Title

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Authors

Smith, Stuart M
Menard, H W
Sharman, George

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WORLD-WIDE OCEAN DEPTHS AND CONTINENTAL ELEVATIONS AVERAGED FOR AREAS APPROXIMATING ONE DEGREE SQUARES OF LATITUDE AND LONGITUDE

by

Stuart M. Smith, H. W. Menard, and George Sharman

INTRODUCTION

This report provides background information on a world-wide set of ocean depths and land elevations recently compiled in meters and averaged over areas roughly equivalent to one degree squares of latitude and longitude at the equator. Averaging was done by visual estimation from contour charts having scales ranging between 1:1 and 1:25 million with contour intervals of 1000 meters or 200 fathoms. A description of the source charts, square referencing, averaging methods, error checks and estimates, will be found in the following sections.

Arrangements for obtaining copies of the average depth/elevation magnetic tape, written in BCD mode at 556 bpi, (see tape format, Appendix I) or a 132 page listing containing only latitude, longitude and depth may be made by contacting the National Oceanographic Data Center, Bldg. 160, Navy Yard Annex, Washington, D. C., 20390.

A large part of the visual estimation of oceanic areas was done by Surendra Mathur with lesser amounts made by the authors; Theodore de Castro and Conrad Young did independent sets of continental elevation estimates. Sarah Buffington transferred the data to the encoding forms and was aided by Susan Emley in the checking and sorting of the data cards. Keypunching was done by Sally Mclellan and Mary Webb of the UCSD Computer Center. This work was supported by the Office of Naval Research Long Range Research contract 2216(12).

SOURCES

Tables Ia and Ib list the charts used as sources for the average depth estimates. The date given is that of publication for the published charts or the date of the latest information used for the unpublished data. Numbers in parentheses in the contour interval column indicate values of contours present in addition to the standard contour interval, e.g. the 200 meter contour as well as the 0, 1000, 2000 contours.

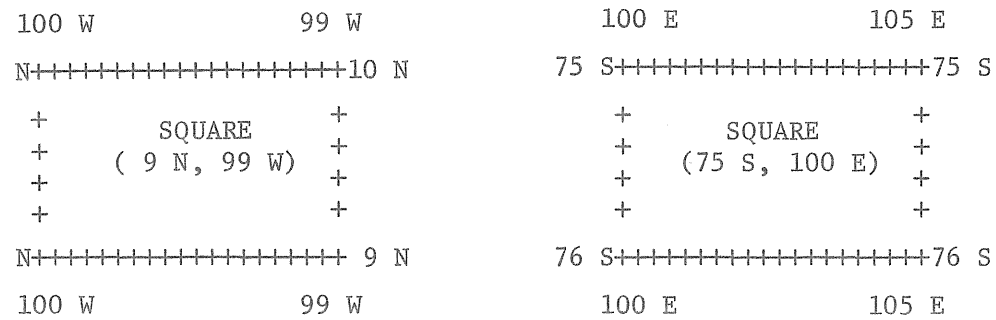
AREAS AVERAGED AND SQUARE REFERENCING

The averaged areas are bounded by one degree of latitude from the equator to the poles. The following longitudinal boundaries were chosen as a compromise between the desire to average equivalent areas and the need for a uniform set of coordinates which could be used on the various scales and projections of the source charts.

0 through 49	degrees latitude,	1 degree longitude
50 through 69	degrees latitude,	2 degrees longitude
70 through 79	degrees latitude,	5 degrees longitude
80 through 89	degrees latitude,	10 degrees longitude

Table II gives the area of the averaged squares at each latitude calculated for a sphere having the same volume as that of the earth (radius = 6,371.221km).

Squares are referenced by the usual coordinates of north and south latitude and east and west longitude. Each square is identified by the corner nearest the origin (the intersection of the prime meridian and the equator). For example,



The four squares adjacent to the origin are labeled (0 N, 0 E), (0 S, 0 E), (0 N, 0 W) and (0 S, 0 W).

ESTIMATION METHOD

One degree grids on clear acetate were placed over each chart and the visual estimates of the mean depths (or elevations) of the areas being averaged were recorded on the overlay. Estimates were made to the nearest 100 meters or 50 fathoms depending on the contour interval. The following information was then encoded on keypunch forms, one square per card.

