

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

HYDROCARBON GASES IN SEDIMENTS FROM NAVARIN BASIN, BERING SEA--
RESULTS FROM 1982 FIELD SEASON

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Open File Report 84-97

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards.

Menlo Park, California
1984

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This report concerns the distribution and origin of hydrocarbon gases methane (C1), ethane (C2), ethene (C2=), propane (C3), propene (C3=), isobutane (i-C4), and normal butane (n-C4) in surficial sediments collected during the 1982 field season from the Navarin Basin province in the Bering Sea. These 1982 field season data are tabulated and compared with results from samples collected during previous field seasons (Vogel and Kvenvolden, 1981; Golan-Bac and Kvenvolden, 1983).

Methods

The previous field seasons of 1980 and 1981 were generally reconnaissance surveys in which a total of 264 samples were analyzed for hydrocarbon gas compositions: 49 cores (93 samples) in 1980; 70 cores (171 samples) in 1981. The samples, ranging in subbottom depth from 44 to 580 cm, were collected along geophysical tracklines during all three field seasons. The 1980 cores were widely distributed, (approximately a 50 km grid spacing), with one area of more intense coverage (approximately a 5 km grid spacing). During the 1981 field season cores were also collected throughout the Navarin Basin province, but with more dense coverage in several parts of the basin following an evaluation of geochemical, paleontological, and sedimentological data obtained during the previous field season. Sample coverage was limited in the 1982 field season to 52 samples from 23 cores. Also, depth of sampling was limited to 300 cm because of equipment constraints. The sampling strategy was to revisit sites of particular interest along geophysical tracklines. In addition, a few cores were taken in areas of sparse sampling density. Almost all the recoverable gravity cores were sampled for gas analysis.

Sampling methods and gas analyses were the same as described in the 1981 field season report (Golan-Bac and Kvenvolden, 1984) with the exception that helium-purged distilled water was used instead of seawater in the analytical procedure. This procedure involved extraction of gas from sediment in a closed container, and gas chromatographic measurement of the gas content of the headspace in the container (Kvenvolden and Redden, 1980). Concentrations are reported in microliters (μ l) or nanoliters (nl) of hydrocarbon gas per liter (l) of wet sediment.

Results

Results from the 52 samples taken for gas analysis in 1982 are summarized in Table 1. This table is divided into 2 sections, based on samples collected from the shelf and slope. Shelf samples were recovered from water depths of 100 to 150 m, and slope samples from water depths of 150 to 2800 m. The rise was not sampled during the 1983 field season. Sample locations are shown in Figure 1. The 150 m and 2800 m contour lines delineate the shelf, slope and rise.

Ranges of both concentrations and ratios of hydrocarbon gases are summarized in Table 2. C1 is the most abundant hydrocarbon gas in each

sample, typically present at concentrations which are one to three orders of magnitude greater than the concentrations of the other low molecular weight hydrocarbons.

Figures 2, 3, and 4 illustrate the areal distributions of maximum concentrations of C1, C2+C3 and nC4+iC4, respectively. In most cases, maximum concentration values were reached in the deepest samples (Table 1). C1 concentrations are less than or equal to 10 μ l/l in slightly more than half the samples (56%) and less than or equal to 100 μ l/l in most of the samples (96%). The maximum C1 concentration of 160 μ l/l is from a core (G2) recovered in the sediment of Navarinsky Canyon. Concentrations of C2 are less than 500 nl/l in approximately 80% of the samples. In the remaining 20% of the samples, the concentration of C2 exceeded this value; three samples (G8-90-100, G9-255-265, and G11-254-264) all from approximately 200 m water depths, had concentrations exceeding 1000 nl/l. Concentrations of C3 are much lower than C2; for 86% of the samples analyzed C3 concentrations were less than 100 nl/l. Figure 3 shows locations of 5 cores where the maximum concentrations of C2+C3 exceed 1000 nl/l. These cores include numbers G2 and G17 in addition to the three cores listed above. Butanes (n-C4 and i-C4) are generally the least abundant low molecular weight hydrocarbons analyzed. Isobutane was detected in only 17% and normal butane in only 14% of the samples studied. Core G17 and core G2 had the highest concentrations of i-C4 (89 nl/l) and n-C4 (53 nl/l). The alkenes (C2= and C3=) are present in almost all the samples analyzed. C2= is present in concentrations less than C2 in 84% of the samples and C3= is present in concentrations less than C3 in 59% of the samples.

