the new data and the older information.

The soundings contained on the master plotting sheets for deep-sea soundings maintained by the U.S. Naval Oceanographic Office, the Lamont Geological Observatory, the hydrographic departments of the United Kingdom, South Africa, Australia, New Zealand, the Netherlands and Germany have been used as the basic source information for a digital library.

Each sounding line was inspected for completeness and accuracy of position and depth, and a rating assigned based on general quality. Precision depth measurements accurate to 1 standard unit (t_e), located by precision methods accurate to better than 1 nautical mile and recorded on charts with a spacing between soundings of no more than 2 miles were given the highest rank. Soundings of unknown origin, scattered soundings, and soundings of known origin where accuracy was less than 100 t_e or spacing more than 15 miles, were in general not included in the library.

Soundings were recorded on punched cards by operators employing recently-developed semi-automatic instruments known as digitizers. (Such devices are manufactured by Gerber, Benson-Lehner, and Auto-Trol). In this procedure, the recording head was set over the sounding to be read from the plotting sheet. Each depth value was punched by operating a keyboard and the coordinates recorded automatically by depressing a switch. The precision of the instrumentation for recording the coordinates is 0.001 inch.

The coordinates and depth values are recorded on punched cards by means of a standard IBM card-punch that is connected to the digitizing equipment. Allowing five digits for each of the coordinates of a sounding and its depth value, a maximum of five soundings may be listed on a standard 80-column punch card. The column following each group of fifteen digits (for coordinates and depth) is left empty and serves as an ignore option in cases of error.

This process results in three pieces of digitized information :

(1) c_x, the linear distance from the map origin to the location of the sounding in the x-direction of the map;
(2) c_y, the linear distance from the map origin to the location of the sounding in the y-direction of the map;
(3) The sounding in units of echo time.

The map distances c_x and c_y recorded by automatic means must be transformed into geographical coordinates X_1 and Y_1, by taking into account the map scale and the geographical coordinates of the origin, X_0 and Y_0. The computational procedure for this is summarized in Appendix A. The computations were performed initially on an IBM 7094 computer, and later on an IBM system/360, Model 75.

Since the whole process is subject to human error, verification is imperative. It is possible to perform all digitizations twice, preferably by two different operators. Two sets of digitized data may be checked one against the other for mutual agreement within predetermined limits of tolerance. Verifying can be done automatically on an electronic computer. For a quick check on position errors, the tracks are plotted either at a reduced scale, or at the original scale, and inspected for errors (figure 1a). By examining computer-plotted vertical profiles (figure 2b), gross discrepancies and inconsistencies were eliminated. Position plots and profiles of the digitized tracks were generated with the aid of a cathode ray recorder (S-C 4020). This device is peripheral to the computer and reads computer-generated magnetic tape from which it produces the plots and depth profiles on 7.5 $\times$ 7.5 inch frames. Position plots and vertical profiles of all tracks are incorporated in the bathymetric library.

The results of the recording, after verification and correction, are stored on magnetic tape. For each recorded sounding, the following data are available :

(1) Coordinates — latitude and longitude.
(2) Echo time depth as listed on source sheet and units of measurement.
(3) Source sheet number.
(4) Source track documentation number.
(5) Source country.
(6) Reliability rating.

BATHYMETRIC LIBRARY – INDIVIDUAL SOUNDING TRACK LOCATION PLOT
TRACK SERIAL NO. 3382 TRACK SOURCE IDENTIFICATION NO. BR–ARGO
SOURCE SHEET IDENTIFICATION NO. 1226
U.S. NAVAL OCEANOGRAPHIC OFFICE PLOTTING SHEET NOS. 2907S 2807S
UNIT OF DEPTH = CORRECTED FATHOMS RELIABILITY RATING = 9
NUMBER OF SOUNDINGS IN TRACK = 193 DATE 07/22/67

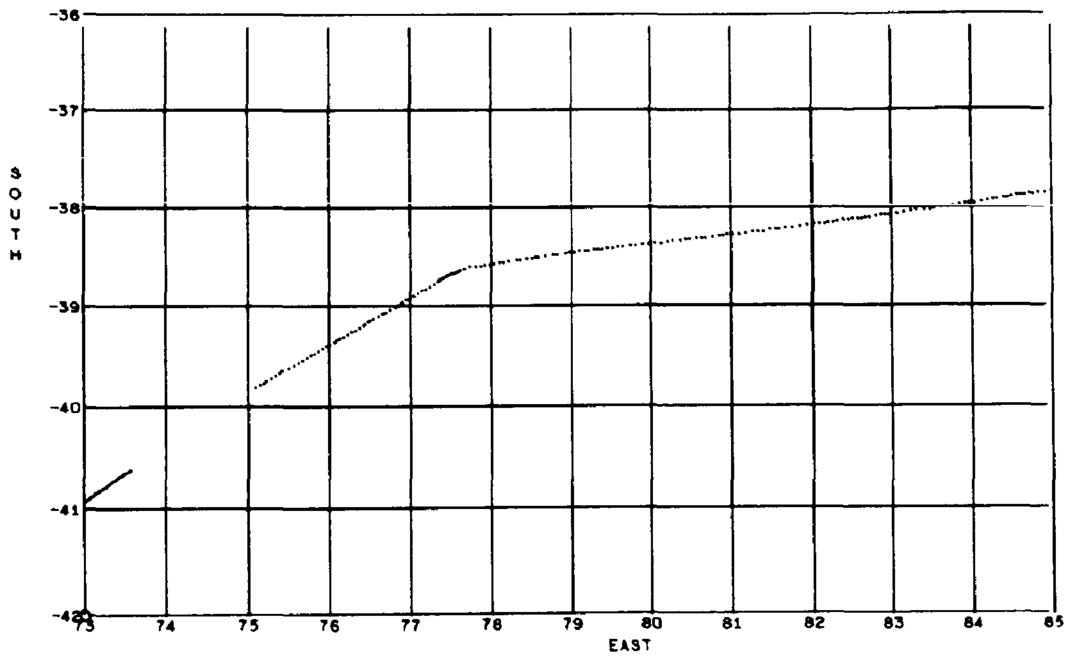


FIG. 1a. — **Sample page of master list No. 1 : Individual sounding track location plot.**

Echo time depths are inserted in the library in the units in which they are given in the source material. These are, for data from U.S. sources, standard units (t_e), i.e. units of 1/400 sec. travel time. Soundings from other source material are given in metres or fathoms, approximately corrected for the velocity of sound according to Matthews' tables [1]. Soundings in other units have not yet been incorporated in the library.

The soundings contained in the library are grouped into track segments. Presently there are 8 375 individual tracks in the library. Each track has been assigned a reliability rating, ranging from 0 to 11. This rating is based on the quality of the echo sounding recording. The factors taken into account for judging the reliability have been the type of echo-sounding equipment used and its resolution, the type of navigation available to the sounding vessel and the associated accuracy, and the density of recordings per unit length of the track (table 1). Sounding tracks have been compiled for 708 plotting areas according to the U.S. Naval Oceanographic Office numbering system. A list is maintained of all tracks in each area including a record of source information, scale, serial number and date entered.

