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Geochemistry of some heavy mineral concentrates from the island of Arran

Geology
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This report relates to work carried out by the British Geological Survey on behalf of the Department of Trade and Industry. The information contained herein must not be published without reference to the Director, British Geological Survey.

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SUMMARY

Mineral concentrates from about 70% of the stream sediments collected from the Arran drainage have been analysed for a range of elements associated with metalliferous mineralisation. Cumulative frequency plots define anomalous populations for most of these elements and the distribution of the anomalies is examined against other elements and the mapped geology.

Discussion of these distributions offers suggestions for follow-up geochemistry and mineralogical collection to examine possibilities of metalliferous concentrations of interest to the mining exploration industry. Among the more interesting elements are Ba, Cu, Mo, Pb, Sb, Sn and U.

INTRODUCTION

In 1981, acting on a proposal to examine the geochemistry of the granites of Arran, 269 samples of hand-panned mineral concentrates collected from the island's drainage were made available by the Regional Geochemical Reconnaissance Programme. It was intended that a further 110 samples should be released, thus completing the coverage effected by RGRP, but these samples were never forthcoming. Unfortunately, it was not possible to take into account a further 110 samples from streams draining the northern granite with which is associated the only worked mineralisation.

The utilisation of samples from other BGS programmes not only avoided expensive duplication of field collection but also provided a preliminary assessment and probable follow-up to RGRP investigations - a valuable service to the mineral industry.

SAMPLE PREPARATION AND ANALYSIS

At each RGRP site a stream sediment sample was collected and, if adequate sediment was available, a heavy mineral concentrate was obtained by hand panning an approximately fixed amount of the sediment. Geochemical analyses of the raw stream sediments will be reported in the RGRP atlas for the Clyde sheet. For this area the RGRP samples were given four figure numbers prefixed by 27; MRP notation for the panned concentrates retains the same four figures but prefixed by the letters XPP.

Some 20-25g of concentrate was mechanically split from the sample and ground in an agate Tema mill to less than 200 mesh BSS. At the BGS laboratories in Gray's Inn Road, London this was analysed by X-ray fluorescence spectrometry (XRF) for the following suite of elements: Ag, As, Ba, Bi, Ca, Ce, Cu, Fe, Mn, Mo, Nb, Ni, Pb, Rb, Sb, Sn, Sr, Th, Ti, U, W, Y, Zn and Zr.

No mineralogical studies have been made on these samples nor has any separation of ore mineral phases been attempted.

RESULTS

The individual sampling sites are shown in Fig. 1 and their broad geological derivation can be ascertained by reference to Fig. 2. Detailed analytical results are listed in the Appendix and a summary of the element statistics is given in Table 1. The limiting values for the anomalous populations in this table were derived from inspection of the respective cumulative frequency plots.

In considering the distribution of anomalous element levels the lack of mineralogical information prevents any certain assignment to mineral species, though in many cases this may be reasonably assumed.

Table 1. Summary of element statistics (in ppm)

n = 269 for all elements

	Range	Mean ± SD	Median	Anomalous populations
Ag	0 - 18	3.44 ± 3.67	2	>8.9(9%)
As	0 - 33	4.66 ± 5.84	3	>17(5%)
Ba	0 - 37200	482 ± 2327	242	>340(28%); >560(8%)
Bi	0 - 17	0.63 ± 1.71	0	Gaussian distribution
Ca	410 - 75960	10019 ± 10530	6600	>22000(12%); >39000(1.8%)
Ce	0 - 7611	292 ± 964	49	>130(22%); >5300(1.5%)
Cu	0 - 1197	19.0 ± 89.4	8	>40(3.3%)
Fe	3900 - 448740	99598 ± 80590	72970	>150000(22%); >250000(5.6%)
Mn	40 - 14410	1486 ± 1736	970	>3450(9%)
Mo	0 - 80	2.38 ± 6.33	1	>9(3%)
Nb	0 - 832	48.8 ± 100.6	22	>37.5(22%); >295(3%)
Ni	0 - 254	25.8 ± 30.7	18	>160(0.7%)
Pb	0 - 2231	60.6 ± 185.4	24	>72(9%); >600(2.2%)
Rb	2 - 140	47.2 ± 35.1	33	>96(12%)
Sb	0 - 23	2.75 ± 3.34	2	>4.4(25%)
Sn	0 - 648	27.7 ± 79.7	5	>20(26%); >330(1.8%)
Sr	2 - 883	63.3 ± 76.0	43	Gaussian distribution?
Th	0 - 412	21.9 ± 52.3	7	>19(17%); >290(1.5%)
Ti	210 - 148700	18090 ± 20320	10800	>35000(14%)
U	0 - 74	4.83 ± 9.12	2	>8(11%)
W	0 - 53	5.84 ± 6.77	4	>17(6%)
Y	8 - 606	48.8 ± 78.0	27	>210(5%)
Zn	11 - 1814	140 ± 170	95	Near-gaussian distribution
Zr	62 - 8265	997 ± 1182	528	>4700(2.6%)

Silver. Interpretation of the cumulative frequency plot (Fig. 3) is probably over-simplified and should correctly display two anomalous populations. This would have the effect of lowering the anomaly threshhold and increasing slightly the proportion of values falling into this high range.

Using the value of 8.9ppm obtained from this plot, a restricted distribution of anomalies results (Fig.27). All bar two of the samples were obtained where streams flow over New Red Sandstone rocks, but it is assumed that the silver content, in sulphides or on iron oxides, derives from the Tertiary igneous sills upstream. The two isolated localities in the north are underlain by granite but upstream from both sites this is extensively intruded by Tertiary basic dykes.

The Ag distribution correlates well with that for Fe and, not surprisingly, with the two anomalies for Ni; there is a partial correlation with Mn, Pb and Sb anomalies but none with As, Ba or Cu. Such associations strongly support the belief that the silver may be present as a secondary adsorption on ferruginous oxides.

Arsenic. The cumulative frequency plot (Fig. 4) shows a marked change of slope at 17ppm and values above this are taken as anomalous. Again, the anomalies are mainly confined to the southern half of the island, with only two in the north (Fig. 28). With four exceptions they occur over mainly arenaceous sedimentary rocks of various ages. Two of the exceptions are those in the north, where they lie over Dalradian metamorphic rocks, the other two are near the margin of the central granite.

There is some correspondence between the As anomalies and those of Ba, Fe and Sb, poor agreement with Sn and no correlation with Ag, Cu, Mn, Pb, U and W, metals with which some association might have been expected.

Barium. More than one population for Ba is evident in the cumulative frequency plot (Fig. 5), a not unexpected situation in view of the varied lithology of the island. A highly anomalous population at values exceeding 560ppm constitutes some 8% of the total samples and is distributed in a somewhat random fashion through the island (Fig. 29). Although barytes has been mined in the lower reaches of Glen Sannox, in north-east Arran, none of the proximate samples are anomalous. It would be valuable to analyse the outstanding samples, which include those from the Sannox and adjacent drainages. Three samples were collected at points which denote a source at or close to the contact of the northern granite, in a position not dissimilar from that of the worked veins, one from just inside the central granite and two from the centre of this mass. None of these is particularly rich in Ba, however, the richest sample coming from north of Machrie on the west coast, in Old Red Sandstone country.

A break of slope at 340ppm Ba marks the lower cut-off for a larger set of moderately anomalous values which are more widely spread over the island. Additional locations lie in both granites, particularly near the contact, but most are in sedimentary or metamorphic areas.

Ba anomalies seem to correlate reasonably well with those of As, Sb and the non-granitic set of Rb anomalies. There is no correlation with Ag, Ca, Pb or U.

Bismuth. There are very few points on the cumulative frequency plot for Bi and these can be accomodated close to a straight line (Fig. 6), indicating a gaussian distribution.

Calcium. Two distinct populations are evident in Fig. 7 and two sets of anomalous values can be extracted, a small one above 3.9% Ca and a more extensive one above 2.2% Of five highly anomalous samples, one lies in the northern granite and two in the central granite, one of these at the margin (Fig. 30). These Ca levels seem unduly high for granite derivation and it may be that they reflect the presence of some calcitic veining in these areas.

Inevitably the larger anomalous set has a wider distribution, encompassing most of the island's lithologies. Some additional sites are located on both of the granites.

Association with Fe and Mn is not marked and there is no obvious correlation with Ba or Pb.