Sources of Hydrocarbon Gas

C1 is the most abundant gas in the sediments sampled from the Navarin Basin province. During the 1982 field season, 96% of the samples yielded concentrations of C1 less than 100 μ l/l. None of the samples analyzed in 1982 had C1 concentrations exceeding 1000 μ l/l whereas samples from 5 cores taken during the 1981 field season and from one core taken during the 1980 field season had C1 concentrations greater than 1000 μ l/l; all these cores were located in Navarinsky Canyon. Concentrations of C1 exceeding 1000 μ l/l were not observed in cores collected in 1982 most likely due to low density sampling and short core length. During 1980 and 1981 these high concentrations of C1 (>1000 μ l/l) were measured in cores at least 190 cm long and more commonly in cores greater than 390 cm in length.

Interpretation of the sources of gas is based on considerations of the amount of C1 relative to the amount of accompanying C2 and C3 and the amount of C2 relative to the amount of C2=. Because C2= is believed to be only biogenic, whereas C2 is both thermogenic and biogenic, a low ratio of C2/C2= suggests a dominant biogenic source. Limits to the ratio C1/(C2+C3) were established by Bernard et al (1978) who suggested that biogenic hydrocarbons should have ratios greater than 1000 and thermogenic hydrocarbons should have ratios less than 50. Whenever C1 concentrations exceeded 1000 μ l/l in Navarin basin province, this ratio was greater than 1000 indicating that the gas has a biogenic source. Most C1 concentrations observed during 1982 were less than 100 μ l/l, and none of these samples had ratios exceeding 1000. In fact, 43% of the samples have ratios less than 50. In most cases, we attribute these low ratios to the preferential loss of biogenic C1 via C1 oxidation and loss through upward migration and diffusion. However, samples from seven cores

(G7, 8, 9, 11, 12, 13, and G17) contain gas of possible thermogenic origin. In the first six cores $C1/(C2+C3)$ ratios are less than 50 while at the same time the ratios of $C2/C2=$ are significantly greater than one. These six cores were taken during a consecutive sampling sequence in the northern part of the province. Core G17 has high $C2/C2=$ values, and low $C1/(C2 + C3)$ values, although not less than 50. This sample is from the same area where core G66 from the 1981 field season was recovered. Core G66 was one of nine cores which had mixtures of gas indicating a possible thermogenic source.

Summary and Conclusions

Methane (C1) was the most abundant hydrocarbon gas in all samples analyzed from the Navarin Basin province. None of the concentrations of C1 exceeded 1000 $\mu\text{l/l}$ as did C1 concentrations in six cores from Navarinsky Canyon taken during the 1980 and 1981 field seasons. Most C1 concentrations observed during the 1982 field season were less than 100 $\mu\text{l/l}$ and none of these samples had $C1/(C2 + C3)$ ratios exceeding 1000. Almost one half of the samples had ratios less than 50. In most cases we attribute these low ratios to preferential loss of biogenic C1 via C1 oxidation and loss through upward migration and diffusion.

Ethane (C2) is the second most abundant hydrocarbon gas in most samples. Propane (C3) concentrations were generally much lower than C2 concentrations. Amounts of $C2 + C3$ exceed 1000 nl/l in five cores taken at three locations. Butanes (n-C4 and i-C4) were not observed in most samples and were present in low concentrations when detected. The alkenes ($C2=$ and $C3=$) were present in almost all samples and were most likely the result of biological activity in the sediment. Ratios of $C1/(C2 + C3)$ values were less than 50 and decreased with depth, and ratios of $C2/C2=$ were greater than one and increased with depth in six cores located adjacent to each other in a consecutive sampling sequence in the northern part of the province. These cores may contain thermogenic gas.

