ATTACHMENT G

CHARACTERISTICS OF ICE GOUGES FORMED FROM 1975 to 1982 ON THE ALASKAN BEAUFORT SEA INNER SHELF

by

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INTRODUCTION

Ice gouging is an important process to consider in the design of pipelines and structural foundations relying on the seabed for stability. Pipelines must be protected from the impact of ice on the seabed either by burial or by defensive structures such as berms or armor. Seafloor relief formed by gouging also affects the lateral shear resistance of bottom founded structures such as mobile exploration islands as their bond with the seafloor is through sediment contact points. In addition, ice gouging is an indication of the rate and intensity of ice events on the central and inner shelf. The size, shape and frequency of new gouges is an indicator of ice keel distribution and of the shape and strength of keels.

In this report we discuss initial observations from an 8 year long sequence of repetitive surveys on the rate and character of ice gouging in the fast ice and inner stamukhi zone. These retitive observations have allowed us to document year-to-year variability of the processes and to evaluate the relationship to year-to-year ice zonation.

Our data are predominantly from the inner shelf, where open-water conditions are most common, and where our precise navigation equipment of limited range is most useful (Fiq. 1 and Table I). Our observations thus are biased toward shallow water and we expect different results when data are gathered from deeper water, where ice conditions and sediment types are different.

Background

Earlier studies of the rates of ice gouging from repetitive surveys suggest that sea ice regularly plows the seabed (Lewis, 1977; Reimnitz et a"l.9 1977; and Barnes et al., 1978). Gouging was found to be ubiquitous in the areas studied, although sediment reworking of gouges by waves and currents is important inshore of 13 meters water depth and influences the data base (Barnes and Reimnitz, 1979). These earlier studies were limited to water depths of less than 20 meters. Gouging was thought to be a winter processes when large integrated ice sheets transmit energy by deep keels from the sea surface to the sea floor. This mode of formation provides more energy than would be available from local atmospheric and oceanic forces acting on an isolated ice block (Kovacs and Mellor, 1974).

Analyses of previously available data from the Canadian shelf and the inner part of Harrison Bay off northern Alaska have shown the rates of seabed reworking by ice on the order of 2% per year. Depth of incision averaged 20 centimeters but ranged up to 1.2 meters. (Barnes et al., 1978)

In this report present the analysis of a much larger data set from a broader geographical area than earlier studies. This new data extends into deeper water and also covers a greater time span than has been reported on previously. We then discuss preliminary interpretations of new gouge maximums, means and other observed trends.

Study Environments

The data set consists of repetitively run tracklines; the information being gathered aboard a small research vessel in the form of fathograms and monographs. Some lines have been resurveyed for up to 8 years, but for most we have only a few years of record. As other researchers may wish to reoccupy these lines the methods of navigation and the location of the shore stations used in surveying each of the lines is given in Table II.

A description of the geologic environments for each of the lines from west to east (Fig. 1) outlines the variability in physical environment encountered along the coast. The ice regime has been discussed by Reimnitz et al. (1978). Briefly, it is composed of a relatively stable winter ice sheet, called fast ice, inshore of a zone of grounded ice ridges called the stamukhi zone. The boundry between the fast ice and the stamukhi zone generally lies in water depths of 15 to 35 meters. Isolated ridges and grounded blocks of ice may occur inshore of the stamukhi zone. In particular, at around 10 meters depth in Harrison Bay, an inner stamukhi zone has been noted in several years and is composed of linear ridges which parallel the isobaths.

Line 9 - This line extends northeast from the chain of sand and gravel islands which stretch east from Point Barrow. Water depths rapidly increase to 5 meters seaward of the islands then steadily increase such that the 20 meter contour is not crossed until more than 18 kilometers from the islands. There are no noticeable shoals or benches along this trackline. The bottom sediments in this area are muds and muddy sands with the coarser sediments occurring inshore.

Line4 - This is another northeast trending line which starts in shallow water offshore from a coastline with 1 to 2 meter high tundra bluffs. The water depths gradually increase to about 15 meters where a 1 to 2 meter high shoal exists. The seafloor continues to deepen seaward from here to 19 meters depth at 24 kilometers from shore. The seafloor then rises a few meters over a broad shoal at the outer end of line. The sediments along this line are characterized as muddy sands and sandy muds although there is no onshore-offshore grainsize pattern.

Line 1 - This is one of our oldest lines having been originally established in 1975 and one for which we have the most repetitive surveys. The line extends northwest from Thetis Island on the eastern side of Harrison Bay. The bottom drops quickly at 7 meters depth seaward of the island, then gently to water depths of 15 meters or more in the central part of Harrison Bay. The sediments along this line are sands and muddy sands inshore with an increasing proportion of muds offshore.

Line 2 - Extending north from Spy Island in the northeast corner of Harrison Bay, this old line is marked by 2t03 meter high shoals at 12 and 15 meter water depths. This line reaches its' seaward limit at a depth of nearly 20 meters. Except for the shoals, which are mostly clean sands and gravels, the sediments are typically seaward fining sands and muds.

Line 3 - Although established in 1975 this line has seldom been repeated due to the persistence of ice in this area. The line extends north equidistant from Cross and Reindeer Islands (north of Prudhoe Bay). The bottom profile is steeper than those of the lines discussed above and the lines from here east to Camden Bay are steeper than those to the west. Proceeding seaward, line 3 crosses a 4 meter high shoal in 13 meters of water then drops to a depth of 19 meters before rising gradually to a small shoal or bench between 18 and 22 meters water depth. The shoal is composed of sand and gravel while the sediments elsewhere along the line are sandy muds and muds. Just inshore of the break in slope at 18 to 22 meters the bottom is an overconsolidated mud which is common here and elsewhere on the shelf (Reimnitz et al., 1980).

Line 6 - This line extends northeastly from the chain of islands stretching east from Prdhoe Bay. Its' steep profile crosses a bench at 18 meters water depth and continues dropping to water depths of more than 25 meters. The sediments in this area are quite varied and are commonly overconsolidated. Sediment descriptions include pebbly clays and stiff sandy muds. At the innermost end of the line boulders up to 50 centimeters in diameter have been observed on underwater TV.

Lines 5 and 8 - Line 5 was established using navigation stations that ultimately could not be reoccupied and we subsequently established a nearby line (line 8) using more permanent benchmarks. Both 5 & 8 increase water depth more rapidly in comparison to the lines further west and show an irregular profile such that the shoal or bench at 18 to 22 meters is difficult to discern. Inshore sediments are sand and gravel while at about 20 meters and seaward overconsolidated sandy muds and pebbly sandy muds are found.

Line 7 - This line is located in Camden Bay and extends north from a coast of tundra bluffs. Starting in water depths of about 6 meters the profile gradually drops to depths of more than 16 meters, similar to the profiles from Harrison Bay westward. Sediments are sands and muddy sands on the inner part of the line while in water depths of about 18 meters overconsolidated sandy muds and clays are found.

METHODS

Navigation

Annual comparison of sidescan and fathometer records were made over one kilometer intervals. The initial kilometer point began, when possible, on the baseline or one kilometer offshore of land (barrier island or coast). From this initial point kilometer intervals were measured on the navigation charts and time at the kilometer points was determined. These times were then used to correlate the monographs and fathograms with the navigation at the established intervals. As pointed out in Attachment K, systematic errors did occur. Therefore, seabed and ice gouge "matches" were used wherever possible to establish comparisons between records.

Measurement of Characteristics

The enumeration of new gouges was accomplished through the comparison of sonograph records. From Table I it will be seen that each line was not surveyed every year. In the case of some lines (3, 4, and 9) two to four years passsed between reruns of the lines.

Side Scan sonar records were used to determine the number of new gouges added during the previous year(s). The total number of gouges in each segment was also determined. The percent of new gouges to the total was calculated for each interval . Other measurements taken from the monographs included gouge orientation , gouge width, disruption width of multiple gouges, length of gouges, and their location along the trackline (±50 meters).

Fathogram records were used to determine the maximum depth of the new gouge below the seafloor, maximum height of ridge of plowed sediments from the new gouge, and the water depth at which the new gouge occured. In the case of multiples only the deepest incision was measured.

Other observations of interest were noted in the comments column of the data sheets (Fig. 2). Ice gouge termination directions were determined whenever possible as this is one of the few ways in which the direction of ice keel movement can be authenticated. Sediment wave orientations were determined whenever observed on the monographs as these have a direct application to sediment movement and infilling related to gouge obliteration. On some lines older gouges formed in cohesive sediments are reexposed when non-cohesive sediment cover is redistributed by waves and currents (Barnes and Reimnitz, 1979). These gouges could be misinterpreted as new gouges and, therefore, where this occured it was noted on the data sheets.

Because the length to width ratio of the monographs varies from year to year due to differences in paper speed through the recorder and boat speed during the survey, templates were used to correct for this distortion. The templates correct for the distortion that occurs in orientation and gouge width measurements.

Year To Year Differences

In addition to the year to year variability of actual ice gouge processes, artificial factors based on the survey techniques and data quality enter into the comparisons. Ice conditions varied from year to year and, thus, the length of the survey lines has varied. Therefore, summarized data for tracklines is not strickly comparable area to area or year to year because of these different lengths, different ice conditions, and different water depths. The variable record quality leads to uncertain correlation from year to year which may have resulted in calling gouges "new" when in reality they were poorly defined on previous records. It is also true that some "new" gouges may have been missed due to poor record quality, sedimentation, or deviations from the set trackline course due to ice. We estimate that, at most, about 25% overcounting of the gouges may have resulted but these would be concentrated in the small, short and shallow gouges which are the least clear on the monographs and fathograms.

