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Anticyclonic Warm Core Gulf Stream Rings off the Northeastern United States during 1982

by

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This report summerizes for the ninth year, 1982, the movements of anticyclonic warm core Gulf Stream rings in the slope water region off the coast of the northeastern United States, primarily from Cape Hatteras, North Carolina, to Georges Bank, south of Nova Scotia. Similar yearly analyses have been prepared for each of the preceeding eight years, by Bisagni (1976) for 1974-75, Mizenko and Chamberlin (1979) for 1976 and 1977, Celone and Chamberlin (1980) for 1978, and Fitzgerald and Chamberlin (1982, 1983) for 1979 and 1980.

Information Sources and Analysis Methods.

The analysis is based primarily on ring positions shown in the Oceanographic Analysis charts prepared jointly by the NOAA National Weather Service and National Earth Satellite & Data Information Service (NESDIS), which are issued three times weekly on Monday, Wednesday and Friday. In addition, remotely sensed imagery from the NOAA polar-orbiting satellites and geostationary satellites (GOES) and computer derived GOES digital sea surface temperature composites, which are received daily, are used to supplement the frontal analysis charts. In weeks for which there was no clear satellite imagery, ring positions were interpolated and then adjusted in the end-of-year analysis. Weekly ring center positions are plotted on the trackline

charts, and the formation and destruction locations plus weekly positions are dated. When ring positions were clearly seen in imagery as a result of: 1) thermal contrast with surrounding water, or 2) encircling bands of colder shelf water or warmer Gulf Stream Water, the center positions were plotted as closed circles (•) and dated with the day of observation. Less certain ring positions, estimated from unclear imagery or questionable entrainment features were plotted as triangles (▲) and dated with the day of observation. Center positions estimated entirely by interpolation were plotted as open circles (◦) and dated with the last day of the weekly compilation chart.

At any time of the year, but especially in summer, rings may not be visible in satellite imagery because of the lack of thermal contrast at the surface. When rings in close proximity to one another are not visible, or hidden by clouds for a number of weeks, there may be uncertainty in distinguishing between the rings when they finally reappear. In such cases, the simplest interpretation of movements has been accepted. Shipboard data, when available, is also used to confirm these interpretations.

Surface boundaries of rings are shown for the estimated date of formation, and at representative stages in the life of the ring. These boundaries, interpreted directly from the satellite imagery, involve errors of unknown magnitude. Surface expressions of rings can at times have a distorted pattern and shipboard observations have shown that the surface expressions may coincide imperfectly in both location and size with the boundary of the ring at depth (Fitzgerald & Chamberlin (1982).

A number of the rings followed in 1982 (rings 81-G, 82-B, 82-D and 82-H) have been intensively studied by the multi-institutional Warm Core Rings Program, sponsored by the National Science Foundation, to describe the behavior and structure of rings and their impacts on marine biological and chemical environments. Data collected from cruises of the Warm Core Rings Program have been incorported into the analyses reported here.

Only rings which occurred west of 60°W during some portion of their lifetime are considered in this analysis. Rings are labelled with the year in which they formed, and alphabetically in the order of formation.

Ring Histories

A total of thirteen warm core Gulf Stream rings occurred in the slope water region between Cape Hatteras, North Carolina and 60°W longitude during 1982. Two rings, 81-F and 81-G, were formed late in 1981 and survived into 1982. Of the eleven rings that formed during 1982, two of them (82-I and 82-J), persisted into 1983. Estimated formation and destruction positions and dates as well as lifespans for each ring are listed in Table 1.

Ring 81-F (Fig. 1) first clearly appeared in satellite imagery on 28 November 1981 near 38.8°N, 66.5°W (Fitzgerald and Chamberlin (in press). On 4 January 1982, 81-F was centered south at Atlantis Canyon at 39.3°N, 70.9°W. During the month of February, ring 81-F, moved rather slowly between Block and Hudson Canyons, then progressed at a steady rate to the vicinity of Cape Hatteras, where it was absorbed by the Gulf Stream on or about 27 May near 36.4°N, 74.2°W.

Ring 81-G, (Fig. 2) formed by 7 December 1981, centered at 39.8°N, 62.5°W (Fitzgerald and Chamberlin , in press). On January 4, 1982, the ring was centered at 40.2°N, 62.4°W. During the first three weeks of February, ring 81-G interacted with the Gulf Stream and entrained warm water along its western edge. During the second week in March, 81-G interacted with a northward propagating meander of the Stream, and may have influenced the formation of a new short lived ring, designated 82-C. Although 81-G was a relatively long-lived ring (290 days) it did not travel westward very far; only approaching Lydonia Canyon shortly before its death. During most of May through September, ring 81-G traced an erratic course while it was located in the vicinity of the New England seamounts. Ring 81-G was resorbed by a large Gulf Stream meander at 40.0°N, 64.9°W on about 22 September.

Ring 82-A (Fig. 3) was estimated to have formed on 15 January, from a large Gulf Stream meander centered at 39.8°N, 64.7°W. Persistent cloud cover continued to hide the ring until 30 January, when it was seen centered southeast of Corsair Canyon. 82-A continued westward along an erratic course until the first week of April, when it was influenced by a westward extending Gulf Stream meander which eventually formed ring 82-D_1, described later in this report. During April, 82-A interacted with and was eroded by the large meander and transported eastward, rather than

following the normal westward course. During the last week in April, ring 82-D_1, a newly formed ring, entrained water from 82-A on its eastern side and eventually absorbed the ring on about 2 May near 40.0°N, 65.9°W.

Ring-B (Fig. 4) detached from a northward propagating meander on 14 February, centered at 38.9°N, 69.4°W. This ring was anomalous in that it formed further west than most rings found south of Georges Bank. 82-B moved steadily westward along the continental shelf break until being absorbed off Cape Hatteras (35.8°N, 74.4°W) during late September.

Ring 82-C (Fig. 5) a short lived ring, formed from a meander that had interacted with ring 81-G during the third week in March. On 20 March it was centered at 40.1°N, 60.9°W. Its existence after 29 March was uncertain, due to a lack of surface thermal contrast and persistent cloud cover. It is estimated that 82-C destroyed on about 2 April near 39.8°N, 61.2°W.

Ring 82-D_1 (Fig. 5) formed from a westward extending Gulf Stream meander on 14 April, centered at 38.3°N, 67.0°W. During late April and early May, strong interaction with the Gulf Stream occurred. As a result the surface area of 82-D_1 increased. Again in early June there was strong interaction with the stream at the surface. By the end of June, 82-D_1 had made contact with the stream in the vicinity of 67°W, resulting in the formation of ring 82-D_2. During the middle of July, 82-D_1 interacted with the stream again, this time reducing its surface area substantially. Ring 82-D_1 followed a generally southwest course through the slope water until about 16 November when it was resorbed by the Gulf Stream off Cape Hatteras near 35.8°N,74.6°W.

Ring 82-D_2 (Fig. 6) formed from the interaction of ring 82-D_1 and the meandering Gulf Stream in the vicinity of 66°W longitude. Ring 82-D_2 was initially thought to be ring 82-C due to unclear imagery, but re-examination of the sequence of events showed it was a separate ring. Its formation date and position are 2 July and 39.7°N, 66.7°W. This relatively short-lived ring was resorbed by the Gulf Stream on 18 August near 39.5°N, 67.4°W.

Ring 82-E (Fig. 6) was a short-lived ring, forming from a large Gulf Stream meander near 40.5°N, 59.8°W on 29 July. Its large surface area prevented free movement westward through the slope water, and interaction with the Gulf Stream resulted. Ring 82-E was estimated to have been absorb-

ed about 2 September by a large Gulf Stream meander, when the ring center was near 39.3°N, 61.5°W.