Of interest are the gases in core G17 where $C1/(C2 = C3)$ ratios are low, and decrease with depth and $C2/C2=$ ratios are high and increase with depth. This core is located in the same region as G66, from the 1981 field season. Both cores contain gas from a possible thermogenic source.

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Table 1. Hydrocarbon Gas (C₁-n-C₄) Concentrations and Ratios from Sediment Samples from the Navarin Basin Province (1982)

Core No. and Interval (cm)	Water Depth (m)	Station No.	C ₁ (µl/l wet sediment)	C ₂	C ₂ :1	C ₃ :1			i-C ₄	n-C ₄	C ₁ / (C ₂ +C ₃)	C ₂ / C ₂ :1	Location	
						n1/1 wet sediment							Latitude	Longitude
<u>Shelf Sediment</u>														
G14	90-100	138	20	36	64	26	31	29	n.d.	n.d.	380	2.5	60° 05.4'	177° 11.5'
	190-200			78	310	18	47	310	n.d.	n.d.	210	17		
	236-246			96	490	24	33	31	n.d.	n.d.	180	20		
G15	90-100	138	21	12	76	26	33	36	n.d.	n.d.	110	3.0	59° 57.9'	177° 25.3'
	171-181			34	290	10	54	130	n.d.	n.d.	99	16		
G35	44-54	131	46	12	110	26	50	50	n.d.	n.d.	73	4.4	58° 55.1'	175° 59.2'
G36	88-98	146	47	39	350	76	130	47	48	37	82	4.6	59° 15.9'	176° 42.0'
<u>Slope Sediment</u>														
G1	90-100	2674	1	2.8	16	18	12	19	n.d.	n.d.	100	.87	60° 01.0'	179° 59.9'
	190-200			63	200	21	48	1000	n.d.	n.d.	250	9.9		
G2	90-100	2047	2	9.5	170	100	130	44	n.d.	19	31	1.7	60° 08.9'	179° 48.2'
	190-200			61	540	180	230	68	45	53	80	3.0		
	244-254			160	880	38	140	1300	n.d.	n.d.	160	23		
G3	90-100	2294	3	1.1	28	35	26	23	n.d.	n.d.	20	.81	60° 14.4'	179° 52.2'
G4	87- 97	1176	10	5.3	52	96	25	28	n.d.	n.d.	69	.54	60° 34.0'	179° 39.0'
G5	90-100	153	11	5.2	87	75	60	27	n.d.	21	35	1.2	61° 16.8'	178° 16.4'
	190-200			12	42	27	n.d.	9	n.d.	n.d.	280	1.6		
	234-244			14	82	74	83	73	n.d.	n.d.	86	1.1		
G6	90-100	202	12	2.7	n.d.	n.d.	24	62	n.d.	n.d.	110	-	60° 54.0'	178° 45.1'
	190-200			5.2	n.d.	n.d.	21	8	n.d.	n.d.	250	-		
	261-271			5.5	170	150	90	79	24	20	22	1.1		
G7	90-100	205	13	2.2	50	21	30	22	n.d.	n.d.	28	2.4	60° 56.0'	178° 45.1'
	190-200			6.3	250	26	12	6	n.d.	n.d.	24	9.7		
	257-267			9.2	460	36	22	24	n.d.	n.d.	19	13		
G8	90-100	213	14	20	2400	15	61	20	n.d.	n.d.	7.9	160	60° 58.0'	178° 45.6'
G9	90-100	208	15	8.4	330	27	57	15	n.d.	n.d.	22	12	61° 00.0'	178° 45.6'
	190-200			13	860	30	79	100	9	n.d.	14	29		
	255-265			16	1200	18	70	19	n.d.	n.d.	12	67		
G10	90-100	206	16	3.9	23	28	15	14	n.d.	n.d.	100	.85	61° 02.0'	178° 45.6'
	190-200			7.1	12	23	15	13	n.d.	n.d.	150	1.4		
G11	90-100	205	17	5.1	160	35	23	16	n.d.	n.d.	28	4.5	61° 03.5'	178° 45.9'
	190-200			8.2	400	41	31	9	n.d.	n.d.	19	9.7		
	254-264			18	1100	35	41	72	n.d.	n.d.	16	30		
G12	90-100	203	18	6.9	55	20	24	19	n.d.	n.d.	88	2.7	61° 05.0'	178° 46.0'
	190-200			5.4	180	19	14	21	n.d.	n.d.	28	9.4		
	253-263			4.7	230	20	42	31	n.d.	n.d.	17	12		

