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Anticyclonic Warm Core Gulf Stream Rings off the Northeastern United States during 1983

by

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This report summarizes for the tenth year, 1983, 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 nine years, by Bisagni (1976) for 1974-75, Mizenko and Chamberlin (1979) for 1976 and 1977, Celone and Chamberlin (1980) for 1978, Fitzgerald and Chamberlin (1981, 1983, 1984) for 1979-81, and Celone and Price (MS 1983) for 1982.

Information Sources and Analysis Methods

This analysis is based primarily on data collected by the Advanced Very High Resolution Radiometer (AVHRR), a sensor onboard the National Oceanic and Atmospheric Administration (NOAA) series of polar-orbiting satellites, primarily NOAA-7 and NOAA-8. Six satellite passes covering the study area are potentially available each day, depending on the degree of cloud cover present. Using the processing facilities of the Oceanographic Remote Sensing Laboratory, University of Rhode Island, the high resolution (∿ 1km) digital data, is atmospherically and geometrically corrected and enhanced to clearly identify thermal features. Data from the geostationary satellites (GOES) are used in conjunction with the AVHRR data to help differentiate between clouds, fog and sea surface thermal features. Oceanographic Analysis charts, prepared jointly by the NOAA National Weather Service and National Environmental Satellite Data & Information Service (NESDIS), issued three times a week, are also utilized to help interpret the relative positions of thermal features. Opportunistic shipboard data received from scientists and fishermen are also integrated when available.

A base map showing submarine canyon locations and the zones utilized in the zonal analysis is provided for reference (Fig.1). Ring center positions are plotted on the respective trackline charts (Figs. 2 -7, 9 and 11 - 15). Formation and destruction locations plus bi-monthly positions are dated. 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 uncertainity in distinguishing between the rings when they reappear. In such cases, the simplest interpretation of movements has been accepted.

Surface boundaries of rings are shown for the estimated date of formation and at representative stages in the life of the ring. The location of these boundaries involves errors of unknown magnitude, though every effort has been made to utilize various enhancement techniques to reduce these errors.

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

Ring Histories

A total of twelve warm core Gulf Stream rings occurred in the slope water region between Cape Hatteras, North Carolina and 60°W longitude during 1983. Two rings, 82-I and 82-J, were formed in late 1982 and survived into 1983. Ring 83-A actually formed in mid-December 1982, but was first labelled after crossing west of 60°W in early January 1983. Nine other rings formed during 1983, two of which (83-F and 83-J) persisted into 1984. Estimated formation and destruction dates as well as lifespans for each ring are listed in Table 1.

Ring 82-I (Fig.2) formed from a westward propagating Gulf Stream meander on 18 October 1982, centered at 41.4°N, 62.9°W. This ring travelled westward until it approached the eastern edge of Georges Bank, where it then progressed in a southwesterly direction (Celone and Price, MS 1983). This long-lived ring continued moving along the edge of the continental shelf entraining water around its periphery until early June, when it interacted with the Gulf Stream near Cape Hatteras. Rings 82-I was resorbed by the Stream on 23 June near 36.8°N, 74.0°W.

Ring 82-J (Fig. 3) formed near 41.3°N, 60.6°W on 25 October 1982 from the same meander that lead to the formation of ring 82-I. This ring moved northward after interacting briefly with the Gulf Stream in early November (Celone and Price, MS 1983). It progressed westward during December and was positioned north of 2 rings (83-A and 83-B) throughout January. Ring 82-J slowly moved westward, approaching the eastern edge of Georges Bank in late April. Its track became somewhat erratic in late June, due to the influence of the Gulf Stream to its south. Ring 82-J continued southwestward along the continental shelf break after an extended interaction with a northward propagating Gulf Stream meander in mid-July. It was eventually resorbed by the Gulf Stream around 1 November near 36.3°N, 74.4°W.

Ring 83-A (Fig. 4) formed from a meander centered at 41.0°N, 59.0°W on 15 December 1982. This short-lived ring moved to the west-northwest crossing 60°W on 11 January 1983. Its movements were restricted throughout its lifetime by ring 82-J to the northwest and ring 83-B to the west. Persistent cloud cover precluded tracking the movement of ring 83-A until late February, when it was observed interacting with the Gulf Stream and was eventually resorbed by the Stream about 2 March near 40.5°N, 63.0°W.

Ring 83-B (Fig.5) detached from a large meander on 10 January, centered at 40.5°N, 63.1°W. During mid-February, the surface area of this ring increased in size due to apparent contact with the Gulf Stream. This ring progressed westward until mid-March, when it was reduced in surface area after interacting with a Gulf Stream meander. It continued moving in a westerly direction until early May when it was absorbed by a new ring, 83-E, on 8 May near 39.7°N, 68.1°W.

Ring 83-C (Fig.6) was first observed in the imagery on 16 March, and was estimated to have formed about 12 March near 40.8°N, 62.5°W. This ring began moving to the northwestward in late March. Its course was diverted by a large Gulf Stream meander in mid-April, which eroded the ring, causing it to move northeastward. This short-lived ring was subsequently absorbed near 41.5°N, 62.0°W about 2 May by a large new ring, 83-D, which formed to its south.

Ring 83-D (Fig. 7) detached from a Gulf Stream meander on 22 April, centered at 40.1°N, 60.4°W. This large ring (having a surface diameter of 324 km (175 nm) at its widest point) moved northwestward, absorbing ring 83-C in early May. During the latter part of May and most of June, this ring interacted with the Gulf Stream and was reduced in surface area. Ring 83-D moved westward in early July, but by mid-month had stopped its progression, due in part to possible interference from the New England seamounts and also because of a large Gulf Stream meander to its southwest. This ring remained relatively stationery near Corsair Canyon until late August when it was able to make its way past the seamounts after propagation of the meander to the east. After clearing the seamounts, ring 83-D travelled southwestward along the continental shelf break until becoming resorbed by the Stream in the vicinity of Cape Hatteras near 36.3°N, 74.4°W. Its destruction date is estimated to be about 7 December.

An XBT section from the MV Oleander on 19-20 October verifies the presence of ring 83-D, pressed against the continental slope south of Hudson Canyon in late October (Fig. 8). Notice that the 15°C isotherm extends to greater than 200 m depth and the 10°C isotherm extends to a depth of 370 m, illustrating the structure of this ring. Relatively high surface salinity in the area of the thermal gradient also indicates the presence of ring 83-D in the area.

Ring 83-E (Fig. 9) was estimated to have formed from a westward propagating tongue of the Gulf Stream near 39.2°N, 67.8°W about 23 April. This ring absorbed a smaller ring, 83 B, in early May as it moved westward. Ring 83-E continued its westerly course, interacting with the Gulf Stream through June and early July. Being bounded by the continental shelf, ring 83-E translated southwestward in August, interacted with the Gulf Stream in late August, and was finally resorbed on 20 September near 36.7°N, 74.2°W.

A hydrographic survey of ring 83-E by the RV Tioga in mid-June, when the ring was centered south of Hydrographer Canyon, showed the 15°C isotherm at 198 m and the 10°C isotherm at a depth of 358 m (Fig. 10). These isotherms are expected to be somewhat deeper in a relatively new ring. This vertical section indicates possible erosion of the ring due to interaction with the Gulf Stream and mixing with the surrounding slope water (data supplied by S.M. Glenn and G.Z. Forristall of the Shell Development Company).

Ring 83-F (Fig. 11) formed from the large meander which had eroded ring 83-D in early July. Its date of formation was estimated to have been about 1 July, centered at 40.8°N, 62.1°W. The ring moved northward, maintaining contact with the Gulf Stream throughout July. It then stalled until early September when it began slowly moving westward, stalling again in early October. By late

November, ring 83-F had approached the eastern edge of Georges Bank. It continued southwestward along the continental shelf break into 1984, with its position centered near 39.8°N, 67.5°W on 9 January 1984..