Ring 82-F (Fig. 7) another short lived ring, formed from the large meander that had resorbed ring 82-E. It is estimated that 82-F detached from the Gulf Stream on about 5 September, centered at 39.2°N, 62.4°W. This relatively large ring interacted with the Gulf Stream for most of its life time, eventually being resorbed by the Stream on about 22 September near 39.6°N, 63.6°W.

Ring 82-G (Fig. 7) formed on 11 September from the meander which had resorbed ring 82-D$_2$, centered at 39.4°N, 68.1°W. Its rate of movement through the slope water region was relatively constant as it travelled southwestward along the continental shelf break. 82-G was estimated to have been resorbed by the Gulf Stream in the vicinity of Cape Hatteras on 17 December, near 35.8°N, 74.8°W.

Ring 82-H (Fig. 8) formed from a large S-shaped meander of the Gulf Stream on 4 October. Its center position when it formed was determined to be at about 39.6°N, 76.0°W. Interaction with the Gulf Stream seemed to have played an important role in ring 82-H's translation to the west. During mid-October, 82-H made contact with the Stream in the vicinity of 66.5°W longitude and interacted with the Stream until late October, causing its surface expression to be drastically reduced. 82-H continued its southwestward progression along the continental shelf until about 15 December when it was estimated to have been resorbed by a westward extending tongue of the Gulf Stream in the vicinity of 38.8°N, 70.7°W.

Ring 82-I (Fig. 9) formed on 18 October, centered at 41.4°N, 62.9°W. After its formation, ring 82-I moved westward until it approached the eastern edge of Georges Bank, where it then progressed in a southwestward direction. Its position on 3 January 1983 was centered at 40.8°N, 65.9°W.

Ring 82-J (Fig. 10) formed a week later from the same meander that developed ring 82-I. Its position at the time of formation on 25 October was centered at 41.3°N, 60.6°W. This ring interacted with the meandering Gulf Stream during early November and subsequently moved northward, as interpreted from satellite imagery on 21 November. Last clearly seen on 27 December, 82-J was centered at 41.8°N, 62.8°W and was expected to persist into 1983.

ZONAL ANALYSIS:

A generalized summary of the movements of rings relative to one another, during 1982, is presented in Table 2, which shows their mid-month positions with respect to the zones diagrammed in Figure 11. Total zone-month occurrence is 51, the highest total recorded in nine years of analysis. (24, 35, 29, 45, 32, 43, 50, and 29, respectively, for the years 1974-1981.) Two rings, 81-F and 81-G, carried over from 1981 and accounted for 27% of this ring-month total.

Two rings occupied the same zone at mid-month twice in 1982. In mid-April, ring 82-A was observed in the northern portion of zone 4, while ring 82-D1 was seen in the extreme southern portion of zone 4. Ring 82-A was subsequently absorbed by ring 82-D in early May within zone 4. In mid-September, ring 82-G was positioned in the middle of zone 3, while ring 82-F was observed in the southeastern portion of zone 3. Both rings were subsequently absorbed by the Gulf Stream in the same general area around 22 September.

Composite Tracklines of Ring Center Positions and Envelope of Surface Boundaries.

A composite of tracklines for ring center positions, derived from Figures 1-10, and an envelope of ring surface boundaries appear in Figure 12. The envelope was composited from boundaries obtained in the modified weekly frontal analysis charts. Ring center locations were concentrated between 65°W and 75°W longitude. Three rings formed and were destroyed east of 65°W longitude and one ring, 81-G, formed east of 65°W and moved to the west as far as 67°W longitude.

Number of Rings, Times of Formation, and Longevity

During 1982, eleven warm core Gulf Stream rings formed between Cape Hatteras, North Carolina and 60°W longitude. Only once in the previous eight years have as many rings formed in one year. During 1974-1981, ring formation averaged eight per year, ranging from a minimum of four in 1974 to a maximum of eleven in 1975. Two rings that had formed in 1981 survived into 1982 and were long lived (122 and 290 days). Of the eleven rings that formed 1982, four had formed by mid-April, two formed during July, and five formed during September through December. Longevity of the rings formed in 1982 ranged from 14 to 221 days.

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1983. Anticyclonic warm-core Gulf Stream eddies off the northeastern United States in 1980. ICES Annales Biol., 37: 41-47.

In press. Anticyclonic warm-core Gulf Stream eddies off the northeastern United States in 1981. ICES Annales Biol., 38: (in press).

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Table 1. Ring Formation and Destruction Dates, and Life Spans.

Ring	Dates*	Life Span (Days)
81-F	(11/28/81 - (5/27/82)	122
81-G	(12/7/81) - 9/22/82	290
82-A	1/15/82 - 5/2/82	108
82-B	2/14/82 - (9/20/82)	221
82-C	3/20/82 - 4/2/82	14
82-D [1]	4/14/82 - (11/16/82)	209
82-D [2]	7/2/82 - 8/18/82	47
82-E	7/29/82 - 9/02/82	47
82-F	(9/25/82 - (9/22/82)	17
82-G	9/11/82 - (12/17/82)	97
82-H	10/4/82 - (12/15/82)	72
82-I	10/18/82 - into 1983	>74
82-J	10/25/82 - into 1983	>67

* Dates not in parentheses are accurate to within a couple days. Dates in parentheses could be off by greater than one week.

Table 2. Ring positions at mid-month with respect to zone during 1982 (locations of zones in Figure 11)

	J	F	M	A	M	J	J	A	S	O	N	D
1.		81-G	82-C					82-E			82-J	82-J
2.	81-G		81-G	81-G						81-I	82-I	
3.	82-A	82-A			81-G	81-G	81-G	81-G	81-G 82-F	82-H		82-I
4.			82-A	82-A 82-D_1	82-D_1	82-D_1	82-D_2	82-D_2			82-H	
5.	82-F	82-B	82-B				82-D_1	82-D_1	82-G			82-H
6.		81-F	81-F	82-B	82-B					82-G		
7.				81-F		82-B	82-B	82-B	82-D	82-D_1	82-G	
8.					81-F				82-B		82-D_1	82-G