BATHYMETRIC LIBRARY — INDIVIDUAL SOUNDING TRACK
TRACK SERIAL NO. 3382 TRACK SOURCE IDENTIFICATION NO. 8R-A800
SOURCE SHEET IDENTIFICATION NO. 1288
U. S. NAVAL OCEANOGRAPHIC OFFICE PLOTTING SHEET NOS. 28073 28073
UNIT OF DEPTH = CORRECTED FATHOMS RELIABILITY RATING = 0
NUMBER OF SOUNDINGS IN TRACK = 193 DATE 07/22/67

LISTING OF DEPTHS AND COORDINATES OF INDIVIDUAL SOUNDINGS

LAT	LONG	DEPTH	LAT	LONG	DEPTH	LAT	LONG	DEPTH	LAT	LONG	DEPTH	LAT	LONG	DEPTH
40.927 S	73.084 E	1970	39.357 S	76.086 E	1798	38.615 S	77.923 E	866	38.314 S	80.908 E	1834	37.993 S	83.954 E	1886
40.913 S	73.042 E	1971	39.342 S	76.128 E	1824	38.606 S	77.981 E	772	38.308 S	80.935 E	1809	37.988 S	84.031 E	1965
40.897 S	73.082 E	1976	39.323 S	76.168 E	1705	38.596 S	78.043 E	671	38.306 S	81.011 E	1841	37.974 S	84.121 E	2036
40.884 S	73.082 E	2002	39.303 S	76.224 E	1776	38.590 S	78.086 E	718	38.299 S	81.094 E	1868	37.966 S	84.197 E	2080
40.873 S	73.112 E	2024	39.283 S	76.268 E	1783	38.583 S	78.155 E	710	38.291 S	81.179 E	1882	37.956 S	84.257 E	2072
40.857 S	73.136 E	2079	39.258 S	76.321 E	1730	38.576 S	78.217 E	805	38.282 S	81.259 E	1912	37.950 S	84.304 E	1879
40.844 S	73.159 E	2085	39.238 S	76.366 E	1718	38.563 S	78.311 E	1005	38.281 S	81.321 E	1880	37.945 S	84.384 E	1934
40.832 S	73.182 E	2128	39.212 S	76.415 E	1680	38.557 S	78.365 E	1140	38.271 S	81.400 E	1917	37.938 S	84.435 E	1891
40.820 S	73.206 E	2128	39.190 S	76.440 E	1744	38.548 S	78.455 E	1710	38.257 S	81.482 E	1882	37.928 S	84.491 E	1978
40.804 S	73.226 E	2173	39.180 S	76.488 E	1738	38.542 S	78.508 E	885	38.255 S	81.541 E	1934	37.921 S	84.545 E	2032
40.794 S	73.258 E	2090	39.167 S	76.513 E	1748	38.537 S	78.556 E	900	38.249 S	81.590 E	1880	37.918 S	84.597 E	1960
40.783 S	73.271 E	2082	39.148 S	76.560 E	1738	38.528 S	78.595 E	840	38.240 S	81.679 E	1919	37.910 S	84.648 E	1951
40.770 S	73.300 E	2086	39.125 S	76.613 E	1739	38.520 S	78.682 E	950	38.232 S	81.761 E	1916	37.904 S	84.710 E	1906
40.755 S	73.324 E	2038	39.105 S	76.661 E	1728	38.512 S	78.771 E	841	38.222 S	81.845 E	1974	37.896 S	84.760 E	1918
40.744 S	73.349 E	2029	39.080 S	76.706 E	1686	38.506 S	78.827 E	748	38.213 S	81.931 E	1911	37.893 S	84.839 E	1910
40.732 S	73.373 E	2035	39.060 S	76.757 E	1667	38.495 S	78.916 E	732	38.205 S	82.019 E	1928	37.882 S	84.919 E	1962
40.719 S	73.392 E	2073	39.037 S	76.811 E	1613	38.485 S	78.976 E	680	38.199 S	82.080 E	1914	37.870 S	85.000 E	1938
40.705 S	73.417 E	2055	39.018 S	76.855 E	1601	38.486 S	79.038 E	887	38.194 S	82.134 E	1976			
40.687 S	73.438 E	2084	39.005 S	76.880 E	1585	38.476 S	79.105 E	1002	38.191 S	82.204 E	1984			
40.678 S	73.469 E	2051	38.986 S	76.904 E	1613	38.466 S	79.167 E	1072	38.181 S	82.280 E	1959			
40.668 S	73.484 E	2025	38.962 S	76.953 E	1580	38.466 S	79.226 E	1202	38.172 S	82.313 E	1917			
40.652 S	73.514 E	2045	38.942 S	77.001 E	1615	38.460 S	79.280 E	1448	38.166 S	82.398 E	1901			
40.640 S	73.536 E	2048	38.920 S	77.052 E	1598	38.456 S	79.335 E	1540	38.161 S	82.456 E	1940			
40.628 S	73.556 E	2090	38.897 S	77.101 E	1580	38.451 S	79.383 E	1720	38.153 S	82.506 E	1917			
39.824 S	75.064 E	2021	38.870 S	77.151 E	1537	38.447 S	79.450 E	1703	38.147 S	82.572 E	1846			
39.798 S	75.141 E	2020	38.853 S	77.195 E	1518	38.442 S	79.513 E	1808	38.142 S	82.622 E	1927			
39.780 S	75.184 E	1988	38.827 S	77.246 E	1380	38.436 S	79.575 E	1825	38.136 S	82.677 E	1911			
39.757 S	75.220 E	1984	38.801 S	77.294 E	1077	38.431 S	79.649 E	1812	38.131 S	82.732 E	1883			
39.734 S	75.280 E	1981	38.782 S	77.339 E	757	38.423 S	79.742 E	1817	38.119 S	82.812 E	1888			
39.711 S	75.334 E	1951	38.767 S	77.359 E	284	38.417 S	79.818 E	1769	38.113 S	82.872 E	1869			
39.684 S	75.379 E	1827	38.756 S	77.384 E	191	38.408 S	79.880 E	1758	38.107 S	82.929 E	1876			
39.661 S	75.426 E	1813	38.743 S	77.417 E	158	38.402 S	79.958 E	1766	38.104 S	82.978 E	1814			
39.633 S	75.498 E	1847	38.720 S	77.438 E	134	38.394 S	80.038 E	1748	38.090 S	83.070 E	1911			
39.602 S	75.568 E	1787	38.717 S	77.483 E	104	38.386 S	80.131 E	1725	38.087 S	83.190 E	1831			
39.577 S	75.616 E	1854	38.705 S	77.494 E	82	38.380 S	80.205 E	1764	38.074 S	83.232 E	1883			
39.557 S	75.664 E	1745	38.694 S	77.515 E	49	38.372 S	80.276 E	1793	38.062 S	83.307 E	1957			
39.533 S	75.716 E	1765	38.706 S	77.531 E	22	38.365 S	80.372 E	1761	38.058 S	83.393 E	1841			
39.509 S	75.764 E	1670	38.694 S	77.564 E	331	38.356 S	80.429 E	1841	38.053 S	83.481 E	1876			
39.491 S	75.808 E	1725	38.681 S	77.585 E	481	38.354 S	80.487 E	1821	38.045 S	83.530 E	1864			
39.465 S	75.858 E	1827	38.664 S	77.628 E	980	38.343 S	80.570 E	1767	38.036 S	83.610 E	1929			
39.444 S	75.905 E	1839	38.649 S	77.677 E	737	38.341 S	80.629 E	1841	38.027 S	83.698 E	1867			
39.421 S	75.957 E	1860	38.626 S	77.744 E	868	38.336 S	80.682 E	1787	38.016 S	83.768 E	1894			
39.404 S	76.002 E	1743	38.627 S	77.810 E	688	38.327 S	80.762 E	1769	38.009 S	83.851 E	1904			
39.378 S	76.097 E	1835	38.616 S	77.863 E	779	38.316 S	80.842 E	1800	37.990 S	83.903 E	1884			

FIG. 1b. — Sample page of master list No. 1 : Listing of depths and coordinates of individual soundings (for track in Figure 1a).

