Hydraulics Research
Wallingford

SLUDGE DISPOSAL IN LIVERPOOL BAY

Fifteenth bed monitoring survey
February 1988

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ABSTRACT

This report describes the fifteenth HR survey carried out in February 1988, continuing the long-term monitoring of the bed sediments of Liverpool Bay. The objective is to determine whether any changes are occurring in the abundance of heavy metals and of organic matter in the finer fraction of the bed sediment as a consequence of sewage sludge disposal. The differences in measured concentration arising from the selection of 90 μm instead of the more traditional 63 μm as the upper limit of the finer fraction is germane to the future conduct of the monitoring programme by the North West Water Authority. The findings of the second half of this two-year study into the expected consequences of making this choice are described.

CONTENTS

1 INTRODUCTION

Surveys of the organic carbon and heavy metals abundance in the sediments of Liverpool Bay have been conducted by Hydraulics Research (HR) on a roughly annual basis since 1973. The objective of this sediment surveillance is to detect whether any long-term trends are taking place in terms of organic and metal enrichment of the surface sediments as a consequence of the discharge of sewage sludge to the Bay. This report presents the results of the latest survey, the fifteenth of the series, which was undertaken in February 1988.

Standard procedure in the past has been to determine the concentration of organic carbon and heavy metals in the so-called mud fraction of the surface 25mm of the bed obtained by grab sampling or by shallow coring. Throughout the survey series HR has adopted the traditional size split at 63 μm as the upper limit of the mud fraction. The present survey marks the end of a two year overlap when both HR and North West Water Authority (NWWA) carried out their own sampling programmes and analysis. Henceforth NWWA will take over responsibility fo the main monitoring programmes. Although NWWA have continued the same sampling pattern that has evolved from the HR programme, they have decided to make the mud size split at 90 μm instead of 63 μm in order to conform to present practice at the Fisheries Laboratory, Burnham-on-Crouch (MAFF). This change may pose problems in relating the results of the NWWA surveys to the long time series collected by HR. Therefore, it has been decided to take advantage of the two-year overlap by attempting to evaluate the effect of changing the size limit. Thus on both the present survey and the last surveys HR have doubled their customary analysis by examining the "less than 63 μm" fraction and the "less than 90 μm" fraction. Furthermore sub-sets of the total sediment from each sampling location have been made available to MAFF and NWWA to permit comprehensive inter-laboratory calibration.

2 SAMPLE RECOVERY

Grab samples were taken from the M.V. Branding on 16-18 February 1988 at 67 sites (Fig 1). The sampling grid included twenty-three of the group of twenty- four standard sites visited regularly since 1973. The remaining one, T6, the closest to the Dee estuary was omitted as it was on the previous two surveys. Because of the requirement to divide the sample into three parts (one for MAFF and one for NWWA as well as one for HR), duplicate grab samples were taken at most sites to ensure sufficient mud was available for analysis. The top 25mm was separated on board the survey vessel and the duplicates bulked prior to their return to the laboratory.

3 LABORATORY TREATMENT

Individual station samples were well mixed and divided into three equal parts as on the last survey (Ref. 1). These were stored, in polythene bags, in a deep-freeze until required. The HR sample was divided into two, one half being split into mud and sand fractions by wet sieving at 63 μm as has been the custom for all HR analyses and the second half split similarly at 90 μm. This provided material to enable comparisons of the organic matter and heavy metal contents of the 0 - 63 μm and 0 - 90 μm fraction to be made. Wet separation was accompanied by hand brushing to break down sediment aggregates. In spite of extra grab samples being taken, the quantity of fine materials available was not always sufficient to enable a full set of analyses to be made. In general, where there was less than about 0.1% of fines (<63 μm or <90 μm) then the organic determination which uses the larger quantity of material was omitted. As on previous surveys, the fine fraction was oven dried at 50°C prior to crushing and mixing before sub-sampling for organic and heavy metal determinations.

Organic carbon determinations were made by the standard wet oxidation method used previously (the organic carbon is reported as organic matter, a factor of 2.5 being used as in the past to convert carbon to the equivalent of dried organic residues).

Standard (NBS 1645) and HR's own reference samples were included with the samples submitted to the commercial analytical laboratory for heavy metal determinations by atomic absorption spectrophotometry as in the previous five surveys. Correction factors were derived and applied to ensure that the results of the current survey are as comparable as possible with those of the previous six surveys for which the data is included in this report.

The factors used on this occasion were:

Hg	1.068	Pb	0.990
Cu	1.072	Ni	1.062
Zn	0.983	Cr	1.016

They are typical of those used in the past and in most cases the individual check samples were within the $\pm$10% claimed accuracy for this method of analysis.

The previous six surveys from which the data is included in this report were made on substantially the same grid covering between 60 and 67 sites so comparisons are more realistic than with some of the earlier surveys with their lower sampling density. Nevertheless, the ability to return to a particular site the following year is limited by navigational accuracy so that local non-uniformity of bed composition rather than temporal change can account for substantial differences from year to year (cf mud, position T13, 45% last year. 0.1% this year).

4 MUD CONTENT

The mud content of each of the 67 sampling positions is shown in Fig.2. The mud content is similar in distribution to that found in past surveys although the absolute values are somewhat lower. We reported in 1987 (Ref.1) on the fourteenth survey that there appeared to be less mud in the surface layer, a mean of 8% compared with the more customary 11% found on the previous four surveys. The present survey shows the mean down to 6.4%. Again, the mean difference owes much to the continued reduction in mud at the particularly mud-rich sites. YY3 and 4 showed an average mud content of 45% compared with 72% and 90% in the winters 1987/8, 1986/7 and 1985/6 respectively. For the first time there are no mud contents above 50% throughout the area.

Several stations showed mud contents of less than 1% for the first time (T13, Q13 and R9) and two showed less than 1% for the second time only in nine or ten surveys (R13, R12). U12 showed less than 1% for the first time but has only been sampled on four occasions.

Observations made on board the survey vessel indicates that several samples had a layer of sand overlying a muddier bed. This was noted at positions U9, S9, S12, P12. This suggests that prevailing weather, tidal or wave conditions had distributed fine sand over certain parts of the bay. The effect of this on the results is to decrease the mud concentration in the top 25mm of bed but not necessarily to alter the heavy metal concentrations in the mud.

At two sites, where duplicate grab samples were taken in order to obtain sufficient mud for analysis, the two individual samples were very different in character, even though taken at nominally the same position. These were at positions P11 and S13 where one of each pair of samples contained much more mud than the other. In these cases, the samples were analysed separately as P11A and B, S13A and B and the results are recorded in Table 1.

5 ORGANIC CONTENT

The distribution of organic matter in the mud fraction (Fig.3) is more comprehensive than in the last survey and shows slightly higher figures although the fourteenth survey results were incomplete and lower than average. The "total" organics in Fig.10 show no values exceeding 1000 tonnes/km^2 for the first time due to the fact that the mud contents were lower. The "total" organics are a product of the organic matter content and the mud content expressed as a weight per unit area of the top 25mm of the bed. The areal distribution is similar to that of previous years.

6 HEAVY METALS

In this section, only the metals in the <63 μm fraction will be considered and the comparisons made will be with past surveys.

The heavy metal concentrations have been illustrated as in previous reports. Figs 4 - 9 show the concentration of metals in the mud fraction of the sediment expressed in micrograms metal per gram of mud. Figs 11 - 16 shown the "total" metals expressed as the product of the metal concentration, the mud percentage, and a factor based on the mean dry bulk density of a number of cores. This "total" metal concentration is expressed as kilograms (mercury only) or tonnes of metal in the top 25mm per square kilometre of bed. If it is assumed that the metal content of the fine sediment (< 63 μm) is mainly derived from adsorption of metals from solution, then this "total" metal figure represents the input to the area from man-made sources together with any natural sources that produce soluble metals.

Mercury concentrations appear much higher after it was reported last year that there had been a 5-year decline in mercury values (Fig. 4). No less than 14 sites show concentrations exceeding 4 μg/g compared with only one last year. Part of the explanation is that as the mud concentrations reduce, then the concentration of reworked mercury per unit weight of mud rises. Nevertheless, there are some sites such as R11 and T8 where mud and mercury values are both above average. Assuming a reducing input of mercury to the area, reworking of buried sediments must account for the apparent increase. The mean mercury concentration of 4.8 μg/g is the highest recorded since the current 60-67 sites have been sampled. The relative standard deviation (RSD) is also the highest at 315%. It is difficult to envisage a scenario that would explain the peak mercury concentration of 124 μg/g at a position such a L7 where pollution should be minimal. Incidentally, the 0 - 90 μm value at this site is 412 μg/g. Assuming the samples were representative of the bulk of the bed and even though the mud concentrations were very low, these results imply a high concentration of mercury in the 60 - 90 μm range. This would not be expected to occur by adsorption processes, which would concentrate the mercury in the finer material, but may derive from mercury containing minerals.

Other southern sites, G7, M8, N8 are normal. The high RSD value and the large variations between mercury concentrations in the 0 - 63 and 0 - 90 μm fractions reinforces the view that mercury distribution is far more uneven than any of the other metals and may well be being concentrated by some so far unknown mechanism. In spite of all this, the total mercury distribution (Fig.11) appears more even, no values above 100 kg/km^2 being recorded, similar to that of the last survey.

Zinc (Figs. 5 and 12) figures are very close to the average of the past five surveys both in mean concentration and total distribution. Higher individual concentrations are again associated with low mud concentrations.

Lead (Figs. 6 and 13) shows four peaks exceeding 300 μg/g but overall the mean is similar to that of the last two surveys and a reduction on the previous three.

Nickel and copper show increases close to the dredged spoil dumping ground north of the Mersey outfall, concentrations of nickel exceeding 100μg/g and copper exceeding 400 μg/g being recorded for the first time in that area (Figs. 7 and 8). However, these higher values make little impression on the total nickel and copper (Figs. 14 and 15) because they are coincident with sediments having very low mud content.

Chromium (Figs 9 and 16) concentrations have been high in the dredging spoil ground since 1984 but the number of sites with high values is increasing with the concentrations themselves also increasing.

Considering all the figures, it is obvious that the metal concentrations are higher than average but the mud concentrations are lower, thus giving a total metal distribution which appears slightly below average.

The distribution of the "total" metals is similar to that of 1985/6 with peaks south of the Mersey outflow, to the far north around S14, slightly to the east of the previous peaks (based on this site alone), a central band between the Mersey and the sludge dumping ground, and lastly to the north of the sludge dumping ground.

The mean values (Mμ g/g) and the relative standard deviation (RSD%) for the last six surveys are given overleaf.

Survey No.		Hg	Zn	Pb	Ni	Cu	Cr
10	M	3.8	388	349	51	86	43
	RSD	135	45	158	37	65	24
11	M	2.0	497	459	56	165	73
	RSD	97	47	120	51	116	50
12	M	2.8	386	266	66	99	85
	RSD	249	43	93	20	50	43
13	M	1.9	465	172	55	90	69
	RSD	39	25	56	17	43	25
14	M	1.7	346	146	51	97	50
	RSD	52	22	45	31	46	51
15	M	* 3.2	397	166	54	143	70
	RSD	*100	34	64	44	77	88

* The excessively high mercury concentration at position L7 in the latest survey has been omitted from the above means.

7 MUD FRACTION COMPARISONS

Separation of the total sediment at 63μm and 90μm to give 0 - 63 and 0 - 90μm fractions yields two sets of results for mud, organic matter and heavy metals (Table 1). The 63μm split has been the standard used at HR and is commonly used elsewhere. Other size limits have been chosen by workers in the same field ranging from 20μm (Ref 3) to no split at all, in other words using the entire sediment (Ref 4). Other workers have assumed the total metal content is confined to the >16μm fraction (Ref 5). MAFF currently split at 90μm, claiming that sediment aggregates are not fully broken down by wet sieving so that more of the metals adsorbed on the clay particles are included in the less than 90μm fraction than in the less than 63μm. Earlier studies (Ref 2, 6) have demonstrated that even when aggregates are fully broken down certain metals such as copper, chromium and iron are present at higher concentrations in the 50 to 100 μm fraction. However, in these cases it is normally assumed that elevations in the non-aggregated 63 to 90 μm fraction are not in the form of adsorbed metals. They are more likely to be of natural origin than the consequence of contamination from sludge disposal or effluent from the Mersey estuary.

From a large number of size gradings made in the period 1973 to 1981 the maximum percentage sediment found in the 63 - 90 μm range was less than 10%. The current comparisons (Table 1) show that on average about one per cent of the sample is in the 63 - 90μm fraction. Sub-sampling errors particularly when dividing the coarser samples resulted in some 63 - 90 μm fractions being apparently negative e.g. G9, M12, P12, S9, S11. However, comparison of the means for the 69 sample pairs indicate that sieving at the 90 μm divide yields 16% more sediment than sieving at 63μm. This figure is in reasonable accord with the proportion obtained on the fourteenth survey, namely 14%.

The principal question to be resolved for the continuation of the time series by NWWA is whether sieving at 90 μm brings about a significant difference in the metal and organic concentrations derived from the "less than 63 μm" fraction. For the limiting case where no metal is present in the "63 - 90μm" fraction then the metal concentration obtained on the "less than 63 μm" of the present survey will be diluted on average to 100/116 = 0.86. It should not be possible to fall below the 0.86 x concentration of "less than 63μm".

However, many individual sample pairs display a greater dilution. In the case of mercury and copper and omitting the occasional freak high value from the comparison the mean concentration obtained from the "less than 90 μm" set is 0.75 and 0.78 respectively of that obtained on the "less than 63 μm" set. Inadequate sample mixing leading to unrepresentative sub-sampling in the first place taken together with minor differences in sieving, grinding, secondary sub-sampling and analysis are responsible for such anomalies. A relative concentration factor of unity means that concentrations derived for a 90 μm split will faithfully represent the concentration derived from a 63 μm split. A value greater than unity implies that the 63 - 90 μm fraction contains a disproportionate excess of that metal. The same argument applies to the relative organic content given by the two sample sets. Examination of the pairs of Table 1 but ignoring any pairs that include freak high values (i.e six mercury pairs, four copper pairs and one chromium pair) gives the following relative concentration factors. The outcome of tests for the null hypothesis to check the order of significance of differences between the means is also given below. the corresponding factors and associated levels of significance found on the previous survey are also shown in brackets.

	Relative concentration factor	
Mercury	0.75 (0.82)	significant (highly significant)
Copper	0.78 (0.88)	highly significant (significant)
Zinc	0.83 (0.94)	highly significant (probably significant)
Lead	0.80 (0.93)	highly significant (not significant)
Nickel	0.80 (0.94)	highly significant (not significant)
Chromium	1.09 (1.32)	not significant (probably significant)
Organic matter	0.89 (0.94)	highly significant (not significant)

Both surveys confirm the absence of mercury in the 63 - 90 μm fraction, which is in accord with earlier HR findings (Ref 2) that mercury is concentrated on the finer fractions with negligible amounts on the coarser particles. The other inference to be drawn from the relative values of mercury in the two sample sets is that wet sieving as practised by HR ie. sieving accompanied by hand brushing, provides adequate reduction of any sediment aggregates.

Our confidence that differences exist between the two sample sets arising from the 63 and 90 μm separations is confirmed by the latest survey results. It is seen that five of the parameters earn the ranking "highly significant" compared with only one on the 14th survey. Both surveys were based on approximately the same number of sample pairs so it is not known why the latest survey should display such a marked improvement in the statistical certainty of the difference.

The sign of the difference between the two sample sets has been established from the analysis: with the exception of chromium the concentration of all parameters is diminished by choosing a 90 μm size split compared with the traditional 63 μm division. It seems that most are only weakly represented in the 63 to 90 μm size fraction. However, the inclusion of the coarser fraction appears to enhance the chromium concentration. The findings for the other metals suggest that this chromium cannot be attached to fines that have escaped the sieving separation by being included in aggregates. Instead it must be present either on or within discrete particles of grain size 63 to 90 μm. It is a moot point whether chromium or any other metals found in sediments of this narrow size band are of anthropogenic origin.

It is not easy to proceed from the fact that differences exist between the two sample sets to an actual quantification of the factors that should be applied to standardise surveys employing different sieve sizes for the separation of the finer fraction. We have already seen that for the latest survey the proportional differences in the means exceeds that which is strictly feasible on five of the seven parameters (relative concentration factors 0.75 to 0.83 cf 0.86). The means of the two surveys, subject to the 0.86 limit, probably represent the best estimate of the factors that should be adopted to convert concentrations ascribed to the HR series of surveys, all based on a 63 μm size split, when comparisons are required with current NWWA surveys utilising the 90 μm split. The appropriate conversion factors are:

Mercury, copper	:	0.86
Zinc, lead, nickel	:	0.88
Chromium	:	1.20
Organic matter	:	0.91

8 CONCLUSIONS

Although the sampling network differed little from that used over the last five years, the average mud content is slightly lower than in the fourteenth survey and considerably lower than in the previous four years. Field observations noted that some sites showed a layer of sand on top of a muddier bed.

The lower mud concentrations give rise to higher values for organics and heavy metals which are noticeable in most cases in Figs. 3 - 9. The total organics and metals show little change from previous years.

Indicates the transfer of metals

The presence of the peak concentrations of mercury and to a lesser extent the other metals within the bed surface, either by dissolution in the anoxic subsurface layer and readsorption or by winnowing of the finer fraction (with the larger surface area for adsorption) into sheltered pockets on the bed surface. Either process could concentrate metals locally. The main conclusion from this is that the bed is essentially static, particulate metal containing sediments are not significantly mixed or dispersed and the metal concentrations are unlikely to fall to any extent in the future.

The second year's investigation of the apparent changes in metal and organic concentrations likely to ensue from changing the upper separation of the fines fraction from 63 μm to 90 μm qualitatively confirm the results of the first year (Ref. 1). The present results however lend a greater statistical certainty to the existence of real differences between the two sample sets. Not surprisingly the addition of the 63 to 90 μm fraction dilutes the concentration of five of the six metals and also of the organic matter. Chromium is the only exception. The 63 to 90 μm fraction is disproportionately rich in chromium but it is unlikely that this additional chromium in the coarser grains is derived from the disposal of sludge.