PRELIMINARY RESULTS

Observations

Of the 146 kilometers of testline that make up the present set of data we have available 308 one kilometer segments for which we have repetitive observations. These data are broken down into22 line comparisons which represent a year or more separation between resurveys of the individual tracklines. In doing this we observed over 2500 new gouges in the seabed with several being over 1 meter in depth and the maximum depth being 1.4 meters. The total number of new gouges accounted for over 12 kilometers of linear disruption when measured at right angles to the gouges.

The average new gouge occured in water 14.3 meters deep and incised the bottom to a depth of 19 centimeters. New gouges averaged 8.2 per kilometer with an average disruption of 39 meters per kil ometer. As with our data set on the areal distribution of ice gouge character (Rearic et al. , 1981) the data weighted heavily for the shallow inshore waters, generally less than20 meters deep. The annual percent of seafloor disturbed ranged from a lowof 0.3 to a high of 7.4 and averaged 3.2, slightly higher than that found in the previous studies of Reimnitz et al. (1977) and Barnes et al. (1978).

Gouge Depth

A comparison of the number of new gouges with their depths exhibits an exponential distribution (Fig. 3). The distribution of new gouge depths is similar to the distribution determined for all gouges on the shelf (Barnes et al., in press). Also of note is the trend in new gouge multiplet depths which are comaprable to the trend established for all new gouges from our lines.

Areal Variability

Despite the variability in geographic, sedimentologic, and ice environments of the different lines, ice gouging occurs ubiquitously in the areas studied and is presently occurring in all water depths studied. Ice gouging is rather uniformly distributed inside the 15 meter contour (Figs. 4 to 10 and Tables 111). Even with the markedly steeper profiles of the lines near Prudhoe Bay (3, 6, 5, and 8) the number of gouges is not noticeably higher than the more gently sloping lines to the east and west. Given the same distribution of ice keels in the ice canopy over the seafloor a steep rather than gently sloping bottom should be impacted by more ice keels per unit distance. This is not born out by data.

Both new gouge incision depths and disruption widths show a tendency to increase in deeper water although this trend is not clear cut (see lines 6 and 9). An increase in these values with deeper water would follow considering that larger and more massive ice ridges can develop or move into these depths. Perhaps the data set does not cover a sufficient time period to observe these expected trends.

At water depths of 15 to 20 meters almost all of the records show a sharp increase in all parameters - numbers of gouges, disruption widths, and incision depths. This water depth is commonly the inner edge of the stamukhi zone each year (Reimnitz et al., 1978). The increase in new gouging in this zone is in keeping with the vastly increased ridging activity here and confirms our earlier postulations that gouging would be more intense in this zone (Reimnitz and Barnes, 1974; Barnes et., 1978; and Barnes et al., in press).

Time Variability

The variability of the ice regime from year to year should be reflected in the intensity of new seafloor gouging. Ice conditions on the inner shelf can vary from a season like 1975 in which at the end of summer large amounts of ice from the previous winter remained and were incorporated in the following winters ice canopy to years like 1980 when the inner shelf was essentially free of older ice. In the former case older ice blocks would act as solid ice pinicles within a moving ice canopy and could form a neucleus for grounded ice ridges. When first-year ice is present its greater density (Attachment J) may al low deeper keels to form. However, these keels would be less competent in their ability to gouge having not undergone extensive welding of sucessive freeze - thaw cycles as have older, multiyear ice blocks(Kovacs and Mellor, 1974). Although they may lack the competency of the older ice keels recent studies show that they are still capable of extensive shallow gouging (Barnes et al., in press).

The time series data we have to examine is rather limited, consisting of 5 years of record on one line and 4 and 3 years of record at two other lines (Figs. hand 12). The most obvious conclusion from this data is that no striking differences are evident from the year to year comparisons. There is some suggestion that the number and size of new gouges in 1979 and 1980 were less than in other years for which we have data. This suggestion is strongest for 1980 on lines 2 and 6 (Figs. 11 and 12) but not at all clear for the same years on line 1 (Fig. 11). Again, the lack of correlation is perhaps due to the short length of record we have in light of the fact that the bottom is only gouged a few percent per year. Further analyses will investigate the intensity of new gouges and the relationship of multiplet gouging to the year to year patterns.

CONCLUSIONS

1. The intensity of new gouging is related to water depth and bottom morphology, and increases offshore at least to water depths of about 25 meters. Inshore of the stamukhi zone the amount of gouging and the depth of gouging is rather uniform even into waters less than 10 meters deep.
2. No correlation exists between the density of new gouges and the depth to which new gouges have penetrated the seafloor. This results because large numbers of new *gouges* are associated with wide shallow multiplet gouging (first-year pressure ridges).
3. Areas that have high gouge densities and large disruption widths are due to multiplet events. A few large multiplet events may account for extensive but shallow disruption of the seafloor.
4. Annual variations in the number of individual verses multiplet gouges may be related to the presence or absence of multi-year ice ridges on the shelf during winter freeze-up.
5. There are annual variations in the data that suggest only minor year to year changes in the areas influenced and the intensity of gouging although major differences in the ice canopy are expected.

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Table I.

Line	Baseline Length	Geographical Name	Survey Year	Time Between Surveys
1	-----	Thetis Is.	1975	Base Year
			1976	1
			197-7	1
			1978	1
			1979	1
			1980	1
			1981	1
			1982	1
2	-----	Spy Is.	1975	Base Year
			1976	1
			1977	1
			1978	1
			1979	1
			1980	1
			19s1	1
3	(14936m)	Cross Is.	1979	Base Year
			1982	3
4	(12622m)	Cape Halkett	197'7	Base Year
			1978	1
			1980	2
			1982	2
5	(16744m)	Flaxman Is.	1979	Base Year
			1980	1
6	(21926m)	Karluk Is.	1979	Base Year
			1980	1
			1981	1
			1982	1
7	(13544m)	Camden Bay	1981	Base Year
			1982	1
8	(18430m)	Flaxman Is.	1981	Base Year
			1982	1
9	(17639m)	Cooper 1s.	1'376	Base Year
			1982	4

Table II.

Line	Course	Navigation (Shore Stations)	Remarks
1	305 T	1) Thetis Is. Benchmark (~10m south of hut) 2) Oliktok Pt. 300ft. Tower	Range alignment of Oliktok tower and Thetis Island hut. Distance along line is measured from Thetis Is. or Oliktok.
z	358 T	1) Spy Is. benchmark (under 1950's wooden tower) 2) Oliktok Pt. 300ft. Tower	Range alighnment of Oliktok tower and tower over Spy Island benchmark. Distance along line measured from Spy Island or Oliktok.
3	000 T	1) Reindeer Is. tower (USGS tower at Humbolt C-1 well (lat. 79 29'12"; long. 148 20'25") 2) Cross Is. (top of USCG RACON tower)	Line is run equidistant from Reindeer and Cross Island.
4	027 T	1) Cape Halkett RACON tower 2) Northeast corner of the sod hut at Esook	Line is run equidistant offshore from the two stations.
5	One shore location has been lost and the testline has not been resurveyed.		
6	028 T	1) Pole Is. (USGS 50ft.tower) 2) Narwhal Is. (150ft.tower)	Line is run equidistant from Pole and Narwhal Island stations.
7	000 T	1) "Collinson Point" benchmark 2) Benchmark "Koganak" (~13.2km east of "Collinson Point")	Line is run equidistant from the two stations.
8	006 T	1) Brownlow Point RACON tower 2) Benchmark "Roda" near Point Thompson	Line is run equidistant from the two stations.
9	020 T	1) Cooper Is. NOS benchmark 2) Igilik Is. benchmark	Line is run equidistant from the two stations.