Cerium. Only a small proportion of the Arran samples are highly anomalous for cerium (Fig. 8), though a broader set of moderately anomalous samples constitutes some 22% of the total. All three of the highest values lie just within the northern granite (Fig. 31) and clearly reflect concentrations of monazite released from that rock. The moderately anomalous samples are also associated in large part with this granite and with the north-western lobe of the central granite. Two isolated anomalies are located in the south-eastern corner of the island.

As might be anticipated the Ce anomalies correlate well with those of the granitic trace elements Nb, Th and Y, and all three anomalies for Zr and all but one for Mo correspond with Ce. There is moderate correlation with Rb, Sb (part only), Sn, U and W and almost no agreement with the more basic affiliated Ni and Pb.

Copper. The disposition of points on the cumulative frequency plot (Fig. 9) is such that alternative interpretations may be preferred to the simple approach used here. Anomalous samples, at more than 40ppm Cu, are widely scattered around the island (Fig. 32) and seem to bear no relationship to the lithology. Some of the Cu values, however, are remarkably high and invite further investigation.

Cu is usually geochemically associated with many other ore metals and with the oxides of iron and manganese. In the Arran samples, however, there is only moderate correlation between anomalies of Cu and Sb, poor with Pb and Sn, and no correspondence with Ag, As, Fe, Mn, Mo and U.

Iron. As might be expected, the cumulative frequency plot for Fe (Fig. 10) shows several distribution populations and the lines drawn between points are highly subjective. A broadly anomalous set can be separated at about 15% Fe and this constitutes some 22% of the total samples, but within this set there is a sub-set consisting of highly anomalous values, above 25% Fe.

Apart from a cluster of four samples located in the south-east of the northern granite (Fig. 33), the iron anomalies are confined to the ferruginous sediments and the more basic igneous members which make up the southern half of the island. The group in the north occurs in an area immediately downstream from several basic dykes which are the presumed source of the Fe anomalies. Correspondence between the Fe and Mn anomalies is extremely good but among the sulphidic ore metals is good only with the highly mobile Ag. Perhaps surprisingly, there is equally close agreement with Ti anomalies.

<u>Manganese</u>. The cumulative frequency diagram for Mn (Fig. 11) is less ambiguous than that for Fe and only the highest population set is taken as anomalous. Areal distribution of these anomalous samples (Fig. 34) is similar to that for Fe, again mainly in the south of the island but with the same four samples grouped near the margin of the northern granite. Mn correlates with the same elements as does Fe.

<u>Molybdenum</u>. In a simple cumulative frequency plot for Mo (Fig. 12)an anomalous population is recognised above 9ppm. Only eight samples fall in this set and all but one are derived from the northern granite (Fig. 35). The odd sample comes from the southern part of the island in a small complex area of Coal Measure sediments, basic and felsitic intrusions; the provenance of the molybdenum is not clear. Because anomalous Mo is related to the granite it correlates with most other granitophile elements, Ce, Nb, Sn, Th, U, W and Y. The southern anomaly also correlates with Nb, but not the other elements mentioned above.

It is presumed that the Mo anomalies arise from the presence of discrete flakes of molybdenite.

<u>Niobium</u>. The lines drawn in the cumulative frequency diagram for Nb (Fig. 13) are somewhat less than satisfactory, but it is reasonably clear that the upper 20% of values are anomalous. Using this cut-off of 37.5ppm produces a widespread distribution pattern (Fig. 36) which encompasses a wide range of lithologies. The highest value set, at greater than 295ppm, is severely restricted to the northern granite and mainly to the marginal parts of that body. Nonetheless not all samples from similar situations are even moderately anomalous. It may be speculated that the eight samples highest in Nb would be worth examining for fine crystals of columbite.

The highest Nb anomalies correlate closely with those for all the other granitophile elements, but the broader set correspond only partially with any of the other elements.

<u>Nickel</u>. In the cumulative frequency plot (Fig. 14) there is a very clear break of slope at 160ppm and the only two samples above this value are deemed to be anomalous. Both are derived from sites spaced fairly close together in the southern part of the island above Lamlash Bay (Fig. 37). Their source is not clear but is presumed to be among the basic sills. Correlation with other elements has little meaning.

<u>Lead</u>. Pb produces a train of log-probability points (Fig. 15) for

which several interpretations can be advanced. In the one adopted the upper two populations are regarded as anomalous. Most of the anomalies lie in the southern half of the island (Fig. 38), with just three in the north and of these two belong to the high set. One is located immediately inside the margin of the northern granite and the other two on Dalradian metamorphic rocks. In the south the anomalies are spread over a range of lithological types.

There are no clear correlations with elements normally regarded as geochemical associates of Pb, except for Ag. The lack of any correlation between Pb and Sn can be taken as evidence that there hasbeen no X-ray fluorescence peak interference between these elements.

Rubidium. The log-probability graph (Fig. 16) is simple and defines an anomalous set above 96ppm Rb. The distribution of anomalous samples is not particularly meaningful, however (Fig. 39). While several are clearly derived from the northern granite there are, nonetheless, many more samples of granitic origin which do not show anomalous Rb. Similarly, the grouping of Rb anomalies in the Dalradian belt to the west of the northern granite is not repeated elsewhere in Dalradian rocks north and south of that intrusion. It may be questioned whether this grouping is due to minerals derived from the granite which have been carried further downstream on this side of the island. From the topographic map, however, the stream courses appear less steep here than to the south of the granite and it therefore seems more probable that the geochemical variations in these concentrates reflects actual differences in lithology between the separate Dalradian outcrops.

Four anomalous samples were derived from the southern part of the island, the westermost from on New Red Sandstone sediments and the other three on the central granite.

There is reasonably good accord between the anomalies for Rb and those for some of the other granitophile elements, notably Ce, Sn and Y, but somewhat less agreement with Nb.

Antimony. Points are sparse on the Sb cumulative frequency plot (Fig. 17) but they seem to fall into two distinct populations, the anomalous one, at values above 4.4ppm, representing a quarter of the total samples. These are widely scattered across the island though concentrated mainly in the south (Fig. 40). Five anomalous samples are found within the outcrop of the northern granite and four within the central igneous complex, all but one in the granite. Six are found on the Dalradian rocks, and the remainder are from streams crossing New Red Sandstone strata and the variety of sills and dykes that cut them. With so many anomalous points it is inevitable that there is partial correspondence with a wide range of other element anomalies; it is debatable how many of these correlations are significantly meaningful.

Tin. The log-probability plot for Sn (Fig. 18) suggests that there are several distribution populations for this metal; it is not clear from the spread of anomalous sample locations whether these various populations have any lithological significance. About three-quarters of the samples return Sn contents of 20ppm or less, this very low figure indicating a provenance generally deficient in tin.

Of particular interest are the highly anomalous samples, those containing 330ppm or more (Fig. 41). There are four, two from sites on the northern granite , one from a stream draining westwards from the central igneous complex and one from near the southern coastline. This latter sample is something of an enigma, lying as it does in an area of Triassic sediments. It might be tempting to believe that the tin is derived from the nearby felsite sill but nowhere else does this body give rise to tin-rich concentrates. It may be that the high Sn content of this sample is the result of contamination.

It may reasonably be presumed that the two samples from the northern granite contain discrete cassiterite. In the Annual Report of the Institute of Geologiacl Sciences for 1975, pp. 36-37, it is recorded that cassiterite had been identified in stream sediments from North Glen Sannox and Glen Catacol. Samples fom these areas are among those yet to be analysed; it would be interesting to see whether further highly anomalous tin values report from this sector of the granite. The high Sn value associated with the central granite is also intriguing since no cassiterite has ever been recorded from this intrusion.

The broader set of tin anomalies are much more widely scattered throughout the island. Many of the samples are from sites on the northern granite, and several from the surrounding Dalradian and Palaeozoic rocks. A few samples taken from close outside the margin if the central granite may contain tin derived from that igneous source, but others from the southern part of the island seem not to relate to any of the acid igneous bodies.

The Sn distribution around the northern granite correlates well with most of the other granitophile elements, Ce, Nb, Th and U. The high temperature ore associates W and Mo present an interesting case. Samples anomalous in these elements are always anomalous for Sn, but the highly Sn anomalous samples are not necessarily anomalous for W or Mo. In the cases of the commonly associated non-metallic elements, anomalies for Sb and Sn show some degree of correlation, though this might be expected on the basis of their respective numbers, but there is no agreement between Sn and As.

<u>Strontium</u>. The cumulative frequency plot for Sr (Fig. 19) probably should be interpreted in terms of several populations but it is nonetheless close to a gaussian distribution and clear-cut separation of the individual sets is difficult. In consequence, no anomalous groupings have been recognsed.