It is inferred from the combined results of the two surveys that the 63 to 90μ m fraction contains little, or no mercury and copper and is also low in zinc, lead and nickel. It is seen therefore that the risk of inclusion of metal-rich fine particles within unbroken aggregages of 63 to 90 μm is not a serious possibility, at least for the typical size separation procedures practised by HR. This finding does not necessarily apply if much gentler size separation techniques are used.

The two-year size comparison study has yielded estimates of the concentration factors (see section 7) that should be adopted to reconcile the results of current and future monitoring by NWWA with past HR bed surveys.

9 ACKNOWLEDGEMENTS

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Table

TABLE 1 SIZE RANGE COMPARISONS

	MUD		ORG		Hg		Cu		Zn		Pb		Ni		Cr	
	<63	<90	<63	<90	<63	<90	<63	<90	<63	<90	<63	<90	<63	<90	<63	<90
G7	2.44	3.29	6.34	5.78	1.48	1.07	170	92	368	317	129	97	72	54	53	60
9	1.96	1.79	5.04	4.71	0.88	1.05	58	43	316	236	117	80	46	35	64	45
11	2.52	2.93	4.70	4.57	0.93	0.80	48	41	261	237	73	62	40	35	36	47
13	3.68	4.15	5.09	3.62	3.78	0.77	40	35	240	232	75	68	37	32	31	42
K9	0.34	0.27	6.86	7.02	2.08	2.14	128	142	374	358	125	137	40	44	39	40
10	6.90	6.90	6.49	6.20	1.37	1.71	78	80	329	349	126	120	44	45	48	55
11	7.23	7.97	5.22	5.17	1.15	1.04	57	47	336	274	112	91	46	36	57	45
L7	0.09	0.16	-	-	131.8	438.8	148	124	402	298	133	89	41	33	45	50
9	0.09	0.13	-	-	i.s.	3.50	229	178	897	709	525	402	49	33	55	70
10	0.22	0.29	8.15	7.23	4.41	4.86	206	196	445	399	197	162	80	80	64	57
11	7.02	8.68	6.80	4.59	3.03	4.13	66	59	313	284	108	101	39	37	64	50
12	13.44	16.60	5.16	4.39	1.24	1.16	44	46	276	266	93	93	39	38	47	44
13	7.58	8.00	5.68	5.51	1.27	1.20	68	64	295	231	97	80	40	41	43	48
M8	0.22	0.34	7.44	10.89	1.98	1.64	229	184	428	291	163	120	87	73	41	54
9	0.08	0.14	-	6.43	22.0	3.50	265	128	636	451	777	513	85	50	45	48
10	5.92	6.49	7.52	5.98	3.26	2.21	136	100	469	398	220	185	58	41	72	69
11	9.66	9.90	6.14	5.51	3.12	1.57	80	75	398	361	149	144	46	62	66	49
12	7.51	4.62	5.66	4.14	2.93	1.51	58	51	332	286	105	94	46	49	33	49
N8	0.19	0.35	4.78	4.65	1.46	1.08	202	88	334	232	110	93	72	44	37	22
9	0.17	0.17	7.13	3.67	4.99	2.14	188	166	443	463	233	235	73	61	39	50
10	0.27	0.30	7.17	6.47	1.72	1.73	170	132	403	392	179	236	59	56	41	44
11	0.47	0.46	8.10	7.75	1.77	2.03	135	108	464	383	249	233	52	45	41	41
12	1.39	1.48	6.64	5.23	4.78	2.19	142	154	364	357	138	134	64	65	56	56
P8	0.07	0.10	-	-	5.54	1.77	202	286	383	317	228	214	63	88	46	47
9	0.10	0.14	-	9.82	2.78	2.58	297	182	749	424	366	211	78	55	57	46
10	0.23	0.24	7.42	7.46	7.37	5.86	144	142	370	356	136	136	76	68	62	58
11A	47.70	51.12	6.74	7.02	2.89	3.08	130	114	692	675	199	199	56	51	45	45
11B	0.92	0.86	5.69	4.45	2.19	3.75	91	76	404	404	177	154	50	46	37	42
12	3.05	2.89	6.59	5.69	4.89	3.09	166	84	377	247	101	79	35	31	60	60

TABLE 1 (con'd) SIZE RANGE COMPARISONS

	MUD		ORG		Hg		Cu		Zn		Pb		Ni		Cr	
	<63	<90	<63	<90	<63	<90	<63	<90	<63	<90	<63	<90	<63	<90	< 63	< 90
Q7	0.06	0.10	-	-	1.52	0.89	208	84	265	202	111	76	41	32	43	42
8	0.22	0.34	5.43	5.43	12.60	5.55	276	185	738	438	395	197	87	68	76	75
9	0.10	0.12	9.75	6.13	1.88	2.04	93	99	288	286	101	95	63	50	37	34
10	1.40	1.69	5.85	4.48	2.54	2.48	87	83	546	492	186	163	46	42	67	35
11	20.67	27.97	5.17	5.58	2.10	1.82	71	66	411	382	157	146	45	45	35	62
12	6.59	7.21	6.10	5.13	3.56	2.51	88	66	440	362	236	186	52	40	94	160
13	0.81	1.77	7.85	5.02	2.80	0.81	187	111	376	283	194	131	55	37	34	49
R8	0.10	0.15	-	3.91	1.83	1.19	116	74	473	377	258	194	46	39	56	78
9	0.21	0.31	5.20	4.46	0.72	0.42	35	23	202	126	63	39	35	23	52	51
10	20.35	32.19	3.11	3.81	2.54	1.99	73	71	436	428	163	149	45	41	57	51
11	12.94	12.29	4.91	4.97	7.42	2.00	104	96	414	322	252	183	35	32	67	124
12	0.33	0.44	4.73	4.16	4.24	3.50	117	124	357	310	147	134	41	46	46	79
13	0.37	0.27	5.93	6.86	2.24	1.73	124	100	406	369	183	174	54	50	46	81
14	0.47	0.48	6.72	4.18	1.15	0.69	99	78	260	227	141	122	37	31	50	52
S8	0.21	0.23	4.17	3.42	3.17	2.72	80	69	613	483	220	210	55	46	48	68
9	7.61	3.02	6.52	8.88	1.24	0.66	130	76	228	139	105	60	47	29	86	83
10	0.24	0.34	3.32	4.49	3.27	2.56	109	102	585	522	197	174	54	48	57	49
11	3.89	1.66	5.70	5.90	2.67	2.57	84	76	470	450	173	166	46	42	58	50
12	16.15	19.79	7.28	5.98	2.34	1.97	79	70	422	354	171	143	44	47	59	65
13A	9.64	11.16	6.05	5.75	1.88	2.26	65	63	370	384	129	131	41	40	39	61
13B	0.39	1.03	-	2.26	0.74	0.98	49	68	282	315	87	95	39	46	72	52
14	17.06	20.56	6.29	5.23	2.62	2.34	66	70	487	430	162	142	39	40	71	64
T8	23.20	24.72	4.66	5.61	8.86	0.74	157	80	215	133	59	37	40	25	30	24
9	16.92	16.51	7.55	6.20	2.44	2.15	191	115	312	198	132	76	47	29	38	37
10	0.06	0.12	-	-	2.02	1.17	70	49	426	326	146	103	45	29	82	85
11	0.09	0.15	-	2.07	2.38	1.12	93	53	296	199	129	75	34	23	115	123
12	22.21	29.27	4.51	3.61	1.36	0.52	143	72	316	192	105	60	46	27	116	110
13	0.11	0.41	4.45	3.60	2.94	8.92	547	265	483	318	189	122	135	79	106	189
14	0.12	0.43	-	1.76	2.68	2.11	78	70	557	519	177	160	39	40	65	74
15	0.03	0.06	-	-	4.71	0.67	407	192	320	187	105	56	102	57	60	34

TABLE 1 (con'd) SIZE RANGE COMPARISONS

	MUD		ORG		Hg		Cu		Zn		Pb		Ni		Cr	
	<63	<90	<63	<90	<63	<90	<63	<90	<63	<90	<63	<90	<63	<90	<63	<90
U9	16.87	17.95	6.43	5.56	1.15	0.66	95	34	261	150	82	43	39	18	157	67
11	0.05	0.14	-	-	1.31	0.25	277	74	294	125	85	37	81	27	151	108
12	0.53	0.84	3.68	1.93	i.s.	5.39	493	77	369	163	155	97	145	35	451	1067
13	0.13	0.41	-	0.69	1.31	0.58	547	218	374	223	91	75	132	71	291	481
14	0.03	0.08	-	-	2.71	2.15	87	75	513	417	175	155	47	39	89	135
15	0.11	0.25	-	-	1.41	6.53	76	51	309	226	120	84	34	28	88	59
YY1	15.68	17.47	7.25	6.38	1.77	1.62	44	41	273	260	83	79	29	24	37	36
2	0.49	0.79	4.69	3.31	2.00	1.58	60	64	368	401	113	120	33	35	49	67
3	47.36	59.93	4.95	3.24	2.19	49.90	89	196	209	362	98	181	21	30	190	173
4	42.86	55.37	4.21	3.43	7.21	2.93	72	111	247	450	152	206	34	44	67	74