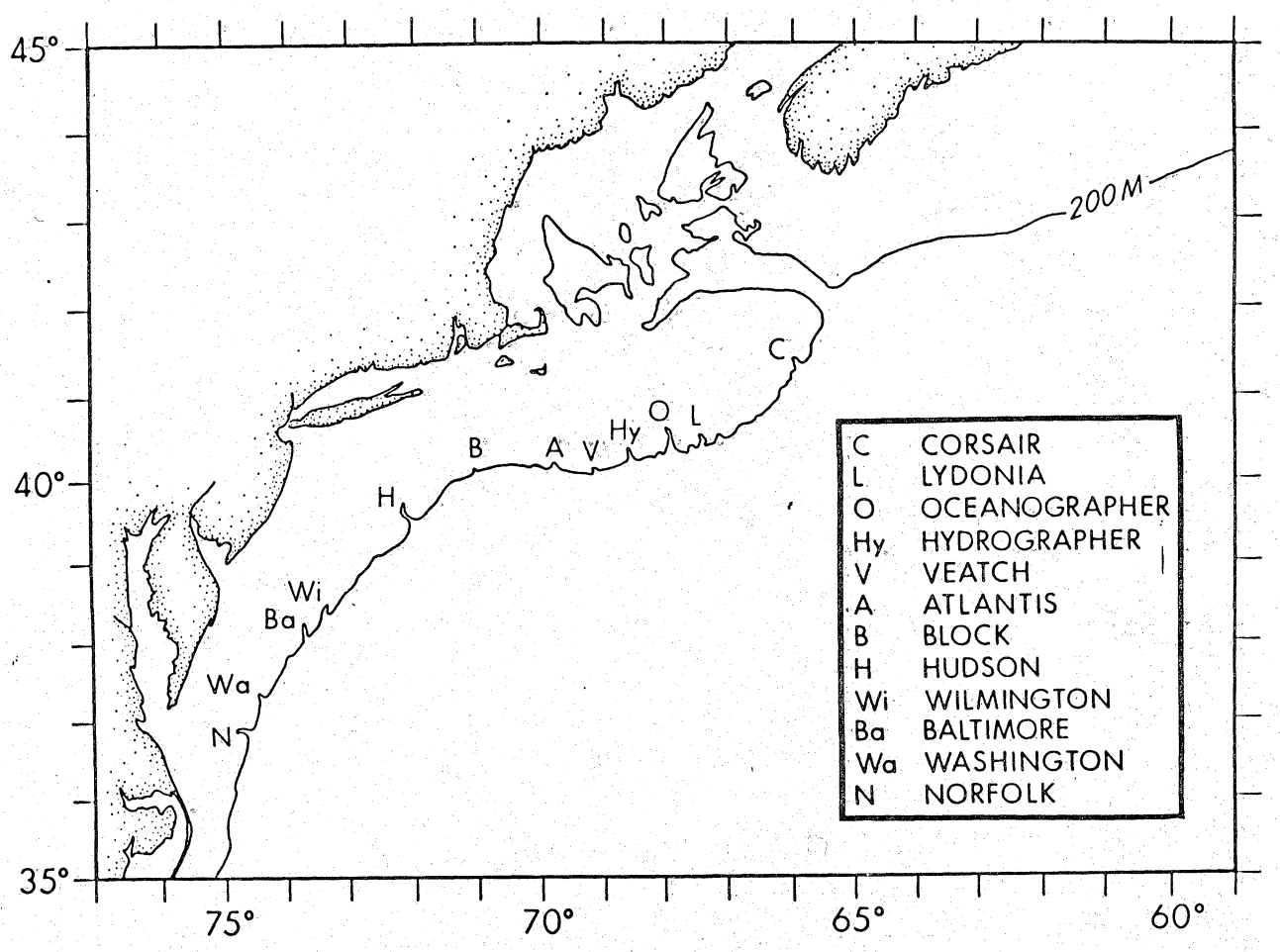

Figure 1. Base map for ring tracklines, showing canyon names

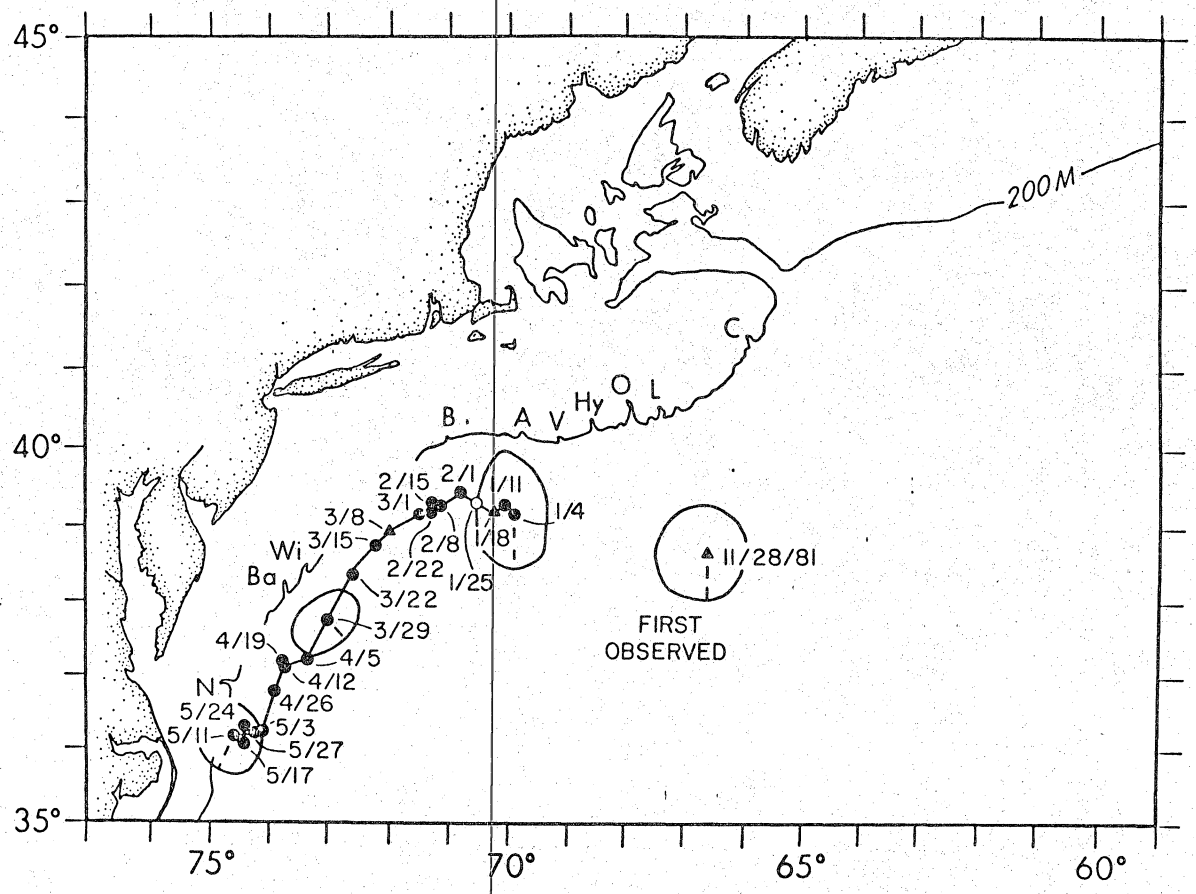

Figure 2. Trackline for Ring 81-F