n.d. = not detectable
- = not reported

Table 1. (Continued)

Core No. and Interval (cm)	Water Depth (m)	Station No.	C ₁ µl/l wet sediment	C ₂	C _{2:1}	n/l			1-C ₄	n-C ₄	$\frac{C_1}{C_2+C_3}$	$\frac{C_2}{C_2:1}$	Location	
						C ₃	C _{3:1}						Latitude	Longitude
<i>Slope Sediment (Cont.)</i>														
G13 90-100	200	19	2.7	61	39	32	20		n.d.	n.d.	29	1.5	61° 6.7'	178° 46.2'
190-200			3.9	130	93	73	69		9	16	19	1.4		
271-281			5.3	140	28	33	15		n.d.	n.d.	30	5.1		
G16 90-100	277	22	51	270	21	36	200		n.d.	n.d.	170	13	59° 28.5'	178° 15.0'
190-200			140	660	n.d.	100	n.d.		n.d.	n.d.	180	-		
G17 90-100	382	23	41	300	23	82	14		25	n.d.	110	13	59° 26.3'	178° 15.1'
190-200			89	840	17	240	63		66	n.d.	82	49		
240-250			98	870	n.d.	240	65		89	n.d.	89	-		
G19 67- 77	852	25	4.8	33	28	15	28		n.d.	n.d.	99	1.2	59° 22.0'	178° 15.0'
G32 90-100	2186	42	.7	29	320	54	56		n.d.	n.d.	8.4	.09	58° 28.0'	176° 21.1'
190-200			.8	58	56	40	23		n.d.	n.d.	8.6	1.0		
264-274			1.8	43	29	31	44		n.d.	n.d.	24	1.5		
G33 90-100	1864	43	6.4	46	54	74	38		n.d.	n.d.	80	.86	58° 28.4'	176° 44.9'
190-200			10	49	45	45	46		n.d.	n.d.	110	1.1		
232-242			7.4	36	27	21	35		n.d.	n.d.	130	1.3		
G34 90-100	845	44	15	75	18	62	27		n.d.	n.d.	110	4.3	58° 32.6'	176° 41.0'
190-200			46	420	190	320	94		36	49	62	2.3		

n.d. = not detectable

- = not reported

Table 2. Summary of Ranges of Gas Concentrations (C1-nC4) and Ratios for Samples from the Shelf and Slope of the Navarin Basin Province (1982). Methane (C1) concentrations are in l/l, the other hydrocarbon concentrations are in nl/l.

	<u>Shelf</u>	<u>Slope</u>
C ₁	12 - 96	.8 - 160
C ₂	64 - 490	n.d. - 2,400
C ₃	31 - 130	n.d. - 320
C ₂ ⁼	18 - 76	n.d. - 320
C ₃ ⁼	29 - 310	n.d. - 1300
iC ₄	n.d. - 48	n.d. - 89
nC ₄	n.d. - 37	n.d. - 53
C ₁ /C ₂ +C ₃	73 - 380	7.9 - 280
C ₂ /C ₂ ⁼	2.5 - 20	.09 - 160