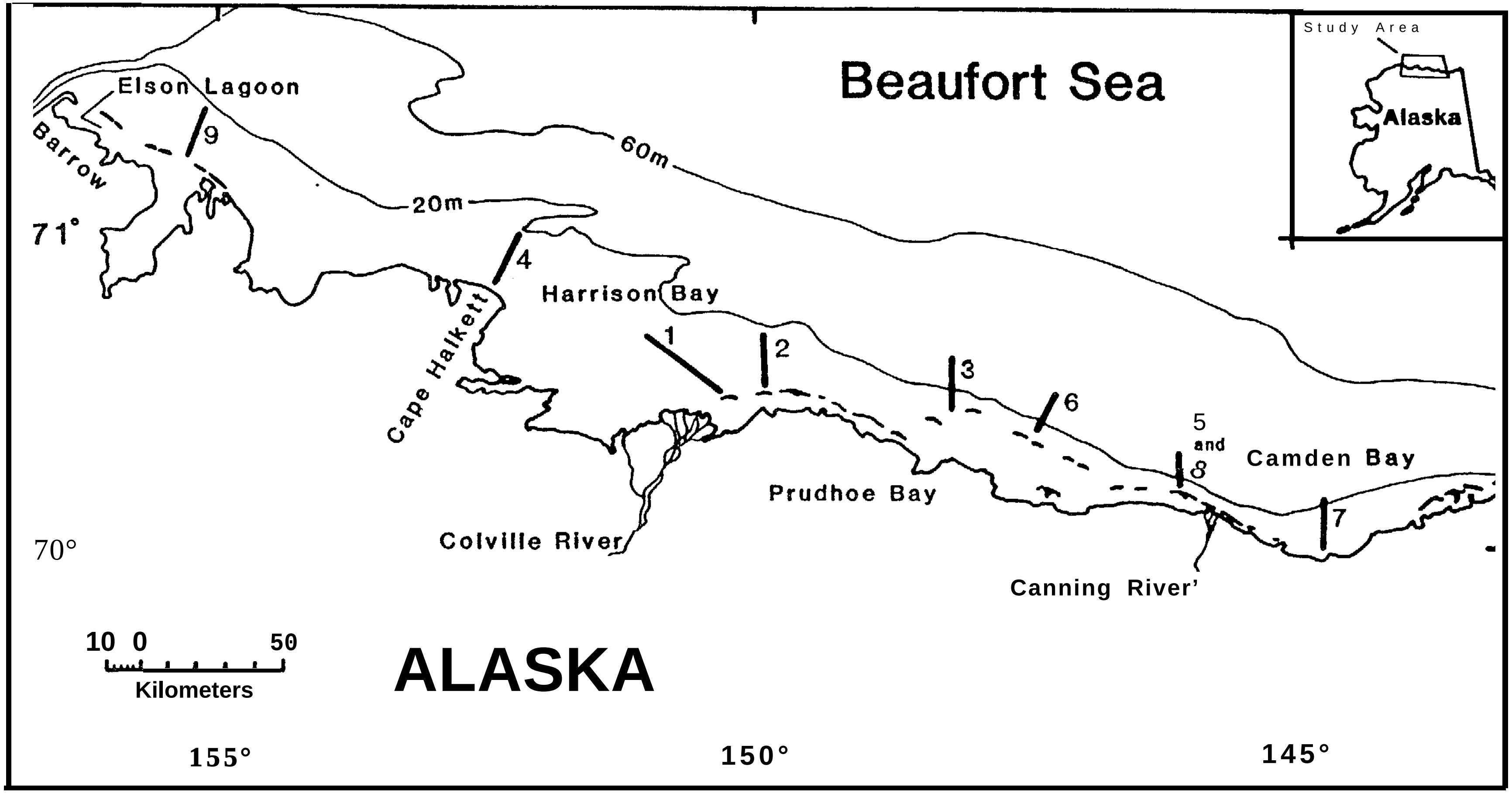

Fig. 1 Test line locations and generalized bathymetry for the Alaskan Beaufort Sea.

TEST LINE: 4	JULIAN DATE: 219	YEAR: 1980								TEMPLATE IDENTIFICATION: 1:1.633					
TRACKLINE NUMBER: 20					Length SINGLE GOUGES					Length MULTIPLE GOUGES					CS: 027°T
SEGMENT	WATER DEPTH (M)	TOTAL GOUGES	TOTAL NEW GOUGES	%	NEW SINGLE GOUGES	GOUGE DEPTH (M)	GOUGE WIDTH (M)	RIDGE HEIGHT (M)	ø (°T)	NEW MULTI. GOUGES	NUMBER OF INCIS.	DEEPEST INCISION (M)	DISRUPT WIDTH (M)	ø (°T)	COMMENTS 55 #7 Bats #14,15
AC/0	—	—													NO SONAR – NO BATHY.
BC/1	3.1	25	5	20.0											Bottom contains many reexposed gouges and
1.15	3.3				NL	<.2	1	<.2	148/175						causes difficulty in observing new ones.
1.50	4.0				NL	<.2	1	<.2	44/71						
1.60	4.2									NL	2	<.2	7	176/23	
1.80	4.8				NL	<.2	1	<.2	50/77						
CD/2	5.1	24	3	12.5											
2.05	5.2				NL	.2	5	.2	52/79						Termination Direction 259°T
2.40	5.9				NL	<.2	2	<.2	65/92						
2.50	6.0				NL	<.2	3	<.2	50/77						
															* *
DE/3	6.6	23	0	0.0											Sand waves on seafloor. Their shifting reexposes
															old gouges in troughs. Many gouges that are
EF/4	7.6	18	4	22.2											on 1978 record are gone (covered by sand) while
4.60	8.3				NL	<.2	1	<.2	136/163						many reexposed older gouges on 1980 record
4.90	$.3									38	3	<.2	21	150/177	were not observed on the 1978 record.
															These old gouges have orientations of 40-80°T.
FG/5	8.8	26	4	15.4											Sand waves have period of 100-150 m with 20-40 m
5.20	8.7									NL	2	<.2	4	160/07	height. * *
5.30	9.0				NL	.4	5	.4	23/60						
5.35	9.0				NL	<.2	3	<.2	122/149						
GH/6	9.2	48	5	10.4											
6.80	10.4				NL	<.2	1	<.2	27/54						
6.90	10.3									NL	3	<.2	12	45/72	
6.95	10.2				50	NC	2	NC	16/43						

Fig. 2 Test line data Sheet used to record new gouges and their characteristics. Note other remarks in the comments column regarding reexposed gouges, sediment waves, and gouge terminations (indicating direction of ice keel movement). Orientations are reported between 0° and 180° true north but do not indicate direction of movement.

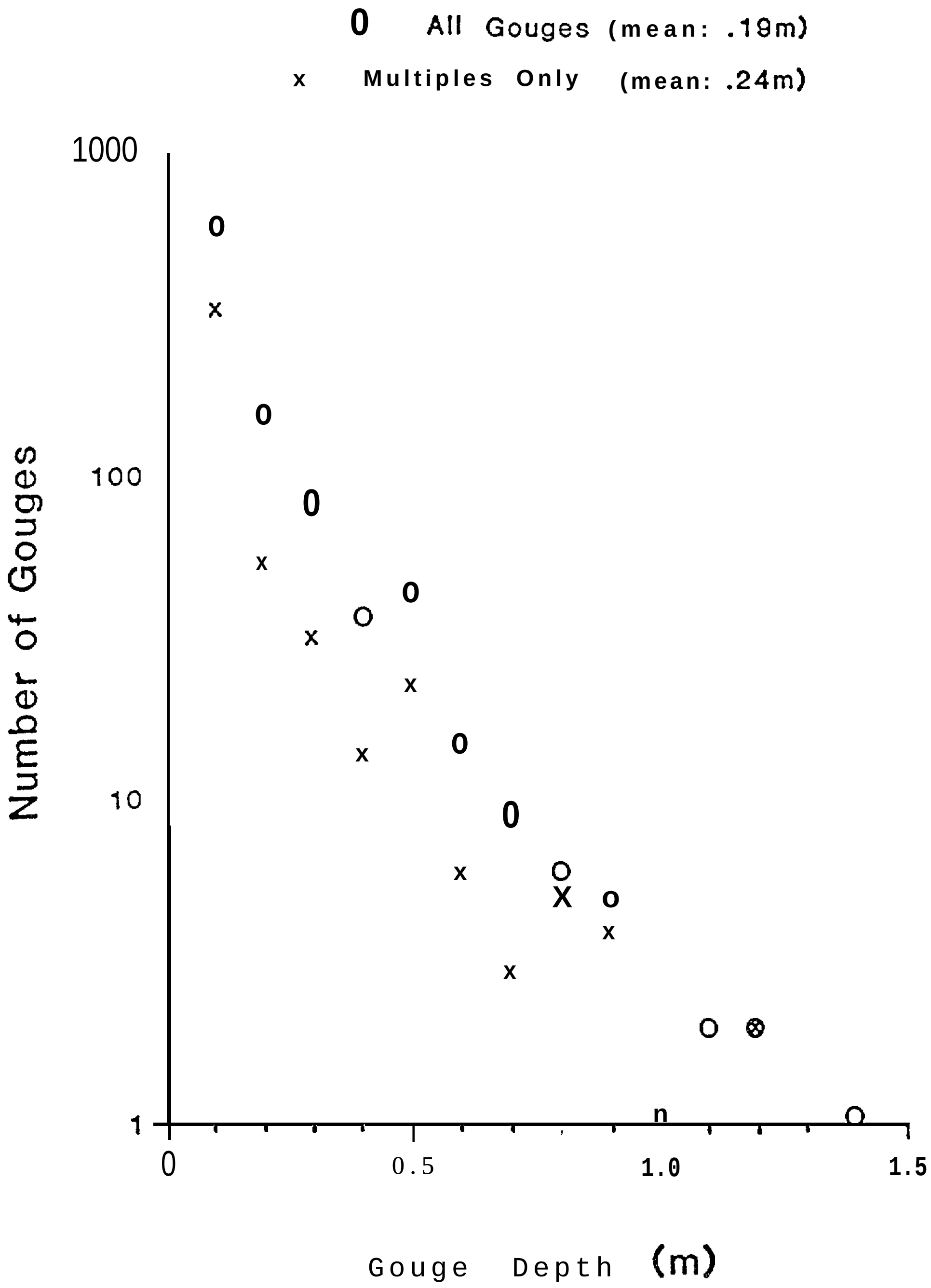

Fig. 3

Graph of the number of new gouges us. gouge depth plotted on semi-log coordinate axes. Gouges between .2 and .9 meters deep approximate a straight line indicating an exponential distribution (see Weeksetal., in press).

