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05

II

FOURTH QUARTERLY PROGRESS REPORT

LANDSAT FOLLOW-ON INVESTIGATION

NO. 21300

E7.6-10285
CR-146655

A. TITLE OF INVESTIGATION: LANDSAT Survey of Near-Shore Ice Conditions Along the Arctic Coast of Alaska

B. PRINCIPAL INVESTIGATOR: Dr. William J. Stringer et al

C. PROBLEMS IMPEDING INVESTIGATION: None

D. PROGRESS REPORT:

1. Accomplishments This Reporting Period

Using LANDSAT band 7 copy at 1:500,000 scale, preliminary Beaufort Sea near-shore ice maps have been compiled for two very complete cycles of Beaufort Sea LANDSAT data in early and mid-spring 1974. These maps have been reproduced here at half scale for reporting convenience. Particular care, described in our previous report, has been taken to locate the ice features relative to geographic coordinates and the bathymetric 10-fathom contour. The half-scale reproductions of these maps have been reproduced here as Appendix A, with annotation discussing the features delineated.

Last quarter we presented half-scale copies of maps made from late winter 1973, 1974 and 1975 LANDSAT cycles of Beaufort Sea imagery.

It should be stressed that these maps are not final products, but represent an initial stage of interpretation of each year's ice conditions. For instance, even though large ridge systems can be identified, many others are shown here as boundaries between distinctive ice categories. Analysis of later LANDSAT images during the melt season will determine to a greater extent the complete identification of these and other features that were observed under construction on the winter and springtime imagery.

No attempt was made here to delineate "shore-fast" ice. Indeed, at this season only "contiguous" ice (ice that is contiguous with the shore without interruption) can be identified. However, active lead systems in the vicinity of the near-shore areas can be monitored for ridge-building activities.

By making late winter maps reported in the last quarterly report, the relative age of major features can be established. For instance, a very extensive ridge system had been formed north and west of Cross Island (off Prudhoe Bay) well before March 10, 1974. This ridge system was located near the 10-fathom contour. Presumably it was grounded. Analysis of melt season data should give a clue regarding this hypothesis. Another question to be answered by subsequent analysis is "Did this ridge system create a relatively stable ice shelf extending between it and the shore?"

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21300

Analysis of springtime data reported here yields information about the relative stability of contiguous ice and the later identification of which ice was actually "shore-fast". Observations have been made of fracture patterns representing stress failure within ice which would probably be identified as "shore-fast" (and therefore stable) on the basics of examination of later LANDSAT data. Hence, the analysis of springtime ice data is quite important to the development of a morphology of near-shore ice conditions.

Once each ice year has been analyzed, the original transparent 1:500,000 scale maps will be overlaid to determine the persistence of major ice conditions from year to year.

2. Review of Results to Date

During the first quarter, LANDSAT coverage maps were prepared for each LANDSAT cycle so that the most useful previous years' data could be obtained for analysis. In the mean time, primary emphasis was placed on analysis of ice motions in the vicinity of Katie's Floeberg, a grounded ice feature located at 73°N, 162°W, some 200 km seaward of Barrow, Alaska. The results of this study were presented at the Port and Ocean Engineering Under Arctic Conditions Conference held in Fairbanks, during August, 1975.

During the second quarter, hard copy at 1:500,000 scale was ordered for the earliest LANDSAT cycle with reasonably complete coverage for each winter season. At the end of the quarter, approximately 50% of the order had arrived. A major accomplishment during this reporting period was the preparation of the transparent map overlays to be used to transfer the LANDSAT data to a geographic map at 1:500,000 scale Lambert Conformal Conic Projection map prepared by the Department of Commerce. Second, bathymetric data was transferred from NOAA Coast and Geodetic Survey Nautical Charts at varying scales to 1:500,000 by means of a pantograph. These overlays became the map base for the maps produced by this project.

During the third quarter, using LANDSAT band 7 hard copy produced at 1:500,000 scale, preliminary Beaufort Sea near-shore ice maps were compiled for late winter (Feb.-March) 1973, 1974 and 1975. These maps were reproduced at half scale for reporting convenience. Particular care was taken to locate the ice features relative to geographic coordinates and bathymetric 10-fathom contours. Half-scale reproductions of these maps were reproduced with annotation discussing the features delineated as part of the quarterly report for the period ending Dec. 31, 1975.

During the fourth quarter, spring sea ice maps for 1973 were drawn. This season yielded an extremely valuable cycle of LANDSAT coverage with no gaps resulting from cloudiness. Half scale reproductions of these maps with annotation appear in this report as Appendix A.

3. Discussion of Results to Date

Although analysis of data is not yet complete a preliminary discussion of results to date can be made.

In general, ice conditions along the Beaufort coast are sufficiently uniform that ice morphology for different geographic areas need not be described separately. Here, these generalities will be discussed without reference to specific geographic localities. However, the final morphology developed will include a detailed map of the Beaufort coast and specific references to particular locations. The general aspects of Beaufort Sea morphology observed are:

A. By mid-February the seaward limit of ice contiguous with the shore can be well beyond the 10-fathom contour. When shearing motions do take place they are roughly along the line parallel to a segmented line drawn between prominent coastal headlands. There appears to be a tendency for this line of shear to be located seaward in mid-winter and move shoreward as the season advances. Although determination of the location of truly grounded ice delineating the boundary of shore-fast ice will depend on detailed analysis of late spring and summer imagery, it is apparent that the 10-fathom contour is roughly the location of the most seaward grounded ice and therefore during this time the seaward boundary of contiguous ice is beyond the boundary of shore-fast ice.

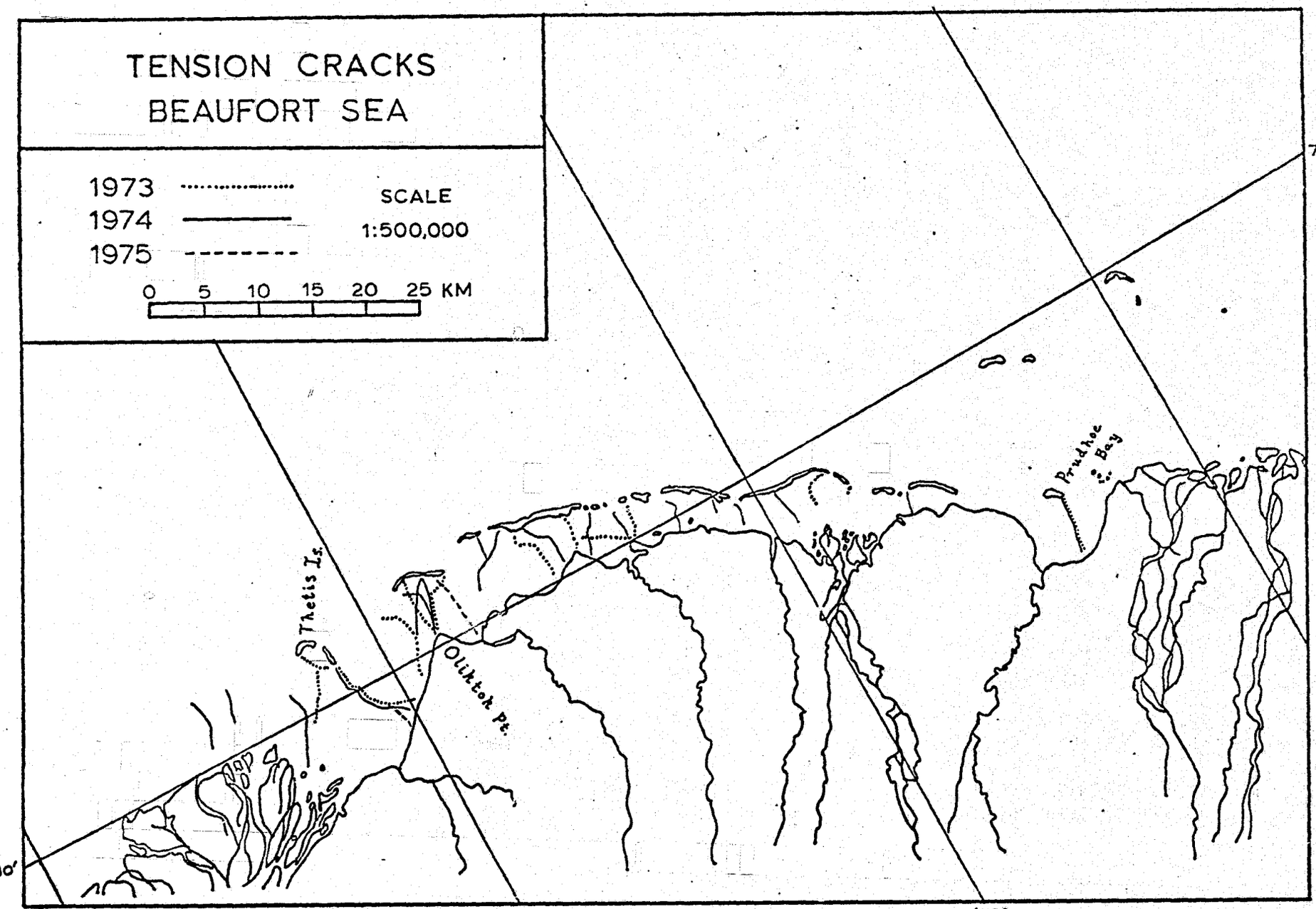
B. By late March, shearing is often taking place along a line extending along the seaward limits of the 10-fathom contours. Embayments of this contour are ignored by the shearing motions. Often, however, lead systems showing a stress-relief pattern do occur within these areas.

C. Ice translation during these midwinter shearing events is often quite small --- on the order of 10 to 20 km. This results from the "locked-in" nature of Beaufort Sea ice: the Canadian Archipellago on the east essentially blocks ice motion toward that direction and ice to the west usually only moves in such a way to allow the limited motion noted here.

D. The significance of the above observations is that the grounded ridge systems responsible for shore-fast ice have been created before mid-February when (until this year) LANDSAT data becomes available after the mid-winter dark period.

4. Conclusions from Preliminary Results

The general conclusions of this study to date are that: 1) The over-all pattern of nearshore sea ice conditions repeats from year to year in the Beaufort Sea region and 2) The specific features (hummock fields, shear ridges, etc.) are somewhat predictable and are formed relatively early in the ice season. This would mean that starting with the return of light in February, a relatively stable platform from which to conduct exploration and other petroleum-related activities could be depended upon with some degree of confidence. This, in turn, could be related to minimal probability of adverse environmental impact resulting from ice-dynamic related environmental hazards as long as the activity was located within a "safe zone".



The determination of the "safe zone" will be made at the time of final compilation of the Beaufort Sea near-shore ice morphology, but it is apparent now that it will generally follow the 10-fathom contour. Beyond this "safe zone", depending on yearly ice conditions, areas of relative safety can be defined. The significance of this conclusion is that before the LANDSAT data from several years had been examined it was not entirely clear that this conclusion could be made.

E. INTERACTION WITH OTHER INVESTIGATORS AND AGENCIES:

The investigation of the possible use by seals of cracks occurring between barrier islands and the coast has continued. During this quarter we have mapped the major cracks occurring in this area during 1973, 1974 and 1975 (see next page). Although the cracks do not occur in exactly the same location from year to year, there is some consistency in their location. This is particularly true of the recurring crack in the vicinity of Thetis Island. By coincidence, this winter a major oil company created an artificial ice island not far away from this area from which they had planned to drill an exploratory well, However, delays were encountered which caused those plans to be suspended for this year.

We plan to conduct LANDSAT ground truth activities in this area during June this year in conjunction with other scientific parties.

In particular, the use of these cracks by seals as locations for breathing holes will be examined.

By chance, we already have some information about the crack in the vicinity of Thetis Island: T.E. Osterkamp, co-principle investigator of this project made several measurements of ice thickness within the crack during the spring of 1973 and projected the date of the crack to mid-January. This date of occurrence introduces the strong likelihood that these crack are formed by stress created when the near-shore ice sheet is subjected to tension created by mid-winter temperatures acting on ice created at much warmer temperatures.

F. PLANS FOR NEXT REPORTING PERIOD:

(1) Compilation of near shore ice maps will continue. This quarter the analysis of melt season data will be initiated.

(2) Several 'special events' observed in ice activity will be documented.

(3) The investigations described in Section E will be carried out.

G. RECOMMENDATIONS: None.

H. FUNDS EXPENDED: As of March 1, 1976, the total funds expended by this project were $9,919 out of a total of $28,337.

I. DATA USE:

Value of Data Allowed	Value of Data Ordered	Value of Data Received as of 1/30/76
$10,300.00	Standing Order	$7462.*

J. PUBLICATIONS:

None this reporting period.

K. SIGNIFICANT RESULTS:

See attached sheet.

L. Appendices:

Appendix A attached.

*The number reported here on our last report, $2800, was in error and reflected the fund balance at that time.

FOURTH QUARTERLY PROGRESS REPORT

LANDSAT FOLLOW-ON INVESTIGATION

NO. 21300

TITLE: LANDSAT Survey of Near-Shore Ice Conditions Along the Arctic Coast of Alaska

PRINCIPAL INVESTIGATOR: William J. Stringer

DISCIPLINE: Oceanography

SUBDISCIPLINE: Ice Dynamics

SUMMARY OF SIGNIFICANT RESULTS: None this reporting period.

APPENDIX A.