Ring 83-G (Fig. 12), a very short-lived ring, formed from a Gulf Stream meander on 8 August, centered at 40.6°N, 61.0°W. Its movement was restricted by ring 83-F, to its north resulting in an interaction with the Gulf Stream in early September. This ring was subsequently resorbed by the Gulf Stream by 9 September near 40.3°N, 62.0°W.

Ring 83-H (Fig. 13) was also short-lived, forming from the meander which absorbed ring 83-G. Ring 83-H formed on 6 September, centered at 40.0°N, 65.5°W and remained in contact with the Gulf Stream, moving very little until mid-October, when it began traveling to the southwest. Interaction with the Gulf Stream in late October, lead to its destruction about 2 November near 39.4°N, 66.6°W.

Ring 83-I (Fig. 14) formed about 7 September centered near 42.1°N, 59.4°W. from a large Gulf Stream meander. This ring was forced northward throughout September by a large ring which formed to its south. In early October, ring 83-I moved to the west of this new ring, and began traveling southwestward in mid-October. In early November, another ring, 83-J, formed to its south, again forcing ring 83-I northward until it was absorbed by ring 83-J about 5 December near 41.1°N, 61.7°W.

Ring 83-J (Fig. 15) detached from a meander about 1 November, centered near 40.5°N, 61.0°W. This ring remained relatively stationary through November, being restricted by a Gulf Stream meander to the west, a newly formed ring to the east, and ring 83-I to the north. In late November, the ring to the east was absorbed by the Gulf Stream allowing movement to the northeast, which resulted in the absorption of ring 83-I in early December. Ring 83-J, which persisted into 1984, was reduced in surface area following an interaction with the Gulf Stream in late December. Its position was centered at 40.9°N, 61.8°W on 9 January 1984.

A number of warm anticyclonic eddies have been observed in the satellite imagery during 1983. Most seem to form from elongated tongues or "shingles" of the meandering Gulf Stream. Due to their warm water characteristics and anticyclonic circulation, they can be, and sometimes are, mistaken for warm core rings. Warm core rings traditionally form from a meander which grows and eventually closes off at its base, enclosing warm Sargasso water as its core. This is represented by depression of the isotherms to a depth of at least 1000m. The warm eddies that have been observed do not contain the core of Sargasso water but are comprised only of Gulf Stream water. Although their surface circulation may be strong, at least initially, their circulation at depth is unknown. The observed anticyclonic features have lifespans ranging from a week to several months, depending on their proximity to the Stream.

Zonal Analysis

A generalized summary of the movements of rings during 1983 is presented in Table 2, which shows their mid-month positions with respect to the zones diagrammed in Figure 1. Total zone-month occurrence is 51. Only once in the previous nine years, during 1982, have as many zone-month occurrences been recorded. During the years 1974-1981, the total zone-month occurences were 24, 35, 29, 45, 32, 43, 50 and 29 respectively. Two rings, 82-I and 82-J, carried over from 1982 and accounted for 31% of this ring-month total. Two rings occupied the same zone at mid-month eight times during 1983.

Composite Tracklines of Ring Center Positions and Envelope of Surface Boundaries

A composite of tracklines of all ring center positions, and an envelope of ring surface boundaries appear in Figure 16. The envelope was developed from boundary positions digitized from satellite data and from the weekly analysis charts. Ten of the twelve rings occurring in 1983 formed very near or east of 63°W; two of which formed east of 60°W. Four of the ten rings never moved west of the 63°W meridian.

Number of Rings, Times of Formation, and Longevity

Eight warm core Gulf Stream rings formed during 1983 between Cape Hatteras, North Carolina and 60°W longitude. During 1974-1982, ring formation averaged eight per year, ranging from a minimum of four in 1974 to a maximum of eleven in 1975 and 1982. Three rings that formed in 1982 survived into 1983; two of which (82-I and 82-J) were long-lived (249 and 373 days). Of the nine rings that formed in 1983, four had formed by mid-April, one formed during July, one formed in August, two formed during September, and one formed during early November. Longevity of the rings formed in 1983 ranged from 33 to 229 days.

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

Ring	Dates [1]	Life Span (days)
82-I	10/18/82 - 6/23/83	249
82-J	10/25/82 - (11/1/83)	373
83-A	12/15/82[2] - (3/2/83)	75
83-B	1/10/83 - 5/8/83	119
83-C	(3/12/82) - (5/2/83)	52
83-D	4/22/83 - (12/7/83)	229
83-E	(4/23/83) - 9/20/83	151
83-F	(7/1/83) - into 1984	> 179
83-G	8/8/83 - (9/9/83)	33
83-H	9/6/83 - (11/2/83)	58
83-I	(9/7/83)[3] - (12/5/83)	90
83-J	(11/1/83)[4] - into 1984	> 61

1 Dates not in parentheses are accurate to within two days. Dates in parentheses could be off by greater than 1 week.

2 This ring was not labelled until it completely crossed west of 60°W on 1/11/83.

3 This ring was not labelled until it completely crossed west of 60°W about 9/30/83.

4 This ring was not labelled until it completely crossed west of 60°W about 12/12/83.

Table 2. Ring positions at mid-month with respect to zone during 1983.
(Zone boundaries shown in Figure 1.)

Zone	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1	82-J 83-A			83-C 83-D				83-F 83-G		83-I	83-I 83-J	83-J
2	83-B	82-J 83-A	82-J 83-C		83-D	83-D	83-F		83-F	83-F		
3	82-I	83-B		82-J	82-J		83-D		83-H	83-H	83-F	83-F
4		82-I	83-B	83-B 83-E		82-J		83-D				
5					83-E	83-E	82-J		83-D			
6			82-I	82-I			83-E	82-J				
7					82-I			83-E	82-J	82-J 83-D		
8						82-I			83-E		83-D	