Latitude

"N" or "S"

Longitude

"E" or "W"

Ocean or continent identification

Depth (-) or Elevation (+)

Units of Measurement (M = meters, F = fathoms)

Elevation of Ice Cap Surface (Antarctica only)

Source number of chart

The format was modified to include two elevation estimates for the continental areas. These cards were then submitted to a test program which calculated the mean of the two estimates and punched a new card in the above format if the difference between the two estimates was less than 10% of their mean for a mean greater than 500 meters, 20% for a mean of 200-500 meters and 50% if the mean was less than 200 meters. If the difference exceeded these limits a diagnostic was printed and the square re-estimated by joint consultation.

New cards with the depth expressed in meters were punched for those squares which had been averaged from fathom contour charts. The cards for

oceanic and continental areas were then combined by quadrant and checks made for order, duplication and omission. A final check was made to eliminate large errors in the estimates which might have arisen from faulty estimation, encoding or punching. The average depth of each square was compared to the values for the adjacent squares to the east and west along a given latitude (no comparison was made with squares to the north or south). A map of each quadrant was printed out which outlined the continents and flagged those squares having an average depth or elevation that differed from the adjacent ones by more than 1500 meters. The maps were then checked and the depth estimate examined for those squares which were flagged but that did not occur in areas of great relief such as continental slopes, large islands or continental mountain chains. Such a test does not, however, eliminate the possibility of processing errors being present in the areas judged to have high relief because the averages for those squares were not individually checked. The information for all four quadrants was then put on a magnetic tape preceded by an information file. A listing of this information file, including the tape format, is reproduced as Appendix I.

OCEAN AND CONTINENTAL IDENTIFIERS

Table III lists the names of the three letter ocean or continental identifier given to each square. Figure 1 shows the approximate boundaries which in general follow conventional usage. There is, however, a rather arbitrary division between the Atlantic and Arctic oceans made at 60° north latitude and the Red Sea and Persian Gulf are considered as parts of the Indian Ocean. Squares containing both ocean and continent are identified as continental, the reasoning being that the oceanic part is usually on the continental shelf and therefore more closely allied structurally to the continent than to the ocean basin. Squares which are on continental shelves but totally under-

water are given the oceanic identifier as are those squares with isolated land such as the Hawaiian Islands.

ESTIMATE OF ERROR

Errors in the averaged values of depth or elevation may arise from incorrect source charts, errors in visual estimation, or data processing. The data processing error checks have already been described. Errors of the source charts are difficult or impossible to evaluate quantitatively. The charts selected were judged to be the best available compilations of recent data having scales and projections suitable for visual estimation.

The precision of the visual estimation method was examined by comparing values estimated by several people and by comparing visual estimates to averages calculated from planimeter measurements. For the continents, five people each estimated 3 blocks of 50 squares in regions of low, medium and high relief. Table IVa lists the mean algebraic deviations of individuals (A to E) for the three areas. The overall algebraic mean deviations ranged from -39 to +24 meters. (The two people, C and D, who later did the estimates of continental elevations had the lowest values of -3 and +6 meters.) Table IVb gives the mean absolute deviations for the same regions with mean absolute deviations ranging from 43 to 55 meters and averaging 50 meters.

Two people made similar comparisons for an oceanic area of high relief and another of low relief (Table IVc). The deviations are comparable to those for the continent except that the mean absolute deviation of the smooth area is much lower.

Planimeter measurements, compiled by ten degree squares from the main source charts, were used to calculate the mean depths and depth distribution between one km contours (Menard and Smith, in press). Because the measurements were limited to the oceanic depth distribution, only those mean depths calcula-

ted for the ten degree squares which contained no land (252 out of 648) could be compared to the mean depths calculated from the one degree square averages. The mean algebraic deviation between the two sets of averages indicated that for these squares, the visual estimate was shallower by 17.8 meters than the average obtained by planimeter, whereas the mean absolute deviation was 78.5 meters.

