TRACE CONTAMINANTS IN SURFACE SEDIMENT OF THE NORTHERN BERING SEA: A STATISTICAL REVIEW

by

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ABSTRACT

Data are presented for concentrations of nine trace elements and three hydrocarbon measures in surface sediment of the northern Bering Sea from past research reports. Further graphs, maps, and analyses are based on the original data compiled in an appendix.

Statistical summaries indicate means and confidence intervals for twelve normally distributed samples. Contour maps illustrate geographic variation within samples from six investigations. Correlation analyses also indicate the extent to which normalizing variables account for variation in six of the contaminants.

Statistical tests reveal that cadmium, copper, and mercury concentrations in the area near Nome differ significantly between investigations, but zinc does not. Arsenic, barium, and chromium levels differ between the Nome area and the remainder of Norton Basin.

The original research reports themselves are categorized on the basis of sponsoring program, quantity of raw data, and sampled material.

TABLE OF CONTENTS

Page

ACKNOWLEDGMENTS 3

ABSTRACT 5

INTRODUCTION 11

METHODS 11

RESULTS 12

Arsenic 12
Barium 13
Cadmium 14
Chromium 14
Copper 14
Lead 16
Mercury 16
Nickel 17
Zinc 17
Acid-extractable concentrations 17
Hydrocarbons 18

DISCUSSION 19

REFERENCES CITED 20

FIGURES 22

Appendix A. Annotated bibliography of trace contaminants in surface sediment and animal tissue in the northern Bering Sea 79

Appendix B. Tables of data from original reports 83

LIST OF TABLES

Table 1. Means of trace element concentrations (ppm dry weight) in surface sediment near Nome, using tabular data in Rusanowski, et al (1988) which fit a normal distribution. The geometric means are calculated from sample distributions made normal by log transformation. Each element is represented by 22 samples, except nickel with 19 samples, collected in 1985, 1986, and 1987 near the Bima dredge. ..12

Table 2. Kolmogorov-Smirnov tests of metals concentrations (ppm dry weight) in northern Bering Sea surface sediment, at .05 level of significance. The null hypotheses are that sample pairs are drawn from the same statistical populations. Statistical significance is the result of large sample differences in either the "location" or "shape" of the frequency distributions, or both. 15

Table 3. The proportion of variation in Norton Basin sediment trace contaminant Concentrations (ppm dry weight) explained by normalizing variables. The proportion of explained variation is the adjusted R-squared for correlation coefficients found significant at the .05 level. 15

Table 4. Geometric means of hydrocarbon concentrations in northern Bering Sea surface sediment, based on data in Kaplan, et al (1979, 1980). The geometric means and their confidence intervals are calculated from distributions made normal by log transformations. ..18

INTRODUCTION

As the northern Bering Sea is leased for mineral extraction, the monitoring of marine pollution will take on increasing importance. · Those charged with detecting pollution from the proposed development will find that some past research will be valuable for measuring later changes in contaminant levels in the area. This report compiles the results of research on trace elements and organic contaminants in surface sediment of the northern Bering Sea and draws contrasts between areas and among investigations.

METHODS

I tabulated the numerical values in reports of trace elements and organic contaminants in surface sediment of the American Bering Sea north of 63 degrees latitude. The area conforms to the Norton Basin lease planning area and includes Norton Sound and Norton Basin, as well as the continental shelf west to the international boundary and north to the Bering Strait. I did not consider data from sea-floor sediment deeper than 10 cm.

All the chemical concentrations and ancillary information reflected in the figures and summary tables of this review can be found in tables in Appendix B. The data in the 'tables of the appendix were extracted, without corrections, from tables in the original published research reports.

I wrote the appendix tables as Lotus 1-2-3 spreadsheets, selecting the variables of interest from the original reports. For statistics and frequency histograms, the data matrix of each spreadsheet was imported to Complete Statistical System (CSS), a commercial application for use on IBM personal computers.

Frequency distributions, shown as histograms, were drawn with CSS-Intergraph. In the graphs, the Y axes denote the number of sediment specimen sites. The X axes' labels denote the upper boundaries of the frequency intervals.

For statistical analyses, chemical concentrations below the lower detection limit were assigned the value of the lower detection limit. For example, I omitted the less-than sign from a datum such as <.005 ppm, and used .005 for subsequent calculations. This practice results in an estimate of the mean biased toward larger values and an estimate of the dispersion biased toward smaller values. These biases are strongest for contaminants whose concentrations are low and therefore close to the lower detection limit. This alternative, however, avoids a high frequency of occurrence in the "zero ppm" class, thereby making samples much more tractable for statistical comparisons.

I tested each analyte in each table for normality of its frequency distribution. Each of these statistical samples was subjected to t-tests for skewness and kurtosis. Those

data found with dispersions significantly different from a normal distribution were transformed logarithmically to create a sample distribution closer to normal and more amenable to parametric treatment. Confidence intervals were calculated only for arithmetic or log-transformed distributions whose skewness and kurtosis were not significantly different from a normal distribution at the .05 level of probability. The 95% confidence limits were defined as plus or minus two standard errors of the mean.

Concentrations are expressed in parts per million on a dry weight basis unless otherwise noted.

All the data reviewed here were taken at face value from original reports. I made no assumptions regarding the appropriateness of collecting, storage, or laboratory methods. I did not evaluate the accuracy of the data and did not select data on the basis of quality.

RESULTS

Arsenic

Rusanowski, et al (1988) reported arsenic concentrations in surface sediment near Nome greater than concentrations reported for Norton Sound in general by Robertson and Abel (1979). Table 1 shows the geometric mean of arsenic closer to Nome, calculated from transformations of the values provided by Rusanowski, et al (1988) . The

Table 1. Means of trace element concentrations (ppm dry weight) in surface sediment near Nome, using tabular data in Rusanowski, et al (1988) which fit a normal distribution. The geometric means are calculated from sample distributions made normal by log transformation. Each element is represented by 22 samples, except nickel with 19 samples, collected in 1985, 1986, and 1987 near the Bima dredge.

Element	Arith. mean	Geom. mean	95% conf. limits low	high
As		31.84	19.81	51.18
Cd		1.76	1.15	2.69
Cr		15.95	12.13	20.97
Cu		18.45	12.85	26.51
Hg		0.0167	0.0093	0.0298
Ni	39.09		29.20	48.98
Pb		8.83	5.76	13*54
Zn	65.62		54.42	76.82

original values are transformed lognormally because they differed significantly from a normal distribution. A two-tailed t-test for a difference in the means, using degrees of freedom modified for variances which are unknown and unequal, is significant ($t'=4.19$, $df=25$, $P<.005$). The arithmetic mean arsenic concentration of Robertson and Abel's six specimen means is 10.88 ppm dry weight, with a 95% confidence interval from 7.012 to 14.755 ppm. The sampling locations of Robertson and Abel (1979) are shown in Figure 1.

Such comparisons of the values of Robertson and Abel (1979) to other reports are questionable, however. Parametric methods require assumptions about the dispersion of the sample frequency distributions. Robertson and Abel (1979) report means rather than individual determinations, and they give no indication of the sample sizes or frequency distributions within each grab specimen. For this report, I assumed that the specimen means that Robertson and Abel (1979) reported were arithmetic means of normally distributed data.

The sampling locations reported by Robertson and Abel (1979) for Norton Sound are illustrated in Figure 1. The frequency histograms of arsenic concentrations near Nome reported by Rusanowski, et al (1988) are shown in Figures 2 and 3, for arithmetic and log-transformed values respectively. The sampling locations described by Rusanowski, et al (1988) are shown in Figure 28.

In the case of arsenic, as for all other analytes which they report, Rusanowski, et al (1986, 1987, 1988) and Northern Technical Services (NORTEC) (1985) do not specify the depth of the sediment grabs. For this report, therefore, I assumed that the grab technique itself did not result in sampling of analyte statistical populations which were different than those of the other investigators.

Barium

Barium concentrations in the northern Bering Sea differ little between the studies of Robertson and Abel (1979) and Larsen, et al (1980). The concentrations all fall within a range of less than one order of magnitude, as shown in Figures 1 and 4. The arithmetic mean of barium based on Robertson and Abel's six cores is 484.3 ppm dry weight, with a 95% confidence interval from 229.1 to 739.5 ppm.

Both of these investigations indicate barium concentrations about two times greater than the concentrations reported by Sharma (1979) from the same region.

Nevertheless. the geographic variation of Larsents barium concentrations (Fig. 4) follow a pattern not unlike that of Sharma (1979: Fig. 10-32). No tabular data are offered in either report to allow a test of the significance of this difference.

Cadmium

For the area near Nome, Sharma (1974) reported cadmium concentrations greater than those reported by Rusanowski, et al (1988). Figure 5 shows geographic distribution of the cadmium levels of Sharma (1974) and Figures 6,7, and 8 show frequency distributions of Sharma's data. Figures 6, 9 and 10 show frequency distributions of Rusanowski's data.

Because Sharma's data are not normally distributed, they are compared to Rusanowski's data using a non-parametric method. A Kolmogorov-Smirnov test (Table 2) indicates that the underlying statistical populations of cadmium are independent, and that the two investigators did not measure the same thing.

Rusanowski's cadmium levels are summarized by their geometric mean and confidence limit in Table 1.

Nearly half of the variation in Rusanowski's cadmium levels is explained by variation in the percentage of solids in the grab samples, as shown in Table 3. A relationship between grain size and concentration is expected for many trace chemicals in sediment.

Chromium

The Norton Sound sample of Robertson and Abel (1979) reflects chromium concentrations significantly greater than those sampled at Nome by Rusanowksi, et al (1988), according to a two-tailed t-test on log-transformed data (t=5.75, df=26, P<.0005).

The arithmetic mean and confidence interval of chromium levels in Norton Basin are 79.67 ppm dry weight, and 60.49 to 98.87 ppm, respectively? based on the six specimens of Robertson and Abel (1979). See Figure 1 for grab locations.

The geometric mean and confidence interval of chromium levels at Nome are shown in Table 1 (Rusanowski, et al 1988) . These chromium values are somewhat affected by percentage solids, as determined from correlation analysis (Table 3). See Figures 11 and 12 for frequency histograms of the sample.

Copper

Rusanowski's copper levels are significantly greater than those of Sharma (1974), according to a Kolmogorov-Smirnov test (Table 2). Geographic distribution in the copper concentrations measured by Sharma (1974) is shown in Figure 13. The sample frequency histograms are shown in Figures 14, 15, 16 and 17. The difference between the two samples is displayed in Figure 18.

Sharma's copper concentrations are affected by organic carbon in the grab samples, as shown in Table 3. However, none of Sharma's three metals are significantly affected by grain size. Moreover, none conforms to a normal

Table 2. Kolmogorov-Smirnov tests of metals concentrations (ppm dry weight) in northern Bering Sea surface sediment, at .05 level of significance.

The null hypotheses are that sample pairs are drawn from the same statistical populations. Statistical significance is the result-of large sample differences in either the "location" or "shape" of the frequency distributions, or both.

Element	Name of sample	N	Arith. mean	SD	Significant difference
Cd	Rusanowski (1988)	22	3.650	7.868	Signif.
	Sharma (1974)	19	5.492	2.679	
Cu	Rusanowski (1988)	22	23.98	14.08	Signif.
	Sharma (1974)	19	15.37	11.45	
Hg	Nelson near Nome	28	.0320	.0246	Signif.
	Rusanowski near Nome	22	.0351	.0401	
Hg	Nelson not near Nome	94	.0371	.0335	NS
	Nelson near Nome	28	.0320	.0246	
Zn	Rusanowski (1988)	22	65.62	25.66	NS
	Sharma (1974)	19	84.00	84.16	

Table 3. The proportion of variation in Norton Basin sediment trace contaminant concentrations (ppm dry weight) explained by normalizing variables. The proportion of explained variation is the adjusted R-squared for correlation coefficients found significant at the .05 level.

Data report and normalizer		Analyte	Adjusted R-squared
Rusanowski, et al (1988)	% solids	Cd, ppm	.472
		Cr, ppm	.255
		Cu, ppm	,281
		Hg, ppm	●338
		Zn, ppm	.257
Sharma (1974)	% wt. non-carbonate carbon	Cu, ppm	.387
		Zn, ppm	.527
Kaplan, et al (1979)	% organic carbon	Aliphatic hydrocarbons	.113

distribution even after correcting for the affect of organic carbon.

Lead

Lead concentrations in surface sediment near Nome are reported by Rusanowski, et al (1988) and are summarized in Table 1. Frequency histograms of the sample distribution, as arithmetic and as log-transformed values, are shown in Figures 19 and 20.

Sharma (1974) reported that lead was not detectable.

Mercury

Nelson, et al (1972) and Rusanowski, et al (1988) sampled mercury populations near Nome which differed greatly in their variances but little in their means. The subset of 28 values of Nelson, et al (1972) near Nome has a geometric mean of .0274 ppm with a 95% confidence interval of .0223 to .0338 ppm. A two-tailed t-test, using log-transformed values and degrees of freedom modified for unequal variances, showed no significant difference in the means of Nelson's and Rusanowski's mercury concentrations near Nome ($t'=1.65$, $df=16$). However, F-tests based on log-transformed values indicate a significant difference between the variances ($F=6.09$; $P<.001$). Similarly, a Kolmogorov-Smirnov test on untransformed values shows that the two samples were from statistical populations characterized by distinctly different dispersions (Table 2).

Figures 21-25 show the frequency distributions of the two samples from the area near Nome. Table 1 summarizes Rusanowski's mercury concentrations.

Offshore Nome

The highest mercury levels in the Nome area appear near Penny River. Geographic distribution in the subset of the concentrations measured by Nelson, et al (1972) near Nome is shown in Figure 26. Figures 27 and 28 give close views of the Penny River area and the mercury samples of Nelson, et al (1972) and Rusanowski, et al (1988), respectively.

For purposes of detecting changes in mercury concentrations, Nelson's sample has more statistical power. Statistical power is the probability of rejecting a hypothesis of no difference when there is a true difference. Statistical power is calculated as 1 minus beta, the probability of rejecting an alternative hypothesis of a difference when the hypothesis is true. Applying such a calculation, it is found that Nelson's log-transformed sample can detect differences in means equal to its standard deviation of 0.54 ppm approximately 95% of the time, using a two-tailed t-test. However, Rusanowski's standard deviation

is large enough that the sample size would have to exceed 100 to detect that difference at that high rate.

Nelson basin-wide

Views of Nelson's sampling locations and mercury concentrations over the northern Bering Sea are shown in Figures 29 and 30. The extensive sampling by Nelson, et al (1972) yielded mercury exceeding 0.10 ppm dry weight only at two points, a station near Penny River and a station 40 km north of the Yukon River delta.

The frequency distribution of Nelsonis samples are shown in Figures 31 and 32. Log normal transformation of the original ppm values resulted in a distribution not significantly different from normal. The geometric mean and its 95% confidence interval calculated for this regional sample are .0269 ppm, and .0234 to .0308 ppm, respectively.

Nelson's sampling shows no significant difference between mercury levels near Nome and mercury levels in the remainder of the northern Bering Sea study area (Table 2).

These mercury data are discussed further by Nelson, et al (1975, 1977) and Patry, et al (1977).

Nickel

Rusanowski's research reports are the only published source of raw data on nickel concentrations in the region (Rusanowski, et al, 1986, 1987, 1988). Summary statistics for nickel are presented in Table 1. Figures 33 and 34 show the frequency histograms.

Zinc

No significant difference in the zinc concentrations sampled near Nome by Sharma (1974) and Rusanowski, et al (1988) is indicated by a Kolmogorov-Smirnov test (Table 2). Such pairs of samples which do not lead to a rejection of the null hypothesis of no difference may be combined as a single sample for analytical purposes.

Frequency histograms for both samples are presented in Figures 35-39. Rusanowski's data are summarized in Table 1.

More than half of the variation in the zinc sampled by Sharma (1974) is explained by differences in organic carbon concentrations in the grab samples (Table 3). Zinc concentrations vary widely among locations near Nome, but show no regular pattern (Figure 40).

Acid-extractable concentrateions

Burrell (1977, 1978) reported acid-extractable concentrations of six elements in surface sediment of Norton Sound. His data reflect trace contaminants from the soluble fraction of the sediment, unlike the other studies which examine the whole-rock fraction. Burrell's concentrations

are therefore not directly comparable to those of the other studies.

The sampling stations of Burrell (1977, 1978) are mapped in Figure 41. The geographic variations in the concentrations of three trace elements are depicted in Figures 42-44. Cadmium concentrations reported by Burrell (1977, 1978) are as high as the lower detection limit at only one station. Thus, cadmium is not mapped here.

Hydrocarbons

Published tabular data on trace levels of hydrocarbons in the northern Bering Sea are available from Kaplan, et al (1979, 1980), Kaplan-and Venkatesan (1981), and Venkatesan, et al (1981).

Geographic variation of total n-alkanes, the odd-to-even ratio of n-alkanes, and the ratio of aliphatics plus aromatics to total organic carbon is shown in Figures 45-47. These variables are common indexes of hydrocarbon levels.

Table 4 displays statistical summaries of three major hydrocarbon indexes and a normalizing variable. Geometric means and confidence intervals are calculated after log transformation.

The concentration of aliphatic hydrocarbons in surface sediment is significantly affected by the percentage of organic carbon based on a regression analysis (P=.034). The adjusted R-squared shows that only 11% of the the variation is explained by percentage organic carbon, a minor affect (Table 3).

The frequency histograms of the major hydrocarbon variables are illustrated in Figures 48-57.

Table 4. Geometric means of hydrocarbon concentrations in northern Bering Sea surface sediment, based on data in Kaplan, et al (1979, 1980). The geometric means and their confidence intervals are calculated from distributions made normal by log transformation.

Analyte	N	Geom. mean	95% conf. limits low	high
% organic carbon	48	.5635	.4745	.6692
aliphatics, ppm	49	3.771	2.861	4.973
aromatics, ppm	48	2.088	1.624	2.684
n-alkanes, ppm	37	41.86	12.08	145.1

Two patterns emerge from these comparisons.

First, the independent investigations sometimes reported different mean levels for the same analytes from the same areas. Statistically significant differences between studies were found for the frequency distributions of cadmium, copper and mercury within the area near Nome. Although the mean levels of mercury near Nome estimated by two studies cannot be considered different, the variances were different, indicating that two independent mercury populations were investigated there. For the region as a whole, mean barium concentrations differed between one pair of studies and a third investigation.

In addition, arsenic and chromium levels differed between areas sampled by independent investigations.

Such discrepancies may represent real variation in the concentrations of analytes in sediment, or they may be the result of methodological differences between research programs which are not apparent in the reports.

The second conclusion is that the samples vary in their suitability for detecting trends.

For example, some research efforts in the northern Bering Sea have resulted in extensive contour mapping of trace metals. Such work is reported by Larson, et al (1980), Nelson, et al (1975), Nelson (1977), and Sharma (1978). In these reports, the original individual data are reduced to isolines to depict continuous geographic trends in chemical concentrations across the region. However, these reports preclude statistical treatment.

Sample data from other reports, although unreduced and allowing some statistical analysis, cannot be treated by parametric methods simply because their frequency distributions are not normal and cannot be made normal by transformation. For example, the concentrations of Sharma (1974) cannot provide the variance estimates necessary for calculating the precision of the analyte means.

Some of the data, however, are amenable to more rigorous comparisons. For example, confidence intervals and multivariate relationships can be calculated for mercury, hydrocarbon indexes, and all the elements measured by Rusanowski, et al (1988) because the samples do not differ significantly from normal frequency distributions. In addition, samples of large size or narrow dispersions, or both, offer the greatest power in detecting differences. Samples with these characteristics provide the strongest basis for measuring variation among investigations, among study areas, and over time.

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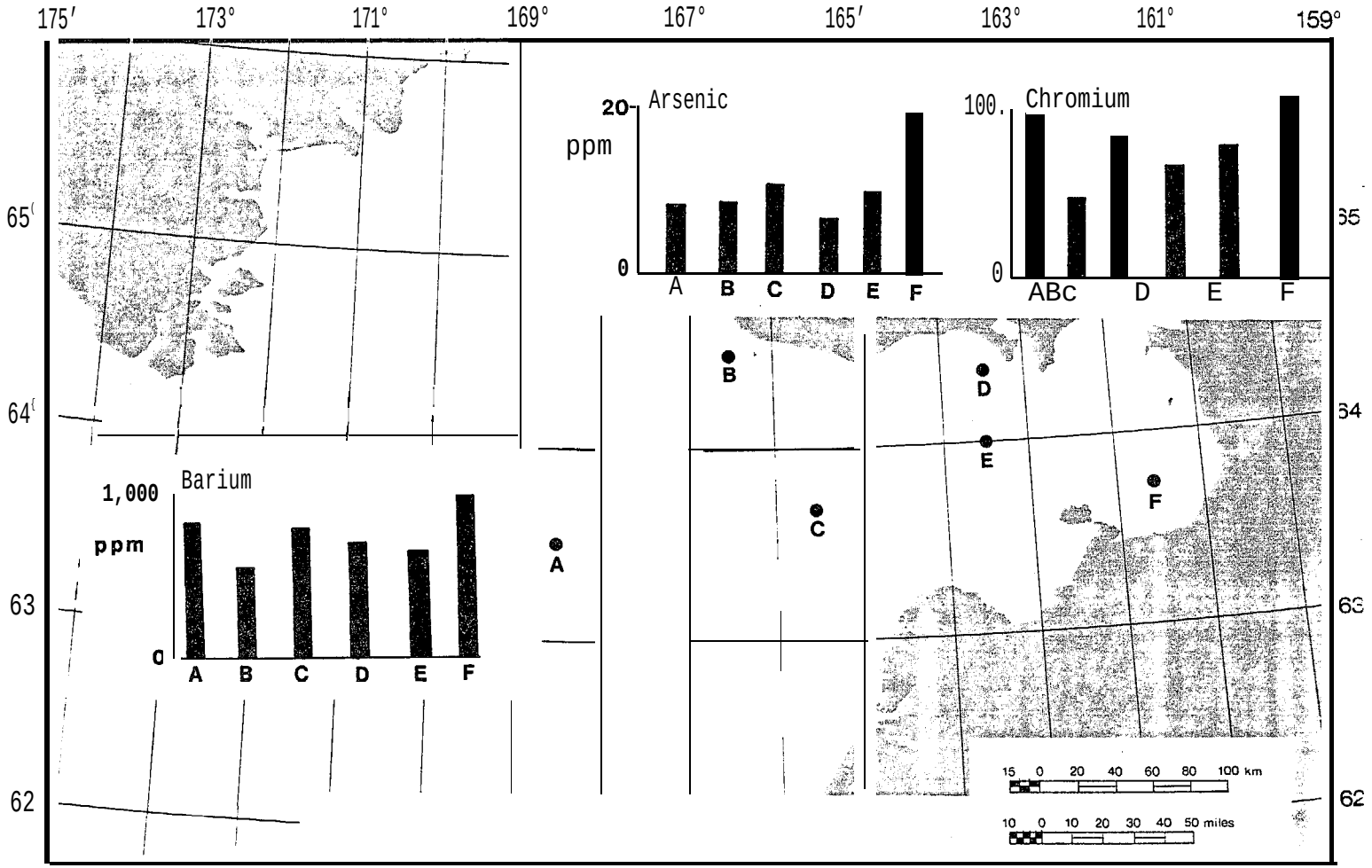

Fig. 1. Mean concentrations of arsenic, barium, and chromium in surface sediment 0-2cm at six HAPS core stations, 1976, in ppm, dry weight. Adapted from Robertson and Abel (1979: Table C.4 and C.5).

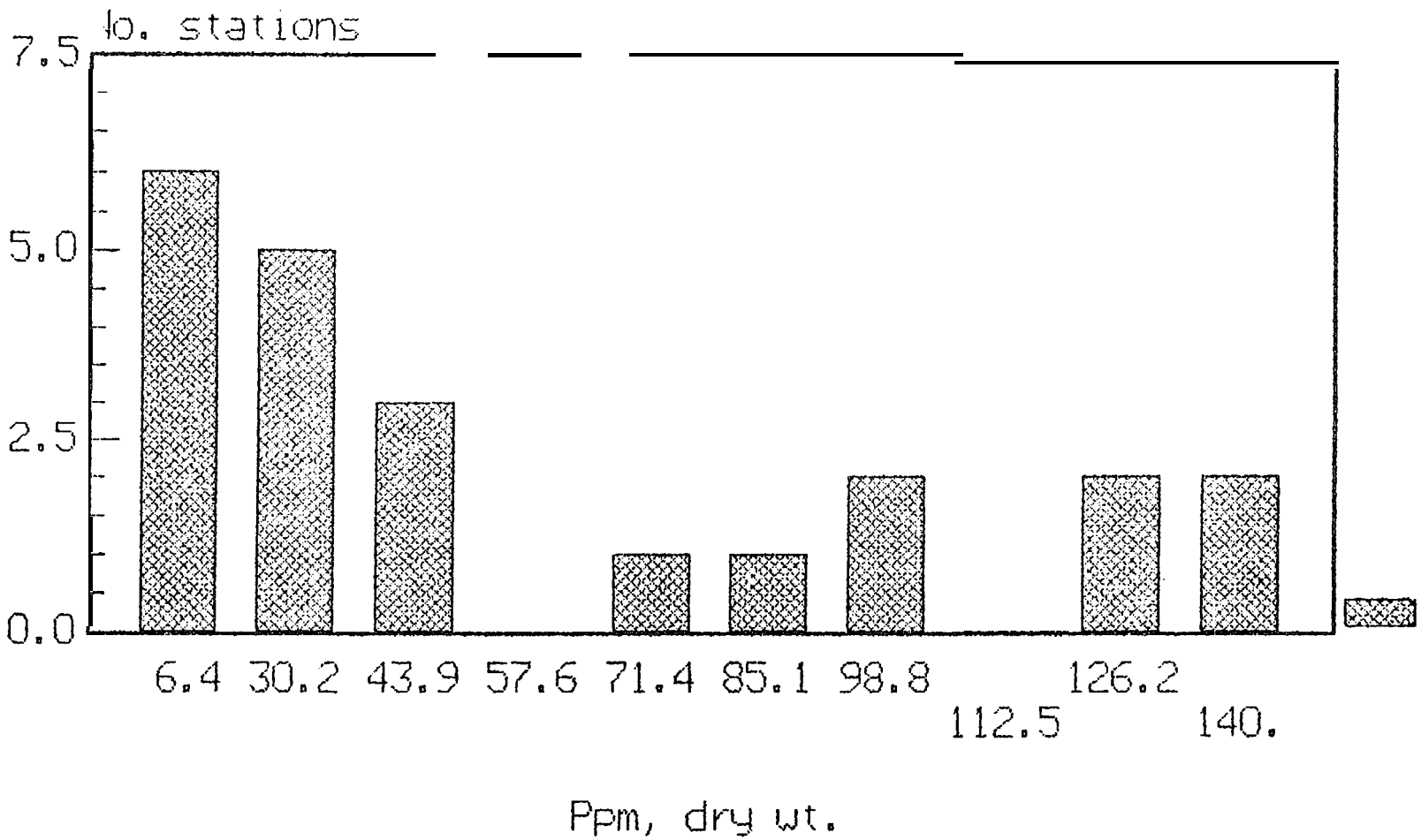

Fig. 2. Arsenic in surface sediment at 22 stations near Nome. Based on Rusanowski, et al (1988).

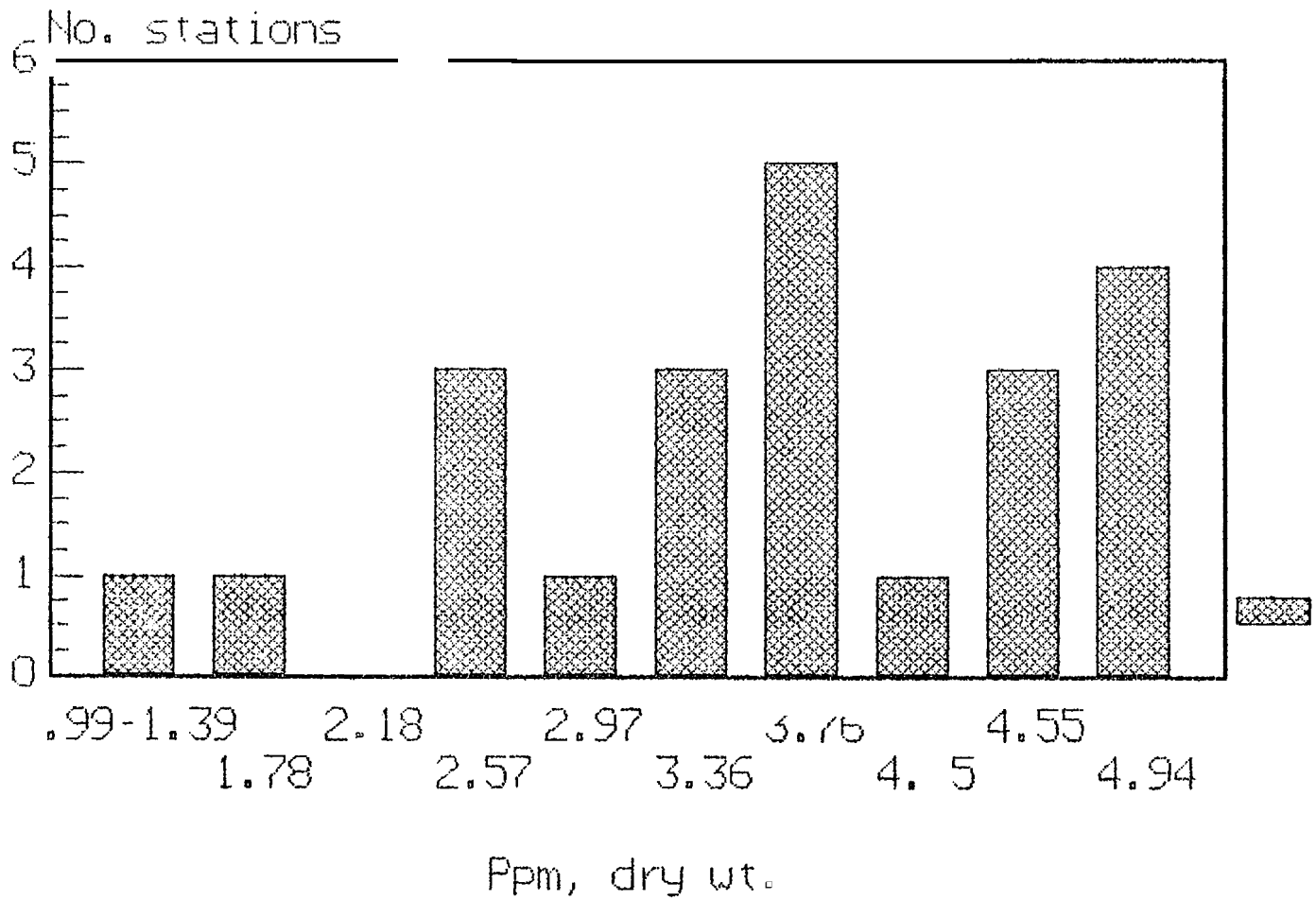

Fig. 3. Log normal of arsenic in surface sediment at 22 stations near Nome. Based on Rusanowski, et al (1988).

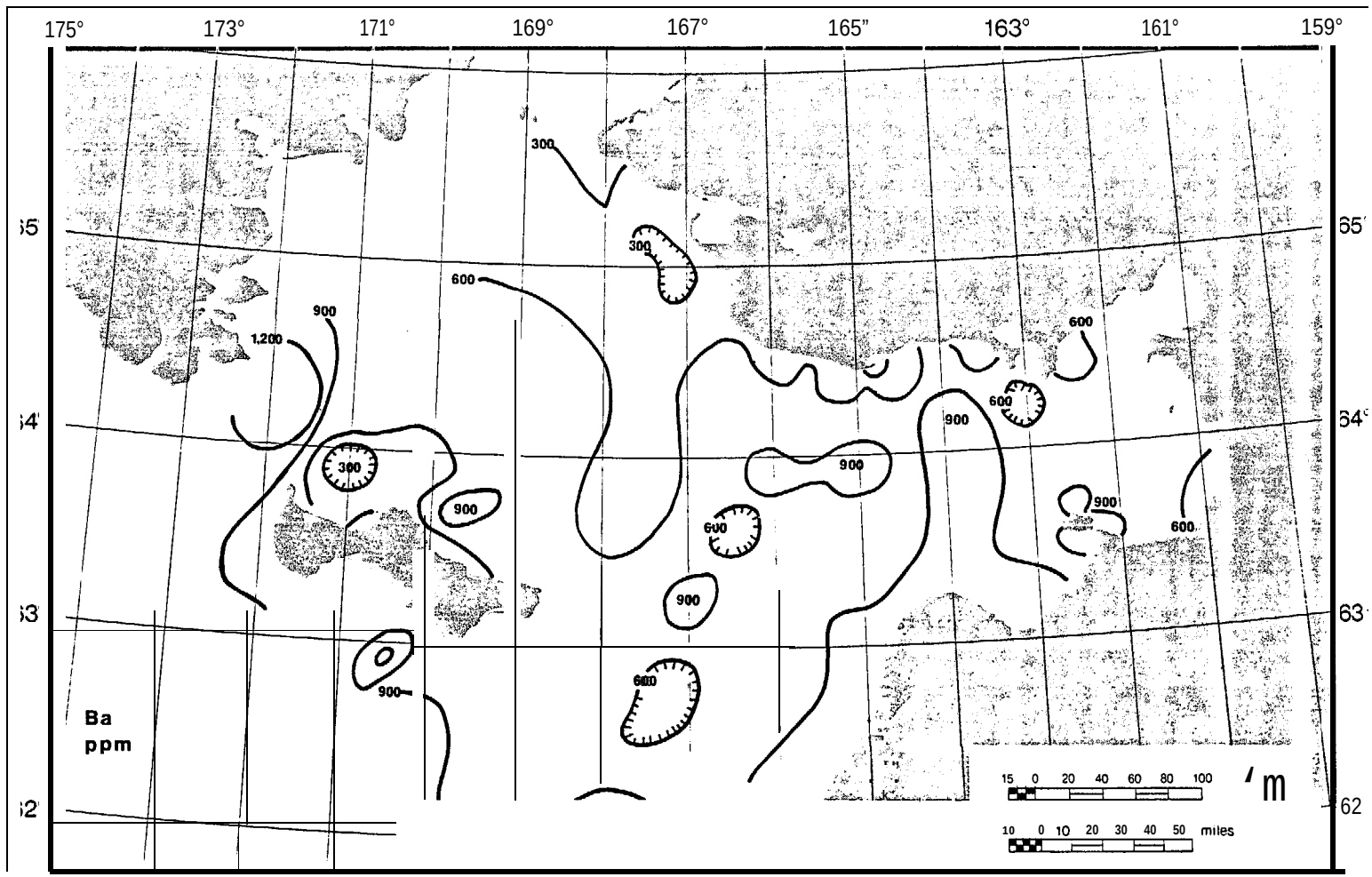

Fig. 4. Barium concentration in surface sediment, O-10CIII, based on 180 van Veen and Soutar van Veen grabs, in ppm dry weight. Adapted from Larsen, et al (1980: Fig. 29).