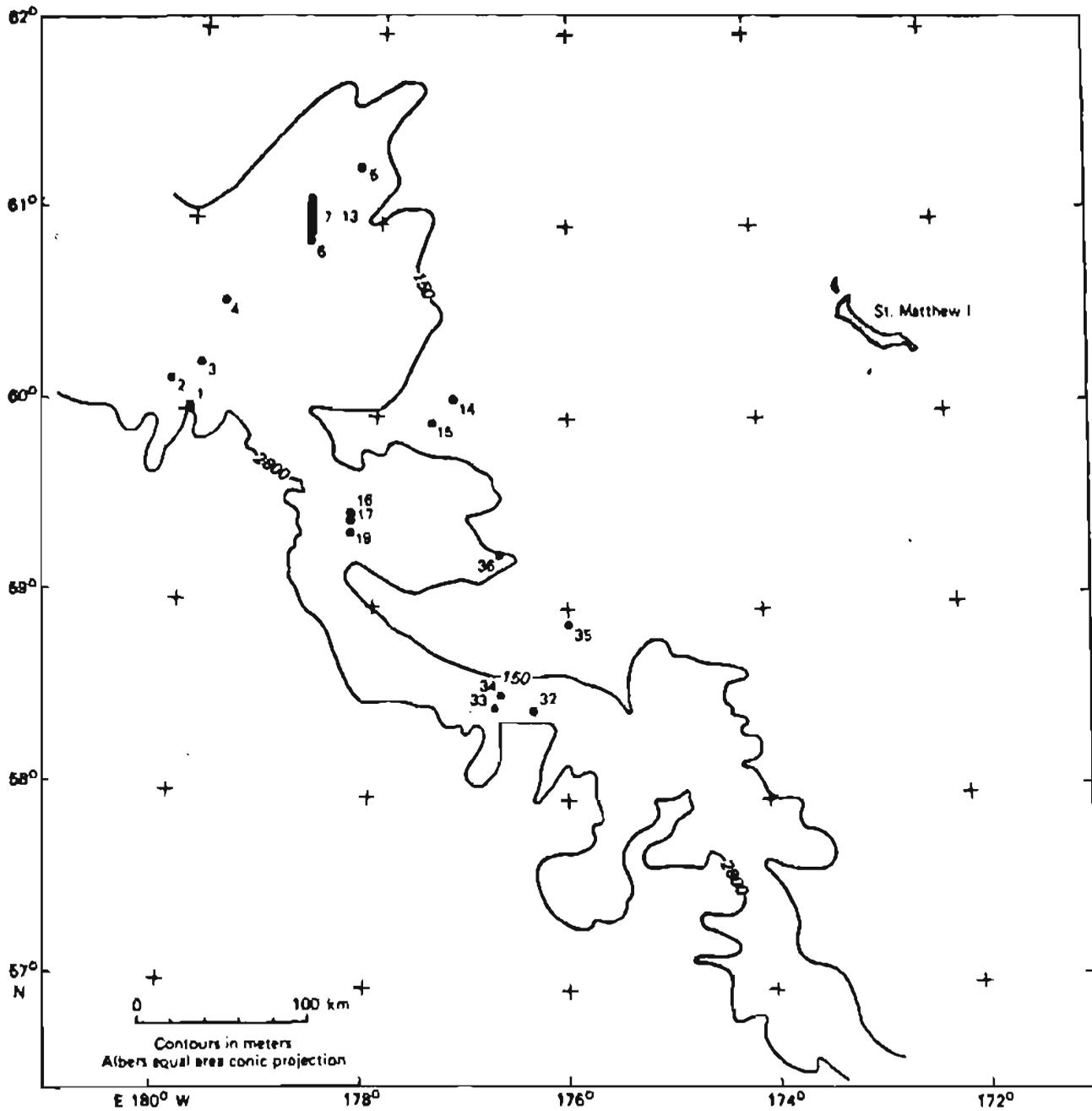


Figure 1. Location of hydrocarbon gas sampling sites from the 1982 field season in the Navarin Basin province. Sites are designated with core numbers.