APPENDIX I: Listing of File 1 of Data Tape

WORLD-WIDE OCEAN DEPTHS AND LAND ELEVATIONS AVERAGED FOR
ONE DEGREE SQUARES OF LATITUDE AND LONGITUDE
BY
STUART M. SMITH, H. W. MENARD AND GEORGE SHARMAN

SCRIPPS INSTITUTION OF OCEANOGRAPHY
LA JOLLA, CALIFORNIA

FILE 1

GENERAL INFORMATION

THE FOLLOWING FOUR FILES ON THIS TAPE CONTAIN OCEAN DEPTHS(-) AND LAND ELEVATIONS(+) IN METERS AVERAGED OVER AREAS APPROXIMATING ONE DEGREE SQUARES OF LATITUDE AND LONGITUDE. THE METHOD OF AVERAGING WAS BY VISUAL ESTIMATION FROM CONTOUR CHARTS OF ONE KILOMETER CONTOUR INTERVAL HAVING SCALES RANGING BETWEEN 10 MILLION TO ONE AND 25 MILLION TO ONE.

THE MAJOR SOURCES WERE THE GENERAL BATHYMETRIC CHART OF THE OCEANS, PUBLISHED BY THE INTERNATIONAL HYDROGRAPHIC BUREAU-MONACO, USED FOR THE LAND, THE EQUAL-AREA CONTOUR CHART BY MENARD AND SMITH FOR THE PACIFIC, AND THE SERIES OF RUSSIAN CHARTS PUBLISHED BY THE MAIN ADMIN. GEODESY AND CARTOGRAPHY, GOVERNMENT GEOLOGICAL COMMITTEE, USSR FOR THE OTHER OCEAN BASINS.

A DETAILED DESCRIPTION OF THE SOURCES, DEPTH ESTIMATION METHOD, ESTIMATION OF ERRORS, AND ERROR CHECKS CARRIED OUT DURING PROCESSING ARE GIVEN IN S.I.O. REFERENCE REPORT 65-8, WHICH SHOULD BE CITED WHENEVER DATA ON THIS TAPE ARE REFERENCED.

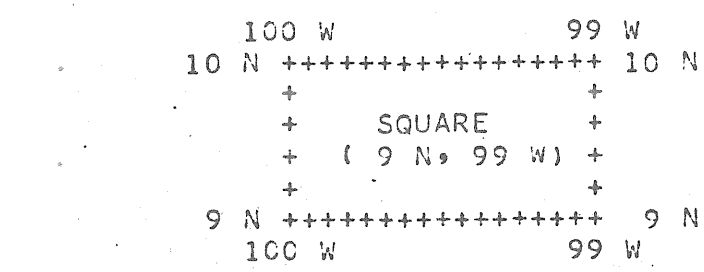
ARRANGEMENTS FOR OBTAINING COPIES OF THIS TAPE, AND/OR A 132 PAGE LISTING CONTAINING ONLY LATITUDE, LONGITUDE AND DEPTH (SEE TAPE FORMAT, BELOW) CAN BE MADE BY CONTACTING THE NATIONAL OCEANOGRAPHIC DATA CENTER, BLDG. 160, NAVY YARD ANNEX, WASHINGTON, D.C., 20390.

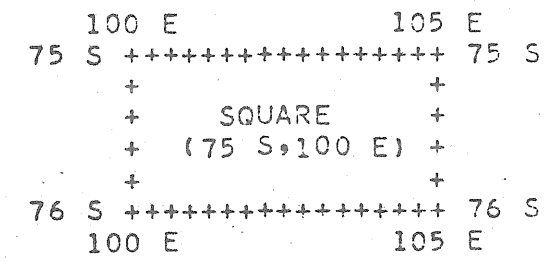
SQUARE REFERENCING

THE AVERAGED AREAS ARE BOUNDED BY ONE DEGREE OF LATITUDE FROM THE EQUATOR TO THE POLES. TO MAINTAIN APPROXIMATELY EQUAL AREAS FOR AVERAGING, THE FOLLOWING LONGITUDE BOUNDARIES WERE USED FOR EACH SQUARE.

0 THROUGH 49 DEGREES LATITUDE,	1 DEGREE	LONGITUDE
50 THROUGH 69 DEGREES LATITUDE,	2 DEGREES	LONGITUDE
70 THROUGH 79 DEGREES LATITUDE,	5 DEGREES	LONGITUDE
80 THROUGH 89 DEGREES LATITUDE,	10 DEGREES	LONGITUDE

EACH SQUARE IS IDENTIFIED BY THE LATITUDE AND LONGITUDE OF THE CORNER NEAREST THE ORIGIN. FOR EXAMPLE,





THE FOUR SQUARES ADJACENT TO THE ORIGIN ARE LABELED (0 N, 0 E), (0 N, 0 W), (0 S, 0 E) AND (0 S, 0 W).