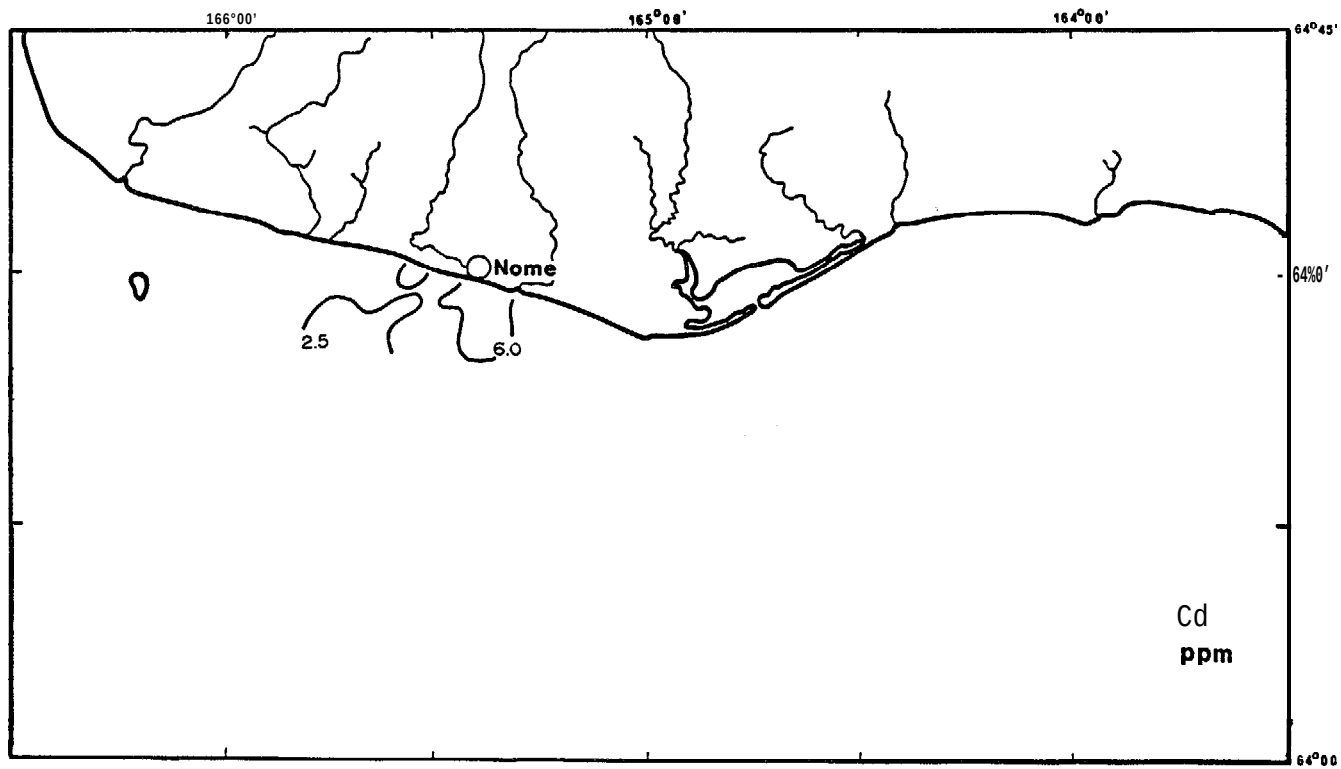

Fig. 5. **Isolines** of cadmium concentration **in** surface sediments based on 19 van **Veen** grabs. Drawn from **Sharma (1974:139).**

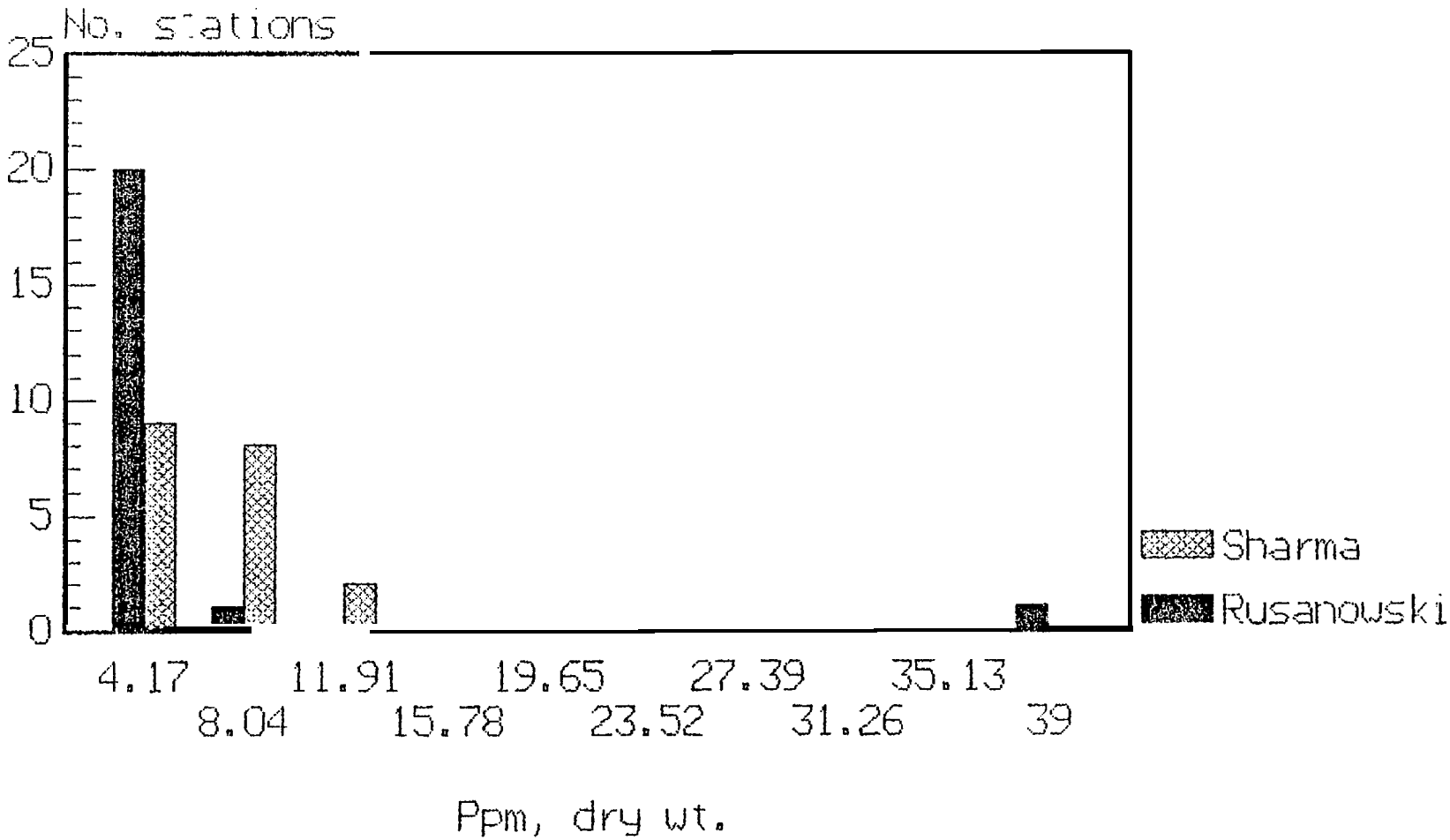

Fig. 6. Cadmium in surface sediment near Nome, based on samples of Rusanowski, et al (1988) and 19 samples Sharma (1974).

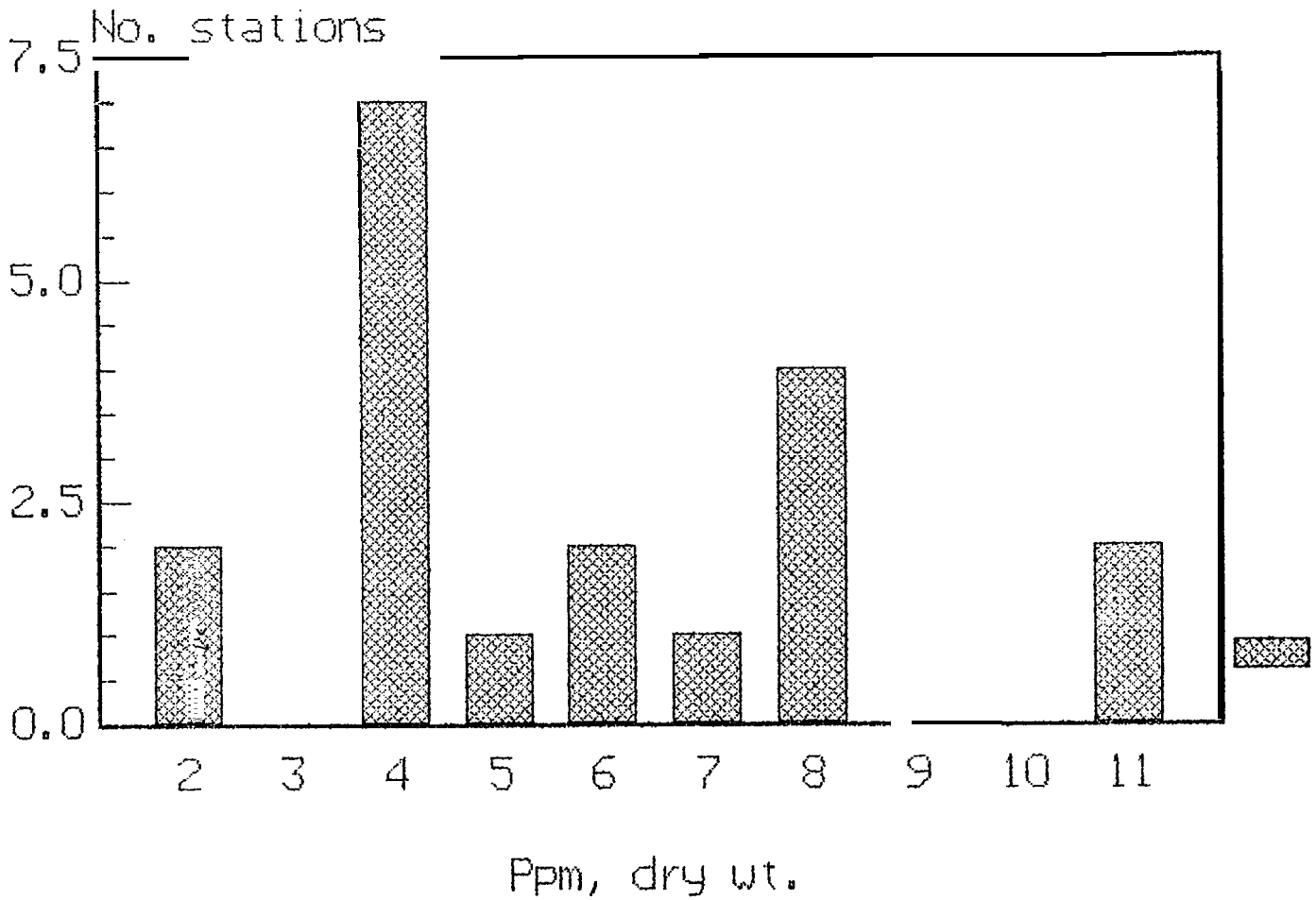

Fig. 7. Cadmium in surface sediment at 19 stations near Nome. Based on Sharma (1974).

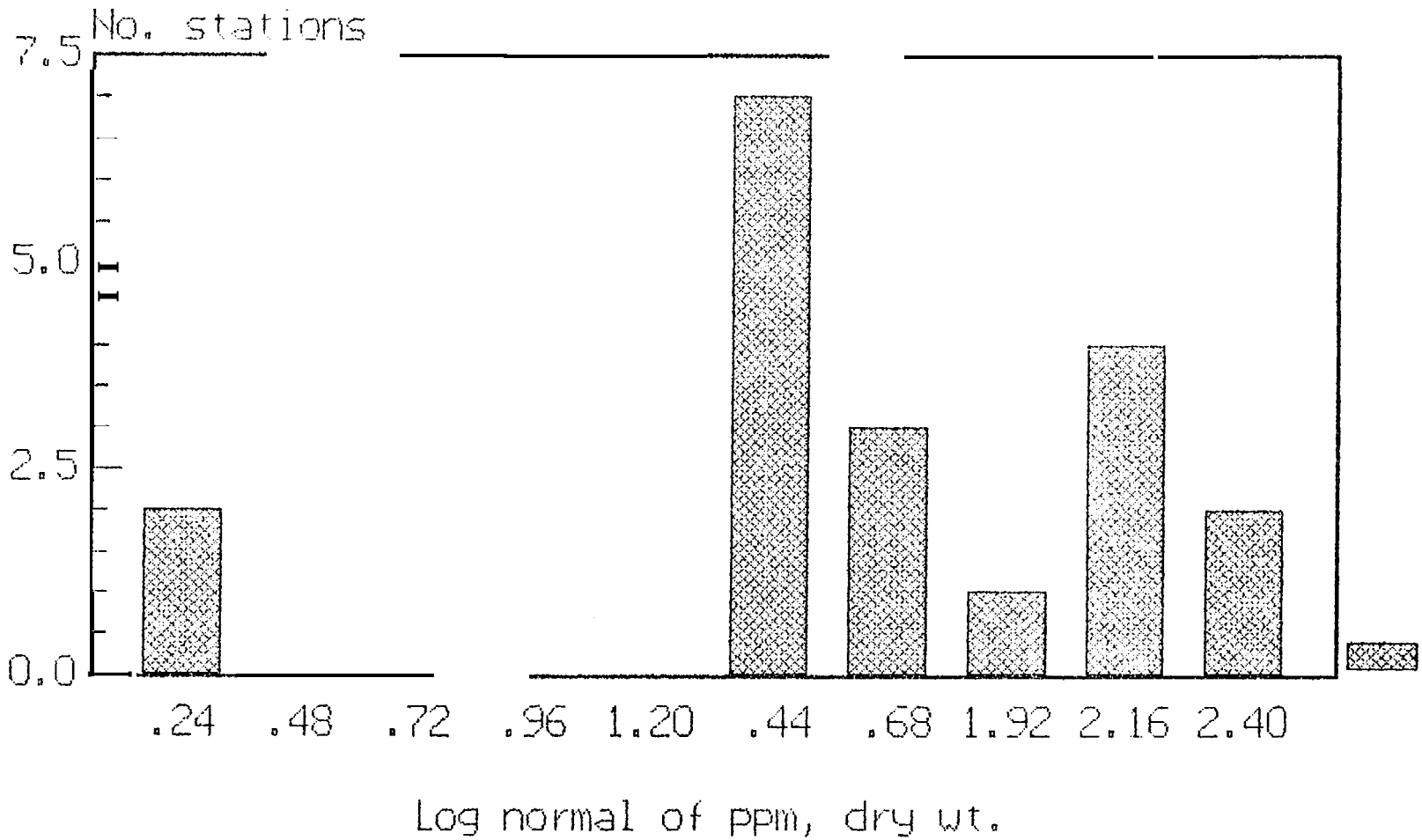

Fig. 8. Log normal of ppm of cadmium in surface sediment at 19 stations near Nome. Based on Sharma (1974).

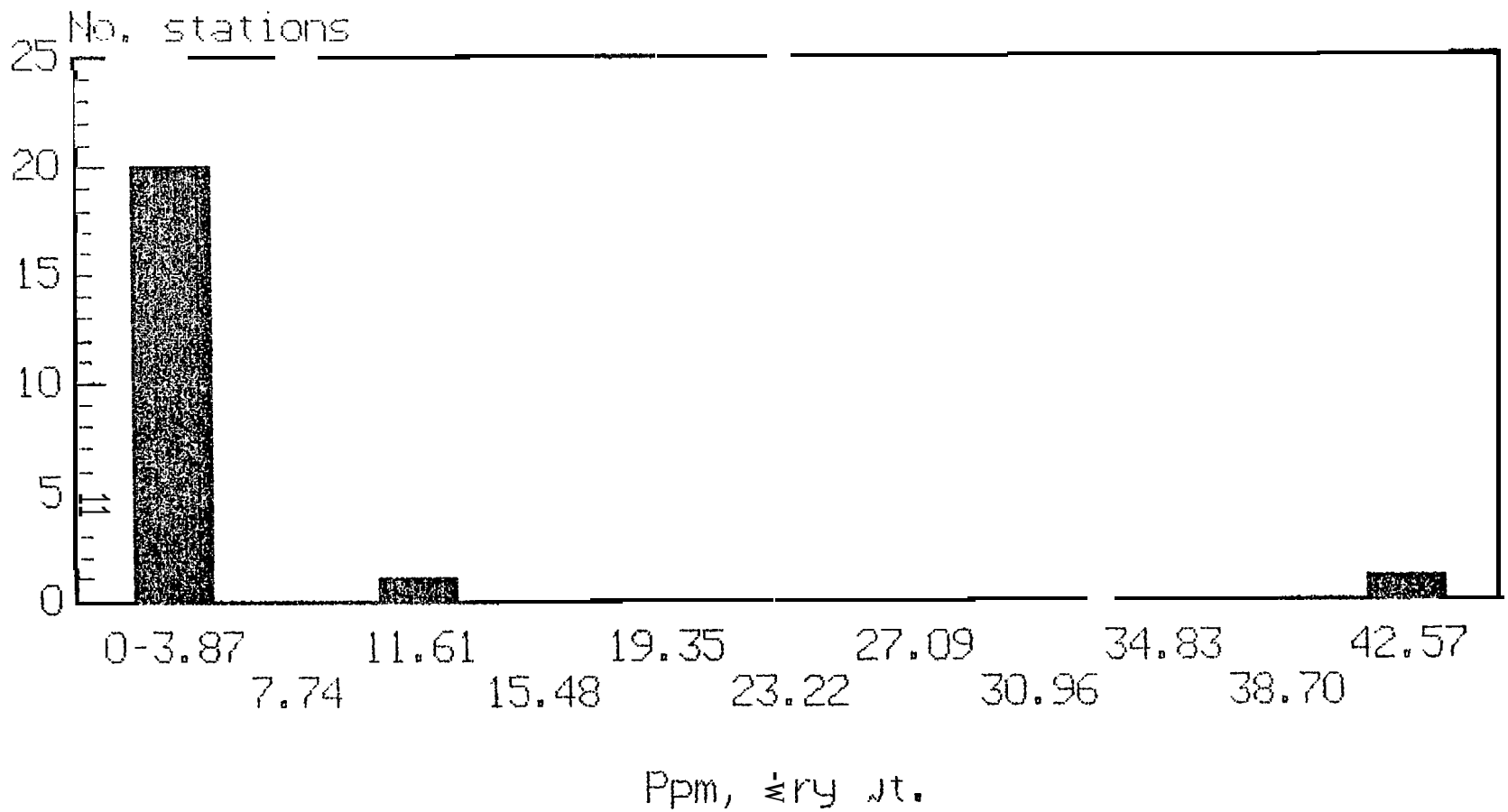

Fig. 9. Cadmium in surface sediment at 22 stations near Nome. Drawn from Rusanowski, et al (1988).

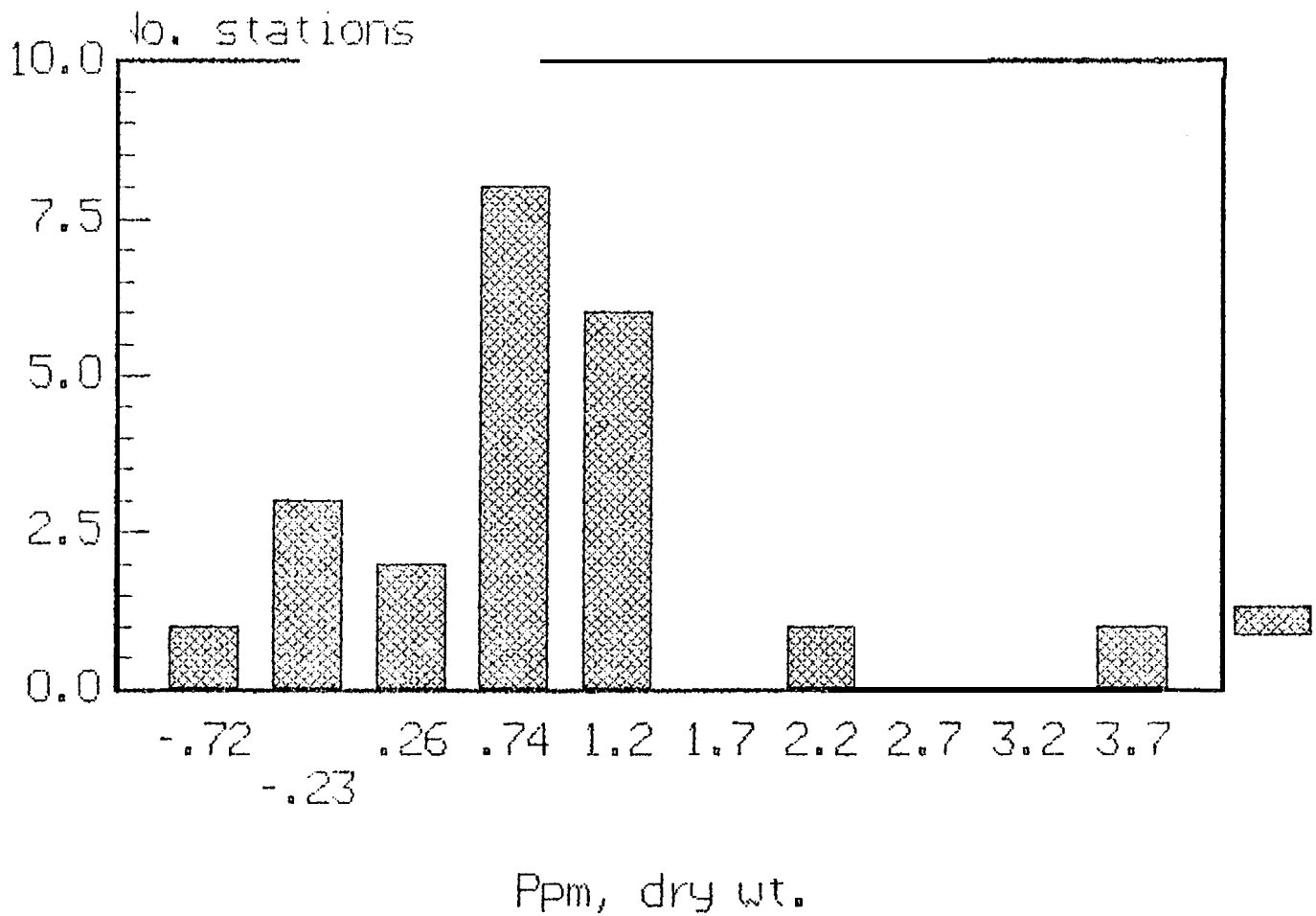

Fig. 10. Log normal of cadmium in surface sediment at 22 stations near Nome. Based on Rusanowski, et al 1988).

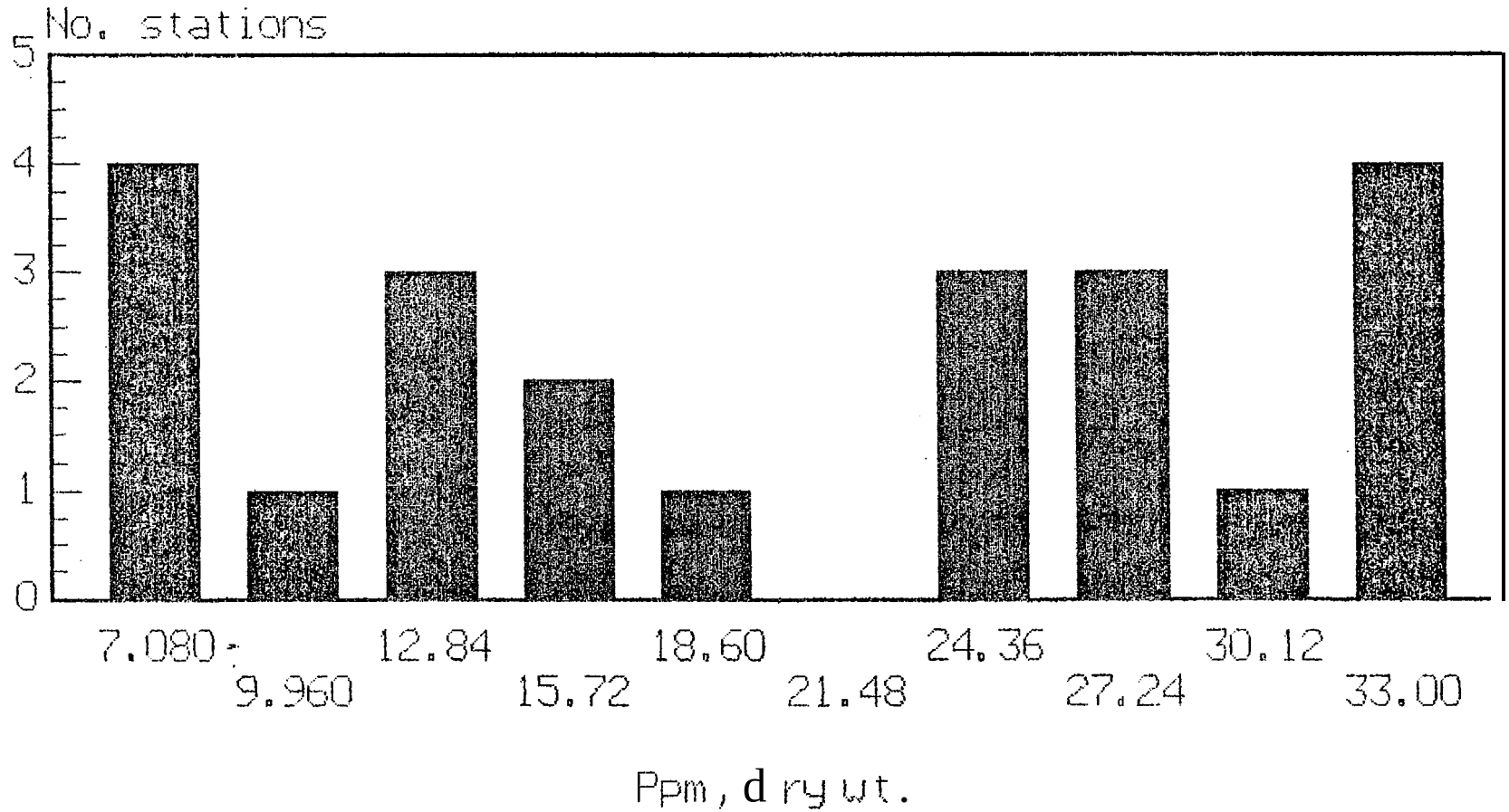

Fig. 11. Chromium in surface sediment at 22 stations near Nome. Drawn from Rusanowski, et al (1988).

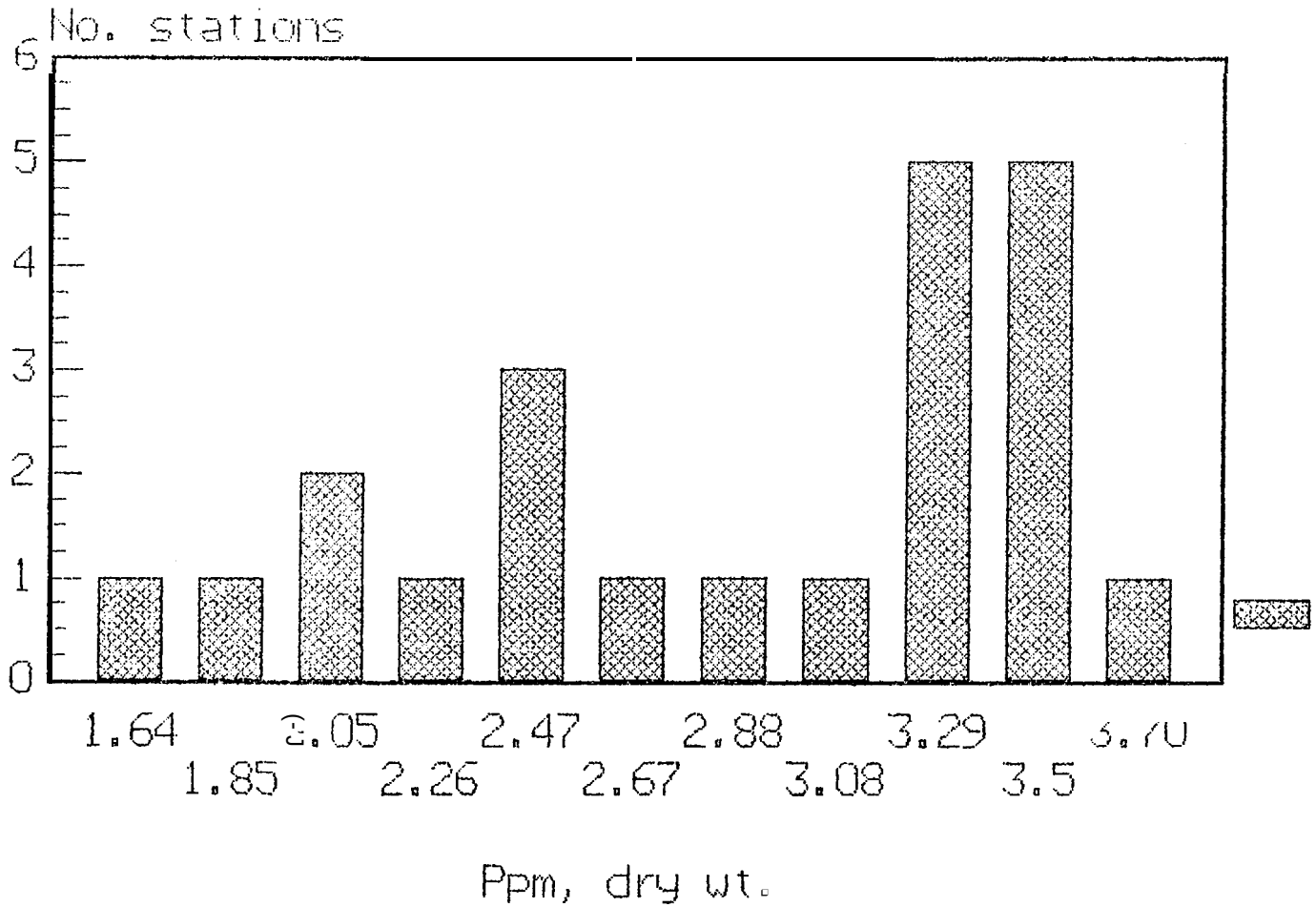

Fig. 12. Log normal of chromium in surface sediment at 22 stations near Nome. Based on Rusanowski, et al (1988).

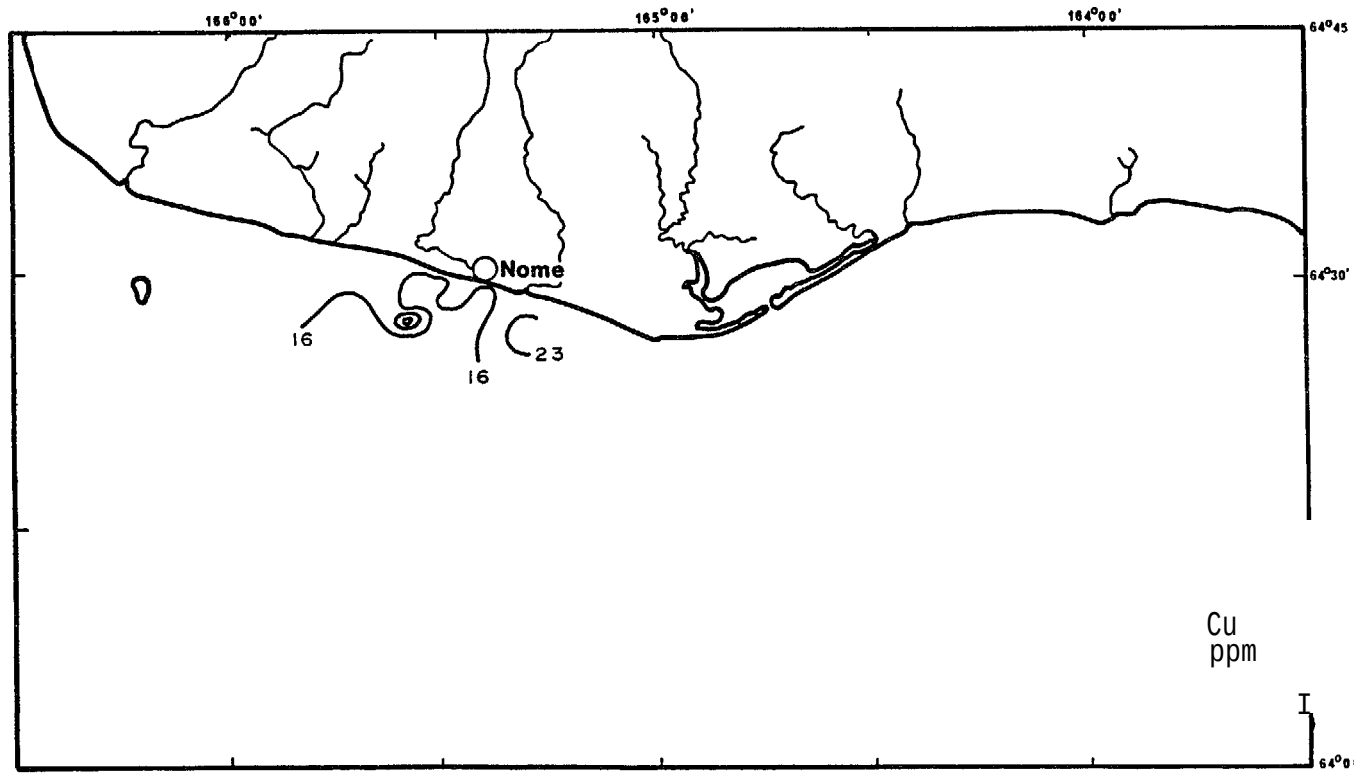

Fig. 13. **Isolines** of copper concentration in surface sediments based on 19 van Veen grabs. Drawn from **Sharma (1974:139).**

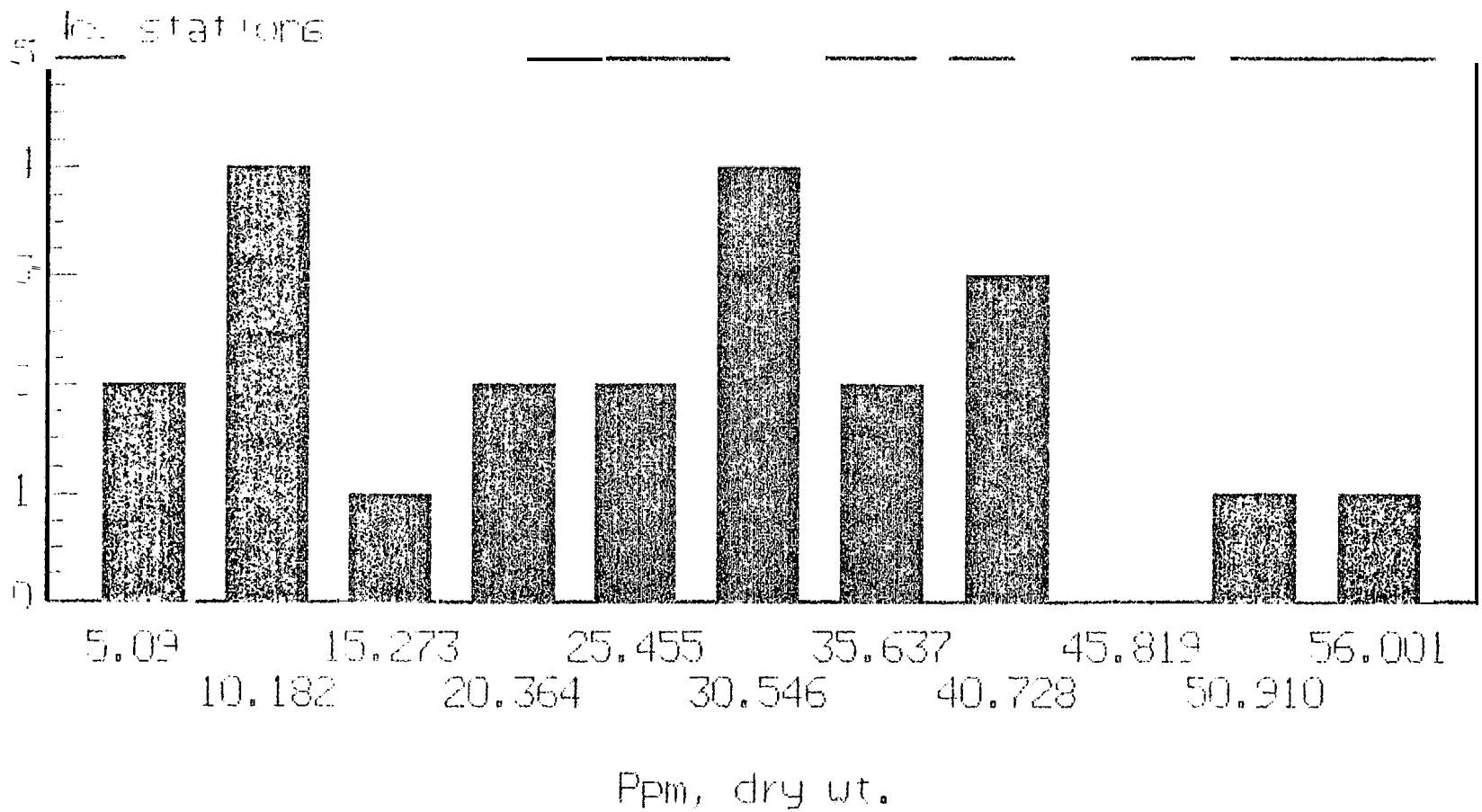

Fig. 14. Copper in surface sediment at 22 stations near Nome. Drawn from Rusanowski, et al 1988).