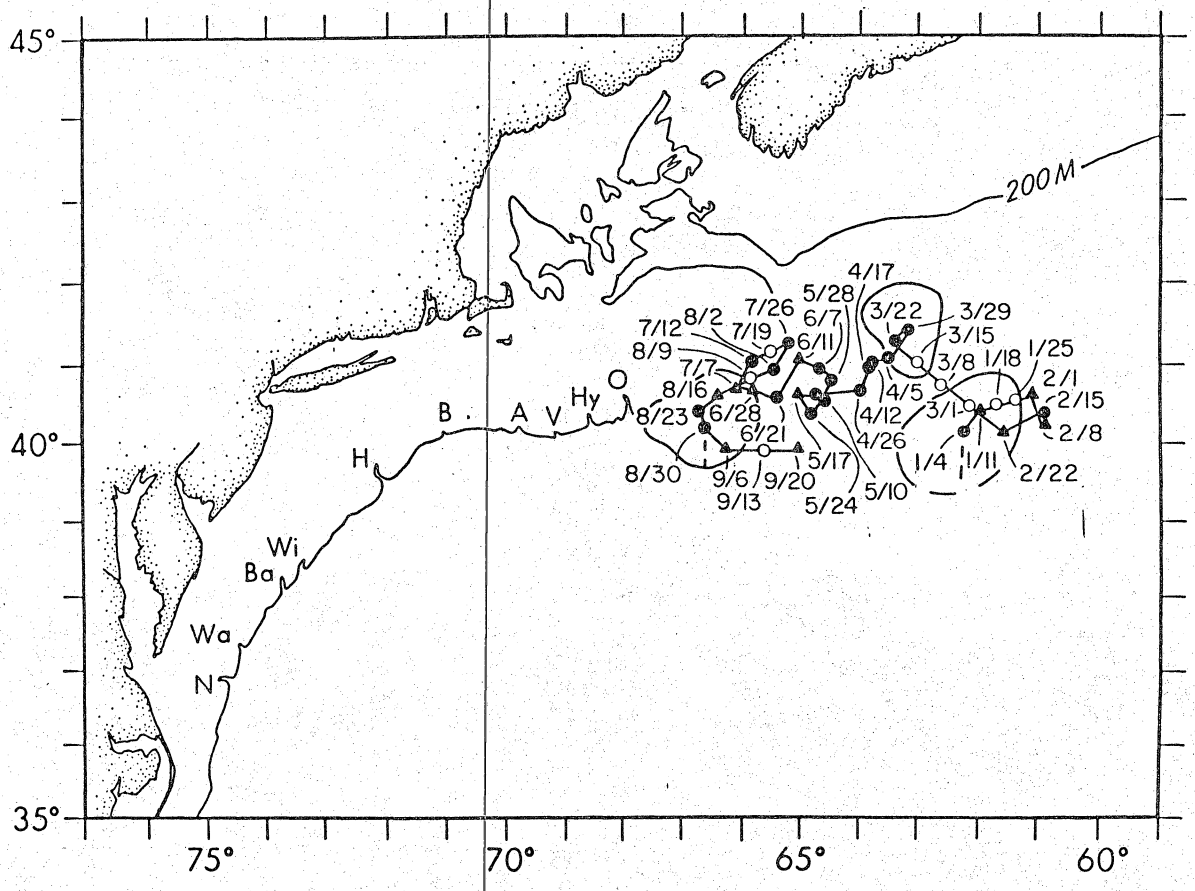

Figure 3. Trackline for Ring 81-G

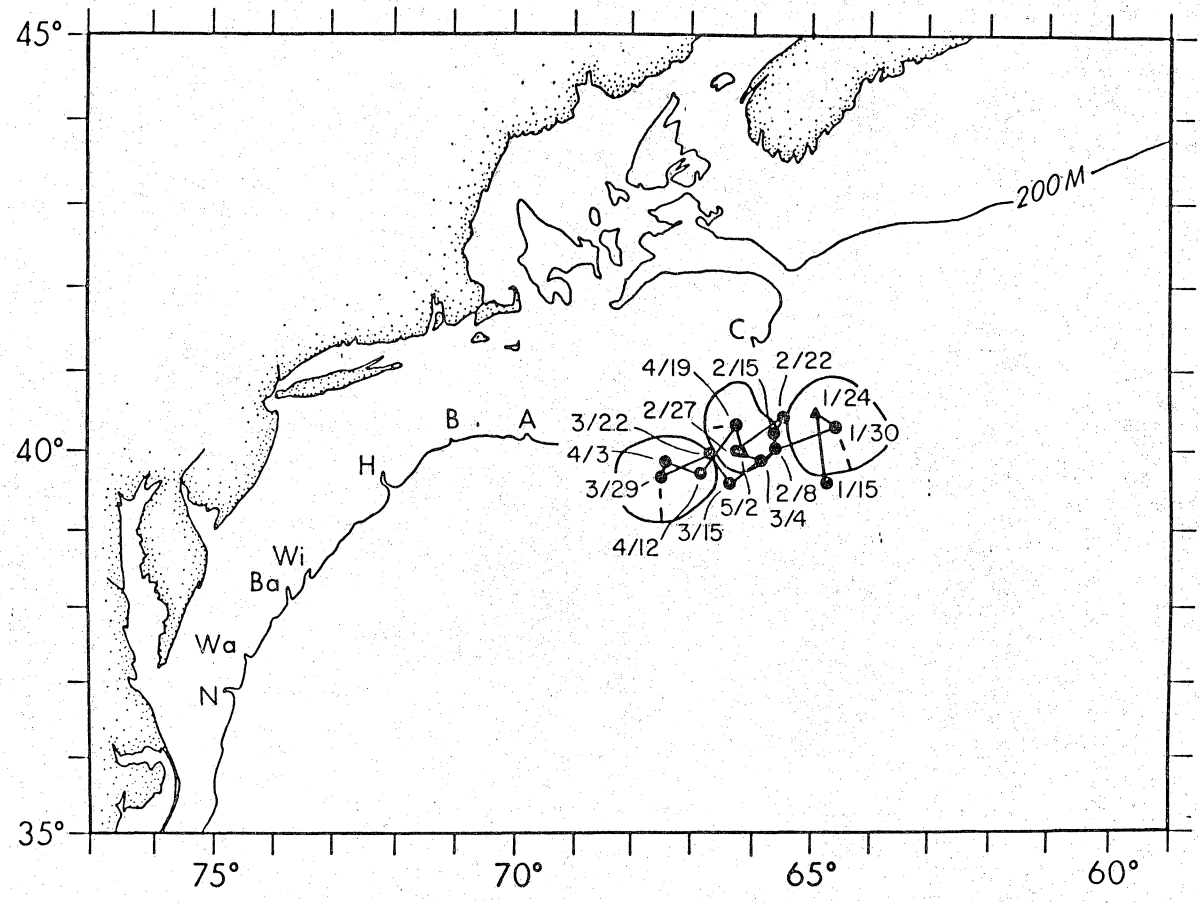

Figure 4. Trackline for Ring 82-A

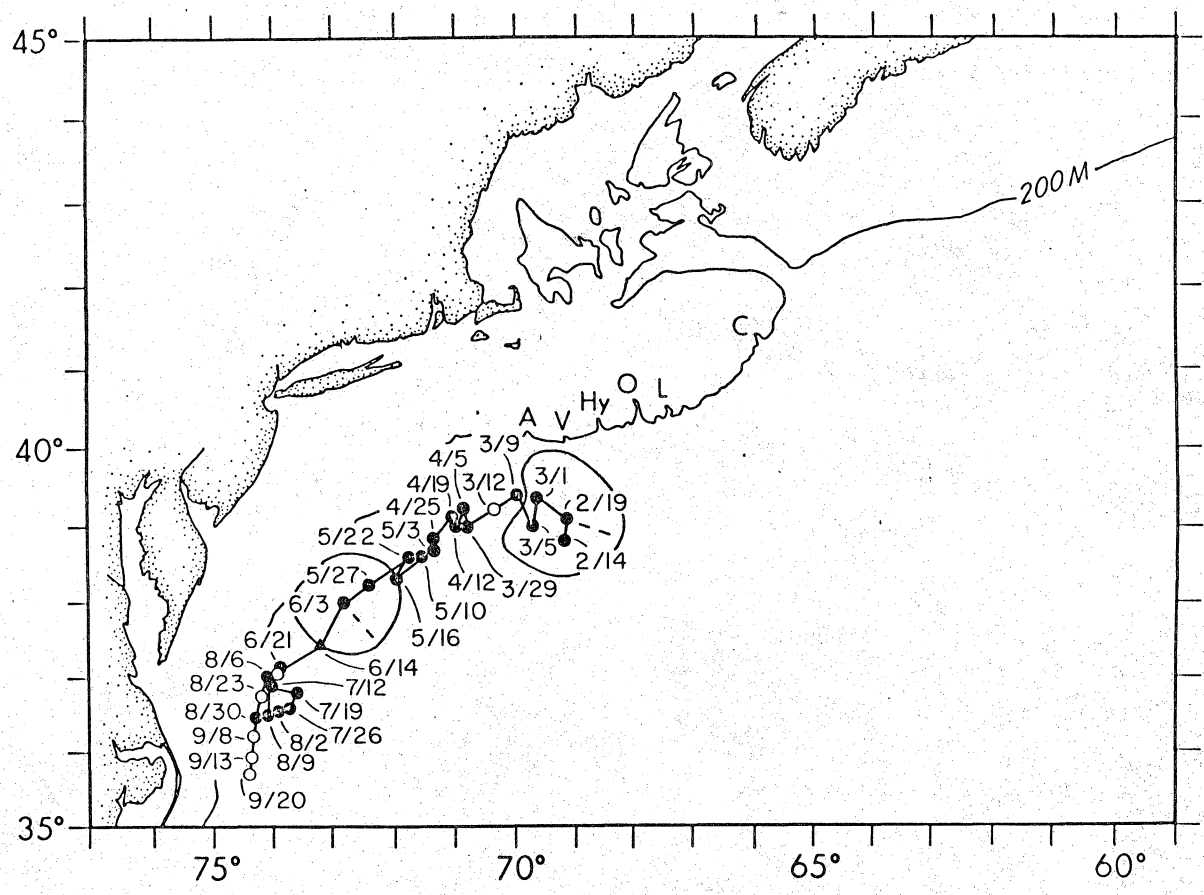