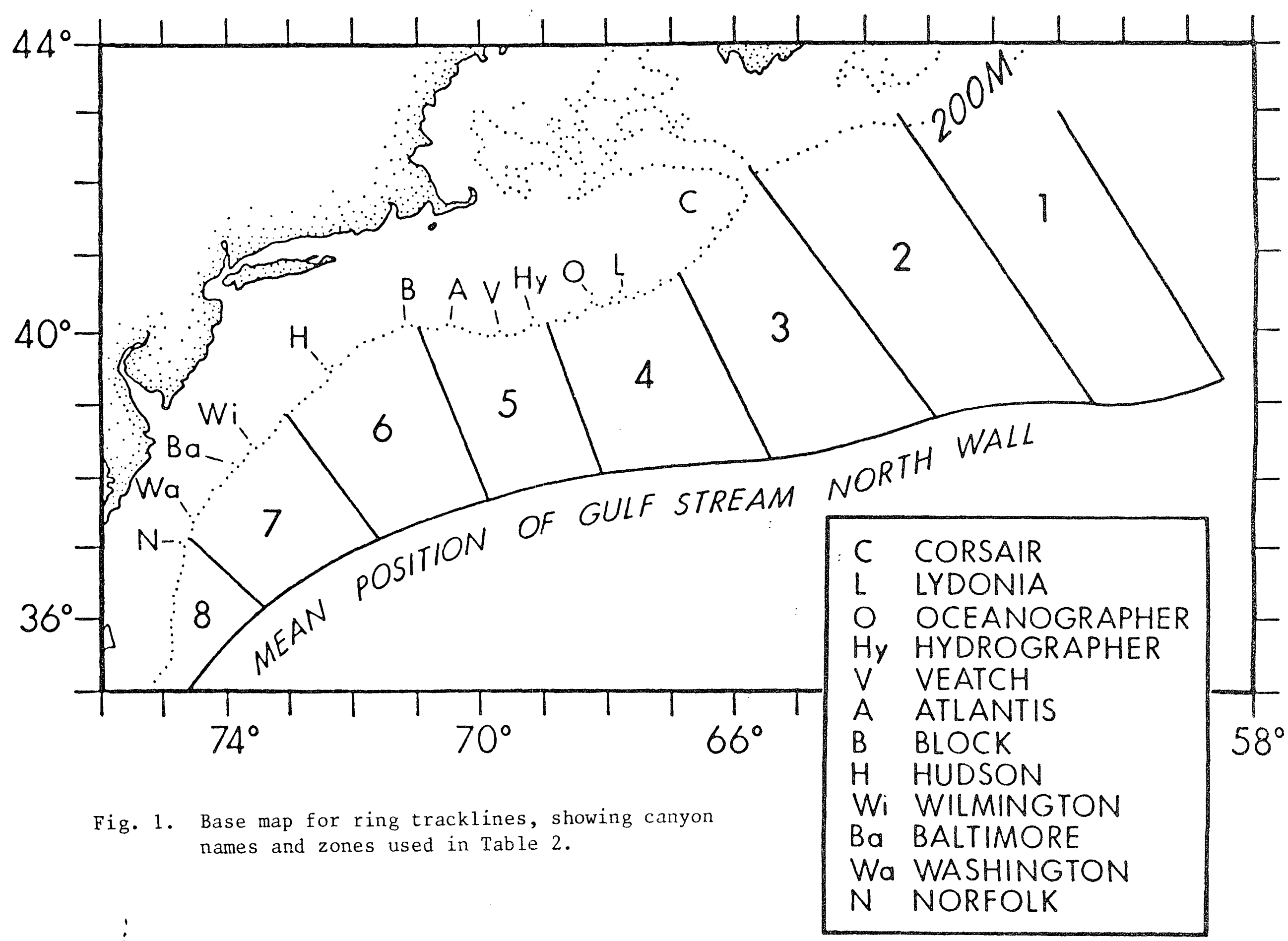

Fig. 1. Base map for ring tracklines, showing canyon names and zones used in Table 2.

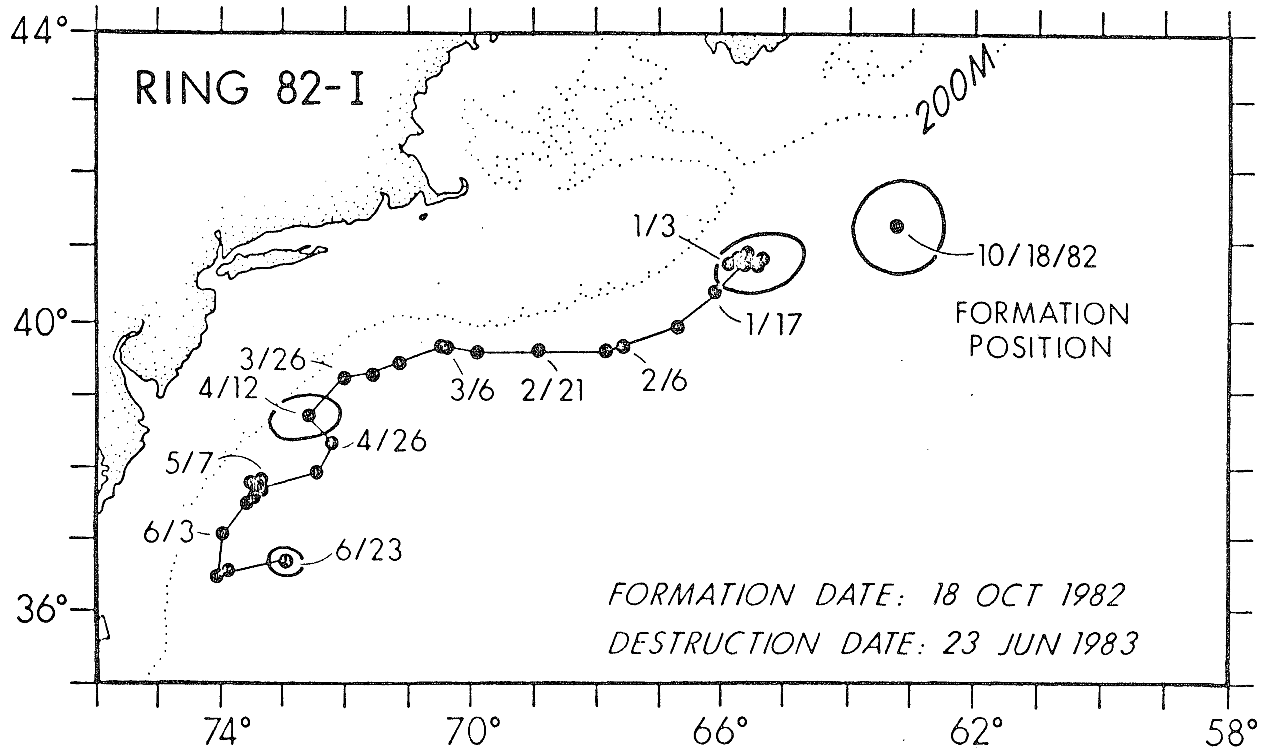

Figure 2. Trackline for ring 82-I.

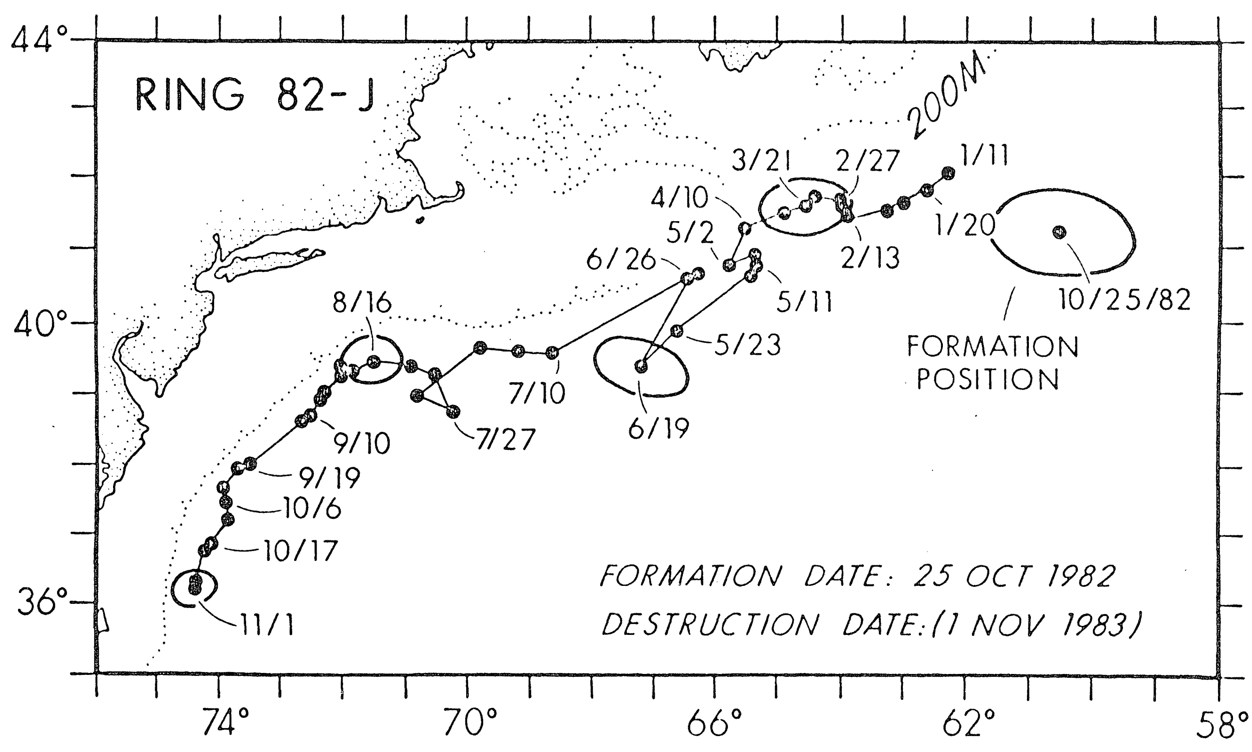

Figure 3. Trackline for ring 82-J.