i.s. - insufficient sample

Figures

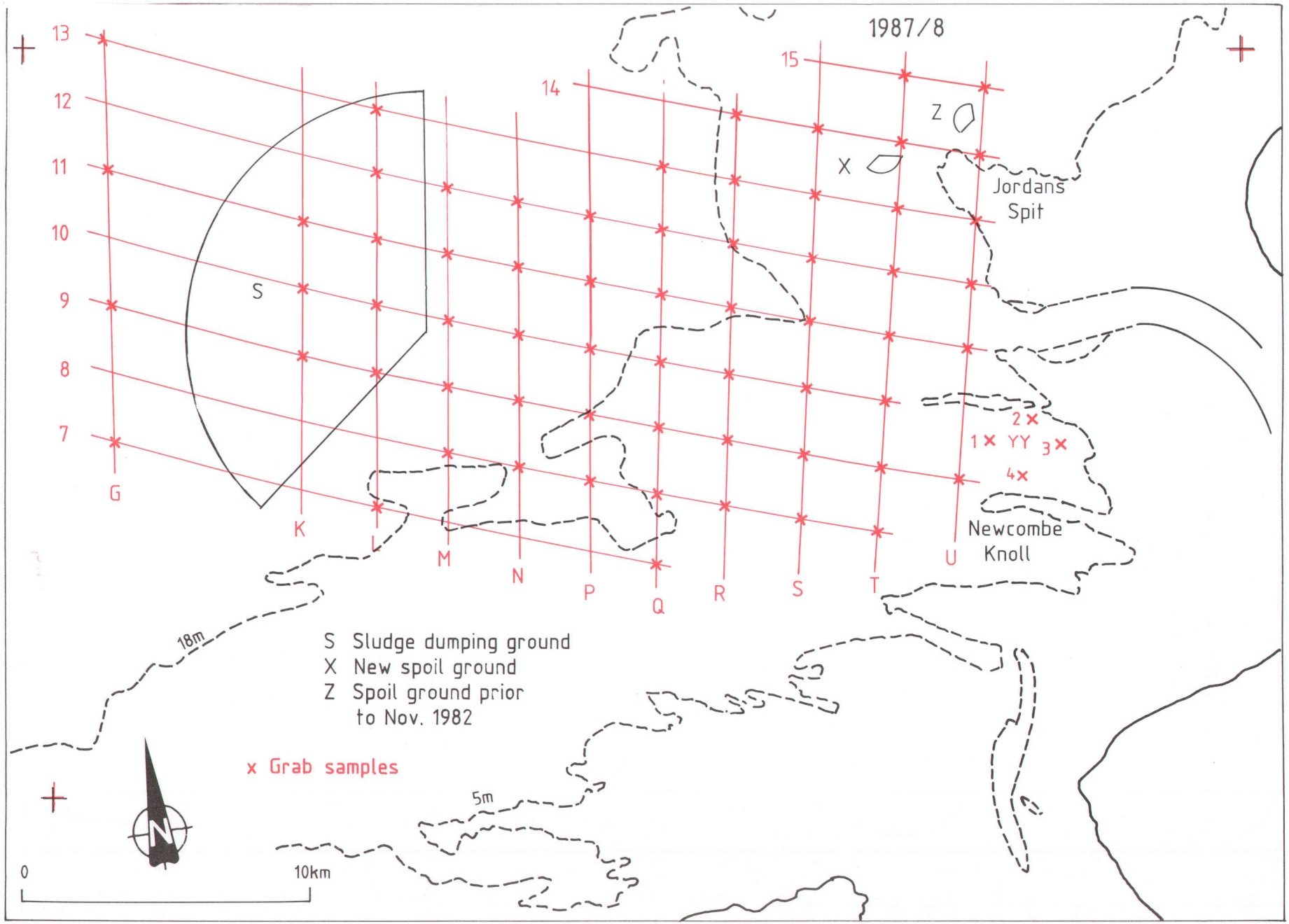


Fig 1 Monitoring positions

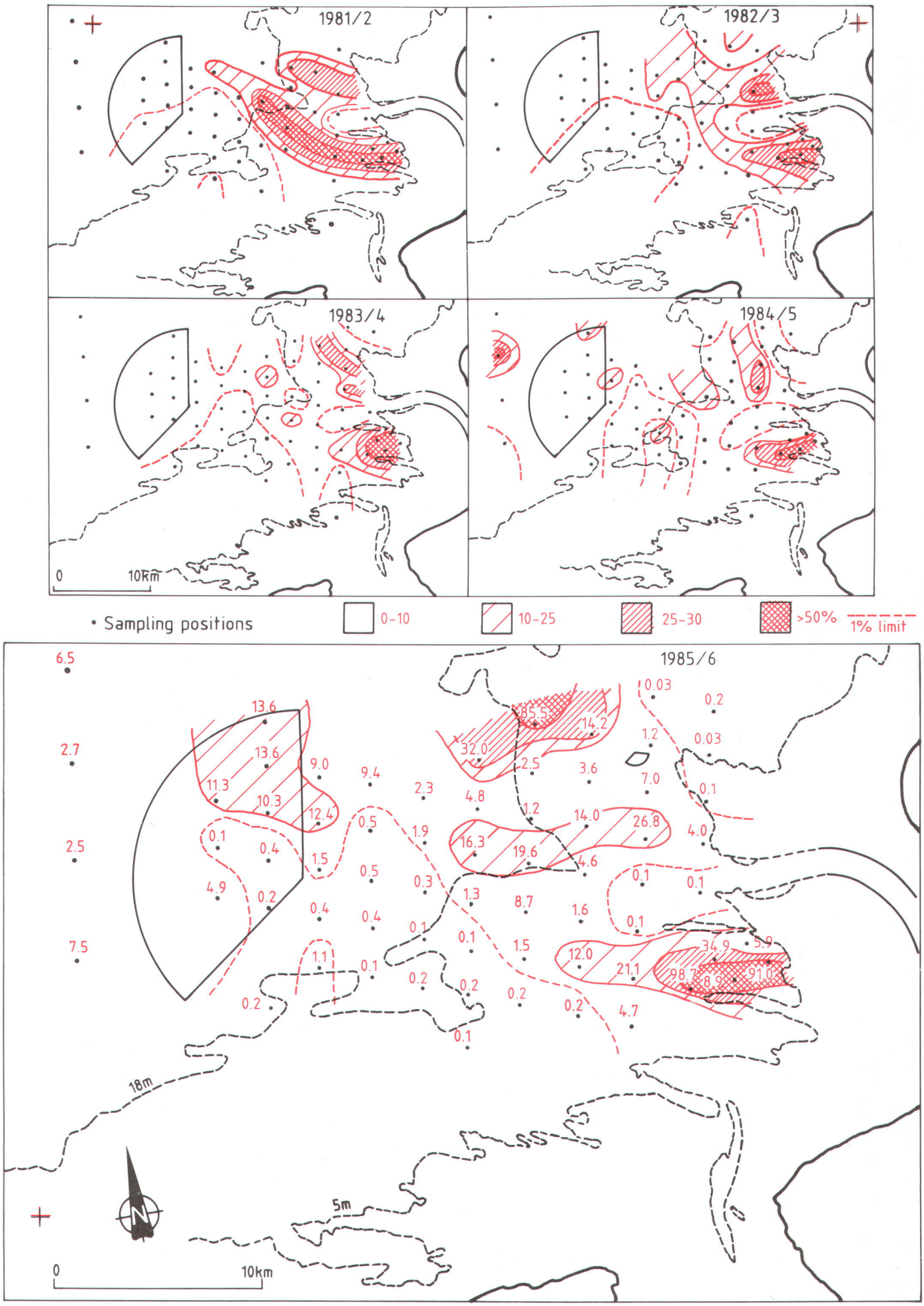


Fig 2 Mud content of the top 25mm of bed

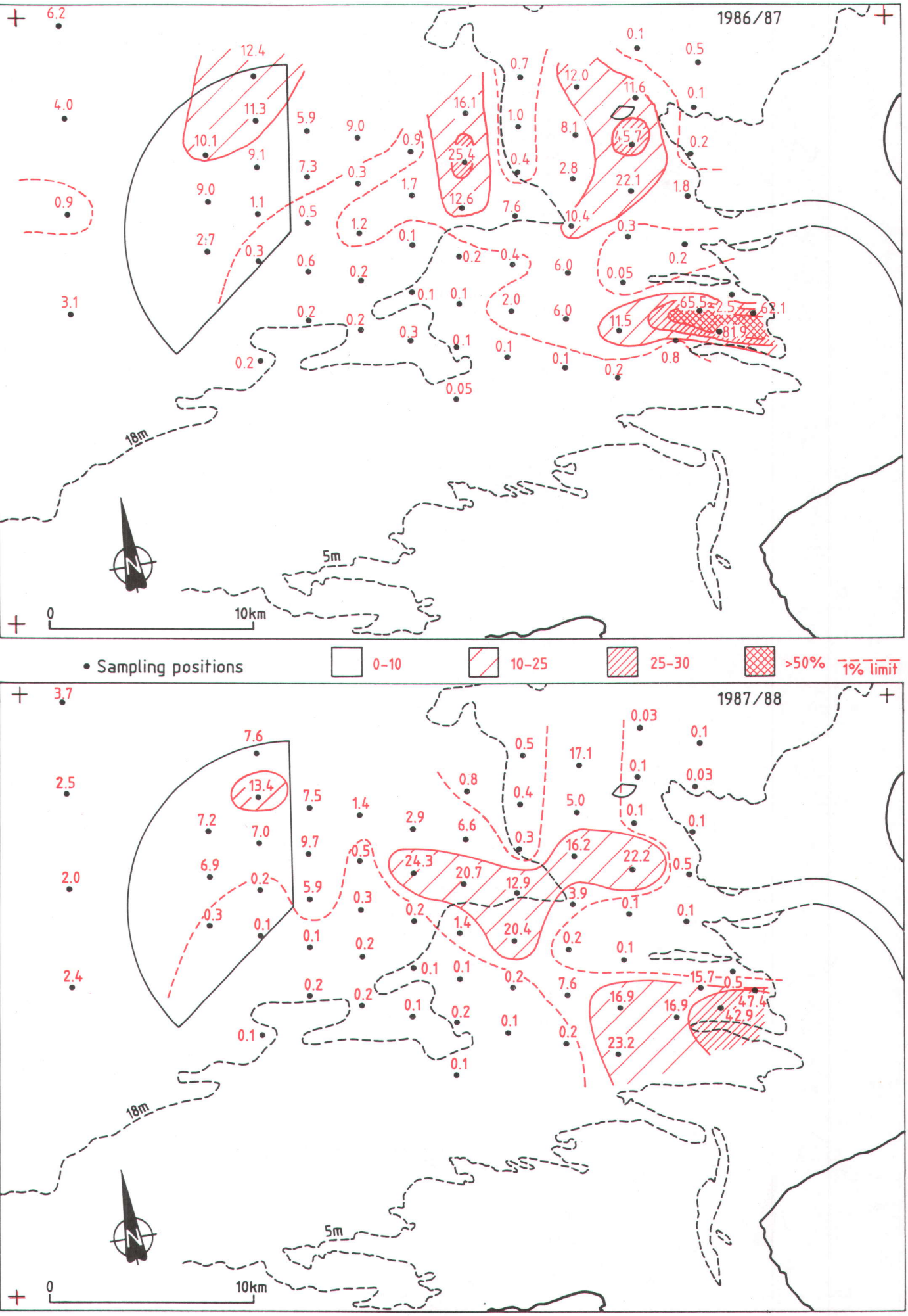


Fig 2 Mud content of the top 25mm of bed

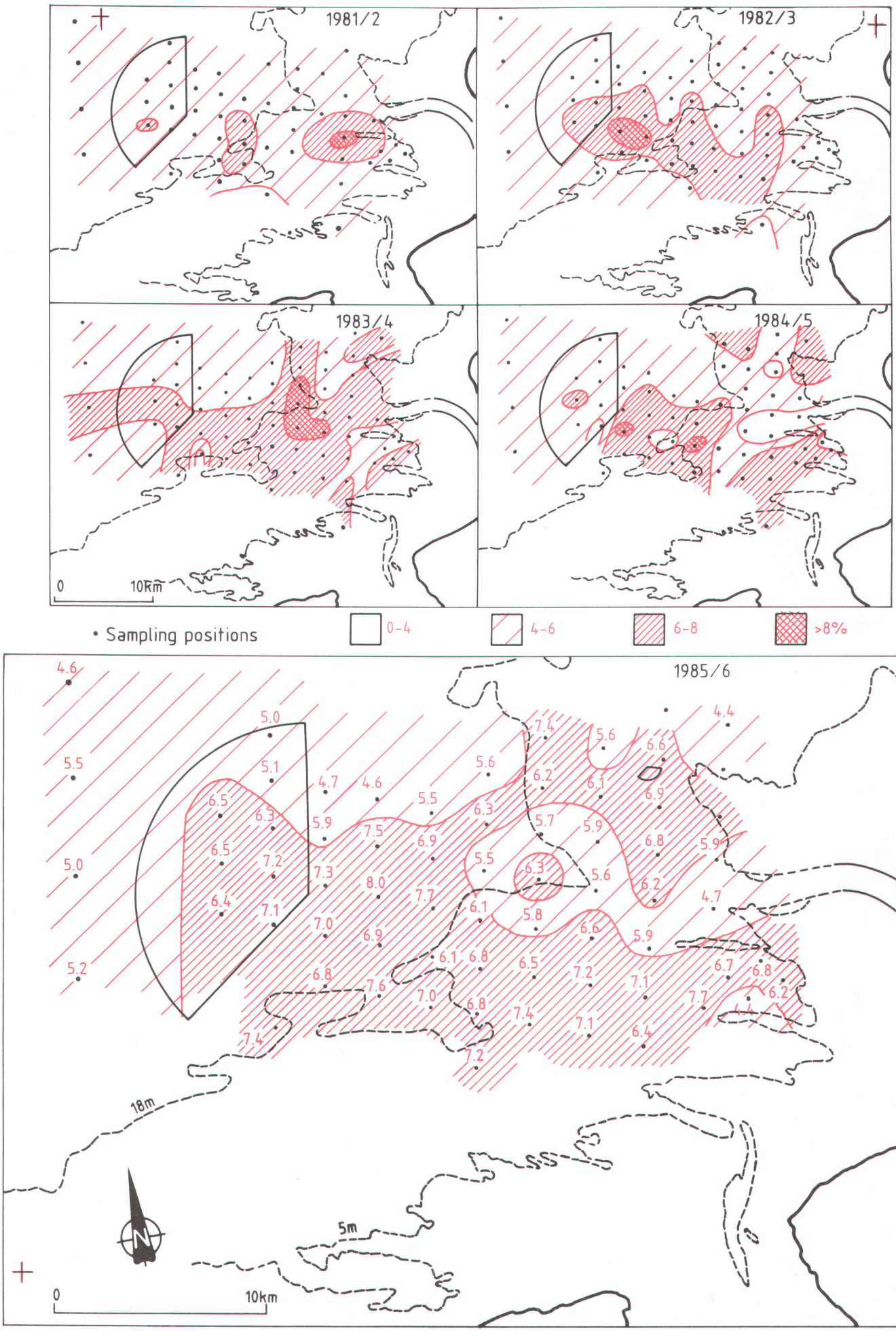


Fig 3 Organic content in mud from the top 25mm of bed

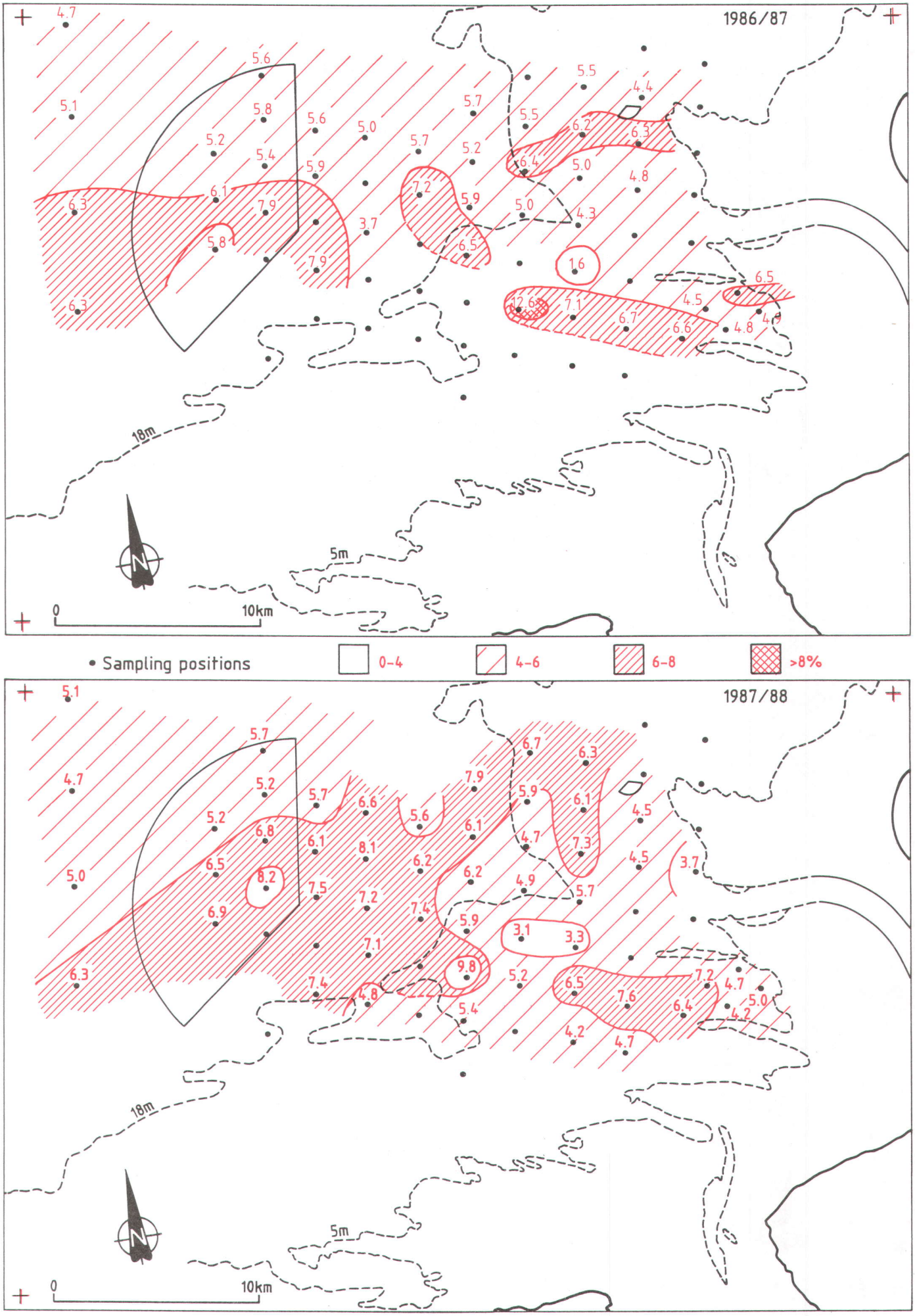