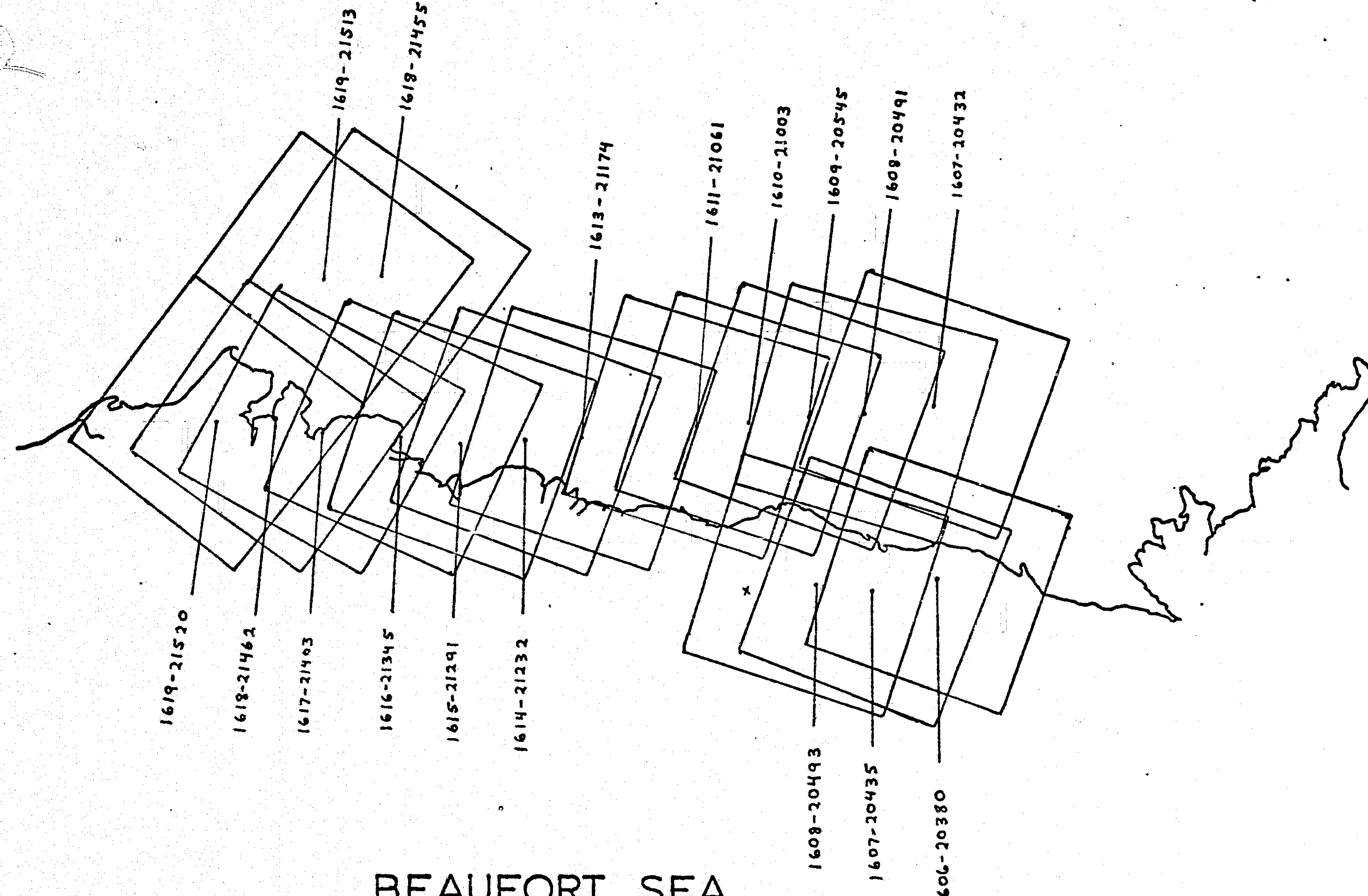
Early and mid-spring near-shear Beaufort Sea Ice Maps for 1974.

The following sets of annotated Beaufort Sea ice maps were prepared from two very complete LANDSAT cycles during early and mid-spring, 1974. Major ice features and the shore have been delineated and the 10-fathom contour shown for correlation of depth to major ice features. As little inference as possible has been made at this stage. The following two pages contain maps showing the near-shore area covered by the images comprising each of these two sets of LANDSAT data. The individual maps then follow a brief definition of the symbols used on the maps made from LANDSAT scenes.

SYMBOLS AND DEFINITIONS

B	Boundary between apparently different ice types.
BN	Broken sheet of new ice.
BPN	Pans in broken matrix of new ice.
BPY	Pans in broken matrix of young ice.
BY	Broken sheet of young ice.
C	Stationary ice - ice which is contiguous with the shore.
CF	Fragmented or broken contiguous ice.
F	Ice floe.
FY(B)	First year ice (broken or fragmented).
G.	Grounded ice floe or stranded ice.
H	Hummocked ice - sea ice piled haphazardly one piece over another to form an uneven surface.
IY	Young ice.
L	A lead, usually open, but may be too narrow to determine if it is open or not.
N	Newly refrozen lead or polyna - a lead or polyna composed of dark ice, not yet fractured and milky, or covered with snow, thin enough to allow light to pass through to the water.
O	Old refrozen lead - a lead old enough to have either turned milky with cracks or been covered by snow; thick enough to reflect most of the incident sunlight and thus appear gray to white.
P	Partially refrozen lead, usually some dark ice with open water.
PN	Pans in matrix of new ice.
PY	Pans in matrix of young ice.
R	Ridge system, may be either pressure ridge or shear ridge system.
T	Tidal or tension cracks - cracks due to tidal action in shallow waters, may be indicated by piled ice and/or snow drifts.

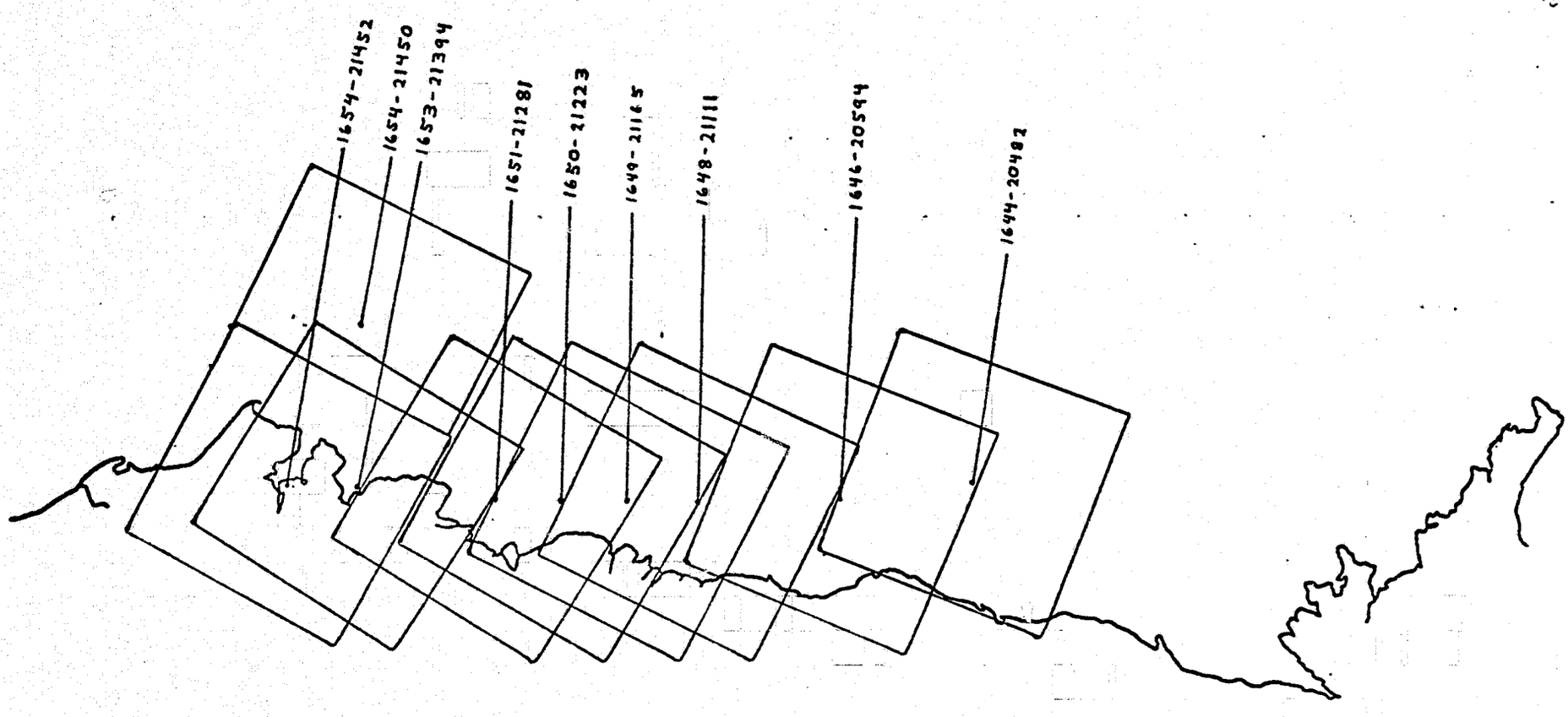
W	Open water.
Y	Polynya.
Z	Zone of shear.