TAPE FORMAT

FILE 1 = THIS INFORMATION (STANDARD BCD LISTING)
FILE 2 = NE QUADRANT (NORTH LAT, EAST LONG)
FILE 3 = SE QUADRANT (SOUTH LAT, EAST LONG)
FILE 4 = NW QUADRANT (NORTH LAT, WEST LONG)
FILE 5 = SW QUADRANT (SOUTH LAT, WEST LONG)

IN EACH QUADRANT,THE FIRST SQUARE IS (0 LAT,0 LONG),FOLLOWED BY (0 LAT,1 LONG),(0 LAT,2 LONG) CONTINUING TO (0 LAT,179 LONG). THE NEXT SQUARE IS (1 LAT,0 LONG),ETC. THE COMPLETE SEQUENCE FOR EACH QUADRANT IS GIVEN BY THE FOLLOWING QUASI-DO-LOOP NOTATION.

```
((SQUARE(LAT,LONG),LONG=0,179, 1)LAT= 0,49,1)
((SQUARE(LAT,LONG),LONG=0,178, 2)LAT=50,69,1)
((SQUARE(LAT,LONG),LONG=0,175, 5)LAT=70,79,1)
((SQUARE(LAT,LONG),LONG=0,170,10)LAT=80,89,1)
```

THE DATA IN FILES 2 THROUGH 5 ARE IN BCD MODE, 240 CHARACTERS PER RECORD, 1134 RECORDS PER FILE. EACH RECORD CONTAINS 10 CARD IMAGES. EACH CARD IMAGE CONTAINS DATA ON ONE SQUARE IN THE FOLLOWING FORMAT OF 24 CHARACTERS

I2	LATITUDE
A1	(N) OR (S)
I3	LONGITUDE
A1	(E) OR (W)
A3	OCEAN OR CONTINENT IDENTIFICATION
I5	DEPTH(-) OR ELEVATION(+) IN METERS
A1	(M) METERS
1X	BLANK
I4	ELEVATION OF ICE CAP SURFACE(ANTARCTICA ONLY)
1X	BLANK
I2	SOURCE NUMBER OF CHART

THE ORIGINAL TAPE WAS PRODUCED IN SEPTEMBER,1965,ON THE CDC 3600 COMPUTER AT THE COMPUTER CENTER,UNIVERSITY OF CALIFORNIA,SAN DIEGO, USING BUFFER STATEMENTS AVAILABLE IN FORTRAN-63.