Fig 3 Organic content in mud from the top 25mm of bed

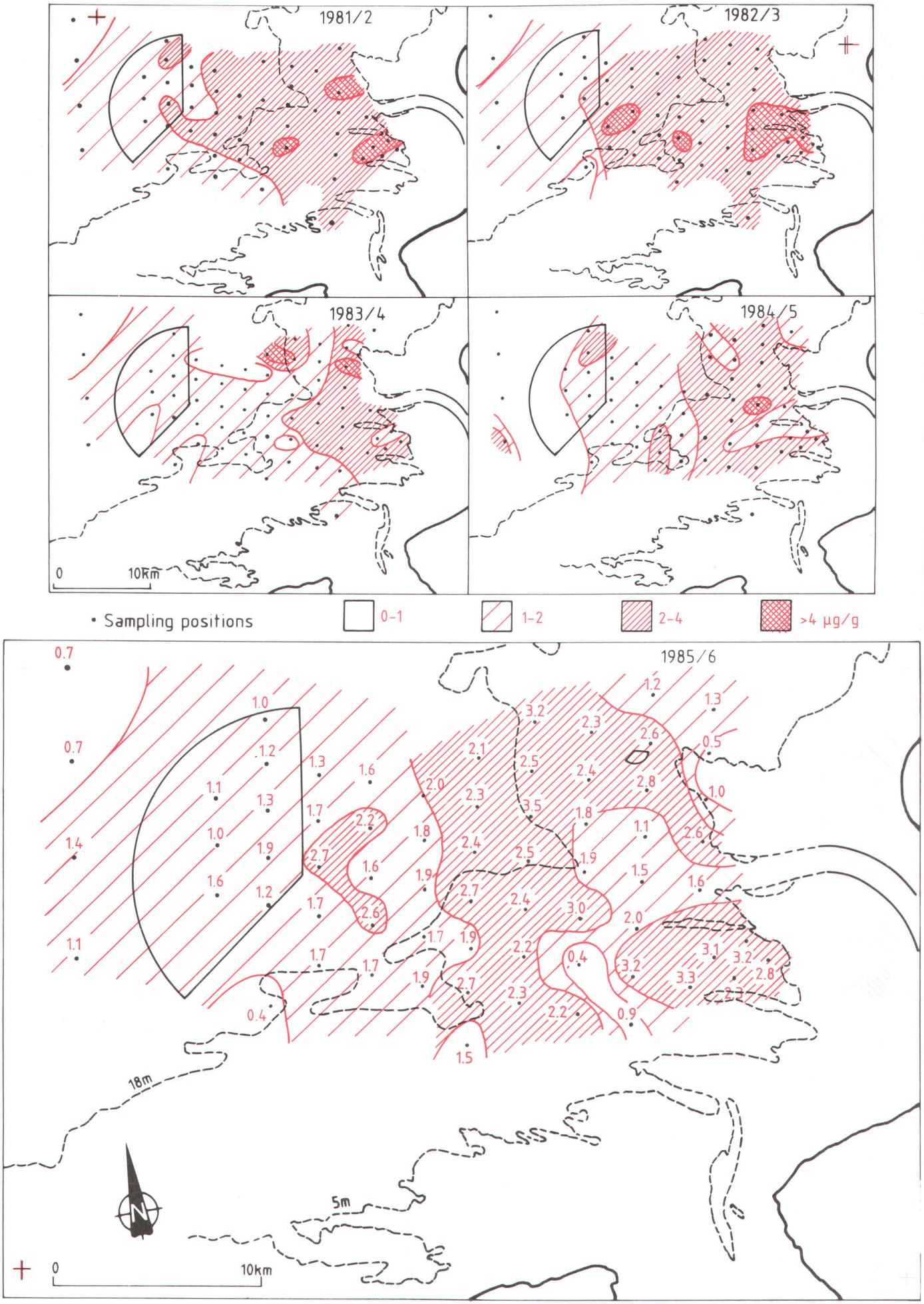


Fig 4 Mercury concentration in mud from the top 25mm of bed

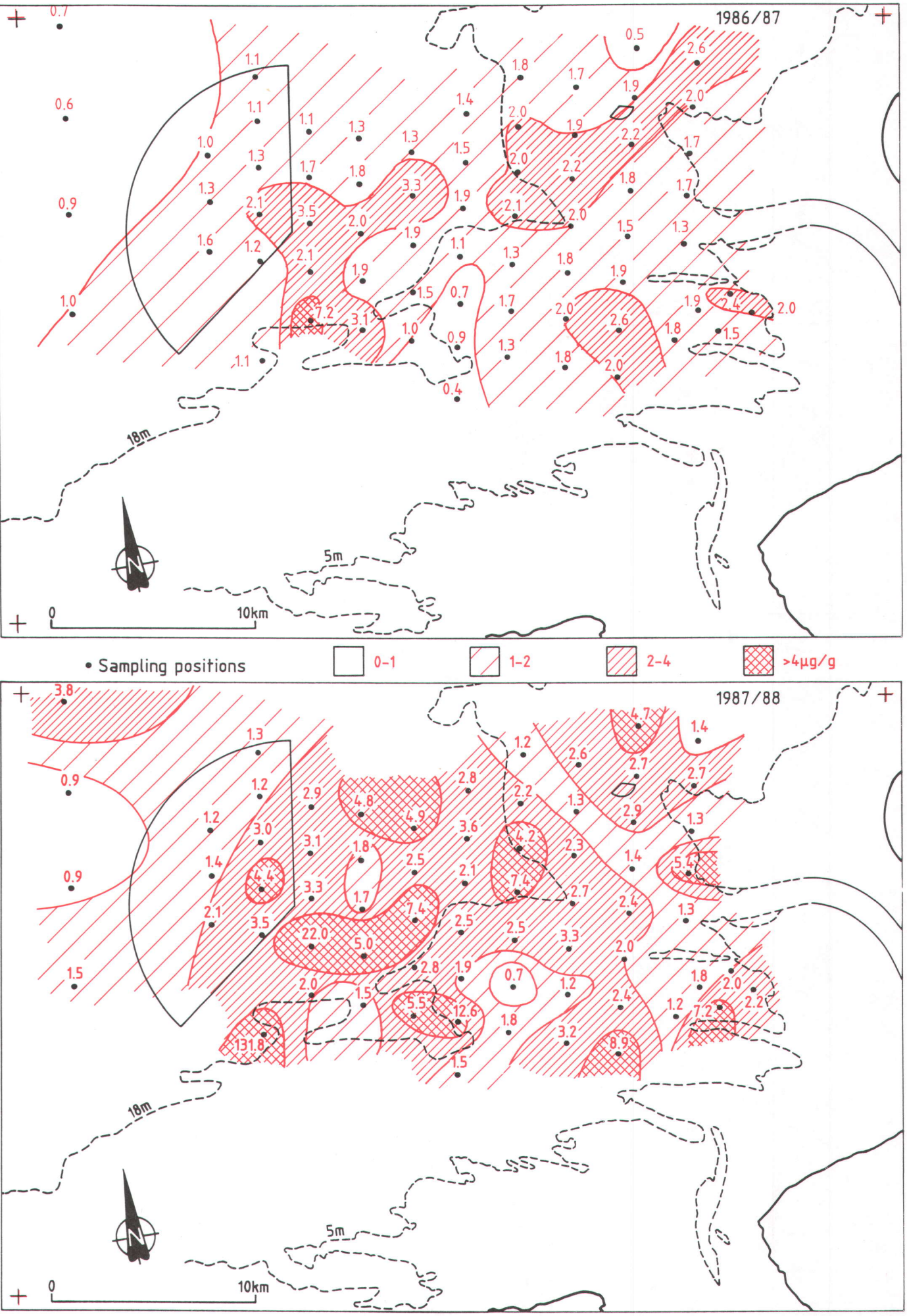


Fig 4 Mercury concentration in mud from the top 25mm of bed

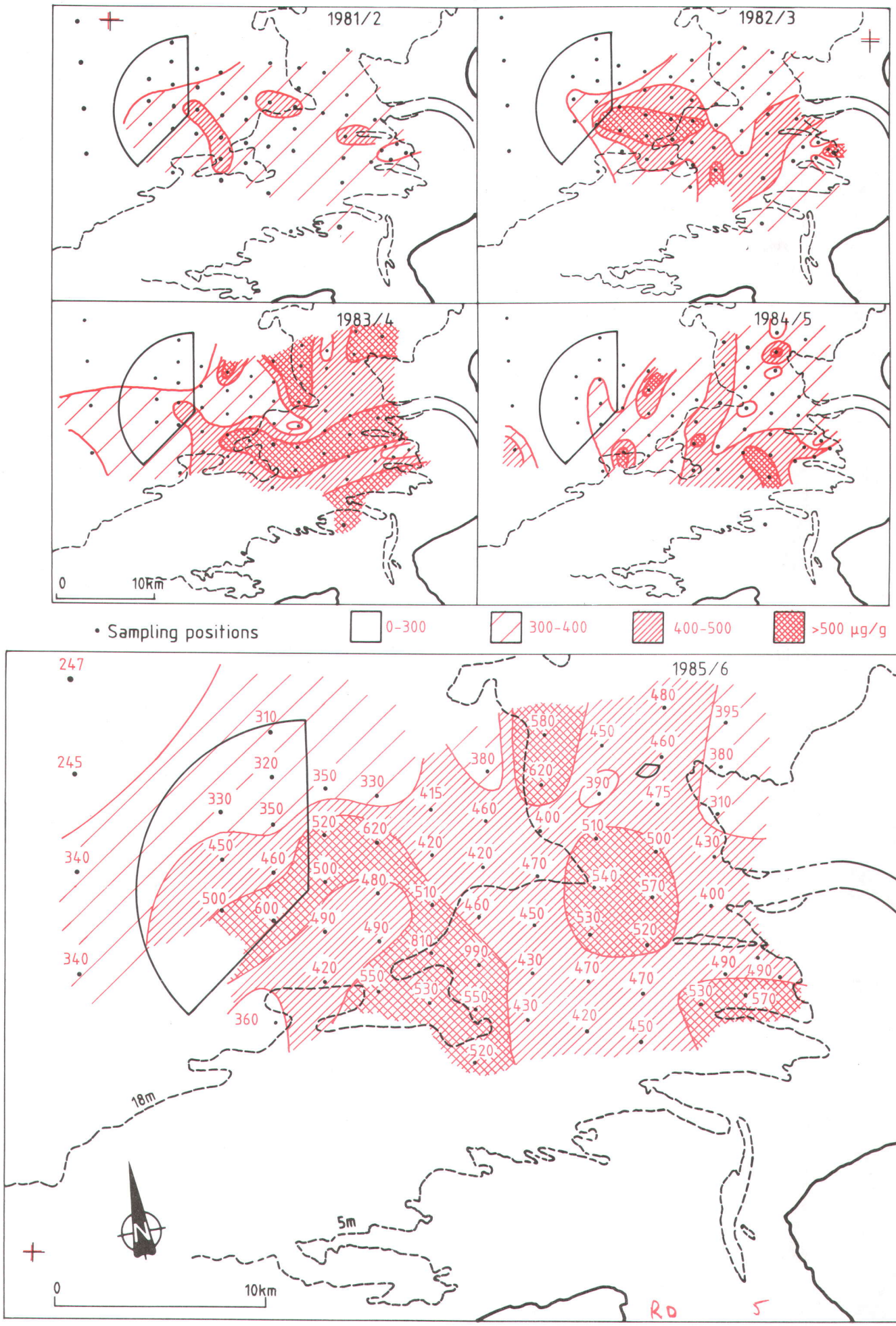


Fig 5 Zinc concentration in mud from the top 25mm of bed

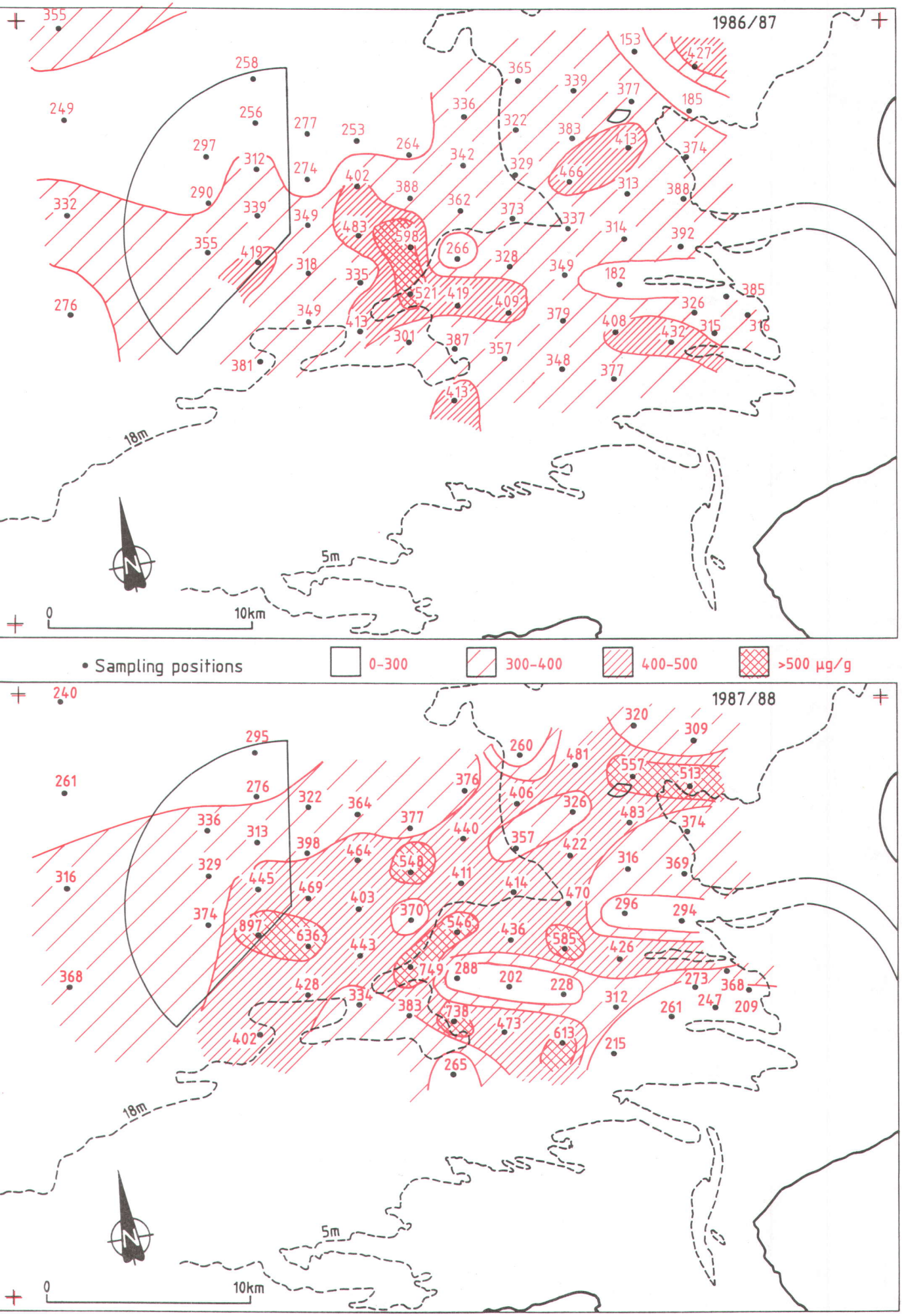
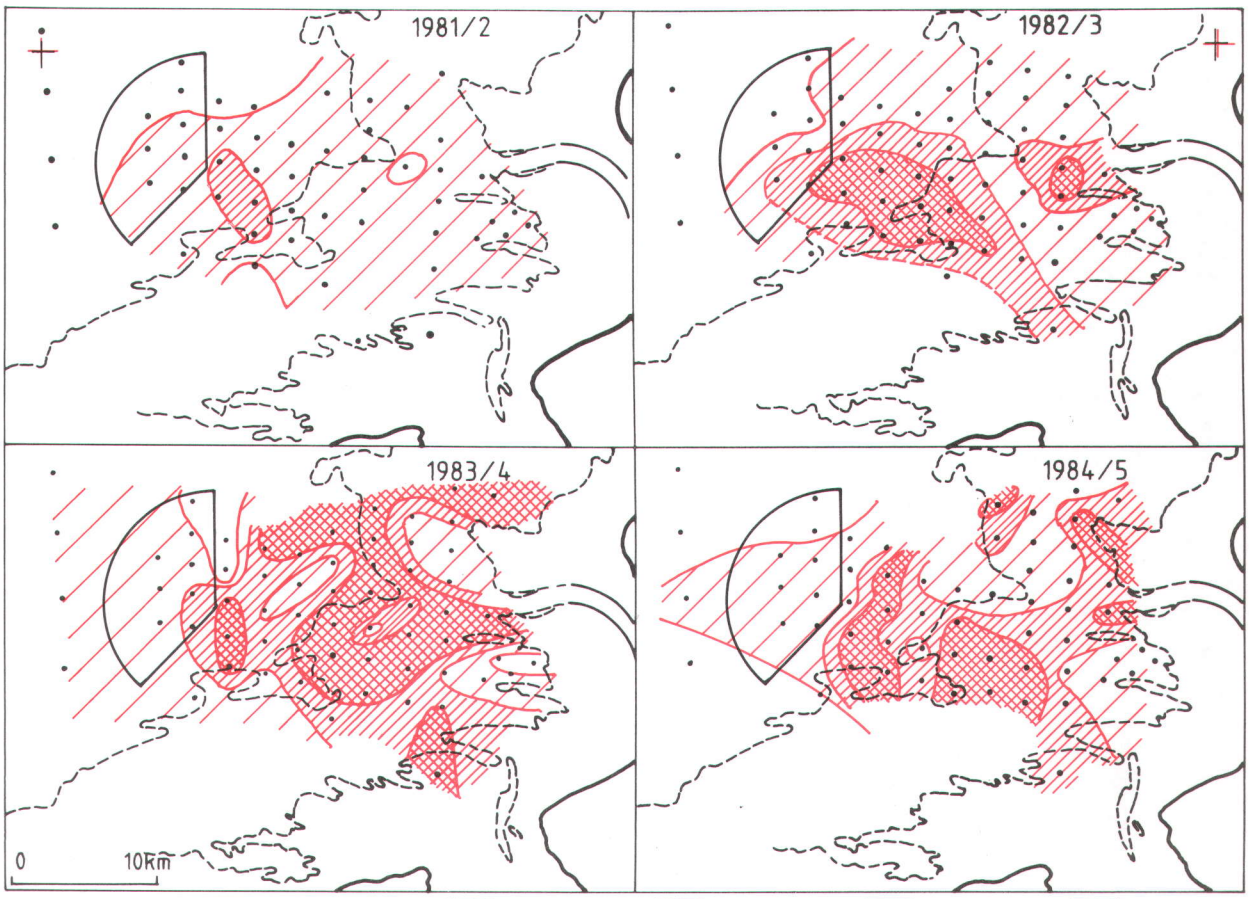