BEAUFORT SEA

MARCH 15 - APRIL 3, 1974

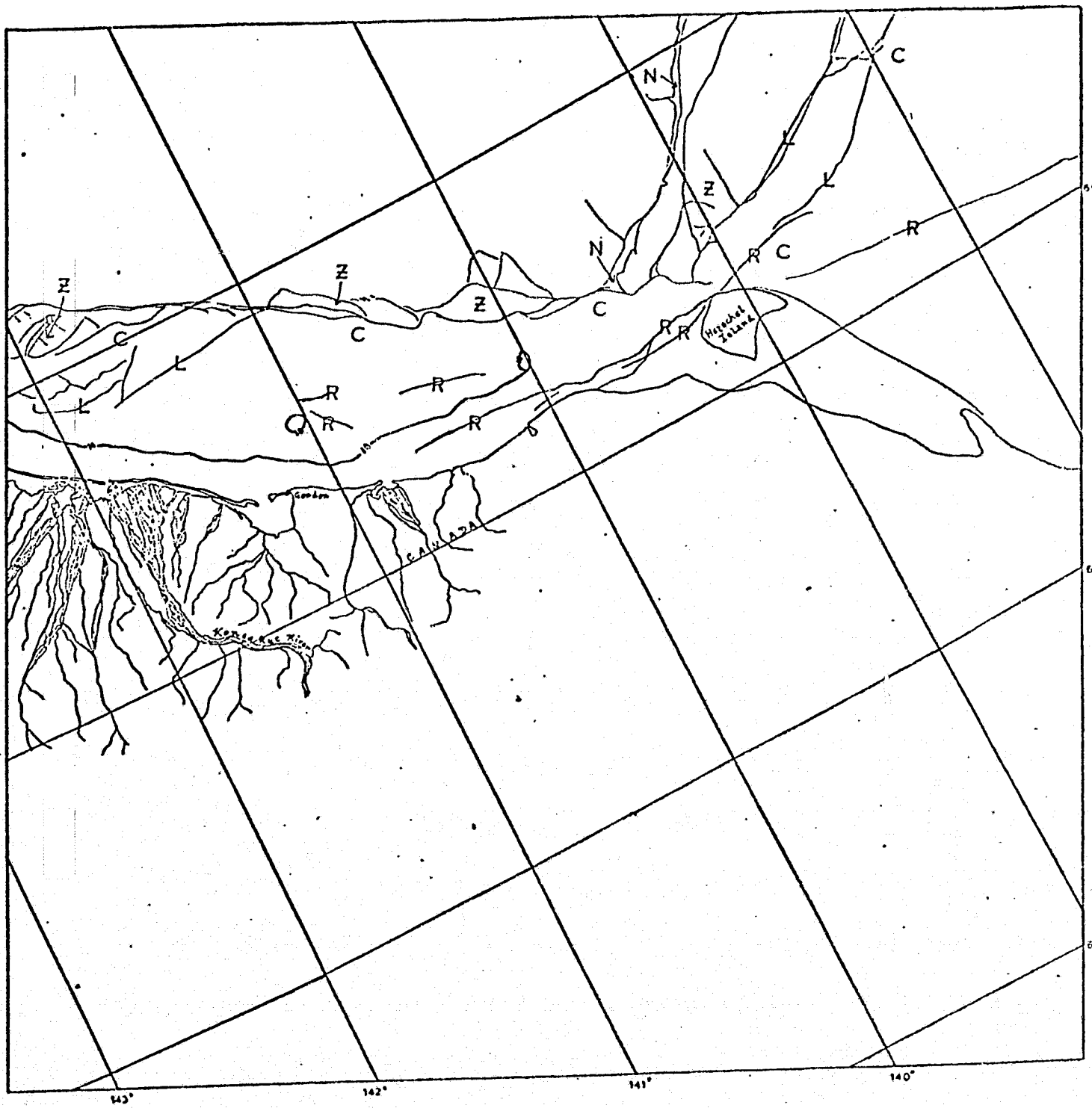
IMAGES: 1600 to 1619



BEAUFORT SEA

APRIL 20 - MAY 8, 1974

IMAGES : 1636 to 1654



E-1606-20380-7
21 MARCH 1974

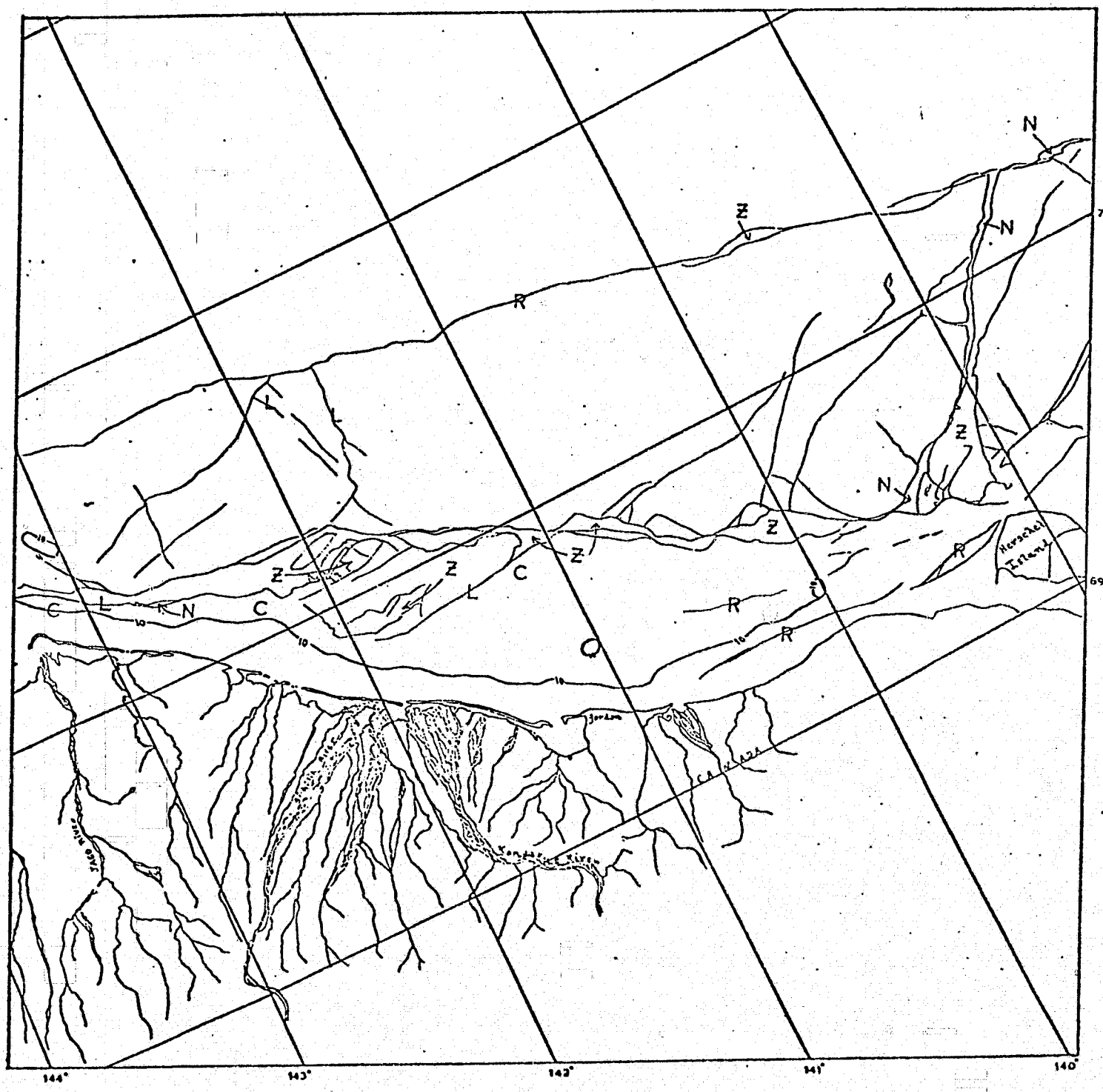
KILOMETERS
0 10 20 30 40 50

SCALE APPROX 1:1,000,000

BEAUFORT SEA

Scene 1606-20380

This scene shows the Canadian border portion of the Beaufort coast. A considerable amount of ridge-building has taken place at an earlier time with the resulting ridges and hummock fields now located well within the area of contiguous ice. Over a large part of this scene contiguous ice extends some distance (10's of km) seaward of the 10-fathom contour; at its edge there is a shear zone toward the area of the 10-fathom contour. As is often observed in MacKenzie Bay, a large, reversed "L"-shaped segment of ice has moved several km westward leaving a north-south lead system in the vicinity of Herschel Island. This westward motion created the zone of fractured ice mentioned earlier.



E-1607-20435-7
E-1607-20432-7
22 MARCH 1974

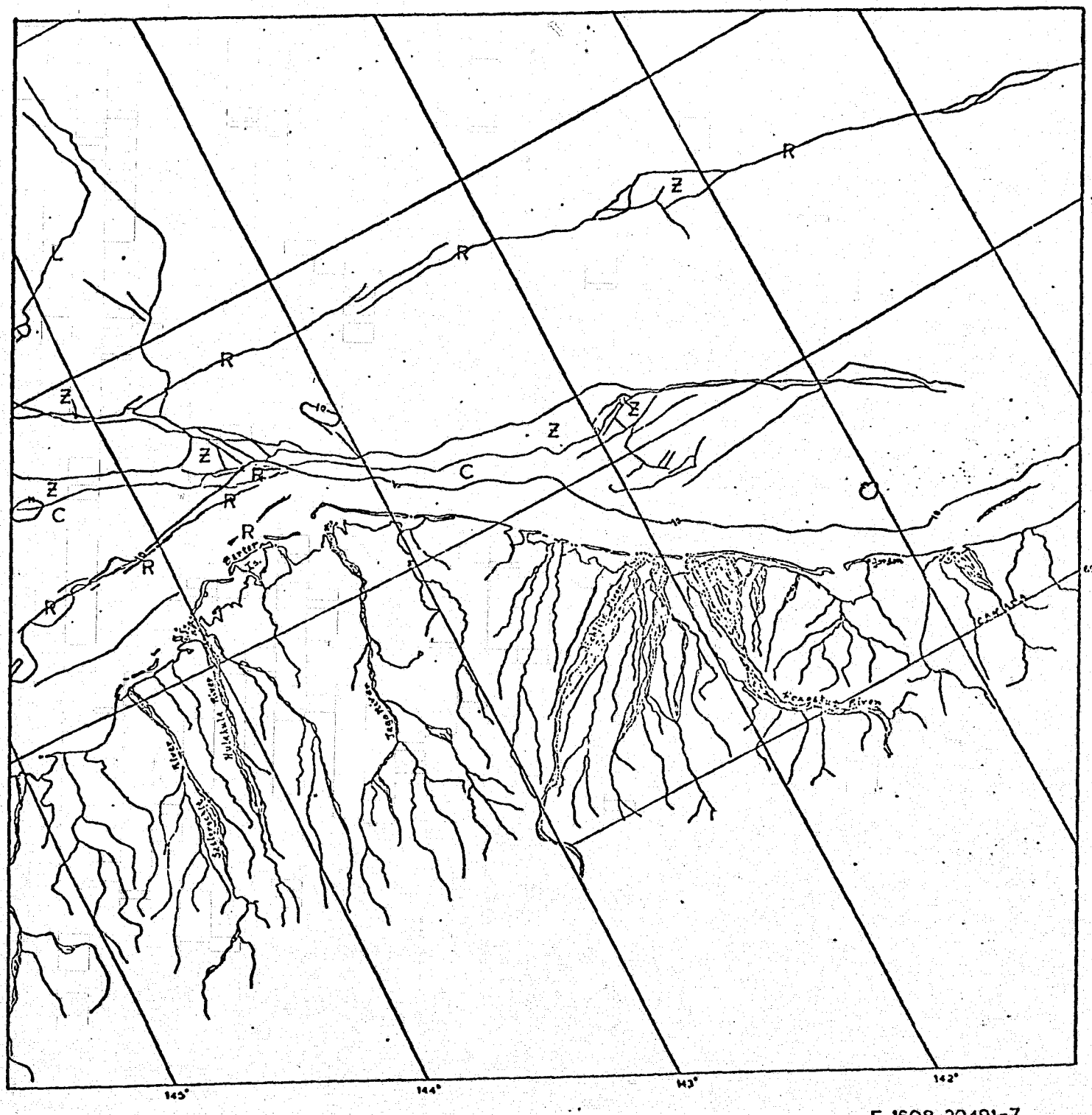
KILOMETERS
0 10 20 30 40 50

SCALE APPROX 1:1,000,000

BEAUFORT SEA

Scenes 1607-20432
1607-20435

These scenes cover the portion of Beaufort Sea coast from the Jago River to Herschel Island. The eastern portion of this scene was discussed for scene 1606-20380. In the western portion the zone of shear can be found just beyond the 10-fathom contour thereby limiting the edge of contiguous ice to that position.



KILOMETERS

0 10 20 30 40 50

SCALE APPROX 1:1,000,000

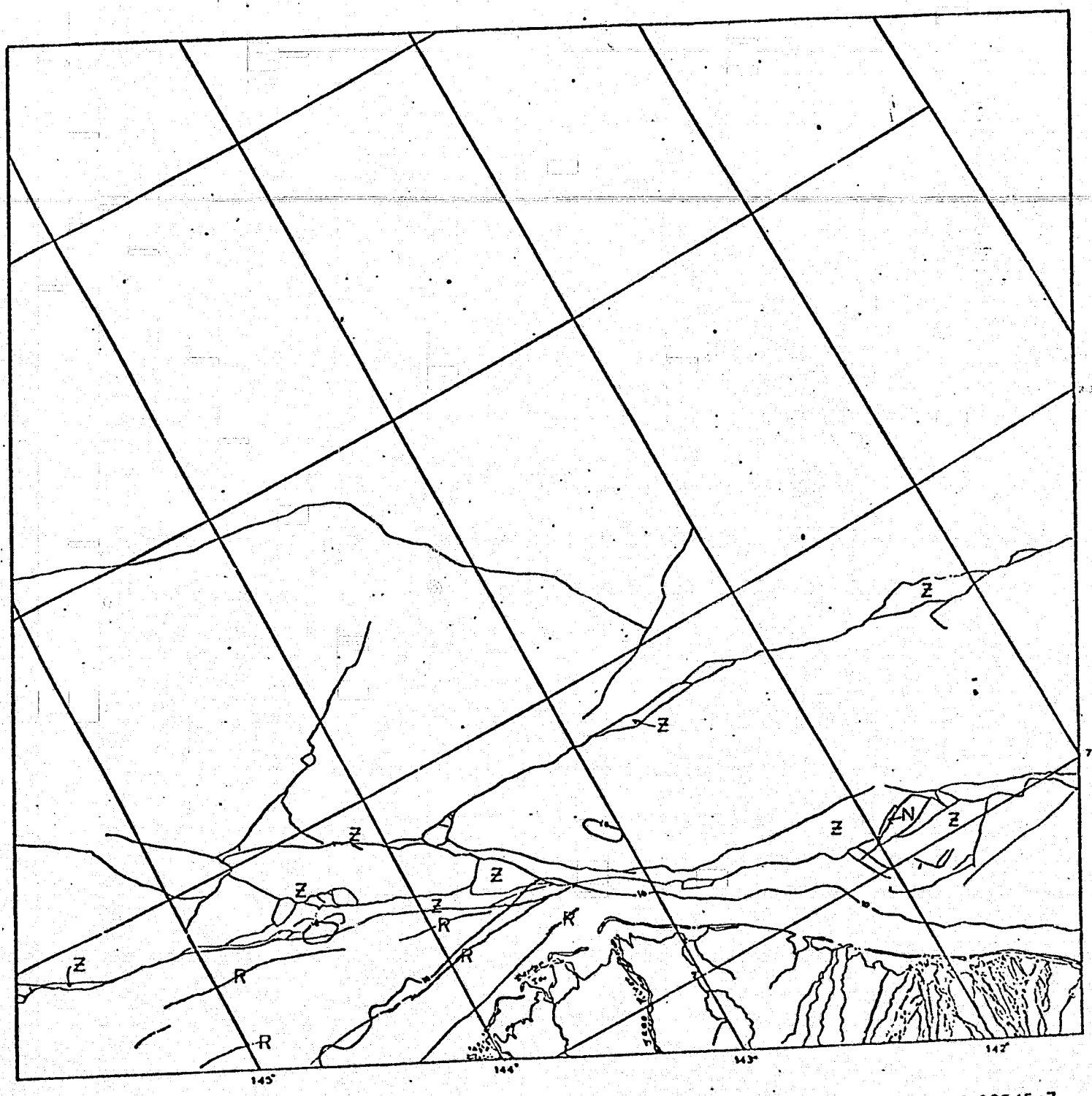
E-1608-20491-7
E-1608-20493-7

23 MARCH 1974

BEAUFORT SEA

Scene 1608-20491
1608-20493

These scenes shows the portion of Beaufort Sea coast from the Canadian border to Barter Island. Only the western portion of this area has not been described for other scenes. In the vicinity of Barter Island the coastline and 10-fathom contour each make an 80-degree bend to cause the coastline to have a bearing along a line somewhat south of west. Near this bend are located several pressure ridges and hummock fields. However, whereas the ridge systems indicate that at one time shear may have taken place along the 10-fathom contour, at this time the zone of shear is not deflected to follow the 10-fathom contour.