Data from the continuing programs of Lamont Geological Observatory and U.S. National Science Foundation's R/V *Eltanin* is continuously fed into the library, and programs exist so that this can be done on a digital computer. Beginning in 1966, all sounding data acquired by the U.S. Naval Oceanographic Office is routinely digitized according to a system compatible with this library.

For easy availability, the contents of the library are arranged in four master lists. The geographical coordinates (latitude and longitude) and the depth for each individual sounding are presented in master list No. 1. For each track, a sounding location plot is given, as well as a detailed listing of depths and coordinates (see sample pages in figures 1a and 1b). The following information is provided for each track :

1) Track serial number (ranging from 1 to 8 375);
2) Track source identification number;
3) Source sheet identification number;
4) U.S. Naval Oceanographic Office Plotting Sheet Nos. of the areas in which the track is located;
5) Unit of echo time depth;

6) Reliability rating;
7) Number of soundings in the track;
8) Date of incorporation into the library.

The entries for each track take up two or more pages : One page for the location plot, and one or more pages for the list of the soundings. The plots have been reproduced in such a manner that 1° longitude on standard U.S. Naval Oceanographic Office plotting sheets is represented by 80 " raster " units of the S-C 4020 CRT recorder used to produce these plots. On standard U.S. Naval Oceanographic Office Plotting Sheets, 1° longitude measures 4 inches. The hard-copy camera of the S-C 4020 instrument records 1023 " raster " units on 7.5 inch. Thus, the reduction in scale from source sheets to the size of hard copy is 1/6.82 (figure 1a).

BATHYMETRIC LIBRARY – DEPTH PROFILE OF INDIVIDUAL SOUNDING TRACK
TRACK SERIAL NO. 3396 TRACK SOURCE IDENTIFICATION NO. 48R–OVEN
SOURCE SHEET IDENTIFICATION NO. 1214
U.S. NAVAL OCEANOGRAPHIC OFFICE PLOTTING SHEET NOS. 3101N
UNIT OF DEPTH = CORRECTED FATHOMS RELIABILITY RATING = 9
NUMBER OF SOUNDINGS IN TRACK = 126 DATE 07/18/67

FIG. 2a. — Sample page of master list No. 2 : Heading for depth profile of individual sounding track (for track in Figure 2b).

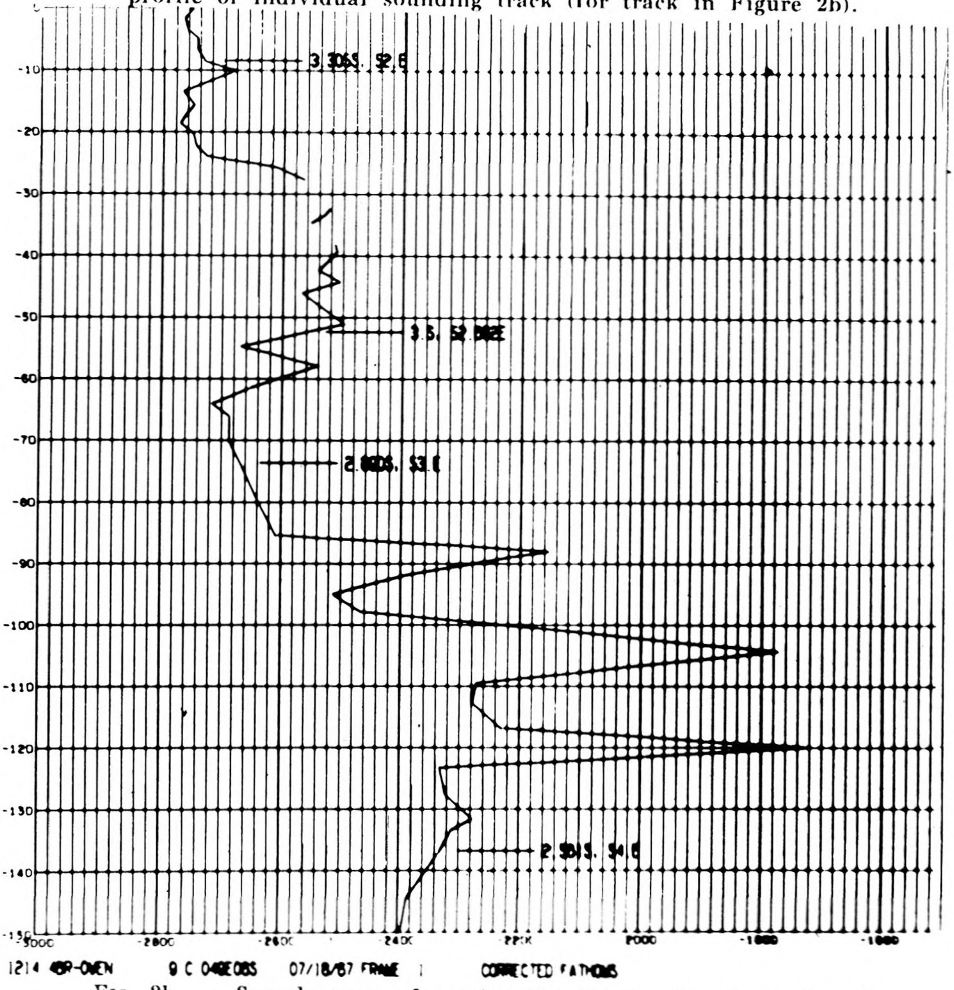
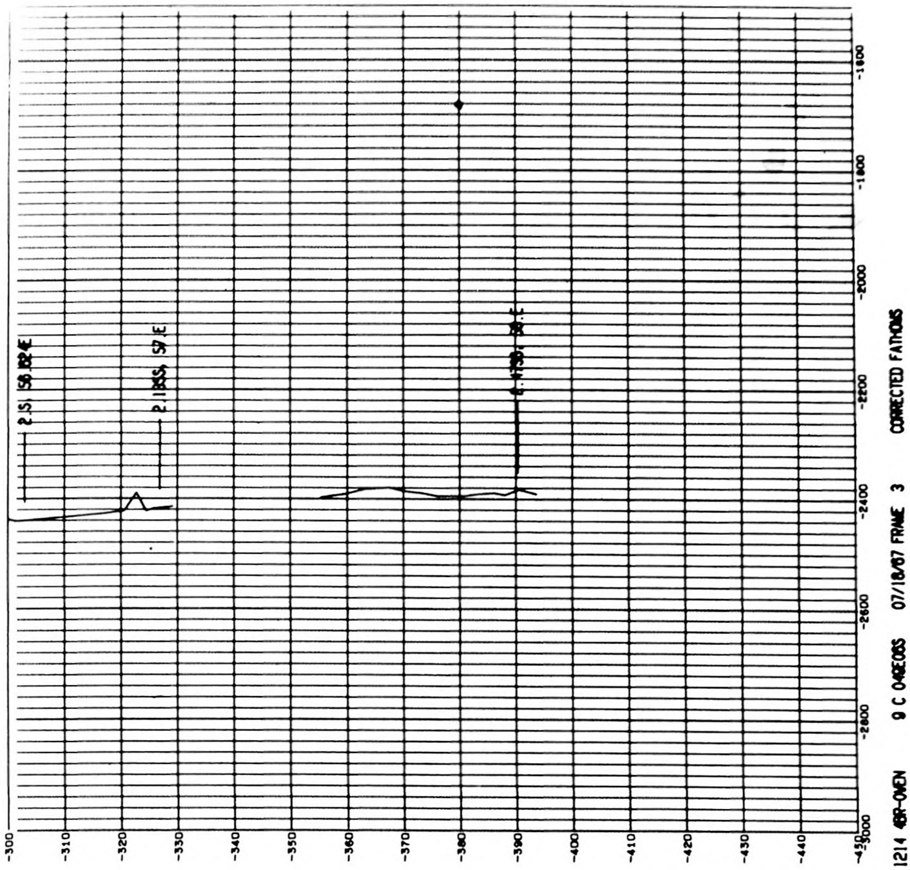