Figure 5. Trackline for Ring 82-B

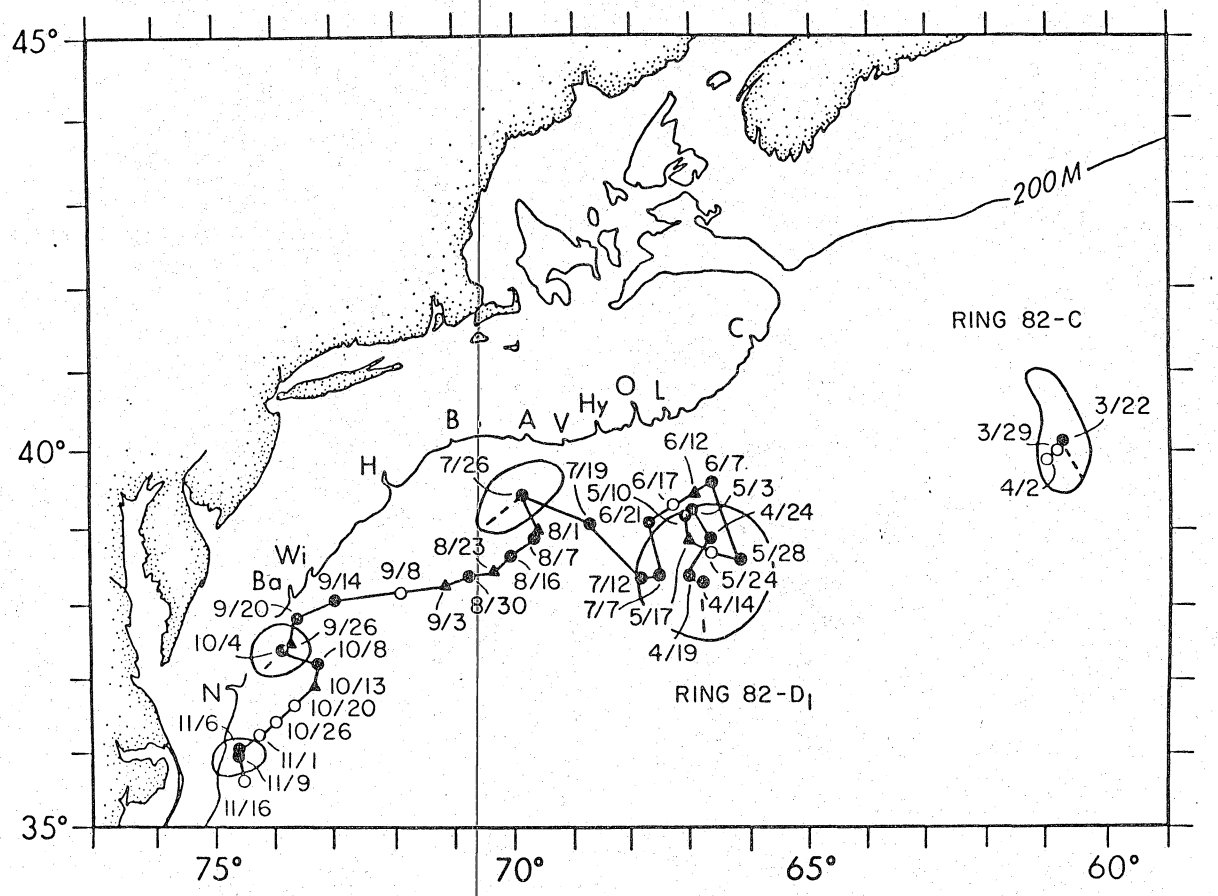

Figure 6. Trackline for Ring 82-C and Ring 82-D

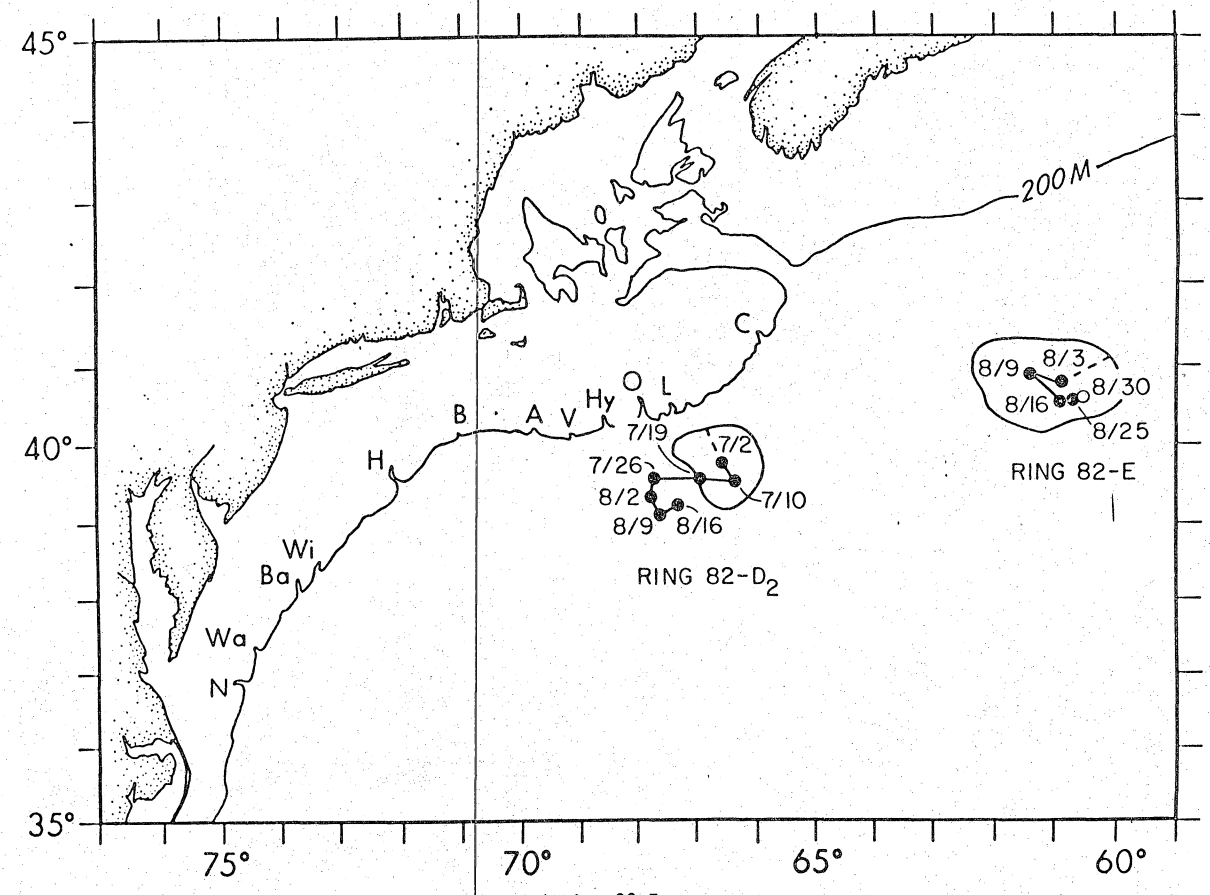