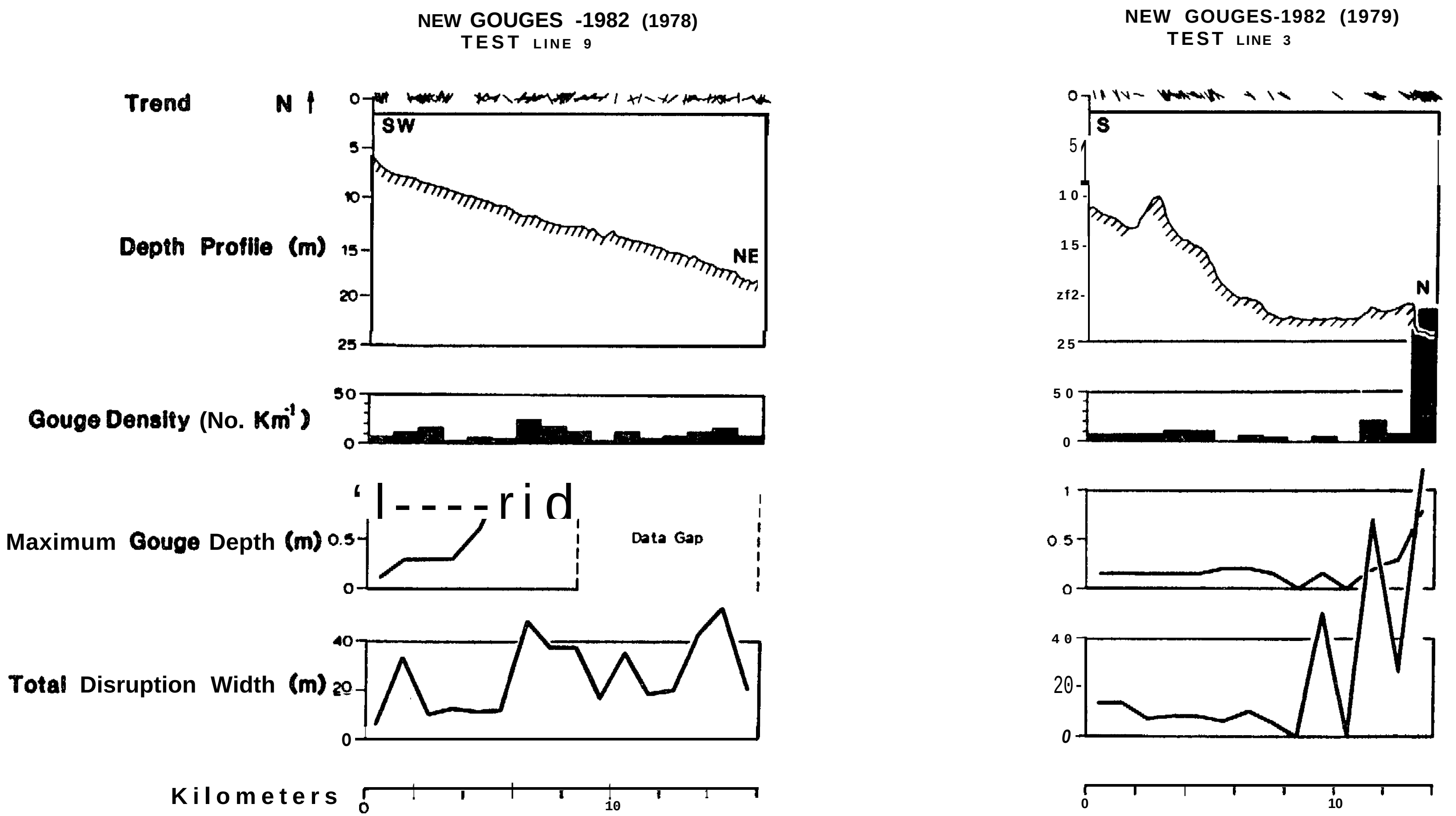

Fig. 4 Graph of new gouge characteristics and bathymetry profile vs. length of trackline for test lines 9 and 3. Vertical exaggeration is 1:400 for figures 4 through 10. The year in parentheses is the base year of the record that the present record is compared to (4 year span between surveys for testline 9; 3 year span for testline 3).

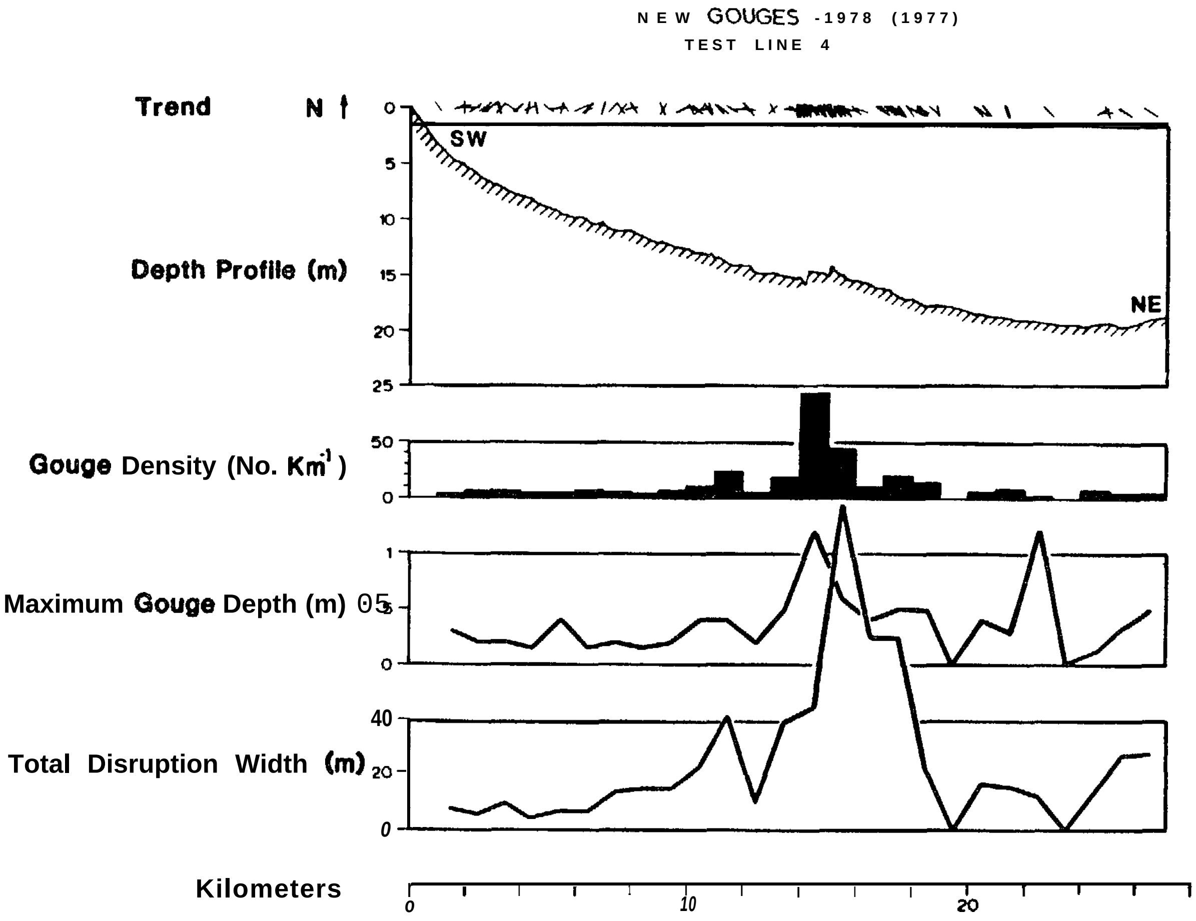

Fig. 5 Graph of new gouge characteristics and bathymetry profile vs. length of track line for test line 4 (1 year span between surveys).

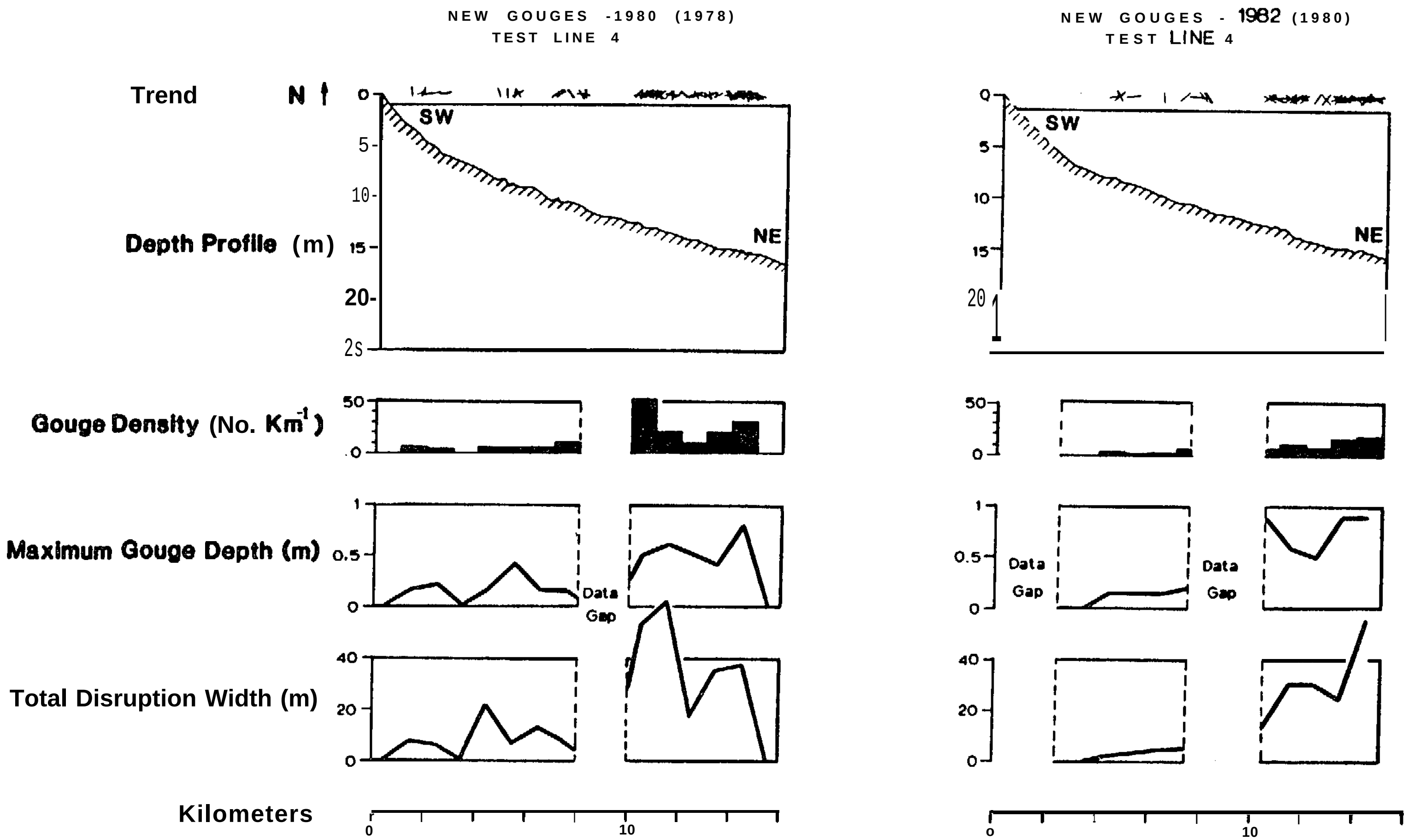

Fig. 6 Graph of new gouge . characteristics and bathymetry profile vs. length of trackline for testline 4 (2 year spans between surveys).