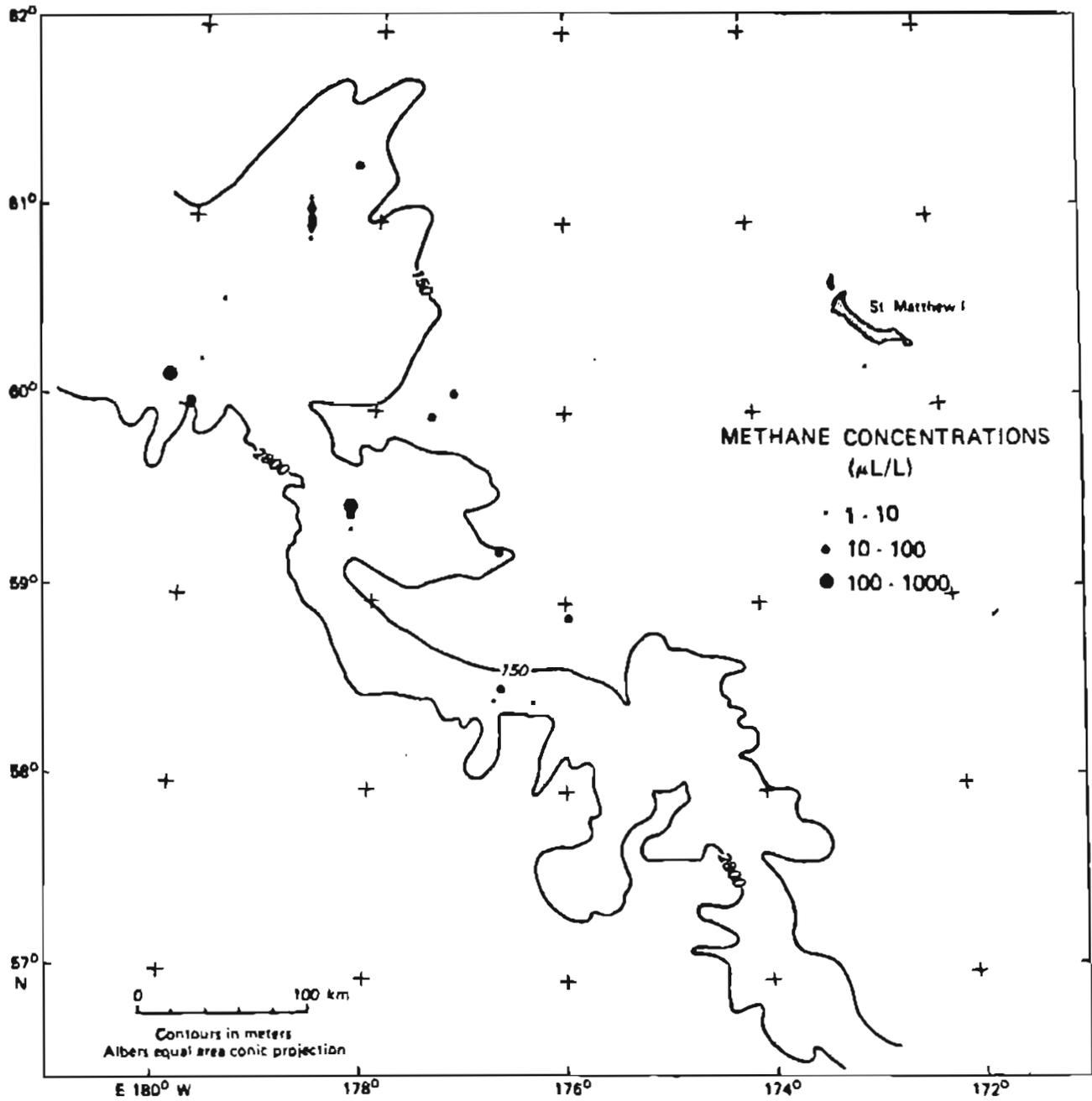


Figure 2. Distribution of maximum concentrations of methane in $\mu\text{l/l}$ of wet sediment.