FIG. 2b. — Sample page of master list No. 2 : Depth profile of individual sounding track (the profile may extend over several pages).


CORRECTED FATHOMS
07/18/67 FRAME 3
1214 45R-OWEN

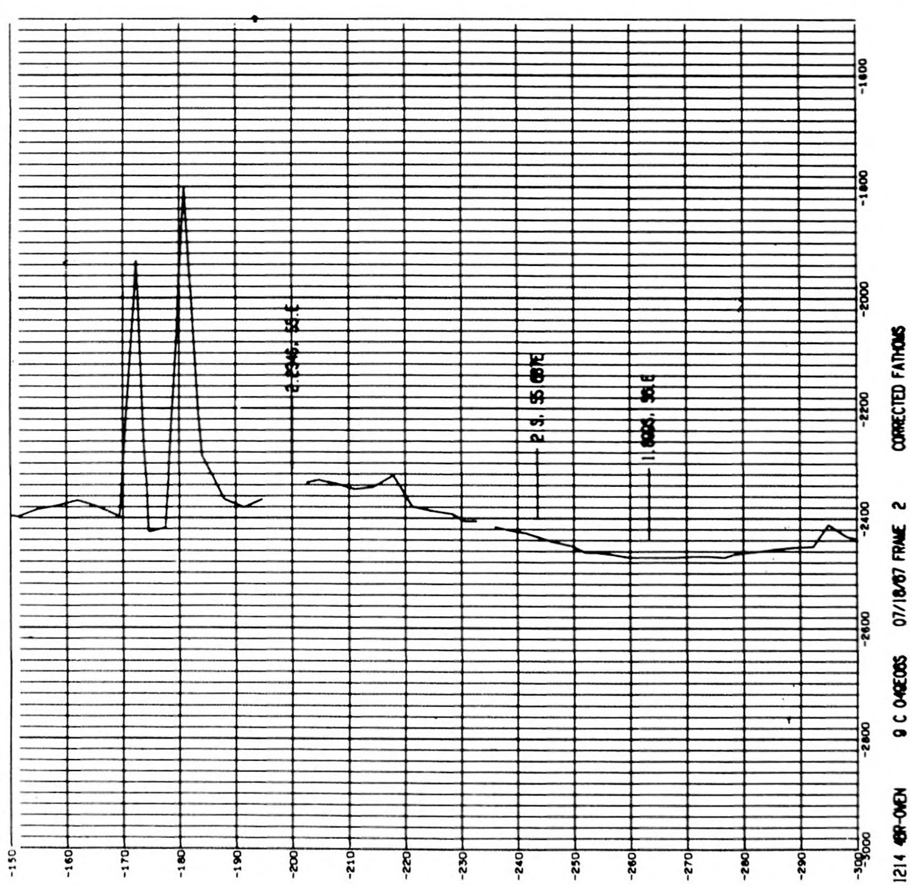

CORRECTED FATHOMS
07/18/67 FRAME 2
1214 45R-OWEN

FIG. 2b (Cont.).

TABLE 1

Reliability rating for digitized sounding tracks

(1) Precision recorders operated on 400 t_e scale, recordings on 18 inch paper or better.
(2) Precision recorders operated on > 400 t_e scale, or recordings on < 18 inch paper.
(3) Non precision recorders operated on 600 t_e scale.
(4) Non precision recorders operated on 600 or 2 000 t_e scale.
(5) Non precision recorders operated on 2 000, 4 000, or 6 000 t_e scale.
(6) Non precision recorders operated on 4 000 or 6 000 t_e scale.
(7) Any other recorders.

Reliability rating	Type of echo-sounding equipment	Resolution	Spacing : approximate number of soundings per degree latitude	Type of navigation	Accuracy of navigational fixes (mile)
11	(1)	± 1 fm	> 10	Lorac or Decca λ	± 0.1
10	(1)	± 1 fm	> 10	Loran C, Transit	± 0.5
9	(1)	± 1 fm	> 10	Loran A or Stars	± 2
8	(2)	± 5 fm	> 5	Poor or unknown	>2
7	(3)	± 5 fm	> 10	Stars or better	± 2
6	(4)	± 10 fm	> 10	Stars or better	± 2
5	(5)	± 25 fm	> 10	Stars or better	± 2
4	(6)	± 50 fm	> 10	Poor or unknown	>2
3	(6)	± 50 fm	< 10	Stars or better	± 2
2	(6)	± 50 fm	< 10	Poor or unknown	>2
1	(7)	—	< 5	—	—
0	(7)	—	< 3	—	—

Depth profiles of each sounding track at 100/1 vertical exaggeration are provided by master list No. 2. The vertical coordinates represent echo time depth in the original units and the horizontal coordinates indicate distance along the track in nautical miles, reckoned from the first recorded sounding. (See sample pages in figures 2a and 2b).

Source sheet information is summarized in master list No. 3 (figure 3). The information for each source sheet recorded on a single page contains the following entries :

(1) Source sheet identification number (ranging from 1 to 2 119);
(2) Name of source country;
(3) Scale of source sheet;
(4) U.S. Naval Oceanographic Office Plotting Sheet Nos. of the areas in which the tracks on this sheet are located;
(5) Number of tracks on this sheet;
(6) Number of soundings on this sheet;
(7) Unit of echo-time depth;
(8) Date of compilation;
(9) For each individual track on this sheet :
  (*a*) The track serial number;
  (*b*) The track source identification number;
  (*c*) The reliability rating;
  (*d*) Number of soundings in the track;
  (*e*) U.S. Naval Oceanographic Office Plotting Sheet Nos. of the areas in which this track is located.