<u>Thorium</u>. This log-probability plot (Fig. 20) is much better defined and two breaks of slope mark the populations ranges. Two levels of anomaly are recognised, a broad set at levels above 19ppm and a smaller group at values more than 290ppm. Four samples comprising the latter are restricted to the marginal regions of the northern granite (Fig. 42); the broader group are distributed more widely both

within and around this body. As has been noted before, there is close accord between Th and the other granitophile elements, notably Ce, Nb, Sn, Y and U. Correlation with the rare earths is a clear indication that much of the thorium resides in monazite, perhaps also in xenotime.

Titanium. The cumulative frequency diagram (Fig. 21) shows three distinct populations, the highest of which contains about 15% of the total samples and has a lower cut-off at 3.5% Ti. These anomalies are distributed mainly in the southernmost parts of the island (Fig. 43), but a cluster of five anomalous samples is found near the south-east margin of the northern granite and two come from the granitic area of the central complex. This scatter accords reasonably closely with generally basic members of the Tertiary igneous suite in which ilmenite may be a significant opaque constituent. As might well be anticipated, Ti anomalies accord best with those of other elements with basic igneous affiliations, notably Fe and Mn, less closely with Ca but also with Ag. This might explain the fact that Ag shows little or no correlation with its common hydrothermal associates, Pb and Zn.

Uranium. From a very simple log-probability plot (Fig. 22) two major populations are recognised, the anomalous one starting at 8ppm. Both this cut-off and the U contents of individual samples are remarkably high, even by granitic standards. As expected, most of the anomalies are associated with granite, almost exclusively the northern one (Fig. 44). However, there is one anomalous sample from the central granite and another from immediately ouside its margin. In the south, sample XPP1689 may reflect the presence upstream of the small outcrop of the southern granite, but the easternmost anomaly is derived from an area far removed from the granites and totally devoid of other acidic intrusions. Reference to the other granite-related elements confirms the almost inevitable correlation. Monazite in the northern granite is almost certainly uraniferous, a presumption borne out by the close correlation of Th and U anomalies. The correlation is not total, however, and additional sources of U must be invoked. It seems probable, therefore, that uraninite may be an accessory mineral in this granite, but there is no compelling evidence from these samples for any vein-type distribution of uranium minerals in or around the northern granite outcrop.

Tungsten. The simplest interpretation of the W cumulative frequency plot (Fig. 23) is as two near-parallel lines. The uppermost of these represents an anomalous population commencing at 17ppm and containing only 6% of the total samples. All the anomalous samples lie within the northern granite, most close to the margin (Fig. 45). They correspond closely with the anomalies for most of the other granitophile elements; the relationship with tin has already been mentioned. It is presumed, from evidence obtained on other granites (eg. Ball and Basham, 1984) that W is contained in fine wolframite occurring as an accessory mineral along with cassiterite: indeed, the two species may be intimately intergrown, hence no W without Sn (see Tin above).

Yttrium. Several populations can be discerned in the cumulative frequency plot (Fig. 24), probably more than have been depicted. It is assumed that most of these reflect the variety of yttrium sources available in such a varied lithology. Such an hypothesis appears to be substantiated by the distribution of the most anomalous set of samples, those with more than 210ppm Y. These are confined exclusively to the outcrop of the northern granite (Fig. 46). This distribution accords well with that for the anomalies of all the other granitophile elements.

Zinc. The distribution of Zn is so near to gaussian that it is not possible to define any separate population ranges (Fig. 25). Such a situation suggests that all the Zn reported is probably bound up with hydrated iron/manganese hydroxides or similar scavenging phases and that no discrete zinc minerals (eg. sphalerite) are present. The possibility of concentrated zinc mineralisation can be discounted, therefore.

Zirconium. This element gives a relatively simple log-probability plot (Fig. 26) with a small set of anomalous values in excess of 4700ppm. The seven samples in this set are distributed as a meaningless scatter through the island (Fig. 47) and, because they are so few, can be believed to correlate with the anomalies for several other elements.

CONCLUSIONS

Although the full collection of Arran panned concentrates unfortunately has not yet been analysed it is nonetheless possible to draw some conclusions about the possibility of mineralisation on the island and to suggest which elements repay further study.

Among the granitophile elements only tin and tungsten seem of major interest, though uranium should also be examined. None of these elements are present in extremely high concentrations but their presence in the granite signifies the possibility, albeit rather remote, of areas of disseminated lower grade but higher tonnage mineralisation. Molybdenum is, perhaps, a somewhat different case. Again, most of the anomalous values are not particularly elevated,but the cluster of samples near the southern margin of the northern granite holds out some hope of zones of quartz-molybdenite veining associated with the marginal areas of this granite.

Of the other elements analysed the most intriguing must be silver. This is quite widely spread in the southern half of the island and appears to be associated with some of the basic minor intrusives. These, of course, are particularly well developed on the island, and if the carriers of silver, must be worth further study. Barytes was formerly worked in the lower reaches of Glen Sannox and further anomalies for this mineral might be expected. There are no analysed samples from the Sannox area but available samples from the environs of the northern granite do include some with highly anomalous Ba levels. The best clustering of high Ba value, however, is found over the Palaeozoic sediments east of Machrie Bay. It seems desirable that these should be examined.

Occasional very high values for Cu and Pb require to be explained since they occur in lithologies which might well host sulphide mineralisation. At this stage there is no evidence to write them off as contamination and, therefore, they need to be taken seriously. Less significant seems the distribution of arsenic and antimony, the common tracer elements for sulphide mineralisation; the former is too wide-spread to be valuable while the latter has an anomalous distribution which, although restricted, seems meaningless.

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APPENDIX: Panned concentrate analyses.

Sample	Grid Ref.	Ce	Ba	Sb	Sn	Pb	Zn	Cu
XPP1401	NR9653.2293	7	320	4	28	10	64	6
1405	NR9310.2700	28	320	3	0	10	36	0
1410	NR9636.2245	8	264	0	2	14	56	3
1412	NR9688.2062	55	193	5	93	26	173	16
1425	NR9649.2357	29	187	5	0	11	85	6
1443	NR9634.2365	16	321	1	5	15	78	5
1445	NR9445.2493	15	383	1	0	46	114	15
1460	NR9359.2486	36	208	4	0	21	81	7
1469	NR9290.2587	31	390	0	0	12	134	18
1470	NR9268.2495	13	292	1	1	12	14	3
1481	NR9276.2575	45	151	6	4	25	288	18
1484	NR9332.2509	34	411	0	0	14	126	12
1490	NR9705.2459	31	177	4	0	16	97	5
1601	NS0323.3463	78	146	2	58	40	51	7
1602	NS0320.2131	21	144	1	29	380	139	11
1603	NS0148.2920	10	119	7	2	27	107	6
1605	NS0354.3230	25	178	0	4	22	99	9
1608	NR9845.2903	25	20	3	5	10	469	3
1609	NR9861.2565	22	314	0	4	20	151	9
1610	NS0135.2921	26	123	0	0	27	260	10
1611	NS0254.2117	156	180	14	50	73	238	25
1612	NR9932.2500	17	271	9	5	16	191	11
1613	NS0278.3513	41	116	0	12	77	73	17
1614	NR9936.2050	33	240	11	45	1158	145	1197
1615	NS0175.3316	10	84	0	8	18	410	20
1616	NR9631.2486	43	138	0	5	20	127	3
1617	NS0108.2962	0	25	8	11	45	575	28
1619	NR9430.2791	18	199	8	2	34	227	17
1620	NR9760.2982	109	210	5	3	79	120	10
1621	NR9808.2864	31	271	2	0	49	251	17
1622	NR9704.3724	753	239	2	62	27	58	4
1623	NS0463.2258	83	161	0	6	31	136	15
1624	NR9212.2328	65	1394	3	430	243	150	89
1625	NS0244.3289	33	86	0	7	21	253	13
1626	NS0395.3488	25	436	14	130	156	63	23
1627	NS0077.2266	27	228	1	2	17	296	3
1628	NR9745.2971	69	217	9	6	90	91	13
1629	NS0170.2338	55	297	3	4	11	57	4
1630	NS0422.3267	23	131	2	45	629	117	14
1632	NS0187.2889	50	136	1	2	21	114	5
1633	NR9982.2193	33	270	0	19	6	91	3
1634	NS0484.3294	118	106	0	12	36	126	14
1635	NR9467.2641	41	283	0	0	38	126	12
1636	NR9959.2860	29	33	3	8	16	420	1
1637	NR9676.2867	23	159	0	0	30	33	8
1638	NR9990.3125	73	181	0	9	152	77	29
1639	NS0190.2347	18	200	0	2	33	350	4
1640	NR9432.2652	20	246	4	2	61	153	28
1641	NR9990.3156	23	1597	4	3	26	56	9
1642	NR9724.2832	8	159	0	4	34	48	10
1643	NR9762.2899	114	172	3	1	125	134	25

APPENDIX (cont.)