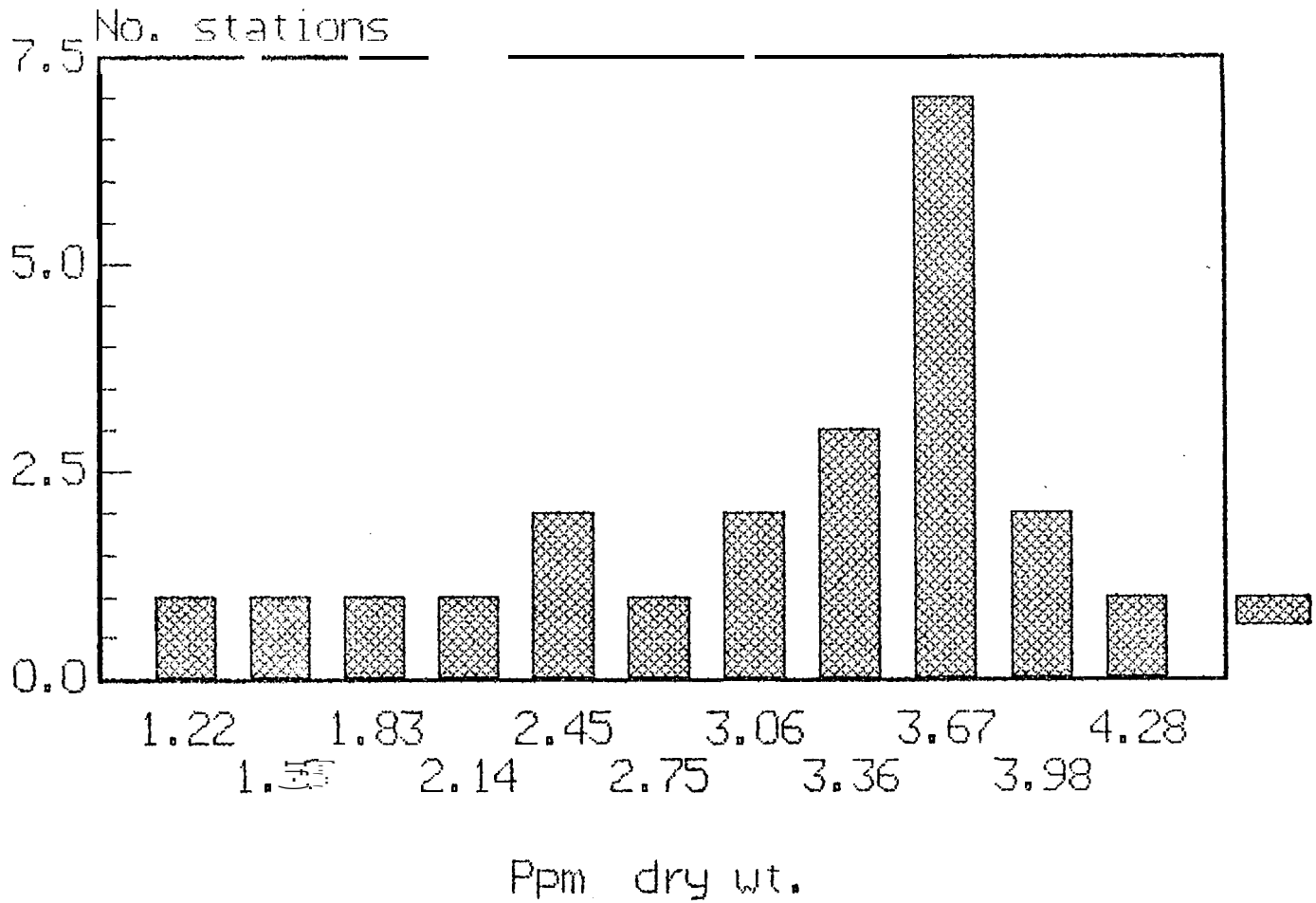

Fig. 15. Log normal of copper in surface sediment at 22 stations near Nome. Based on Rusanowski, et al (1988).

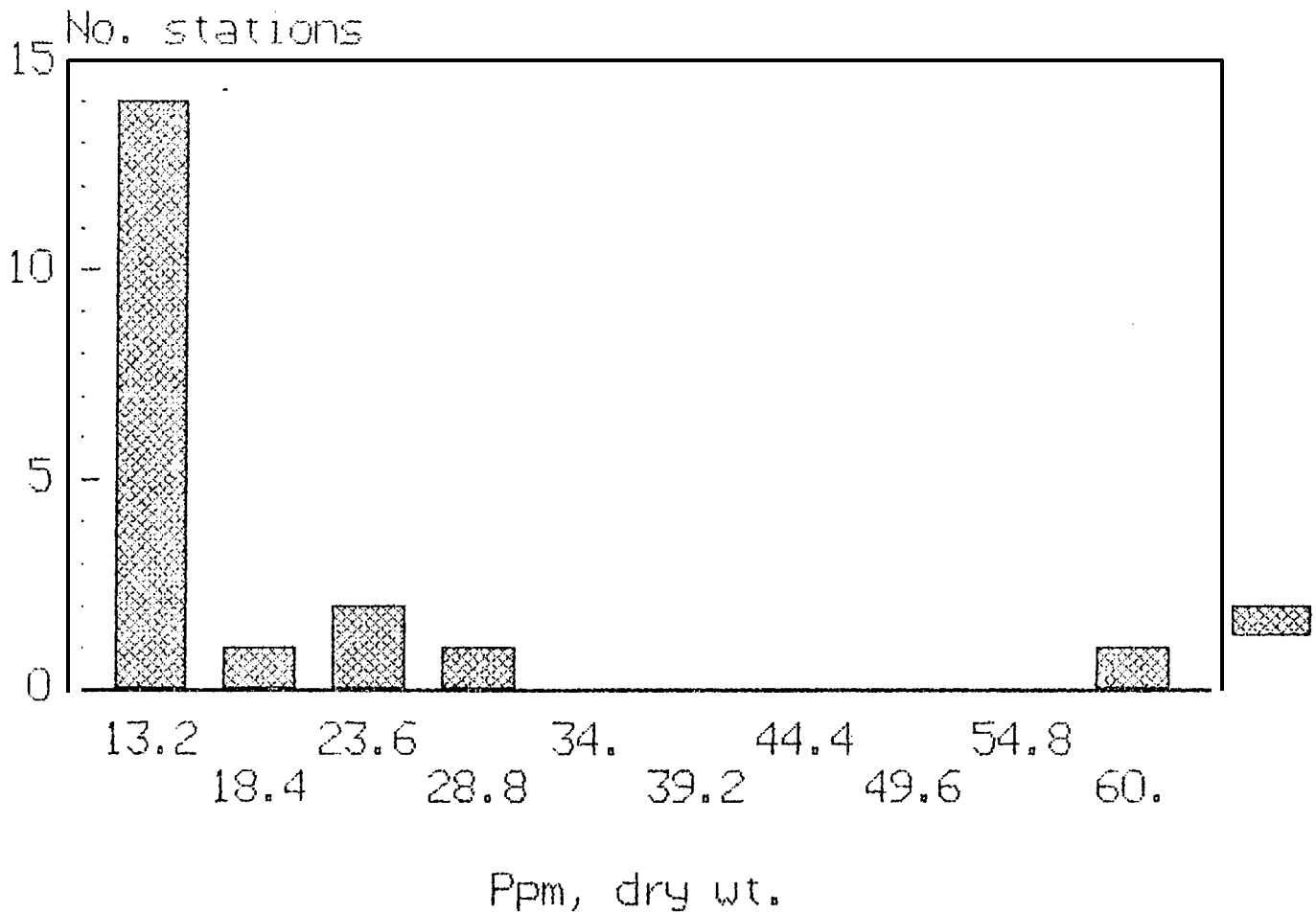

Fig. 16. Copper in surface sediment at 19 stations near **Nome.** Based on Sharma (1974).

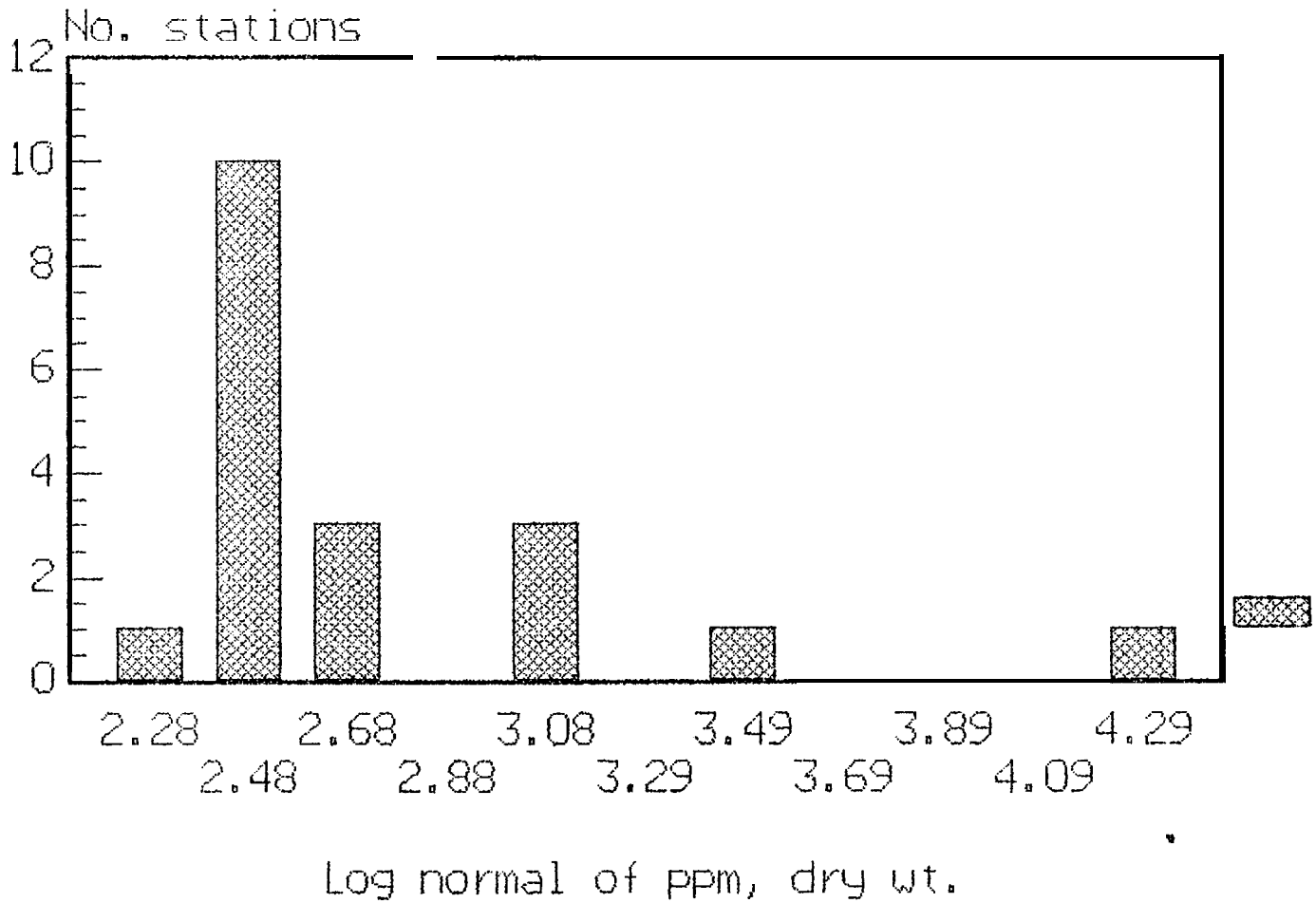

Fig. 17. Log normal of ppm of copper in surface sediment at 19 stations near Nome. Based on Sharma (1974).

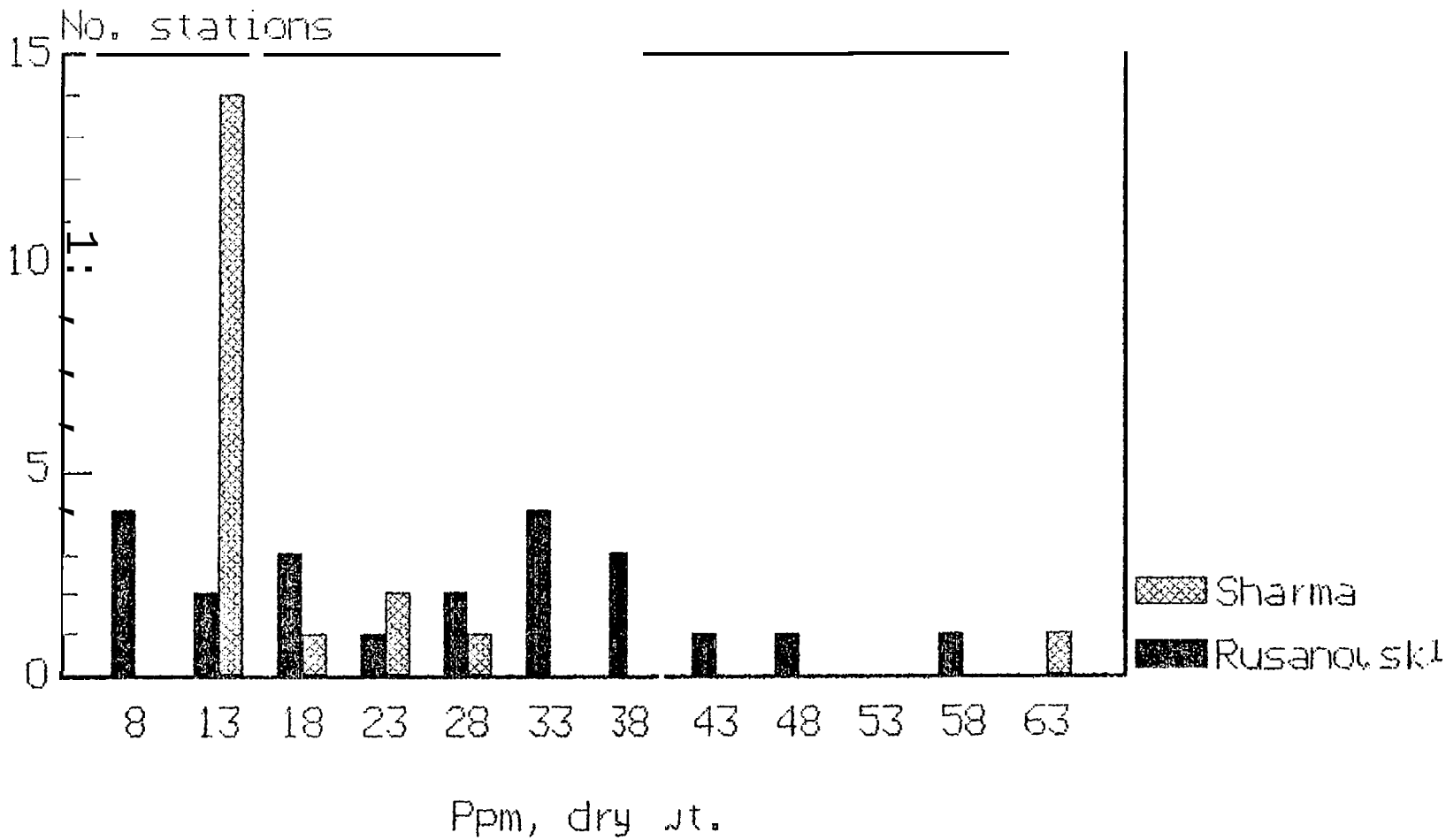

Fig. 18. Copper in surface sediment near Nome, based on 22 samples of Rusanowski, et al (1988) and 19 samples of Sharma (1974).

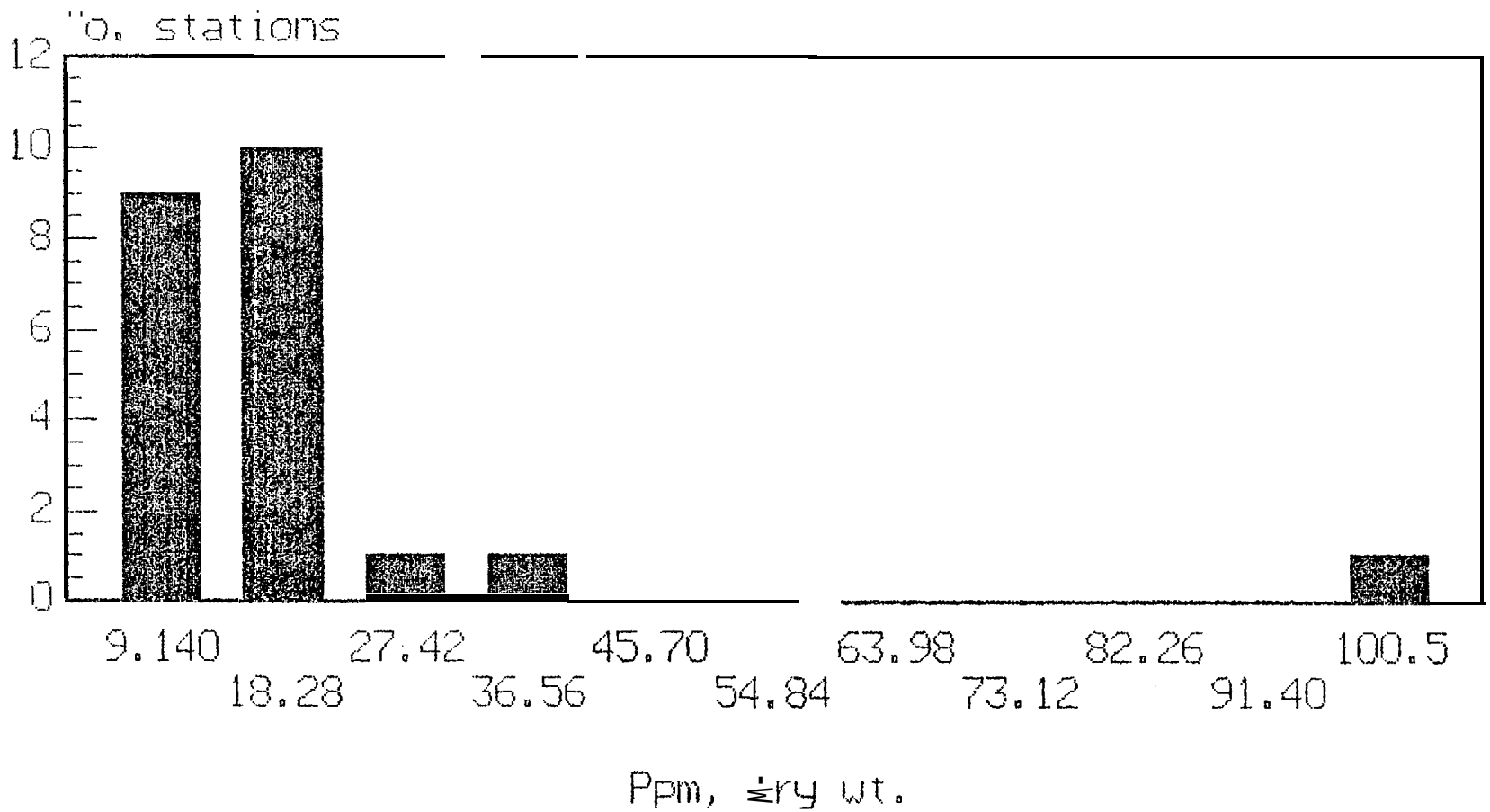

Fig. 19. Lead in surface sediment at 22 stations near Nome. Drawn from Rusanowski, et al (1988).

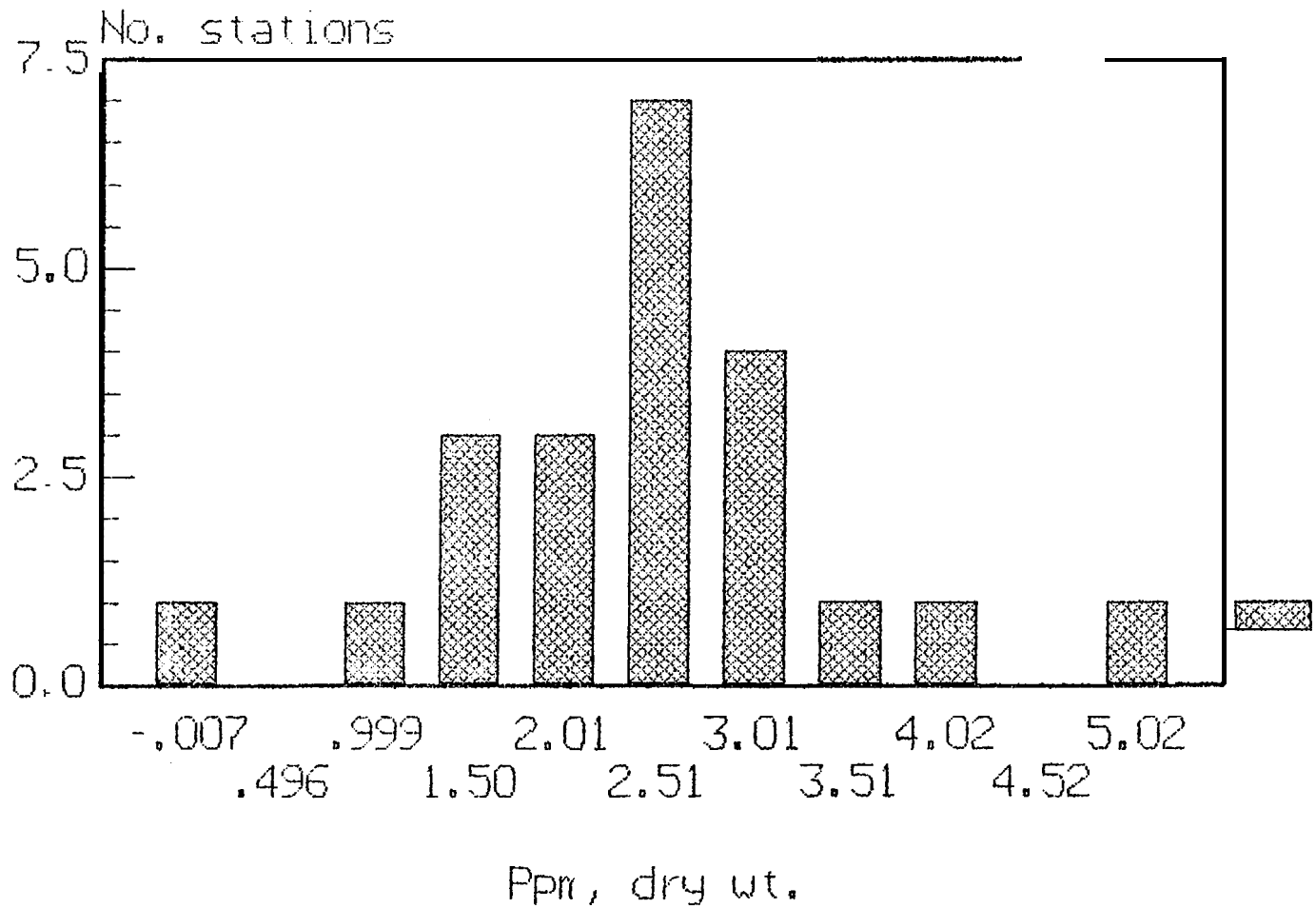

Fig. 20. Log normal of lead in surface sediment at 22 stations near Nome. Based on Rusanowski, et al (1988).

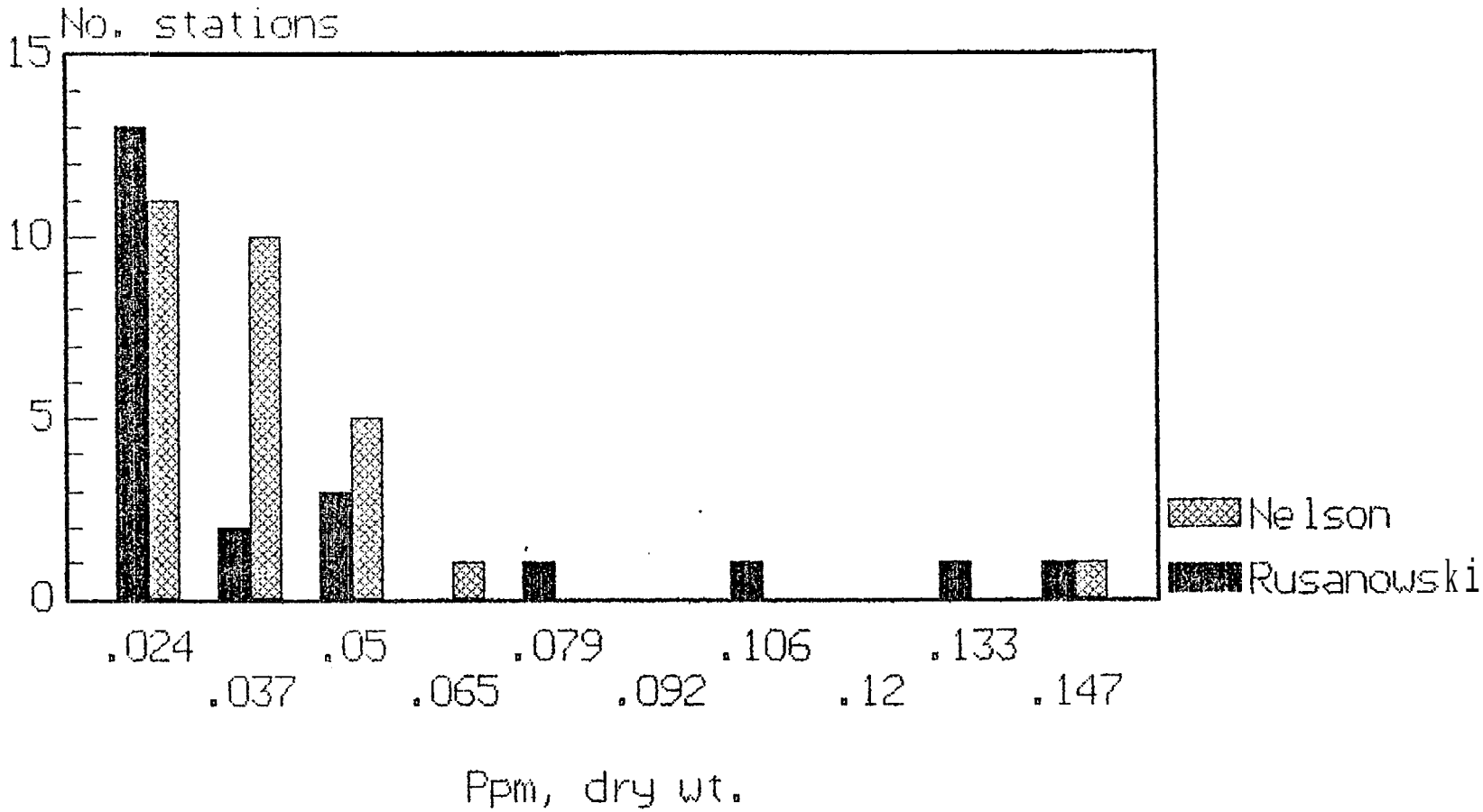

Fig. 21. Mercury in surface sediment near **Nome,** based on 28 samples of Nelson, et al **(1972)** and 22 samples of **Rusanowski,** et **al** (1988).

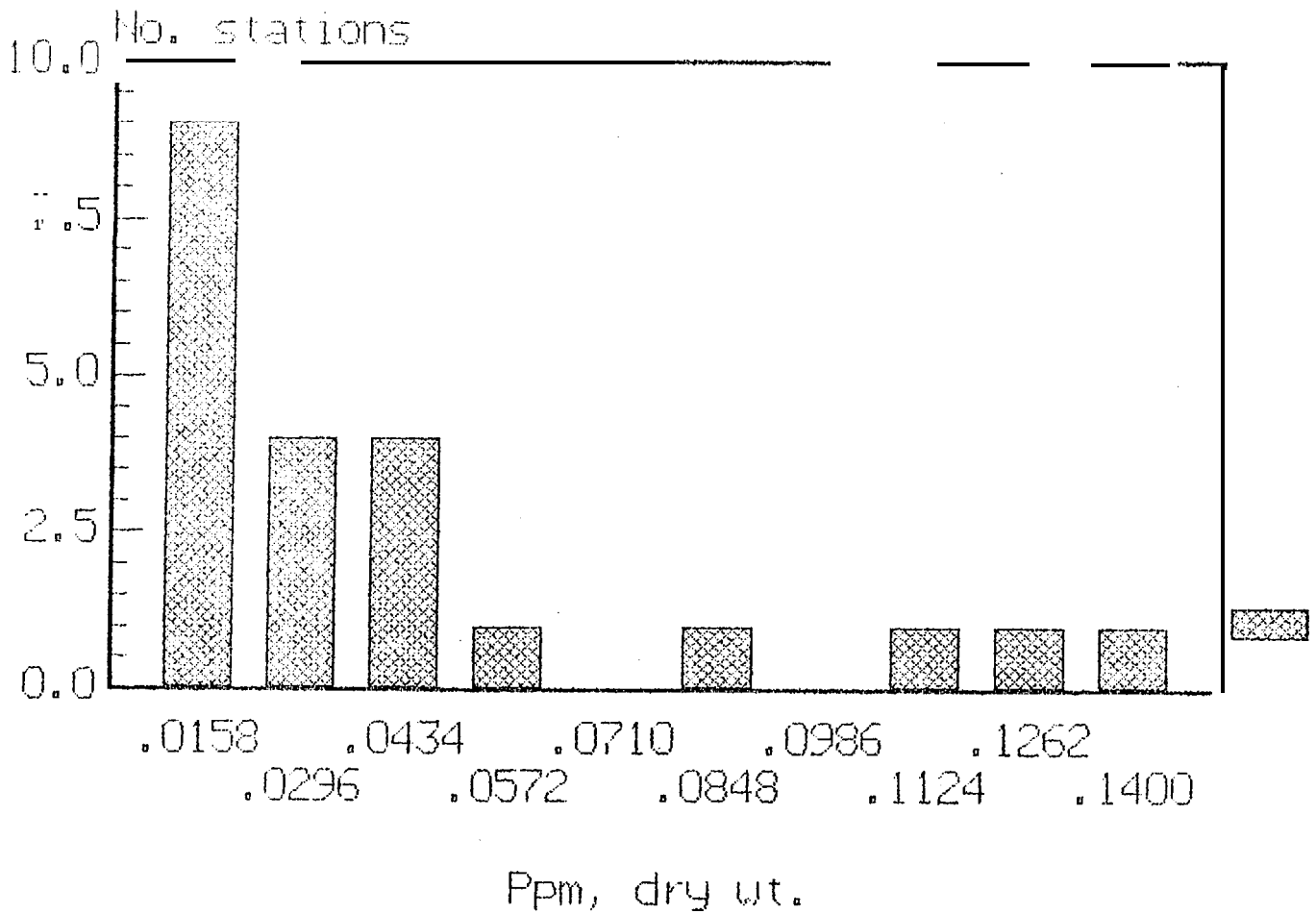

Fig. 22. Mercury concentration in surface sediment at 22 stations near **Nome.** Based on **Rusanowski,** et al (1988).

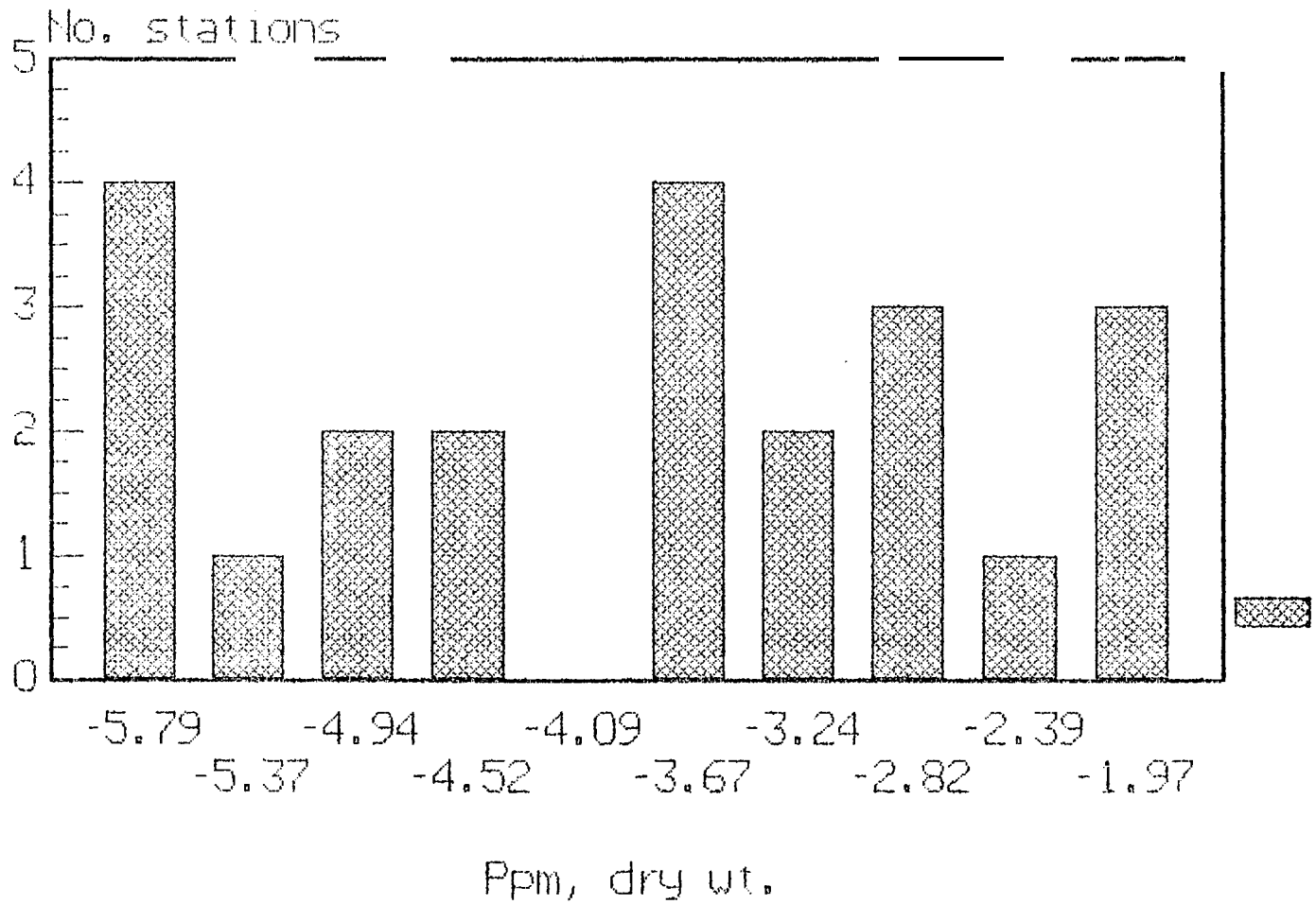

Fig. 23. Log normal of mercury in surface sediment at 2 stations near Nome. Based on Rusanowski, et al (1988).