KILOMETERS

0 10 20 30 40 50

SCALE APPROX 1:1,000,000

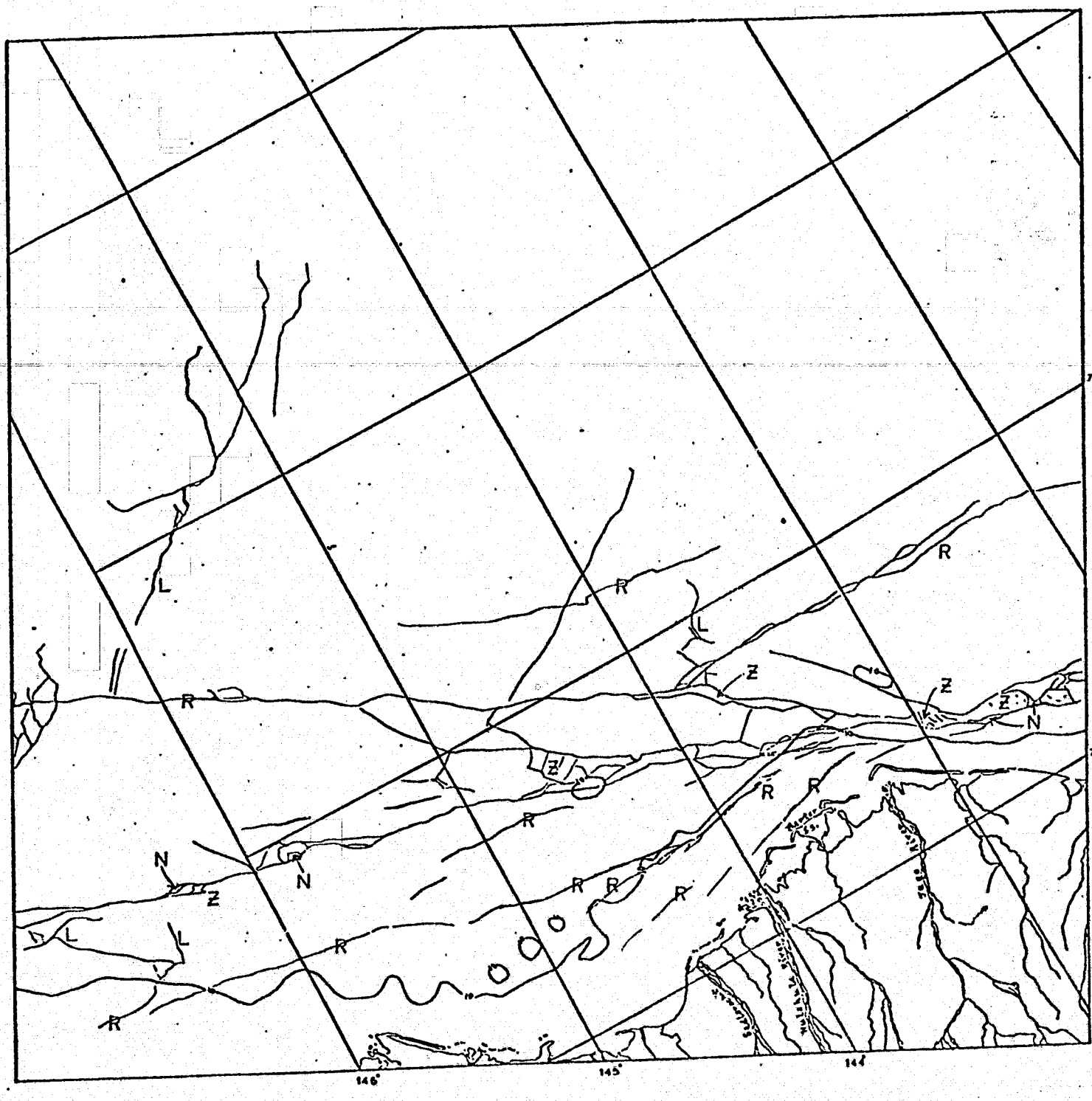
BEAUFORT SEA

E-1609-20545-7

24 MARCH 1974

Scene 1609-20545

This scene of the Beaufort coast centered on Barter Island shows the zone of shear to the west of Barter Island not following the indented 10-fathom contour into Camden Bay. There is evidence from the several concentric ridge systems that at earlier times this boundary did indent to follow the coastline and 10-fathom contour more closely.



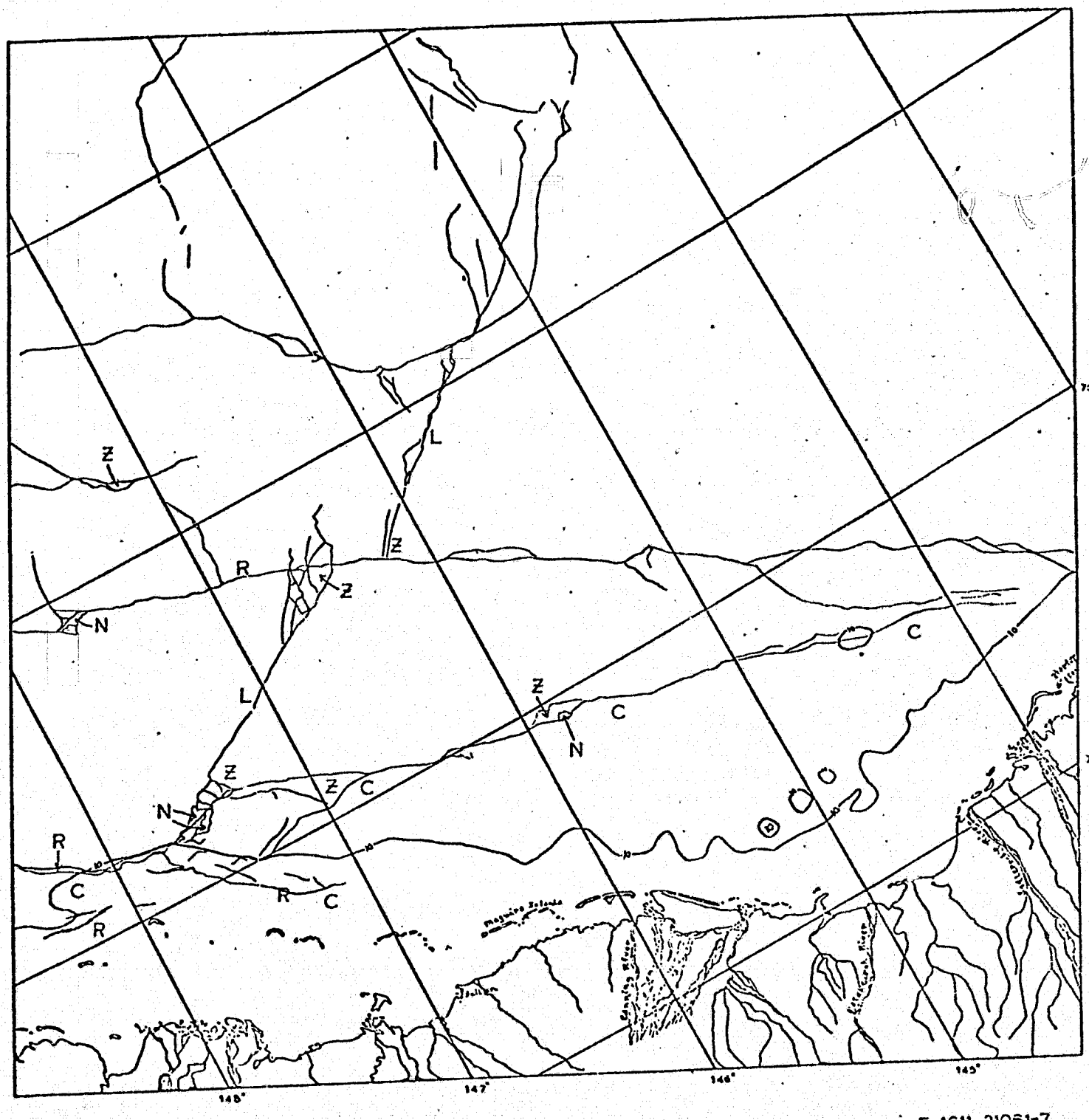
E-1610-21003-7
25 MARCH 1974

KILOMETERS
0 10 20 30 40 50
SCALE APPROX 1:1,000,000

BEAUFORT SEA

Scene 1610-21003

This scene of the Beaufort coast centered on Barter Island shows the zone of shear to the west of Barter Island not following the indented 10-fathom contour into Camden Bay. There is evidence from the several concentric ridge systems that at earlier times this boundary did indent to follow the coastline and 10-fathom contour more closely.



E-1611-21061-7
26 MARCH 1974

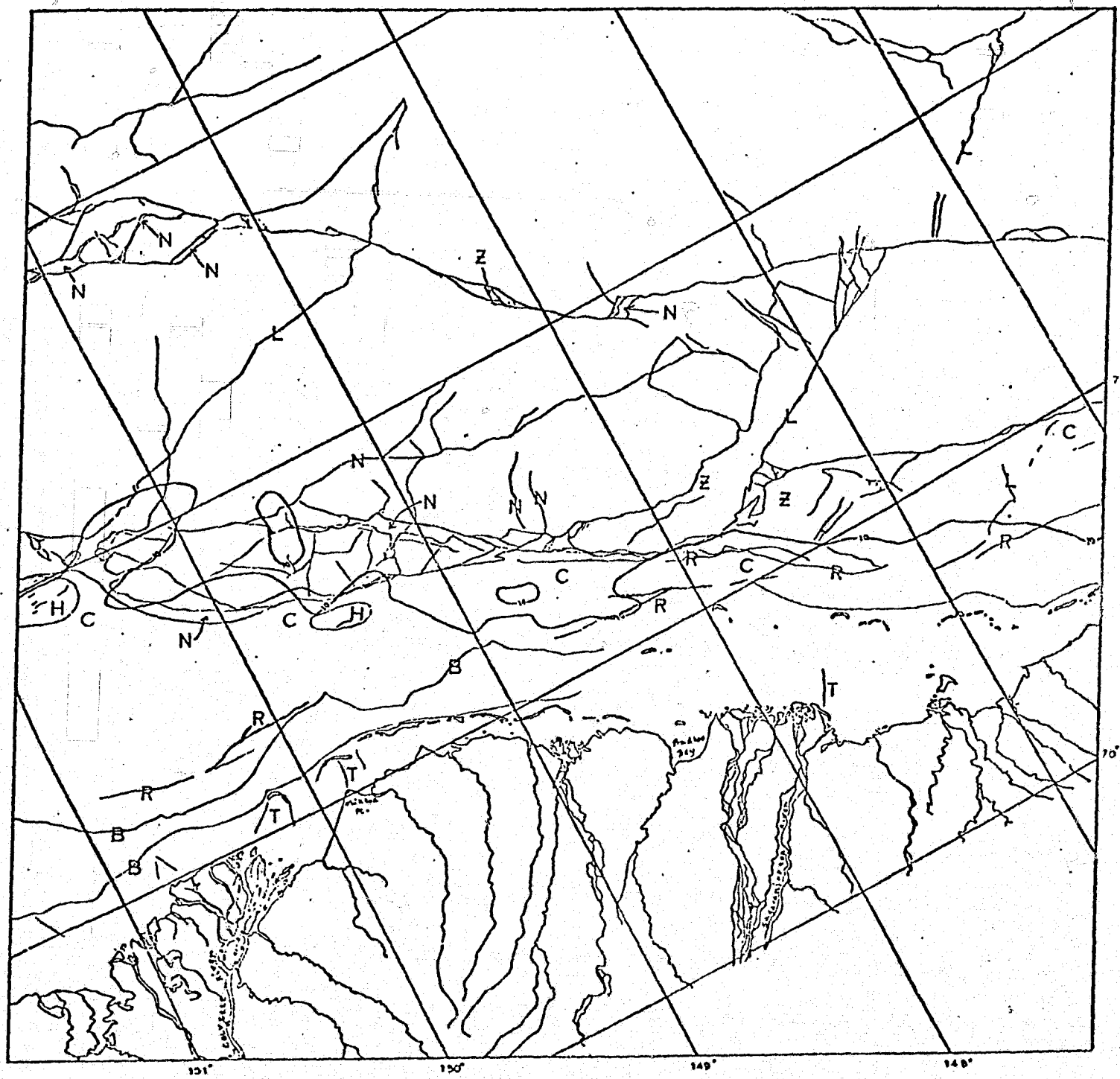
KILOMETERS
0 10 20 30 40 50

SCALE APPROX 1:1,000,000

BEAUFORT SEA

Scene 1611-21061

This scene shows the Beaufort coast from Prudhoe Bay on the west to Barter Island on the east. Only the western portion of this scene is not obscured by cloud. The areas under cloud have been mapped from previous scenes. The large lead aligned NE-SW appears to be fairly new. It extends shoreward to the vicinity of the east-west shear zone where it rejoins the 10-fathom contour.



KILOMETERS

0 10 20 30 40 50

SCALE APPROX 1:1,000,000

E-1613-21174-7

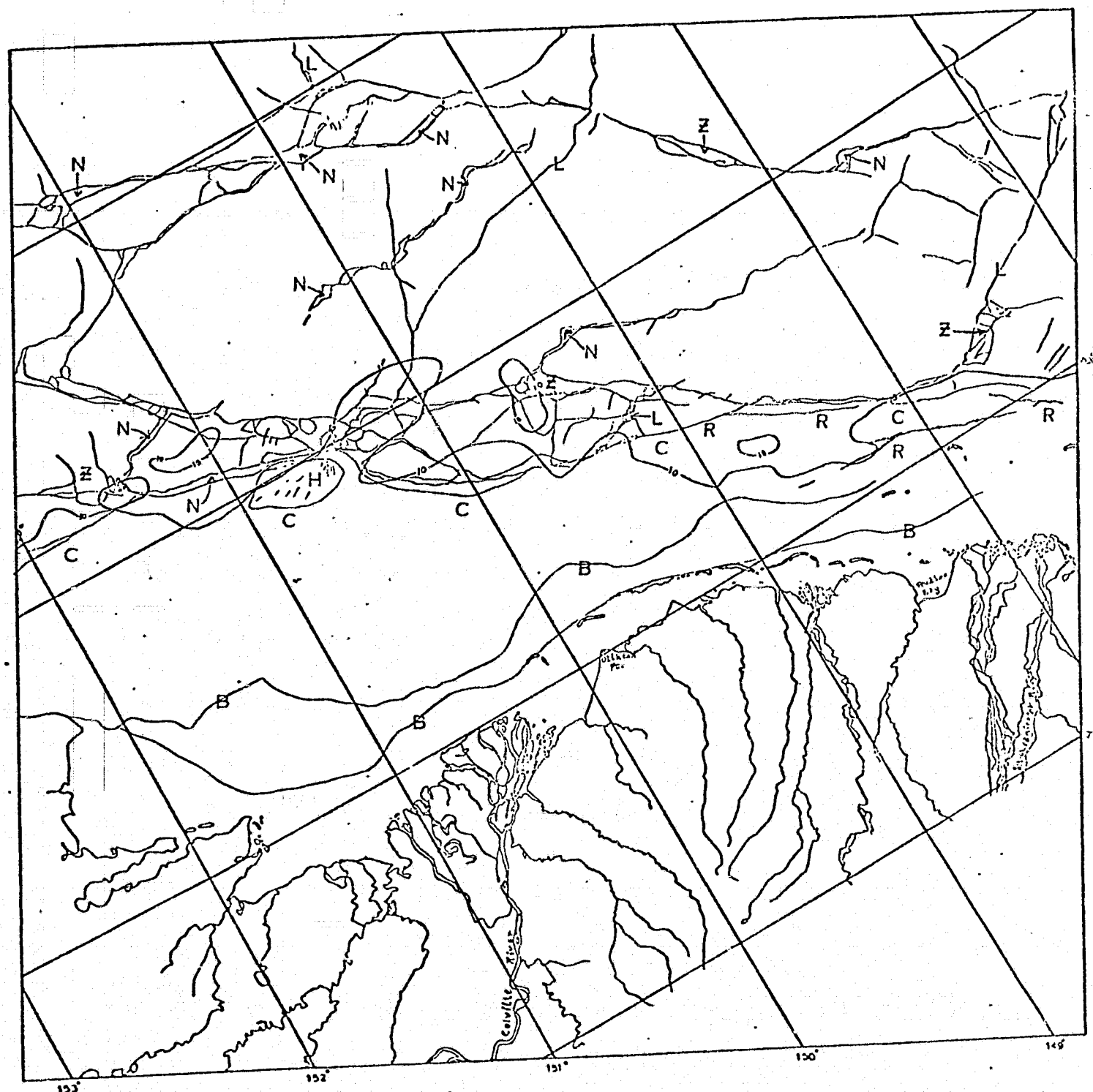
28 MARCH 1974

BEAUFORT SEA

25

Scene 1613-21174

This Beaufort coast scene centered on the mouth of the Kuparuk River shows the eastern two thirds of Harrison Bay. Throughout most of this area the zone of shear is roughly aligned with the 10-fathom contour except in areas of local indentations. Several large ridge systems can be found shoreward of the shear zone indicating that at an earlier date shear was taking place at these locations.