Fig 5 Zinc concentration in mud from the top 25mm of bed



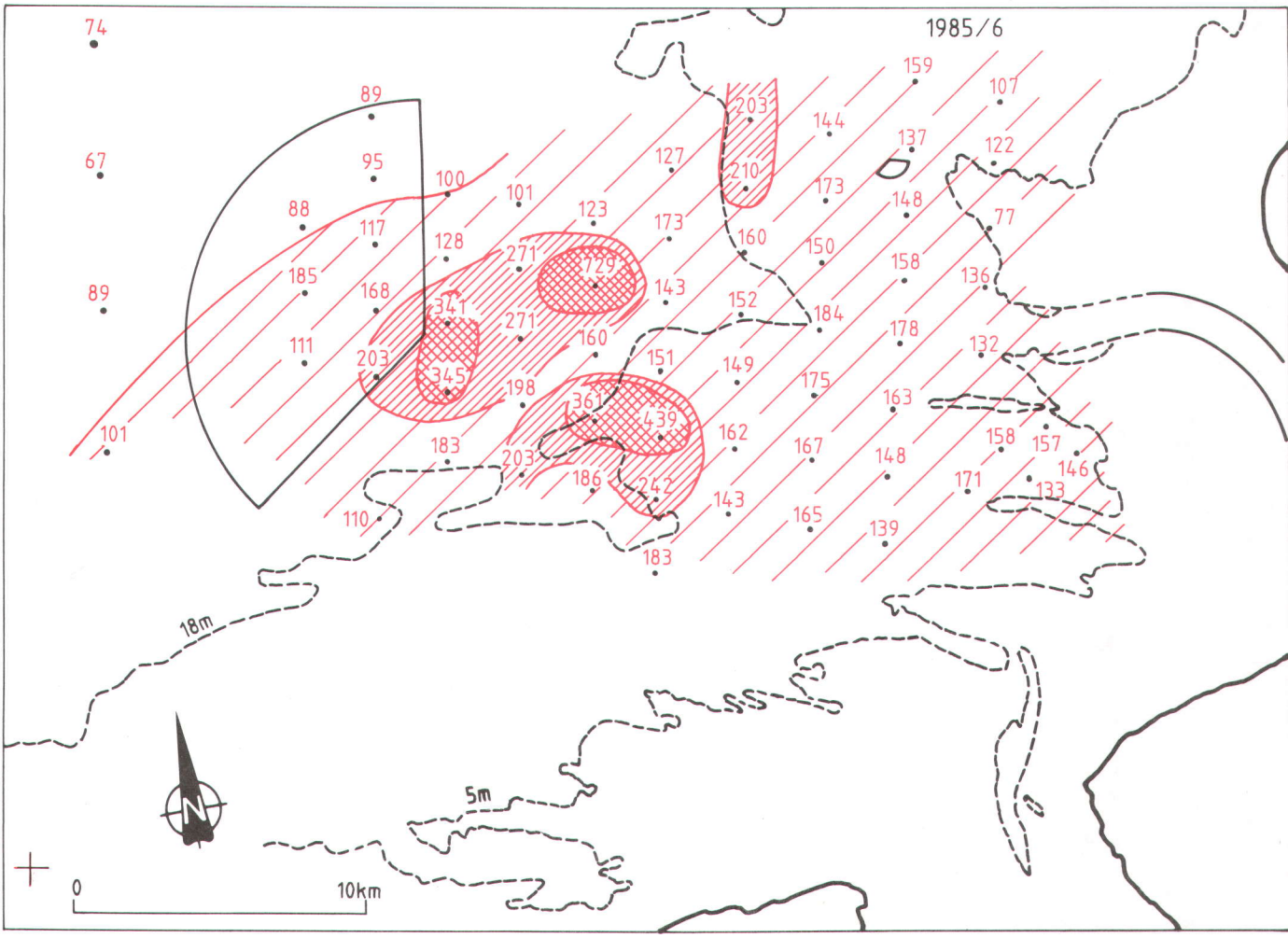


Fig 6 Lead concentration in mud from the top 25mm of bed

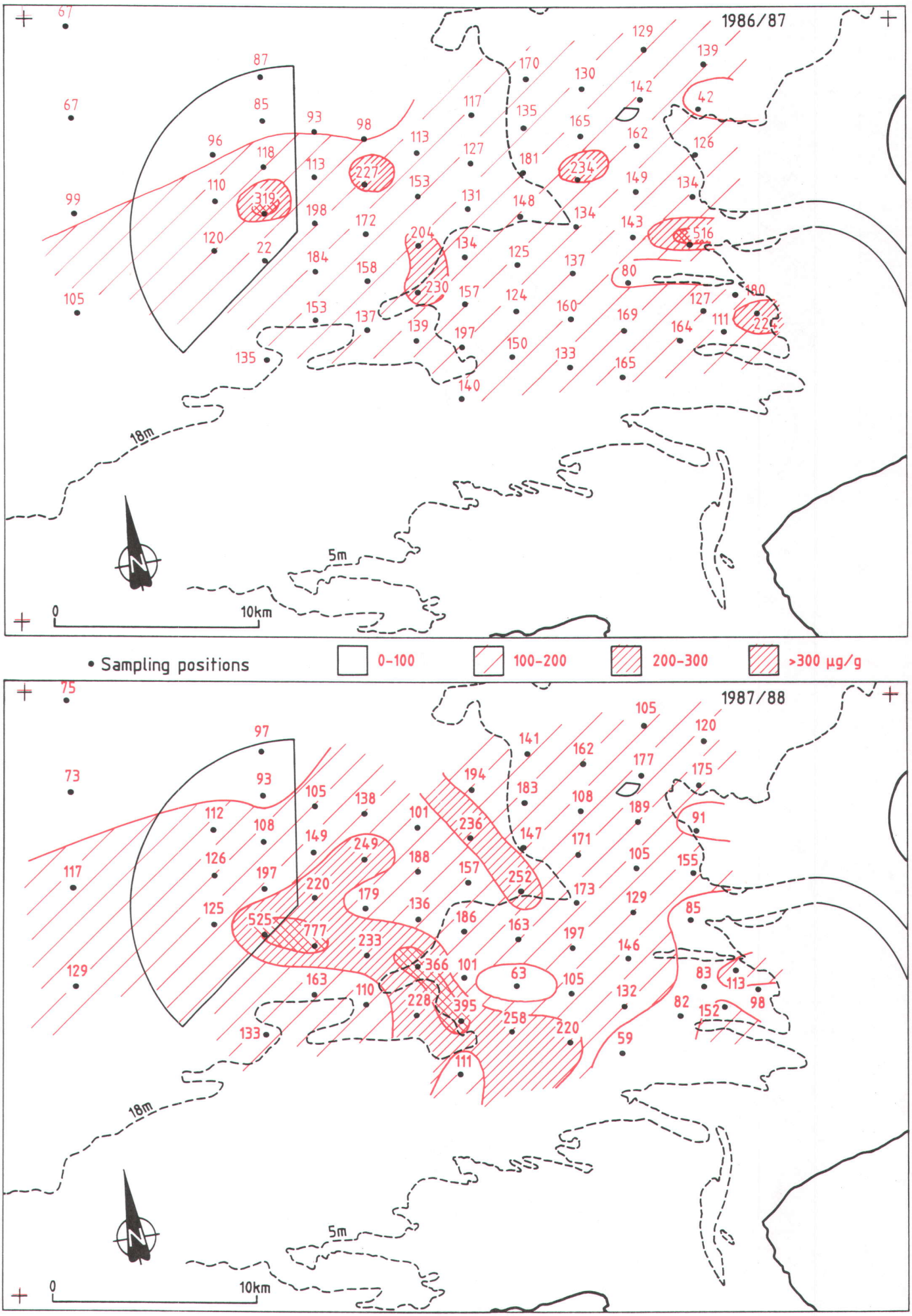


Fig 6 Lead concentration in mud from the top 25mm of bed

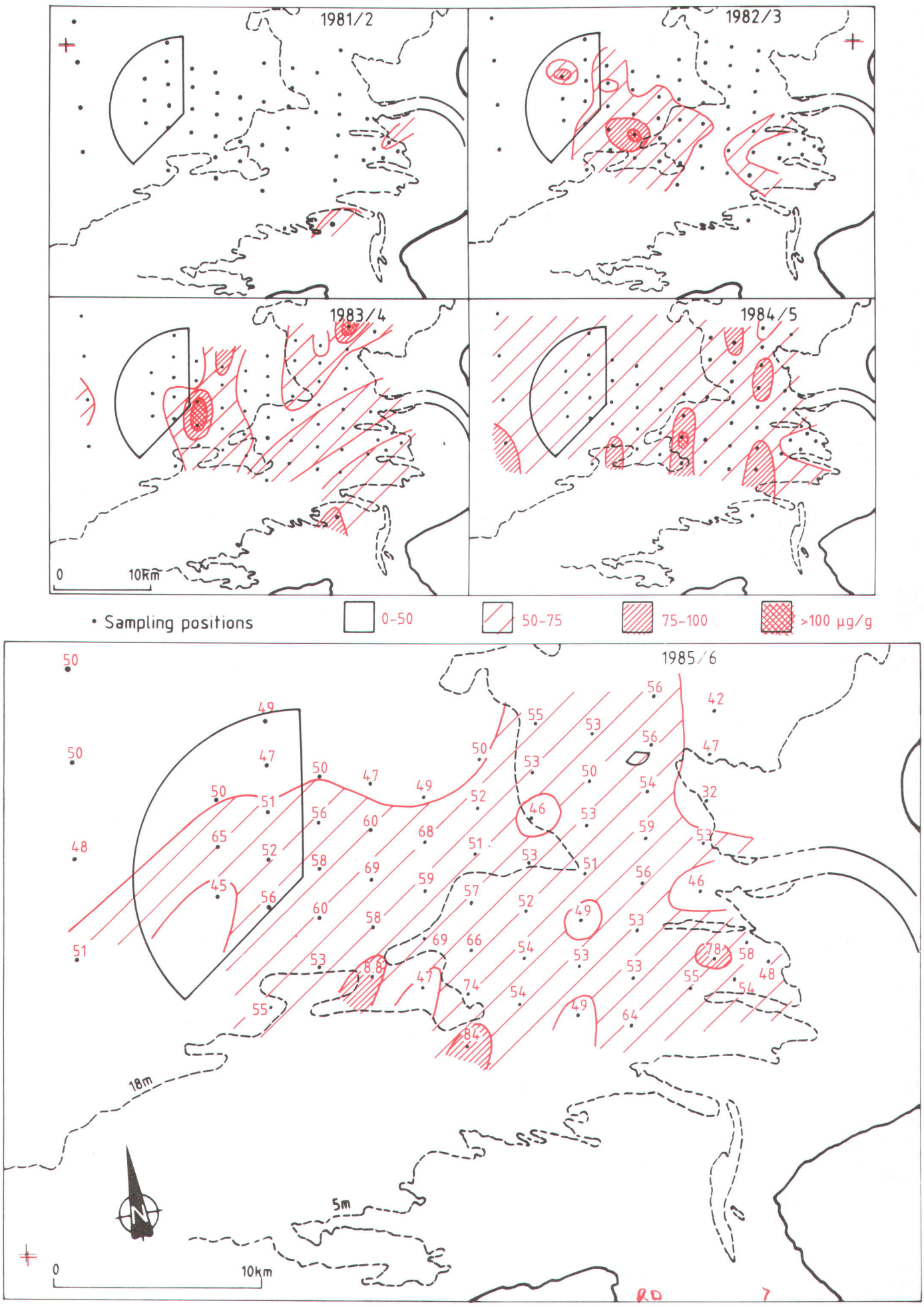


Fig 7 Nickel concentration in mud from the top 25mm of bed

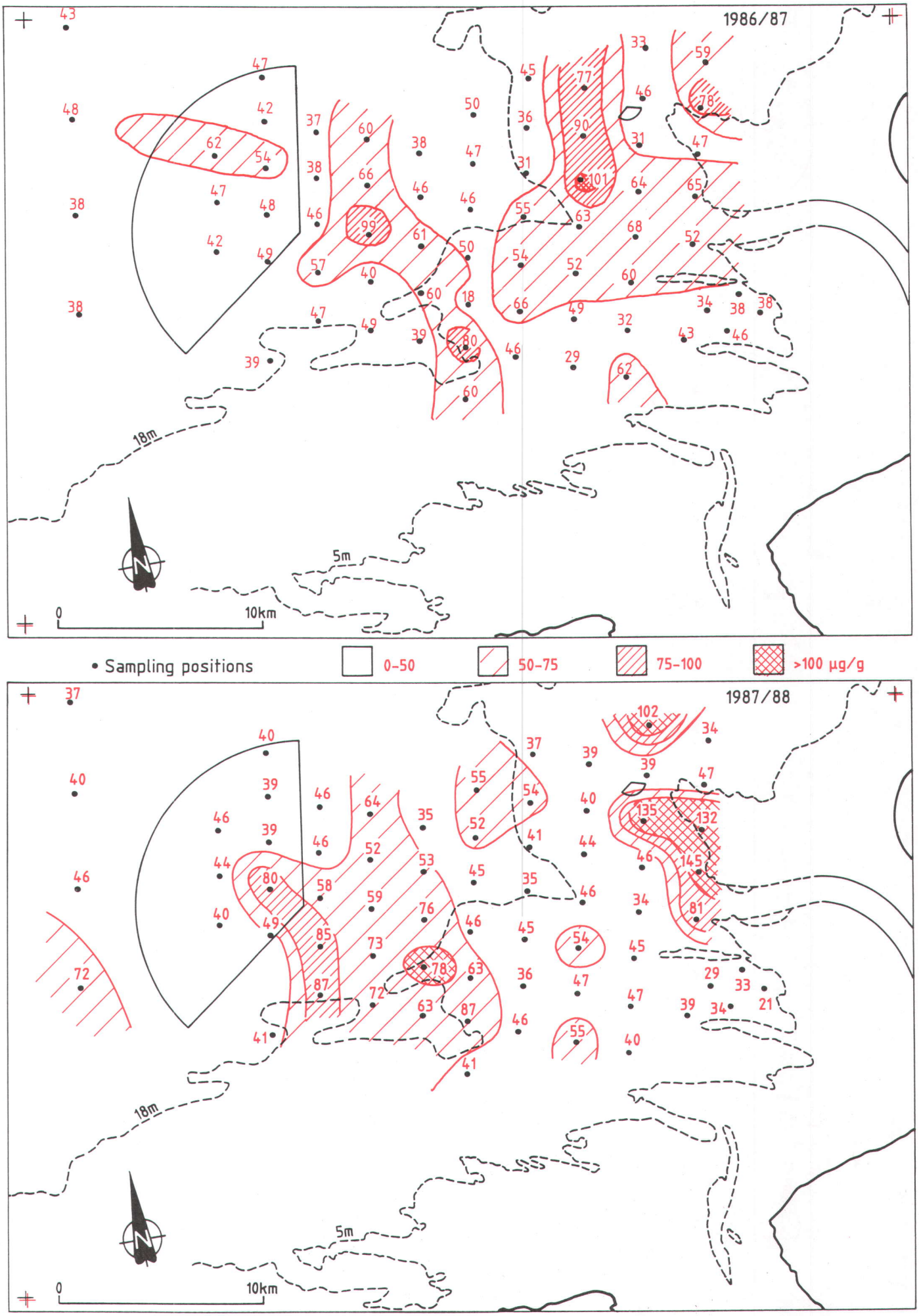


Fig 7 Nickel concentration in mud from the top 25mm of bed

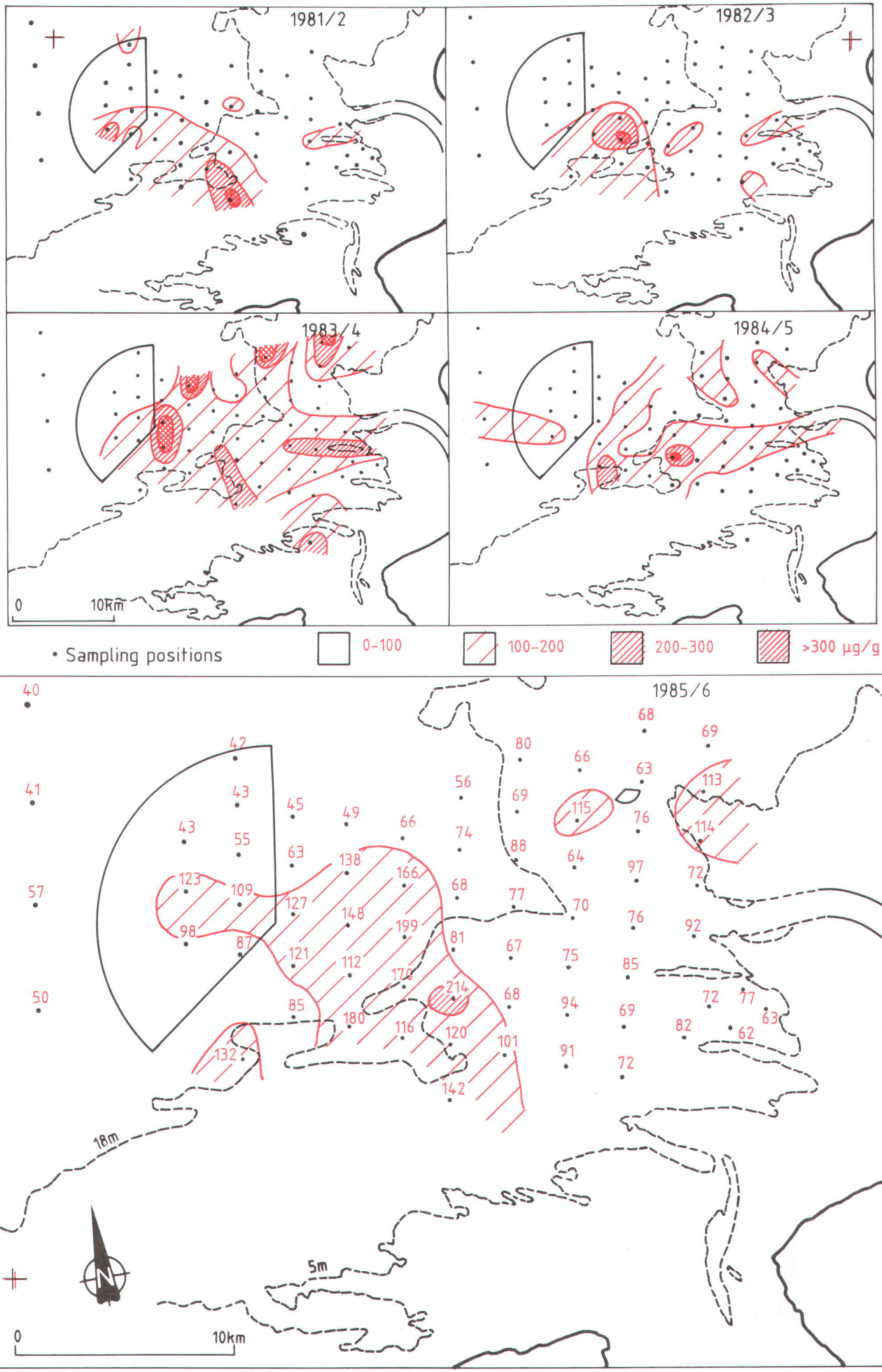


Fig 8 Copper concentration in mud from the top 25mm of bed