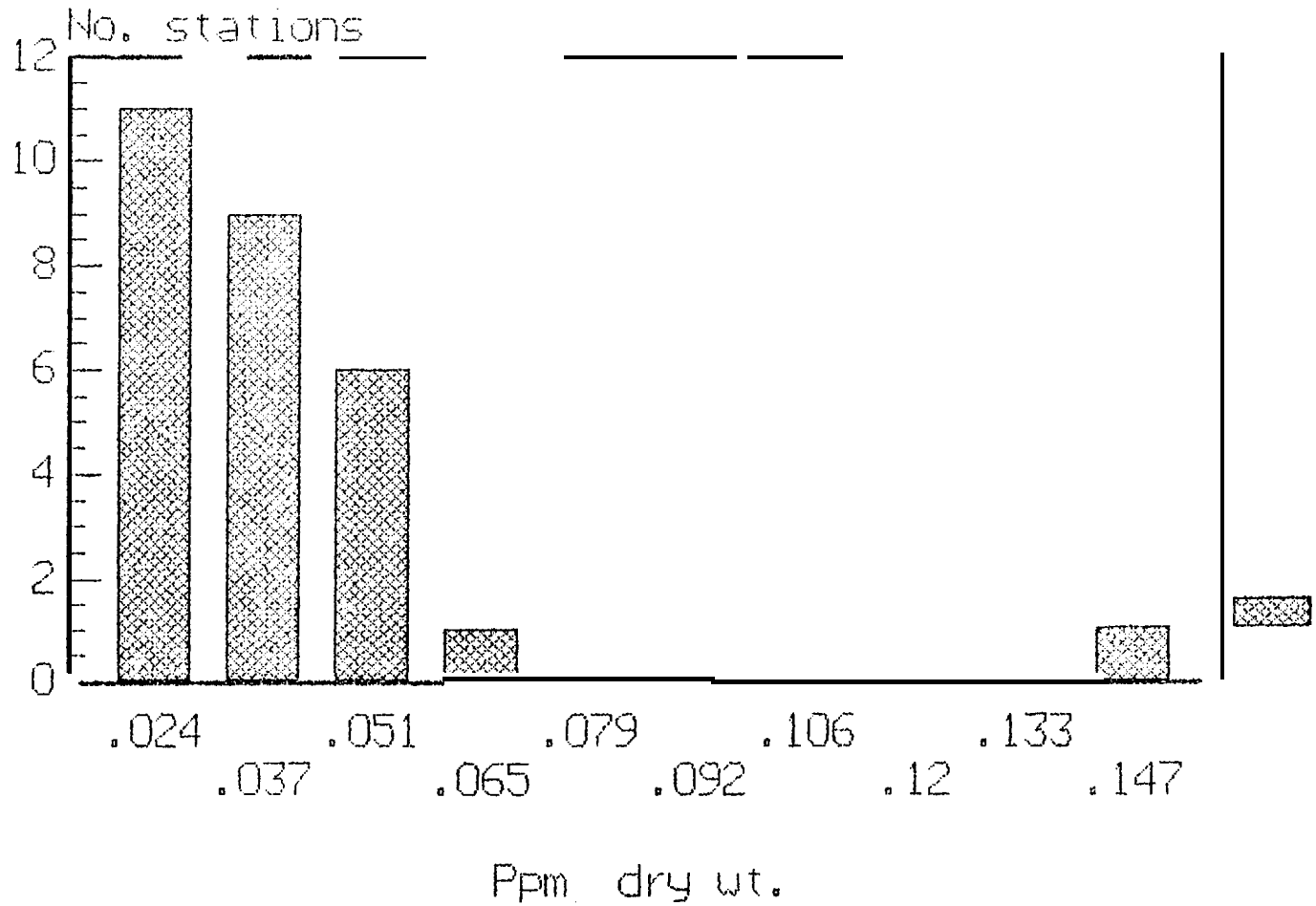

Fig. 24. Mercury concentration in surface sediment at 28 stations near Nome. Based on Nelson, et al (1972).

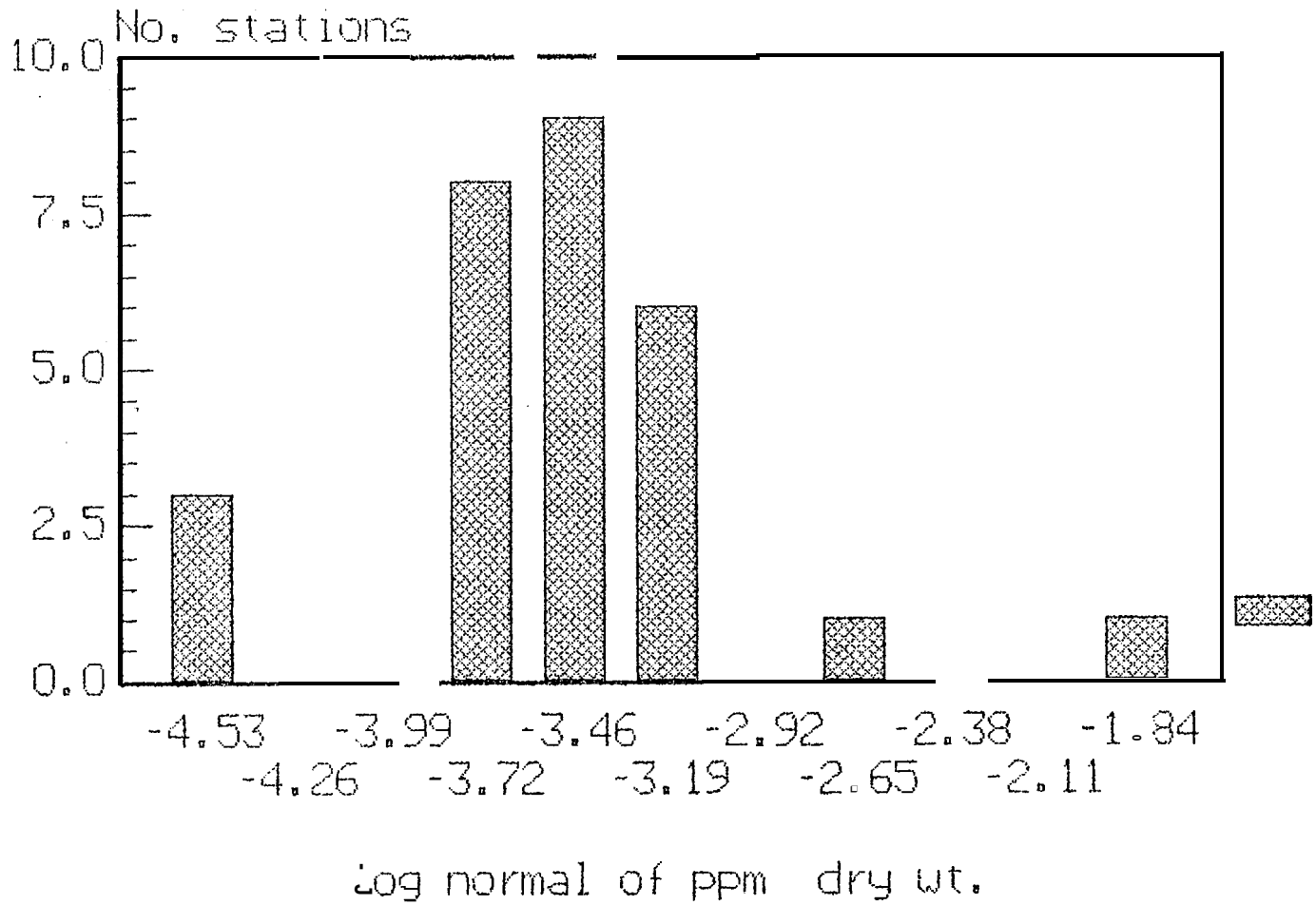

Fig. 25. Log normal of mercury in surface sediment at 28 stations near Nome. Based on Nelson, et al (1972).

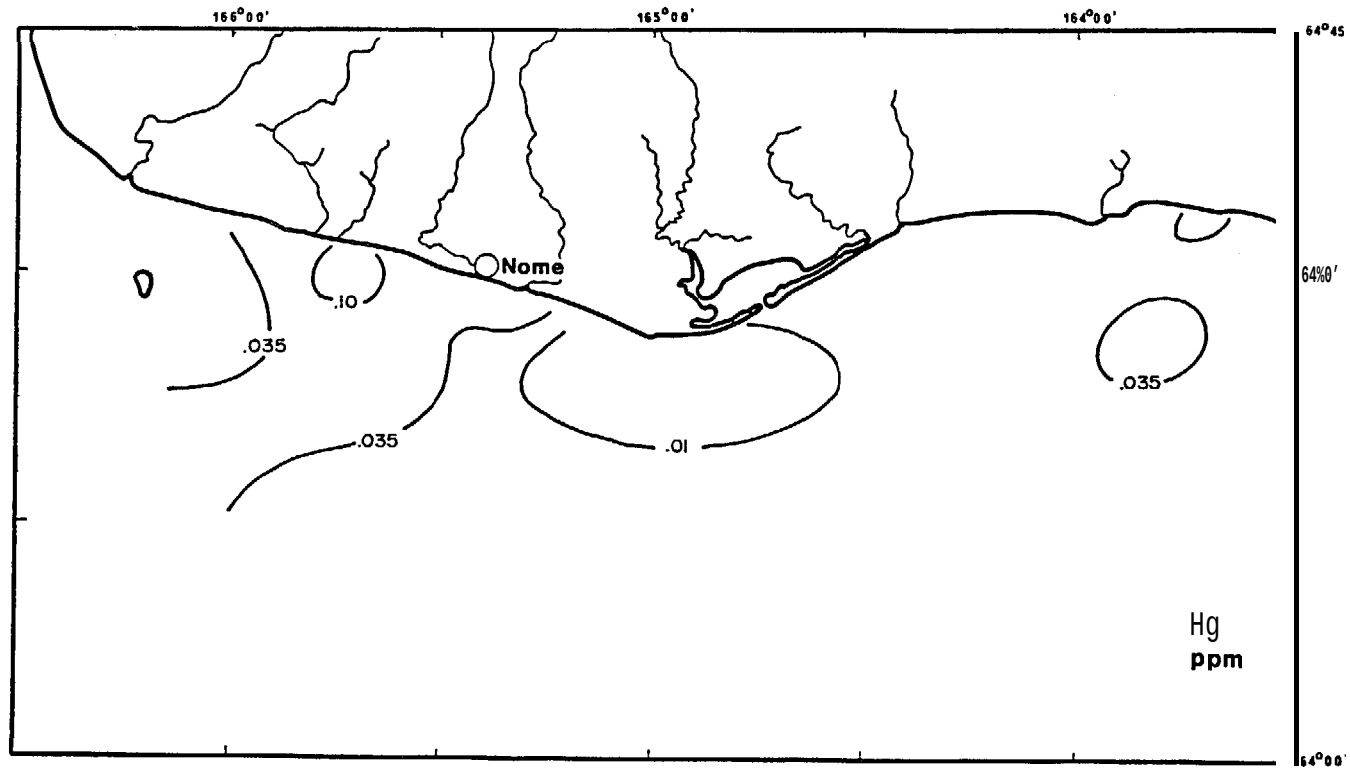

Fig. 26. **Isolines** of mercury concentration in surface sediments, 0-10 cm, based on 28 van Veen grab and box core samples, in ppm dry weight. Drawn from Nelson, et al (1972: Appendix I).

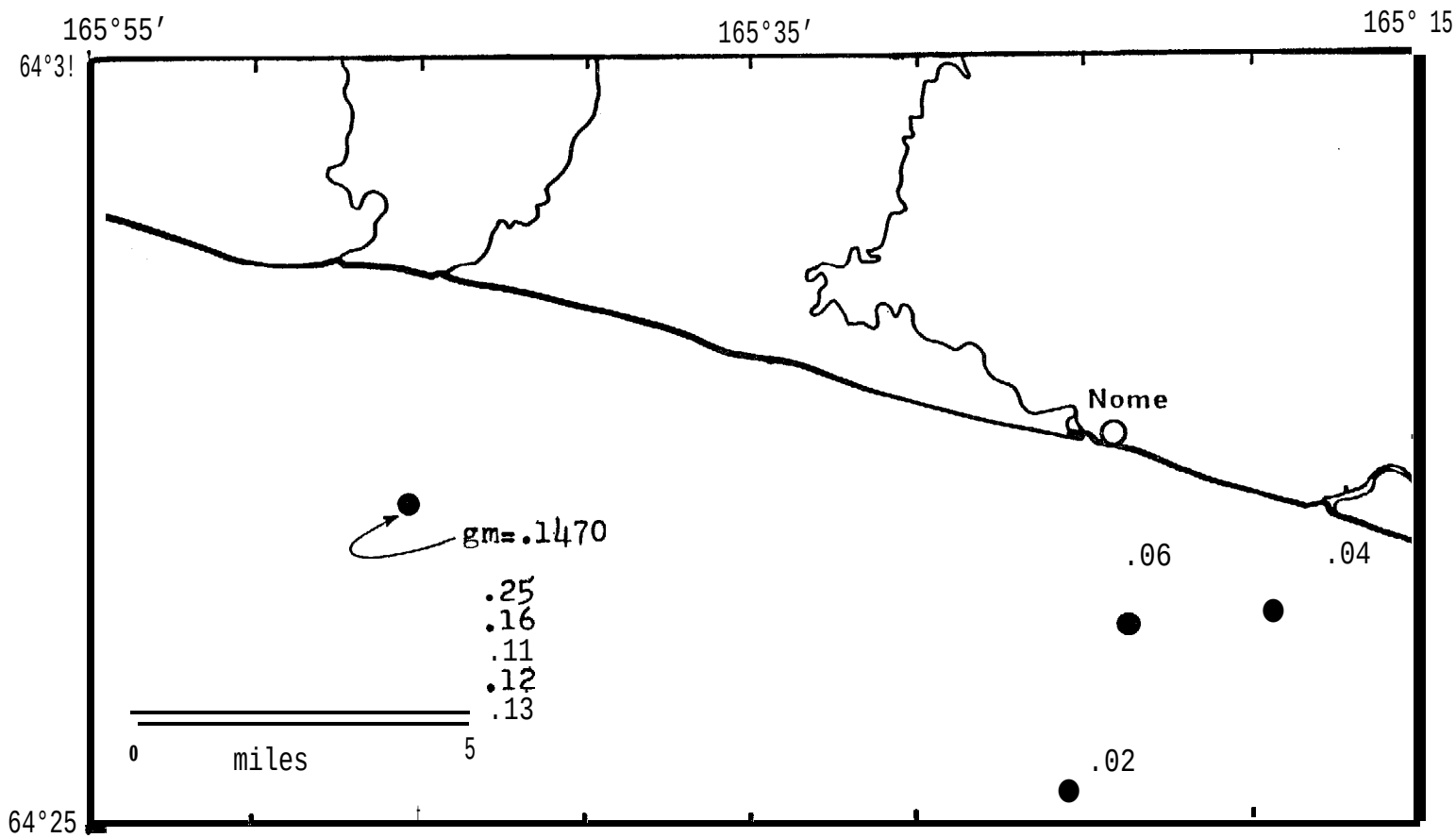

Fig. 27. Mercury concentrations in surface sediments 0-10 cm, off Nome, in ppm dry weight. Sampled by van Veen grabs and box corers. The western station represents the geometric mean of five subsamples of a single grab. Adapted from Nelson, et al (1972).

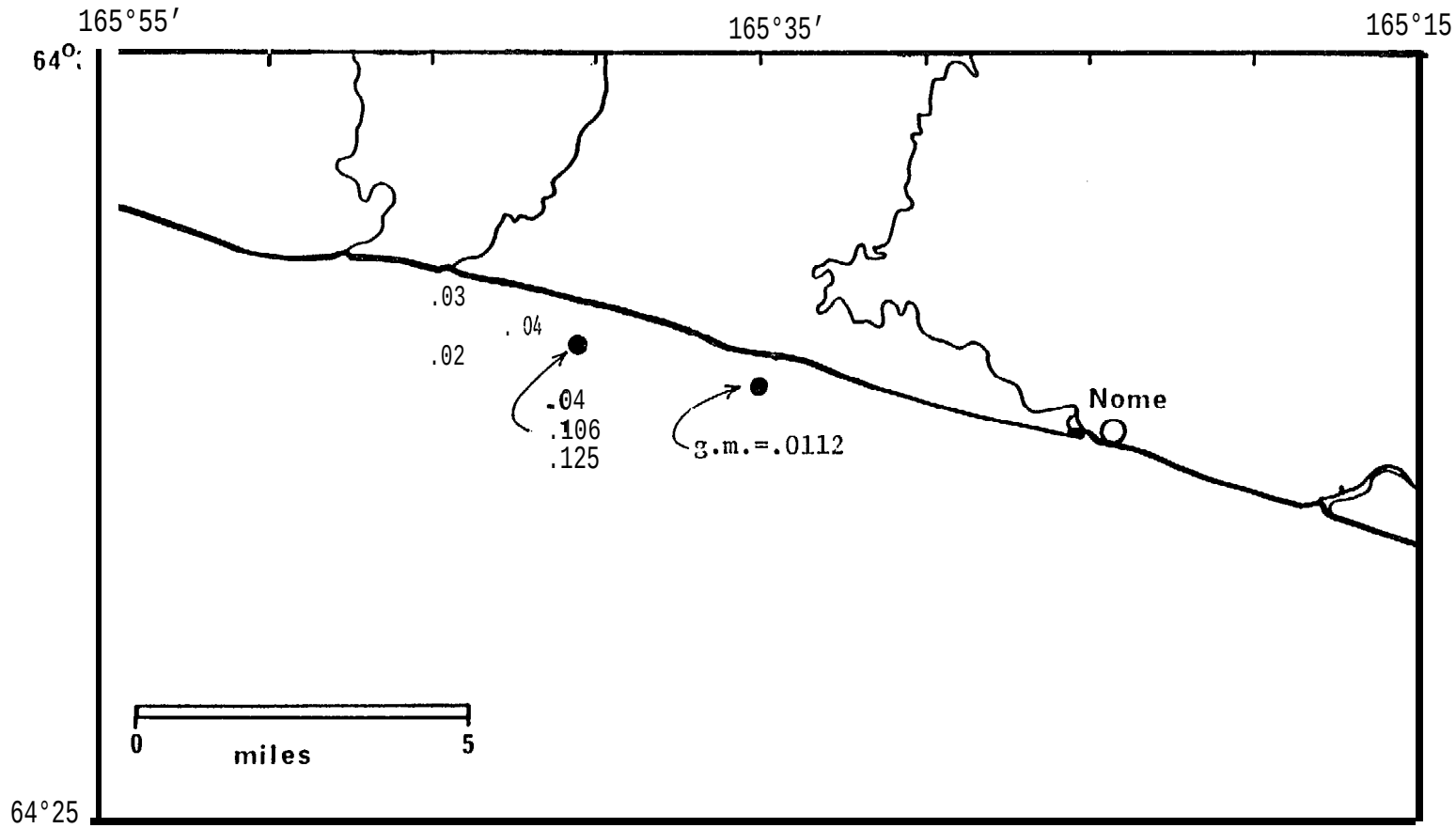

Fig. 28. Background mercury concentrations in surface sediments near the BIMA dredge, 1985-1987, in ppm dry weight. Shown are six determinations at four approximate locations, and the geometric mean of sixteen grabs and determinations at the eastern-most location. The geometric mean was calculated from sixteen values, including seven values equal to lower detection limit, Drawn from Rusanowski, et al (1988: Table 3.3-1).

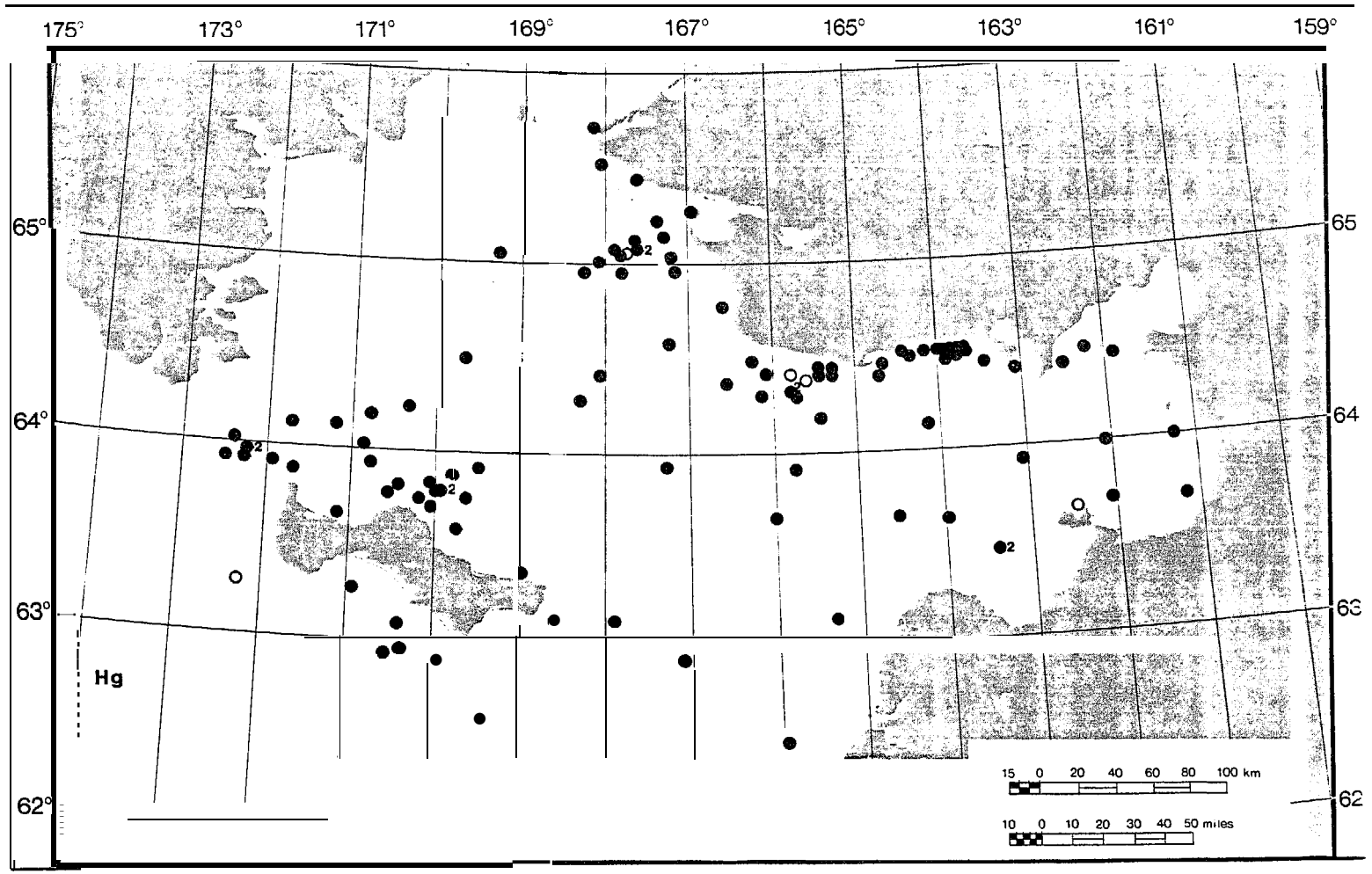

Fig. 29. Sampling locations for mercury concentrations in surface sediment, 0-10 cm, using van Veen grabs and box corers. At five locations, two determinations were made. At another five locations, five determinations were made; these locations are represented by open circles. Adapted from Nelson, et al (1972: Appendix I).

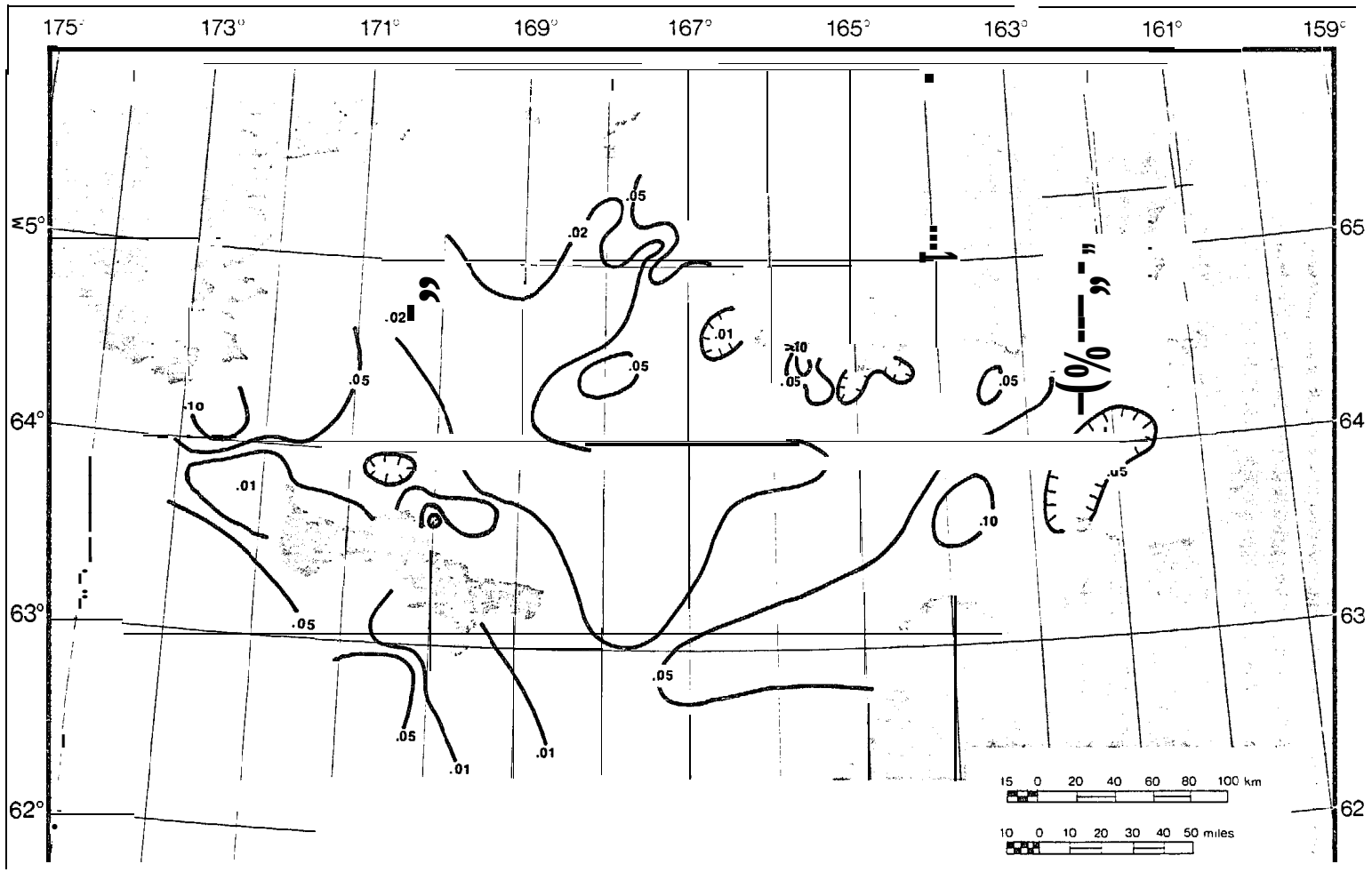

Fig. 30. Mercury concentrations in surface sediments 0-10 cm, based on 105 van Veen grabs and box core samples; ppm dry weight. Drawn from tabular data in Nelson, et al (1972: Appendix I).

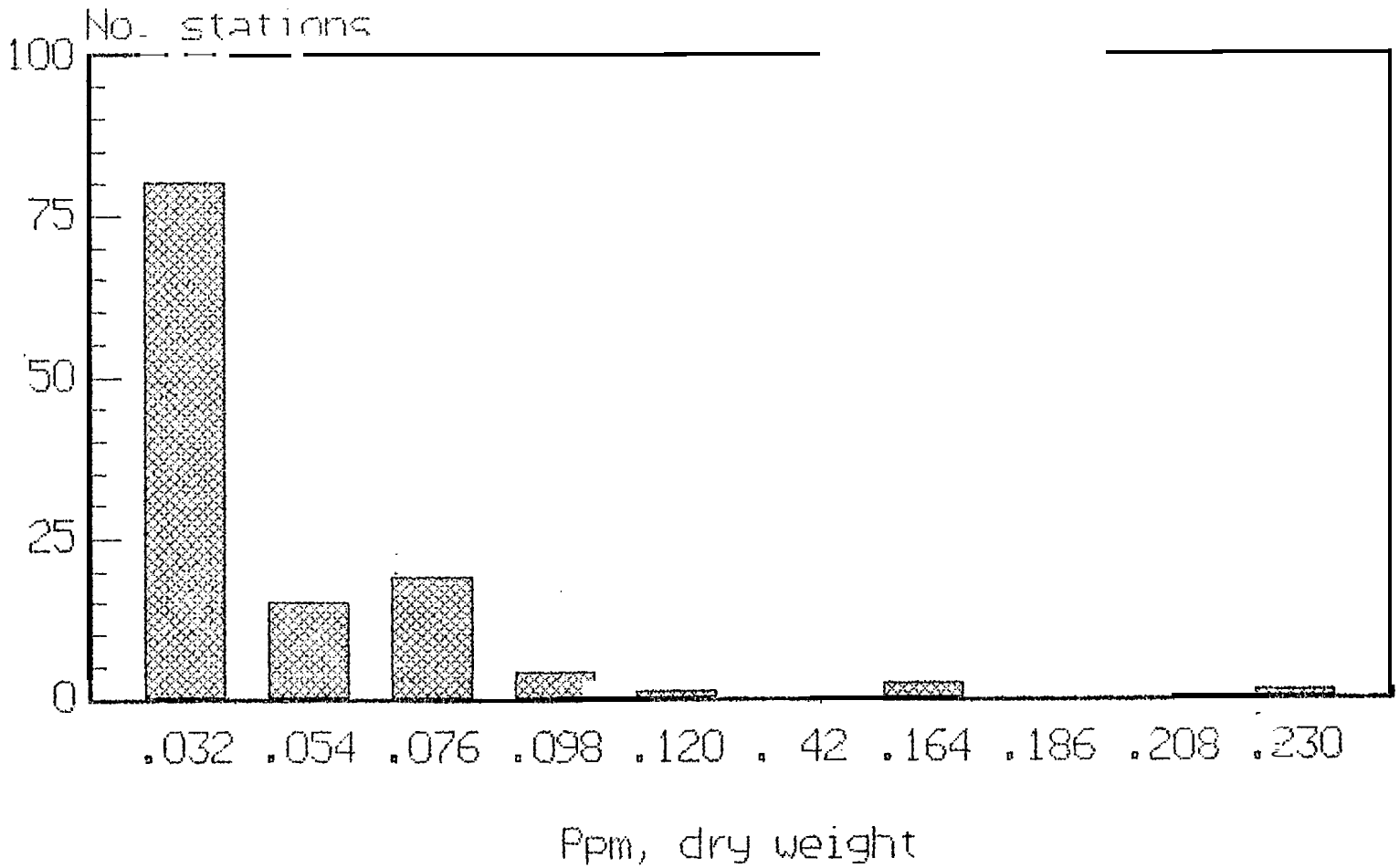

Fig. 31. Mercury in surface sediment at 122 stations in Norton Basin area, Alaska. Based on Nelson, et al (1972).

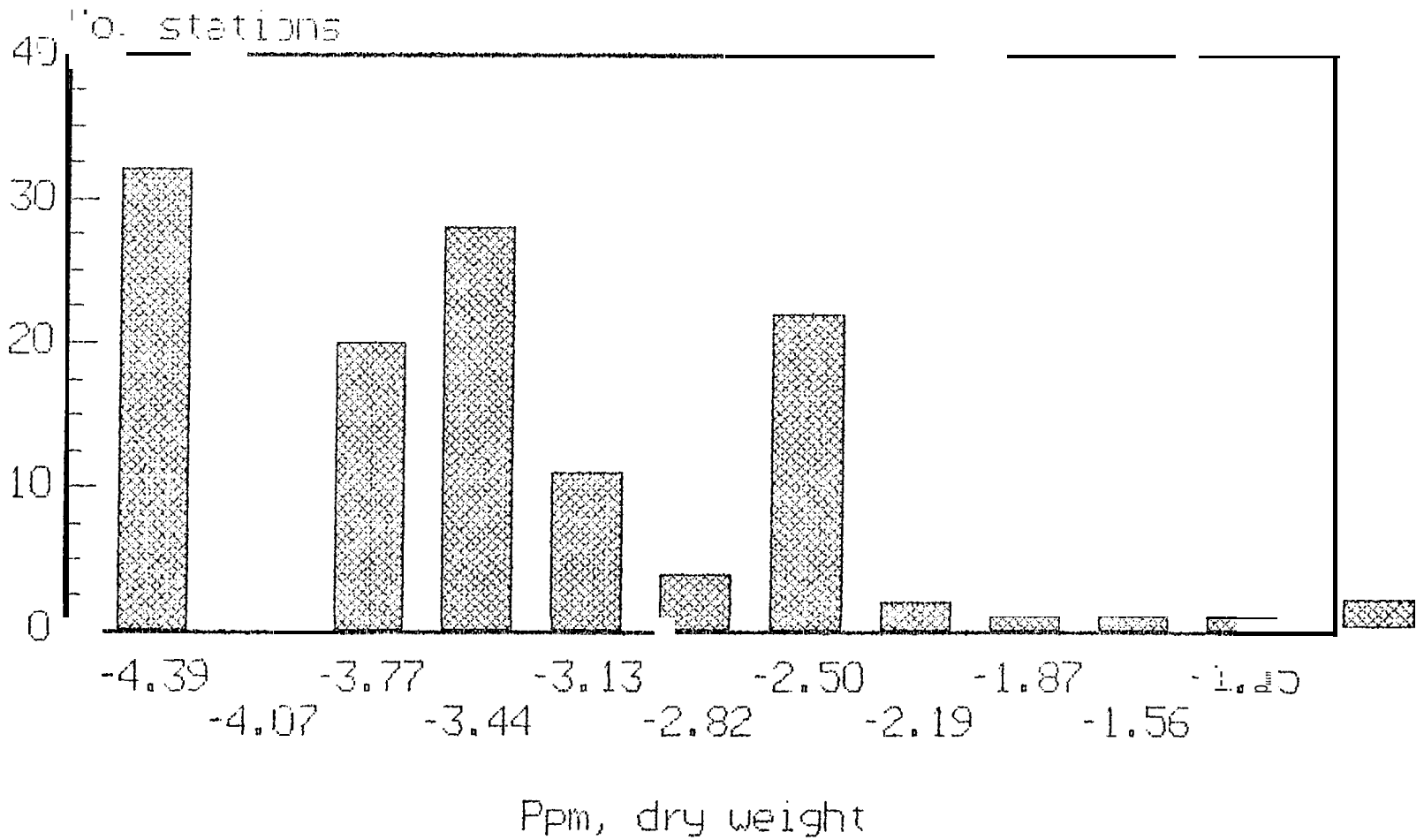

Fig. 32. Log normal of ppm mercury at 122 stations in Norton Basin area, Alaska. Based on Nelson, et al (1972).