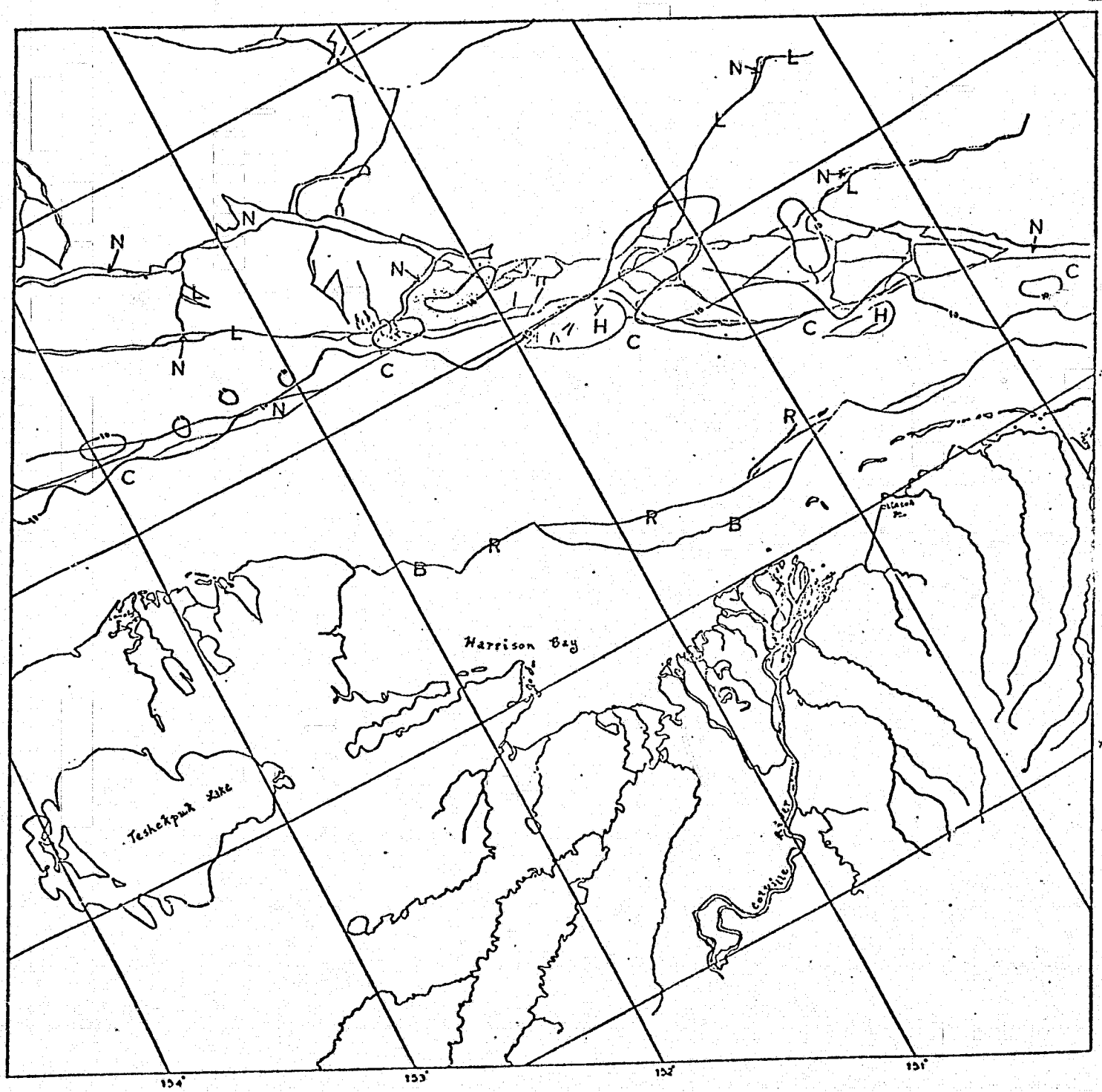
E-1614-21232-7
29 MARCH 1974

KILOMETERS
0 10 20 30 40 50
SCALE APPROX 1:1,000,000

BEAUFORT SEA

Scene 1614-21232

This scene includes the portion of coast from Cape Halkett to Prudhoe Bay. The edge of contiguous ice coincides quite well with the 10-fathom contour across most of this image. The only deviation from this general rule is found where the 10-fathom contour makes a major indentation west of Cross Island.



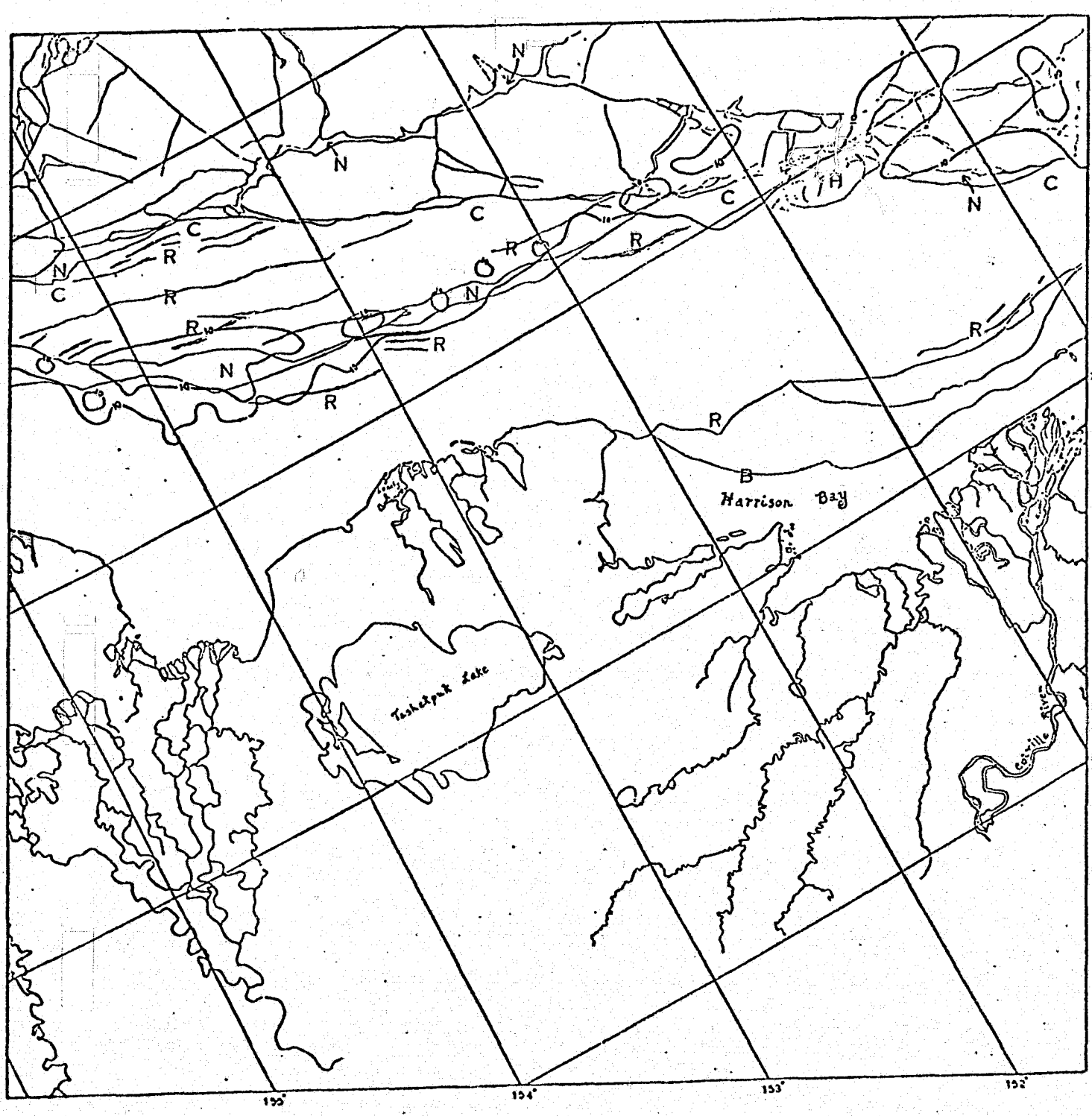
E-1615-21291-7
30 MARCH 1974

KILOMETERS
0 10 20 30 40 50
SCALE APPROX 1:1,000,000

BEAUFORT SEA

Scene 1615-21291

This scene, centered on Harrison Bay again shows a close correlation between the limit of contiguous ice and the 10-fathom contours. The ridges and boundaries within the contiguous ice appear to be quite old. Two large hummock fields can be found in outer Harrison Bay which appear to be at least partly responsible for the local configuration of lead systems.



E-1616-21345-7
31 MARCH 1974

KILOMETERS
0 10 20 30 40 50
SCALE APPROX 1:1,000,000

BEAUFORT SEA

Scene 1616-21345

This scene shows the Alaska coastline from Smith Bay to the mouth of Colville. From the east the edge of the contiguous ice follows closely the 10-fathom contour until it reaches the hummock field in outer Harrison Bay. Then it continues westward while the 10-fathom contour indents toward Smith Bay. In the recent past, the contiguous ice in the Smith Bay area has broken and been displaced several km eastward in this area and, interestingly, this break was along the 10-fathom contours. Since that time the open water created by that break has frozen. Inshore of this recent break and nearly coinciding with the 10-fathom contour are several massive ridge systems which probably represent the boundary of contiguous ice at earlier times.

E-1617-21403-7

1 APRIL 1974

KILOMETERS

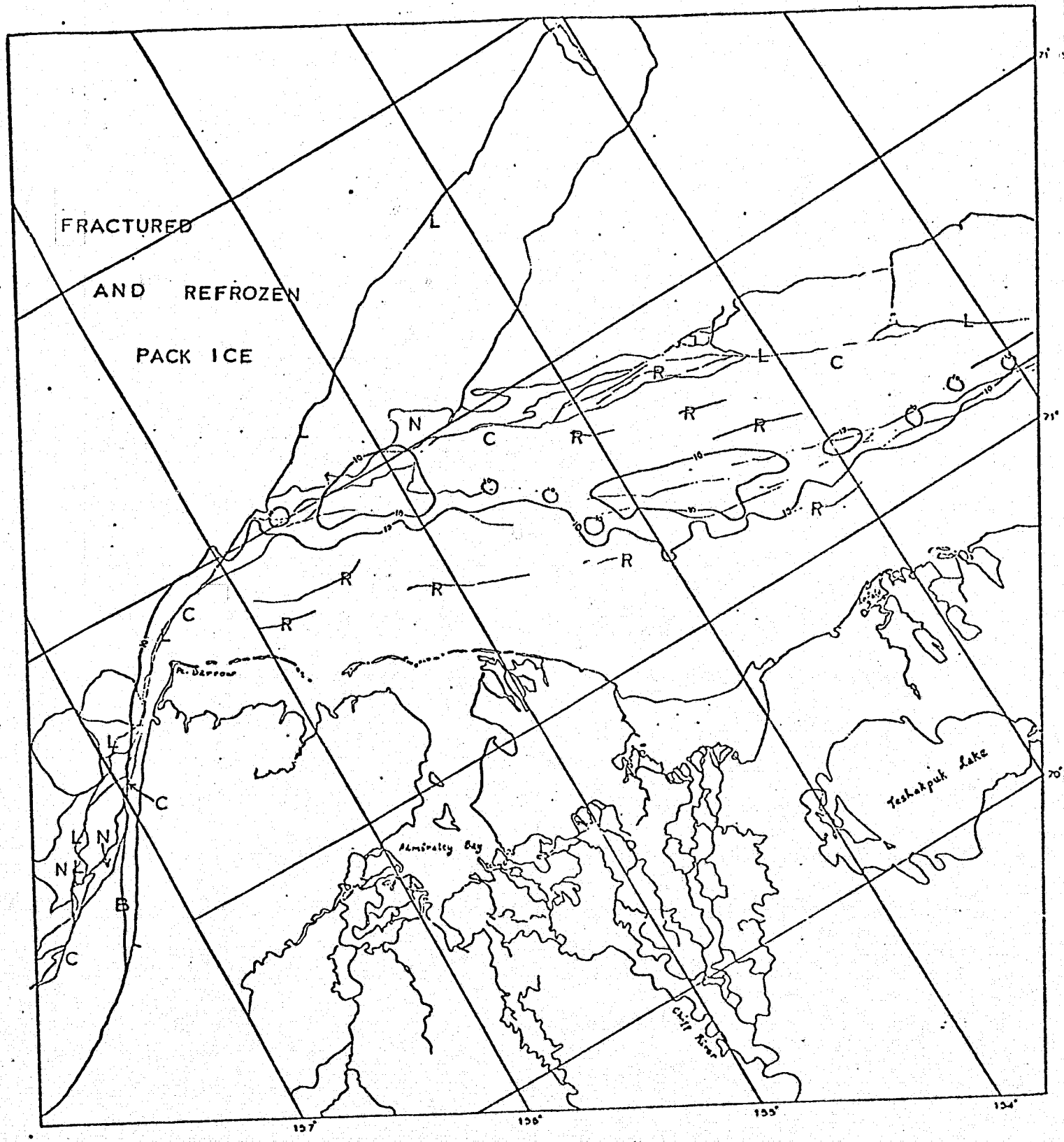
0 10 20 30 40 50

SCALE APPROX 1:1,000,000

BEAUFORT SEA

Scene 1617-21403

This scene shows the Beaufort Coast from Admiralty Bay to Harrison Bay. At this time contiguous ice extends considerably seaward of the 10-fathom contour in the Smith Bay area. In the recent past it has indented toward Smith Bay generally following the 10-fathom contour. A large block of contiguous ice had broken loose and drifted several km east causing a large lead to open. By this date the lead had frozen over so that ice was contiguous out to the more remote location described earlier. Considerably inshore of the 10-fathom contour is located a more-or-less continuous line of ridges which apparently mark the position of shear at a much earlier date.