Sample	Ca	Ni	Fe	Mn	Ti	Ag	U	Rb	Th
XPP1401	2830	6	43670	440	9940	0	0	36	5
1405	3650	7	30950	250	3810	0	1	40	3
1410	5880	11	40620	500	7920	3	2	33	5
1412	18880	28	124530	2440	24750	2	2	15	6
1425	7630	14	60470	870	15580	0	1	20	2
1443	2330	12	54850	650	10800	1	0	37	3
1445	8250	24	93880	940	10830	4	0	25	0
1460	6310	16	80540	990	12230	3	2	23	3
1469	13830	40	68070	1350	11440	2	4	55	5
1470	2790	2	16430	180	2470	0	2	40	1
1481	11220	40	215750	4830	38200	8	6	15	12
1484	12480	28	84620	1410	9840	3	0	53	3
1490	7520	12	75810	1160	23180	3	0	17	2
1601	2560	17	163650	730	13020	6	2	13	3
1602	20670	25	108750	1450	26540	3	0	12	4
1603	8930	22	84170	770	14050	3	3	13	2
1605	4710	21	120890	670	19630	5	6	24	7
1608	9110	6	291060	14410	148700	16	0	3	1
1609	4740	17	93600	1400	31820	7	0	44	2
1610	8830	48	173530	2460	38900	8	0	13	7
1611	17500	42	233340	4360	43270	8	4	8	15
1612	7260	17	86030	1510	19930	5	1	54	3
1613	1630	24	275220	1290	24370	9	9	17	11
1614	7980	14	95050	1560	20560	4	2	39	10
1615	10930	167	249450	4840	77000	8	0	5	0
1616	2920	17	138480	2260	51500	7	5	11	5
1617	16230	146	287290	7030	110500	14	0	2	3
1619	27890	42	114370	1880	13250	5	3	22	8
1620	2140	60	182680	1080	15990	5	3	22	5
1621	5980	67	109640	1840	14250	1	3	40	5
1622	28580	16	62470	1100	15010	0	4	47	65
1623	10980	24	149540	2140	25990	6	5	17	2
1624	8330	32	149310	1700	24460	2	1	27	6
1625	13950	78	166880	2500	42700	8	0	7	3
1626	1570	40	376990	1710	14210	13	2	9	2
1627	16980	11	160900	2960	40000	6	1	25	5
1628	3550	84	209730	1490	12500	5	4	28	7
1629	4980	11	54310	680	10240	1	1	42	6
1630	5160	26	166140	1090	26910	7	1	14	7
1632	6600	31	128220	1160	23310	4	2	14	2
1633	7340	7	79510	1790	17250	0	3	34	9
1634	10080	40	168530	1520	36050	6	5	15	14
1635	7360	35	103430	1430	8820	3	0	35	6
1636	23800	4	253330	9190	130900	18	0	7	2
1637	920	6	44700	210	3900	0	1	24	0
1638	2510	152	392700	4510	15490	12	2	7	11
1639	19260	14	181270	3230	44300	9	0	22	7
1640	15330	44	120200	1620	10690	6	3	29	6
1641	2570	23	61080	600	5270	2	2	29	3
1642	5130	19	68830	600	6150	1	1	18	3
1643	2960	90	334110	3140	20570	14	6	17	4

APPENDIX (cont.)

Sample	Nb	Sr	Zr	Y	Mo	As	W	Bi
1401	17	31	343	15	1	2	4	0
1405	12	61	347	15	0	3	2	0
1410	11	39	173	14	0	4	3	0
1412	16	45	1284	53	0	1	4	1
1425	14	27	197	12	0	2	2	0
1443	15	51	265	11	1	1	4	1
1445	13	41	486	16	0	6	3	0
1460	11	39	290	16	1	5	5	0
1469	10	112	469	23	0	5	3	0
1470	8	48	227	11	1	1	6	0
1481	49	46	4643	75	5	2	9	2
1484	11	82	172	21	1	3	4	0
1490	22	25	229	13	2	4	1	0
1601	25	22	2251	23	4	8	3	1
1602	15	50	588	24	2	1	3	0
1603	6	25	591	10	0	0	1	0
1605	28	36	4986	38	4	0	6	3
1608	75	16	406	23	10	1	0	1
1609	28	44	638	20	2	2	4	0
1610	15	28	489	11	4	2	2	0
1611	44	44	2710	70	5	8	10	0
1612	19	79	528	29	0	2	3	0
1613	37	26	4451	31	8	12	4	2
1614	24	59	3325	47	1	2	5	3
1615	22	31	372	9	1	0	0	0
1616	70	16	3830	34	4	3	5	3
1617	28	35	489	9	5	2	0	1
1619	15	41	648	20	1	8	3	0
1620	33	34	1242	21	2	11	2	0
1621	21	36	384	15	2	8	4	0
1622	116	121	1609	88	0	9	8	0
1623	23	40	1777	44	1	3	6	0
1624	26	67	956	29	4	5	4	3
1625	22	29	587	13	4	3	2	0
1626	20	33	939	15	7	23	3	0
1627	39	72	1348	47	2	4	4	0
1628	25	48	777	24	2	8	0	0
1629	18	47	1439	28	1	1	4	0
1630	25	31	2339	21	2	5	0	2
1632	15	26	626	12	3	7	0	0
1633	21	55	1932	58	0	1	8	0
1634	49	38	5279	42	3	3	5	5
1635	14	51	278	19	1	6	1	0
1636	82	30	280	29	9	0	5	0
1637	17	18	968	16	0	6	6	0
1638	29	42	310	26	4	17	2	0
1639	33	43	389	27	2	7	0	0
1640	10	51	217	19	3	10	4	0
1641	12	37	813	15	0	3	3	1
1642	10	24	280	10	1	10	5	0
1643	35	39	1191	29	7	19	0	0

APPENDIX (cont.)

Sample	Grid Ref.	Ce	Ba	Sb	Sn	Pb	Zn	Cu
XPP1644	NR9530.2428	14	8500	1	0	26	151	12
1645	NR9839.2512	35	134	0	0	20	103	3
1646	NS0324.3235	32	335	5	34	223	194	17
1647	NR9904.2208	27	177	0	42	22	171	20
1648	NR9609.2683	0	170	7	4	26	513	18
1650	NR9934.2953	27	411	1	0	40	162	11
1651	NS0222.2300	192	77	6	11	19	214	6
1652	NS0098.2272	25	141	8	12	11	498	10
1653	NS0260.3281	38	119	4	21	47	126	15
1654	NR9799.2055	58	167	0	141	121	188	28
1655	NR9980.2862	39	131	0	3	10	198	2
1656	NR9920.3002	27	106	0	1	15	14	6
1657	NR9842.2885	57	211	0	0	24	136	7
1658	NR9874.3119	76	147	0	3	139	71	28
1659	NR9123.2422	49	280	1	9	25	159	13
1660	NS0470.2456	17	142	5	581	876	257	74
1661	NR9990.2499	59	107	2	0	32	196	11
1663	NR9883.2650	28	182	0	6	13	206	4
1665	NR9564.2617	48	209	3	3	49	333	13
1666	NR9552.2580	24	195	0	3	11	72	2
1668	NS0161.2178	23	187	4	0	25	392	109
1669	NR9555.3830	21	322	8	2	10	52	7
1670	NS0225.2272	29	209	11	1	25	161	11
1671	NR9889.3137	56	187	4	5	42	62	10
1672	NR9746.2065	27	418	1	38	21	109	16
1673	NR9615.2824	32	185	0	0	56	79	11
1675	NR9779.3125	75	128	14	7	188	63	32
1676	NR9640.3685	122	468	0	4	13	48	2
1677	NS0206.3462	35	134	2	13	22	33	1
1678	NS0197.2215	41	159	1	50	8	82	19
1679	NR9377.2368	28	1277	5	3	106	71	10
1680	NR9953.2455	64	148	6	8	22	229	20
1681	NS0286.3261	40	122	2	59	47	108	13
1683	NR9691.2875	40	247	0	7	54	93	18
1684	NS0478.2271	38	152	0	23	25	106	7
1685	NR9895.2655	28	268	0	5	22	261	8
1686	NS0005.2831	13	185	3	4	13	76	5
1687	NR9512.2728	27	676	0	0	26	63	7
1688	NR9999.2167	33	311	0	5	13	75	6
1689	NR9524.2443	10	344	7	11	29	99	42
1692	NR9664.2785	25	378	6	3	166	119	4
1694	NS0429.3294	29	159	0	12	37	95	10
1695	NS0300.2223	0	271	6	1	14	113	14
1697	NR9633.2740	47	152	0	2	62	156	11
1698	NS0165.3429	26	432	4	0	25	33	9
1699	NS0112.2164	28	285	5	0	15	194	37
1700	NS0095.2283	12	65	6	6	33	563	11
1801	NS0311.2815	9	203	0	7	14	142	17
1802	NR9712.3507	34	144	0	0	9	99	13
1803	NR9543.3425	68	254	2	0	32	205	18
1804	NR9880.3348	35	111	7	5	26	68	3

APPENDIX (cont.)

