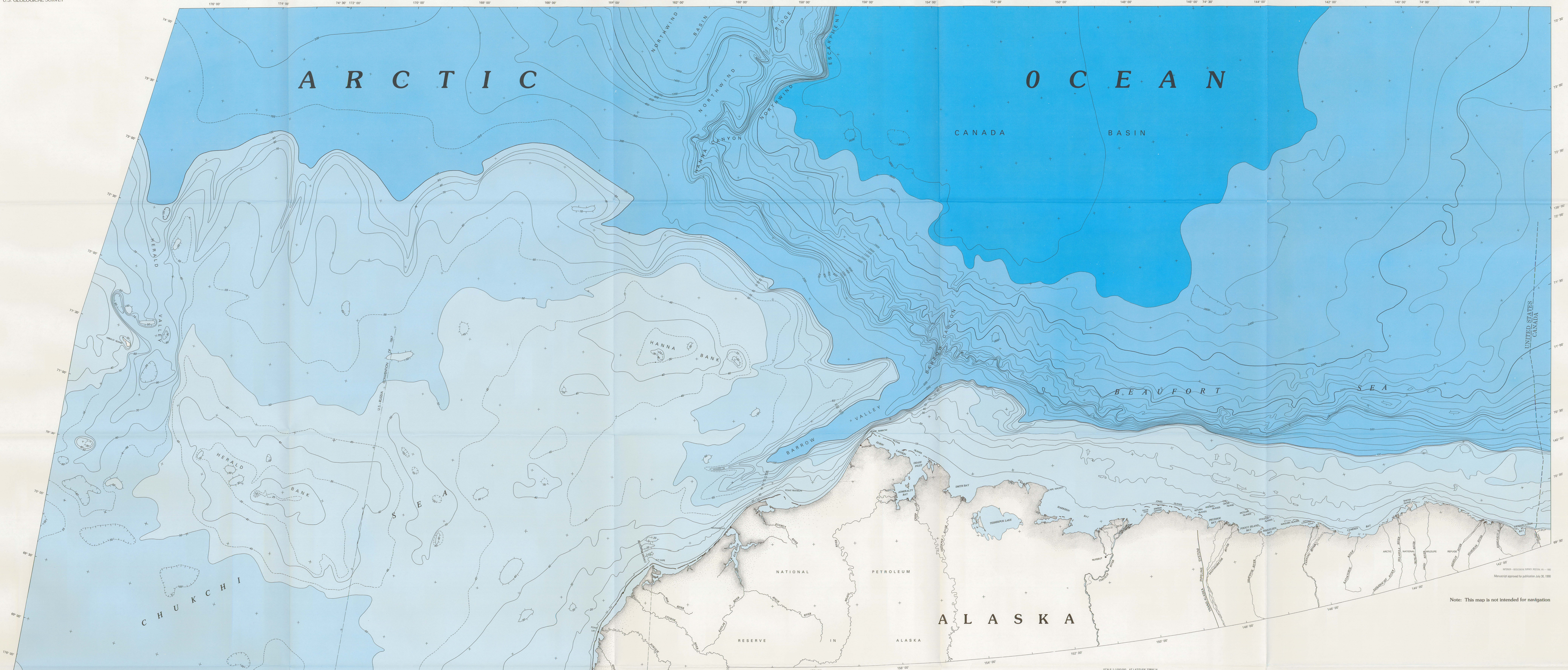
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

MISCELLANEOUS INVESTIGATIONS SERIES
MARINE GEOLOGY ATLAS
CHUKCHI SEA
I-1182-I



Note: This map is not intended for navigation

SCALE 1:1000000 AT LATITUDE 72°00' N.

POLAR STEREOGRAPHIC PROJECTION
(SGEMSA) IN METRIC
SUPPLEMENTARY GEBATHS AT 5, 50, AND 100-M INTERVALS

EXPLANATION

Depth, in meters

- 0 - 50 m
- 50 - 100 m
- 100 - 3600 m
- > 3600 m

Isobath, in meters—Dashed where inferred

Supplementary isobath, in meters

Localized depression—Hachures show direction of slope

Localized high—Hachures show direction of slope

DISCUSSION

USES OF THIS MAP

The "Bathymetric Map of the Chukchi and Beaufort Seas and Adjacent Arctic Ocean" was prepared as a base for displaying regional physiographic and geologic data from the continental margin north of Alaska. It was not designed to serve as a chart for navigation.

DATA SOURCES

This map was compiled from the sources shown in figure 1. Most of the data were used earlier to compile bathymetric maps of the Beaufort Sea (Greenberg and others, 1981) and the Chukchi Sea (Hill and others, 1984), which are the principal sources for the present compilation. Most of the following text was also adapted from these earlier maps. Figures 2 and 3 were taken from Greenberg and others (1981).