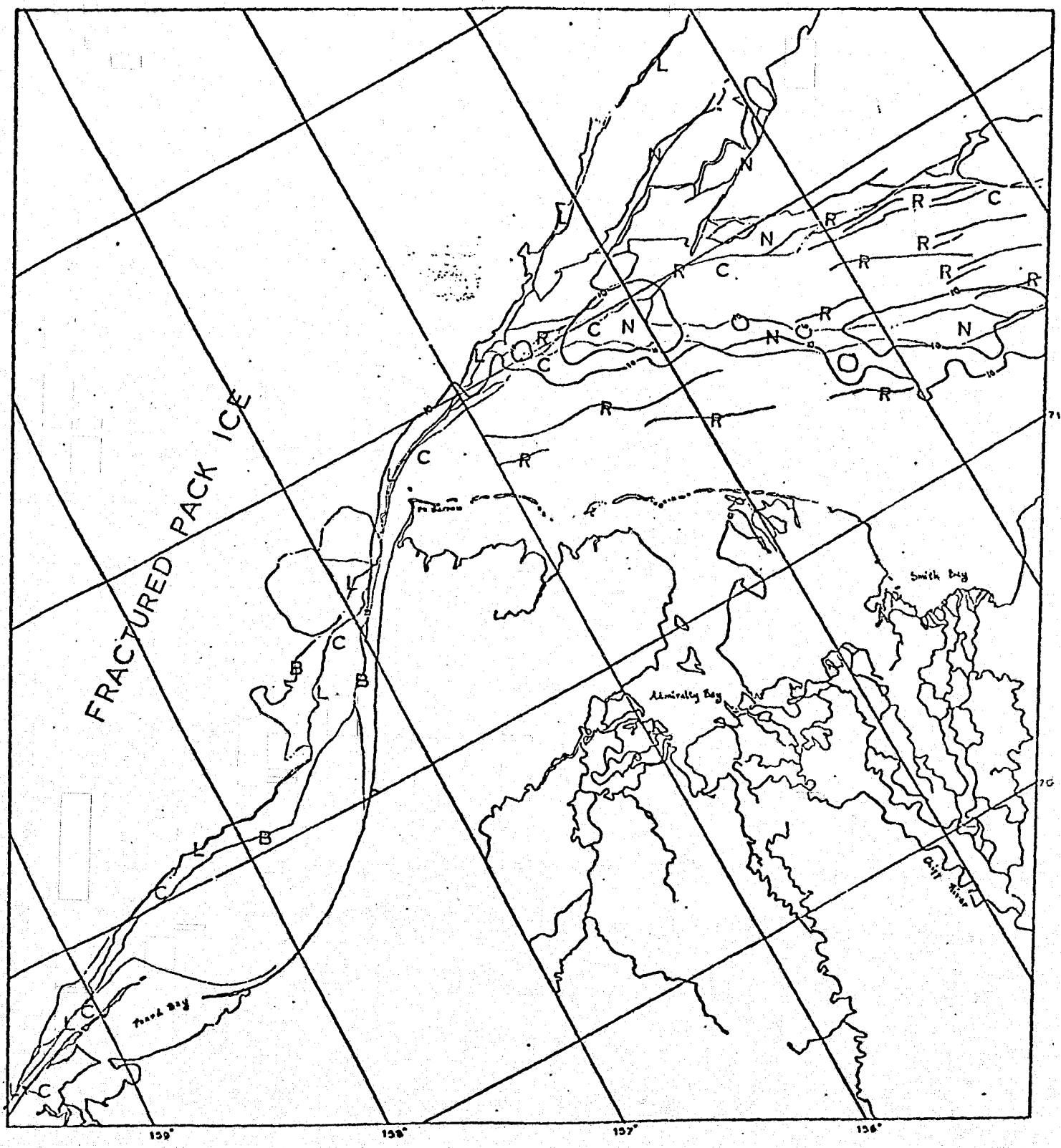


BEAUFORT SEA

E-1618-21455-7
E-1618-21462-7
2 APRIL 1974

Scene 1618-21455
1618-21462

These scenes show the Beaufort coast from Pt. Barrow east almost to Cape Halkett. Presently shear is taking place along a line extending from north of Pt. Barrow to a hummock field located in outer Harrison Bay. This represents a chord to the arc made by the 10-fathom contour as it follows the indentation of the coastline in this area. At a recent time a large piece of contiguous ice located between the chord and arc has broken loose and moved several km to the east opening up new water which has frozen and thereby extending contiguous ice out to the present limit. It is interesting to note the line of large ridge systems located well within the 10-fathom contour. These may well represent the edge of contiguous ice at an earlier date.



KILOMETERS

0 10 20 30 40 50

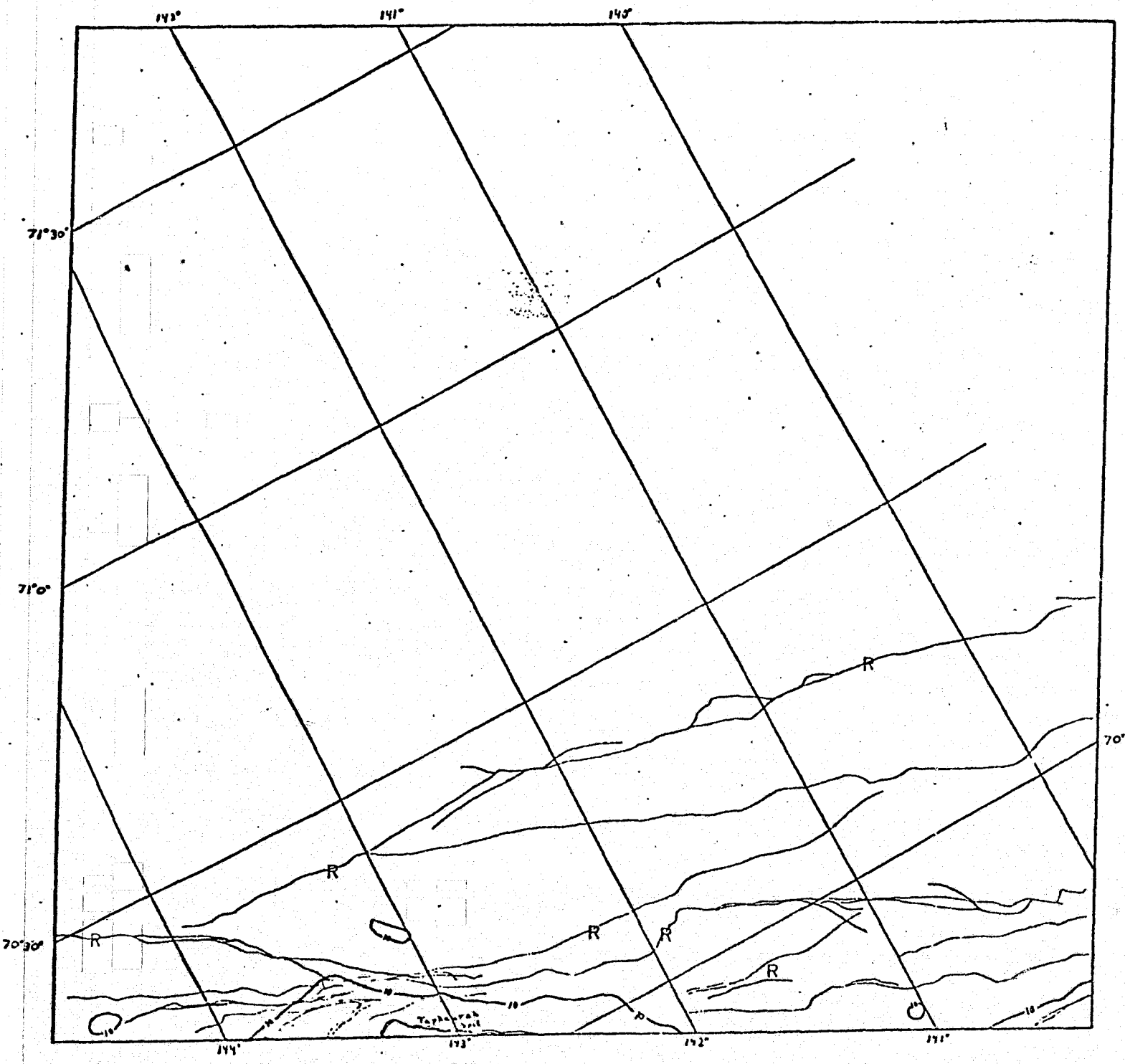
SCALE APPROX 1:1,000,000

BEAUFORT SEA

E-1619-21513-7
E-1619-21520-7
3 APRIL 1974

Scene 1619-29520

This combination of scenes is of the area from Peard Bay to Point Barrow to Smith Bay. From Peard Bay to Point Barrow and extending north-eastward, a narrow lead has opened up, separating the fractured pack ice of Chukchi and northwestern Beaufort Seas from the contiguous ice along the Chukchi coast and the more solid pack ice of the Beaufort Sea. A fairly new ridge-lead system separates the contiguous ice from the pack ice in the Beaufort Sea. Shoreward of this boundary, many large ridge systems are visible. In this area, a large lead had opened up, truncating many of the ridge systems, but has since refrozen.



E-1644-20482
28 APRIL 1974

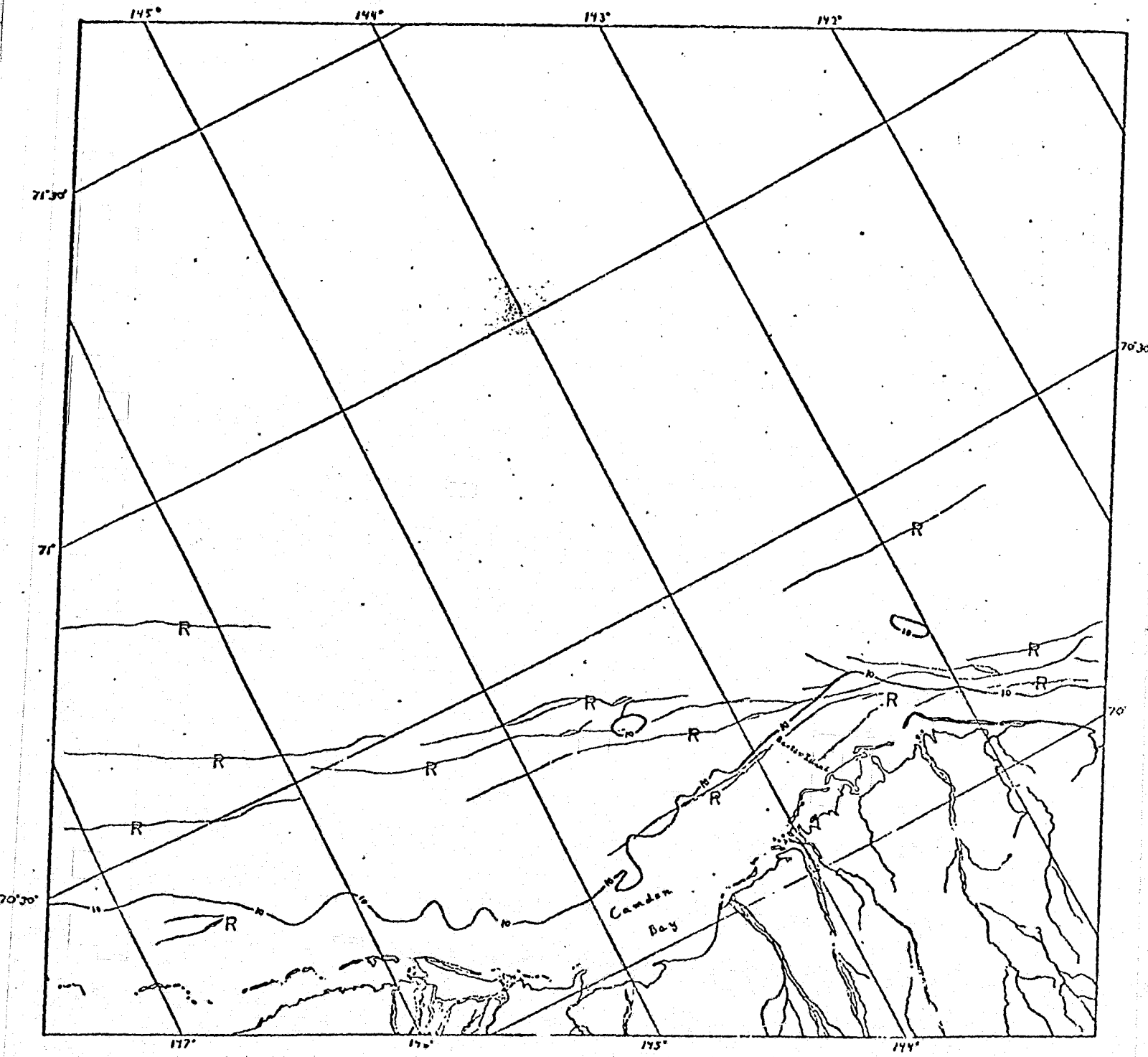
KILOMETERS
0 10 20 30 40 50

SCALE APPROX 1:1,000,000

BEAUFORT SEA

Scene 1644-20482

This scene shows the Beaufort coast in the vicinity of the Barter Island, NWT. Comparison should be made with scene 1608-20491 obtained a little more than a month previously. Apparently, during this time there has been little or no ice motion. Contiguous ice extends beyond the edges of the landsat scene.