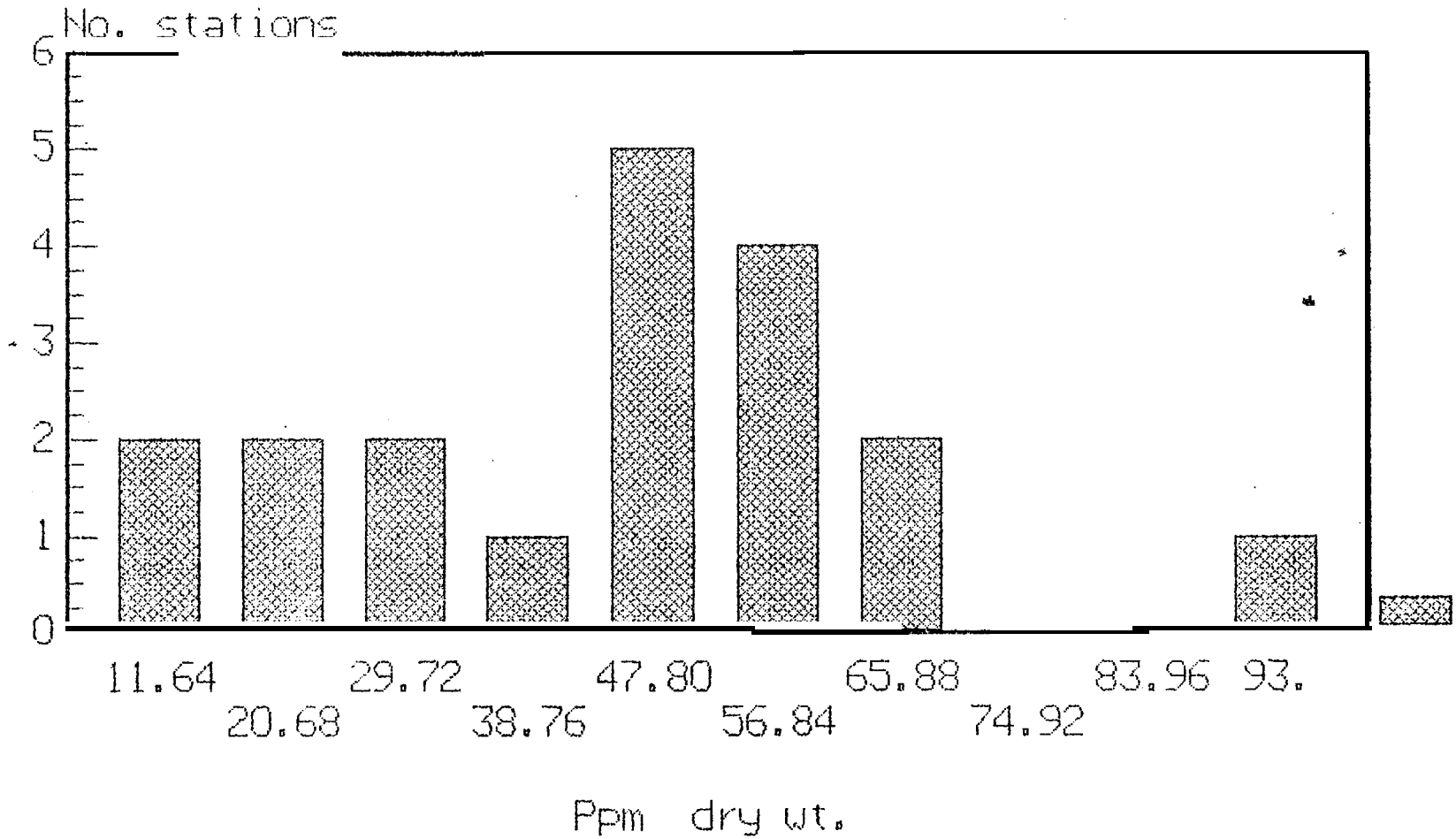

Fig. 33. Nickel in surface sediment at 19 stations near Nome. Based on Rusanowski, et al (1988).

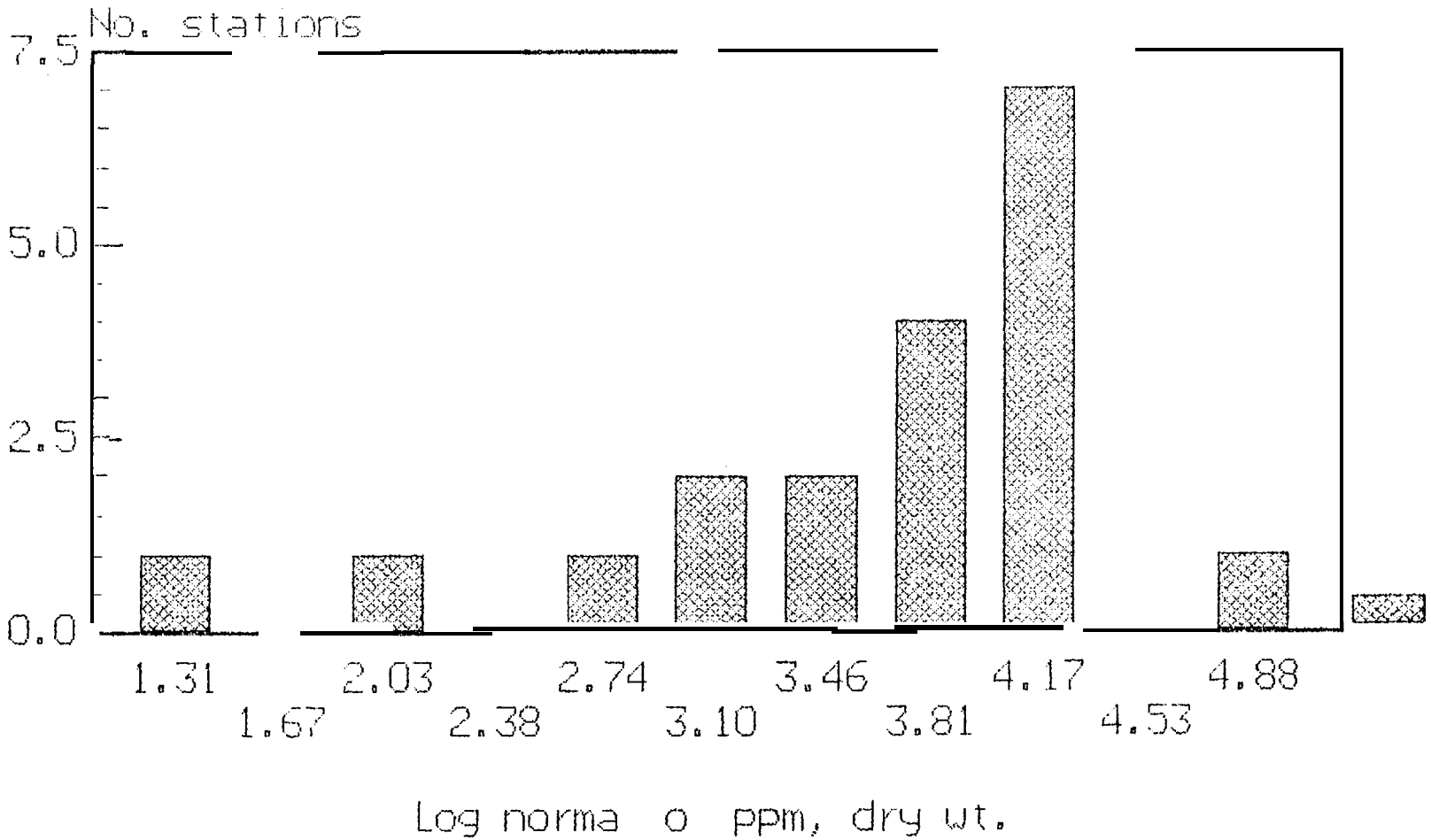

Fig. 34. Log normal of ppm of nickel in surface sediment at 19 stations near Nome. Based on Rusanowski, et al (1988).

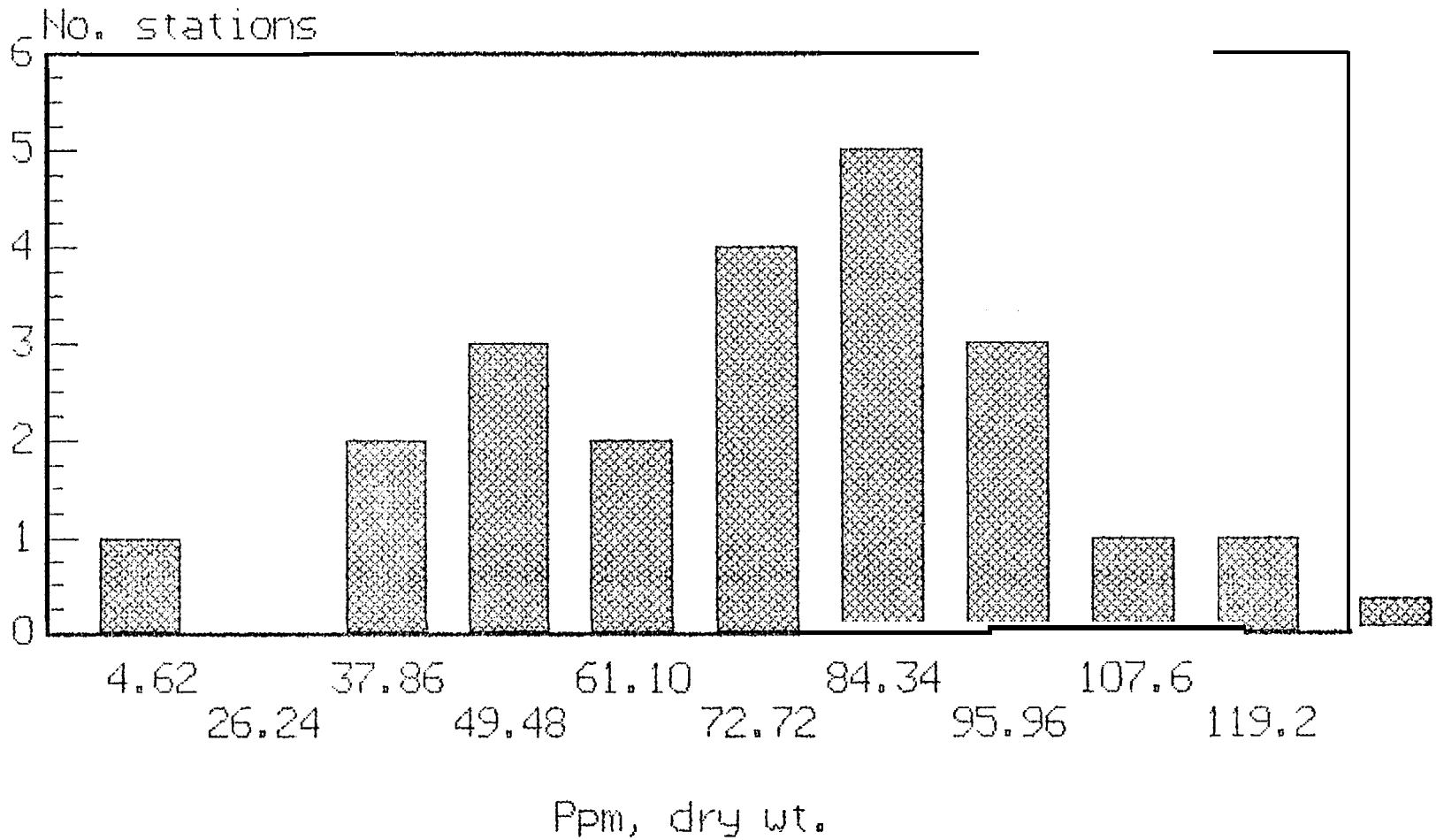

Fig. 35. Zinc in surface sediment at 22 stations near Nome. Based on Rusanowski, et al (1988).

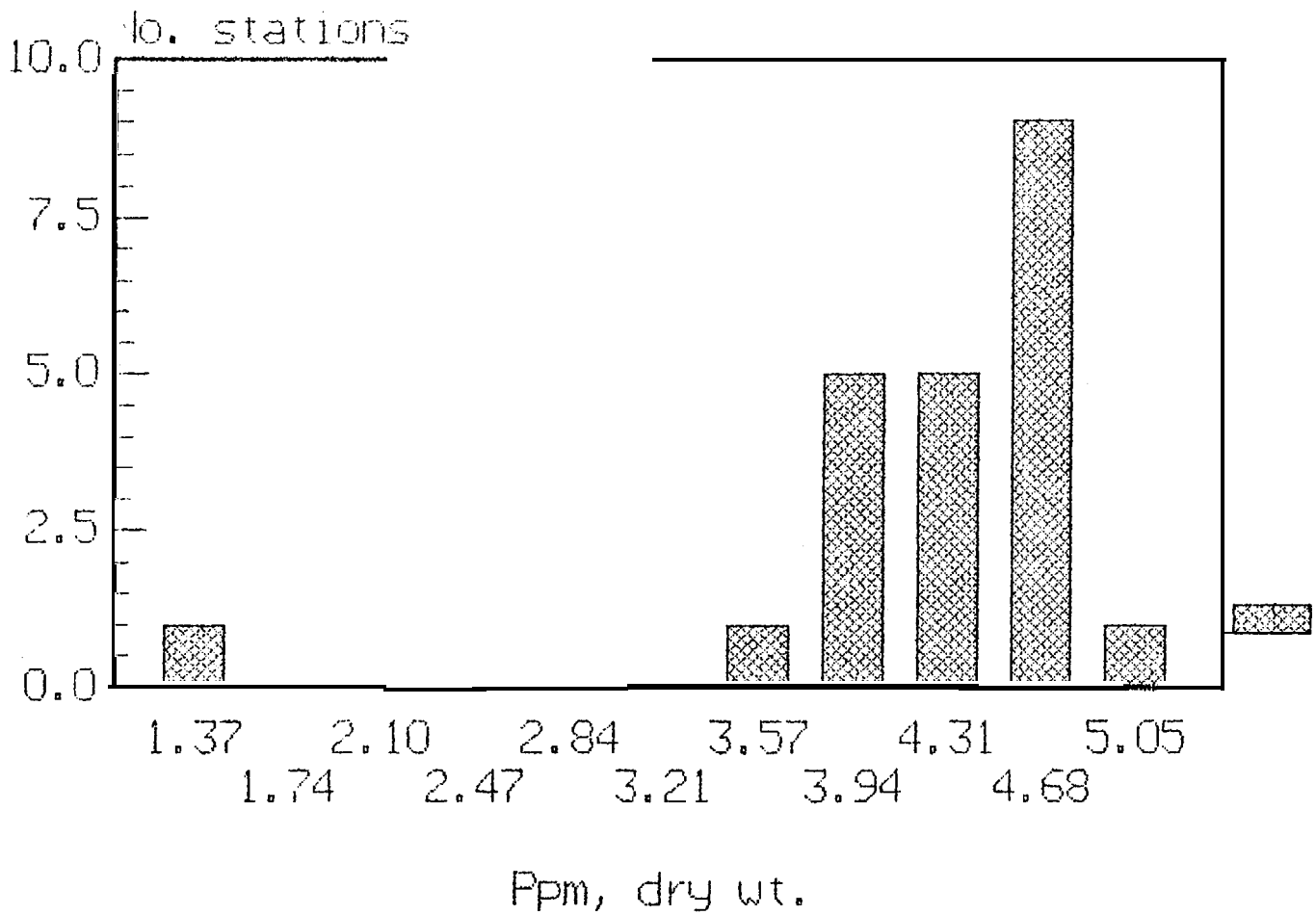

Fig. 36. Log normal of zinc in surface sediment at 22 stations near Nome. Based on Rusanowski, et al (1988).

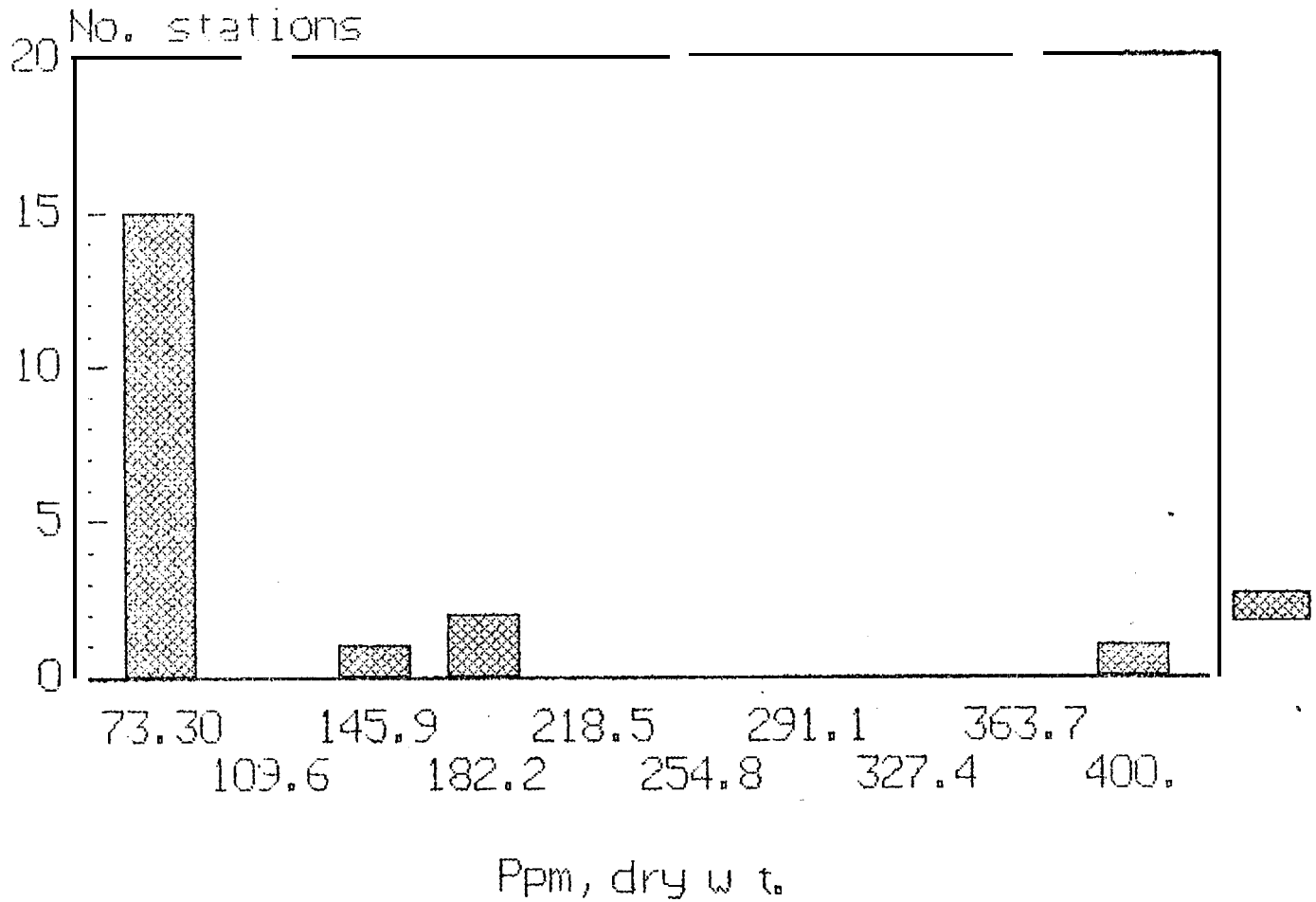

Fig. 37. Zinc in surface sediment at 19 stations near Nome. Based on Sharma (1974).

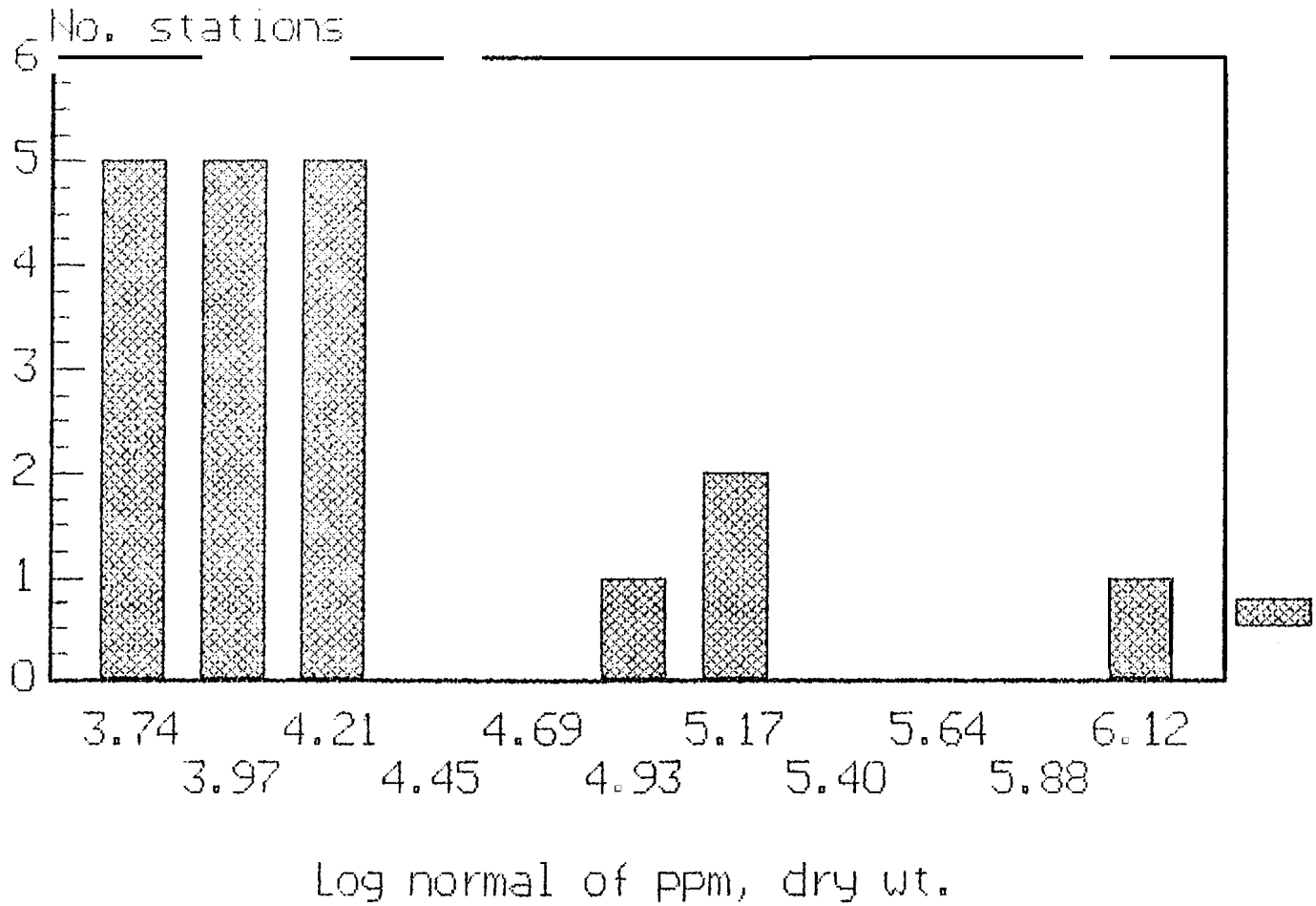

Fig. 38. Log normal of zinc in surface sediment at 19 stations near Nome. Based on Sharma (1974).

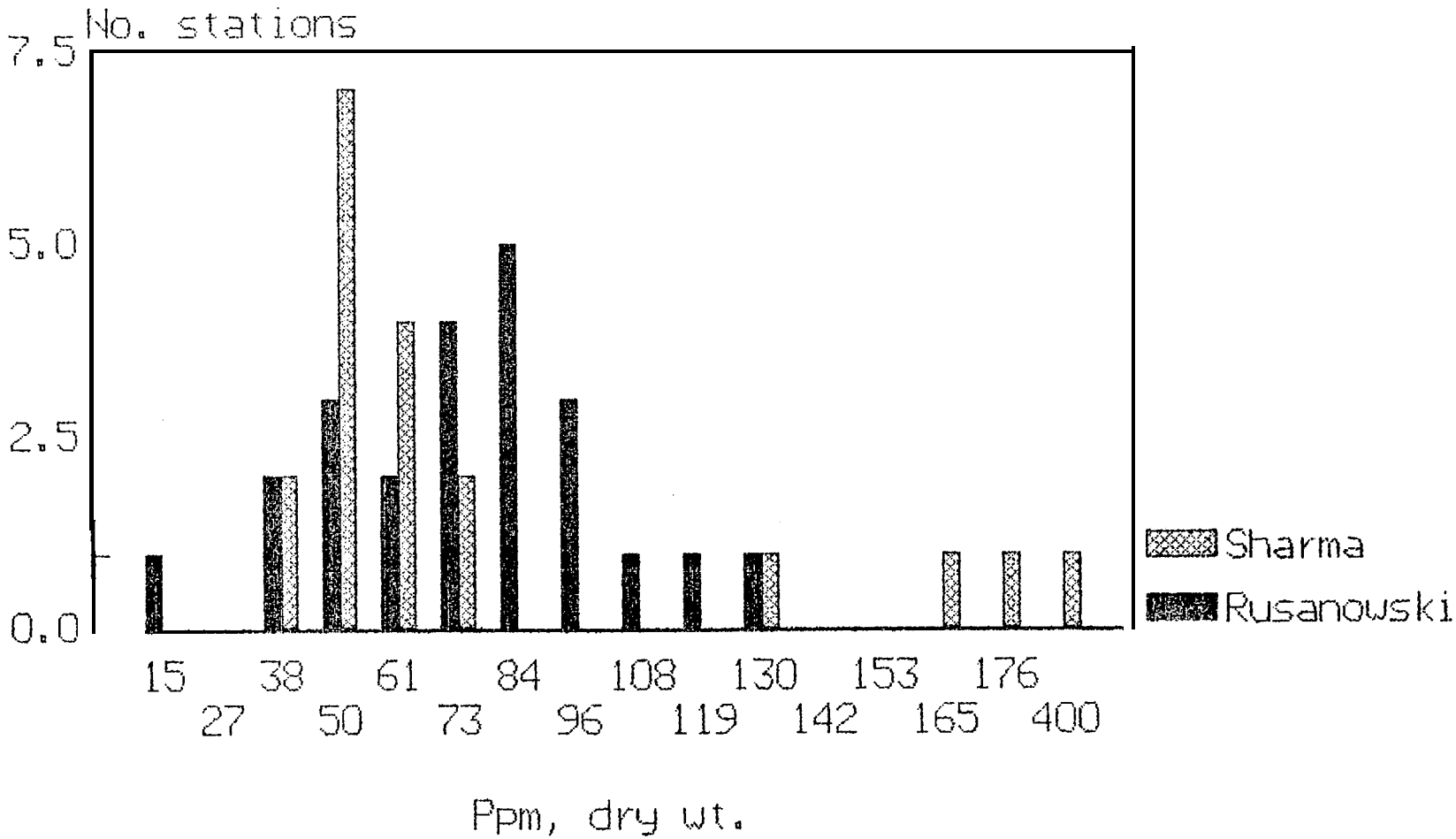

Fig. 39. Zinc in surface sediment near Nome, based on 22 samples of **Rusanowski,** et al (1988) and 19 samples of Sharma (1974).

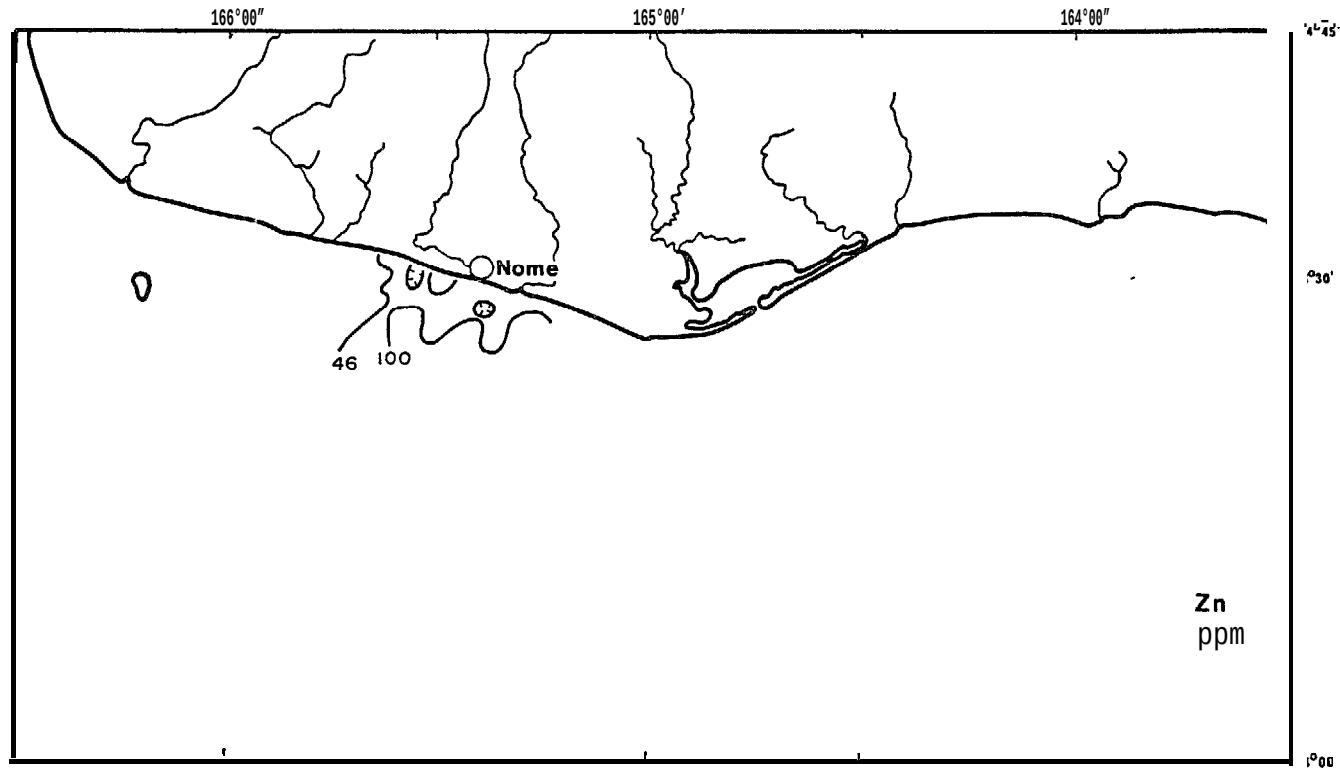

Fig. 40. **Isolines** of zinc concentration in surface sediments based on 19 van Veen grabs. Drawn from **Sharma (1974:139).**

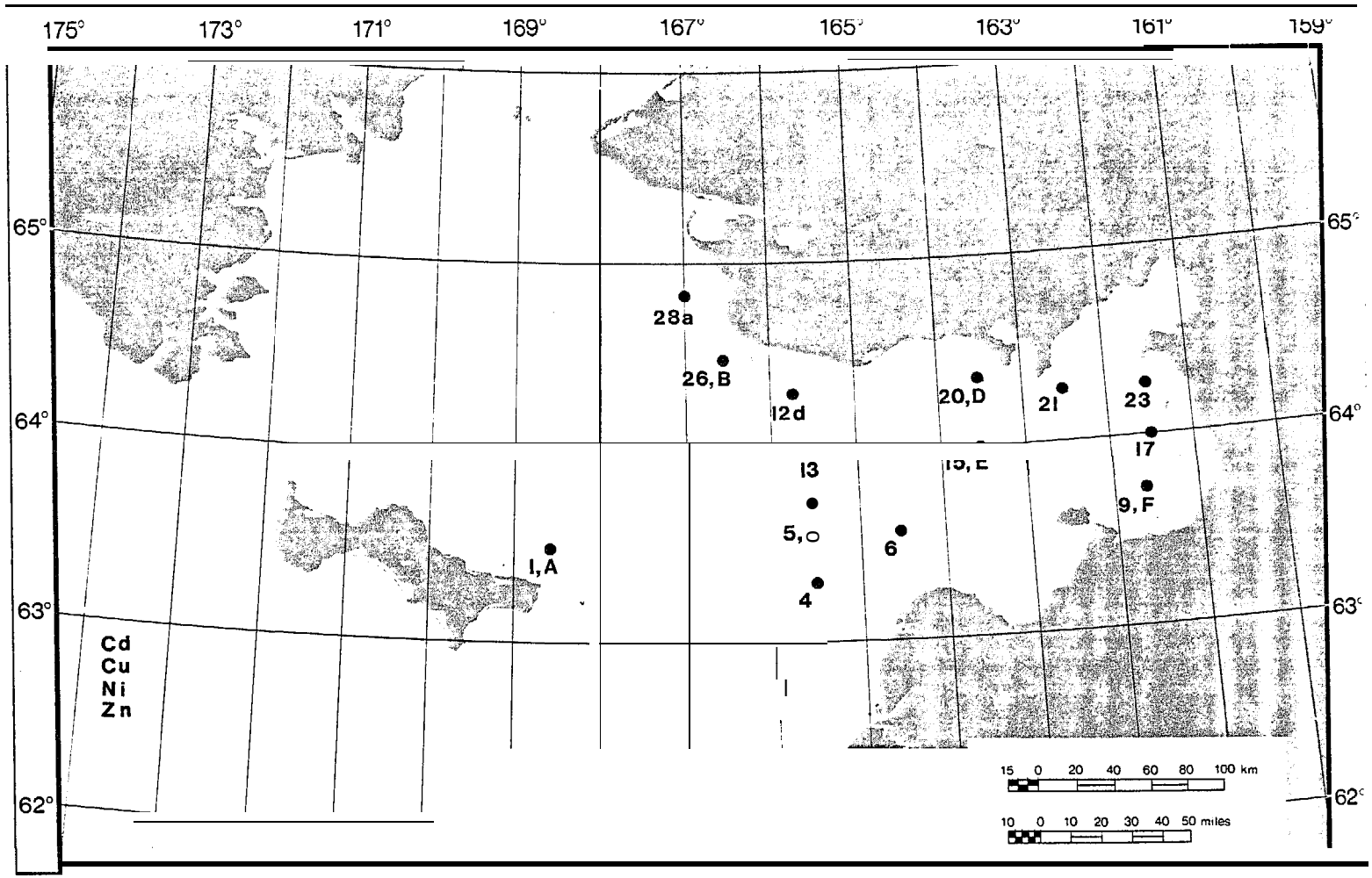

Fig. 41. Locations sampled for "acid-extractable" concentrations of cadmium, copper, nickel, and zinc by HAPS corer. The numbers are station labels of Burrell (1977). The letters are labels of stations analyzed for other metals in "whole-rock" samples by Robertson and Abel (1979).

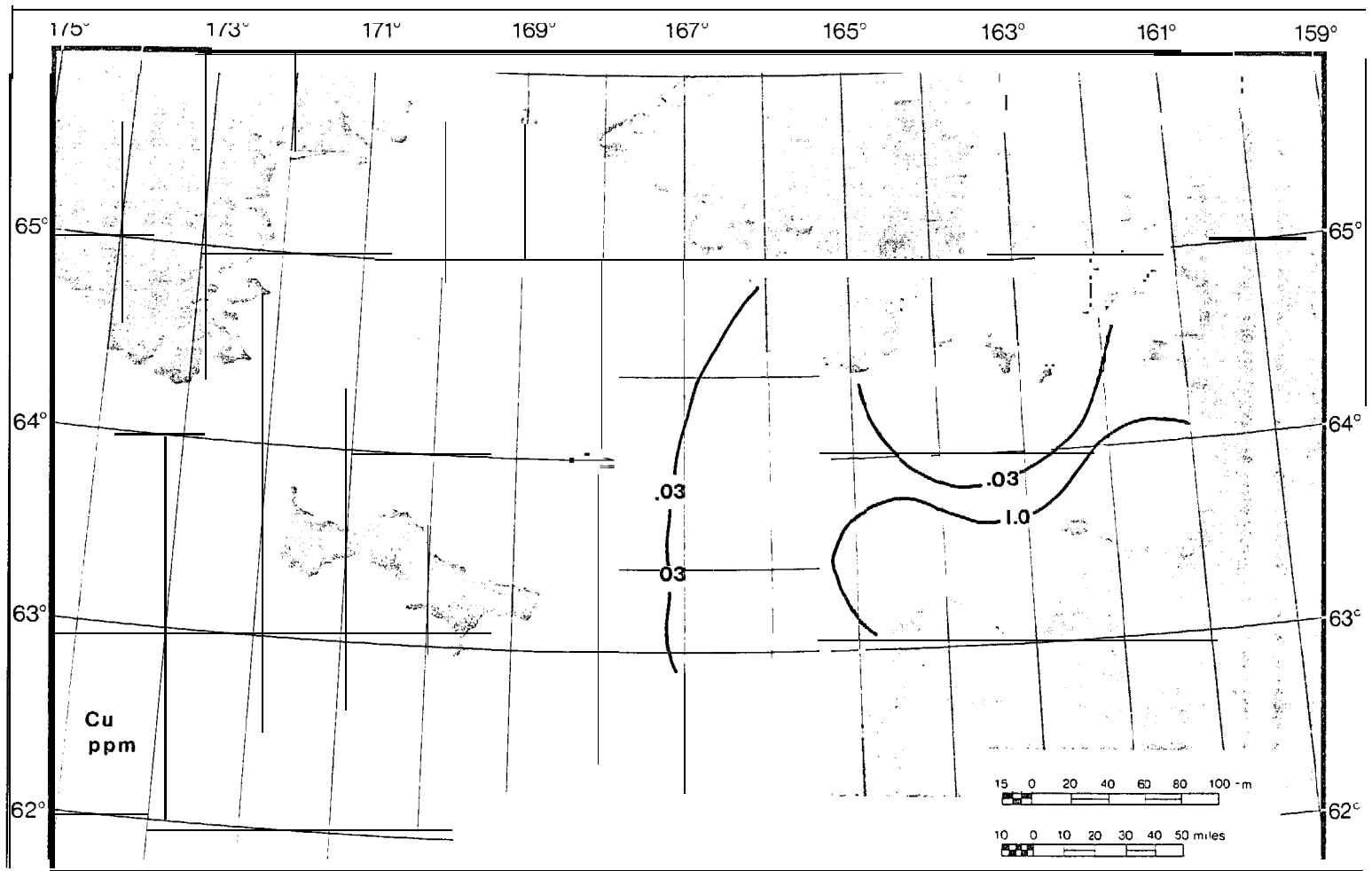

Fig. 42. Isolines of the concentration of extractable copper in surface sediment, based on 14 HAPS cores, 1976, in ppm. Adapted from Burrell 1978: Table 1).