Sample	Ca	Ni	Fe	Mn	Ti	Ag	U	Rb	Th
XPP1644	4450	21	107790	1680	26490	4	3	29	7
1645	4990	6	104600	2010	63200	7	3	17	0
1646	4240	36	276700	2190	46050	8	5	7	7
1647	10330	23	134670	1220	16660	3	1	19	3
1648	20510	84	243030	5670	41700	10	0	10	0
1650	10440	19	129780	3180	30050	7	0	21	3
1651	17780	32	227130	8480	62700	9	8	6	14
1652	24070	9	286010	4830	72800	13	1	14	0
1653	10920	35	195330	1640	28700	10	4	12	1
1654	20670	27	121870	2320	28170	8	2	15	3
1655	47840	6	143280	5270	65300	9	0	11	2
1656	410	5	46980	120	5240	2	2	21	6
1657	2230	23	93030	1150	22630	2	5	27	4
1658	1940	163	412920	4920	14630	13	6	10	10
1659	6170	23	141310	1630	26980	5	2	31	5
1660	25030	35	151000	2450	42650	7	0	9	0
1661	9510	34	156970	2090	41600	7	4	14	6
1663	6800	5	144560	2430	54800	7	4	16	2
1665	12090	62	230430	4320	43830	9	0	5	2
1666	2940	11	58710	580	10390	4	0	26	2
1668	27210	37	184580	3360	37900	9	1	16	1
1669	1480	8	21550	350	3290	0	1	50	9
1670	22170	18	101470	1780	27720	2	2	21	2
1671	1650	59	158590	1690	8210	1	2	18	1
1672	8880	20	61830	990	9470	1	1	51	6
1673	3120	34	168100	1180	12770	4	6	23	9
1675	1600	176	448740	5700	15710	16	6	8	15
1676	9490	16	38570	340	4290	1	1	80	12
1677	930	9	114690	750	7880	5	5	17	6
1678	12550	16	93570	1980	15010	2	0	18	3
1679	6330	15	58930	710	6250	0	0	38	4
1680	19100	34	138390	1910	39940	5	3	16	7
1681	6990	22	154670	1220	29410	7	3	12	4
1683	4120	39	132630	1150	9170	3	1	26	6
1684	7850	19	112060	1080	22220	6	4	19	6
1685	8020	15	167320	3320	59200	8	3	26	5
1686	35490	33	55390	840	16560	3	3	32	3
1687	7780	28	94240	750	8700	3	0	20	3
1688	7540	9	56910	720	12580	1	4	46	7
1689	3160	16	130210	1150	30800	5	9	23	10
1692	1770	13	79370	1720	18460	5	2	31	5
1694	6080	18	86190	600	16410	2	2	20	5
1695	22430	23	97340	2500	12650	6	2	27	4
1697	3800	39	167010	1520	24250	5	0	20	8
1698	1650	11	93300	440	9550	2	6	21	3
1699	25400	29	128410	2460	27840	4	0	22	2
1700	12970	9	318470	3860	100800	17	1	11	0
1801	15600	21	79220	800	23000	0	3	25	2
1802	35570	31	93070	1590	17170	4	2	19	5
1803	22060	35	112240	1240	11130	5	2	31	7
1804	9630	22	60250	460	4980	0	2	19	0

APPENDIX (cont.)

Sample	Nb	Sr	Zr	Y	Mo	As	W	Bi
XPP1644	28	122	3415	32	3	1	6	1
1645	86	19	1836	27	3	0	2	3
1646	32	25	2825	24	4	8	0	3
1647	17	37	1277	23	2	11	5	0
1648	22	61	378	18	6	0	0	0
1650	20	34	279	16	0	17	3	1
1651	75	23	5287	153	3	2	13	2
1652	31	63	279	19	3	3	0	0
1653	20	45	1181	19	1	4	2	1
1654	21	43	1498	44	1	2	9	0
1655	59	120	199	35	4	0	1	0
1656	12	14	1656	16	0	0	5	0
1657	25	28	377	15	0	3	6	1
1658	25	48	248	22	4	14	3	0
1659	34	51	890	21	2	4	3	0
1660	14	50	306	17	1	1	5	2
1661	34	31	2235	27	6	9	5	1
1663	61	29	1089	23	2	3	3	1
1665	28	31	766	22	2	5	0	0
1666	14	27	812	12	0	1	0	0
1668	16	58	761	31	2	0	0	0
1669	12	40	1293	23	0	0	3	0
1670	13	49	572	35	0	0	2	0
1671	16	34	688	13	0	9	1	0
1672	16	74	1298	30	0	1	4	0
1673	27	32	2109	23	3	8	2	2
1675	32	44	281	21	8	14	3	0
1676	21	73	246	22	0	2	8	0
1677	19	21	988	14	0	5	2	0
1678	13	39	889	52	0	1	6	0
1679	10	54	254	18	0	4	2	4
1680	35	46	4555	49	1	4	6	2
1681	22	25	2748	20	2	3	3	2
1683	18	36	1026	16	0	13	2	0
1684	21	33	2202	26	0	0	4	0
1685	75	43	624	28	4	3	3	0
1686	20	53	530	29	0	1	4	0
1687	18	54	403	15	0	4	0	0
1688	21	77	3081	34	0	0	4	0
1689	35	31	5154	45	4	4	8	2
1692	23	28	1424	20	0	5	2	2
1694	12	32	1142	16	0	0	1	0
1695	9	62	864	53	1	3	6	0
1697	25	25	1585	21	3	7	7	0
1698	18	27	1193	17	0	3	4	0
1699	13	78	237	32	1	1	6	0
1700	39	34	201	17	8	16	0	0
1801	11	56	827	15	0	0	3	0
1802	14	70	420	26	1	1	1	0
1803	15	112	363	25	1	11	7	1
1804	13	52	240	10	0	4	4	0

APPENDIX (cont.)

Sample	Grid Ref.	Ce	Ba	Sb	Sn	Pb	Zn	Cu
XPP1805	NR9929.3694	225	703	1	15	38	84	5
1807	NR9731.3438	60	189	0	15	16	32	6
1808	NR9650.3667	148	447	0	0	11	66	46
1809	NR9201.3415	766	968	6	47	64	146	24
1810	NR9930.2384	33	136	2	7	17	318	25
1811	NS0017.3473	30	111	1	24	57	29	4
1813	NR9688.3561	29	157	0	0	20	218	20
1815	NR9236.3018	51	245	4	6	20	145	22
1816	NR9617.3094	50	333	1	8	25	169	25
1817	NS0005.2379	18	236	6	0	14	47	4
1818	NR9531.3599	120	376	0	0	13	57	9
1819	NR9120.3185	116	340	0	0	20	37	3
1820	NR9672.3115	82	348	7	3	68	105	10
1821	NS0180.2572	22	450	0	0	14	110	12
1822	NS0018.3130	40	95	1	4	44	278	16
1823	NR9956.3422	9	77	0	0	28	45	3
1824	NS0331.2694	14	242	0	0	7	63	6
1825	NR9118.3376	252	178	0	5	13	41	8
1826	NR9591.3309	18	1051	3	0	12	59	10
1828	NR9347.2985	51	161	13	3	63	160	28
1829	NS0017.2491	0	245	3	3	13	110	10
1831	NS0096.2799	4	187	0	1	15	33	0
1832	NR9967.3648	34	151	6	4	24	54	8
1833	NS0160.2663	44	2939	0	0	23	78	8
1834	NR9194.3267	41	228	3	0	16	132	9
1835	NR9791.3630	10	233	4	0	6	62	2
1836	NR9866.2305	82	208	0	8	8	25	2
1837	NR9803.3455	104	881	0	0	44	144	0
1838	NR9448.3205	3	419	1	0	13	37	0
1840	NS0105.2598	22	262	4	1	13	63	10
1841	NS0196.2550	31	179	0	8	8	63	3
1842	NR9452.3190	20	381	0	0	14	57	0
1844	NS0293.2855	24	217	1	0	10	30	5
1845	NR9480.3232	19	610	3	1	22	31	0
1846	NR9972.3454	77	83	0	12	63	55	11
1847	NS0056.2577	58	246	3	6	16	110	10
1849	NR9803.3467	21	175	4	0	0	27	0
1850	NS0439.2525	36	349	0	3	12	171	18
1852	NS0234.3244	19	125	1	7	30	55	4
1853	NS0172.3098	21	116	6	94	19	43	1
1854	NR9348.3194	54	396	7	4	30	102	9
1856	NR9649.3531	115	297	1	6	27	361	15
1857	NR9978.2435	36	105	1	1	30	355	28
1858	NS0158.3092	43	196	0	49	132	97	13
1860	NR9514.3430	62	304	3	3	23	128	7
1861	NR9505.3596	195	256	9	21	25	48	5
1862	NR9881.3650	75	718	0	0	27	78	8
1863	NR9585.3055	15	206	8	6	11	25	3
1864	NR8970.3190	94	198	0	4	45	22	2
1865	NS0012.3911	176	476	5	41	27	119	5
1866	NR9237.2888	20	345	0	2	18	105	13