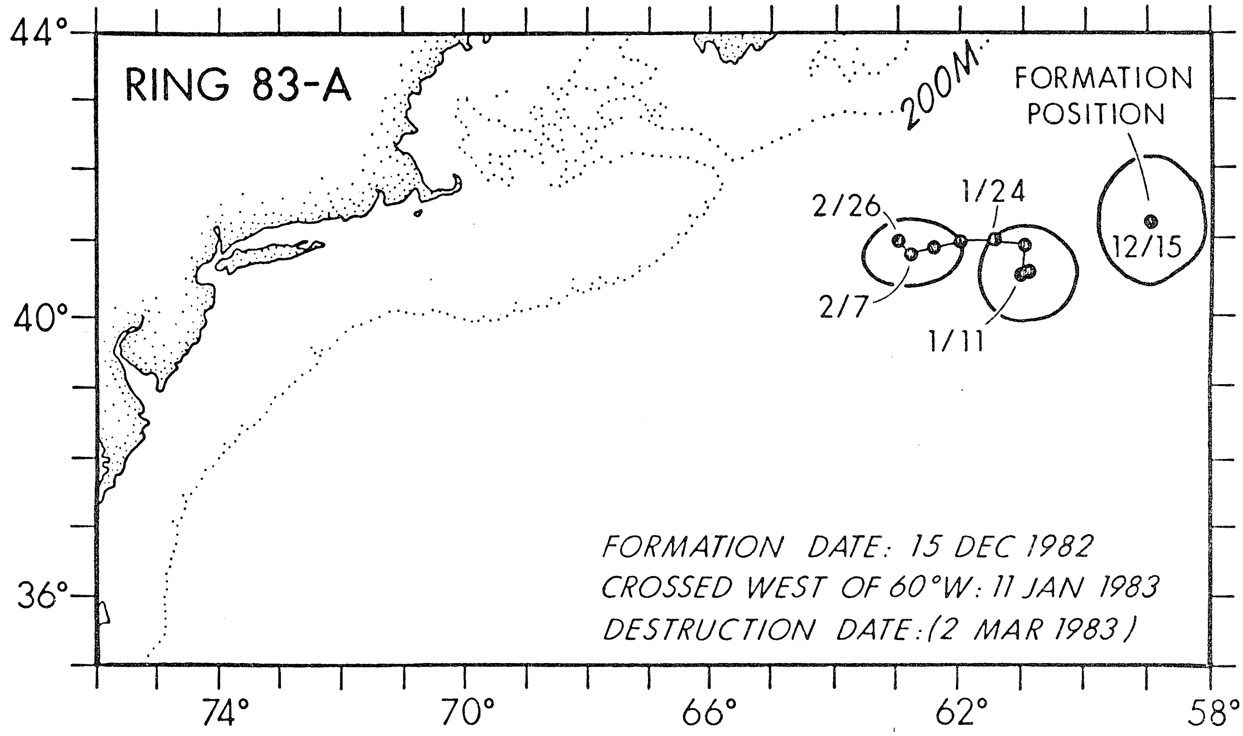

Figure 4. Trackline for ring 83-A.

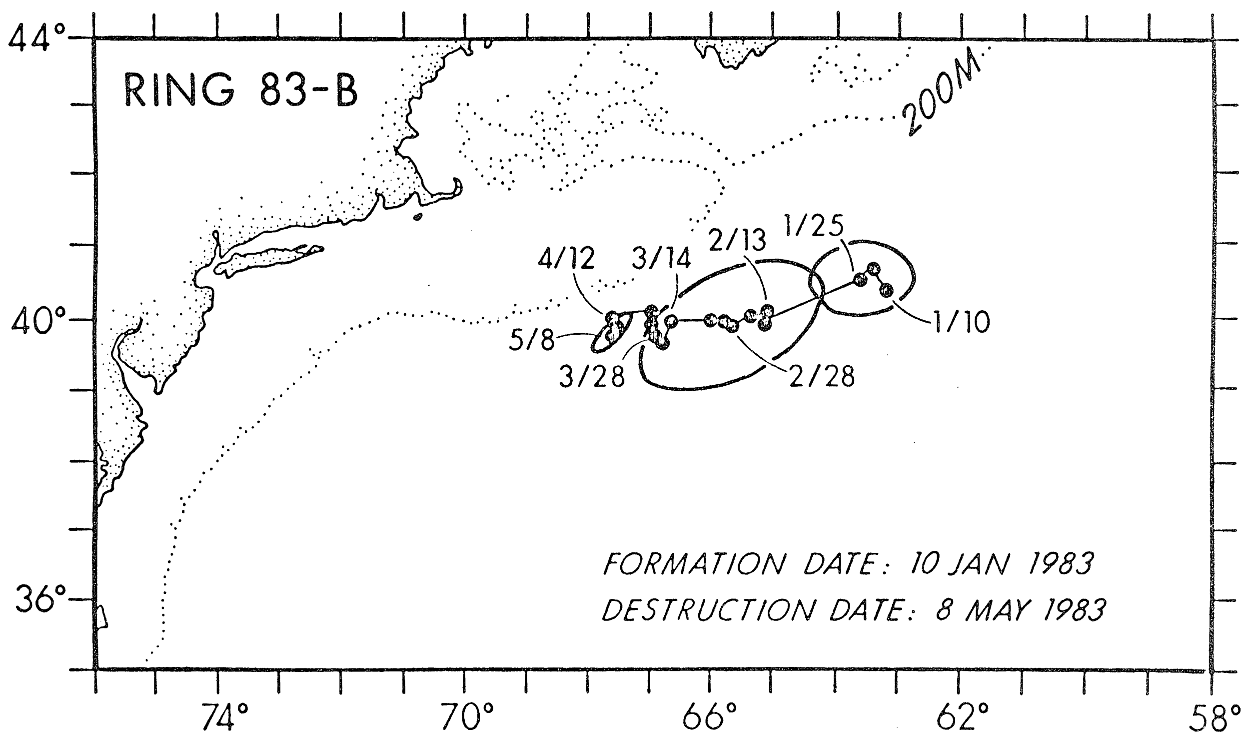

Figure 5. Trackline for ring 83-B.

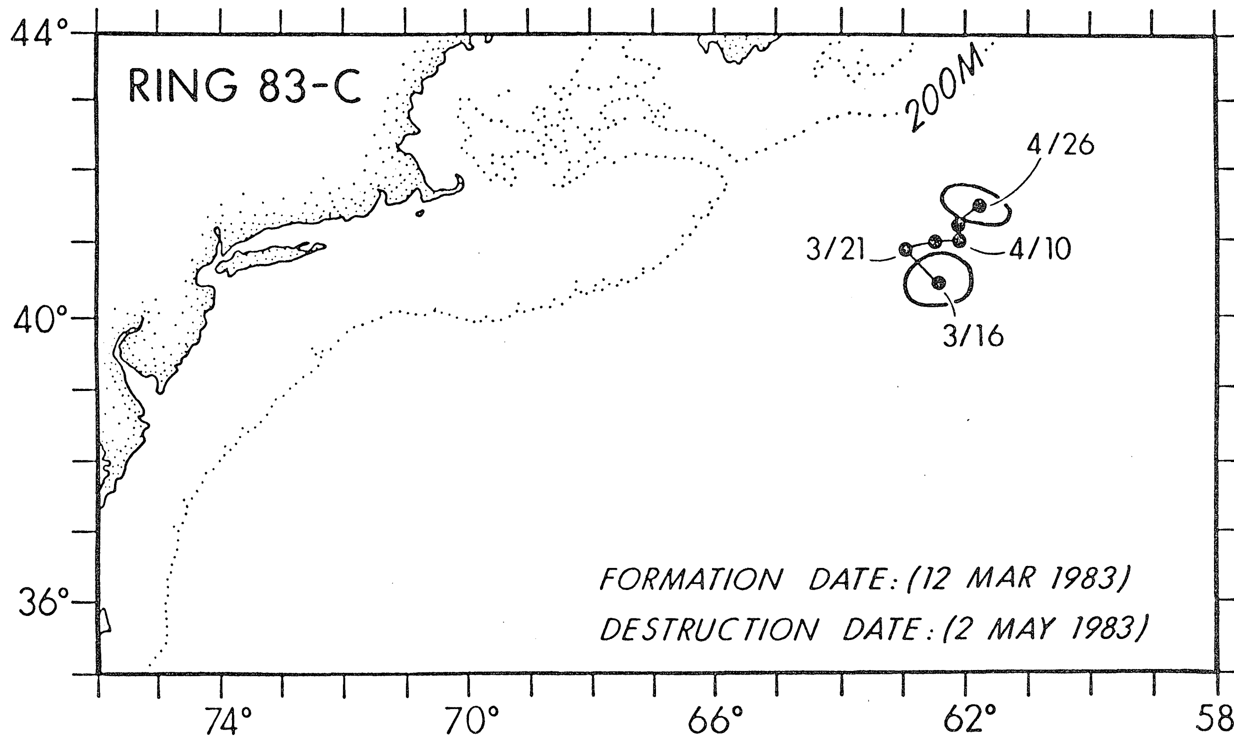

Figure 6. Trackline for ring 83-C.