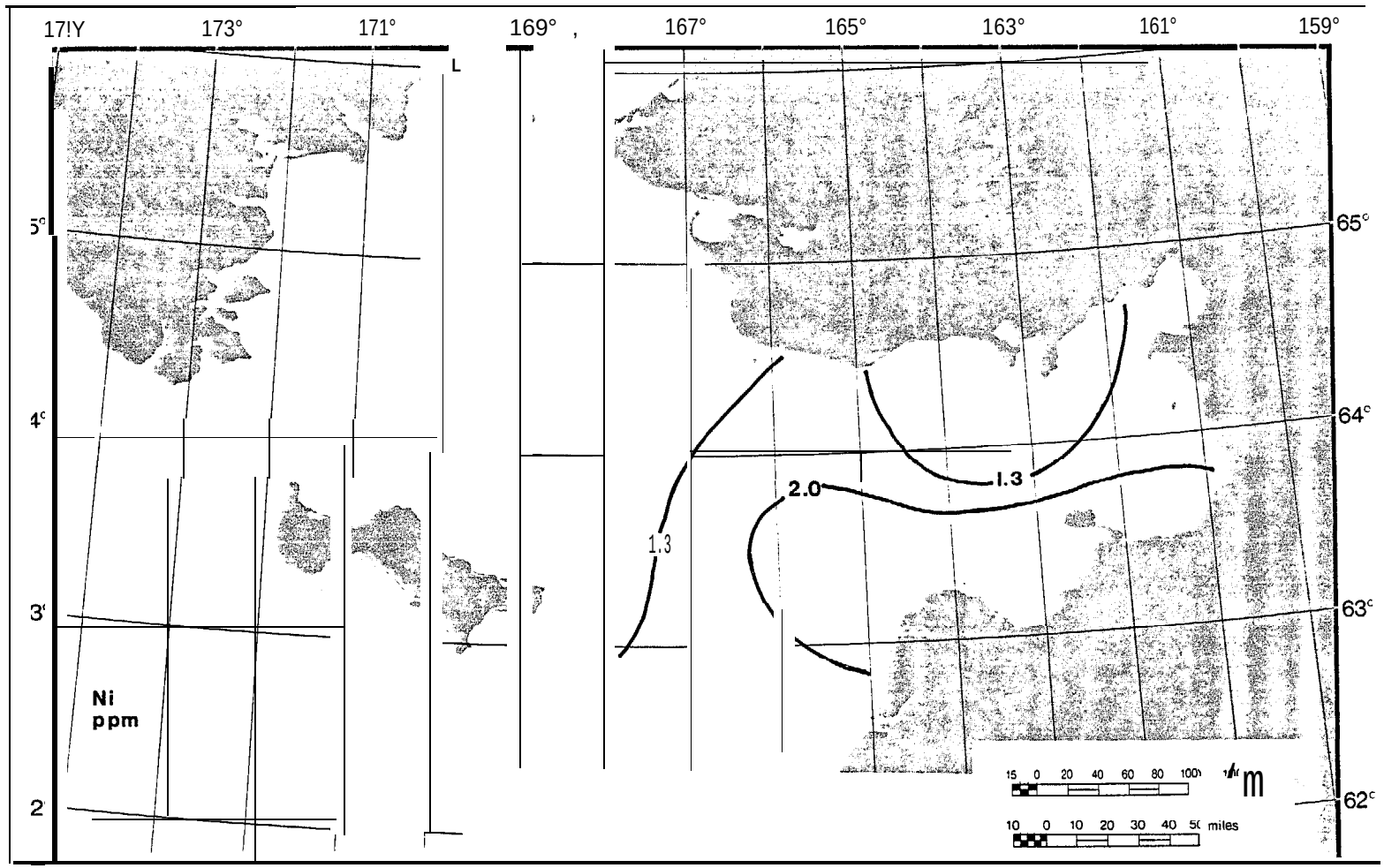

Fig. 43. **Isolines** of the concentration of extractable nickel in surface sediment, based on 14 HAPS cores, 1976, in **ppm.** Adapted from **Burrell** (1978: Table **1).**

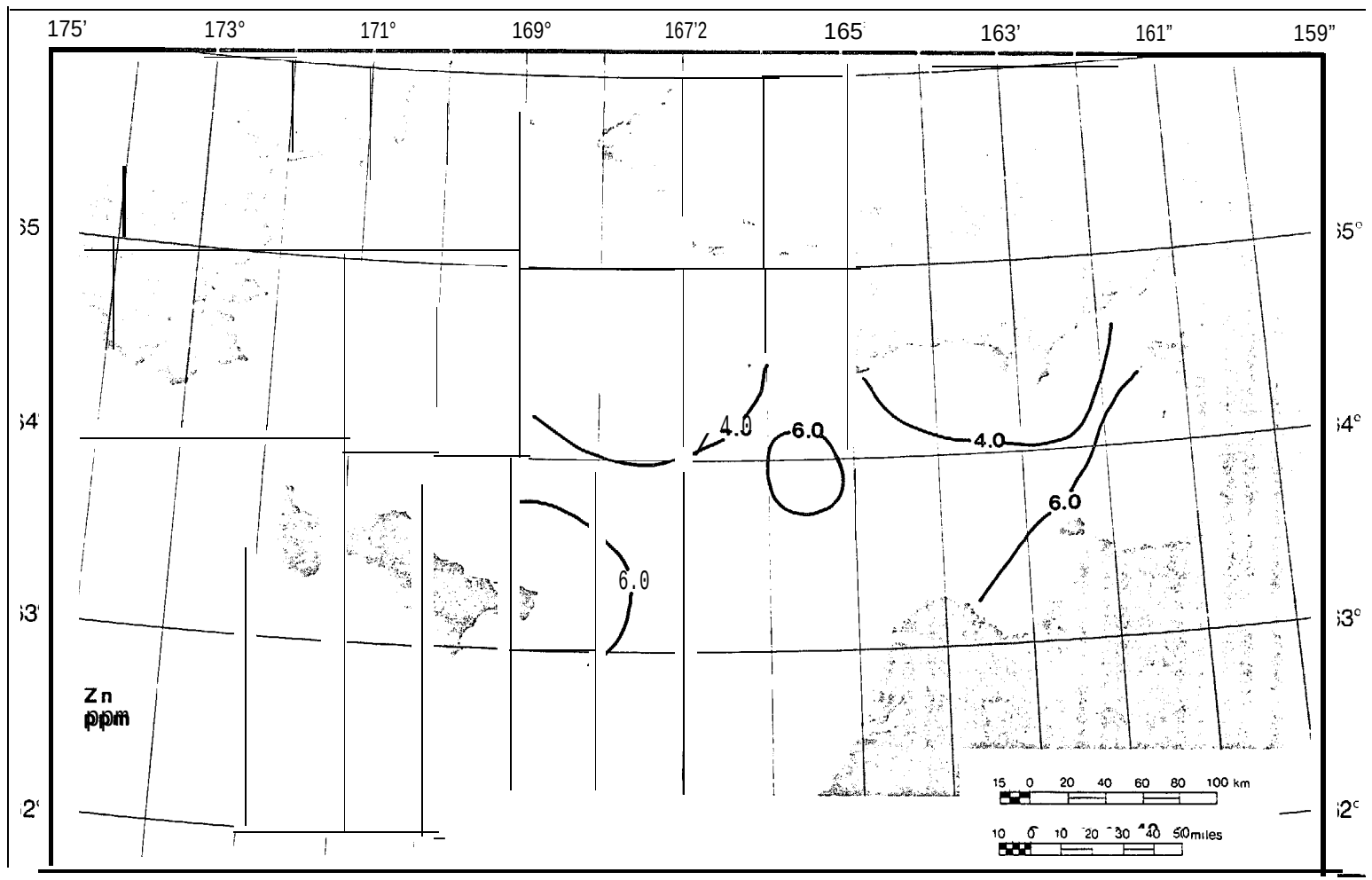

Fig. 44. **Isolines** of the concentration of extractable zinc in surface sediment, based on 14 HAPS cores, 1976, in ppm. Adapted from **Burrell** (1978: Table 1).

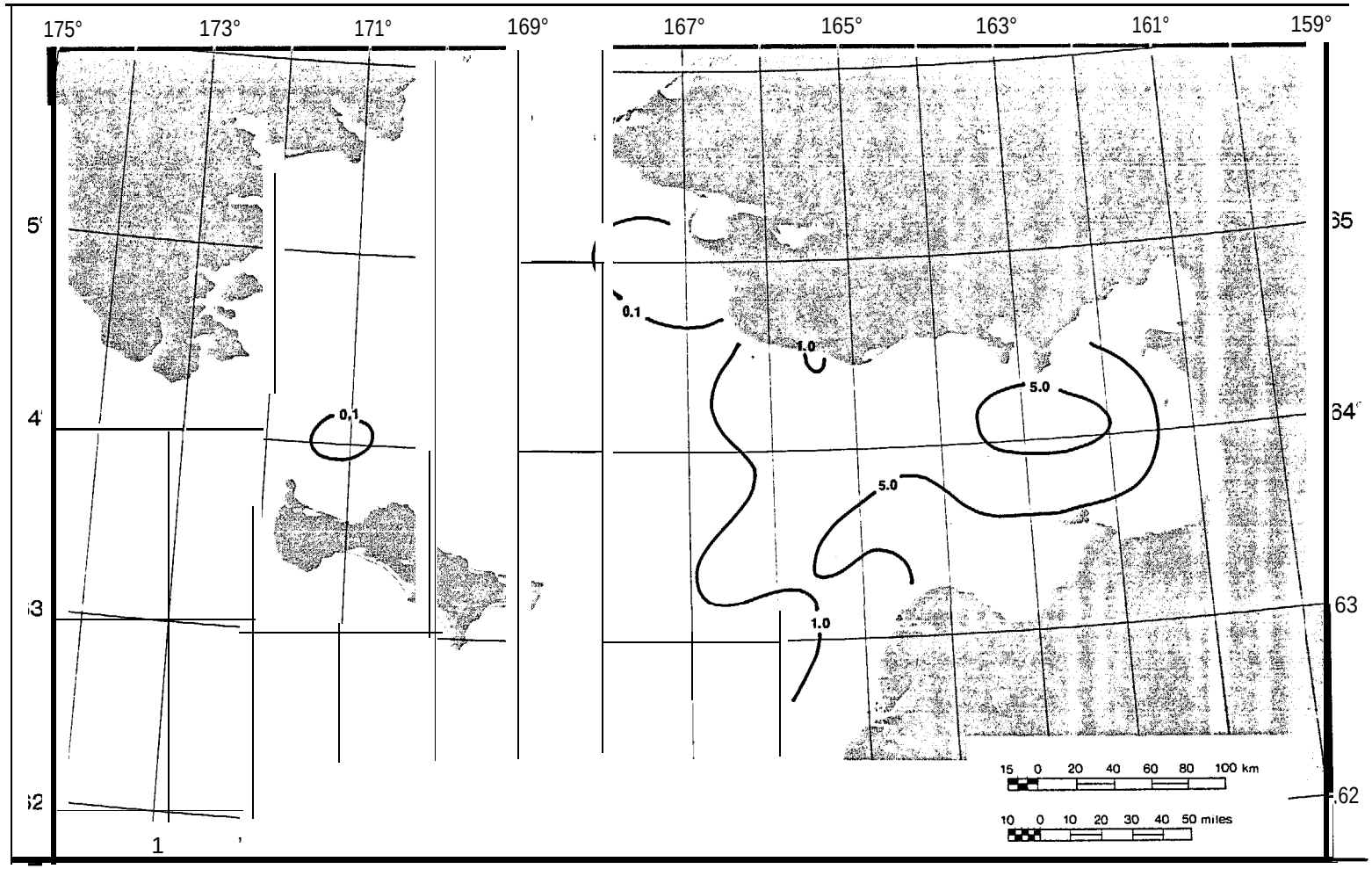

Fig. 45. **Isolines of** the concentration **of** total **n-alkanes,** resolved **by** gas chromatography, from c15 to c34, in ppm dry weight, in surface sediment. Based on 41 samples obtained by various methods in 1976, 1977, and 1979. Drawn from tabular data in Kaplan, et al (1980).

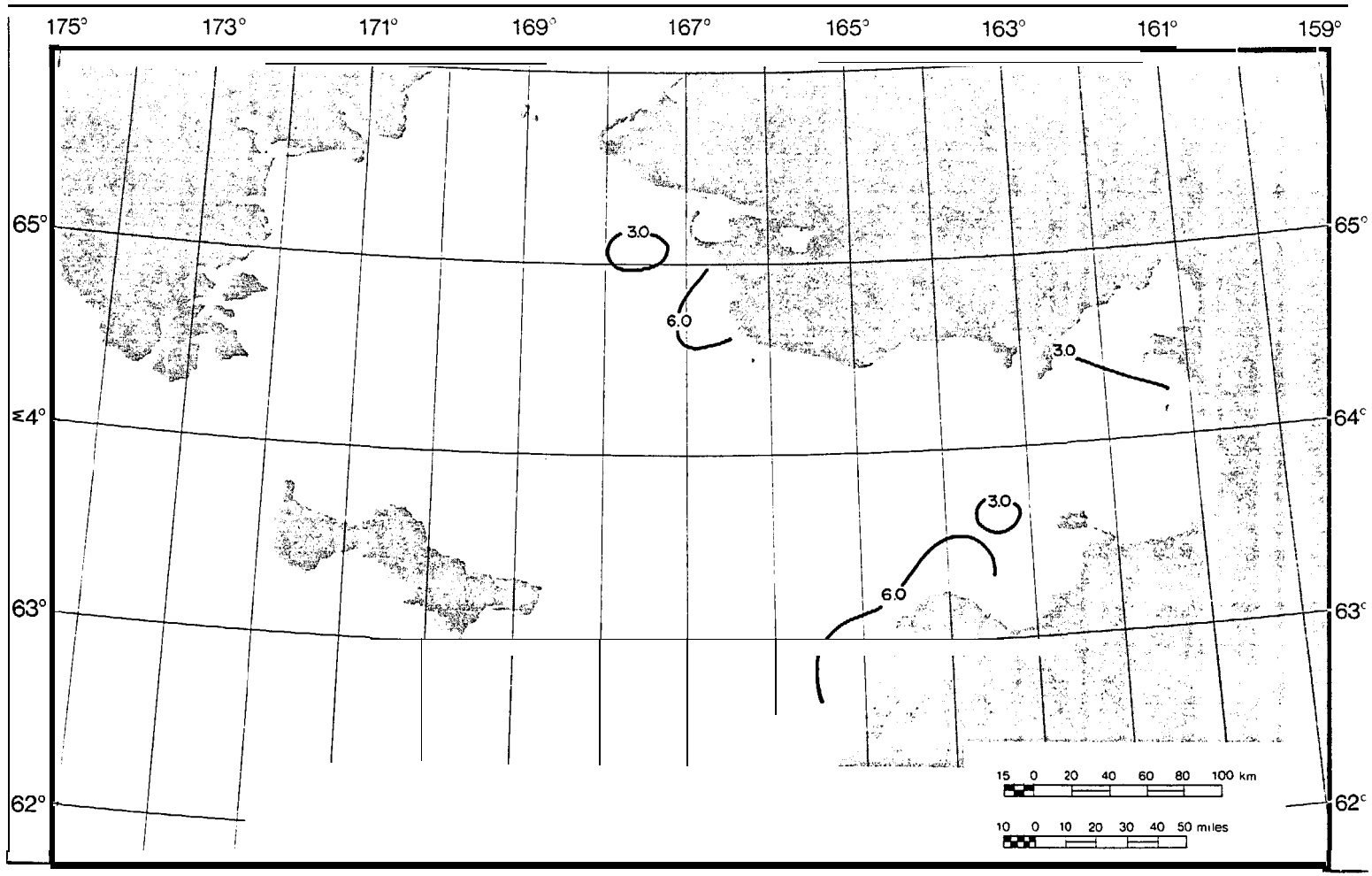

Fig. 46. Isolines of the odd-to-even ratio for n-alkanes summed from C15 to C34 in surface sediments. Based on 41 samples obtained by various methods in 1976, 1977, and 1979. Drawn from tabular data in Kaplan, et al (1980).

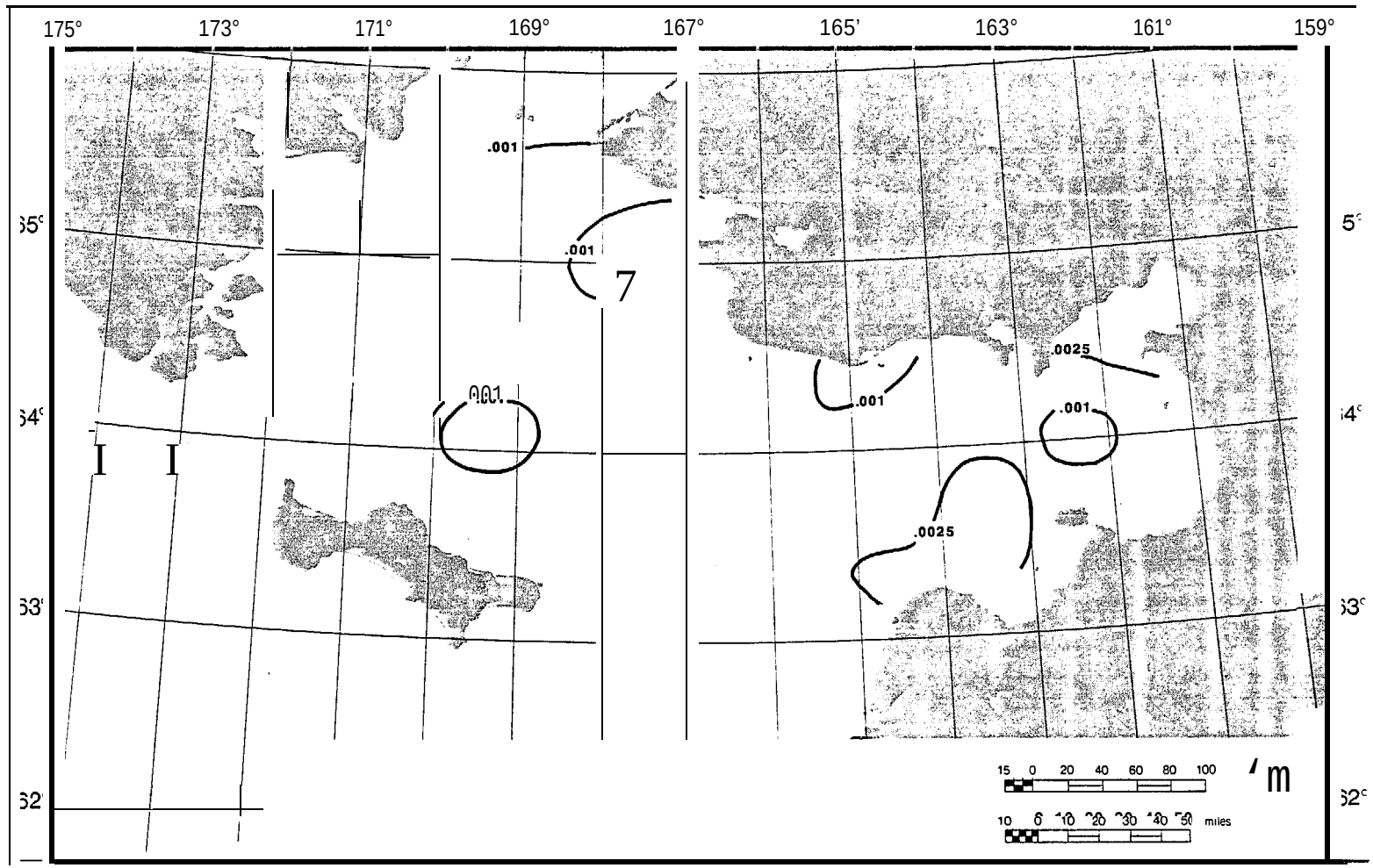

Fig. 47. **Isolines** of the ratio of the sum of the **aliphatic** and aromatic fractions (ppm dry wt.) to total organic carbon in surface sediments. Based on 33 samples obtained by various methods in 1976, 1977, and 1979. Drawn from tabular data in Kaplan, et **al** (1980).

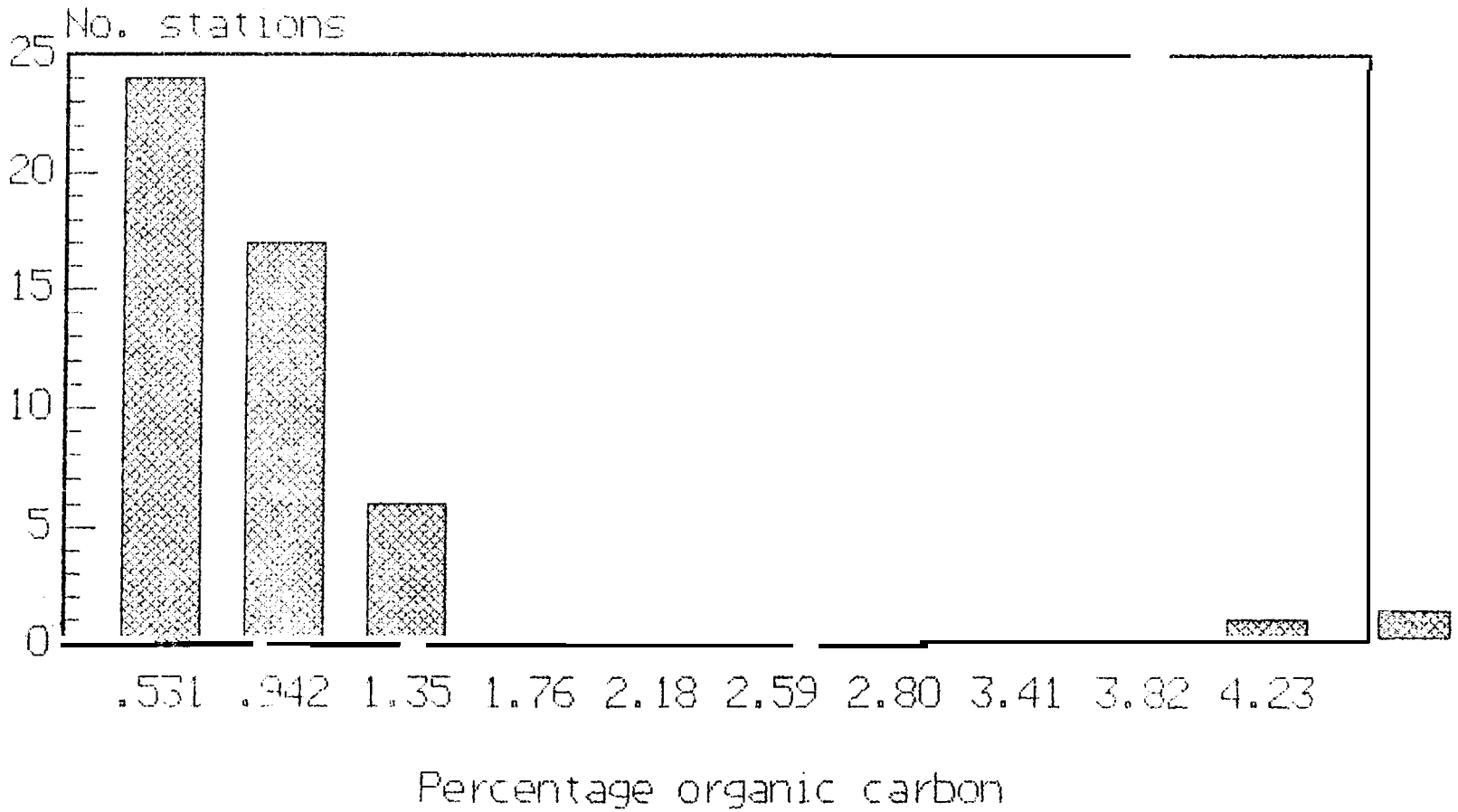

Fig. 48. Percentage of organic carbon in surface sediment at 48 stations in Norton Sound. Based on Kaplan, et al (1979).

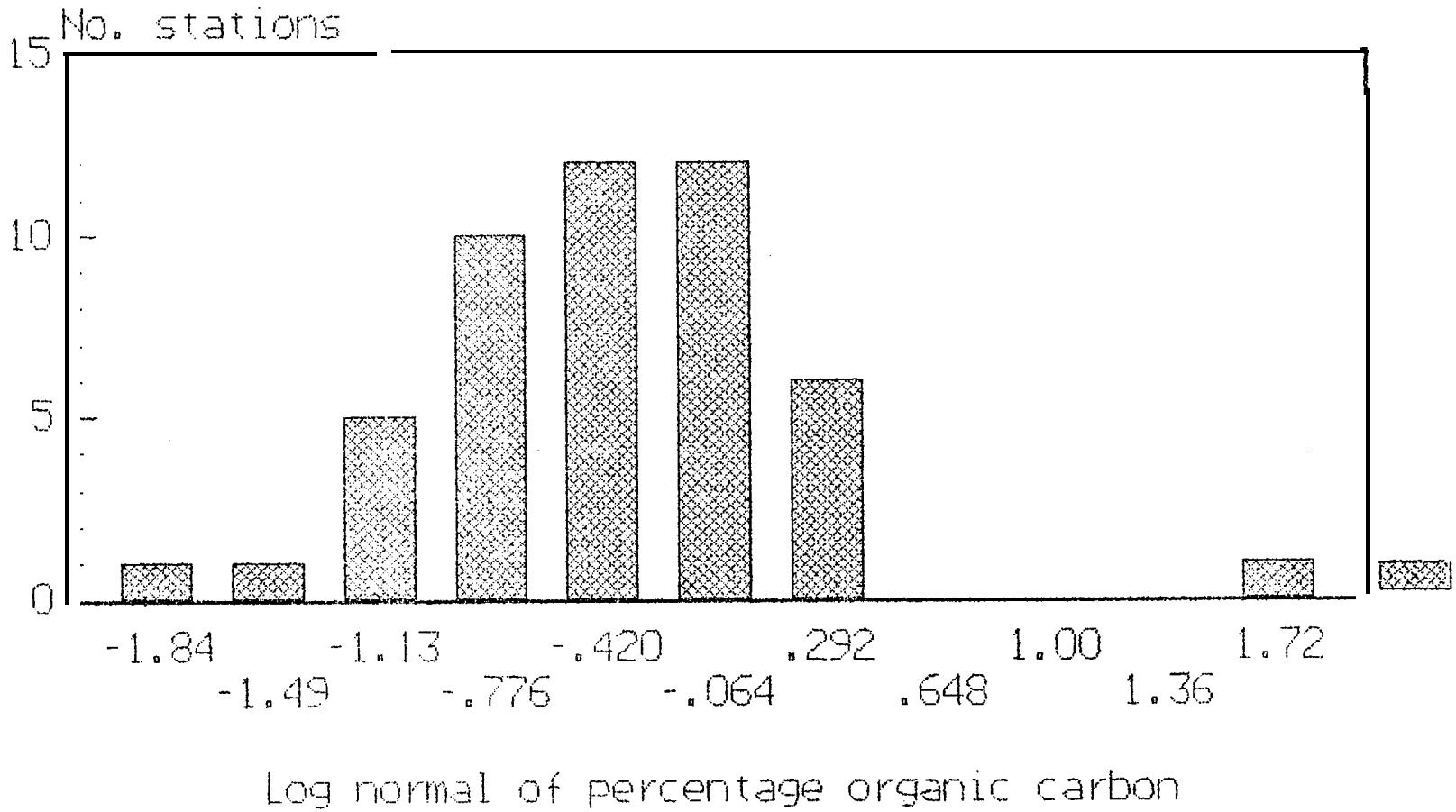

Fig. 49. Log normal of percentage of organic carbon in surface sediment **at** 48 stations **in** Norton Sound. Based on Kaplan, et al (1979).

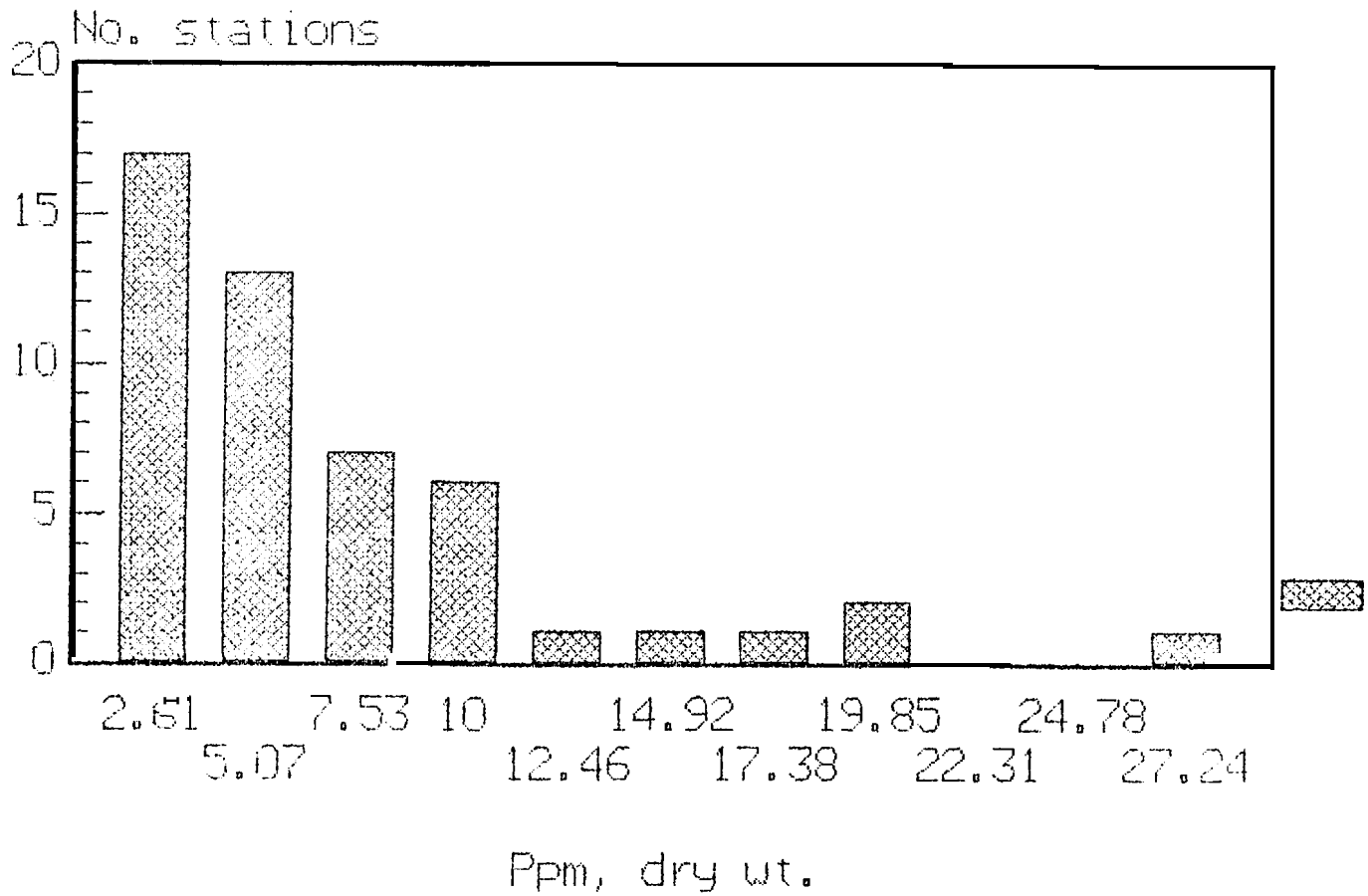

Fig. 50. Aliphatic hydrocarbons in surface sediment at 49 stations in Norton Basin. Based on Kaplan, et al (1979).

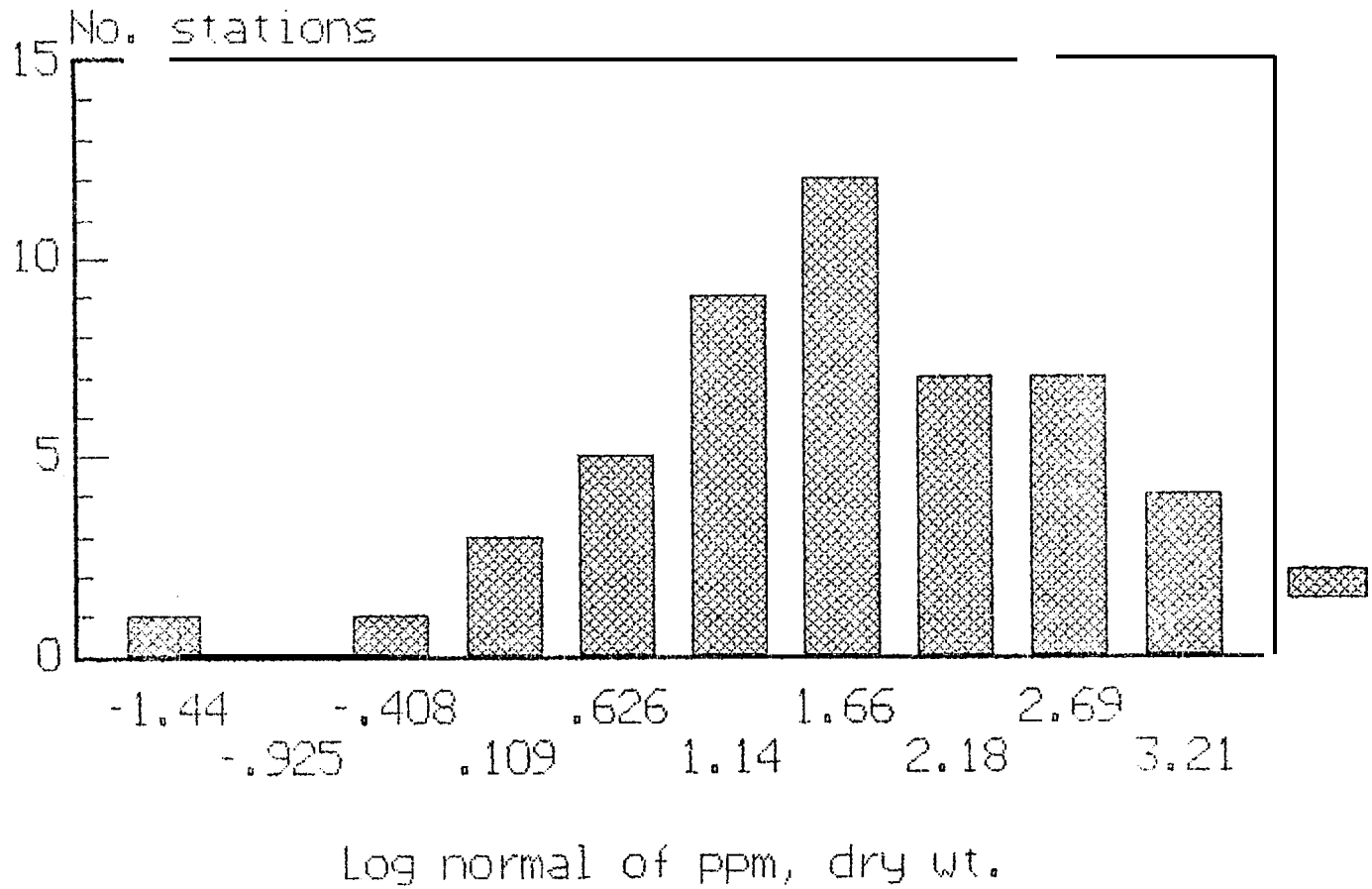

Fig. 51. Log normal of **ppm of aliphatic** hydrocarbons in surface sediment at 49 stations in Norton Basin. Based on Kaplan, et al (1979).