END FILE 1 REVISED 1 APRIL 1966

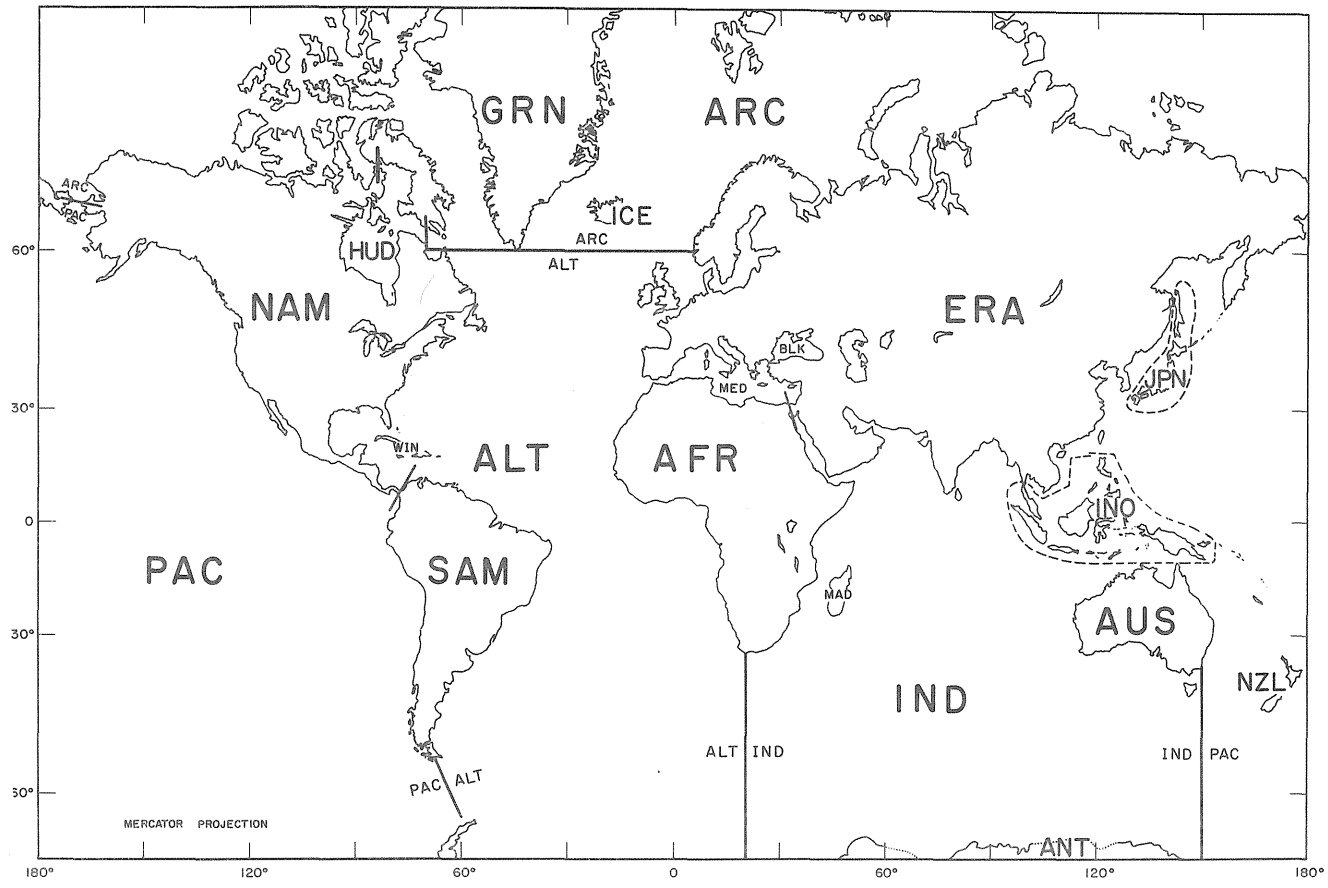


Figure 1: Approximate ocean boundaries and abbreviations of continent and ocean identifiers (see Table III).

TABLE I a

Charts used for Average Depth Estimations

Source Number	Title	Date	Approximate Scale ($\times 10^6$)	Contour Interval	Projection	Reference (see table Ib)
1-24	B.C.F. Topographic Charts (No. 1-24)	1960-1964	1:0.69	200 Fm	Mercator	A
25	Galapagos Rise, Southeast Pacific	1964	1:6	500 M	" "	B
26	Peru-Chile Trench	1962	1:6	500 M	" "	C
27	French Oceania	1959	1:2	500 M	" "	D
28-30	Cable and Wireless Charts (Nos. 19,20,21)	1962	1:1	200 Fm	" "	D
31	Chart(40-46°N,124-134°W)Contours by R.J.Hurley	1958	1:1	100 Fm	" "	D
32	(not used in final compilation)					
33	Contours on U.S.H.O.Chart 0824	1960	1:6	200 Fm	" "	D
34	Antarctica	1962	1:5	500 M	Stereographic	E
35	Indian Ocean	1963	1:15	1000M(200)	Lambert Azmuthal Equal-Area	F
36	Southern Hemisphere	1963	1:25	1000M(200)	Polar Azmuthal Equal-Area	F
37	Tectonic Chart of the Arctic	1963	1:10	1000M(200,500)	" "	G
38	Atlantic Ocean	1963	1:20	1000M(200)	Lateral Projection	F
39	(same as source chart 46)					
40	Bathymetry of the Pacific Basin	1964	1:20	1000 M	Lambert Azmuthal Equal-Area	H
41	(same as source charts 44 and 45)					
42-54	Cartes Generales Bathymetrique des Oceans	1937-1961	1:10	1000M(200,500)	Mercator	I

TABLE Ib

References for Source Charts

A. U. S. Bureau of Commercial Fisheries, Tuna Resources Laboratory, La Jolla, California.

B. Menard, H. W., Chase, T. E., and Smith, S. M., 1964, Galapagos Rise in the southeastern Pacific. Deep-Sea Research, Vol. 11, pp. 233-242.