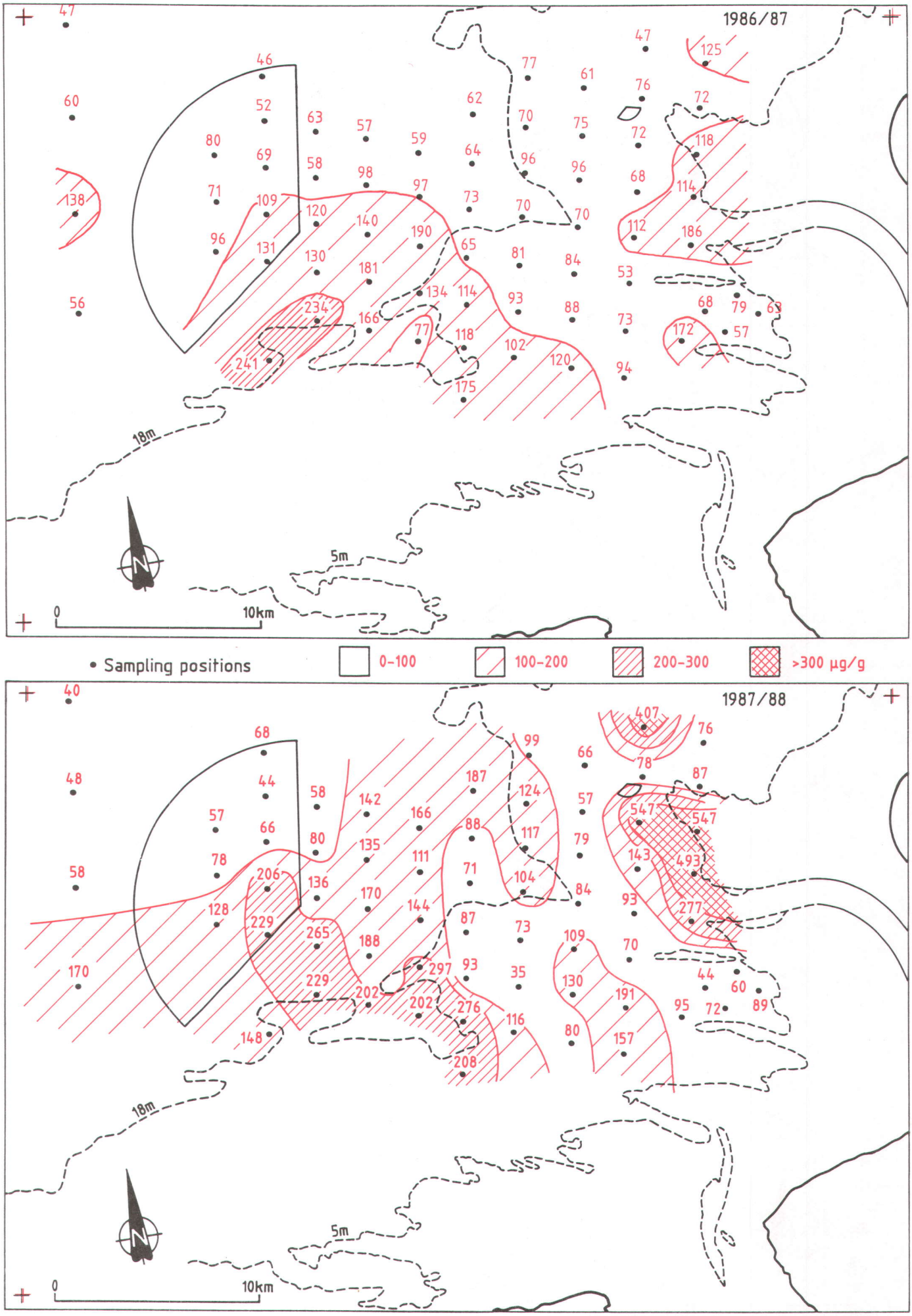


Fig 8 Copper concentration in mud from the top 25mm of bed

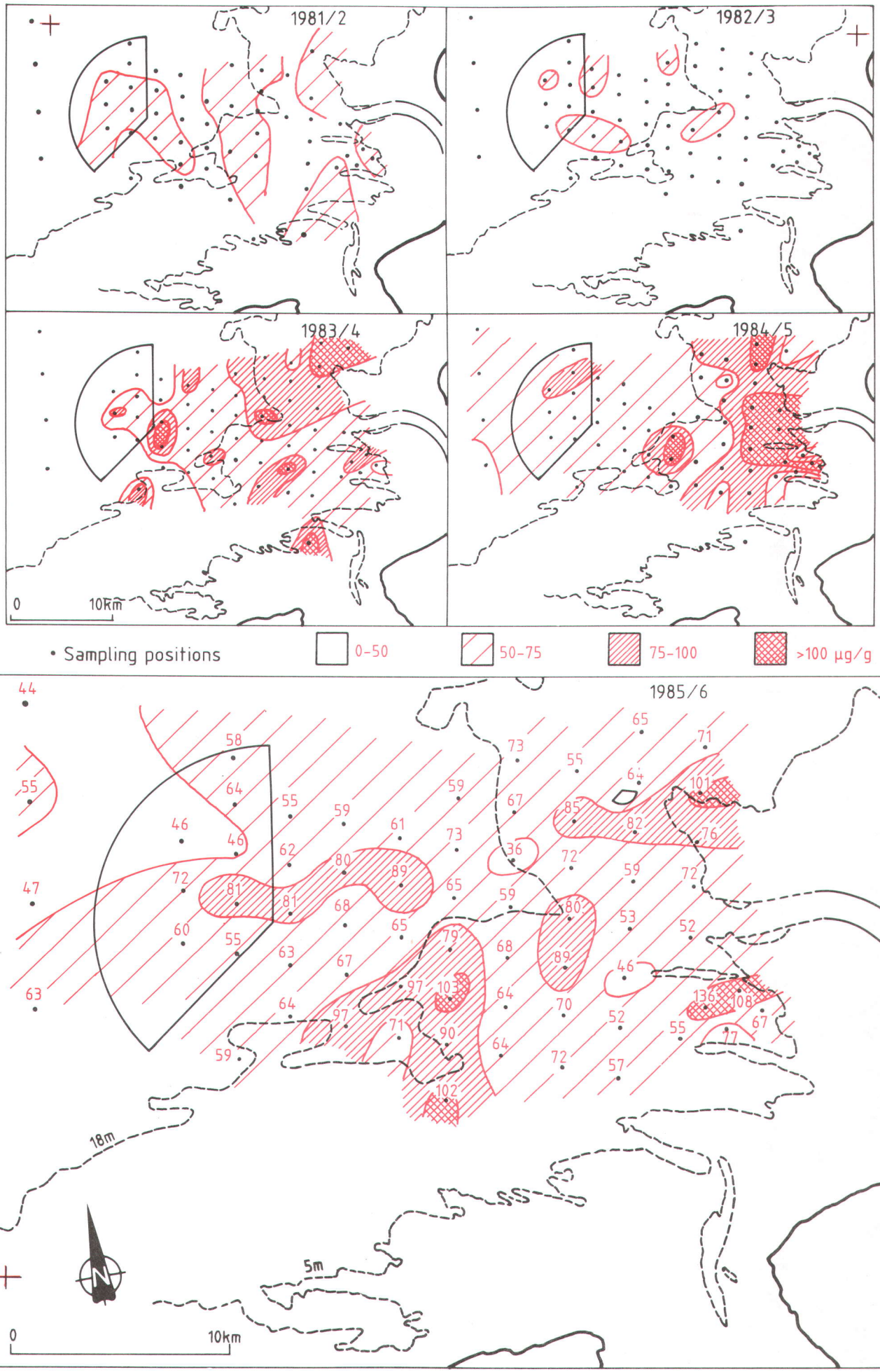


Fig 9 Chromium concentration in mud from the top 25mm of bed

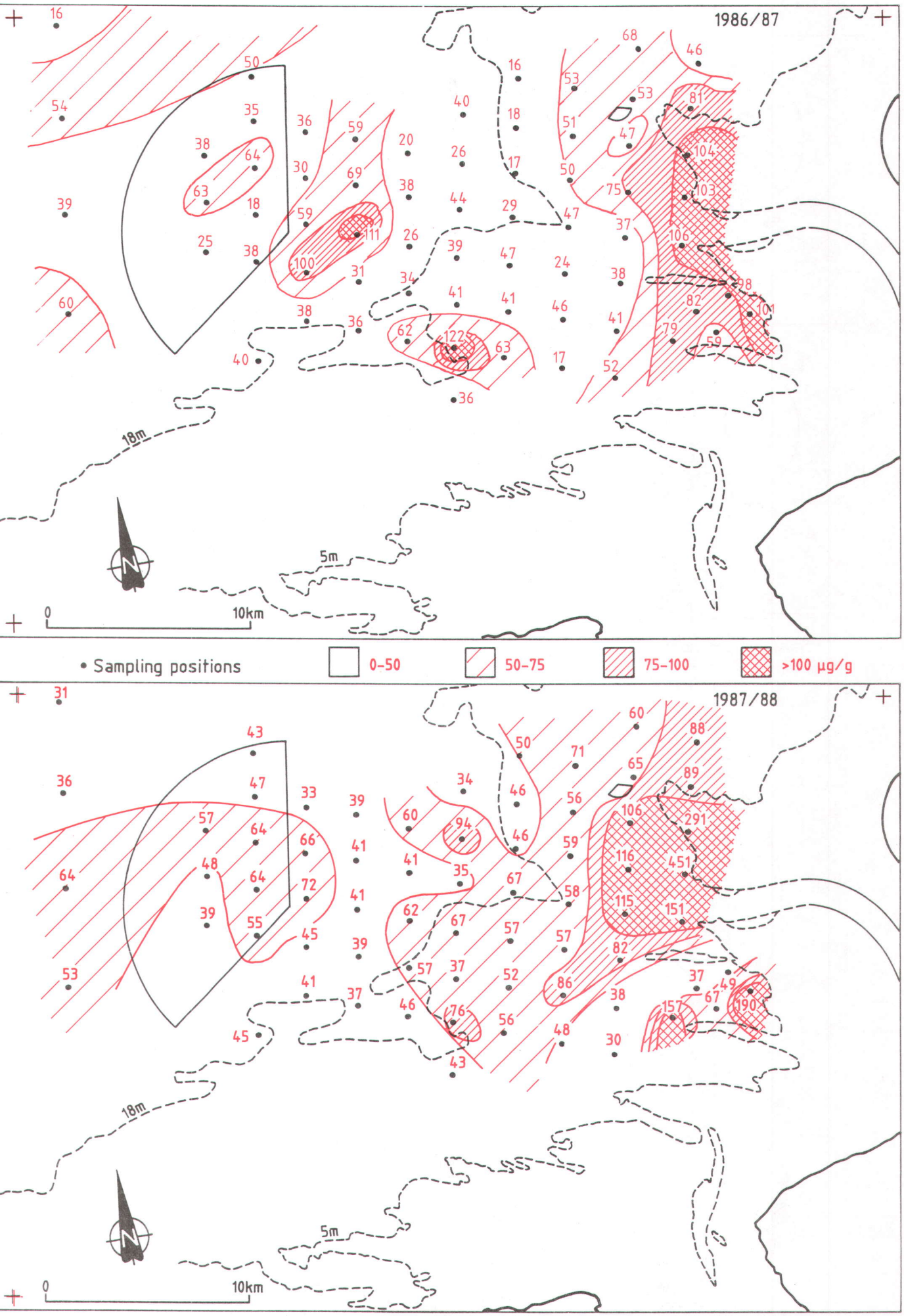


Fig 9 Chromium concentration in mud from the top 25mm of bed

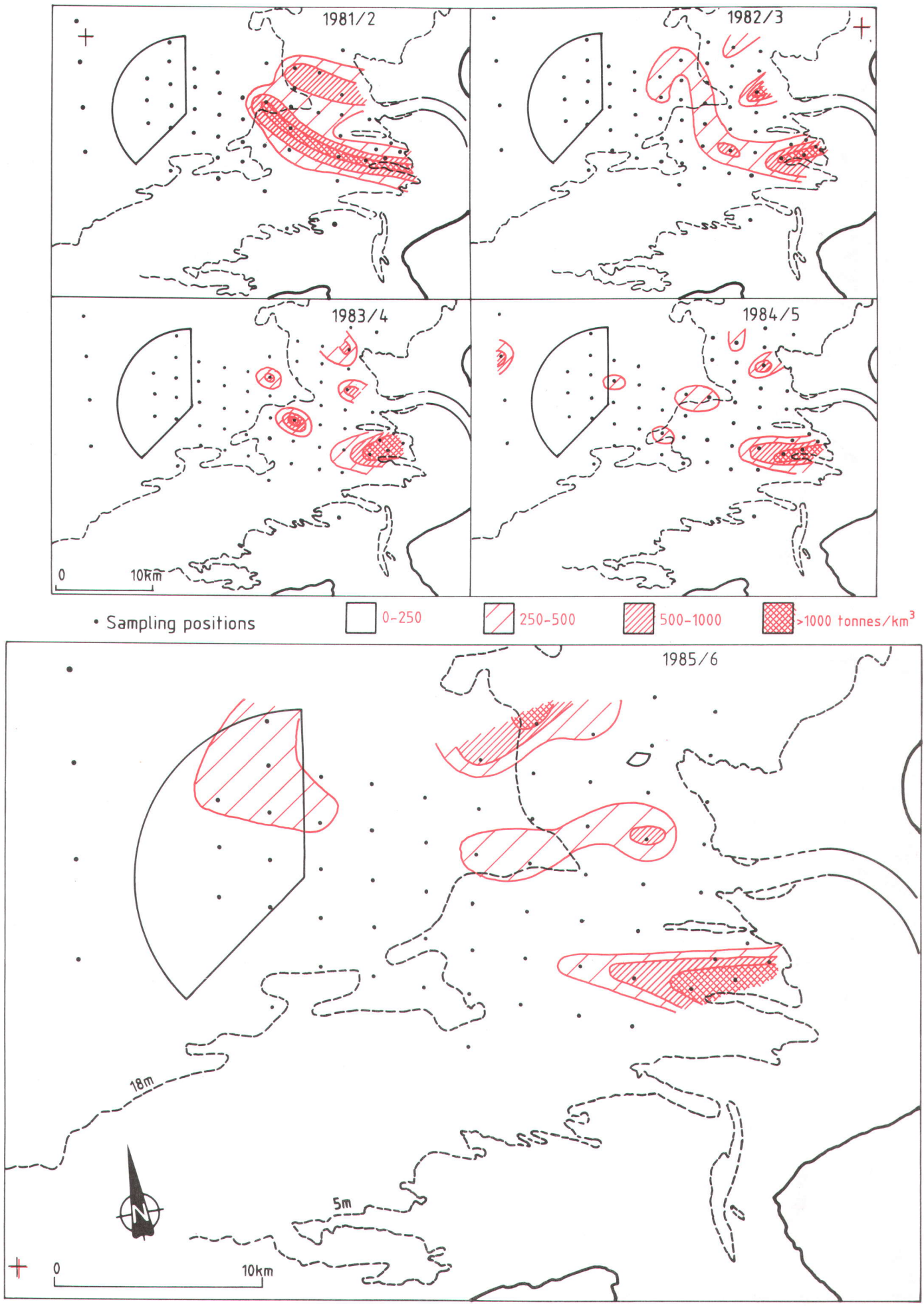


Fig 10 Total organics in mud from the top 25mm of bed

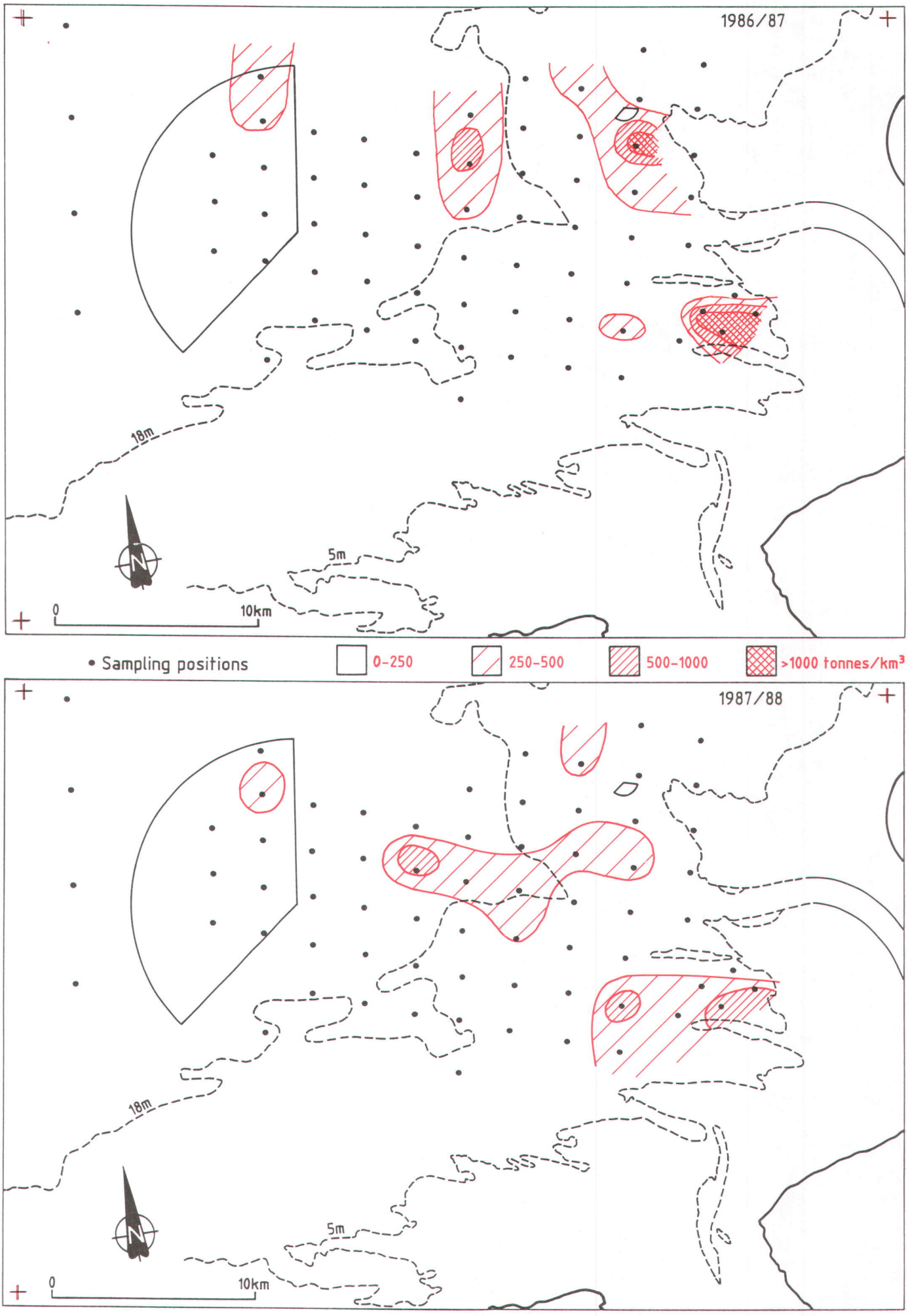


Fig 10 Total organics in mud from the top 25mm of bed