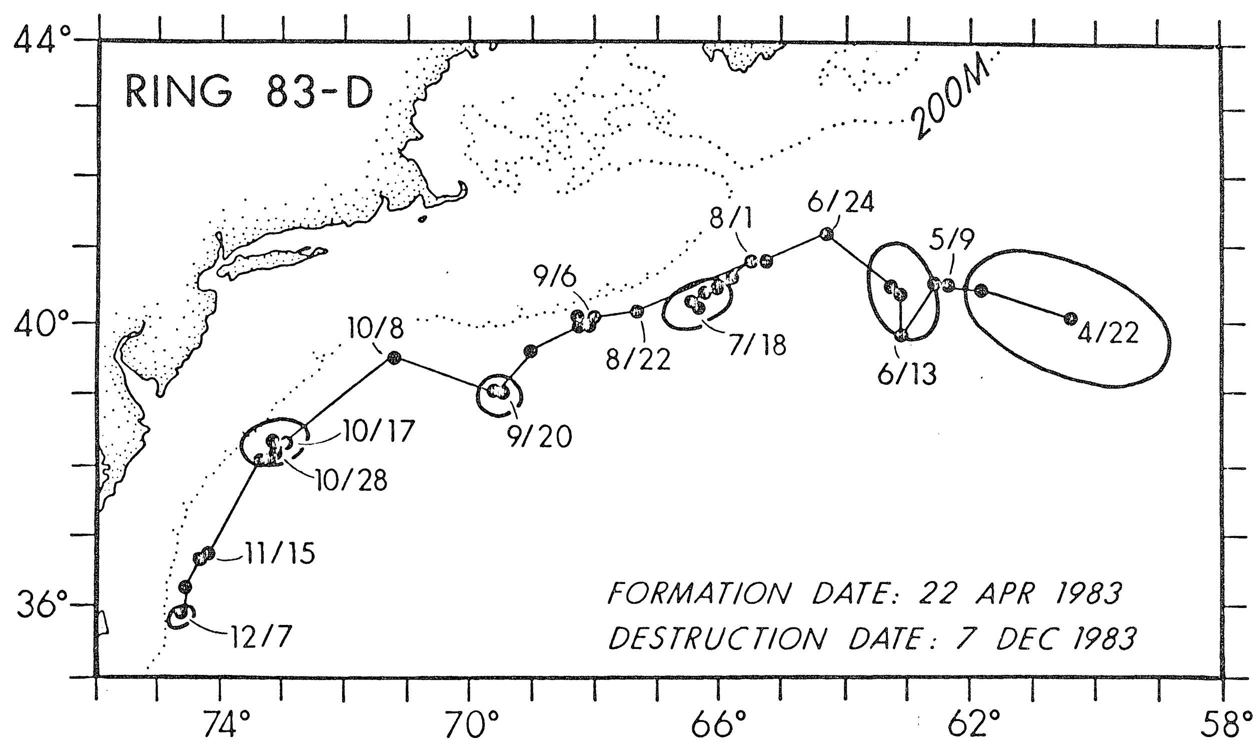

Figure 7. Trackline for ring 83-D.

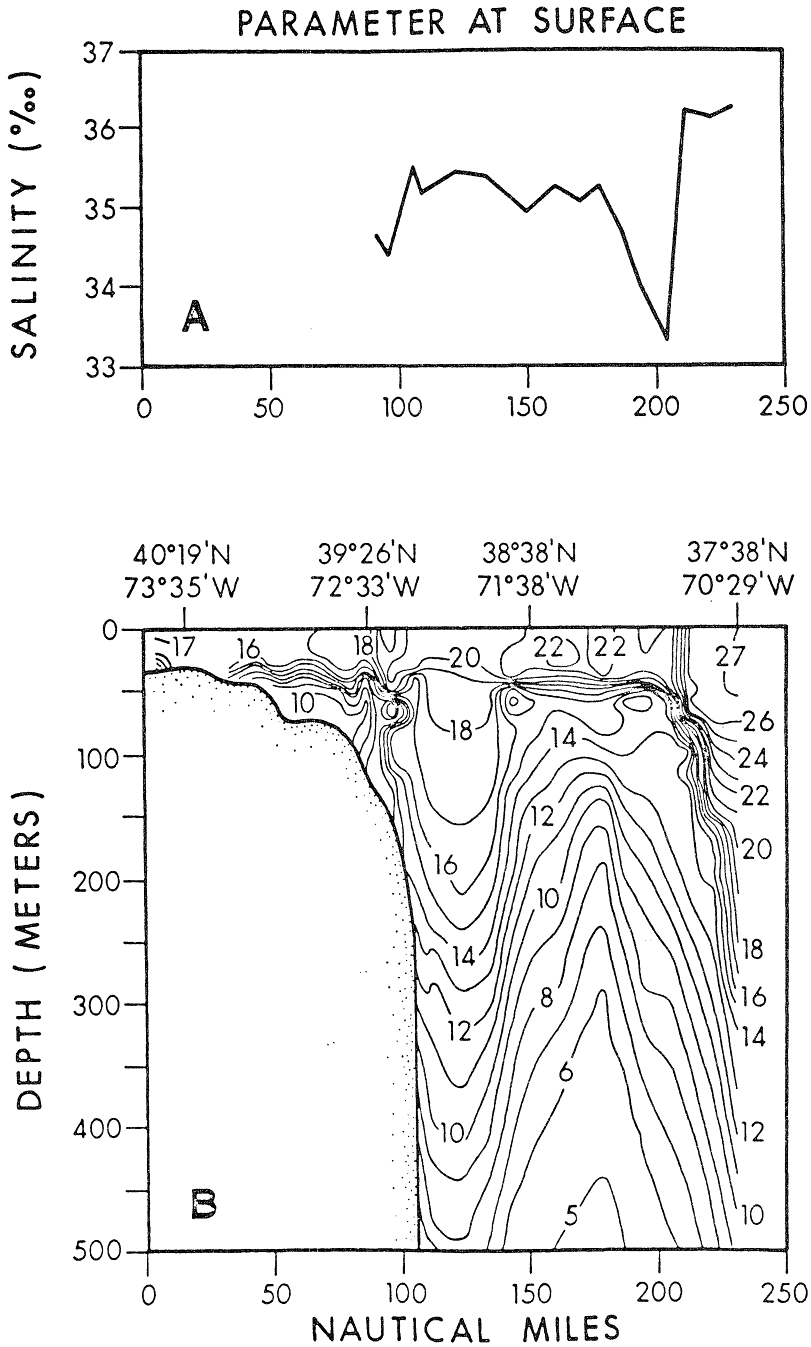

Figure 8. Hydrographic measurements obtained south of Hudson Canyon, in the vicinity of ring 83-D, by the M/V Oleander on 19-20 October 1983. (A.) Sea surface salinities, and B) XBT section showing ring 83-D pressed against the continental slope.