BATHYMETRIC LIBRARY – SOURCE SHEET INFORMATION
SOURCE SHEET IDENTIFICATION NO. 1266
SOURCE COUNTRY SOUTH AFRICA
SCALE OF SOURCE SHEET 1/1000000 AT 46 DEGREES LATITUDE
U.S. NAVAL OCEANOGRAPHIC OFFICE PLOTTING SHEET NOS. 3506S 3507S 3406S 3407S 3505S
NUMBER OF TRACKS ON THIS SHEET 45
NUMBER OF SOUNDINGS ON THIS SHEET 1697
UNIT OF DEPTH CORRECTED METERS DATE 07/16/67

TRACK SERIAL NO.	TRACK SOURCE IDENTIFICATION NO.	QUALITY RATING	NUMBER OF SOUNDINGS IN TRACK	U. S. NAVAL OCEANOGRAPHIC OFFICE PLOTTING SHEET NOS.
4013	SA-01402	7	109	3506S 3507S
4046	SA-02402	7	47	3506S
4010	SA-03402	7	27	3507S 3506S
4000	SA-04402	7	45	3507S 3506S
3995	SA-05402	7	26	3407S 3406S
4005	SA-06402	7	19	3506S
3988	SA-08402	7	36	3506S
4011	SA-09402	7	51	3406S
3984	1SA-AFRI	7	49	3506S 3507S
3985	1SA-DANA	4	8	3406S
4008	1SA-DIS2	3	7	3506S
4012	1SA-METE	7	42	3506S 3507S
3992	1SA-NATA	7	34	3406S
3994	1SA-PROT	5	32	3506S
3998	1SA-PTEA	5	42	3506S 3505S
3987	1SA-SHAC	5	11	3407S
4016	2SA-AFRI	7	39	3506S
4009	2SA-DANA	4	122	3506S
4007	2SA-DIS2	3	5	3506S
4002	2SA-METE	7	28	3507S 3506S
3991	2SA-NATA	7	55	3406S
3996	2SA-PROT	5	7	3506S
4014	2SA-PTEA	5	59	3505S 3506S
4043	2SA-PUMA	5	30	3506S
4004	2SA-SHAC	5	14	3407S
4017	3SA-AFRI	7	29	3506S
4006	3SA-DIS2	3	25	3506S
4022	3SA-METE	7	23	3506S
3990	3SA-NATA	7	11	3406S
4045	3SA-PROT	5	50	3506S
3997	3SA-PTEA	5	47	3506S 3505S
4003	3SA-SHAC	5	55	3407S 3406S 3506S
4018	4SA-AFRI	7	29	3506S
3989	4SA-NATA	7	23	3406S
4047	4SA-PTEA	5	16	3506S 3505S
3986	4SA-SHAC	5	47	3506S 3507S
4044	5SA-NATA	7	27	3406S
4020	5SA-PTEA	5	101	3506S
4015	5SA-SHAC	5	30	3506S
3999	6SA-NATA	7	27	3406S
4019	6SA-PTEA	5	97	3506S
3993	6SA-SHAC	5	31	3506S
4642	7SA-NATA	7	52	3506S
4001	7SA-PTEA	5	12	3506S
4021	8SA-NATA	7	21	3506S

FIG. 3. — Sample page of master list No. 3 : Listing of source sheet information.

The first page (see sample in figure 4a) of master list No. 4 contains a position plot of all the soundings in a plotting area (figure 5). The second page (see sample in figure 4b) contains a list of the serial numbers of the tracks which include soundings in the area. By referring to master lists Nos. 1 or 2 one may obtain the coordinates or echo time depths of the

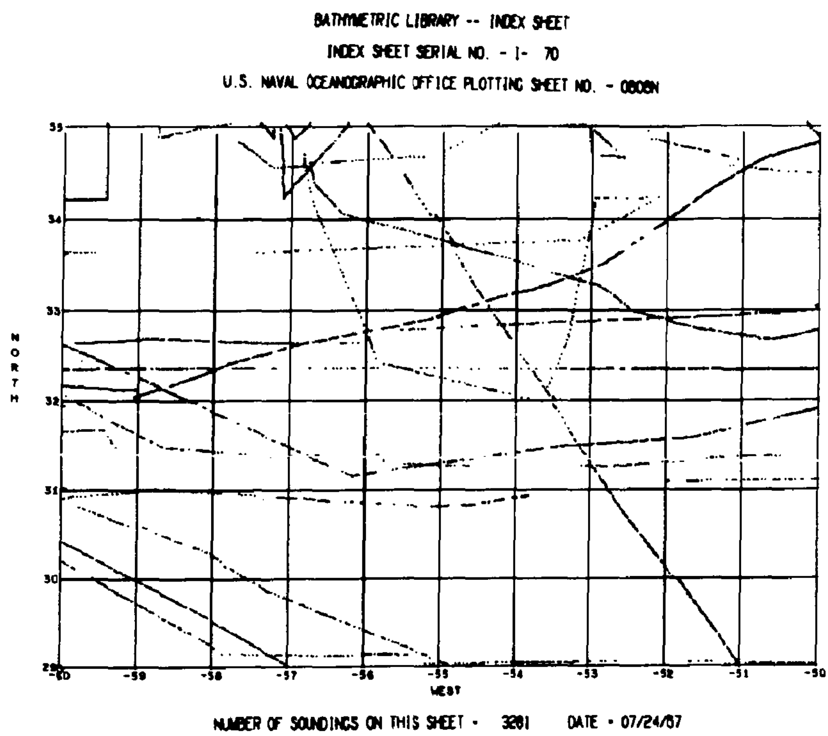


FIG. 4a. — Sample page of master list No. 4 : Index sheet for position plot of all soundings in a plotting area. Total number of soundings is listed on bottom of page.

BATHYMETRIC LIBRARY -- INDEX SHEET

INDEX SHEET SERIAL NO. - 1- 70

U.S. NAVAL OCEANOGRAPHIC OFFICE PLOTTING SHEET NO. - 0808N

SERIAL NUMBER OF SOUNDING TRACKS ON THIS SHEET

78 79 157 187 188 189 515 518 520 584 580 788 781 1105 1107 1138 1140 1157 1158 1348
3937 3938 5540

FIG. 4b. — Sample page of master list No. 4 : Serial numbers of sounding tracks on Index Sheet (for sheet in Figure 4a).