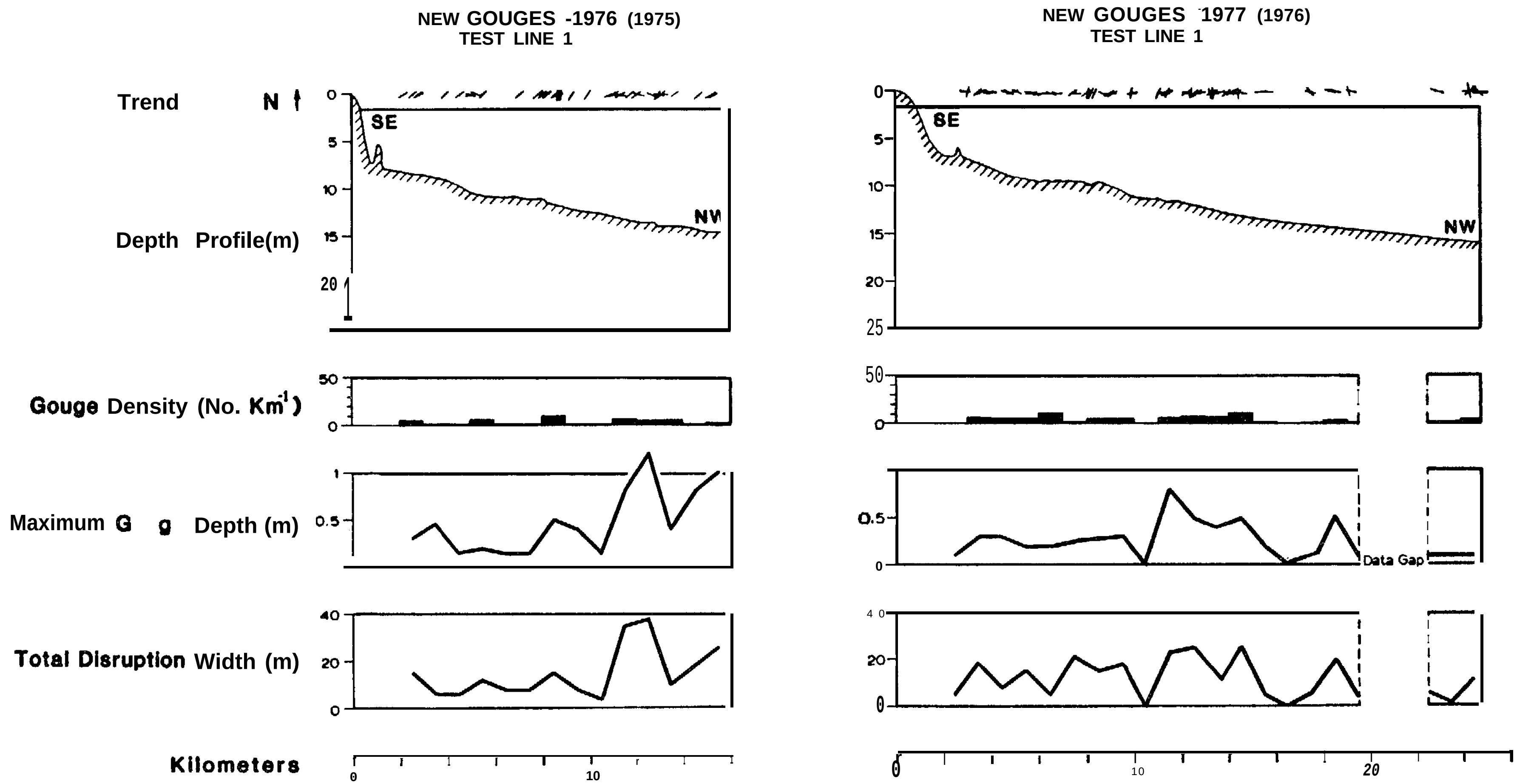

Fig. 7 Graph of new gouge characteristics and bathymetry profile us. length of track line for- test line 1 (1 year spans between surveys]. See USGS Open-File Report $$78-730 for data tables for these survey years.

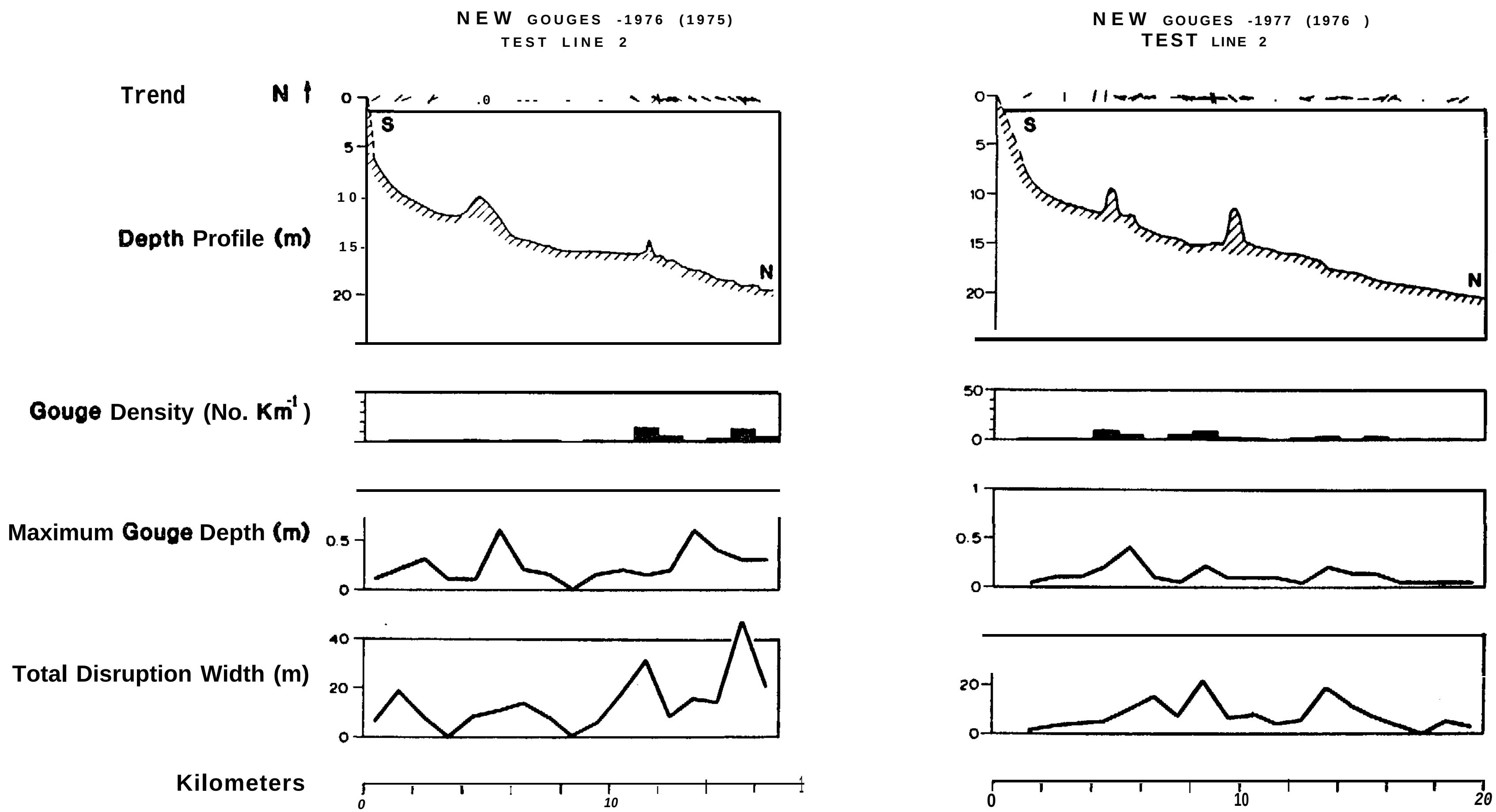

Fig. 8 Graph of new gouge characteristics and bathymetry profile vs. length of track line for test line Z (1 year spans between surveys]. See USGS Open-File Report 878-730 for data tables for these survey years.