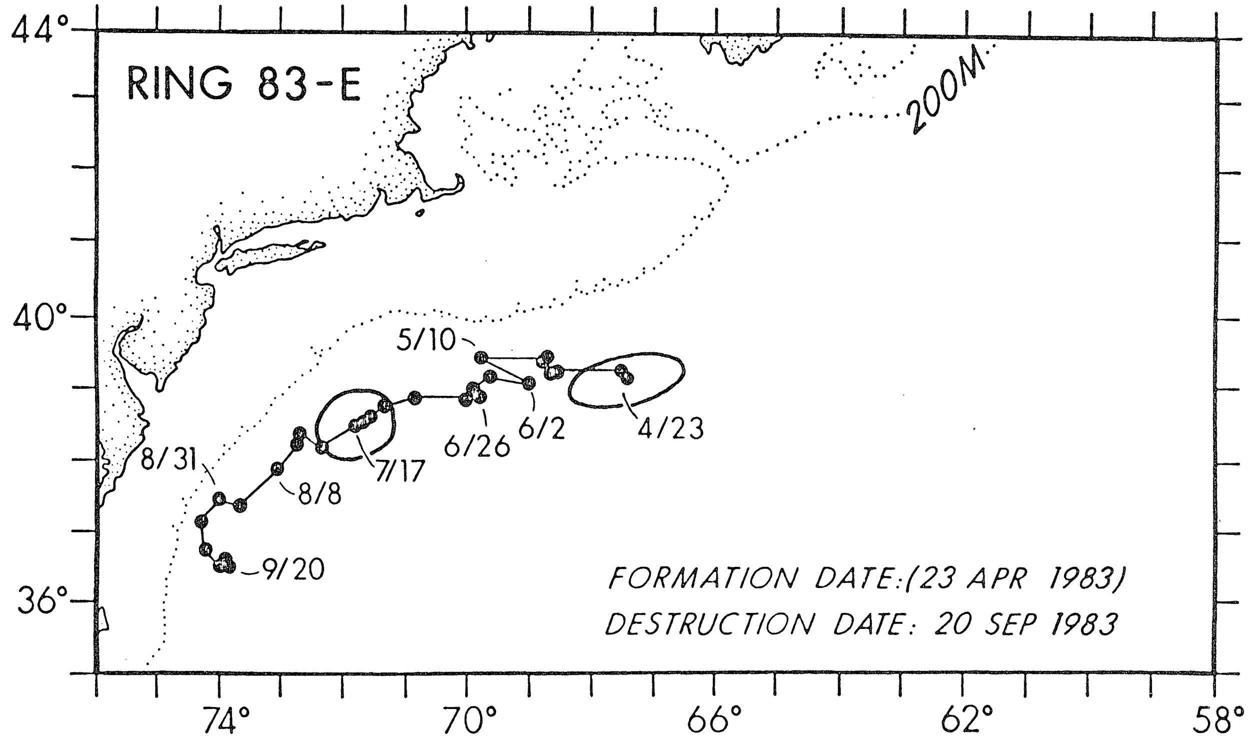

Figure 9. Trackline for ring 83-E.

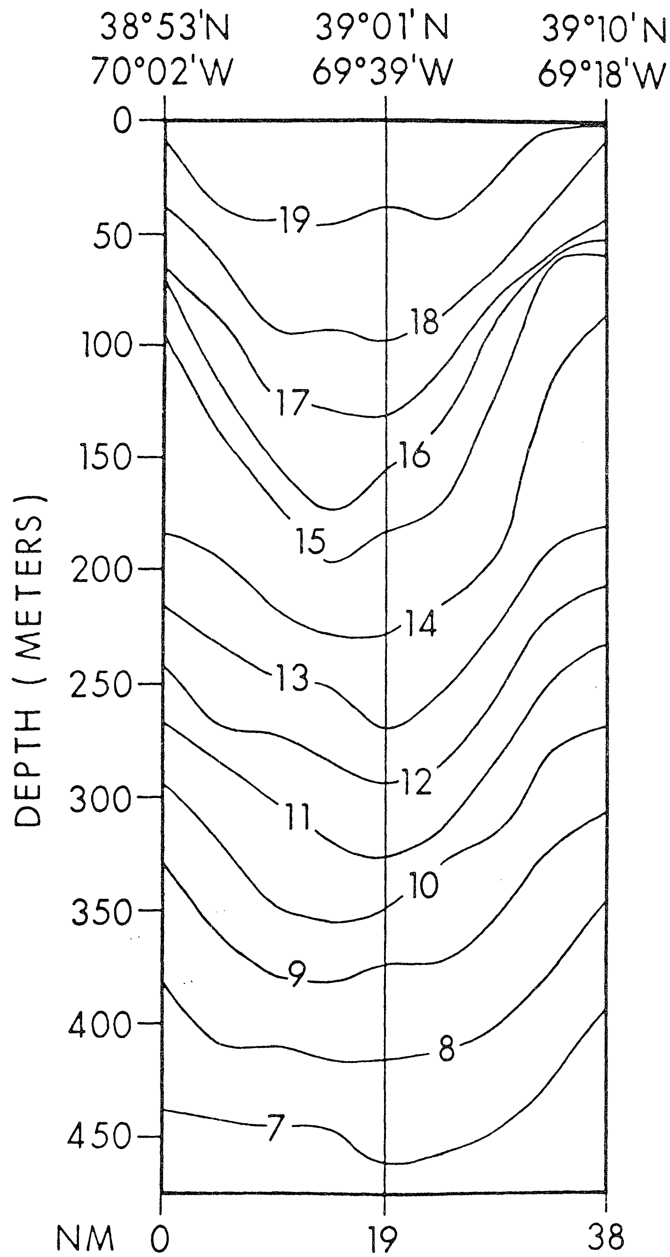

Figure 10. XBT section taken in the vicinity of ring 83-E by the R/V Tioga on 14-15 June 1983 (supplied by S.M. Glenn and G.F. Foristall, Shell Development Company).

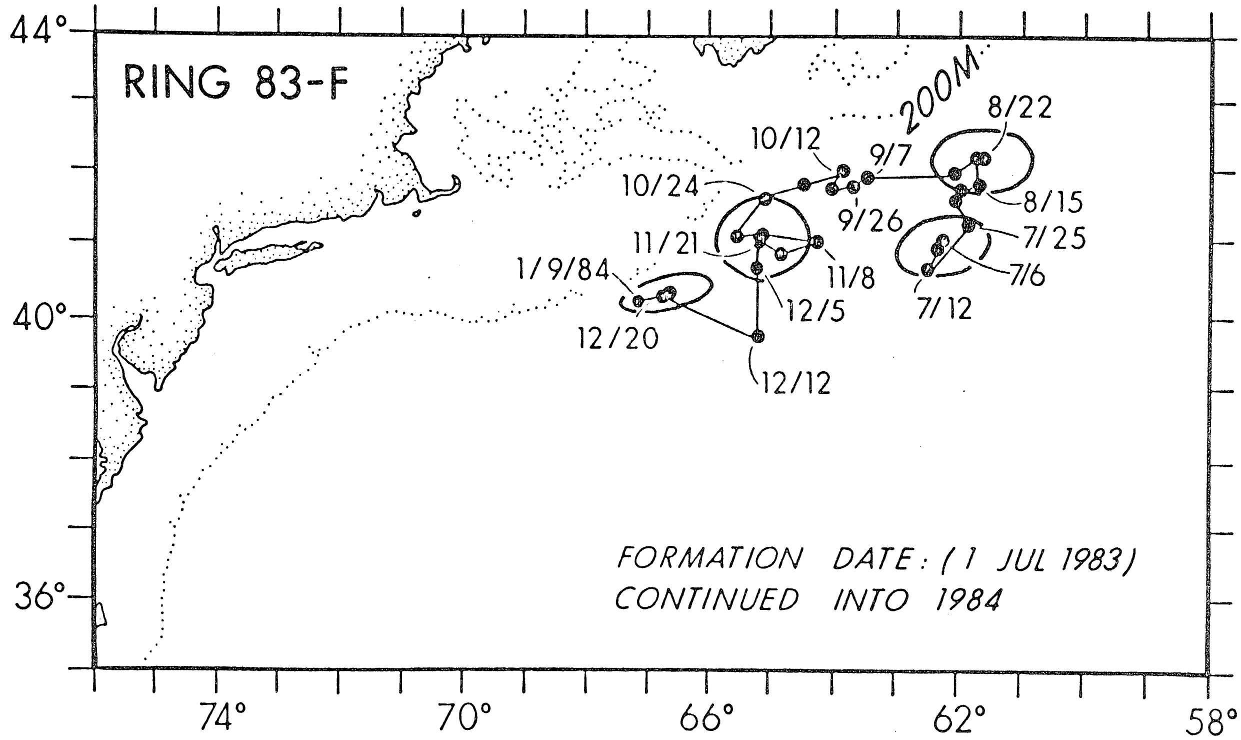

Figure 11. Trackline for ring 83-F.