New bathymetric data incorporated in the present map are also shown in figure 1. These data were collected by the U.S. Geological Survey (USGS) in 1988 and 1989 from the U.S. Coast Guard icebreaker *Polar Star* using a 12 kHz echo sounder. Navigation on the *Polar Star* was by Global Positioning System (GPS) satellite supplemented by satellite navigation (NNSS) when GPS satellites were out of range. Other new data are soundings collected by the U.S. Geological Survey in 1982 and 1985 from the USGS research vessel *Karluk* using NNSS navigation and bathymetric contours from Canadian Hydrographic Survey Chart WA10167. Where data sets of comparable quality conflict, the contours were generalized rather than arbitrarily shifted to fit one data set or the other.

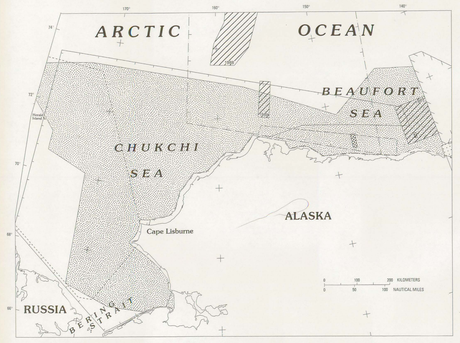
DATUM AND SOURCES OF ERROR

The bathymetry is plotted on a polar stereographic projection with a scale of 1:1,000,000 at lat 72° 00' N. Inherent inaccuracies in the computer-generated base and inaccuracies introduced during photographic reduction and splicing are estimated to have produced errors from these sources that are no larger than 1 km in the position of grid points and bathymetry. In many places the locally wide spacing of the bathymetric profiles and digital data points from which the contours were drawn undoubtedly resulted in even larger inaccuracies in the position of the bathymetric contours.

Datum for the U.S. National Ocean Survey charts, our primary data source nearshore, is mean lower low water. None of the other data sets were adjusted for tides because tidal data are sparse north of Bering Strait and because the diurnal tidal range along the coast is inferred from existing data to be generally much less than half a meter. Thus, the diurnal tidal range is only 12 cm at Point Barrow (U.S. National Ocean Survey, 1981), 35 cm at Kotzebue, on the coast of the southeastern Chukchi Sea between Point Hope and Kotzebue (Creager and McManus, 1965), and 82 cm at Kiusaluk, at the head of Kotzebue Sound (U.S. National Ocean Survey, 1981). The southward increase in periodic tidal range from the open ocean on the north to the head of landlocked Kotzebue Sound to the southeast is consistent with the observation that the tidal wave in the Chukchi Sea moves southward across the shelf from the Arctic Ocean (Hunkins and Kaplan, 1966) and the fact that tidal waves are amplified upon entering shallow coastal waters.

Variations in sea level related to changes in water temperature and salinity (steric variations), wind, and excursions of barometric pressure can be larger that the diurnal tide range in the Chukchi and Beaufort Seas. Thus Beal (1968) reports that steric and barometric variations cause an annual seasonal (winter-to-summer) fluctuation of sea level at Barrow of 30 to 40 cm. He also reports that identical seasonal sea level fluctuations were simultaneously measured at Cape Schmidt on the Siberian Coast, suggesting the possibility of concurrent seasonal sea level variations over the entire Chukchi Sea. Exceptional storm surges have been reported to raise sea level 3 to 4 m at Barrow (Hume and Schalk, 1967) and 2.7 m at Point Lay (Aagaard, 1978), although the effect is presumably much reduced offshore. No corrections for such effects were attempted. Other sources of bathymetric error are electronic noise and water-column inhomogeneities, commonly manifested as "acoustic multipaths" (Mammerickx, 1971, p. 7) and "sound channels" (Ewing, 1950). The error indicated by these sources is considered to be insignificant over the large areas of the map that depict the shallow waters and low-relief bottom features of the Chukchi and Beaufort continental shelves.

Over the steep continental slope, nonvertical echoes can produce significant bathymetric errors. Thus the continental slope north of the Chukchi and Beaufort shelves is commonly inclined about 4° to 12°, with local steeper pitches of 16° or more. Nonvertical echoes along bathymetric profiles that trend directly down uniform slopes indicate depths that are too shallow by about 0.3 percent where the slope is 4°, by about 2.2 percent where the slope is 12°, and about 4 percent where the slope is 16°.



CONVERSION OF REFLECTION TIME TO WATER DEPTH

Most of the depth values used to construct the bathymetric map were not corrected for the increase in velocity of sound with depth in the water column. Instead, a constant velocity was used to convert the transit time of echo-sounder signals to depth. The USGS soundings were converted using a constant velocity of 1,464 m/s (meters per second) for the entire jaster column, and the Geophysical Corporation of Alaska soundings were converted using a constant velocity of 1,448 m/s, a good approximation for the shallow shelf areas where most of their profiles are located. The different assumed velocities on the shelf yield depth differences ranging from 0.1 m at depth of 10 m to 2.0 m at depths of 180 m. All other data sets were computed using an assumed velocity of 1,463 m/s except for most of the Canadian Earth Physics Branch data along the east margin of the map, which were corrected by a velocity function that increases with depth. For water depths exceeding 2,200 m, where slopes become gentle and the depth correction is significant, we removed the variable depth correction from the Canadian soundings to make them consistent with the other data sets.