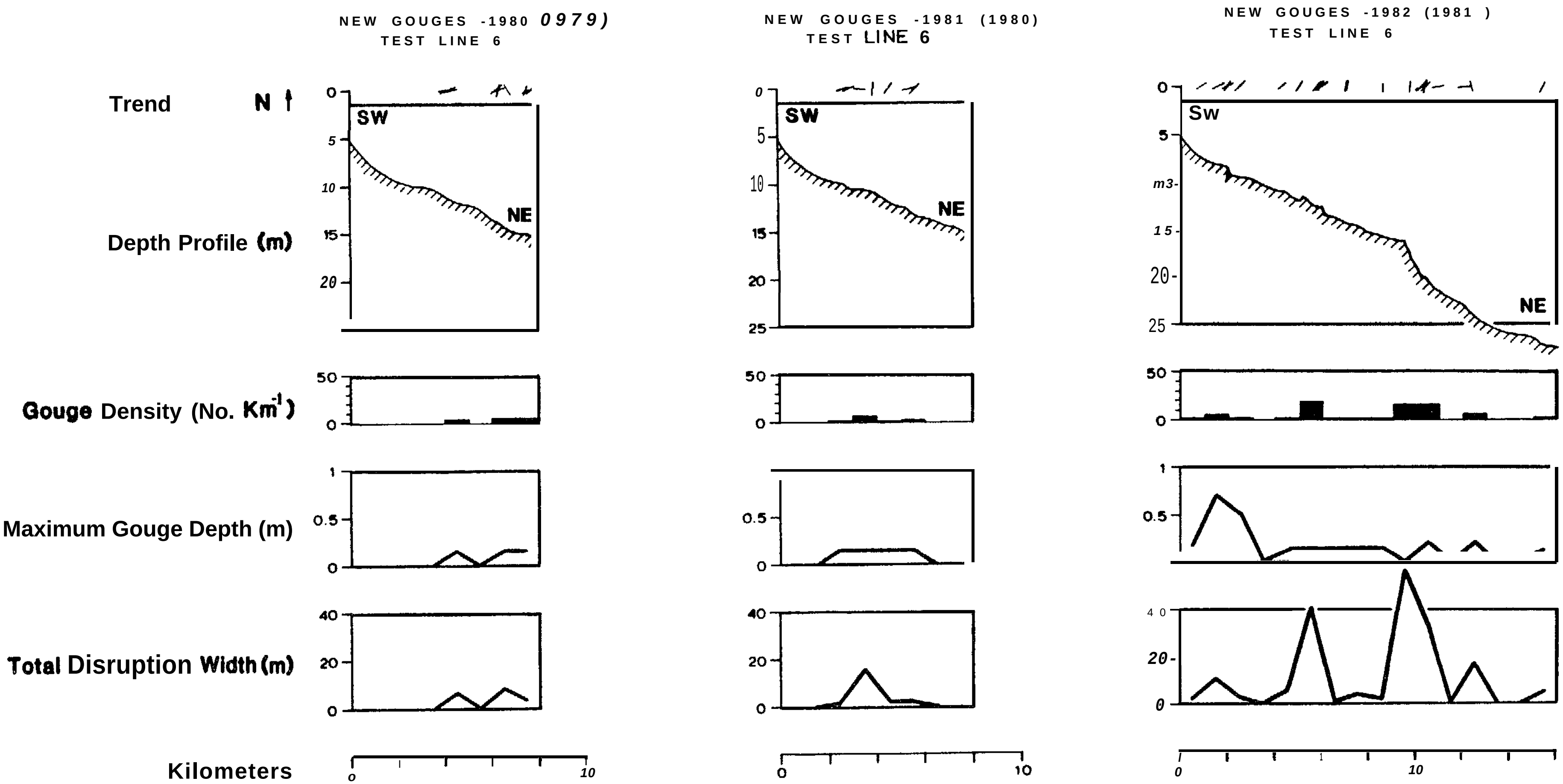

Fig. 9 Graph of new gouge characteristics and bathymetry profile vs. length of track line for test line 6 (1 year spans between surveys).

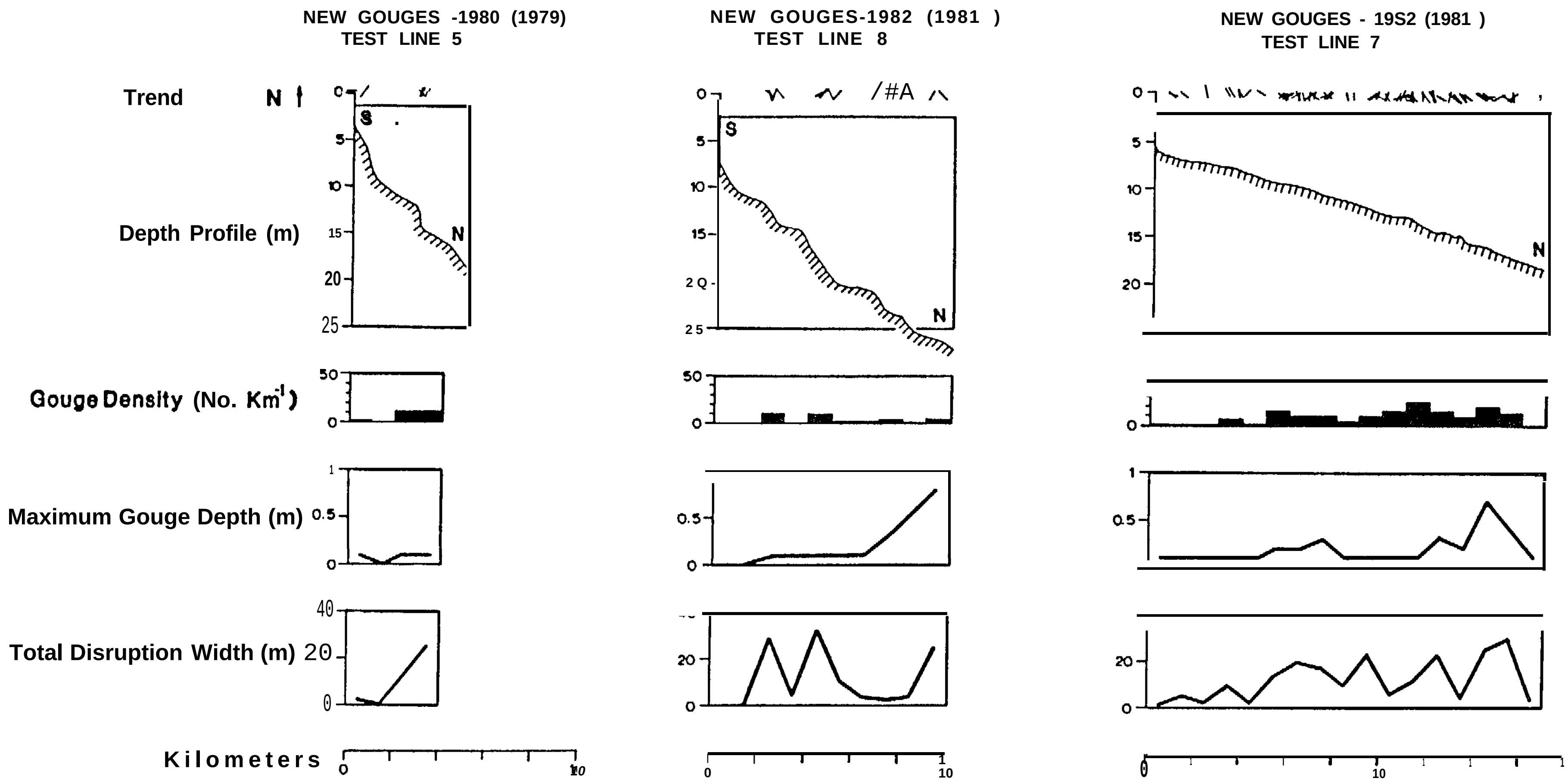

Fig. 10 Graph of new gouge characteristics and bathymetryprofile us. length of track line for test lines 5, B, and 7 (1 year spans between surveys).