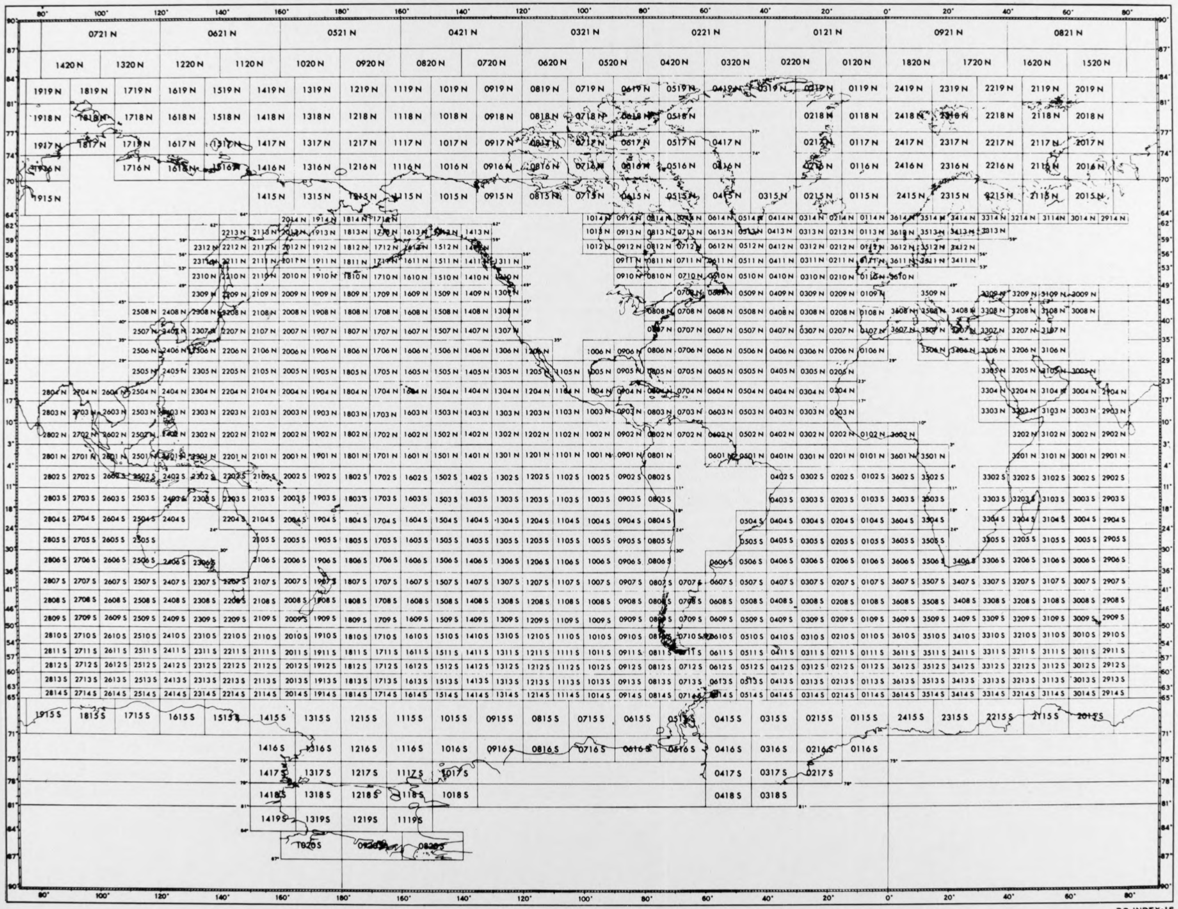
soundings along a particular track. The index sheets in this list are designated with the pertinent U.S. Naval Oceanographic Office plotting sheet numbers. They also bear running Sheet Index Numbers.

The four master lists are quite voluminous : list No. 1 comprises about 20 000 pages, list No. 2 about 40 000 pages, list No. 3 about 2 000 pages, and list No. 4 comprises 1 416 pages.

In addition, a magnetic tape with library information has been prepared. This tape contains in digital form the basic data from which the library lists have been constructed. The tape contains the original verified digitizations for each track of soundings. These quantities are c_x and c_y, the distances, in digitizer counts of 1/1 000 inch, from map origin to the location of the sounding along the coordinate axes, z, the key-punched echo time depth value, and a count number indicating the position of the sounding in the track.

Various FORTRAN programs have been written in connection with the establishment of this data library. For example, one such auxiliary

PLOTTING SHEET INDEX



PS INDEX-15

Fig. 5. — U.S. Naval Oceanographic Office Plotting Sheet Index.

program inserts or removes corrections for the velocity of sound according to Matthews' Tables [1], selecting also the proper Matthews Area, according to geographical location of the sounding to be corrected.

The index sheets of master list No. 4 have been reproduced in full [5]. Microfilmed copies have been made of all master lists, as well as the library magnetic tape.

CONCLUDING REMARKS

The library was established to satisfy three general needs. The initial motivation stemmed from the need for an average ocean depth model for numerical computations of a global geophysical character. One of the first intended uses of the library will be to compute such an average ocean depth model for use in tidal studies [2]. Such a model is also needed in other dynamic problems of sea motion and the propagation of tsunamis. It will also be useful in geodesy in general, and in the spherical harmonic analysis of earth topography.

The library facility will provide a more efficient method of compiling and plotting soundings recorded in a variety of units, scales, and formats. The variety of charts and vertical profiles required in physiographic studies [3] will be prepared by machine.

A third use relates to quantitative textural analysis of topography (slopes, wave lengths, amplitudes) and to detailed hypsometric studies — subjects now of increasing interest to oceanographers [4].

APPENDIX A

Computation of Coordinates on Digitized Maps

This Appendix summarizes the computational procedure for finding the geographical coordinates of soundings which are digitized from oceanographic plotting sheets. The sheets are in Mercator scale.

It is assumed that the origin for digitization is located at a point (X_0, Y_0) on the map (figure 6). X and Y are geographical coordinates. X ranges from 0° to 360° in the East direction. Y ranges from 90° at the North Pole through 0° at the Equator to — 90° at the South Pole.

It is required to find the geographical coordinates X_1 and Y_1 of a digitized sounding, which is c_x digitizer counts along the X-axis and c_y counts along the Y-axis away from the origin. c_x is counted positive by going eastward, and c_y is counted positive by going northward from the origin. The resolution of the reading system is r counts per inch of reading head travel for each axis. For the instrumentation used to establish the present data library, $r = 1\ 000$.

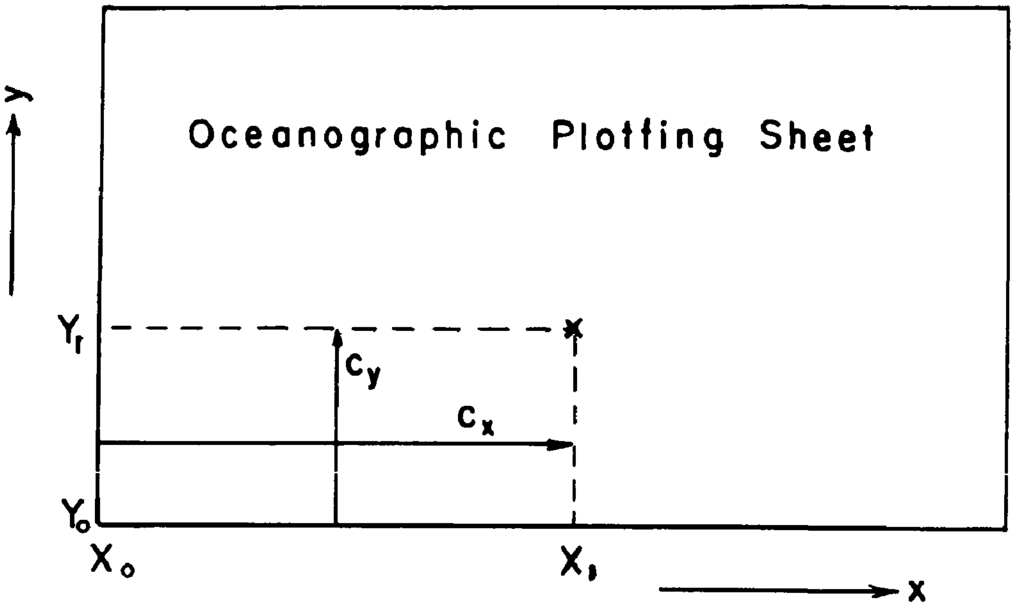


FIG. 6. — Coordinate system for digitization of soundings from oceanographic plotting sheets :

c_x, c_y : distances along axes in digitizer counts
X_0, Y_0 : origin for digitization
X_1, Y_1 : location of digitized sounding.