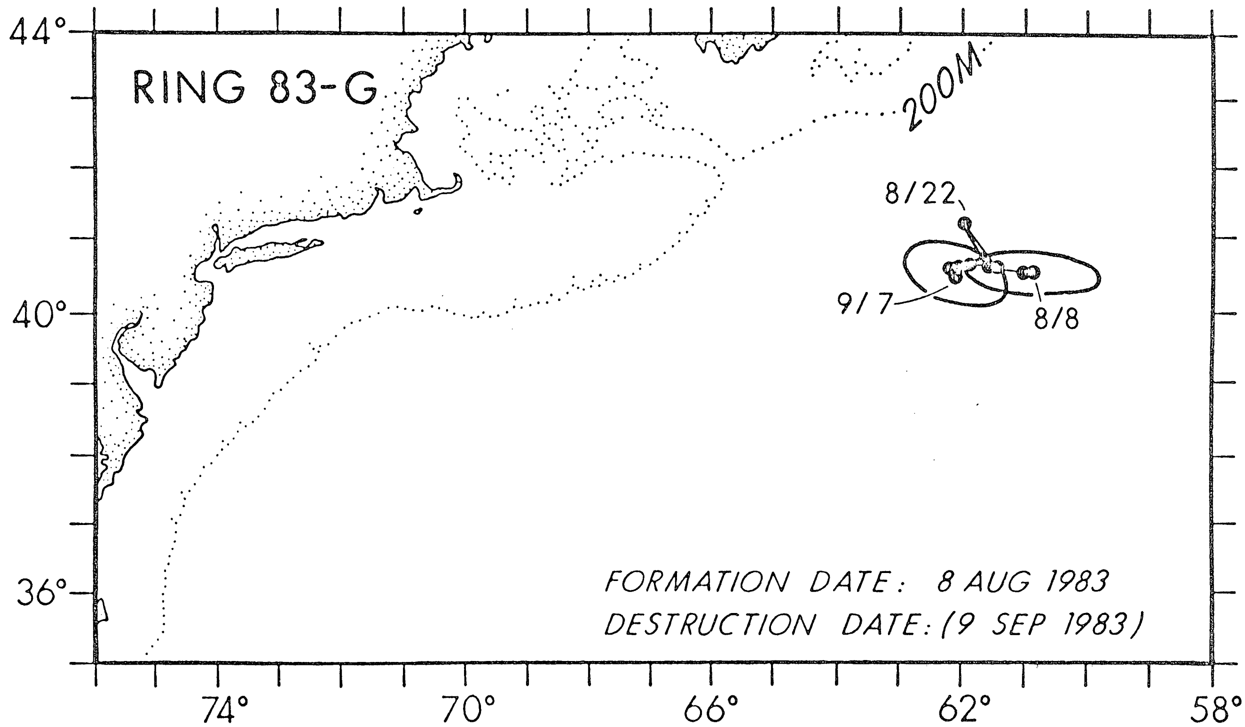

Figure 12. Trackline for ring 83-G.

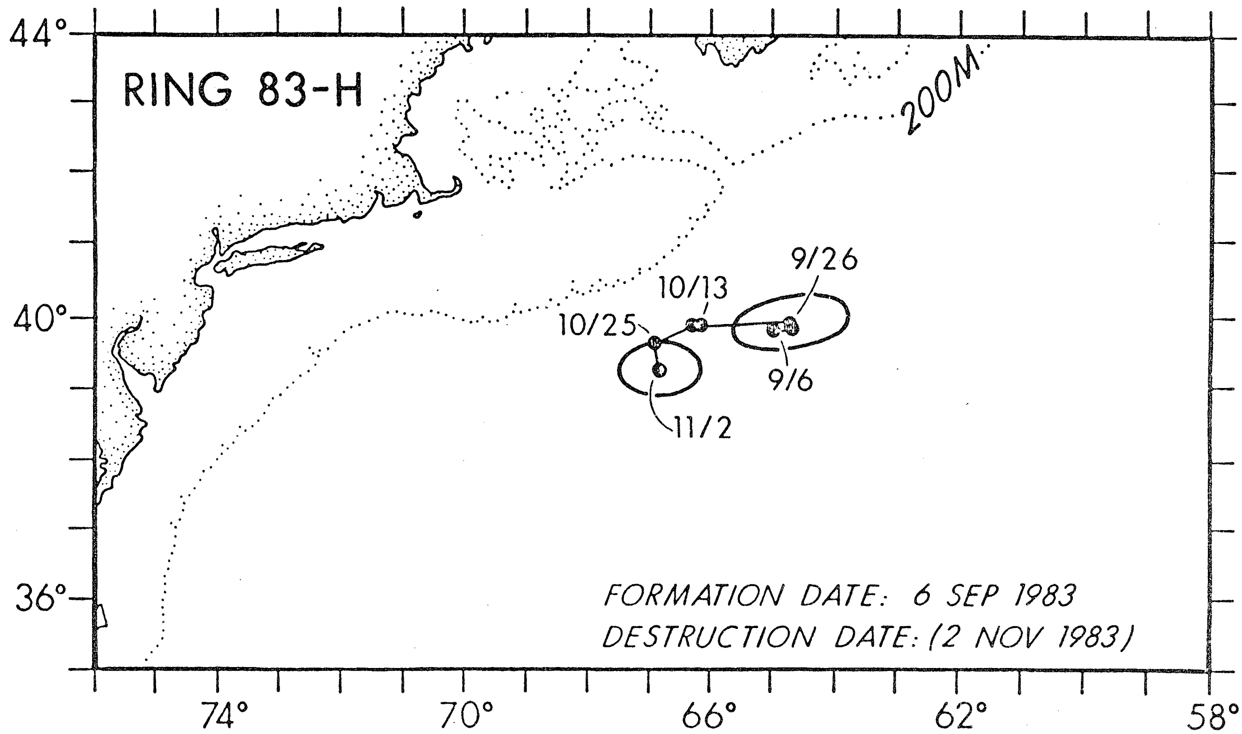

Figure 13. Trackline for ring 83-H.