APPENDIX (cont.)

Sample	Ca	Ni	Fe	Mn	Ti	Ag	U	Rb	Th
XPP1805	4200	22	78640	510	11450	1	5	43	13
1807	8830	8	63120	480	7320	1	2	28	6
1808	15290	25	53280	510	7580	2	1	78	16
1809	5720	24	127600	1610	18170	3	11	54	52
1810	32930	47	183300	5020	49960	6	3	14	2
1811	1060	15	181300	1040	6900	4	2	9	1
1813	15840	81	207150	3430	44560	8	3	21	2
1815	8230	24	127690	1550	19970	3	1	29	2
1816	27420	54	195850	2690	26980	8	3	29	4
1817	3320	5	38740	960	4350	0	0	44	4
1818	13430	20	49760	510	7570	2	2	58	14
1819	6780	9	49990	410	8500	0	4	41	10
1820	28810	54	165880	2090	18650	6	5	27	7
1821	21540	39	69240	1110	11560	4	3	21	3
1822	13310	254	268760	3950	43000	10	1	5	2
1823	1750	13	81990	740	4420	1	2	11	3
1824	7290	12	47880	640	7690	0	1	31	4
1825	1690	8	61410	790	9570	1	5	31	21
1826	12470	19	42950	510	3710	2	1	75	8
1828	4880	40	246090	2220	32040	10	2	16	10
1829	9500	15	57900	1030	14180	1	3	27	4
1831	7100	5	26410	200	5790	0	1	30	3
1832	1220	14	70800	400	10710	2	4	18	7
1833	4040	30	68760	1100	6890	0	0	50	7
1834	13730	22	102430	2130	24140	3	2	24	3
1835	8790	17	27370	570	3300	0	3	36	3
1836	4670	4	23050	240	4050	0	2	30	11
1837	860	0	54360	1840	1320	2	7	83	14
1838	980	0	11140	130	950	0	1	90	8
1840	5090	11	44940	740	6620	2	1	32	3
1841	8020	17	76360	620	13260	1	0	25	4
1842	2670	3	23250	200	1950	0	3	83	9
1844	3560	7	29650	240	4550	1	5	34	1
1845	640	0	11540	120	810	0	3	130	8
1846	3190	11	245960	1210	24460	10	1	8	7
1847	6030	10	92890	1210	19060	5	4	27	3
1849	4040	0	30390	230	2950	0	2	31	6
1850	22500	18	131760	1870	22890	4	2	29	3
1852	1830	4	124590	500	13380	4	4	19	0
1853	2430	1	68570	430	12340	2	1	16	4
1854	1290	9	37650	220	2260	0	5	121	11
1856	30870	15	179710	2920	27540	8	11	41	11
1857	30960	28	185150	3540	54600	8	4	10	0
1858	3580	13	177160	1250	24210	5	1	23	8
1860	9630	7	91500	760	10460	0	3	49	12
1861	21510	5	49240	630	10200	2	2	51	15
1862	4410	8	95800	580	9590	1	3	44	7
1863	3390	3	26110	400	5830	2	0	30	3
1864	1600	2	19420	220	3550	0	5	28	9
1865	7320	5	51130	460	6770	4	4	94	20
1866	13920	13	46230	790	5640	3	0	40	2

APPENDIX (cont.)

Sample	Nb	Sr	Zr	Y	Mo	As	W	Bi
XPP1805	49	147	879	33	0	4	2	0
1807	15	68	286	20	0	3	3	0
1808	25	118	662	32	0	3	6	0
1809	134	103	1644	80	6	22	11	0
1810	18	81	1166	67	0	2	5	0
1811	10	18	358	8	2	10	0	0
1813	17	59	280	13	1	1	0	1
1815	22	58	520	25	3	8	1	0
1816	19	104	217	24	2	22	0	1
1817	8	58	715	37	0	1	6	0
1818	23	109	363	27	1	4	5	0
1819	30	83	736	28	0	2	5	1
1820	23	130	411	24	2	29	6	1
1821	8	39	510	19	0	2	1	0
1822	0	30	438	13	4	7	2	1
1823	9	21	303	8	2	3	4	0
1824	6	36	375	27	1	0	2	0
1825	45	37	1241	31	0	6	4	0
1826	12	74	176	28	0	5	6	0
1828	44	31	1557	28	4	30	6	0
1829	10	51	291	14	1	0	2	0
1831	15	22	231	12	1	0	7	0
1832	27	69	2557	34	0	17	1	2
1833	14	277	498	16	1	4	4	0
1834	20	56	1453	56	2	2	6	2
1835	8	39	151	11	1	0	3	0
1836	19	65	435	14	0	1	3	0
1837	28	33	366	55	1	1	4	1
1838	7	26	228	27	0	5	7	1
1840	11	38	1097	31	1	1	5	1
1841	12	34	575	14	0	7	0	0
1842	11	38	217	30	2	3	5	0
1844	6	41	862	14	0	2	4	0
1845	8	33	255	33	1	8	7	0
1846	37	20	3266	28	1	11	3	2
1847	20	34	1907	26	1	2	4	1
1849	11	44	231	24	1	0	4	0
1850	14	76	2664	34	3	0	5	0
1852	18	18	1327	13	0	3	5	0
1853	12	18	580	15	0	1	3	0
1854	14	36	335	52	2	33	5	1
1856	31	72	309	43	4	0	8	0
1857	24	169	711	25	3	5	1	0
1858	23	32	1943	21	2	6	2	0
1860	32	65	507	35	5	9	5	0
1861	39	123	1679	36	0	1	7	0
1862	19	296	496	17	1	5	1	0
1863	6	34	266	7	0	5	10	0
1864	19	37	499	19	1	1	4	0
1865	56	83	452	59	2	0	7	0
1866	11	56	297	18	1	2	2	0

APPENDIX (cont.)