It is necessary to know the scale of the maps to be digitized. For standard plotting sheets of the U.S. Naval Oceanographic Office, between 64° North and 65° South (sheets XX01N — XX14N and sheets XX02S — XX14S, where XX ranges from 01 to 36), the distance between meridians, 1° apart, is exactly 4 inches. This corresponds to a scale of 1/1 093 614 at the equator. On sheets XX15N — XX19N and sheets XX15S — XX19S the distance between two adjacent meridians, which are 1° apart, is 2 inches, corresponding to a scale of 1/2 187 228 at the equator. If we assign in the computations a scale factor $s = 1$ for the " standard " U.S. Naval Oceanographic Office plotting sheets between 64° North and 65° South, then obviously the aforementioned higher latitude sheets XX15 — XX19 have a scale factor $s = 0.5$. For maps in Mercator scale from other sources the scale factor is determined by

$$s = \frac{1093614 \cos\theta}{m} \qquad (1)$$

Here θ is the latitude at which the map scale 1/m is given.

We now proceed to compute X_1 and Y_1.

Computation of X_1 :

$$X_1 = X_0 + \frac{c_x}{4 \,.\, r \,.\, s} \qquad (2)$$

Computation of Y_1 :

$$Y_1 = \frac{360}{\pi}\left\{\text{arc tan } (e^{\tau_1})\right\} - 90 \qquad (3)$$

where

$$\tau_1 = \tau_0 + \frac{c_y}{4 . r . s} \cdot \frac{\pi}{180} \tag{4}$$

and

$$\tau_0 = \ln\tan\left\{\frac{1}{2} Y_0 + 45\right\} \tag{5}$$

if the argument of ln (*) tan is expressed in degrees,
or

$$\tau_0 = \ln\tan\left\{\left(\frac{Y_0}{360} + \frac{1}{4}\right)\pi\right\} \tag{6}$$

if the argument of ln tan is expressed in radians.

A modification in the computation of Y_1 is necessary for cases of maps which are linearly subdivided between lines of latitudes. This applies to U.S. Naval Oceanographic Office Plotting Sheets XX01N — XX14N and XX02S — XX14S (the region between 64° North and 65° South). It also applies to oceanographic sheets from other sources, if so indicated. In these cases :

$$Y_1\text{modified} = [Y_1] + \frac{\tau_1 - \tau_A}{\tau_B - \tau_A} \quad \text{in the Northern Hemisphere} \tag{7}$$

$$= [Y_1] - \frac{\tau_1 - \tau_A}{\tau_B - \tau_A} \quad \text{in the Southern Hemisphere} \tag{8}$$

where [Y] = Integral part of Y in degrees. (9)
τ_1 is as defined in equation (4).

$$\tau_A = \ln\tan\left\{\frac{1}{2}[Y_1] + 45\right\} \tag{10}$$

if the argument of ln tan is expressed in degrees,
or

$$\tau_A = \ln\tan\left\{\left(\frac{[Y_1]}{360} + \frac{1}{4}\right)\pi\right\} \tag{11}$$

if the argument of ln tan is expressed in radians.

$$\tau_B = \ln\tan\left\{\frac{1}{2}[Y_1 \pm 1] + 45\right\} \tag{12}$$

if the argument of ln tan is expressed in degrees,
or

$$\tau_B = \ln\tan\left\{\left(\frac{[Y_1 \pm 1]}{360} + \frac{1}{4}\right)\pi\right\} \tag{13}$$

if the argument of ln tan is expressed in radians.

In equations (12) and (13), the positive sign is taken for locations in the northern hemisphere, while the negative sign applies to locations in the southern hemisphere.

(*) ln = Napierian logarithm.

The varying information which has been used to compute X_1 and Y_1 in each specific case for the present holdings of the library is presented in table 2.

TABLE 2

Source information for digitized sounding tracks

Legend for Unit of Depth :

t_e : echo times in units of 1/400 sec.
C : corrected fathoms, according to Matthews' Tables
M : corrected metres, according to Matthews' Tables

Source sheet identification No.	Source country	Map source sheet scale 1/m	Latitude for map source sheet scale	Scale factor s	Linear subdivision	Unit of depth
1-177	U.S.	1/1 093 614	Equator	1	yes	t_e
178	U.S.	1/972 101	Equator	1.125	yes	t_e
179-224	U.S.	1/1 093 614	Equator	1	yes	t_e
225-232	U.S.	1/972 101	Equator	1.125	yes	t_e
233-1 159	U.S.	1/1 093 614	Equator	1	yes	t_e
1 160-1 188	U.S.	1/2 187 228	Equator	0.5	no	t_e
1 189-1 220	U.K.	1/1 000 000	33°	0.917181	yes	C
1 221-1 231	U.K.	1/1 000 000	46°	0.759688	yes	C
1 232-1 240	Australia	1/1 000 000	46°	0.759688	yes	C
1 241-1 264	Australia	1/1 000 000	33°	0.917181	yes	C
1 265-1 270	U.S.	1/1 093 614	Equator	1	yes	t_e
1 271-1 273	Australia	1/1 000 000	46°	0.759688	yes	C
1 274-1 277	So. Africa	1/1 000 000	46°	0.759688	yes	M
1 278-1 280	U.K.	1/1 000 000	57°	0.595625	yes	C
1 281-1 288	So. Africa	1/1 000 000	46°	0.759688	yes	M
1 289-1 294	Germany	1/1 000 000	46°	0.759688	yes	M
1 295-1 311	Germany	1/1 000 000	33°	0.917181	yes	M
1 312-1 319	So. Africa	1/1 000 000	33°	0.917181	yes	M
1 320-1 328	U.K.	1/1 000 000	46°	0.759688	yes	C
1 329-1 334	U.K.	1/1 000 000	57°	0.595625	yes	C
1 335-1 336	So. Africa	1/1 000 000	57°	0.595625	yes	C
1 337-1 339	So. Africa	1/1 000 000	33°	0.917181	yes	C
1 340-1 346	U.K.	1/1 000 000	33°	0.917181	yes	C
1 347-1 356	Australia	1/1 000 000	33°	0.917181	yes	C
1357	So. Africa	1/1000000	46°	0.759688	yes	M
1358-1359	So. Africa	1/1000000	46°	0.759688	yes	C
1360	So. Africa	1/1000000	46°	0.759688	yes	M
1361	So. Africa	1/1000000	46°	0.759688	yes	C
1362-1363	So. Africa	1/1000000	46°	0.759688	yes	M
1364-1400	U.S.	1/546807	Equator	2	yes	t_e
1401-1447	U.S.	1/1093614	Equator	1	yes	t_e
1448	U.S.	1/2187228	Equator	0.5	no	t_e
1449-1485	U.S.	1/1093614	Equator	1	yes	t_e
1486-1489	U.S.	1/2187228	Equator	0.5	no	t_e
1490-1494	U.S.	1/1093614	Equator	1	yes	t_e
1495-1512	U.S.	1/546807	Equator	2	yes	t_e
1513	Australia	1/1000000	46°	0.759688	yes	C
1514	U.K.	1/1000000	57°	0.595625	yes	C
1515	U.K.	1/1000000	65°	0.462181	yes	C