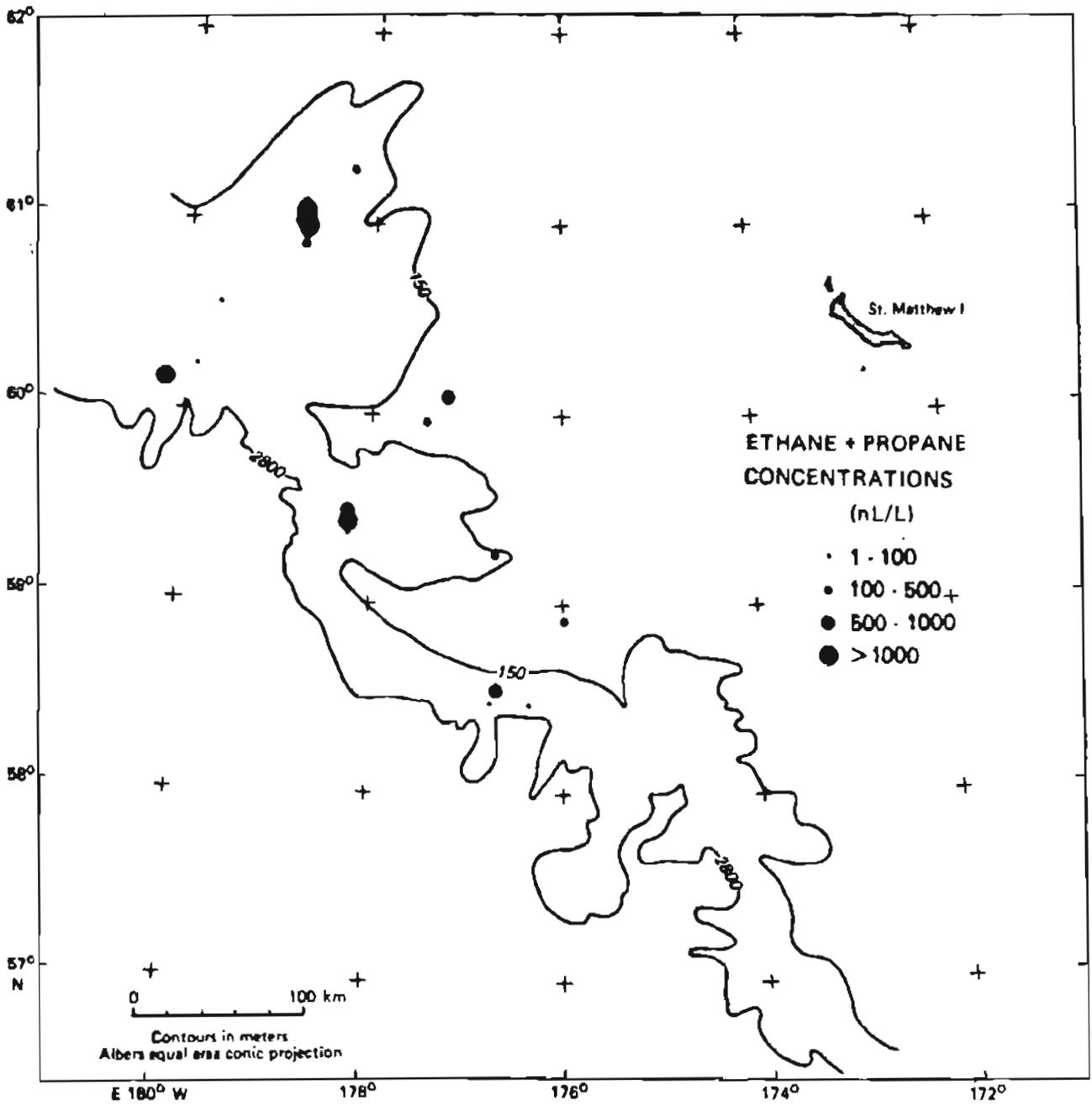


Figure 3. Distribution of maximum concentrations of ethane plus propane in nL/L of wet sediment.