Figure 7. Trackline for Ring 82-D_2 and Ring 82-E

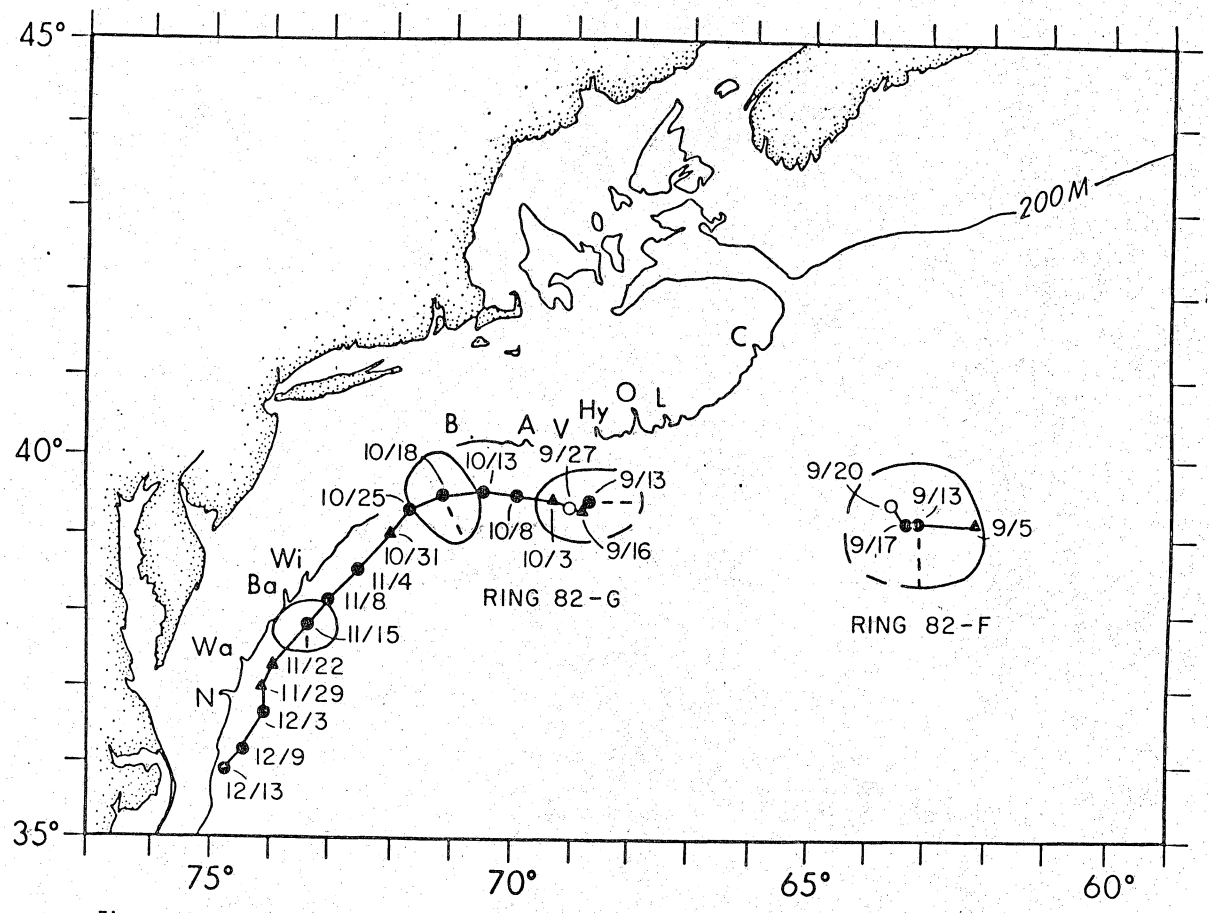

Figure 8. Trackline for Ring 82-F and Ring 82-G

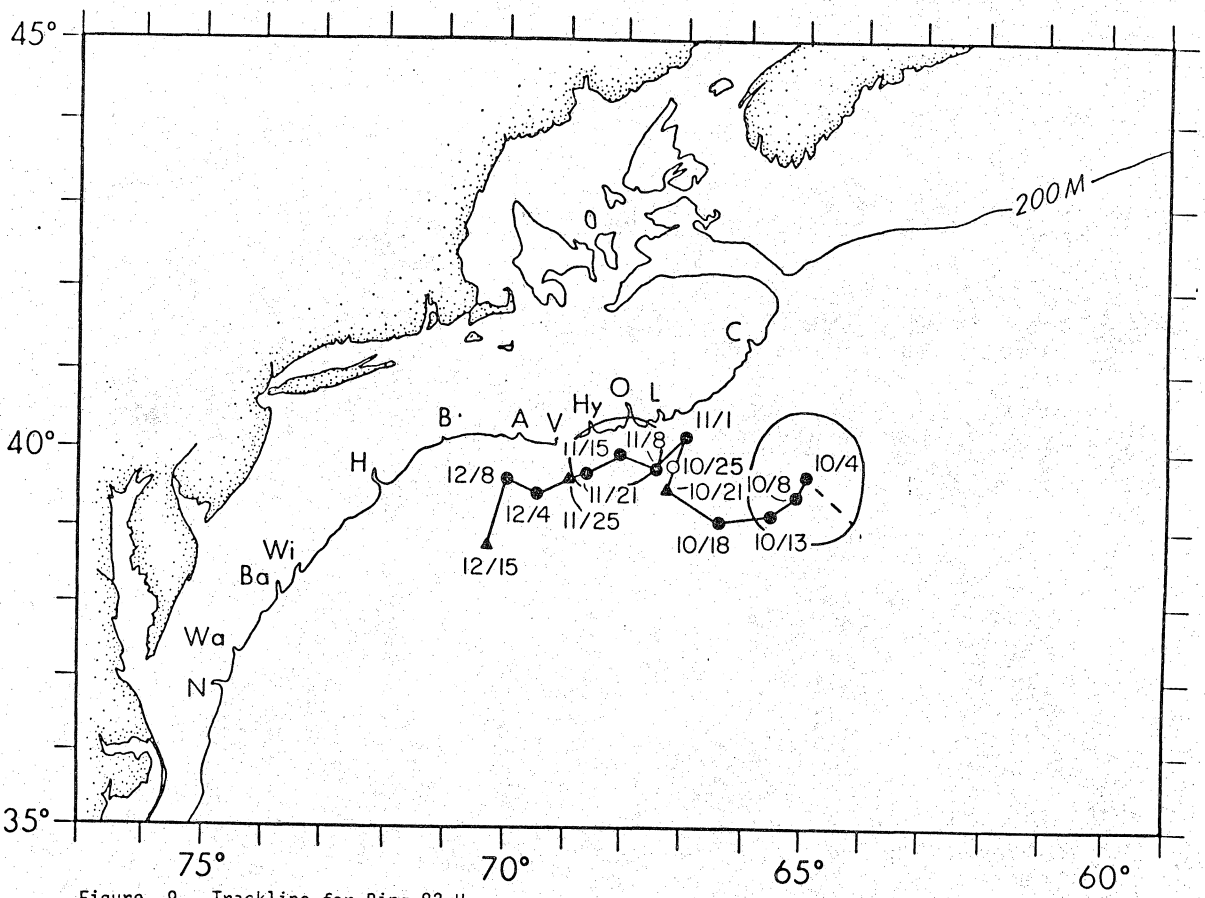