TABLE 2
(continued)
Source information for digitized sounding tracks

Source sheet identification No.	Source country	Map source sheet scale 1/m	Latitude for map source sheet scale	Scale factor s	Linear subdivision	Unit of depth
1516-1523	U.K.	1/729076	Equator	1.5	yes	C
1524	Germany	1/306979	Equator	3.5625	yes	M
1525-1526	U.S.	1/1093614	Equator	1	yes	t_e
1527-1531	U.K.	1/1000000	33°	0.917181	yes	C
1532-1541	U.S.	1/1093614	Equator	1	yes	t_e
1542-1544	U.S.	1/2187228	Equator	0.5	no	t_e
1545-1559	U.S.	1/1093614	Equator	1	yes	t_e
1560	U.S.	1/2187228	Equator	0.5	no	t_e
1561	Germany	1/1000000	70°	0.374038	no	M
1562-1603	U.S.	1/1093614	Equator	1	yes	t_e
1604	U.S.	1/2187228	Equator	0.5	no	t_e
1605-1628	U.S.	1/1093614	Equator	1	yes	t_e
1629	U.S.	1/2187228	Equator	0.5	no	t_e
1630-1678	U.S.	1/1093614	Equator	1	yes	t_e
1679-1682	U.S.	1/2187228	Equator	0.5	no	t_e
1683-1817	U.S.	1/1093614	Equator	1	yes	t_e
1818-1822	U.S.	1/2187228	Equator	0.5	no	t_e
1823-2033	U.S.	1/1093614	Equator	1	yes	t_e
2034	U.S.	1/2187228	Equator	0.5	no	t_e
2035-2118	U.S.	1/1093614	Equator	1	yes	t_e
2119	U.S.	1/546807	Equator	2	yes	t_e

Transformation of Origin :

The origin for digitization may be located anywhere on the map. We refer to an origin (X_0, Y_0) as " standard ", if it is at the lower left corner of the map. An origin (X_0', Y_0') elsewhere on the map is " non-standard ". Corresponding to the previous definition of c_x and c_y for standard origin, c_x' and c_y' are the distances in digitizer counts from a non-standard origin to a digitized sounding of geographical coordinates X_1 and Y_1.

If a sounding has been digitized with respect to a non-standard origin, it may be related to the standard origin by the use of the following formulas :

$$c_x = c_x' + 4 \,.\, r \,.\, s(X_0' - X_0) \tag{14}$$

$$c_y = c_y' + \frac{720}{\pi} \,.\, r \,.\, s \left[\ln \tan \left\{ \left(\frac{Y_0'}{360} + \frac{1}{4} \right) \pi \right\} - \ln \tan \left\{ \left(\frac{Y_0}{360} + \frac{1}{4} \right) \pi \right\} \right] \tag{15}$$

The argument of ln tan in (15) is expressed in radians.

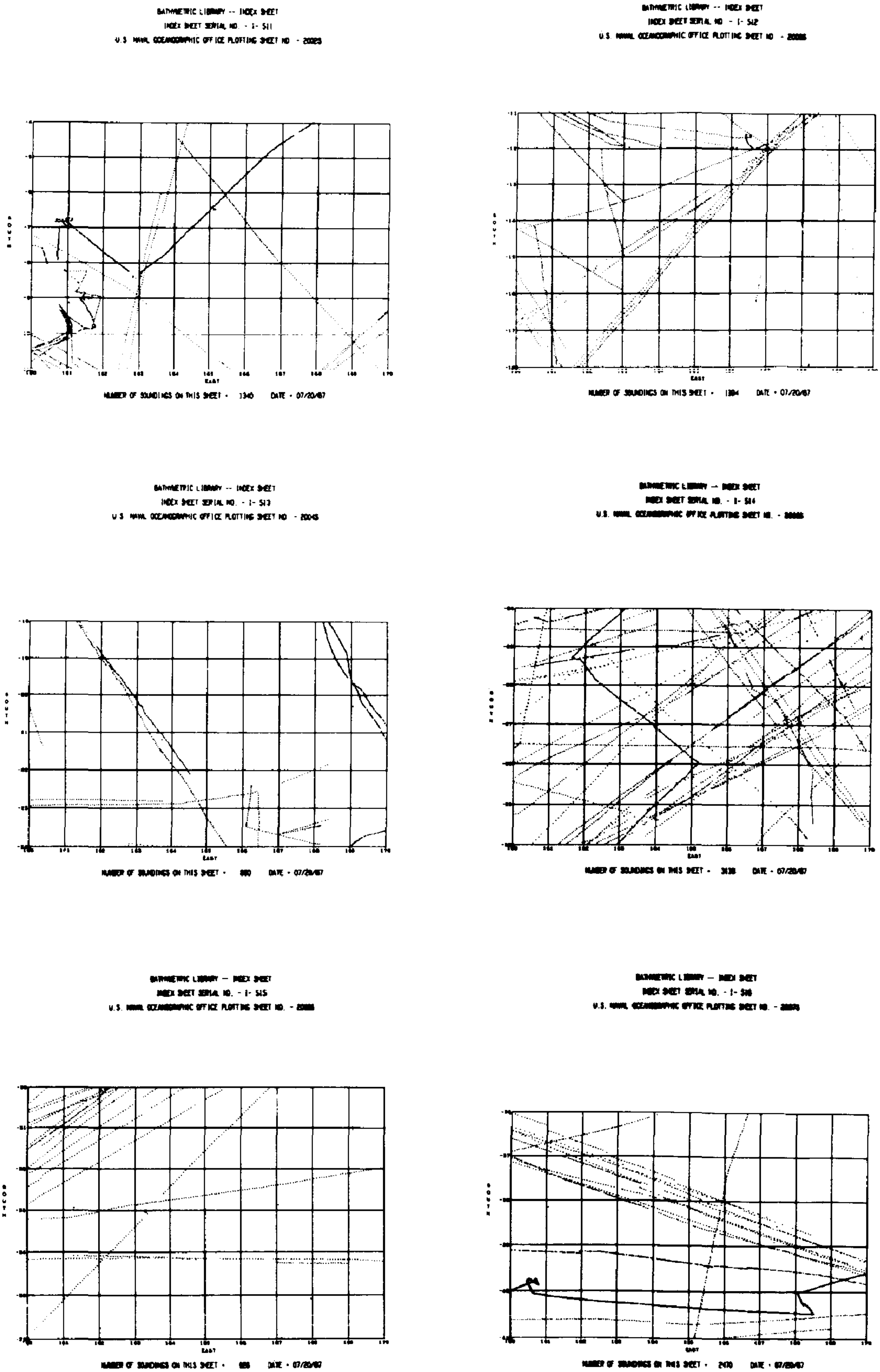


FIG. 7. — Sample page of Appendix B.

APPENDIX B

This appendix contains 708 index sheets of master list No. 4. The sheets are arranged in the following order, according to the Naval Oceanographic Office Plotting Sheet Index Areas :

Low Latitudes	North	(Sheets 0101N — 3614N)
Low Latitudes	South	(Sheets 0201S — 3614S)
High Latitudes	North	(Sheets 0115N — 2418N)
High Latitudes	South	(Sheets 0115S — 2418S)

Areas that do not contain any soundings are omitted.

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