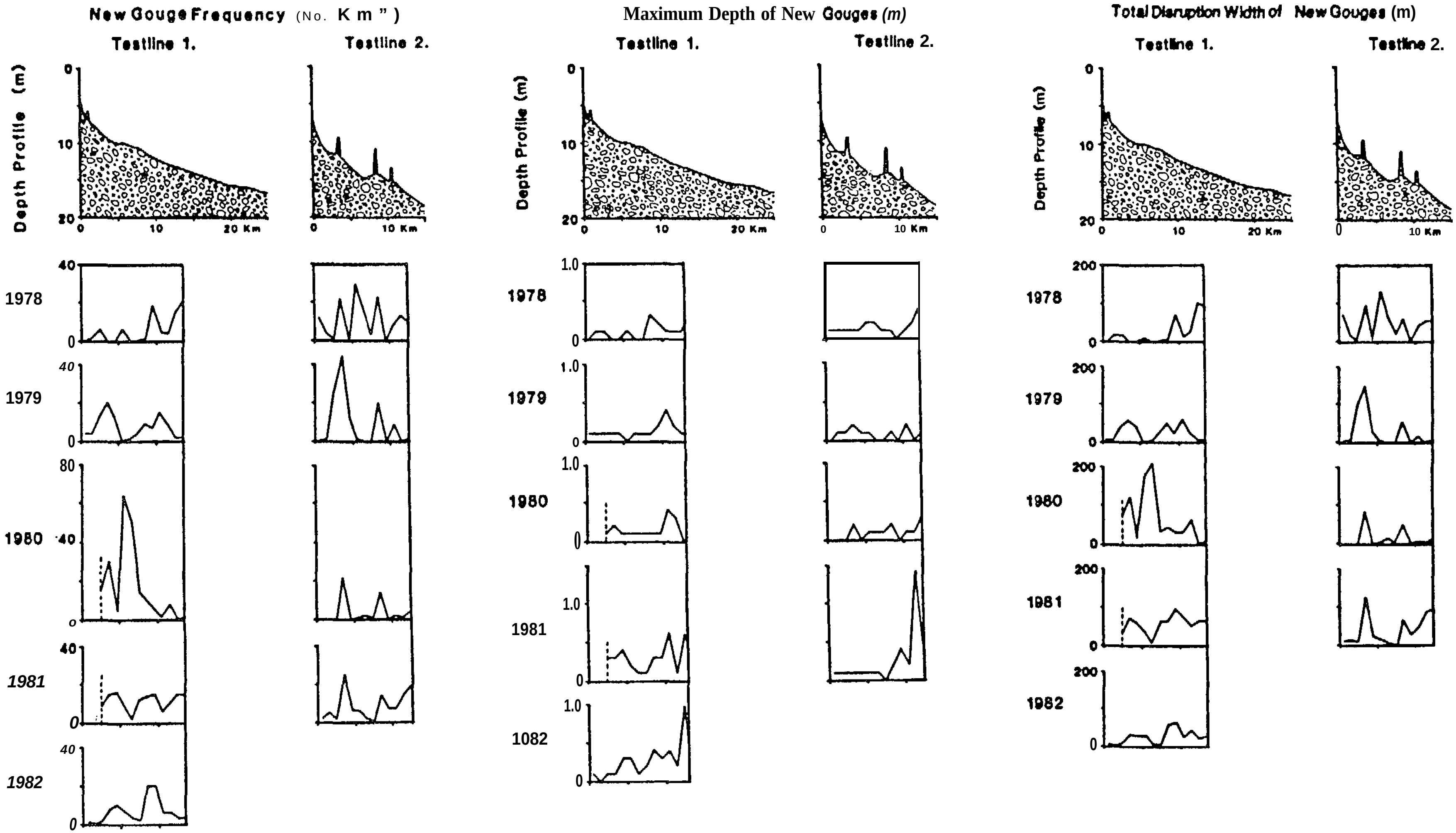

Fig. 11 Graph of new gouge characteristics and bathymetry profile vs. length of track line for test lines 1 and 2 (1 year spans between surveys). Vertical exaggeration is 1:1000. Although data on the characteristics extends beyond the plotted trackline length for most surveys (Table III) the shortest survey determines the length that may be used in a time series analysis of the characteristics.

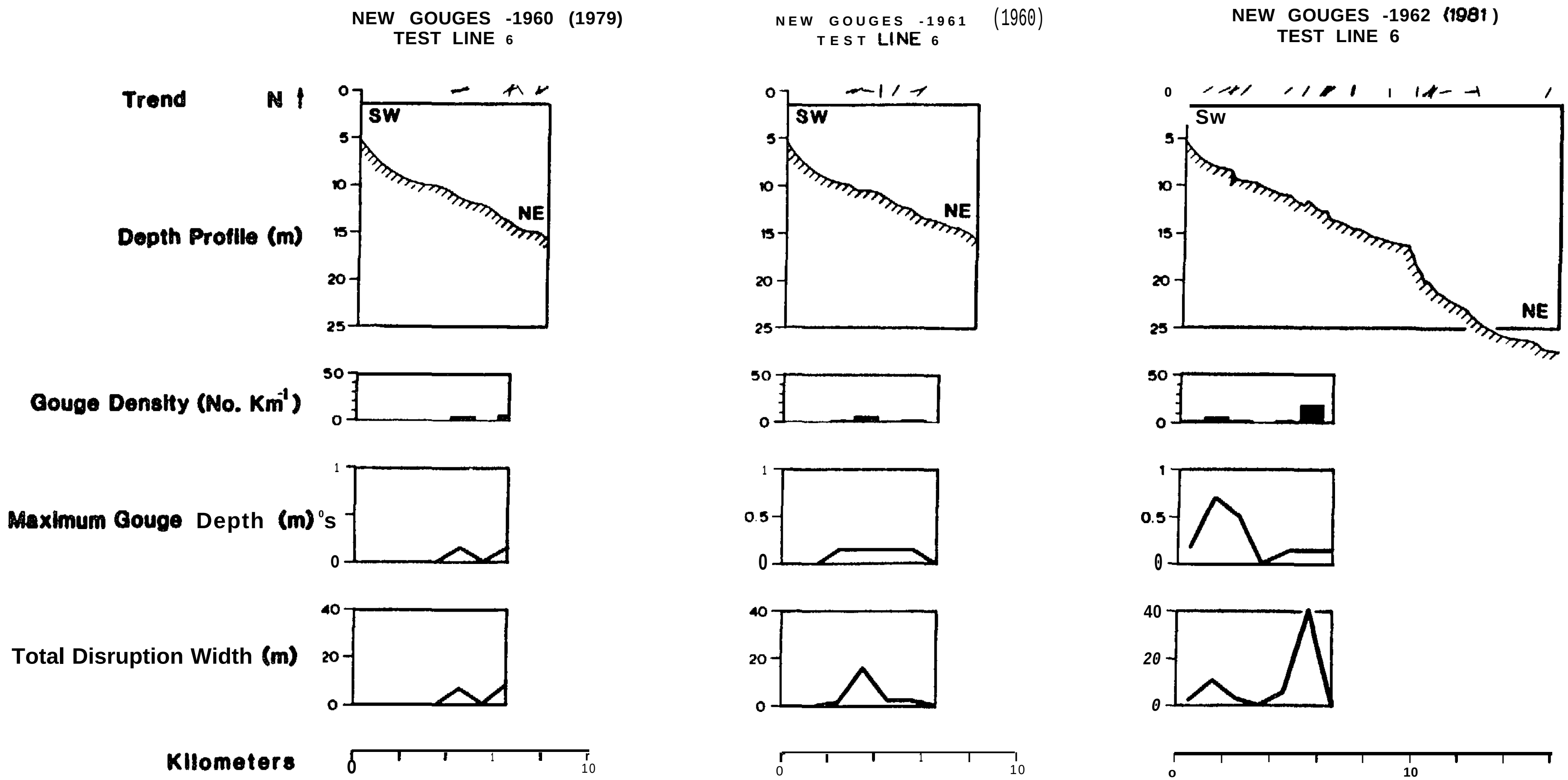

Fig. 12 Graph of new gouge characteristics and bathymetry profile vs. length of track line for test line 6 (1 year spans between surveys). Vertical exaggeration is 1:400. Data from the longer surveys have been deleted in order to reduce all tracklines to the same length for time series analysis (see figure 9 for complete graphs).

Table III.

Testline 9-COOPER ISLAND

		Total	avg/Km	% disturbed (in 4 yr)
Water Depth (m)	6.0 7.7 8.5 9.3 10.0 10.9 11.8 12.4 13.0 13.5 14.0 74.6 15.4 16.2 17.0 18.2 18.7			
No. of New Gouges (m) 1978-1982	7 1 0 1 6 I 7 5 2 3 1 8 1 2 2 1 1 4 7 12 16 7	158	9.9	
Maximum Gouge Depth (m) 1978-1902	.1 .3 .3 .3 .6 1.1 1.1 .7 .9 x .2 x x x x x	Deepest .1		
Total Disruption Width (m) 1970-1902	19 53 71 13 49 51 159 147 132 23 83 43 72 107 142 86	1250	78.1	7.8

Total NO. of New Gouges-158 Deepest New Gouge - 1.1 m Total Disruption Width . 1250 m Mean % disturbed = 2.0

see Fig. 4

Testline 4-CAPE HALKETT

		Total	avg/Km	%disturbed
Kilometers	0 1 2 3 4 5 6 7 8 9 1 0 1 1 1 2 1 3 1 4 1 5 1 6 1 7 1 8 1 9 2 0 2 1 2 2 2 3 2 4 2 5 2 6 2 7			
Water Depth (m)	x 3.2 5.1 6.8 7.8 8.7 9.5 10.4 11.0 11.9 12.5 13.1 14.0 14.7 15.0 15.4 16.2 16.6 17.5 18.2 18.7 19.0 19.3 19.6 19.9 19.7 19.7 18.5			
No. of New Gouges 1977-1978	x 4 6 7 4 4 6 5 4 6 1 1 2 4 5 1 9 9 8 45 11 21 1 3 0 6 7 2 , 3 6 5 5	Tots 1 322	12.4	
1978-1900	x 5 3 0 4 4 5 9 x x 5 2 2 0 1 0 2 1 31 x x	164	13.7	
1980-1982	x x 0 0 3 1 1 6 . . 8 1 3 8 17 19	76	6.9	
Maximum Gouge Depth (r,) 1977-1978	x .3 .2 .2 .1 .4 .1 .2 .1 .2 .4 .4 .2 .5 1.2 .5 .4 .5 .5 0 .4 .3 1.2 0 .1 .3 .5	Deepest 1.2		
1978-1980	x . 1 . 2 0 . 1 . 4 . 1 .1 x x .5 .6 .5 .4 .8 x x	.8		
1980-1982	x x 0 0 .1 .1 . 1 . 2 , X .9 .6 .5 .9 .9	.9		
Total Disruption Width (m) 1977-1978	x 16 16 13 13 19 16 24 18 36 46 134 24 96 398 321 122 200 68 0 33 34 13 0 29 39 28	1756	67.5	6.8
1978-1980	x 1 1 1 3 0 2 2 1 4 1 6 2 2 . , 223 77 79 101 212 x x	790	65.8	6.6 (2 yrs.)
1980-1982	x x 0 0 6 4 5 20 x x 46 76 61 134 1 44	496	45.1	(24;..)

Total No. of New Gouges - 562 Deepest New Gouge - 1.2 . Total Disruption Width - 3042 m Mean% disturbed = 4.1 per year

see Figs. 5 and 6

Note : x's refer to no record available for segment; o's refer to no gouge parameter observed on record.