Figure 9. Trackline for Ring 82-H

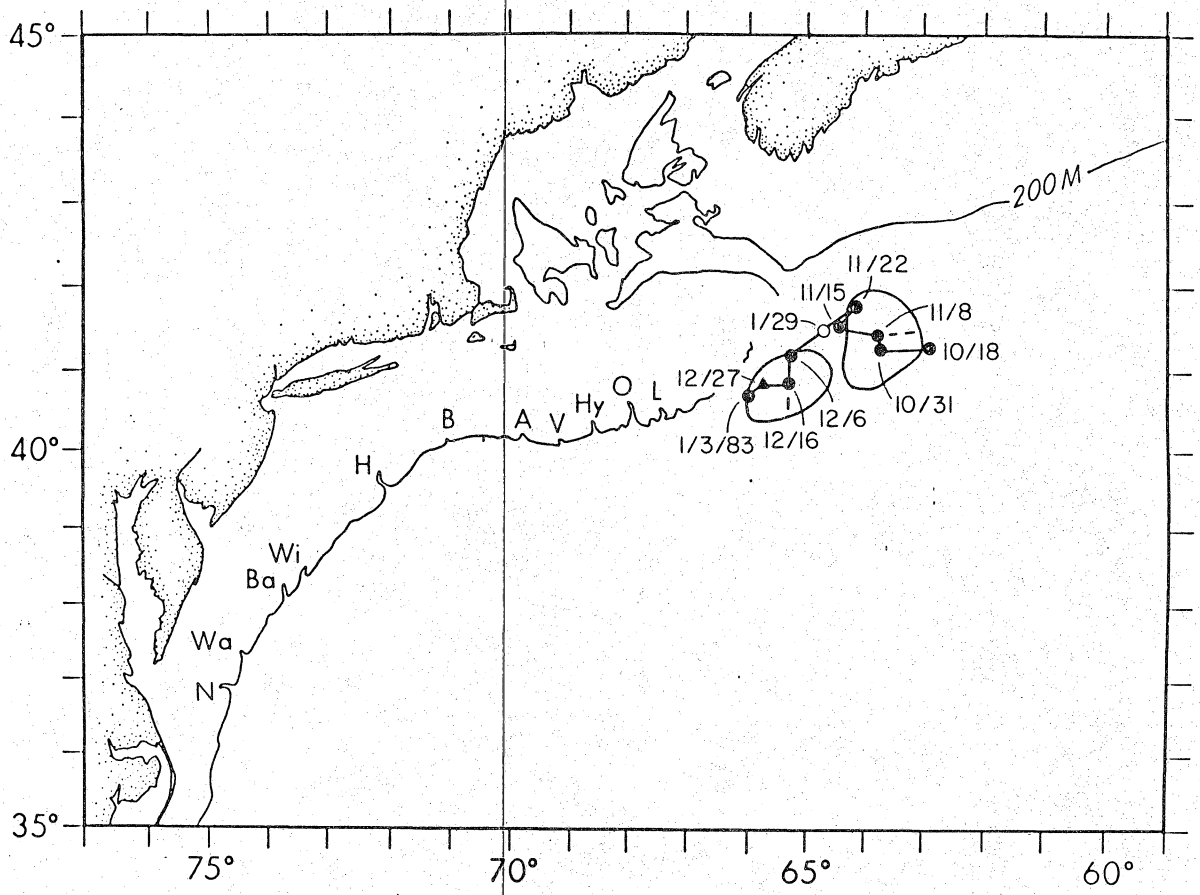

Figure 10. Trackline for Ring 82-I

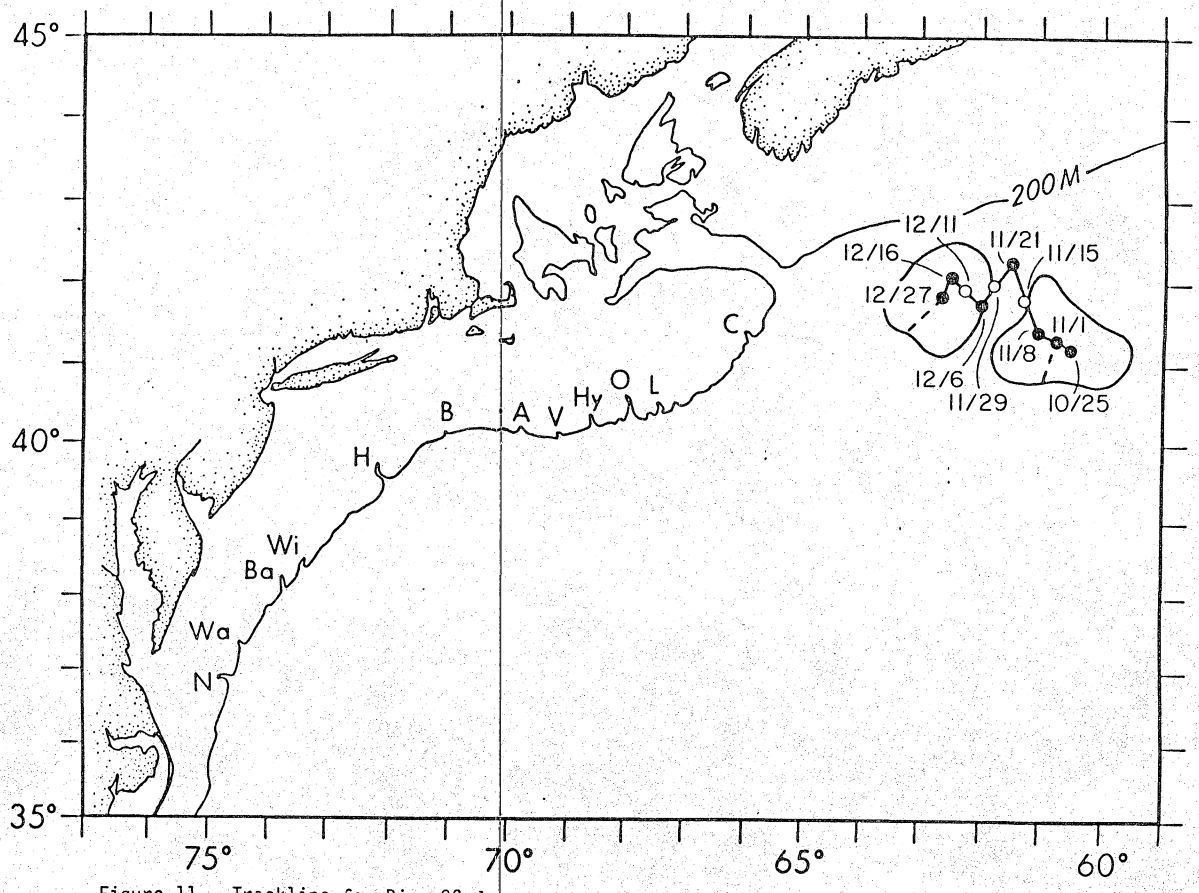

Figure 11. Trackline for Ring 82-J