The departure of the isobaths based on an average velocity of sound in the map area of 1,464 m/s from water depths based on a model in which sound velocity increases with depth is shown in figure 2. Curve A shows the variation of sound velocity with depth calculated from the variation of temperature and salinity with depth in the Beaufort Sea as given by Coachman and Aagaard (1974, fig. 4, p. 1) using tables in U.S. Naval Oceanographic Office Special Publication SP-58 (1962). Because temperature and salinity both contribute and Coachman is the principal influence on velocity below 1,000 m, the curve was extrapolated to 4,000 m from the deepest readings (1,800 m) given by Coachman and Aagaard (1974). A constant slope of 0.01725 m/s/m (curve B, fig. 2) approximates the increases in velocity of sound with depth in the Beaufort Sea. This approximation is poorest in the upper 100-200 m of the water column in summer, when local variations in temperature and salinity produced by shifting ice pack, currents, and local plumes of river discharge can create velocity variations as large as 2 or 3 percent. Depths determined from the 0.01725 m/s/m approximation vary by a maximum of 0.8 percent (at 890 m) from depths determined from the actual velocity-depth plot (curve A, fig. 2), but at most depths the difference is small. The isobaths, which are mostly based on an assumed constant water-column velocity of 1,463 or 1,464 m/s (curve C, fig. 2), can be converted to depths based on the constantly increasing velocity model (curve B, fig. 2) by means of a correction factor (fig. 3). The maximum correction at the deepest isobath (3,900 m) is +1.1 percent. In waters deeper than 200 m this curve may be generally useful for approximating true depths from calculated depth values. Decreased salinity and, in summer, increased water temperature in the southern part of the map area would probably require larger corrections, but these corrections are overshadowed by tidal and other effects in these shallow waters, and their magnitude was not assessed.

Area on map	Year surveyed	Organization	Format of data used in compilation	Navigation
	1998, 1989	U.S. Geological Survey	Continuous bathymetric profiles	G.P.S. and Integrated satellite
	1982, 1985	U.S. Geological Survey	Continuous bathymetric profiles	Integrated satellite
	1977, 1978, 1980, 1982	U.S. Geological Survey	Continuous bathymetric profiles	Integrated satellite
	1969-74, 1976	U.S. Geological Survey[1]	Continuous bathymetric profiles	Satellite
	1973	Geophysical Corporation of Alaska	Continuous bathymetric profiles	Integrated satellite
	1984	Canadian Hydrographic Service	CHS chart WA 10167	Integrated satellite
	1968, 1970, 1971	Earth Physics Branch, Department of Energy, Mines and Resources, Canada	Spot soundings	Lambda Decca and Loran-C
	Editions released 1951 and 1974-78	National Ocean Survey	NOS charts: 16003,16041-46, 16061-67, 16081-86, 16101-103	Visual methods (sextant) supplemented by fathometer
Not shown	1972	University of Connecticut	Spot soundings	Satellite
	1961	Naval Electronics Laboratory[2]	Spot soundings	Electronic position indicator
	1951, 1952, 1957	Scripps Institution of Oceanography, Naval Electronics Laboratory[3]	Unpublished charts	Radar and celestial
Entire map area	Compiled from government, academic, and private sources	U.S. Naval Oceanographic Office and Defense Mapping Agency	Hydrographic Charts: NO 16024, NO 16600, NO 36006, NO 36007, NO 36008, and unpublished spot soundings	Mostly celestial, some radar

[1]Maps showing the tracklines of the surveys conducted by the U.S. Geological Survey in 1969, 1970, 1971, 1972, 1973, 1974, 1976, 1977, 1978, 1980, 1982, 1984, 1985, 1989, and 1990 are in Grantz and Mullen (1992).
[2]A map showing the tracklines of the survey conducted by the Naval Electronics Laboratory on the USNS *USC&GS Hecharchel* in 1961, from which these spot soundings were obtained, has been published in Creager and McManus (1966).
[3]In part published by Fisher and others (1959).

Figure 1. Index map and table showing location, source, format, and navigational control of bathymetric data sets.

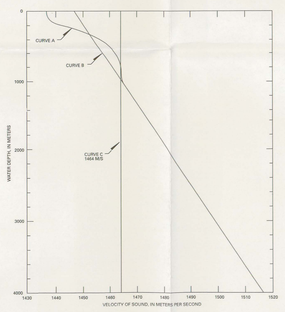
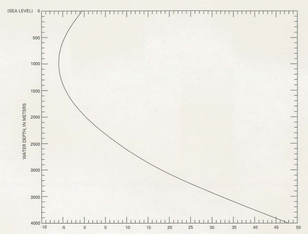



Figure 2. Curve A, general variation of velocity of sound with depth in the Beaufort Sea constructed according to tables in U.S. Naval Oceanographic Office (1962) from plots of variation of temperature and salinity with depth in Coachman and Aagaard (1974, p. 7). Curve B, linear approximation of curve A used to compute corrections shown in figure 3. Curve C, average velocity of sound used to convert echo-sounder transit times to depths in most of the bathymetric data sets (see text).