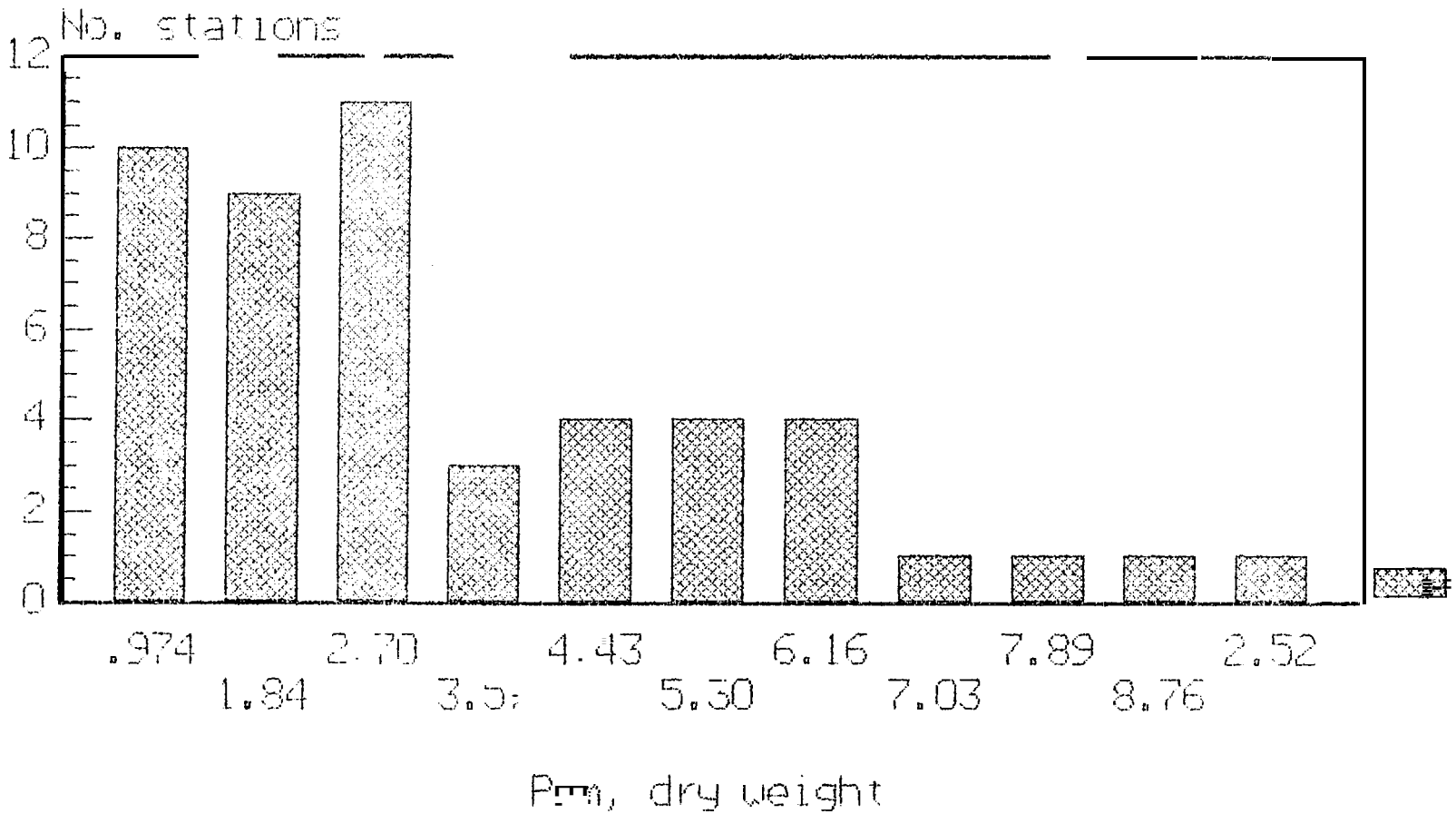

Fig. 52. Aromatic hydrocarbons in surface sediment at 40 stations in Norton Basin area, Alaska. Based on Kaplan, et al (1979).

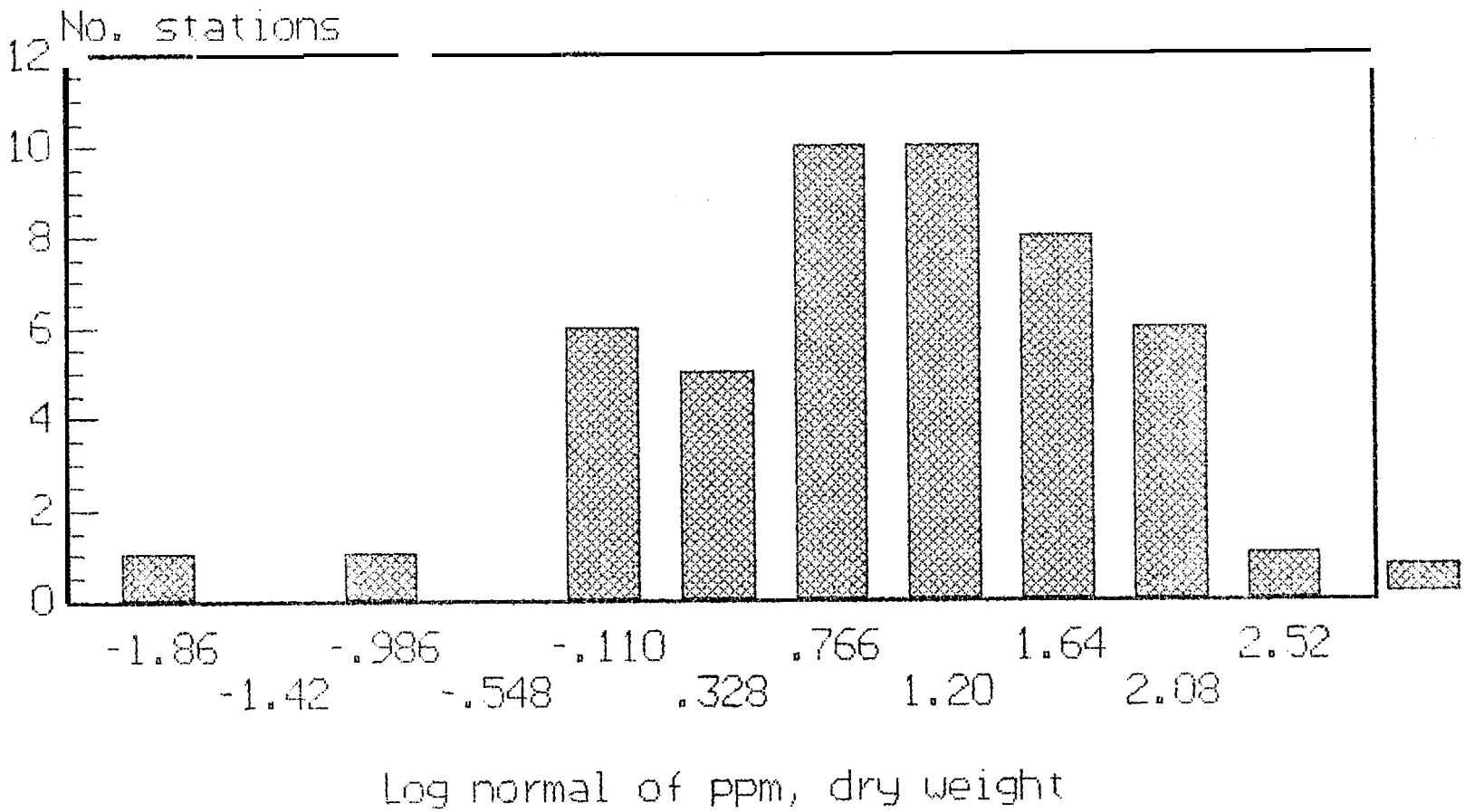

Fig. 53. Log normal of aromatics in surface sediment at 48 stations in Norton Basin area, Alaska. Based on Kaplan, et al (1979).

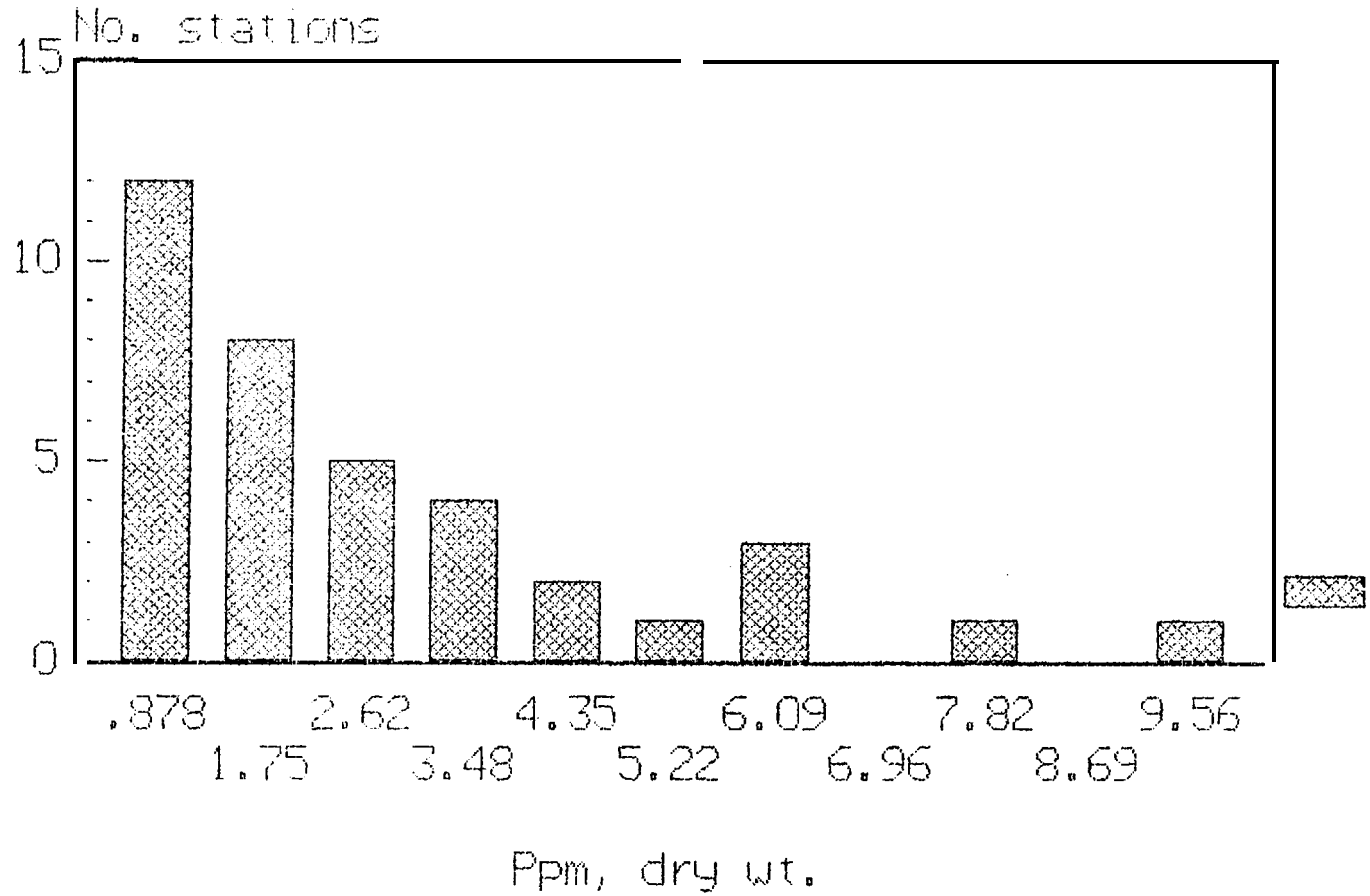

Fig. 54. N-alkane hydrocarbons in surface sediment at 37 stations in Norton Basin. Based on Kaplan, et al (1979).

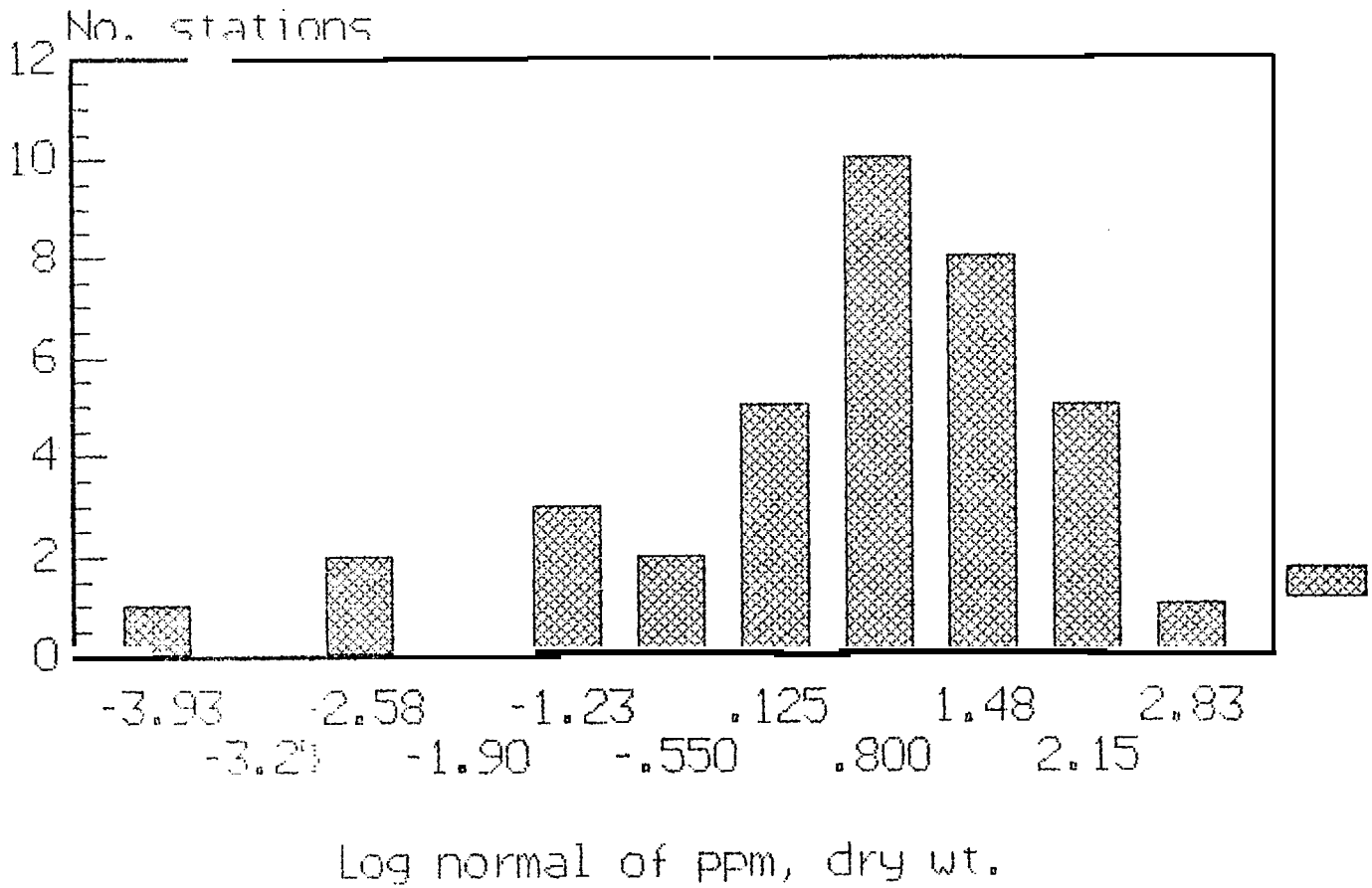

Fig. 55. Log normal of n-alkane hydrocarbons in surface sediment at 37 stations in Norton Basin. Based on Kaplan, et al (1979).

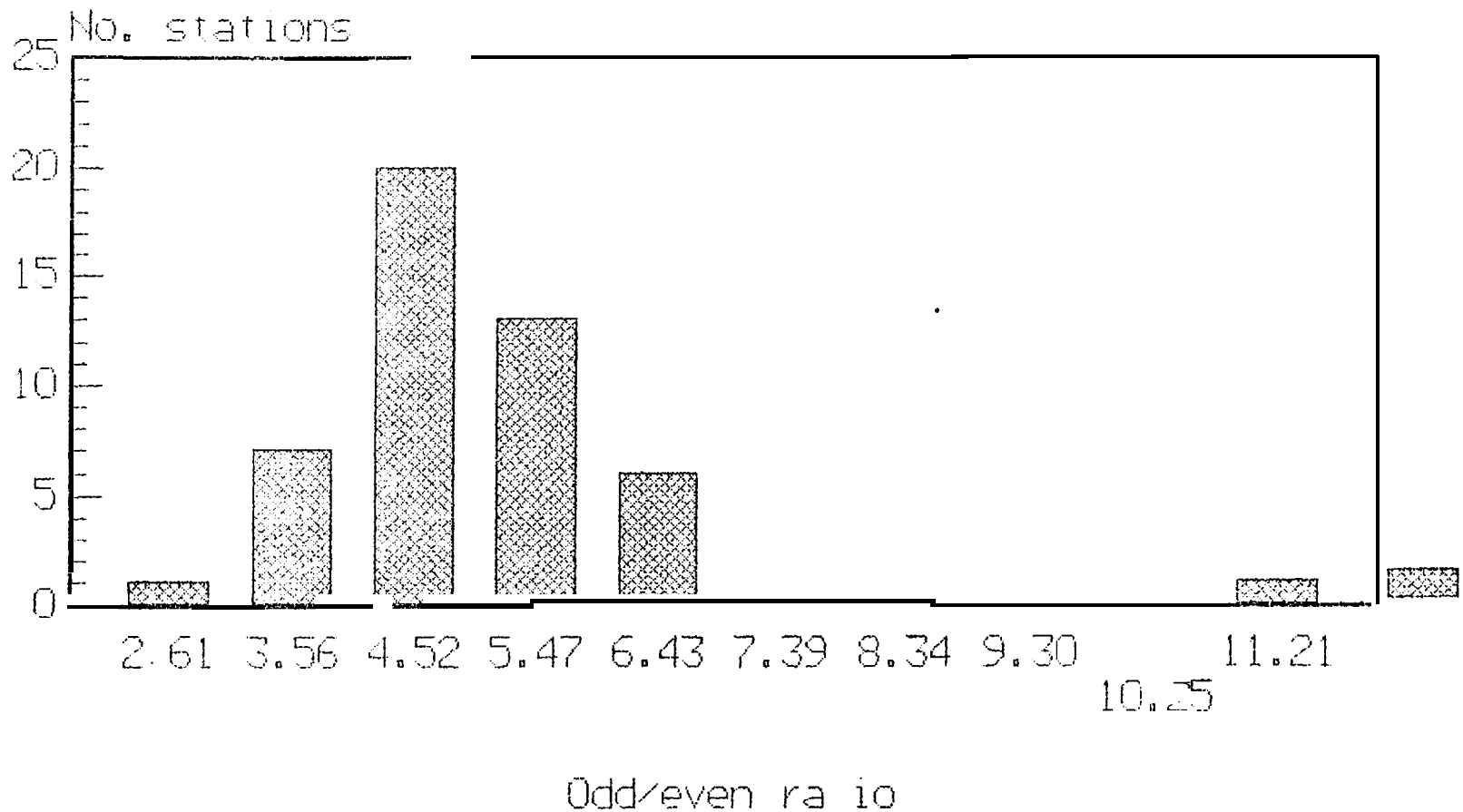

Fig. 56. Odd/even ratio of n-alkane hydrocarbons in surface sediment at 48 stations in Norton Basin. Based on Kaplan, et al (1979).

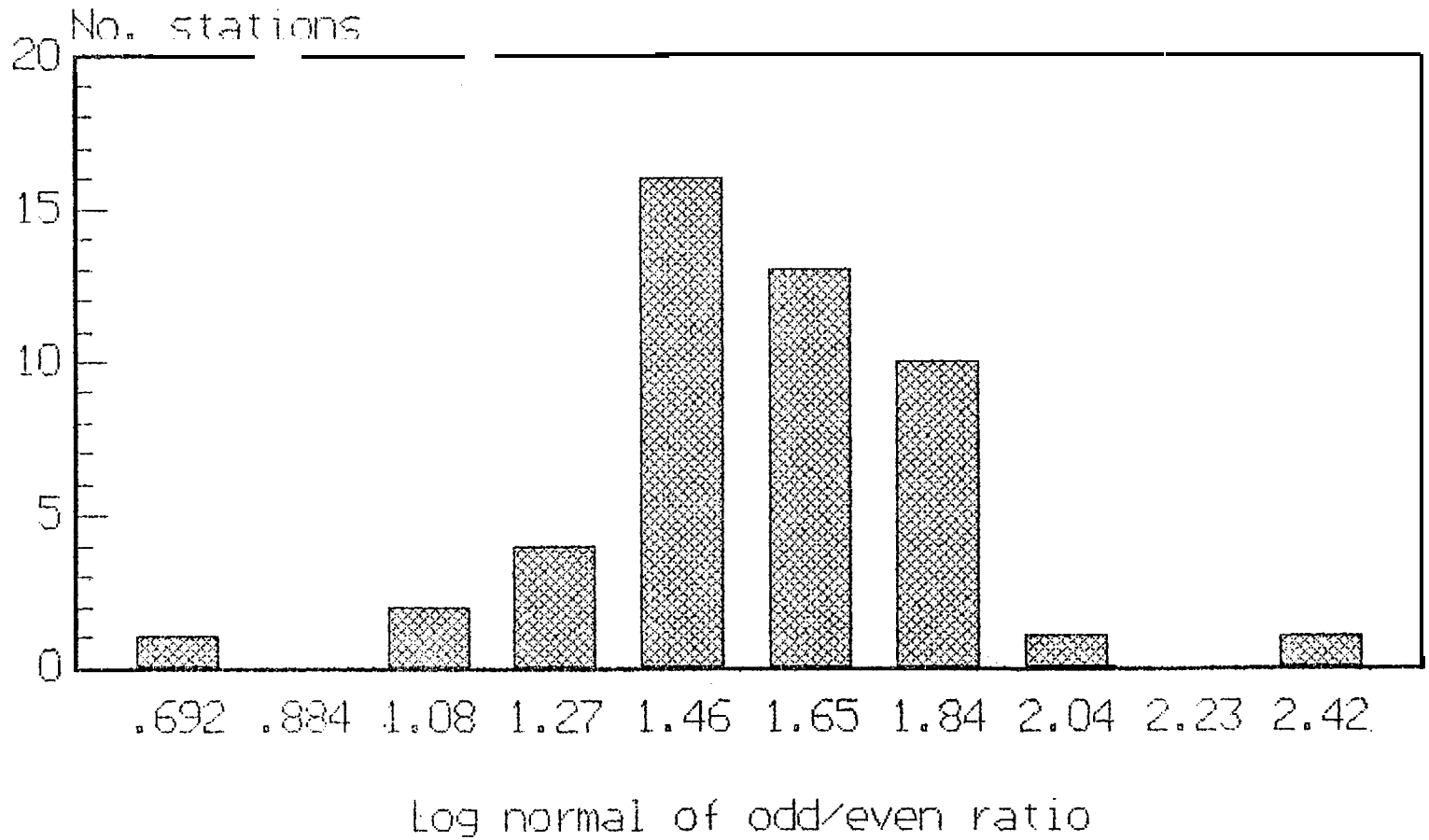

Fig. 57. Log normal of the odd/even ratio of n-alkane hydrocarbons in surface sediment at 48 stations in Norton Basin. Based in Kaplan, et al (1979).'

APPENDIX A

Annotated bibliography of data reports on trace contaminants in surface sediment and animal tissue in the northern Bering Sea

Trace contaminant concentrations data for the surface sediment and animal tissues of the northern Bering Sea are available in twenty research reports. These reports, both published and unpublished, present the results of four investigations sponsored by the Outer Continental Shelf Environmental Assessment Program as well as four other independent programs.

The contents of the data reports are briefly characterized in Table Al and Table A2 by analytes and type of sampled material.

Table A3 shows the research programs responsible for the data reports.

All the reports are available as copies at the Alaska Office of the Ocean Assessment Division of NOAA. The OAD office also has magnetic spreadsheets and print files from those reports which presented tabular data.

Table Al. Reports of trace contaminants data from surface sediment of the Bering Sea north of 63 degrees and funded through the Outer Continental Shelf Environmental Assessment Program. Full citations are listed in the References section.

Citations	Analytes	Material
Burrell 1977, 1978, 1979	6 metals from extracts	sediment
Kaplan 1979, 1980, 1981	hydrocarbons	sediment
Larsen 1980	>50 elements	sediment
Nelson 1977	22 elements	sediment
Patry 1977	27 elements	sediment
Robertson 1979	17 elements	sediment
Venkatesan 1981	hydrocarbons	sediment

Table A2. Reports of trace contaminants data from surface sediment and animal tissue in the Bering Sea north of 63 degrees which were not part of the Outer Continental Shelf Environmental Assessment Program. Full citations are listed in the References section.

Citation	Analytes	Material	Taxa
Metsker 1984	5 metals & 2 org.chlor.	blubber	walrus
		liver	walrus
		kidney	walrus
Nelson 1972, 1975	mercury	sediment	--
NORTEC 1985	47 elements	sediment	--
Rusanowski 1986, 1987, 1988	8 elements	sediment	--
		muscle	red king crab
		hepatopancreas	red king crab
		unknown	8 invert. genera
		liver	least cisco
		liver	saffron cod
		muscle	least cisco
		muscle	saffron cod
		liver	spotted seal
		kidney	spotted seal
		blubber	spotted seal
		muscle	spotted seal
		liver	bearded seal
		kidney	bearded seal
		blubber	bearded seal
		muscle	bearded seal
Sharma 1974	4 elements	sediment	--
Sharma 1979	15 elements	sediment	--

Table A3. Reports of trace contaminants data from surface sediment and animal tissue in the Bering Sea north of 63 degrees, grouped within their research programs. Full citations are listed in the References section.

Research program	Citation
OCSEAP research unit 162	Burrell 1977 Burrell 1978 Burrell 1979
OCSEAP research unit 413	Larsen 1980 Nelson 1977 Patry 1977
OCSEAP research unit 480	Kaplan 1979 Kaplan 1980 Kaplan 1981 Venkatesan 1981
OCSEAP research unit 506	Robertson 1969
USFWS, Resource Contaminant Assessment Program	Metsker 1984
USGS	Nelson 1972 Nelson 1975
Nome Offshore Placer Project	NORTEC 1985 Rusanowski 1986 Rusanowski 1987 Rusanowski 1988
Alaska Sea Grant Program	Sharma 1974 Sharma 1979

Appendix B

Tables of data from original reports

Table B1. Concentrations (ppm, dry wt.) of metals in 14 HAPS core "acid-extracts" of sediment from greater Norton Sound, September, 1976. Adapted from Burrell (1977:32) and Burrell (1978:73).

Sta.	% clay & silt	Lat. Deg	Lat. Min.	Lang. Deg.	Lang. Min.	Water depth (m)	Cd	Cu	Ni	Zn	Fe	Mn
1	22.1	63	31.8	168	32.2	29	<0.1	<0.3	<1.3	6.2	746	8
4	87.0	63	19.7	165	29.9	21	<0.1	0.5	2.5	5.0	3050	48
5	64.3	63	39.5	165	32.1	22	<0.1	0.5	2.9	5.0	2843	86
6	86.4	63	38.4	164	31.0	13	<0.1	2.0	3.3	5.7	3084	121
9	89.0	63	41.5	161	31.1	15	<0.1	1.1	4.3	8.0	4250	79
12d	59.5	64	23.5	165	44.8	26	<0.1	0.6	1.4	5.1	1609	230
13	81.9	64	59.7	165	29.7	20	<0.1	0.5	1.8	6.0	2086	283
15	81.9	64	0.3	163	30.5	20	<0.1	<0.3	<1.3	5.1	1779	75
17	85.6	64	0.0	161	30.3	18.5	0.1	2.2	4.2	9.1	2961	193
20	35.2	64	20.1	163	31.0	20	<0.1	<0.3	<1.3	3.5	966	58
21	21.5	64	15.3	162	29.7	19	<0.1	0.3	<1.3	3.5	1219	52
23	43.8	64	17.5	161	30.7	15	<0.1	0.6	1.8	6.6	2066	70
26	17.6	64	30.2	166	31.5	28	<0.1	<0.3	<1.3	2.5	565	60
28a	14.8	64	44.6	167	1.0	24	<0.1	<0.3	<1.3	2.5	745	20

Table B2. Index ratios for hydrocarbons in Norton Sound sediments, 1976. Adapted from Kaplan (1979: Table 6).

Std.	(n-alkanes/ organic carbon) x10e4	Pristane/ n-C17	Phytane/ n-C 18	Pristane/ phytane	Odd/ even
47	3.74	0.38	0.20	2.00	5.38
49	5.08	0.30	0.14	1.50	6.06
70	0.03	2.66	0.25	8.00	1.65
88b	1.30	2.03	3.80	2.14	4.11
105	0.08	L	L	L	11.21
125	1.25	0.40	0.19	2.00	4.02
131	16.32	L	L	L	2.80
137		0.64	0.18	3.00	4.07
147	6.79	0.60	0.36	1.80	2.85
154	5.51	0.64	0.17	3.60	5.69
156	3.89	0.50	0.19	2.67	5.57
162	0.49	0.50	0.23	2.00	4.75
166s	0.14	0.67	0.23	4.00	5.16
168s	1.35	0.56	0.17	3.50	5.26
169s	2.89	0.58	0.23	3.60	4.47
170s	4.95	0.46	L	L	5.80
172s	3.33	L	L	L	4.70
174s	2.19	2.00	2.20	6.00	4.50

Table B3. Concentrations (dry wt.) of hydrocarbons in Norton Sound surface sediments, 1976. Samples are from 0-2cm except B- bulk and S- surface. L represents concentrations below detection limit, i.e. "too low to be calculated accurately." Adapted from Kaplan, et al (1979: Tables 4, 5, 6).

Sta.	Sample depth	Lat. Deg Min	Long Deg Min	Depth (m)	% Total carbon	% Organic carbon	Aliphatic fr. (ppm)	Aromatic fr. (ppm)	PPB NORMAL ALKANES: n-C15	n-C16
47	0-2cm	64 25.00	165 29.00	15	1.02	0.93	9.644	7.47	L	L
49	0-2cm	63 27.77	163 52.57	10	1.4	1.12	24.782	4.13	L	L
70	0-2cm	65 6.13	167 40.40	31	0.37	0.31	2.207	15.186		0.1
88b	bulk 0-10cm	65 46.01	168 5.51	9	0.84	0.53	3.953	5.682	6.\	4.5
105	0-2cm	64 49.00	1615 44.00	15	1.29	0.93	1.845	0.886	L	L
121	0-2cm	63 52.39	163 1.34	20	1.37	1.18				
125	0-2cm	64 0.12	162 24.60	18	0.98	0.55	0.141	2.438	1.6	1.4
131	0-2cm	64 23.60	161 49.27	17	0.96	0.44	9.035	2.988	L	L
137	0-2cm	63 40.89	161 13.29	4			17.766	4.531	L	L
147	0-2cm	63 47.00	163 41.50	17	0.87	0.33	6.773	2.293	4.6	L
152	0-2cm	64 5.00	164 26.50	22	0.5	0.35				
154	0-2cm	63 45.08	164 37.43	18	1.25	0.99	16.264	4.182	L	L
156	0-2cm	63 28.39	165 19.28	17	1.4	1.3	7.113	5.511	L	L
157s	surface 1mm	63 18.11	165 3.26	8	1.16	0.82				
160s	surface 1mm	62 54.50	165 8.15	10	2.4	0.7				
162	0-2cm	63 2.80	165 53.99	21	1.26	0.92	45.09	2.316	1.1	1.1
166s	surface 1mm	63 14.62	167 2.21	26	1.54	1.16	39.93	0.756	L	L
168s	surface 1mm	63 26.25	166 29.64	28	1.33	1.1	57.03	2.113	L	L
169s	surface 1mm	63 34.79	166 5.53	27	1.09	0.33	117.12	4.001	3.2	2.6
170s	surface 1mm	63 41.72	165 45.81	25	0.87	0.52	62.139	2.208	L	L
172s	surface 1mm	64 0.10	165 29.25	20	1.36	0.87	80.14	3.773	L	L
174s	surface 1mm	64 21.15	165 0.40	36	1.48	0.82	53.21	2.005	L	L

Table B3 con't

n-C17	Pris-tane	n-C18	Phy-tane	n-C19	n-C20	n-C21	n-C22	n-C23	n-C24	n-C25	n-C26	n-C27
10.7	L	11.9	L	35	43.7	164.5	142.4	384.3	1.4	434.1	111.5	740.1
L	L	L	L	45.9	61.3	226.2	201.8	552	200.9	624.4	154.9	1351.9
0.3	0.8	0.4	0.1	0.6	0.5	0.6	0.6	0.7	0.6	0.7	0.5	0.9
10	20.3	2.5	9.5	19.3	13.3	257.4	14.6	23.1	17	31.1	20.4	75.6
L	L	L	L	L	L	2.6	2.9	8.3	3.2	9.7	L	19.1
3.5	1.4	3.7	0.7	9	9.8	L	26.5	66.4	28	78.9	25	151.4
21.3	L	L	L	30.6	37.7	174.7	150.5	469.9	169.6	647.4	169.1	1490.2
13.1	L	18.5	L	61.9	85.5	291.1	283.7	761.3	316.4	883.7	292	1861
14.4	L	11.3	L	32.2	37.2	113.6	100	262.8	108.5	299.6	79.3	533.7
13.4	L	15.8	L	51	58.2	215.4	182.2	501.8	177.4	594.9	149.1	375.4
15.7	L	15.1	L	40.4	49	178.3	158.2	446.3	169.1	557.7	132.1	1304
2.4	1.2	2.1	L	5.6	5.6	21.5	16.9	46.8	17.4	53.5	14.3	107.5
0.9	0.6	0.6	L	1.3	1.5	4.3	4.6	12.8	5.8	16.9	5	36.6
L	L	L	L	9.1	11.2	42.8	40.2	128.2	50.5	167.1	48.4	347
6.2	3.6	4.3	1	9.4	10.1	31.6	29.7	83.2	34.4	127.5	38.9	199.5
L	L	L	L	L	4.3	63.2	66.5	218.3	79.7	288.3	73.9	631.2
L	L	L	L	L	L	84.3	67	261.3	68.2	339.3	65	616.9
L	L	L	L	7.7	13.5	56.2	54.5	261.3	59.2	201.2	52.9	416.7

Table B3 con't

n-C28	n-C29	n-C30	n-C31	n-C32	n-C33	n-C34	Total n-a 1 kanes (ppm)
132.1	539.6	131.4	480.5	21.1	143.9	L	3.277
139.5	956.2	47.4	114.1	L	266.3	L	5.688
0.5	1.3	0.4		0.3	0.3	L	0.0102
32.6	57.4	7.8	59.:	10.7	18.5	6.2	0. 688
L	13.2	L	15.6	L	L	L	0. 0745
21.2	106	12.4	9'3	6.3	31.5	3.3	0.6876
1.67.9	1 098	925.3	1051.'3	28.6	310.1	L	7.1134
243. 9	1362. 1	344.9	1296.7	87.9	486.6	42.2	8. 694
52.3	310.4	168.4	16.6	L	71.2	L	2.241
132.6	879 .1	67.6	63.13	L	40.7	L	5.451
119.9	821.6	5'3. 1	702	38.7	224.7		5.061
10.6	63.4	5. 1	52.2	3.5	15.9	1.4	0.4477
4.6	26.9	2.2	24.6	1.3	7.5	L	0. 1571
43.5	255. 1	33.4	230.5	9.1	64.4	L	1.481
26.5	143.5	14.9	132.6	8.3	43.1	3.6	0.'354
62.1	44.3.5	72.6	432.2	7.7	117.6	L	2.573
60.8	521	168. 1	454.1	78.5	109.6	L	2.1394
46	285 .3	73.5	272. 5	7.7	72.6	L	1.792

Table B4. Index ratios for hydrocarbons in Norton Sound sediments, 1'377. Adapted from Kaplan, et al (1979: Table 9).