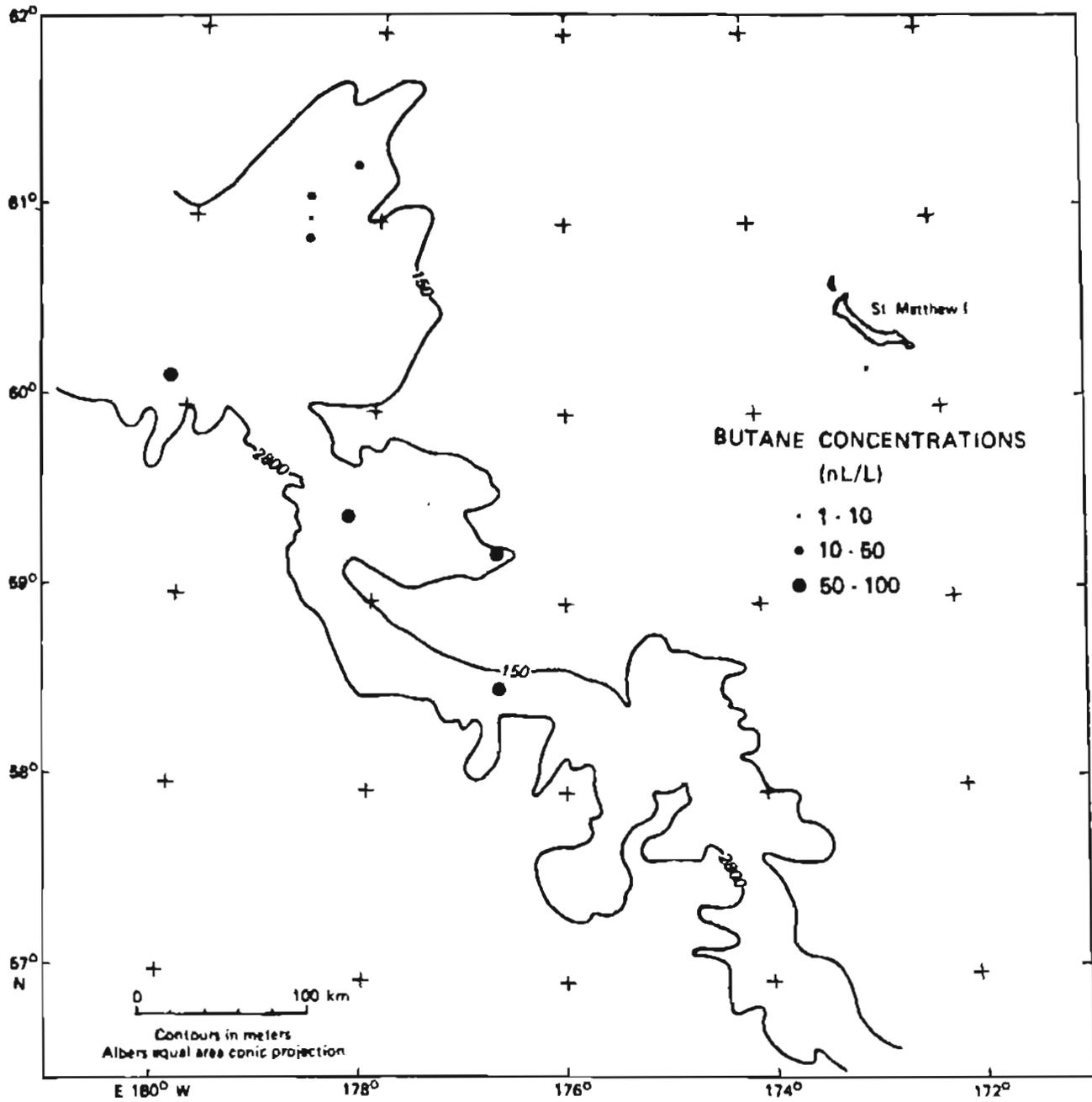


Figure 4. Distribution of maximum concentrations of butane in nL/L of wet sediment.