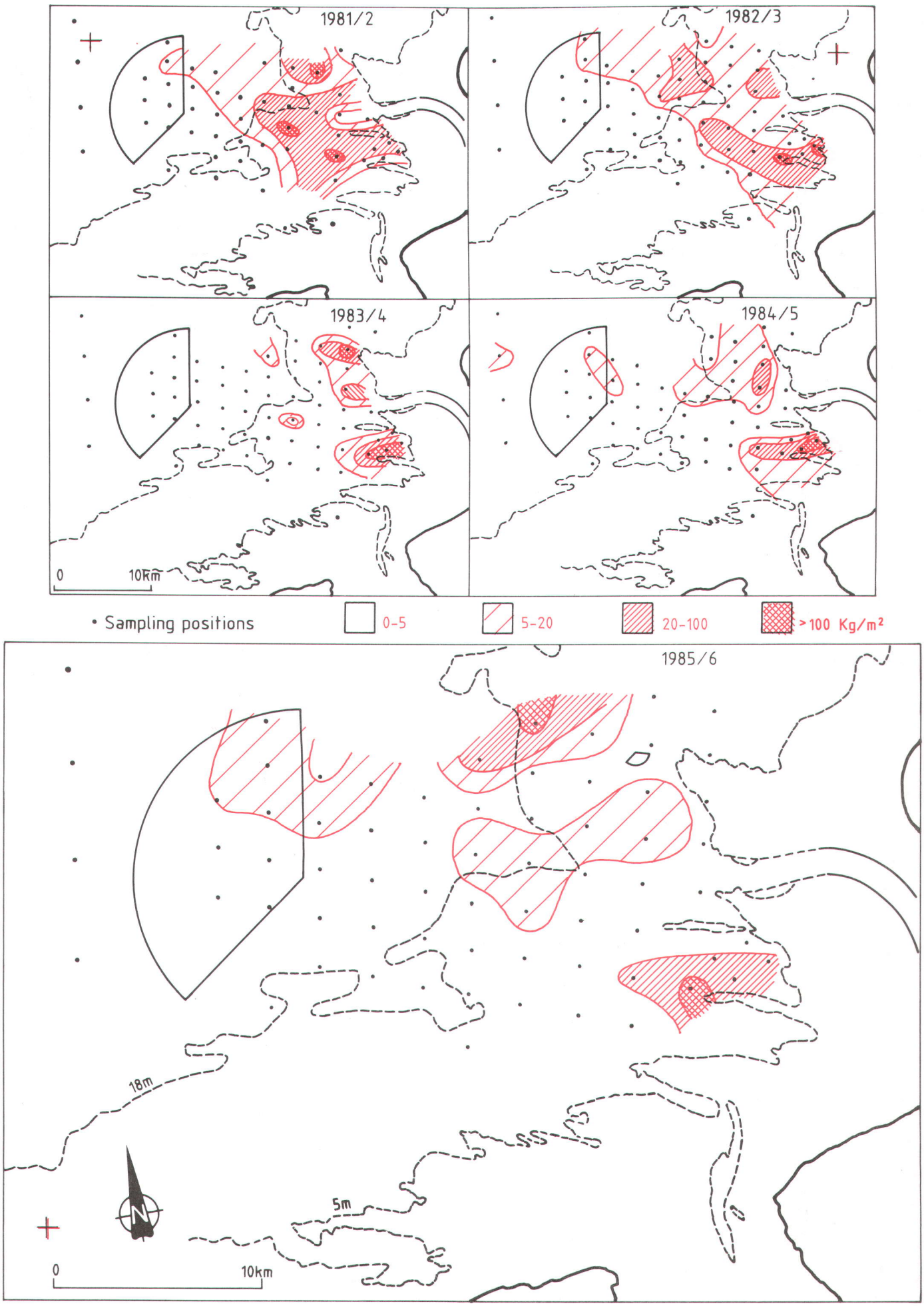


Fig 11 Total mercury in mud from the top 25mm of bed

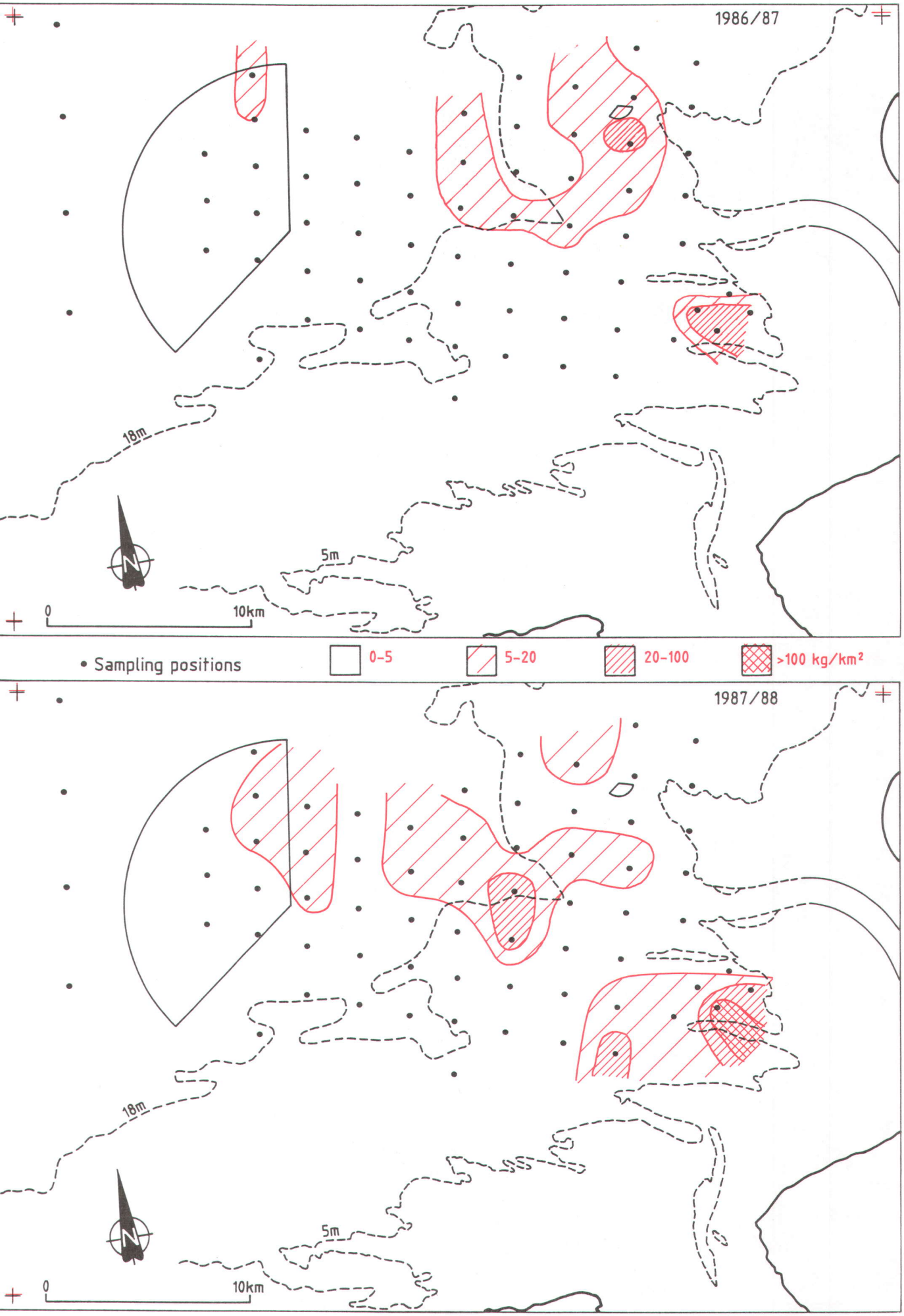


Fig 11 Total mercury in mud from the top 25mm of bed

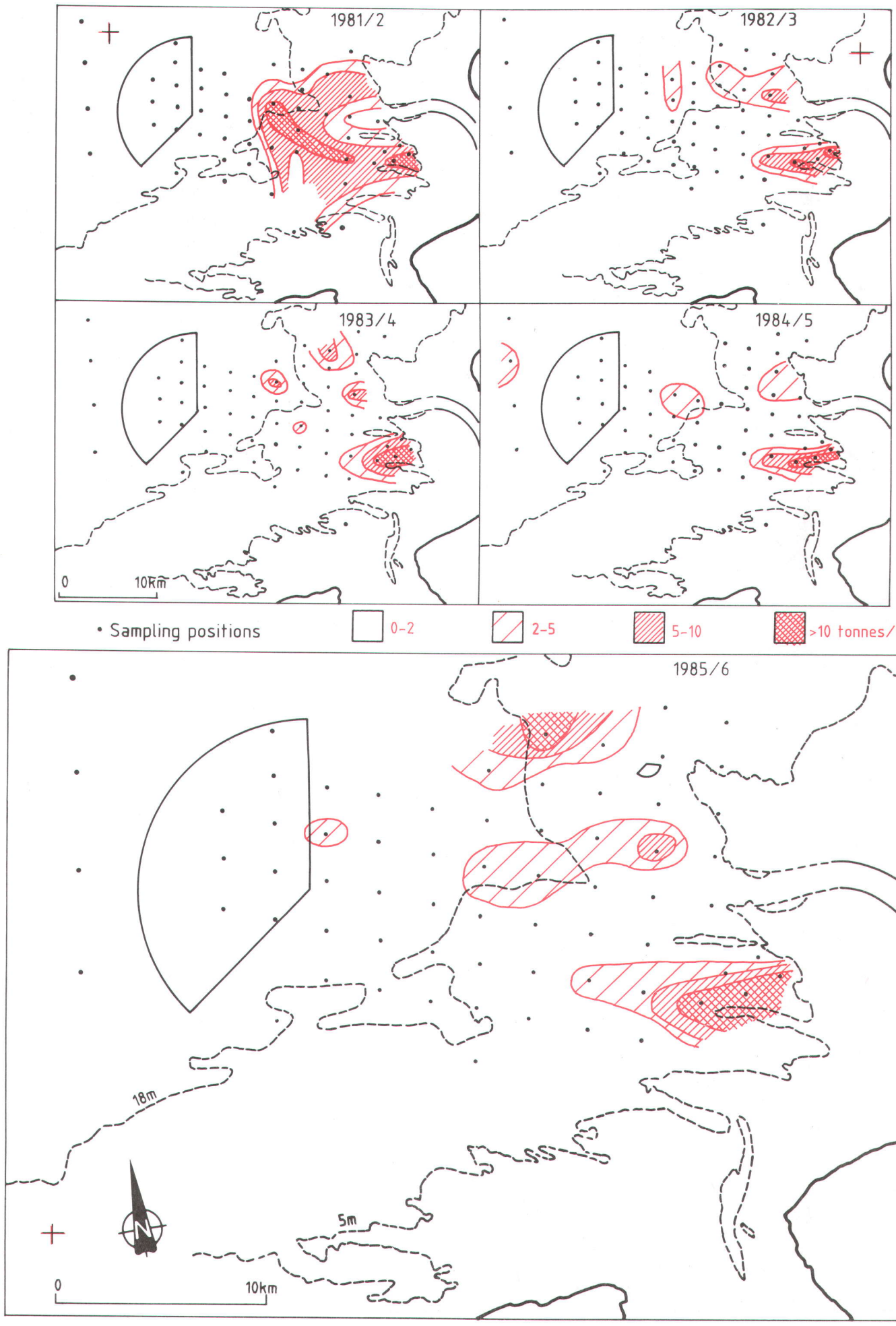


Fig 12 Total zinc in mud from the top 25mm of bed

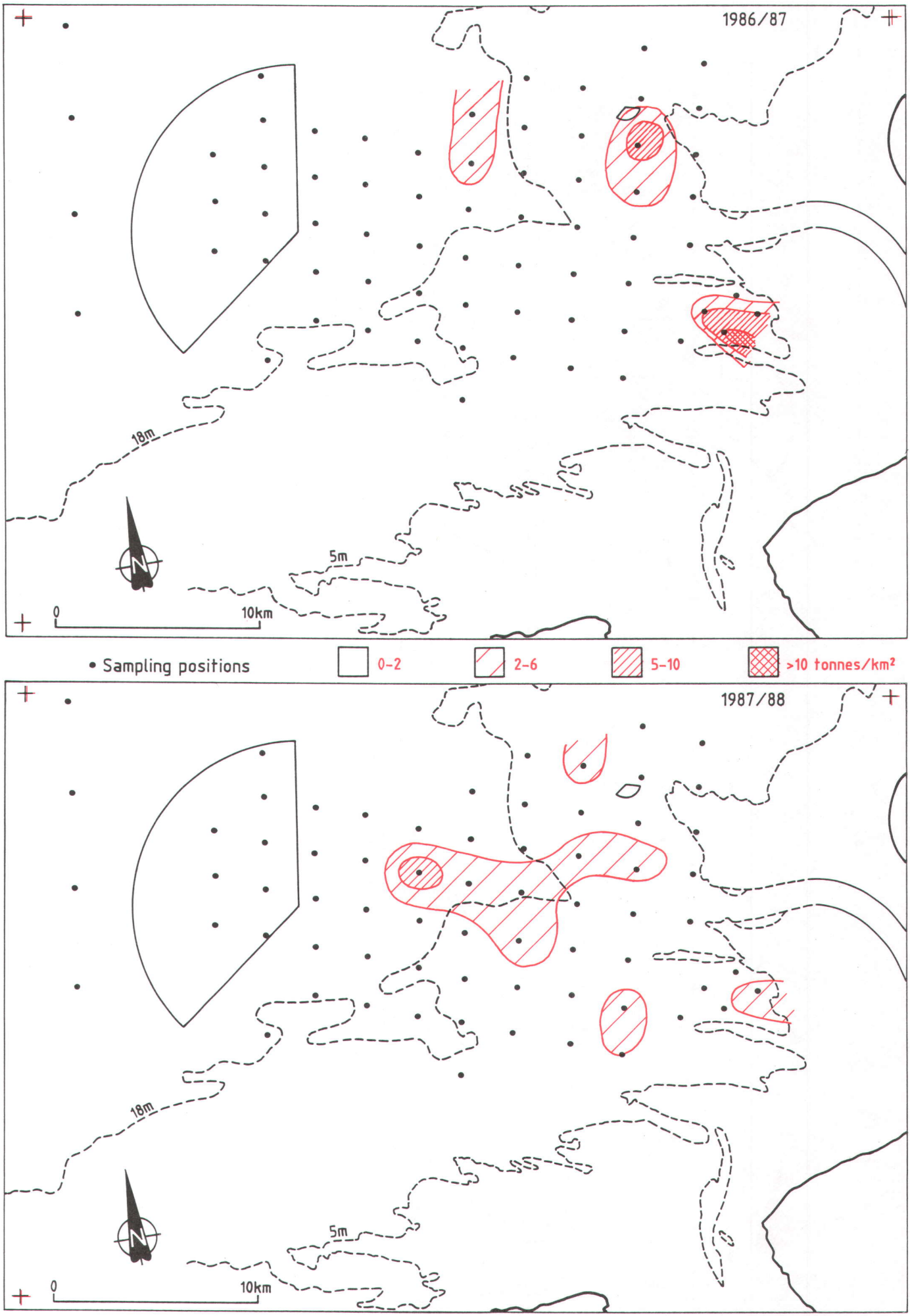


Fig 12 Total zinc in mud from the top 25mm of bed

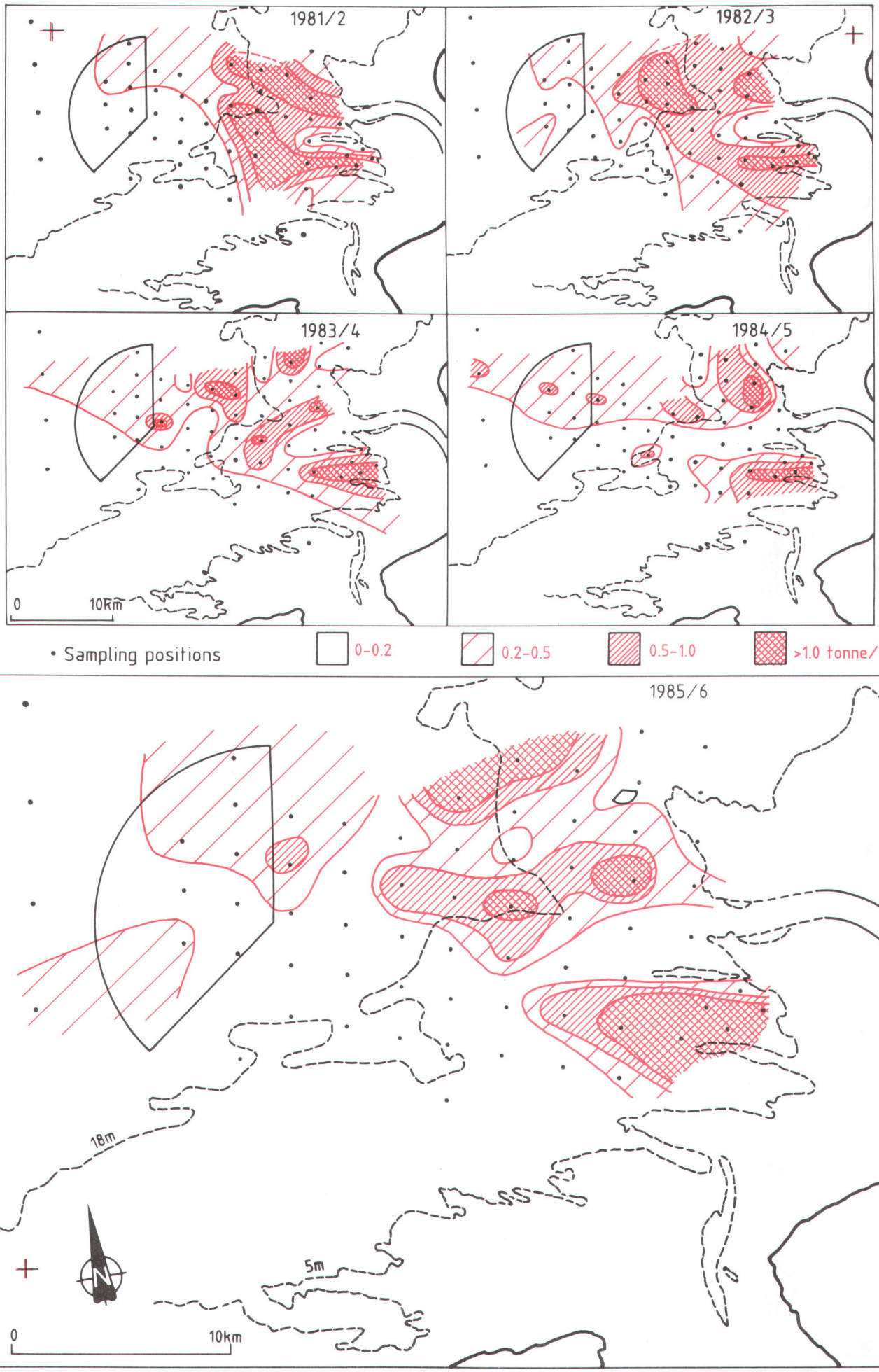


Fig 13 Total lead in mud from the top 25mm of bed

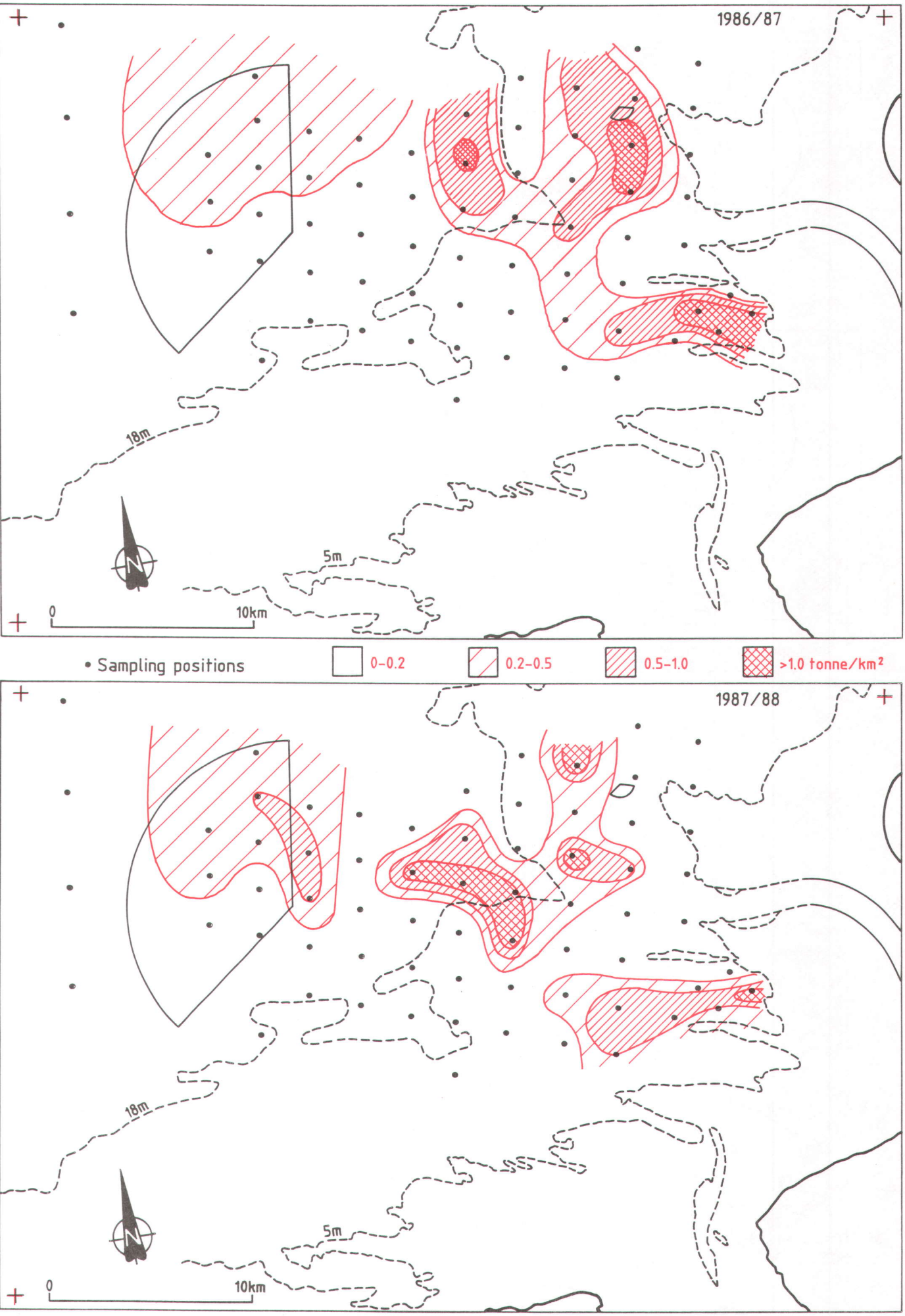


Fig 13 Total lead in mud from the top 25mm of bed