C. Fisher, R. F. and Raitt, R. W., 1962, Topography and structure of the Peru-Chile Trench. Deep-Sea Research, Vol. 9, pp. 423-443.

D. Unpublished data (H. W. Menard, Scripps Inst. Oceanogr.)

E. American Geographical Society, Broadway at 156th St., New York 32, New York.

F. Main Administration in Geodesy and Cartography of the Government Geological Committee of the USSR, Moscow.

G. Geological Institute, Academy of Science, Moscow, USSR.

H. Menard, H. W., 1964, Marine Geology of the Pacific. McGraw-Hill Book Co., New York, 273 p.

I. International Hydrographic Bureau, Monaco.

TABLE II

AREAS OF THE SQUARES AS A FUNCTION OF LATITUDE

Area in units of ten thousand square kilometers. Calculated for a sphere having the same volume as the earth (radius = 6,371.221 km)

One Degree Longitude

Latitude	Area
0	1.236454
1	1.236078
2	1.235324
3	1.234195
4	1.232690
5	1.230809
6	1.228553
7	1.225923
8	1.222919
9	1.219543
10	1.215796
11	1.211678
12	1.207191
13	1.202337
14	1.197116
15	1.191530
16	1.185582
17	1.179272
18	1.172605
19	1.165577
20	1.158196
21	1.150462
22	1.142378
23	1.133946
24	1.125168
25	1.116048
26	1.106587
27	1.096790
28	1.086658
29	1.076196
30	1.065406
31	1.054291
32	1.042855
33	1.031101
34	1.019033
35	1.006655
36	.993970
37	.980982
38	.967696
39	.954115
40	.940243
41	.926085
42	.911644
43	.896926
44	.881935
45	.866675
46	.851151
47	.835368
48	.819331
49	.803043

Two Degrees Longitude

Latitude	Area
50	1.573023
51	1.539480
52	1.505469
53	1.470998
54	1.436080
55	1.400724
56	1.364942
57	1.328743
58	1.292140
59	1.255144
60	1.217765
61	1.180015
62	1.141905
63	1.103448
64	1.064655
65	1.025537
66	.986107
67	.946377
68	.906358
69	.866064

Five Degrees Longitude

Latitude	Area
70	2.063763
71	1.961738
72	1.859116
73	1.755927
74	1.652203
75	1.547976
76	1.443277
77	1.338139
78	1.232594
79	1.126672

Ten Degrees Longitude

Latitude	Area
80	2.040816
81	1.827665
82	1.613958
83	1.399759
84	1.185134
85	.970148
86	.754866
87	.539354
88	.323678
89	.107904

TABLE III

Ocean and Continental Identifiers

PAC	Pacific Ocean
ALT	Atlantic Ocean
IND	Indian Ocean
ARC	Arctic Ocean
MED	Mediterranean Sea
BLK	Black Sea
HUD	Hudson Bay
NAM	North America
SAM	South America
ERA	Eurasia
AUS	Australia
AFR	Africa
NZL	New Zealand
GRN	Greenland
ICE	Iceland
MAD	Madagascar
INO	Indonesia
JPN	Japan
ANT	Antarctica
WIN	West Indies

TABLE IVa

Mean Algebraic Deviations
for Continental Test Areas (in meters)

Relief	A	B	C	D	E
High	-19	+31	- 7	-44	+32
Moderate	- 7	+14	-13	+ 8	+ 2
Low	-87	-11	+12	+52	+29
Average per person	-38	+11	- 8	+ 5	+21

TABLE IVb

Mean Absolute Deviations for
Continental Test Areas

Relief	A	B	C	D	E	Average for relief type
High	60	68	97	75	98	80
Moderate	18	24	19	13	17	18
Low	87	36	43	65	29	52
Average for person	55	43	53	51	48	50

TABLE IVc

Mean Algebraic and Absolute Deviations
for Oceanic Test Areas

Relief	Algebraic	Absolute
High	± 1	11
Low	± 9	59