Sample	Grid Ref.	Ce	Ba	Sb	Sn	Pb	Zn	Cu
XPP1867	NR9597.3321	13	336	3	0	19	142	9
1869	NS0244.3225	35	67	7	12	55	244	14
1870	NR9887.3793	359	457	2	5	11	191	28
1871	NS0055.3815	294	1528	5	133	29	249	15
1872	NR9782.3295	35	128	0	0	15	80	17
1873	NS0121.2677	14	301	0	3	10	89	9
1874	NR9618.3525	126	250	2	5	17	356	22
1875	NR9953.3465	65	193	23	0	2231	58	15
1876	NR9563.3359	30	483	6	2	25	60	4
1877	NR9869.3364	12	102	5	3	21	261	23
1878	NR9586.3379	28	268	0	1	15	122	7
1879	NS0225.2999	7	132	1	13	11	21	1
1880	NR9651.3567	5	86	3	0	68	292	19
1881	NR9476.3558	107	196	0	3	21	45	1
1882	NS0297.2625	0	313	0	0	14	50	6
1883	NR9080.3368	482	297	7	9	21	49	8
1884	NS0062.2731	8	299	0	0	9	165	14
1885	NS0094.3095	71	189	1	4	21	101	10
1886	NS0417.2825	33	265	6	6	22	167	13
1888	NR9545.3384	0	361	5	2	9	32	0
1889	NS0253.2468	21	236	3	2	8	307	31
1890	NS0291.2546	3	472	2	0	16	148	11
1891	NR9860.3469	20	341	5	0	23	107	8
1892	NR9783.3280	22	128	5	0	24	59	6
1893	NS0251.2831	0	291	3	0	12	119	7
1894	NR9241.3085	164	237	9	8	26	94	11
1895	NR9845.3588	55	313	0	3	14	50	8
1897	NR9472.3501	32	329	0	0	23	133	20
1899	NR9149.3260	154	104	2	35	17	82	0
1900	NR9898.3650	159	389	6	3	14	39	0
2001	NR9345.3934	45	181	2	33	15	47	0
2002	NR9231.3614	72	1786	0	6	33	128	14
2003	NR9520.3865	2555	145	0	25	29	264	3
2004	NR9229.3832	63	83	2	18	18	43	0
2005	NR9664.3989	3166	92	0	352	51	723	19
2006	NR8957.3824	130	106	0	5	20	31	4
2008	NR8910.4661	1435	311	5	12	22	77	0
2009	NR9502.4817	269	114	2	6	27	42	0
2010	NR8912.3934	734	427	1	97	33	80	9
2011	NR8786.4300	77	327	2	24	26	49	0
2012	NR9699.3866	4459	0	9	193	43	830	11
2013	NR8728.3905	65	513	2	2	22	85	0
2015	NR9385.4195	155	41	0	648	20	79	0
2016	NR9510.4615	26	25	1	13	20	11	0
2017	NR8654.4085	110	474	5	6	18	85	4
2018	NR9025.3414	114	447	4	3	27	63	8
2019	NR8875.3797	119	287	3	5	25	48	1
2021	NR9650.3979	5829	0	0	111	50	1276	20
2022	NR9040.4035	115	70	1	4	9	19	0
2023	NR8775.4377	387	361	3	29	44	149	22
2024	NR8717.3954	75	504	4	52	24	175	20

APPENDIX (cont.)

Sample	Ca	Ni	Fe	Mn	Ti	Ag	U	Rb	Th
XPP1867	13410	27	46570	1230	4660	1	1	46	6
1869	7640	72	248660	3750	52600	9	1	5	5
1870	37620	88	95620	1520	16120	5	3	28	25
1871	15570	26	98600	1120	10270	2	6	75	34
1872	13880	26	72510	1200	18360	3	0	20	6
1873	11610	20	29020	670	3250	0	1	38	2
1874	28480	45	229850	3730	34560	8	3	29	14
1875	4240	23	172700	1370	5430	4	5	25	6
1876	3670	5	32480	380	2170	0	2	108	10
1877	29680	88	211330	4210	43990	8	0	10	0
1878	18960	19	53860	560	3840	2	3	40	5
1879	1390	5	31620	170	4640	0	3	27	1
1880	75960	67	152700	3030	25010	8	1	7	3
1881	13430	14	52430	410	6890	0	1	36	11
1882	4700	9	27150	330	3610	0	4	54	7
1883	3330	11	43390	510	8800	0	8	59	34
1884	37670	71	57860	1240	6480	2	0	31	4
1885	6850	61	128620	1090	45500	7	1	20	7
1886	15160	47	164520	1940	33560	6	3	14	1
1888	1840	3	22600	150	1610	0	2	84	4
1889	62400	96	117720	2600	22190	4	0	10	2
1890	12670	23	90020	1390	15800	5	0	31	2
1891	4290	9	37100	950	2090	1	3	56	7
1892	25260	26	70790	1410	23120	2	0	14	5
1893	6040	18	67920	830	16840	1	1	23	1
1894	8390	16	113780	1540	25990	6	3	29	14
1895	2500	18	60330	470	9920	2	0	29	6
1897	21820	37	96550	1740	7980	0	3	48	5
1899	2680	1	28300	290	2560	0	4	126	25
1900	2080	10	24310	280	2590	0	4	82	14
2001	3070	5	16450	180	2190	0	2	37	7
2002	4210	37	145380	1410	21800	5	2	23	8
2003	5040	6	69760	960	14900	0	24	90	166
2004	2120	3	27500	370	3660	0	9	67	23
2005	24460	37	195610	4030	48150	6	37	57	192
2006	2600	4	17030	140	1850	0	2	77	18
2008	7960	13	46670	850	11010	0	14	95	94
2009	6820	4	29030	300	3390	0	10	129	42
2010	7670	17	62300	1030	15580	1	16	90	62
2011	2940	1	16540	150	1100	1	1	99	10
2012	25860	34	209760	5810	53400	10	47	50	255
2013	3120	28	63530	770	5830	0	0	115	13
2015	4360	4	33870	320	3830	0	8	106	23
2016	540	0	3900	40	210	3	3	129	5
2017	2940	23	51360	450	5020	1	1	96	13
2018	2150	13	63630	920	5170	0	3	45	11
2019	4630	8	30890	400	4060	1	0	90	15
2021	17300	39	268200	7480	66100	8	61	56	327
2022	1120	0	6380	70	1150	0	5	79	16
2023	9860	34	65020	1760	9380	2	7	107	31
2024	7300	48	75680	1190	5930	0	2	116	8

APPENDIX (cont.)

Sample	Nb	Sr	Zr	Y	Mo	As	W	Bi
XPP1867	9	94	166	20	1	7	2	1
1869	30	23	1561	17	4	7	4	2
1870	44	323	566	53	2	1	4	0
1871	53	169	806	83	7	3	5	14
1872	23	60	580	19	0	6	3	2
1873	3	43	160	11	0	1	1	0
1874	34	66	455	43	4	0	2	0
1875	15	40	436	20	5	23	8	3
1876	14	46	269	33	2	4	4	0
1877	15	48	139	15	1	2	1	1
1878	12	101	157	17	1	5	5	0
1879	8	23	859	11	0	0	4	0
1880	6	113	147	24	2	0	0	0
1881	21	145	459	25	2	2	5	1
1882	10	56	1424	20	0	2	2	0
1883	58	69	815	55	0	9	7	0
1884	6	41	151	21	0	4	5	0
1885	30	34	2773	24	1	0	3	1
1886	13	40	276	14	2	5	0	0
1888	10	32	195	28	0	3	5	0
1889	8	132	282	24	0	0	4	0
1890	12	61	716	26	0	0	0	0
1891	13	48	270	33	1	3	4	1
1892	16	85	127	15	0	2	2	0
1893	7	28	360	8	0	0	1	0
1894	54	65	2445	46	1	2	8	1
1895	19	56	464	16	0	8	3	0
1897	16	108	185	29	1	9	4	0
1899	49	11	377	70	2	0	12	0
1900	26	49	214	24	0	2	6	0
2001	12	44	238	19	0	3	4	0
2002	23	98	781	29	1	10	5	0
2003	229	22	2239	271	9	0	18	8
2004	31	22	414	40	5	7	12	0
2005	431	32	3459	344	24	0	28	2
2006	34	14	250	39	0	2	11	0
2008	153	64	957	125	1	1	13	1
2009	31	17	402	85	1	0	9	0
2010	130	94	871	80	2	14	11	0
2011	24	26	230	47	0	0	3	0
2012	668	22	4394	403	33	0	34	7
2013	25	58	229	23	0	5	1	0
2015	34	6	293	53	3	4	9	1
2016	8	3	62	20	0	0	4	0
2017	21	83	353	22	0	6	3	0
2018	15	59	354	22	0	10	4	0
2019	29	51	294	28	4	4	5	0
2021	676	15	5402	588	44	0	53	5
2022	25	6	196	31	0	0	7	0
2023	63	64	546	57	2	11	2	1
2024	14	103	191	22	1	17	3	0

APPENDIX (cont.)