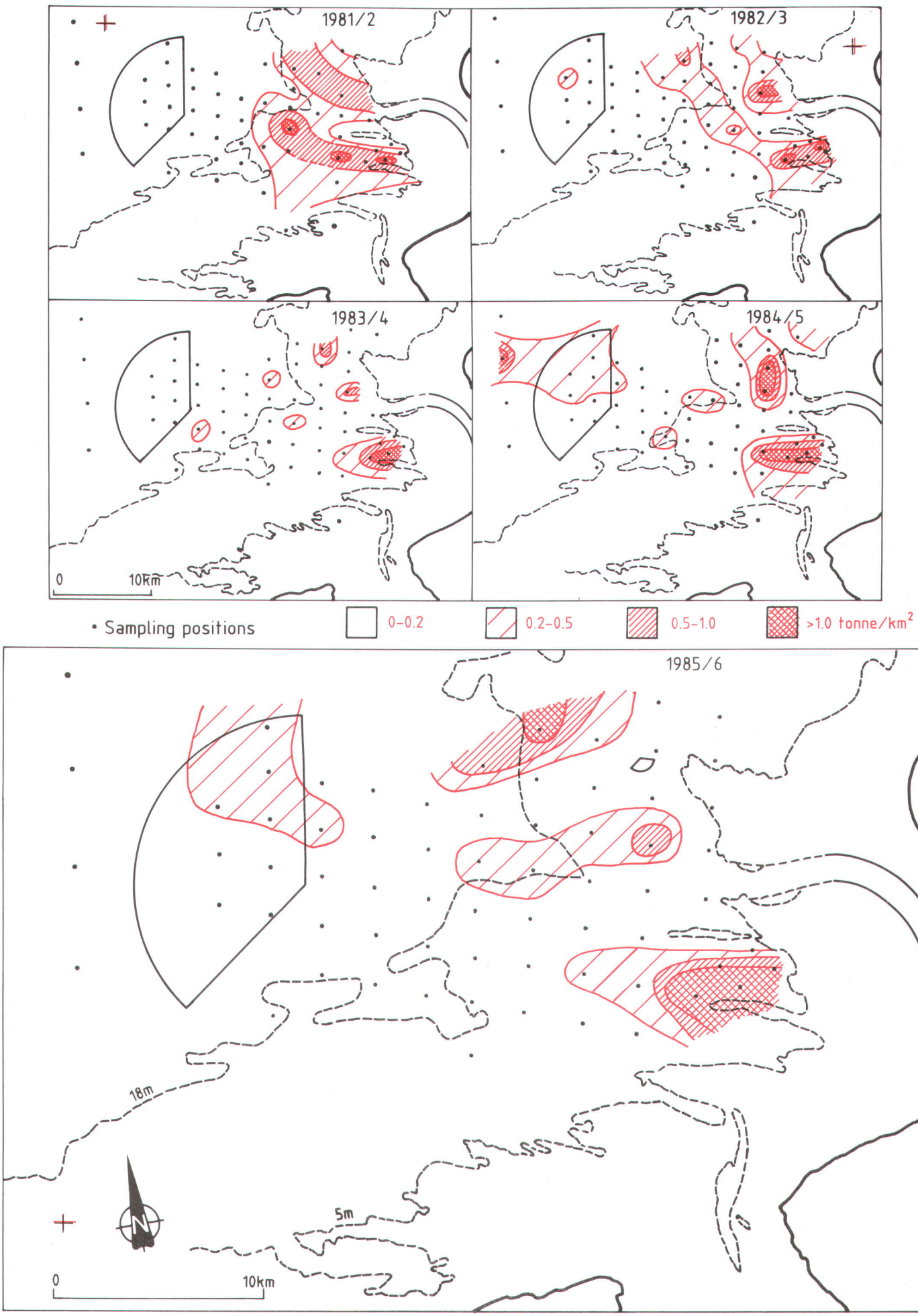


Fig 14 Total nickel in mud from the top 25mm of bed

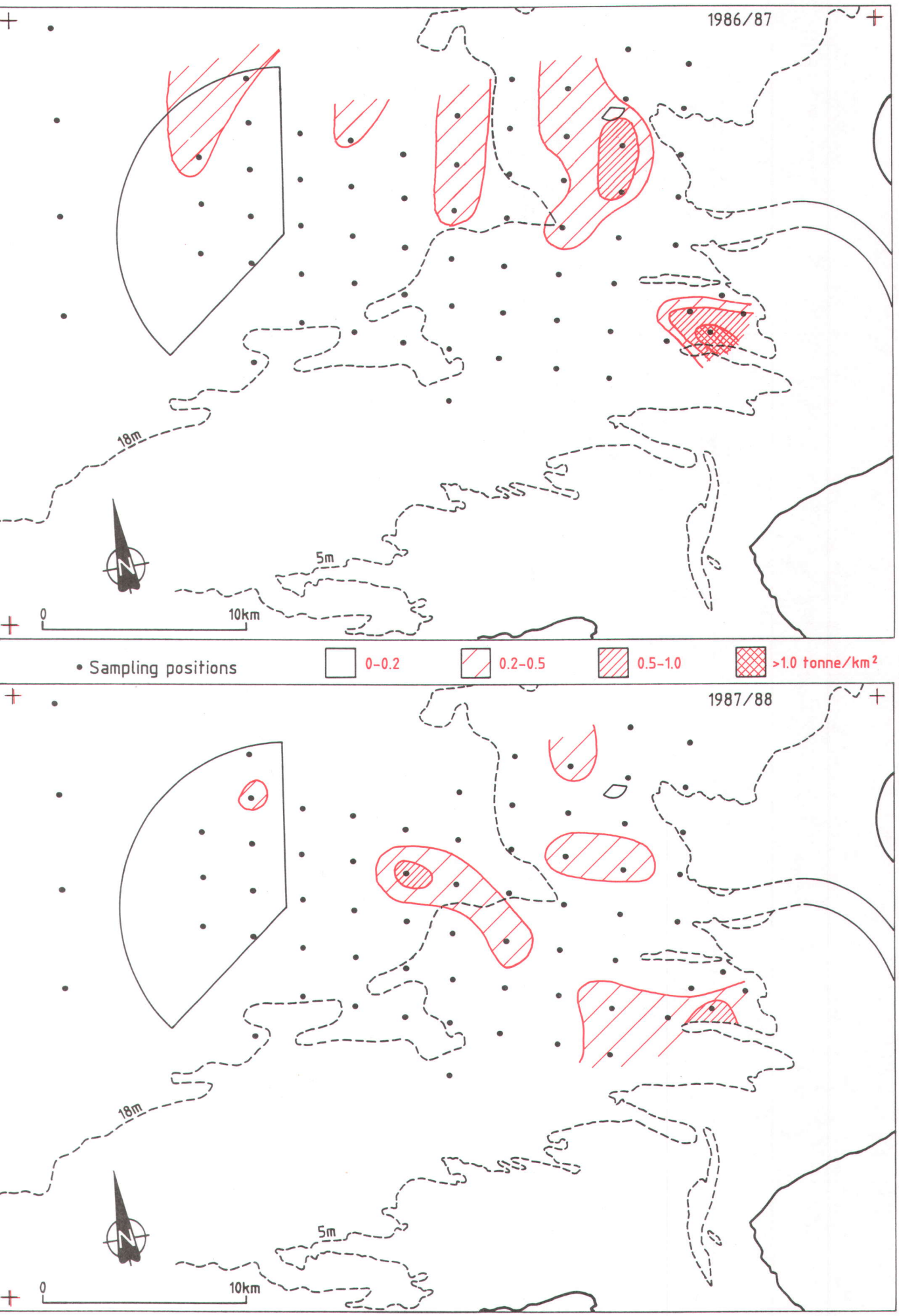


Fig 14 Total nickel in mud from the top 25mm of bed

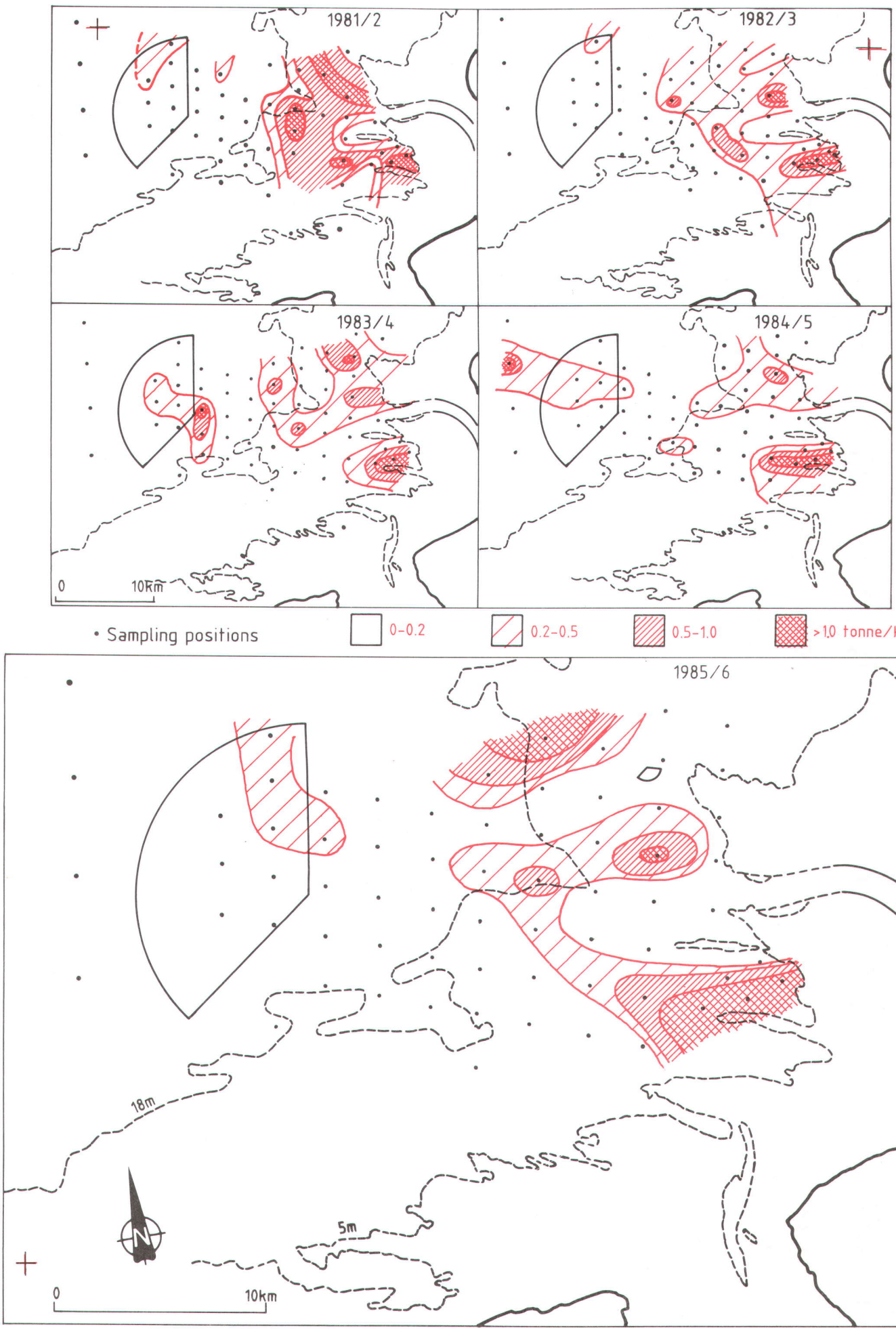


Fig 15 Total copper in mud from the top 25mm of bed

Fig 15 Total copper in mud from the top 25mm of bed

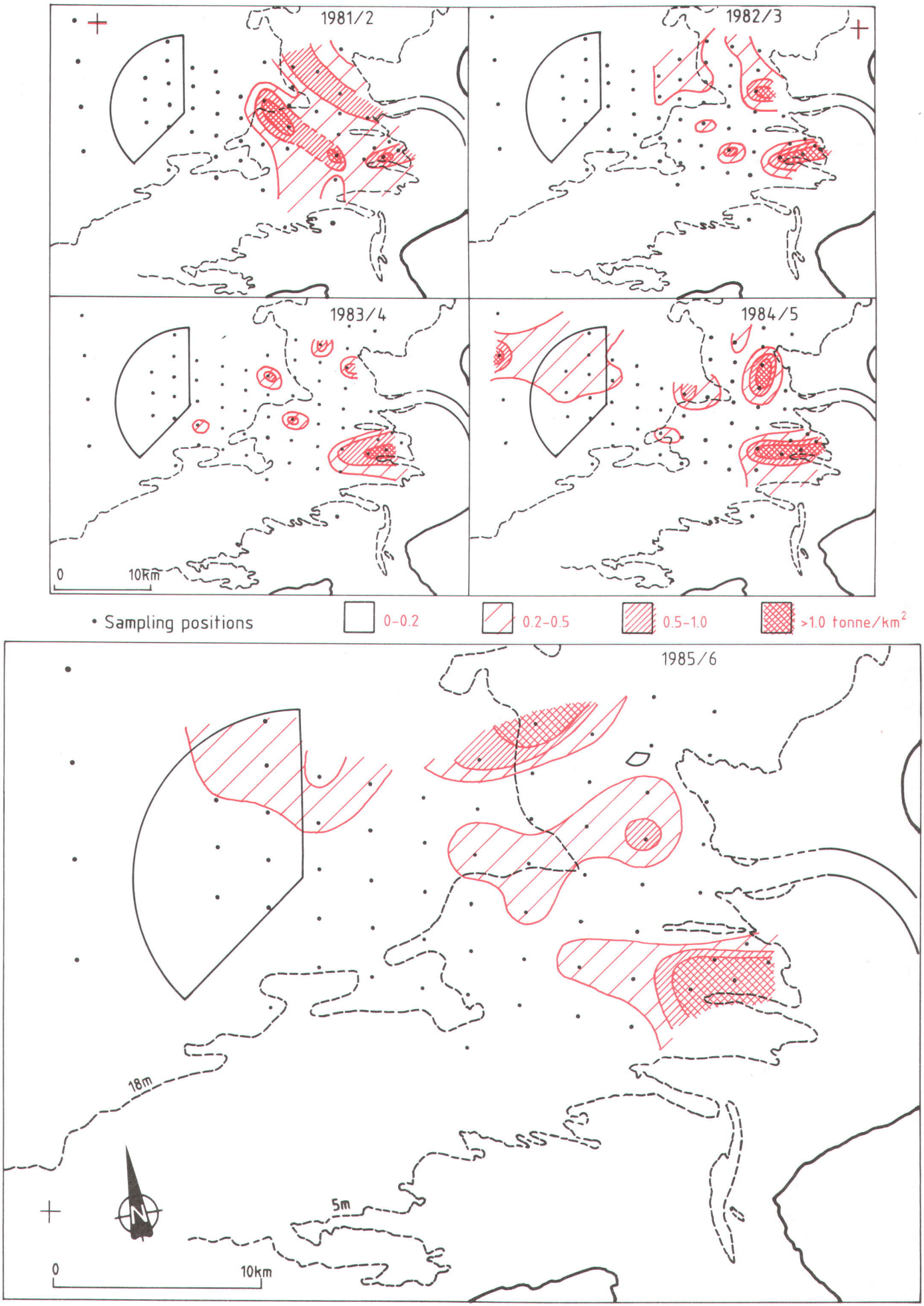


Fig 16 Total chromium in mud from the top 25mm of bed

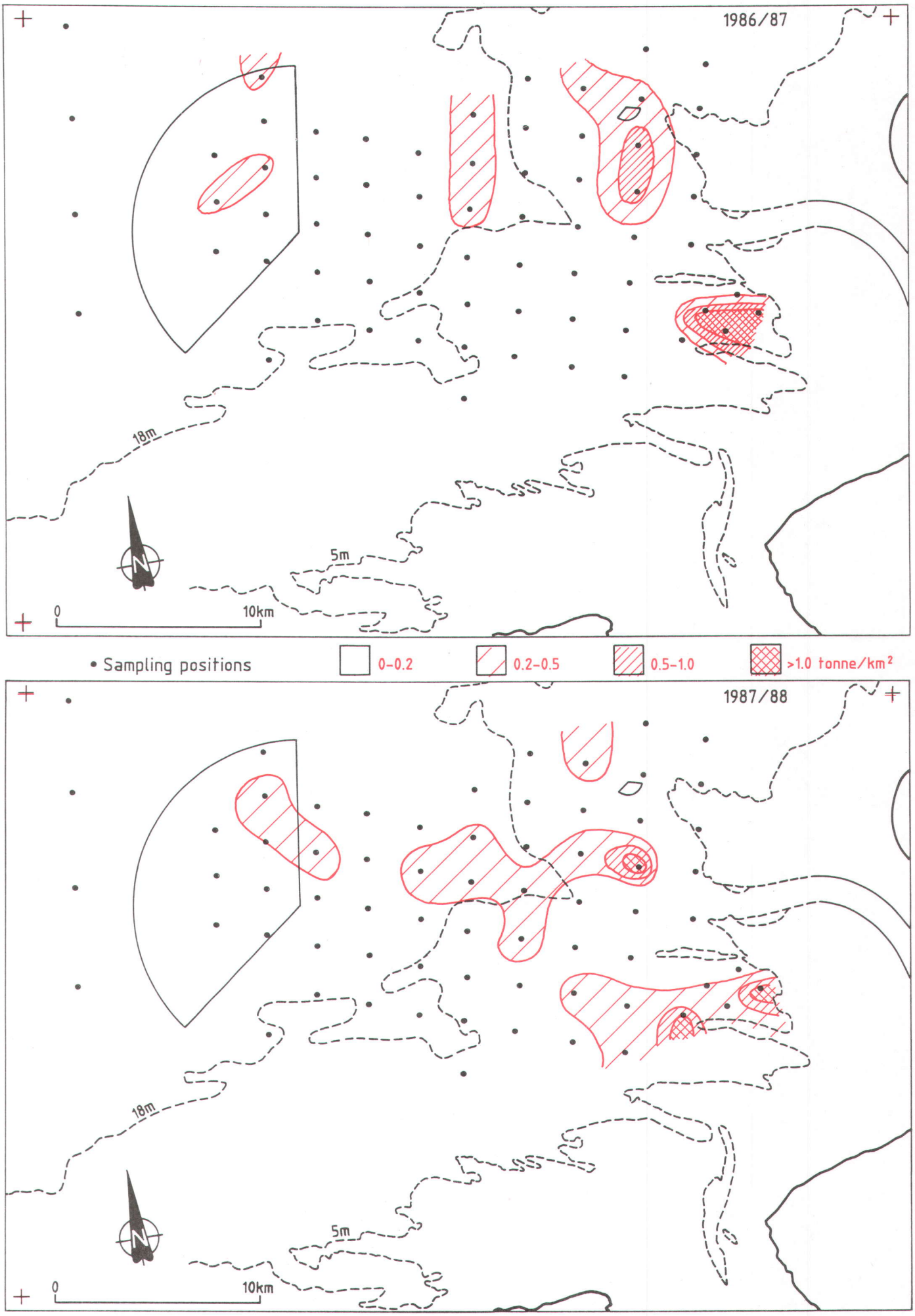


Fig 16 Total chromium in mud from the top 25mm of bed