KILOMETERS

0 10 20 30 40 50

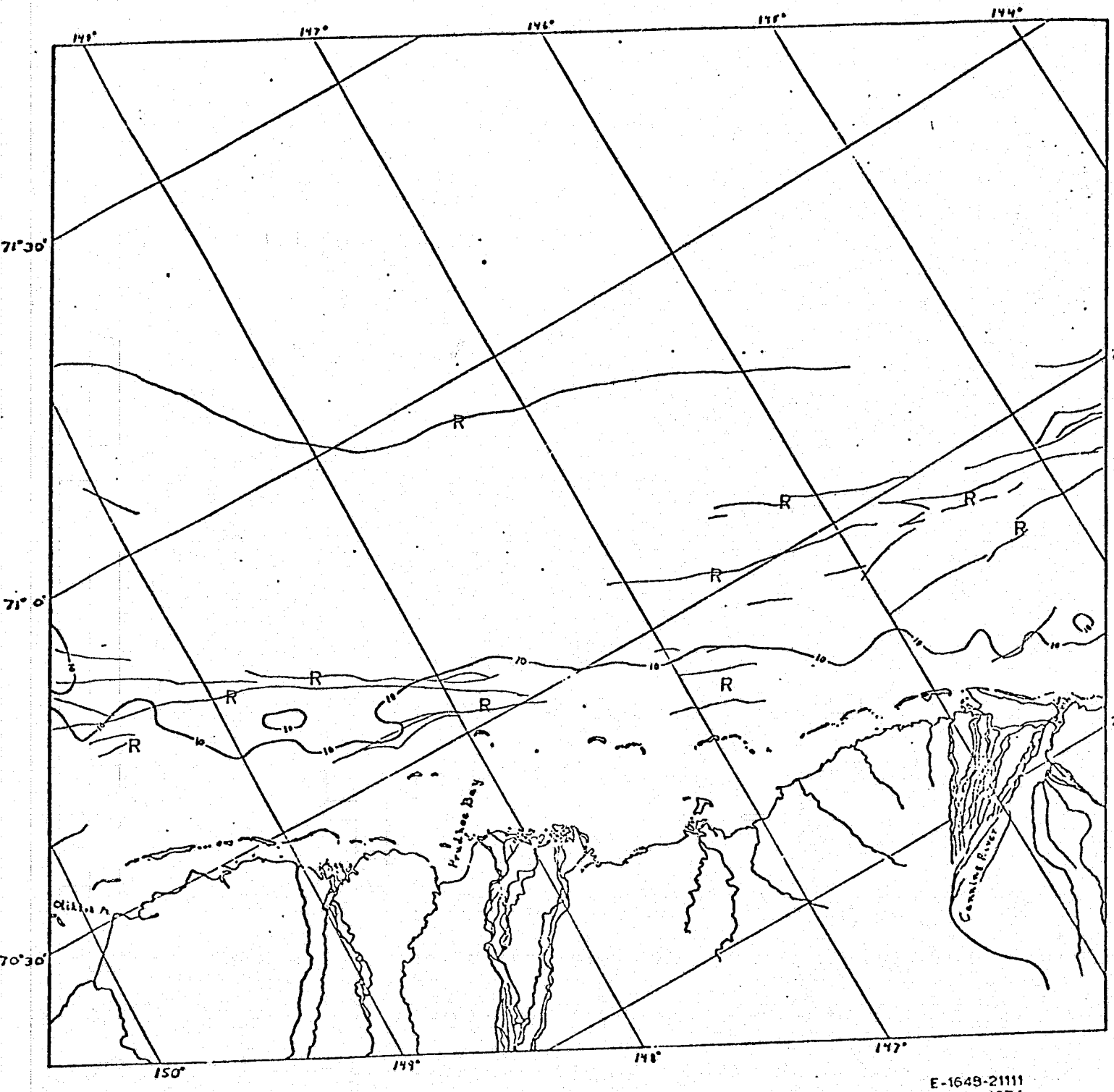
SCALE APPROX 1:1,000,000

E-1646-20594
30 APRIL 1974

BEAUFORT SEA

Scene 1646-20594

This scene shows the Beaufort coast in the vicinity of Camden Bay. Comparison should be made with scene 1610-21003 obtained 36 days previously. Apparently, during this time there has been little or no ice motion and consequently no leads formed. Ridge systems can be identified in the locations of active shear on the earlier scene. Contiguous ice extends past the limits of the landsat scene.



E-1648-21111
2 MAY 1974

KILOMETERS

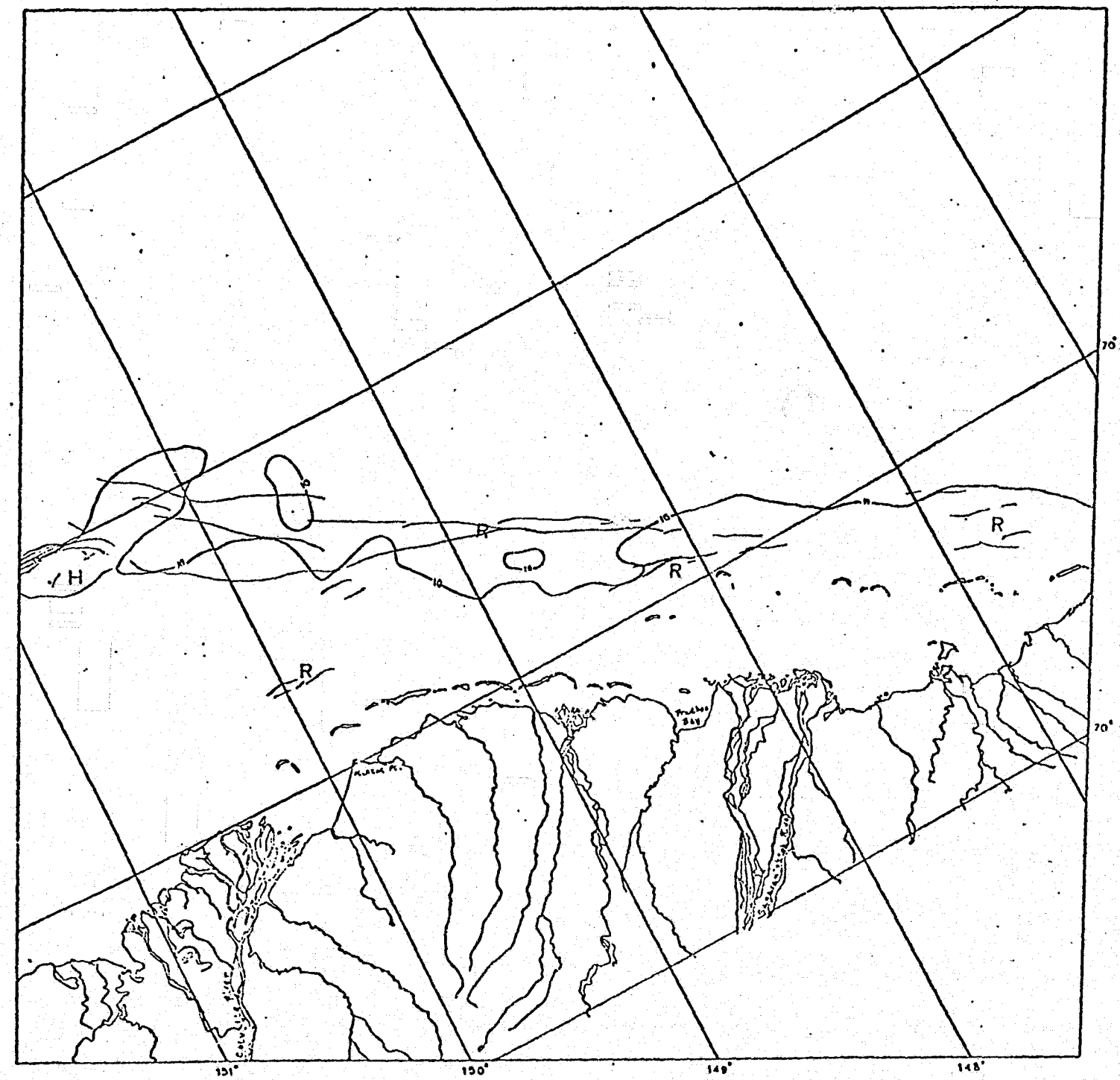
0 10 20 30 40 50

SCALE APPROX 1:1,000,000

BEAUFORT SEA

Scene 1648-21111

This scene shows the Beaufort coast in the vicinity of Prudhoe Bay and should be contrasted with the nearly corresponding scene, 1613-21174, obtained 35 days previously. Apparently, during this time there has been little or no ice motion with the result that contiguous ice extends beyond the edge of the landsat scene.



E-1649-21165-7

3 MAY 1974

KILOMETERS

0 10 20 30 40 50

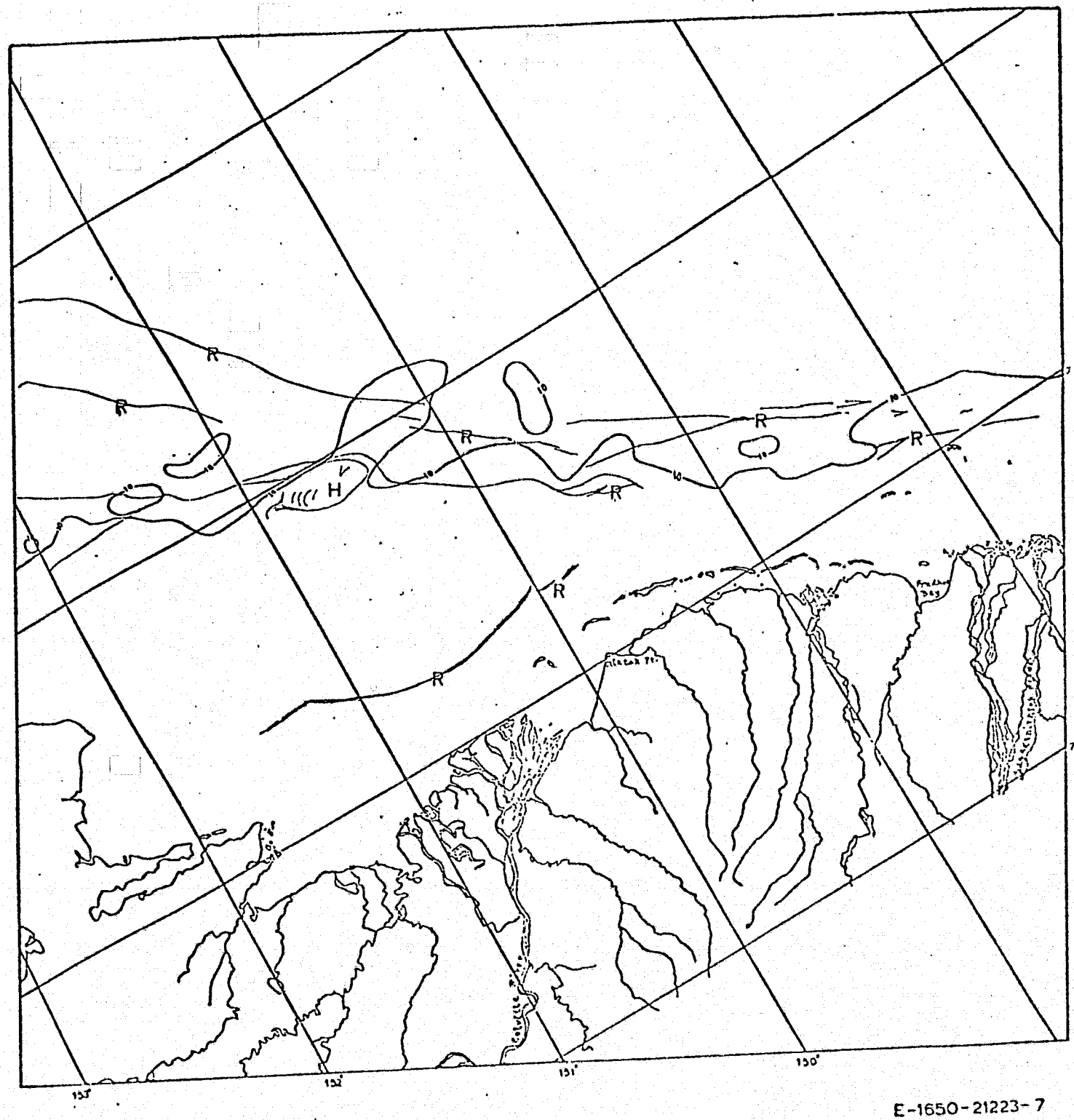
SCALE APPROX 1:1,000,000

BEAUFORT SEA

115

Scene 1649-21165

This scene showing the Beaufort coast eastward from Harrison Bay should be contrasted with scene 1613-21174 obtained 36 days earlier. During this time there has been little or no ice motion with the result that all leads have frozen and all shear motion has ceased. The result is that contiguous ice now extends beyond the limits of the scene.