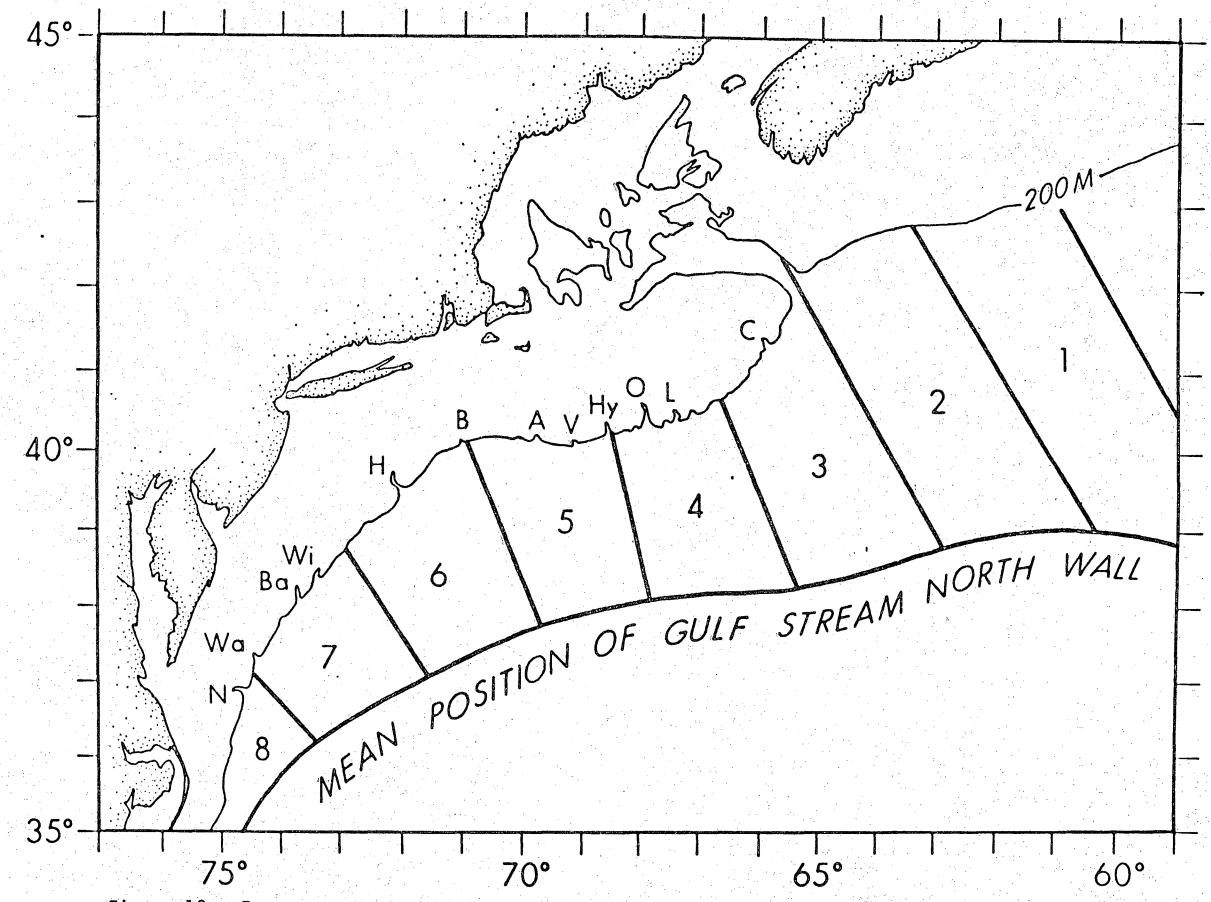

Figure 12. Zones used for Table 2

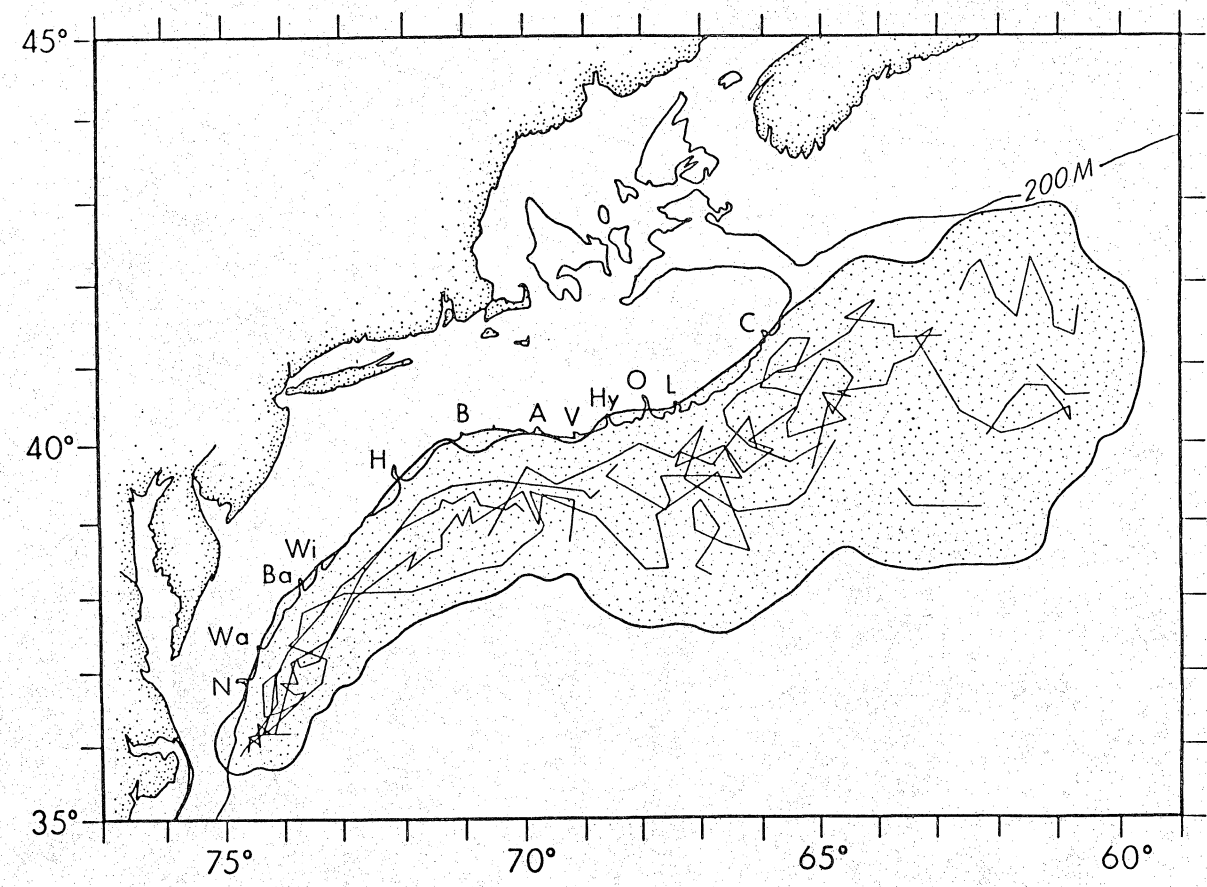

Figure 13. Composite of ring tracklines and envelope of ring surface boundaries