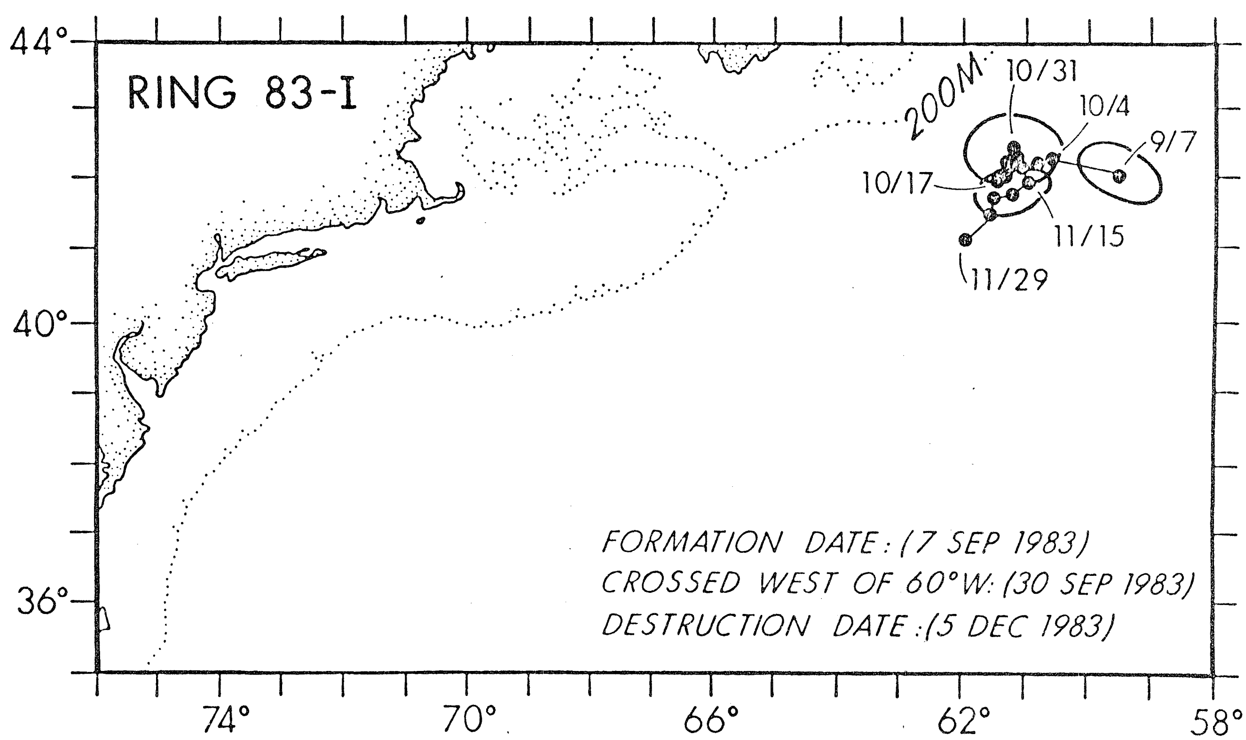

Figure 14. Trackline for ring 83-I.

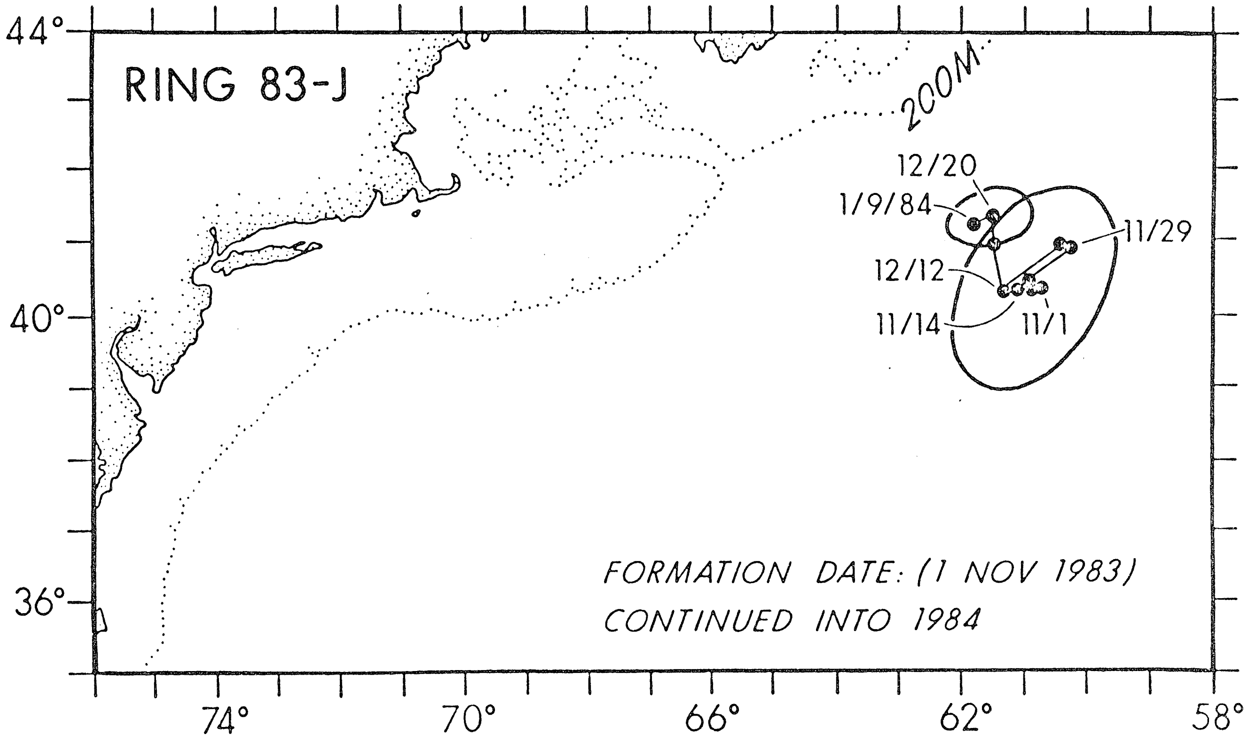

Figure 15. Trackline for ring 83-J.

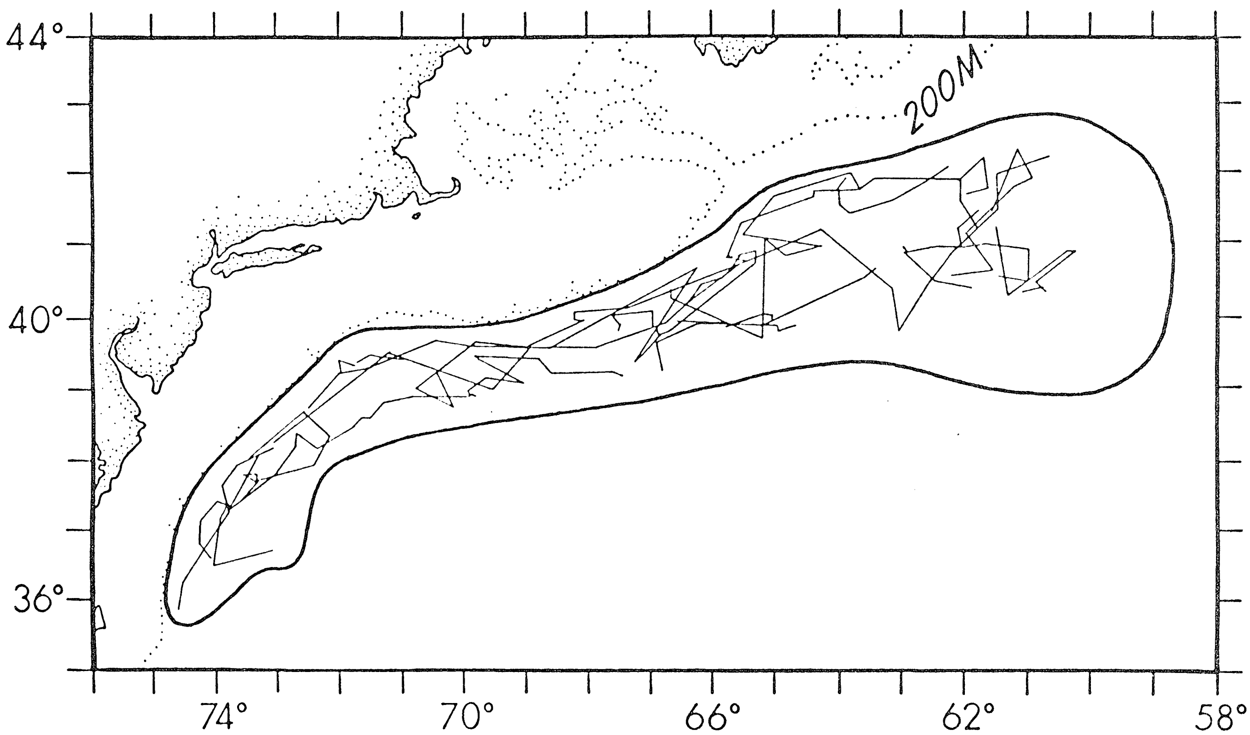

Figure 16. Composite of ring tracklines and envelope of ring surface boundaries.