E-1650-21223-7

4 MAY 1974

KILOMETERS

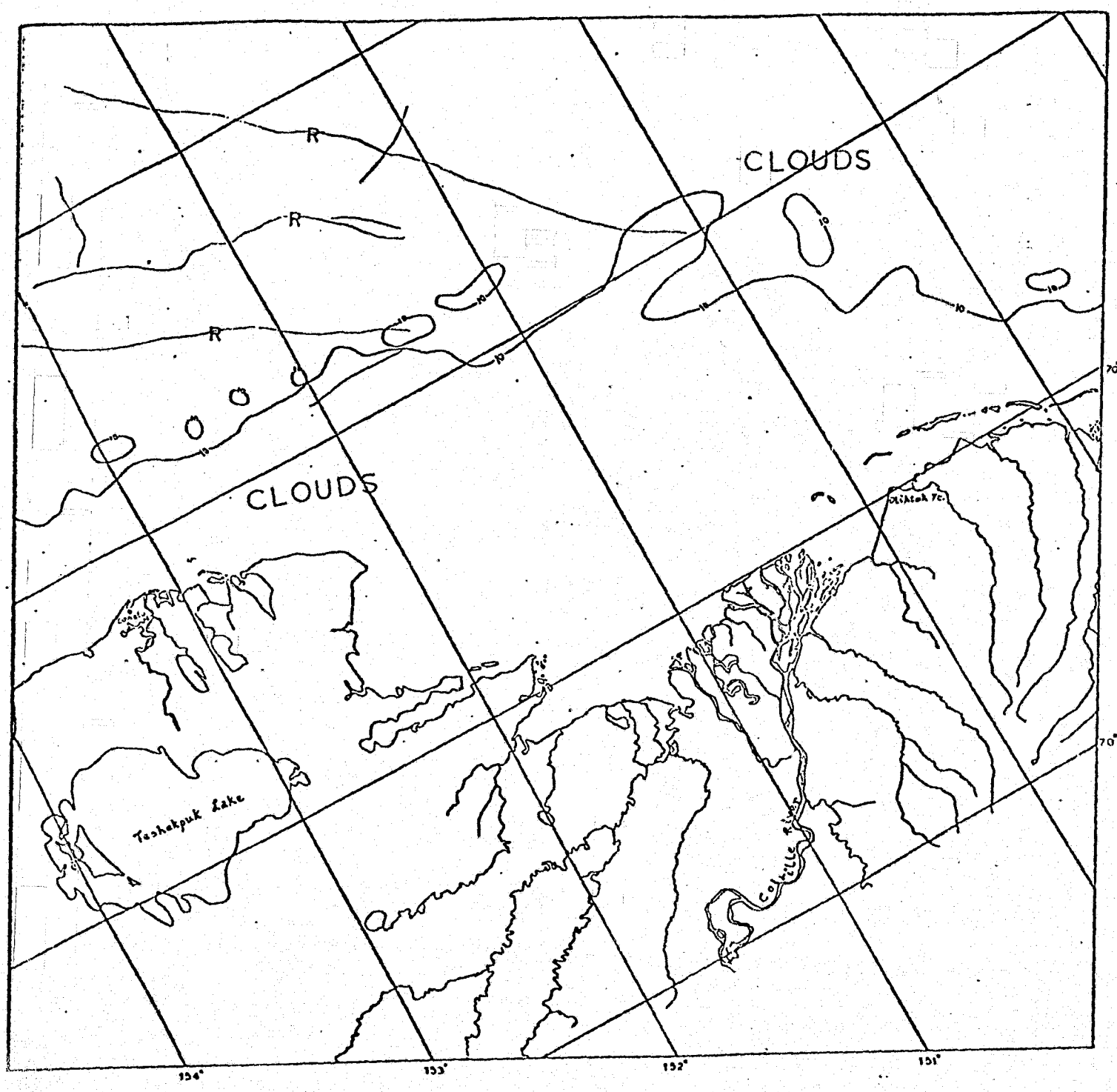
10 20 30 40 50

SCALE APPROX 1:1,000,000

BEAUFORT SEA

Scene 1650-21223

This scene showing the Beaufort coast from Harrison Bay to Prudhoe Bay should be contrasted with scene 1614-21232 obtained 36 days previously when considerable shearing motion had just taken place. During the interval between these scenes there has been little or no ice motion with the result that all leads have frozen and all shearing motion has ceased. The result is that contiguous ice now extends beyond the limits of the scene.



E-1651-21281-7

5 MAY 1974

KILOMETERS

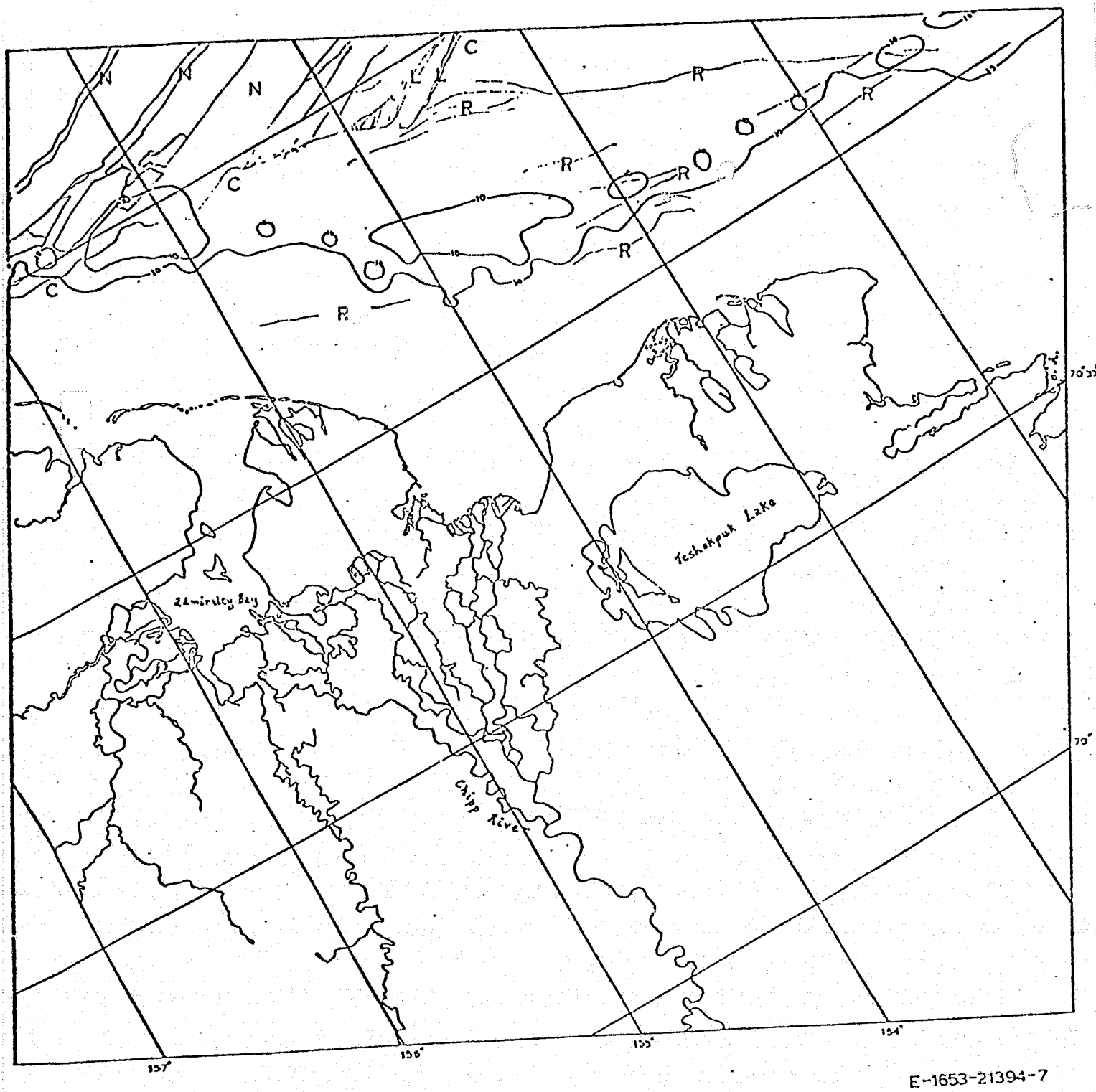
10 20 30 40 50

SCALE APPROX 1:1,000,000

BEAUFORT SEA

Scene 1651-21281

This scene showing the Beaufort coast from Harrison Bay to Prudhoe Bay should be contrasted with scene 1615-21291 obtained 36 days previously when considerable shearing motion had just taken place. During the interval between these scenes there has been little or no ice motion with the result that all leads have frozen and all shearing motion had ceased. The result is that contiguous ice now extends beyond the limits of the scene.



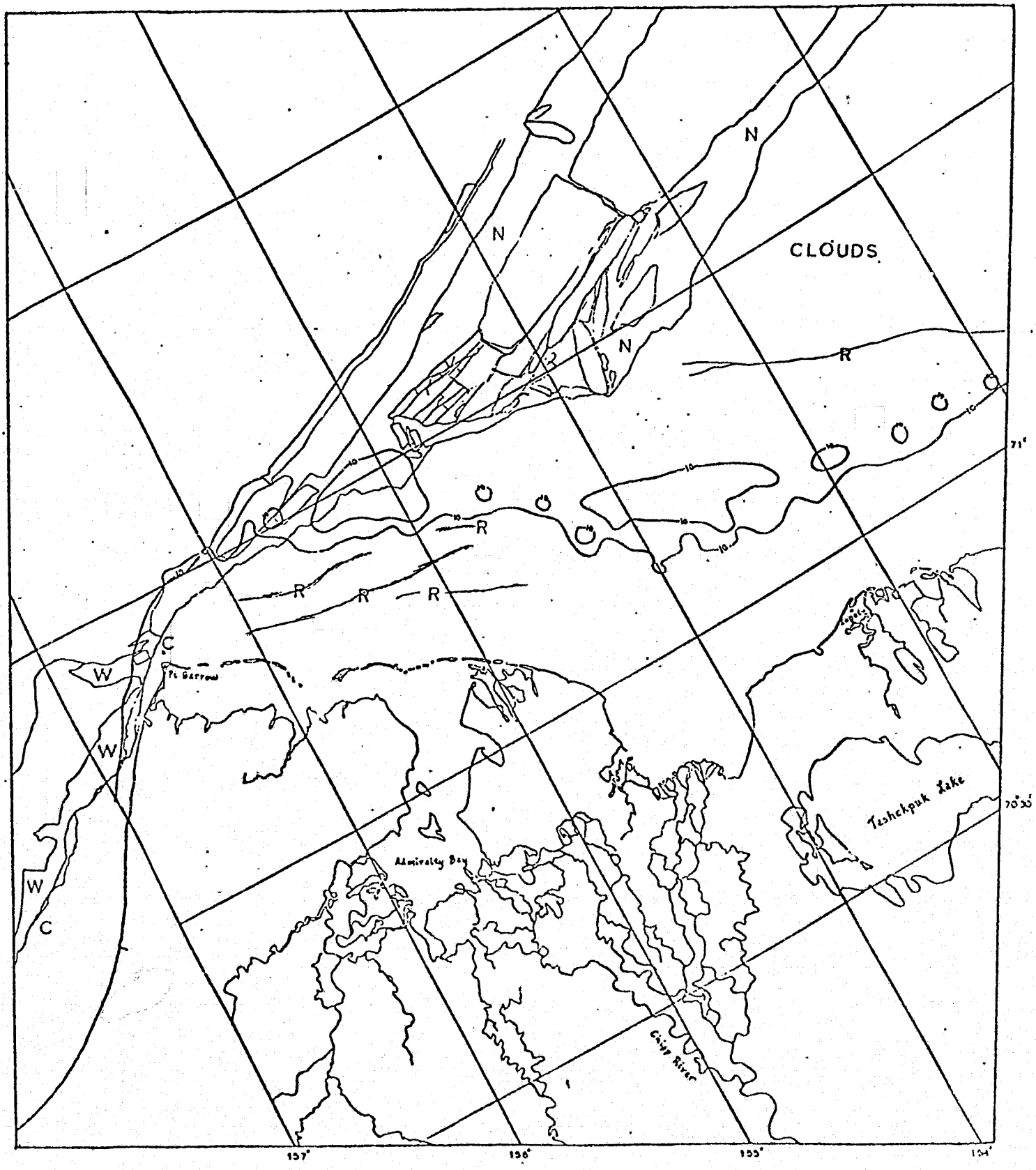
E-1653-21394-7
7 MAY 1974

KILOMETERS
10 20 30 40 50
SCALE APPROX 1:1,000,000

BEAUFORT SEA

Scene 1653-21394

This Beaufort scene centered on Smith Bay should be compared with scene 1617-21403 obtained 36 days previously. The ice to the east of the active lead system shown here has apparently not moved during this interval with the result that all leads have frozen and shearing motions ceased. However, there is an active lead system north and east of Pt. Barrow in this new scene which appears somewhat similar to the lead system seen in this location on the earlier scene.



KILOMETERS

10 20 30 40 50

SCALE APPROX 1:1,000,000

BEAUFORT SEA

E-1654-21450-7
E-1654-21452-7
8 MAY 1974

Scene 1654-21450
1654-21452

This scene showing the Beaufort coast eastward from Pt. Barrow should be compared with scene 1618-21462 obtained 36 days earlier. Shearing motions are taking place in much the same location as in the earlier scene: slightly inshore of the 10-fathom contour at Barrow and far beyond that contour around the point to the east. Little or no shearing motion has taken place to the east of the active lead system shown in this image.