Table III. (con't)

Testline 1 Thetis Island

kilometers	0		2	3	4	5	6	7	8	9	10	11	12	3	4														
									[illegible]	[illegible]	12.0	12.4	12.6	13.1	13.0	13.6	14.2	14.6	14.9	15.1	15.2	15.5	15.4	16.0	16.5	16.7			
No. of New Gouges																													
1977-1978	0	2	6	0	0	6	0	0	1	18	5	4	15	21	18	8	4	0	0	0	0	10	4	5	0		Total	avg/km	
1978-1979	4	4	13	20	12	0	1	4	9	7	15	9	2	2	6	24	8	3	8	1	x	x	0				127	5.1	
1979-1980	x	x	16	30	4	64	51	14	10	5	2	8	0	1	3	40	4	x	13	13	0						142	6.8	
1980-1981	x	x	9	15	16	9	2	12	14	15	6	11	15	15	22	30	7	9									278	15.4	
1981-1982	1	0	2	8	10	7	3	2	20	20	6	6	3	3													207	12.4	
	5	6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	54	65	34	38	35	42															
Maximum Gouge Depth (m)																													
1977-1978	0	.1	.1	0	0	.1	0	0	.3	.2	.1	.1	.1	.3	.2	.3	.5	0	0	0	0	.5	.3	.3	0		Deepest		
1978-1979	.1	.1	.1	.1	.1	0	.1	.1	.1	.2	.4	.2	.1	.1	.1	.1	.2	.1	.2	.2	x	x	0				.5		
1979-1980	x	x	.1	.2	.1	.1	.1	.1	.1	.1	.4	.3	0	.1	.2	.4	.2	x	.3	.3	0						.4		
1980-1981	x	x	.3	.7	.4	.2	.1	.1	.3	.3	.6	.1	.6	.3	.2	.3	.3	.2									.4		
1981-1982	.1	0	.1	.1	.3	.3	.1	.2	.4	.3	.4	.2	1.0	.5													.7		
Total Disruption Width (m)																													
1977-1978	0	18	20	0	0	9	0	0	4	70	3	29	102	92	46	60	37	0	0	0	0	49	24	46	0		Total	avg/km	% disturbed
1978-1979	8	8	42	59	45	0	3	25	50	24	60	25	6	5	23	101	30	12	33	4	x	x	0				609	24.4	2.4
1979-1980	x	x	71	123	14	174	214	31	43	33	31	62	0	10	27	146	21	0	82	82	0						563	26.8	2.7
1980-1981	x	x	30	70	58	36	8	64	62	96	71	51	74	62	105	113	35	40									1164	61.3	6.1
1981-1982	1	0	10	31	31	29	4	5	58	62	25	42	22	28													975	60.9	6.1
	9	26	173	283	148	248	229	125	217	285	190	209	204	197	201	420	123	52	115	86	0	49	24	46			348	24.9	2.5

Total No. of New Gouges = 845   Deepest New Gouge = 1.0 m   Total Disruption Width = 3659 m   Mean % disturbed = 4.0

see Fig. 11

Testline 2. - Spy Island

Kilometers																		
Water Depth (m)																		
No. of New Gouges																		
1977-1978	12	4	1	22	1	30	17	4	23	0	8	13	11	17	7	Total	avg/Km	
1978-1979	0	1	25	44	12	1	0	0	20	0	9	0	1			170	11.3	
1979-1980	0	0	0	21	0	1	2	1	14	0	2	1	4			133	10.2	
1980-1981	2	5	2	25	7	6	2	0	14	7	7	14	19	8		46	3.5	
																118	8.4	
Maximum Gouge Depth (m)	14	10	28	112	20	38	21	5	71	7	26	28	35	25	7			
1977-1978	.1	.1	.1	.1	.1	.2	.2	.1	.1	0	.1	.2	.4	.7	.5	Deepest		
1978-1979	0	.1	.1	.2	.1	.1	0	0	.1	0	.2	0	.1			.5		
1979-1980	0	0	0	.2	0	.1	.1	.1	.2	0	.1	.1	.3			.2		
1980-1981	.1	.1	.1	.1	.1	.1	.1	0	.2	.4	.2	1.4	.3	.3		.3		
																1.4		
Total Disruption Width (m)																Total	avg/Km	% disturbed
1977-1978	72	19	3	97	9	134	65	20	50	0	44	58	56	139	60	826	55.1	5.5
1978-1979	0	4	97	149	30	3	0	0	53	0	18	0	4			358	27.5	2.8
1979-1980	0	0	0	82	0	3	15	3	48	0	4	1	15			171	13.1	1.3
1980-1981	11	13	5	121	21	14	4	0	64	28	49	88	88	34		540	38.6	3.9
	83	36	105	449	60	154	84	23	215	28	115	147	163	173	60			

Total No. New Gouges = 447   Deepest New Gouge = 1.4 m   Total Disruption Width = 1895 m   Mean % disturbed = 3.4

see Fig. 11

Note: x's refer to no record available for segment; -'s refer to no gouge parameter observed on record.

Table 111. (con't)

Testline 3-CROSS ISLAND

Kilometers	0 1 2 3 4 5 6 7 8 9 1 0 1 1 1 2 1 3 1 4			
Water Depth (m)	11.5 12.5 12.3 12.0 15.0 17.8 20.5 21.6 22.4 22.7 22.5 22.2 21.7 21.0 24.1			
No. of New Gouges Depth (m)		Total	w'3/-	
1981-1982	6 7 6 1 1 9 2 5 3 0 4 0 22 8 134	217	15.5	
Maximum Gouge Depth (m)		Deepest		
1907-1982	.1 .1 .1 .1 .1 .2 .2 .1 0 .1 0 .2 .3 .8	8		
Total Disruption Width [m]		Total	avg/Km	%disturbed (in 3 yrs.)
1981-1982	2 3 2 2 1 5 3 0 2 5 1 3 1 5 9 0 50 0 169 71 600	1042	14.4	7.4

Total No. of New Gouges - 217 Deepest New Gouge - .8 Total Dis ruption Width - 1042 m man % disturbed . 2.5

see Fig. 4

Test line 6-KARLUK ISLAND

Kilometers	0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16			
Water Depth (m)	5.4 8.0 9.5 10.2 11.1 12.0 13.5 14.6 15.7 16.2 19.3 21.7 23.2 25.2 26.0 26.5 27.4			
No. of New Gouge..		Total	avg/Km	
1979-1980	X X x x 3 x 5 4	12	4.0	
1980-1981	0 0 2 5 1 2 0 0	10	1.3	
1901-1982	1 5 1 0 1 1 8 1 1 1 1 5 1 5 0 6 0 0 1	66	4.1	
Maximum Gouge Depth (m)		Deepest		
1979-1980	x x x x . 1 x .1 .1	.1		
1900-1981	0 0 . 1 . 1 . 1 . 1 0 0	.1		
1981-1982	.1 .7 .5 0 .1 .1 . 7 . 1 . 1 . 1 . 2 0 . 2 0 0 .1	.7		
Total Disruption Width (m)		Total	avg/Km	● disturbed
1979-7900	x x x x 1 1 x 16 8	35	11.7	1.2
1980-1981	0 0 3 1 6 3 4 0 0	26	3.3	0.3
19 81-1982	3 1 5 4 0 6 8 3 1 5 3 5 7 5 6 0 2 5 0 0 6	264	16,5	1.7

Total No. of New Gouges - 88 Deepest New Gouge .7 m Total Disruption Width = 325 m Mean % disturbed - 1.1

see Fig. 9

Note: x's refer to no record available for segment; o's refer to no gouge parameter observed on record.

Table III. (con't)

Testline 5 & 8-FLAXMAN ISLAND

Ki lometers	0 1 2 3 4 5 6 7 8 9 1 0 1 1			
Water Depth (m)	7.1 10.6 11.9 14.1 16.8 19.8 20.5 22.5 24.3 25.8 27.0 21.7			
No. of New Gouges		Tota 1	avg/Km	
1979-1980 (TL5)	1 0 I 2 1 2 X	25	6.3	
1981-1982 (TL8)	0 0 1 2 1 1 2 2 2 4 1 5 x	39	3.9	
Maximum Gouge Depth (m)		Deepest		
1979-1980 (TL5)	. 1 0 . 1 . 1 .	.1		
1981-1982 (TL8)	0 0 . 1 . 1 . 1 . 1 . 1 . 3 . 1 . 8 x	.8		
Total Disruption Width (.)		Tota 1	avg/Km	% disturbed
1979-1980 (TL5)	. 1 0 2 9 2 5 x	55	13.8	1.4
1981-1982 (TL8)	0 0 5 4 4 5 8 1 0 6 1 0 4 2 9 x	175	17.5	1.8

(TL5) Total No. of New Gouges - 2S Deepest New Gouge - .1. Total Disruption Width - 55m Mean % disturbed . 1.4
(TL8) Total No. of New Gouges - 39 Deepest New Gouge - .8m Total Disruption Width - 175m Mean % disturbed - 1.8

see Fig. 10

Note: testline 8 is 500m west of testline 5

Tes tline 7-CAMDEN BAY

Ki lometers	0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17			
Water Depth (")	5.5 6.7 7.1 7.4 8.2 9.0 9.5 10.2 10.8 11.7 12.5 13.0 14.3 15.0 15.9 16.8 17.7 10.6			
No. of New Gouges		Tota l	awi-	
1981-1982	2 2 2 7 2 1 5 8 8 4 9 14 23 15 9 18 12 1	151	8.9	
Maximum Gouge Depth (m)		Deep.t		
1901-1982	.1 .1 .1 .1 .1 .2 .1 .3 .1 .1 .1 .1 .3 .2 .7 .4 .1	.7		
Total Disruption Width (m)		Total	avg/Km	% disturbed
1981- 1982	4 9 4 2 0 5 5 0 3 0 4 0 1 4 3 8 3 2 6 8 7 1 2 8 9 5 6 6 3	577	33.9	3.4

Total No. of New Gouges - 151 Deepest New Gouge - .7 m Total Disruption = 577 m Mean ● dis turbed - 3.4

see Fig. 10

Note: x's refer to no record available for segment; 0's refer to no gouge parameter observed on record.