Sta.	Samp 1 e depth	(alkanes/ organic carbon) x10a4	Pristane/ n-C 17	Phytane/ n-C18	Pristane/ phytane	Odd/ even
34	0-2cm	0.75	1.3s	0.14	2.00	4.55
35	0-2cm	0.87	1.67	0.22	7.00	5.15
39	surface lmm	0.24	1.44	0.33	2.50	5.35
41	surface lmm	0.53	1.00	0.25	4.00	4.78
42	surface lmm	2.60	1.02	0.25	5.50	4.78
43	0-2cm	0.64	1.06	0.16	6.50	4.22
44	0-2cm	0.48	1.44	0.13	6.00	3.21
48	surface lmm	0.38	"1. 38	0.17	5.00	6.37
14	IK 0-3cm	4.37	0.55	0.23	3.10	5.26
17	0-3cm	2.04	2.03	0.19	1.30	5.12
17	SV 0-3cm	6.40	0.50	0.17	2.00	5.67

Table B5. Concentrations of hydrocarbons in Norton Sound surface sediments, 1977. L represents concentrations below detection limit, i.e. "too low to be calculated accurately." Adapted from Kaplan, et al (1979: Tables 7 and 8).

Sta.	Sample depth	Lat. Deg.	Lat. min.	Long. Deg.	Long. min.	Water depth (m)	% Total carbon	% organic carbon	Aliphatic fraction (ppm)	Aromatic fraction (ppm)	PPB ALKANES: n-C 17
34	0-2cm	64	52.30	167	39.65	32	0.35	0.12	0.809	0.670	L
35	0-2cm	65	14.90	167	45.70	52	0.67	0.59	2.248	1.132	1.4
39	surface lmm	64	7.09	171	18.00	34	1.54	0.3s	0.643	0.247	0.2
41	surface lmm	64	2.75	171	36.10	27	0.91	0.44	2.466	0.847	L
42	surface lmm	63	58.40	169	22.65	39	1.76	0.32	4.444	1.922	1.7
43	0-2cm	63	57.85	167	48.03	35	0.63	0.6	1.01	1.714	1.2
44	0-2cm	63	45.40	167	0.50	31	0.66	0.52	2.072	0.9	L
48	surface lmm	62	58.20	165	16.25	10	9.08	4.23	5.029	5.012	4
14	IK 0-3cm	64	14.80	165	25.50	18	1.12	0.28	5.36	1.296	4.4
17	sv 0-3cm	64	5.10	165	28.62	19	1.09	0.86	14.066	2.220	2.7
17	0-3cm	64	5.10	165	28.62	19	0.31	0.24	5.494	2.667	L

Pristane	n-C18	Phytane	n-C19	n-C20	n-C21	n-C22	n-C23	n-C24	n-C25	n-C26	n-C27
L	L	L	0.9	1.2	3.2	3.3	7.7	3.3	8.6	3.2	18.9
2.4	1.5	L	3.2	4	13.2	13.4	39.8	17.2	52.2	16.9	117.8
0.3	0.3	L	0.7	0.8	1.8	2	5.1	2.8	7.8	3	19.6
L	L	L	1.3	1.8	6	6.1	18	8.8	24.7	8.8	49.5
3.2	1.8	L	9.7	7.1	23.7	22.3	63.8	27.8	79.7	27.1	170.2
1.3	1.2	L	3.5	3.9	12.1	11.s	1.6	14.2	41.6	14.2	88.6
L	0.6	L	1.7	2.5	9.2	14.3	34.5	22.3	34.1	13	49.5
5.6	5.1	L	16.7	17.3	66.3	43.3	136.5	47.5	105.1	39.1	459
L	4.6	L	11.1	13.1	42.3	36.8	104.2	42.7	129.9	35.9	284.8
L	4.5	L	14.6	18.3	63	55.3	149.3	59.2	180.5	53.7	409
L	L	L	22.7	15.6	54.5	49.2	130	53.6	166.1	45	367.7

n-C28	n-C29	n-C30	n-C31	n-C32	n-C33	n-C34
2.9	14.9	1.4	14.7	0.9	4.9	L
16.5	95.4	10.4	101	6.6	32.3	2.6
3.1	17	0.4	19.2	1.3	6.2	0.7
8.6	41.1	4	41.2	2.4	11.6	L
27.5	142.8	16	148.1	10.2	45.2	3.2
13.5	70.2	7.6	69.4	4.6	21.9	2
6.3	28.4	0.9	22.8	L	6.4	L
39.4	260.8	14.7	190.7	9.9	59.6	L
32.6	201.6	18.1	186.8	11.7	62.5	L
46.8	292.4	26.1	268	16.1	07.3	0.66
40.3	256.2	18.4	223.8	12.1	71.7	L

Table B6. Index ratios for hydrocarbons in Norton Sound sediment, 1979. Adapted from Kaplan, et al (1979: Table 17).

Std.	(n-alkanes/ organic carbon) x10e4	Pristane/ n-c 17	Phytane/ n-/C18	Pristane/ phytane	Odd/ even
1	4.92	0.37	0.18	0.75	3.37
5	7.74	1. 06			3.91
7	7.58	#. '35			3.80
8	12.93	0.48	0.25	1.71	3.27
13	5.48	0.59	0.24	1.65	4.32
15	3.39	0.5	0.17	2.47	3.81
18	4.62	0.44	0. 19	1.86	4.04
20	3.76	0.44			4.03
21	6.07	0.62			4.40
22	3.29	0.42	0. 18	2.44	3.35
25	2.38	0.41			4.12
29a	3.38	0.37	0.23	1.50	4.33
29b	2.49	0.31			3.56
33a		0.54			4.09
36					3.97
40	0. 38				5.27
47a		0.62			4.29
49		2.27	0.28	8.88	4.18
50	0.9	0.75			3.67

Table B7. Concentrations (dry wt.) of hydrocarbons in Norton Sound surface sediments, 1979. Lre presents concentrations below detection limit. Adapted from Kaplan, et al (1979: Tables 15 and 16).

Sta.	Lat. Deg	Lat. Min	Long. Deg	Long. Min	Depth (m)	% Total carbon	% Organic carbon	Aliphatic fraction (ppm)	Aromatic fraction (ppm)	PPB ALKANES: n-C15	n-C16
1	64	19.20	162	0.50	17	1.2	0.72	4.68	3.31	3.2	3.3
5	63	39.90	161	17.00	13	1.63	0.74	17.83	8.76	4.7	4.7
7	63	40.30	1 62	59.80	17	1.28	#.57	9.66	6.00	L	2.4
8	64	0.30	163	4.00	20	0.69	0.46	1.56	1.49	0.8	0.9
13	63	20.20	165	12.40	15	0.65	0.38	4.51	5.14	L	L
15	63	59.60	164	58. 50	18	0.73	0.48	3.96	1.79	L	L
18	64	19.90	165	23. 20	25	0.62	0.48	3.15	1.53	L	L
20	64	6.60	165	30.40	18	0.64	0.4	5.4	1.52	L	L
21	64	12.10	165	30. 50	18	0.72	0.47	9.08	5.14	L	1.8
22	64	19.80	165	42.70	21	1.34	0.86	8.87	5.54	5.9	5.5
25	64	20.20	166	0.80	22	1.14	0.66	5.19	1.95	L	L
29a	63	50.30	165	41.70	20	0.61	0.41	2.77	0.96	L	L
29b	63	46.10	166	7.50	27	0.96	0.54	3.93		2	1.3
33a	62	25.40	166	40.20	20			1.68	0.87	L	L
36	63	40.00	167	2.80	29			0.67	1.73	L	L
40	64	40.20	167	3.60	26	0.2	0.17	2.25	0.11	L	0.5
47a	62	26.00	160	48. 60				1.37	1.14	0.7	1
49	64	20.10	169	0. 30	40			2.45	3.04	1	0.5
50	64	39.40	169	0.30	44	0.33	0.28	1.67	1.92	1.1	

Table B7 con't

n-C17	Pris-tane	n-C18	Phy-tane	n-C19	n-C20	n-C21	n-C22	n-C23	n-C24	n-C25	n-C26	n-C27	n-C28
9.3	7.6	8.7	1.6	25.4	30.7	116	96.3	289	124.1	332.5	154.9	875.4	98.7
12.7	13.4	14.4	L	43.1	59.8	199.4	105.9	504.5	215.2	795.8	233.8	1154	153.8
11.1	10.5	13.1	L	3$.8	49.4	163.6	138.7	369.2	154.9	570.2	172.3	892.1	116.7
2.5	1.2	2.0	0.7	7.8	8.9	26	20.9	50.2	23.2	73.1	22.6	105.5	15.7
4.3	2.6	6.5	1.6		31.7	101.9	84.6	218	85	242.4	60.5	415.7	41
4.1	2	4.9	0.8	14%	19.8	70.4	63.3	166.4	69.6	195.9	55.8	322.4	36.9
4.1	1.8	5.2	1	15.7	20.3	68.6	62.9	175.9	80.4	280.6	64.8	492:6	59.4
5.1	2.3	5.2	L	15	19.9	65.9	57.1	148.7	60.2	171.9	49.7	287.2	33.3
6.3	3.9	7.2	L	22.3	28.9	100.5	83	230.0	09.3	435.6	115	694.7	71.4
12.7	5.3	12.3	2.2	33.1	42.1	157.4	133.4	346.5	136.6	363.2	97.6	493.4	50.1
5.7	2.7	6.1	L	16.2	20.3	66.4	57.9	150.6	61	177.3	60.2	295.8	35.6
4.1	1.5	4.4	1	13.3	16	50.4	44	120.1	49.3	180.8	55.6	301.4	38.2
3.5	1.1	3.4	L	10.7	13.2	46.9	47.4	128.9	69.3	218.6	77.6	287.9	42
1.3	0.7	1.7	L		5	13.2	10.9	26.6	11.7	39.5	11.5	60.6	7.5
2.1	L	L	L	12.:	14.4	52.7	44.3	132.6	54.6	251.6	71.9	416.4	48.9
L	L	L	L	0.7	1.2	3	3.3	7.2	L	10.2	3.5	14.2	2.2
1.3	0.8	0.8	L	4	4.7	21.6	12.2	35.3	16	58.5	18.2	91.6	13
2.6	5.9	5.9	0.7	7.1	8	23	22.5	57	27.8	73.9	23.1	125.4	17.4
0.8	0.6	0.6	L	2.4	3	9	8.4	22.7	9.8	27.5	9.3	44.3	6.8

n-C29	n-C30	n-C31	n-C32	n-C33	n-C34	Total n-alkanes
536.2	252.5	422.5	22.7	121.4	121.4	3540.3
814.6	186.2	673.3	42.?	198.5	190.5	5526.7
634.7	193.1	570.2	33.7	168.8	168.8	4318.9
76.5	33.0	82.7	5.7	28.1	28.1	594.7
325.5	65.1	278.8	14.9	85.3	85.3	2084.8
249.6	68.7	206	11.5	60.3	60.3	1627.7
348.2	64.4	299.9	46a	91	91	2217
232.2	52.5	2113.7	8.9	67.9	67.9	1503.2
400.1	107.1	346.1	11.8	88.6	88.6	2853.9
363	141.5	311.9	18.6	94.5	94.5	2833.2
240.9	51.5	232	11.3	76	76	1567.5
211.9	32.2	104.2	10.9	57.6	57.6	1384.1
178.7	23.2	136.5	8.7	35.7	35.7	1344
40.6	4.6	34.6	1.2	9.3	9.3	286
263.6	100.8	210.7	7.9	50.7	50.7	1743.7
10.3	L	8.4	L	L	L	64.2
68.9	11.2	60.5	3.8	17.9	17.9	444.1
97.0	9.2	86.2	4.5	22.3	22.3	614.9
33.7	3.5	32.6	1.5	9"3	9.3	253.3

Table 88. Concentrations of heavy metals and organochlorine contaminants in walrus samples taken from the Alaska native subsistence harvest of 1981 and 1982. Pesticides analyzed for in blubber but not detected are DOE, DDD, DDT, dieldrin, heptachlor epoxide, trans-monachlor, cis-monachlor, endrin, toxaphene, hexachlorobenzene, mirex, and PCB's. Ppm, presumably wet weight basis. Adapted from Metsker, et al (1984: Table 1).

Tissue by village	Date	Sex	Rge (yr)	Pb	Cd	Hg	As	Se	dieldrin	oxychlordane
Liver:										
Savoonga	1981			0.15	5.6	0.85		2.0		
Savoonga	1981				5.6	0.69	0.13	4.5		
Savoonga	1%31				16.0	0.60		2.3		
Savoonga	1981				16.0	0.68		2.7		
Savoonga	1981				9.5	3.80		4.9		
Savoonga	19$1				13.0	#.65		4.1		
Savoonga	19$1				16.0	0.68		3.8		
Little Diomede	1982	M	14	0.11	3.7	0.20	2.7		0.12	0.12
Little Diomede	1982	M	15		6.0	0.14	1.9		0.16	0.15
Little Diomede	1982	M	20		8.4	0.46	2.3			0.11
Little Diomede	1982	F	24		5.2	0.13	2.2		0.12	
Little Diomede	1982	F	16	0.22	8.7	0.06	2.8		0.12	0.17
Little Diomede	1982	M	15		5.5	0.22	1.9			
Little Diomede	19132	II	19		1.4	0.048	1.4		0.18	0.19
Little Diomede	1982	M	16	0.22	5.6	0.15	1.4		0.26	0.29
Gambell	1981	F	11	0.10	8.9	#.66		12.0		
Gambel 1	1981	F	14-15		5.2	0.98		2.7		
Gambel 1	1981	M	21		30.0	0.39		0.05		
Gambell	1981	F	15	0.17	5.8	0.73		4.1		

Tissue by village	Date	Sex	Age (yr)	Pb	Cd	Hg	As	Se	dieldrin	oxychlordane
Kidney:										
Little Diomede	1982	M	15		28.0					
Little Diomede	1932	M	14		33.0					
Little Diomede	1982	M	19	0.16	10.0					
Little Diomede	1982	M	16	0.83	40.0					
Little Diomede	1%32	F	16	0.22	41.0					
Little Diomede	1982	M	15	0.22	32.0					
Little Diomede	1982	F	24	0.11	56.0					
Little Diomede	198.2	M	20		46.0					
Gambe 11	1981	M	21		87.0					
Gambell	1981	F	14-15		43.0					
Gambell	1981	F	11		33.0					
Gambel 1	1981	F	15		15.0					
Blubber:										
Little Diomede	1982	F	16						0.12	0.17
Little Diomede	1982	M	20							0.11
Little Diomede	1982	M	19						0.18	0.19
Little Diomede	1982	M	14						0.12	0.12
Little Diomede	1982	M	15						0.16	0.15
Little Diomede	1982	F	24							
Little Diomede	1982	M	16						0.26	0.29
Little Diomede	1982	M	15						0.16	0.15
Gambel 1	1981	F	14-15						0.11	
Gambe 11	1981	M	21						0.15	0.13

Table B9. Mercuryconcentrations(ppm dry wt.) in Norton Basin surface sediment, 0-10 cm, sampled by van Veen grab and box corer. Lower detection limit is 0.01 ppm. Adapted from Nelson, et al (1972: Appendix I).

Sample	Lat. Deg.	Lat. Min.	Long. Deg.	Long. Min.	Water depth (ft.)	Hg (ppm)
67 ANC 30	64	27.560	165	19.768	45	0.04
68 AWF 310	64	28.128	164	41.928	31	0.02
68 AWF 327	64	32.192	164	25.192		0.02
68 AWF 338	64	32.655	163	59.800	46	0.03
68 AWF 343	64	32.768	163	54.288	14	0.03
68 AWF 344	64	33.384	163	50.672	20	0.03
68 AWF 345	64	33.384	163	48.000	22	0.03
68 AWF 346	64	33.384	163	45.384	10	0.03
68 AWF 350	64	32.000	163	50.672	47	0.01
68 AWF 354	64	33.000	163	43.480	24	0.04
68 AWF 355	63	33.000	163	41.096	20	0.03
68 AWF 357	64	30.768	163	41.096	50	0.02
68 AWF 410	64	30.160	164	11.800	64	0.02
68 AWF 430	64	28.416	164	26.480	71	0.02
68 AWF 440	64	23.640	164	46.496	84	<0.01
68 AWF 505	64	32.768	166	15.000	40	0.03
68 ANC 30B	65	42.755	168	7.700	25	0.03
68 ANC 6113	65	25.000	167	36.864	49	0.06
68 ANC 70B	65	32.096	168	2.300	87	0.03
68 ANC 95B	63	49.000	171	40.000	121	0.03
68 ANC 105B	63	37.000	171	10.768	42	0.01
68 ANC 112B	63	42.000	170	38.000	117	0.02
68 ANC 115B	63	44.000	170	25.192	143	0.08
68 ANC 118A	63	41.000	170	11.000	142	0.03
68 ANC 120B	63	39.800	170	1.500	143	0.01
68 ANC 126B	63	32.000	169	44.576	121	0.02
68 ANC 140B	63	22.480	168	36.000	87	0.03
68 ANC 154B	63	50.000	169	47.000	104	0.01
68 ANC 166B	64	57.000	167	49.000	136	0.01
68 ANC 179T	65	16.192	166	57.192	50	0.07
68 ANC 181B	65	13.000	167	26.768	69	0.01
68 ANC 182B	65	10.576	167	23.384	63	0.01
68 ANC 18713	65	2.100	167	21.080	76	0.08
68 ANC 190B	64	58.000	167	10.480	45	0.03
68 ANC 200B	64	39.672	166	36.480	72	<0.01
68 ANC 212T	64	37.512	167	14.416	96	0.02
68 ANC 215B	64	26.000	168	4.600	119	0.06
68 ANC 216A	64	18.480	168	20.768	130	0.02
68 ANC 231B	64	20.768	166	8.400	135	0.04
68 ANC 233B	64	26.480	166	4.500	106	0.03
68 ANC 234B	64	29.864	166	2.300	67	0.02

68	ANC 235T	64	29.480	165	45.864	66	0.25
68	ANC 235T	64	29.480	165	45.864	66	0.16
68	ANC 235T	64	29.480	165	45.864	66	0.11
68	ANC 235T	64	29.480	165	45.864	66	0.12
68	ANC 235T	64	29.480	165	45.864	66	0.13
68	ANC 240B	64	18.192	165	40.192	69	0.03
68	ANC 241T	64	24.000	165	35.000	102	0.11
68	ANC 241T	64	24.000	165	35.000	102	0.08
68	ANC 241T	64	24.000	165	35.000	102	0.03
68	ANC 241T	64	24.000	165	35.000	102	0.02
68	ANC 241T	64	24.000	165	35.000	102	0.02
68	ANC 244T	64	27.384	165	24.672	69	0.06
68	ANC 248B	64	10.192	165	24.000	65	0.02
68	ANC 251B	64	25.000	165	14.384	71	<0.01
69	ANC 100S	63	39.192	162	29.096	53	0.14
69	ANC 100S	63	39.192	162	29.096	53	0.03
69	ANC 100S	63	39.192	162	29.096	53	0.02
69	ANC 100S	63	39.192	162	29.096	53	0.01
69	ANC 100S	63	39.192	162	29.096	53	0.02
69	ANC 101B	64	9.700	164	7.600	74	0.03
69	ANC 105B	64	20.376	166	33.672	95	0.02
69	ANC 107B	63	52.000	167	18.768	110	0.01
69	ANC 114	62	31.384	165	57.480	44	0.03
69	ANC 116	63	12.480	165	19.672	42	0.06
69	ANC 118	63	45.576	166	0.670	88	0.02
69	ANC 120S	63	39.480	164	37.000	42	0.02
69	ANC 121	63	35.480	163	59.000	47	0.16
69	ANC 122S	64	22.480	165	44.768	88	0.05
69	ANC 122U	64	22.480	165	44.768	88	0.01
69	ANC 155B	63	52.000	165	44.320	110	0.01
69	ANC 200B	64	25.808	165	25.256	39	0.02
69	ANC 204H III	63	46.576	170	1.500	141	0.04
69	ANC 206S	63	41.000	170	0.000	144	0.03
69	ANC 207	63	43.672	169	54.192	138	0.14
69	ANC 207	63	43.672	169	54.192	138	<0.01
69	ANC 208B	63	42.576	169	36.576	125	0.05
69	ANC 209B	63	53.384	169	29.768	105	<0.01
69	ANC 215	63	54.000	170	48.480	93	0.01
69	ANC 216	64	0.900	170	49.480	89	0.02
69	ANC 220 B	63	51.288	171	59.384	125	0.01
69	ANC 221 B	63	52.288	172	18.000	177	<0.01
69	ANC 222 H II	63	56.768	172	31.000	180	0.1
69	ANC 223	64	0.900	172	25.100	184	0.23
69	ANC 224 A	63	58.288	172	12.768	177	0.01
69	ANC 224 B	63	58.288	172	12.768	177	0.03
69	ANC 227 B	64	8.200	171	47.288	159	0.06
69	ANC 229	64	8.100	171	13.120	118	0.04
69	ANC 230	64	13.000	170	52.120	118	0.02
69	ANC 232	64	15.480	170	18.000	125	0.04
69	ANC 235	64	29.864	169	39.672	121	0.01
69	ANC 237	65	4.500	169	14.672	164	0.03
69	ANC 245 H II	65	11.192	167	53.192	102	0.03
69	ANC 247H VII	65	13.864	167	39.480	118	0.03
69	ANC 251S	65	6.300	167	37.192	69	0.03
69	ANC 251T	65	6.300	167	37.192	69	0.02
69	ANC 252H IV	65	5.100	167	43.384	120	0.28

69	ANC252H IV	65	5.100	167	43.384	120	0.08
69	ANC 252H IV	65	5.100	167	43.384	120	0.05
69	ANC 252H IV	65	5.100	167	43.384	120	0.03
69	ANC 252H IV	65	5.100	167	43.384	120	0.02
69	ANC 252H IV	65	5.100	167	43.384	120	0.03
69	ANC 253S	65	5.100	167	47.000	102	0.01
69	ANC 254B	65	1.600	168	5.000	112	0.01
69	ANC 255UH	64	57.000	168	15.000	134	0.03
70	ANC 7B	63	17.480	172	18.000	202	0.16
70	ANC 7B	63	17.4$30	172	18.000	202	0.04
70	ANC 7B	63	17.480	172	18.000	202	0.01
70	ANC 7B	63	17.480	172	18.000	209	0.01
70	ANC 7B	63	17.480	172	18.000	209	0.03
70	ANC 11B	63	18.480	170	55.864	88	0.06
70	ANC 13B	63	8.200	170	28.000	124	<0.01
70	ANC 14B	62	54.768	170	36.768	139	0.06
70	ANC 15S	62	57.672	170	27.384	147	0.06
70	ANC 16S	62	54.000	169	58.000	137	0.01
70	ANC 20S	62	37.288	169	24.000	115	<0.01
70	ANC 24S	63	10.000	168	38.000	8a	0.04
70	ANC 27B	63	9.600	167	56.864	77	<0.01
70	ANC 29S	62	52.000	167	4.000	91	0.07
70	ANC 32B	64	26.672	163	51.288	58	0.04
70	ANC 35S	64	28.576	163	25.48S)	53	0.09
70	ANC 40B	64	23.288	163	2.500	39	0.03
70	ANC 45S	64	23.768	162	32.768	61	0.07
70	ANC 47B	64	31.672	162	14.000	42	<0.01
70	ANC 48B	64	30.288	161	56.576	43	0.07
70	ANC 53S	64	0.000	162	1.500	60	0.03
70	ANC 54S	64	1.500	161	16.576	51	0.06
70	ANC 56B	63	41.384	161	11.576	42	0.07
70	ANC 58S	63	45.480	162	2.500	52	0.07
70	ANC 59T	63	53.100	163	5.576	61	0.08
70	ANC 61S	63	26.100	163	27.192	36	0.09
7C)	ANC 61T	63	26.100	163	27.192	36	0.05
71	ADE 3	60	32.384	172	53.192	95	0.01
71	ADE 6	60	30.100	172	50.672	76	0.01
71	ADE 10	60	25.288	172	26.768	135	0.01
71	ADE 13	60	28.576	172	22.000	192	0.01
71	ADE 15	60	30.576	172	29.480	173	0.02
71	ADE 16T	60	34.338	172	32.672	168	0.03
71	ADE 17	60	33.100	172	34.864	163	0.07
71	ADE 19	60	35.864	172	42.672	146	0.05
71	ADE 20	60	32.480	172	47.576	132	0.04
71	ADE 22	60	29.384	172	41.384	92	0.02
71	ADE26	60	24.672	172	34.192	93	0.03
71	ADE 30	60	20.192	172	25.480	42	0.05
71	ADE 32	60	23.480	172	48.000	42	0.01
71	ADE 35	60	35.192	172	53.864	117	0.01
71	ADE 36	60	37.768	172	58.100	120	<0.01
71	ADE 38	60	38.864	173	3.670	50	0.01

Table B10. Mercury concentrations (ppm, dry wt.) in surficial sediments sampled by box corer and van Veen grab in Norton Basin as adapted from Nelson, et al (1975: Table III).

	n	Arith. mean	median	Range of 70% of values	Total range min. to max.
Surface lmm for:					
all areas	20	0.06	0.04	0.02 to 0.14	0.01 to 0.23
Surface 0-10cm for:					
less than 40km from shore	83	0.04	0.03	0.01 to 0.08	<0.01 to 0.23
more than 40km from shore	17	0.03	0.02	0.01 to 0.06	<0.01 to 0.07
less than 20km From Wales shoreline	3	0.04	0.03	0.03 -	0.03 to 0.06
less than 20 km from Nome shoreline	10	0.04	0.03	0.01 to 0.06	<0.01 to 0.15
less than 20km from Bluff shoreline	8	0.03	0.03	0.02 to 0.04	0.01 to 0.09
less than 20 km from St. Lawrence Is	29	0.04	0.03	0.01 to 0.07	<0.01 to 0.23

Table B11. Mean concentrations (dry wt.) of elements in "whole rock" surficial sediment at 0-2 cm, from six Norton Sound HRPS core samples, September 1976. Values are arithmetic mean and, presumably, one standard error. Sample size comprising each mean is not specified in the original report. Adapted from Robertson and Abel (1973: Tables C.3, C.4, C.5).

Station		N-1		N-5		N-9		N-15		N-20		N-26	
Deg/min N.		63	31.8	63	39.5	63	41.5	64	0.3	64	20.1	64	30.2
Deg/min W.		168	32.2	165	32.1	161	31.1	163	30.5	163	31	166	31.5
Depth (m)		23		22		15		20		20		28	
Element	Units	mean	S.E.	mean	S.E.	mean	S.E.	mean	S.E.	mean	S.E.	mean	S.E.
Al	%	5.35	0.1a	6.18	0.21	7.32	0.24	5.88	0.2	5.57	0.19	4.43	1.5
Ti	%	0.45	0.09	0.46	0.09	0.36	0.09	0.45	0.09	0.46	0.09	0.36	0.08
Mn	ppm	344	21	586	30	544	29	458	25	396	23	417	54
u	ppm	82	10	113	12	149	14	102	11	73	10	56	9
Na	%	2.03	0.01	2.02	0.01	2.31	0.01	2.01	0.01	1.65	0.01	1.72	0.01
K	ppm	lea	0.24	1.65	0.22	2.14	0.24	1.14	0.18	1.60	0.19	1.29	0.17
As	ppm	7.0	1.1	11.8	1.2	19.s	1.1	10.7	1.0	6.9	0.8	8.3	0.8
La	ppm	24.6	1.1	30.2	0.9	36.8	13.8	29.0	0.7	31.2	0.8	19.7	0.6
Sm	ppm	3.5	0.1		0.1	5.5	0.1	4.2	0.1	4.7	0.1	3.3	0.1
Sc	ppm	9.40	0.08	11%!	0.08	16.98	0.08	10.49	0.08	8.00	0.06	8.80	0.09
Cr	ppm	96	2	83	1	114	2	71	1	67	1	47	1
Fe	ppm	2.34	0.07	3.16	0.08	4.92	0.09	2.76	0.05	2.10	0.04	2.49	0.05
Co	ppm	8.49	0.05	12.53	0.17	19.05	0.10	11.27	0.23	9.31	0.06	7.29	0.08
Sb	ppm	0.68	0.06	0.97	0.05	1.79	0.08	1.03	0.07	0.76	0.04	0.84	0.06
Ba	ppm	790	30	730	20	970	30	620	30	670	20	520	30
Cs	ppm	1.85	0.09	0.66	0.05	5.61	0.17	2.42	0.10	2.44	0.08	2.18	0.09
Eu	ppm	0.92	0.03	1.08	0.02	1.36	0.02	1.03	0.03	1.02	0.02	0.87	0.02
Tb	ppm	0.58	0.05	0.78	0.06	0.84	0.06	0.69	0.06	0.64	0.05	0.62	0.05
Ta	ppm	0.60	0.05	0.75	0.08	0.93	0.09	0.65	0.07	0.72	0.07	1.32	0.13
Th	ppm	5.48	0.07	7.36	0.06	11.60	0.10	0.62	0.07	6.92	0.06	4.75	0.06

Table B12. Concentrations (ppm, dry wt.) of recoverable background trace metals in surficial sediments near Nome. The method of sampling is not specified in the original reports. Adapted from Rusanowski, et al (1986: Table 3.22), Rusanowski, et al (1987: Table 3.3-1), Rusanowski, et al (1988: Table 3.3-1).

*Sediment sample was gray colored and very sticky; handled like a silt high in clay-sized material; different in appearance from all other sediment samples.
**Different in appearance from other sediment samples as evidenced by by the percent total solids value.

Location	Date	As	Cd	Cr	Cu	Pb	Zn	Hg	Ni	% total solids
1985										
Norton Sound		24.9	0.80	13.3	10.6	4.44	53.8	0.139		
Offshore Penny River	10/10/85	29.3	0.50	10.2	6.12	4.29	51.2	0.020		
Surfzone Penny River	10/10/85	37.1	1.50	15.5	14.5	7.25	68.6	0.030		
1985 dredge location	10/10/85	27.9	<0.5	10.4	6.95	4.4	46.9	0.040		
1986										
500m upstream of dredge	8/21/86	15.8	8.00	4.2	2.5	5	36.4	0.040	15.0	77.3
500m upstream of dredge	9/2/86*	62.99	3.26	31.35	53.41	13.57	119.2	0.125	58.8	49.8
500m upstream of dredge	9/25/86	9.35	2.46	12.92	16.88	1.99	39.31	0.106	19.7	74.0
1987										
500m upstream of dredge	6/26/87	120.0	1.90	11	22.0	10.0	65.0	0.077	30.0	78.9
500m upstream of dredge	7/8/87**	77.0	39.00	24	32.0	22.0	75.0	0.140	53.0	10.0
500m upstream of dredge	7/16/87**	4.3	1.35	26	29.0	34.0	76.0	0.050	39.0	40.1
500m upstream of dredge	7/23/87	29.2	1.87	32	40.0	10.0	85.0	0.002	49.0	67.1
500m upstream of dredge	7/29/87	28.6	2.37	32	38.0	13.0	85.0	0.003	48.0	63.3
500m upstream of dredge	8/5/87	24.1	0.30	28	34.0	11.0	80.0	0.003	40.0	69.4
500m upstream of dredge	8/12/87	130.0	1.30	18	25.0	<9	69.0	<0.005	43.0	73.9
500m upstream of dredge	8/26/87	9.3	2.40	23	29.0	14.0	80.0	0.009	46.0	76.8
500m upstream of dredge	9/3/87	11.0	1.50	33	36.0	92.0	78.0	0.004	52.0	72.1
500m upstream of dredge	9/9/87	31.5	0.97	<8.8	<8.8	17.0	29.0	<0.02	<2.6	75.3
500m upstream of dredge	9/16/87	33.0	2.50	6.9	10.0	4.3	42.0	0.024	22.0	92.4
500m upstream of dredge	9/22/87	140.0	1.80	25	47.0	12.0	100.0	<0.035	60.0	57.7
500m upstream of dredge	9/29/87	89.0	3.30	7	17.0	4.8	53.0	<0.023	24.0	86.4
500m upstream of dredge	10/7/87	92.0	<0.93	24	26.0	12.0	68.0	<0.009	93.0	74.0
500m upstream of dredge	10/27/87	2.7	0.69	<5.6	<3.4	0.6	3.0	<0.002	<5.6	98.6
500m upstream of dredge	11/8/87	120.0	1.90	27	30.0	<9.4	94.0	<0.005	42.0	72.9

Table B13 . Concentrations (ppm, dry wt.) of trace metals in sediments between Cripple River and Nome River within 5 miles of shore. Lead was not detectable in any sample. Modified van Veen grab, July 1973. Adapted from Sharma (1974: 111-142).

Sample no.	Wt. % of 1.5 to 2.0 phi	Wt. % of 2.5 to 3.0 phi	Wt. % non-carbonate carbon	Minutes 64 deg.	Minutes 165 deg.	Water depth (m)	Co	Cu	Zn
NS-1	3.6	5.3	0.66	26.2	25.9	27	11	10	130
NS-3	2.5	4.4	0.542	28.1	24.8	18	11	10	38
NS-4	4.5	4.68	0.666	29.1	24.2	13	7.7	12	58
NS-5	0.5	39.8	0.364	29.35	34.2	8	7.7	10	37
NS-8	7.34	17.3	0.893	28.6	29.3	20	6.5	18	55
NS-9	2	9.5	0.9	27.4	30	23	5.1	13	48
NS-10	11.8	29.7	0.827	26.7	30.4	21	5.1	10	62
NS-11	0.6	3.2	1.568	27.2	35.2	23	7.7	60	170
NS-12	0.6	1.5	0.904	28.1	34.5	20	1.05	11	52
NS-13	0.7	0.15	1.355	29.3	30.4	14	4	8	160
NS-16	9.8	27.7	0.611	30.9	37.7	11	4	10	67
NS-18	7.1	1.4	0.423	29.9	38.2	14	4	10	42
NS-19	1.88	6.07	0.837	28.7	38.8	20	4	11	55
NS-20	2.6	1.28	0.694	28	40	22	4	12	45
NS-21	5	24.76	0.786	28.2	43.8	24	1	19	42
NS-23	2.08	0.5		30.7	43.3	16			
NS-24	0.12	0.13		31.5	42.5	13			
NS-26	45.9	3.41	0.356	31.1	47.7	16.5	5	11	45
NS-27	1.4	0.6		29.5	48	18			
NS-28	1.37	3.9	0.704	28.8	48.5	18	4	11	40
NS-29	6.45	5.5	0.868	26.3	23.2	20	7.5	19	50
NS-30	5.87	8.35	0.855	26	20.5	21	4	27	>400

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