Sample	Grid Ref.	Ce	Ba	Sb	Sn	Pb	Zn	Cu
XPP2025	NR9812.3870	741	3349	0	39	27	163	10
2026	NS0001.3898	89	479	0	3	27	101	5
2027	NR8931.3581	27	37200	0	2	13	60	9
2028	NR9524.4616	23	40	1	30	29	39	0
2029	NR8975.3482	92	266	7	25	245	41	12
2030	NR9485.4828	7478	29	0	147	15	209	4
2032	NR9112.4142	41	17	8	34	15	14	0
2033	NS0124.4007	212	416	5	54	37	62	2
2034	NR9425.3652	594	399	10	28	14	54	6
2035	NR8851.4706	242	341	4	6	31	82	7
2036	NR9223.3621	360	287	5	11	15	31	0
2037	NR9457.3766	558	325	3	14	23	23	2
2038	NR9634.3880	6428	94	4	27	21	206	0
2039	NR8794.4496	98	510	6	7	29	115	110
2040	NR9471.3754	700	313	11	9	1017	35	0
2041	NR8931.4425	564	265	3	4	16	59	0
2042	NR9396.3640	373	296	2	23	21	63	0
2043	NS0110.3871	166	455	2	10	36	63	8
2044	NR8908.4378	2088	205	0	51	13	402	3
2046	NR9610.4665	402	83	0	6	23	120	31
2047	NR9347.3794	134	255	0	36	21	18	0
2048	NR9532.4737	319	118	5	6	23	28	2
2049	NR8993.3945	100	112	7	188	14	28	0
2050	NR9030.3684	58	132	0	17	12	22	0
2051	NR8685.4023	82	373	7	29	17	106	9
2052	NR9389.3559	469	401	0	40	29	82	2
2054	NR9254.3852	50	319	6	19	29	39	0
2055	NR8789.4414	385	278	0	5	19	34	0
2056	NR9395.3466	84	290	2	6	471	209	19
2058	NS0110.4000	93	256	4	13	30	44	0
2059	NR9713.3839	2264	299	0	119	26	143	4
2060	NR9428.3480	38	145	0	1	6	286	20
2061	NR9823.3898	7611	0	0	329	34	1814	18
2062	NR9821.4670	4385	246	0	30	31	263	0
2064	NR9294.3172	58	259	3	9	40	239	16
2065	NR8895.4690	123	493	8	3	28	81	9
2066	NR9564.4313	153	191	0	5	36	71	0
2067	NR9333.3498	182	408	1	23	25	60	11
2068	NR9064.3486	318	399	5	44	39	98	10
2069	NR8740.3869	76	349	2	11	25	190	27
2070	NR9951.3993	1004	200	0	44	17	87	0
2071	NR9465.4915	1982	245	0	73	21	302	5
2072	NR8960.4407	70	30	0	27	24	63	0
2073	NR9318.4041	68	17	0	113	34	85	0
2074	NR9747.3829	128	387	2	0	24	31	0
2075	NR9253.3121	31	309	10	645	476	57	820
2076	NR8705.4308	71	665	0	27	98	407	31
2078	NR9306.3255	61	203	2	0	49	174	34
2079	NR9504.4750	518	68	0	39	21	31	0
2081	NR9405.4107	751	143	1	81	25	230	0
2082	NR9535.3823	656	566	9	17	744	42	0

APPENDIX (cont.)

Sample	Ca	Ni	Fe	Mn	Ti	Ag	U	Rb	Th
XPP2025	12060	14	69820	830	9630	2	8	71	56
2026	8200	19	47660	710	5920	0	0	79	11
2027	4340	13	28050	450	4110	5	3	64	15
2028	5280	4	19940	170	1720	0	3	125	10
2029	2210	15	87740	620	7520	3	3	37	9
2030	5390	10	59700	2080	28660	0	74	105	412
2032	960	0	4050	80	370	0	0	84	7
2033	17550	23	37910	500	5850	0	5	62	19
2034	9120	10	37790	510	8300	1	8	74	41
2035	15700	20	58100	790	6140	1	2	70	14
2036	2750	5	19030	330	3500	0	2	76	25
2037	2740	4	16130	410	6890	2	9	91	53
2038	7180	9	70220	1870	36850	2	45	84	306
2039	13500	126	67420	660	4710	0	2	105	7
2040	3240	2	15620	240	4770	0	8	87	55
2041	2010	1	21250	260	4550	2	12	108	52
2042	9600	15	55330	890	13710	2	9	52	37
2043	13050	26	72970	450	8130	3	1	61	16
2044	5280	4	108170	1450	19080	4	16	82	125
2046	56130	47	100830	1540	11200	4	6	18	39
2047	1610	2	14640	220	1810	0	1	89	13
2048	6220	5	17990	200	1820	3	12	131	46
2049	1560	0	11310	110	1280	1	1	92	12
2050	2560	3	11470	190	1430	0	5	81	13
2051	1730	25	72820	440	10760	1	1	127	13
2052	9900	15	50800	610	10170	1	9	65	43
2054	2140	2	21740	330	2090	0	3	91	13
2055	2310	2	16420	280	4380	0	5	90	27
2056	22550	34	164870	3150	45360	8	1	39	8
2058	20620	13	31850	330	2650	0	2	59	11
2059	14910	13	61020	1260	22460	4	26	79	163
2060	47200	53	185520	3440	31360	6	0	17	2
2061	8560	17	321240	10360	67100	13	62	48	360
2062	6020	6	78770	1570	23660	2	18	115	220
2064	5340	13	67540	930	5110	2	3	65	15
2065	12570	19	54560	810	3680	0	2	109	10
2066	3360	1	19010	200	2230	1	4	102	20
2067	14930	14	38630	570	5490	1	2	53	13
2068	1900	30	164020	1590	29860	5	11	36	42
2069	3340	43	59700	800	5800	2	4	125	11
2070	3170	3	30390	520	9870	0	23	77	118
2071	4390	6	98320	1760	18720	3	24	112	126
2072	1760	1	14870	170	1250	0	13	135	30
2073	1640	1	30110	260	2130	0	6	91	22
2074	4820	5	26960	350	3650	0	5	65	12
2075	2380	10	41080	310	5850	1	1	50	3
2076	3050	44	77800	700	4740	1	1	123	7
2078	6100	31	185720	1430	20840	8	3	31	8
2079	2470	3	11930	160	1480	2	29	116	96
2081	2230	4	57290	680	7780	0	28	96	106
2082	3770	1	16220	300	6040	0	8	116	57

APPENDIX (cont.)

Sample	Nb	Sr	Zr	Y	Mo	As	W	Bi
XPP2025	88	103	940	108	7	5	18	0
2026	23	143	417	26	0	5	4	0
2027	22	883	372	27	1	1	6	0
2028	14	8	132	29	0	0	2	0
2029	20	61	996	21	2	22	6	0
2030	507	17	3310	473	5	0	44	17
2032	11	2	101	24	0	0	22	0
2033	44	465	617	41	0	6	7	0
2034	88	98	733	67	0	1	6	0
2035	33	209	383	34	0	17	6	0
2036	39	34	313	43	1	3	8	0
2037	108	32	966	70	0	0	8	0
2038	609	29	3142	391	6	0	38	3
2039	17	89	183	27	0	9	5	1
2040	84	27	518	76	0	0	8	0
2041	82	17	731	83	1	2	11	0
2042	116	153	1623	59	0	2	7	1
2043	33	291	635	33	0	5	7	0
2044	225	25	2600	218	14	0	20	0
2046	42	80	572	102	2	0	8	0
2047	22	26	232	31	0	8	6	0
2048	25	12	572	95	1	0	11	0
2049	28	9	204	33	3	0	6	0
2050	17	24	241	26	0	0	8	0
2051	38	122	1268	57	0	1	3	0
2052	89	127	1179	65	1	2	4	0
2054	31	29	287	32	0	12	6	0
2055	70	26	499	47	0	2	6	0
2056	53	90	764	42	5	0	5	0
2058	19	298	186	21	0	5	6	0
2059	350	42	2391	240	5	0	20	1
2060	17	71	372	25	2	0	4	0
2061	832	9	8265	606	80	2	41	6
2062	386	35	2486	311	15	0	23	2
2064	23	50	418	42	2	19	5	0
2065	21	124	223	38	0	7	5	0
2066	26	15	317	60	0	0	7	0
2067	36	153	531	27	0	4	7	0
2068	123	47	5608	90	4	10	9	0
2069	19	65	296	26	0	10	5	0
2070	183	20	1413	225	2	0	22	0
2071	245	20	2157	213	11	0	20	1
2072	41	5	598	66	0	0	10	1
2073	32	3	393	62	3	0	13	0
2074	29	38	312	26	0	4	5	0
2075	17	54	1008	18	0	6	4	2
2076	13	112	214	18	1	22	2	0
2078	20	40	684	26	2	23	6	0
2079	36	8	779	214	0	0	20	1
2081	105	10	1578	275	6	0	23	1
2082	117	41	666	83	2	2	10	1

APPENDIX (cont.)

Sample	Grid Ref.	Ce	Ba	Sb	Sn	Pb	Zn	Cu
XPP2083	NR8667.4119	96	538	0	8	13	109	6
2084	NR8903.4090	1496	507	0	146	33	55	2
2085	NR9120.3533	397	2037	0	11	20	64	6
2086	NR9965.4007	253	152	0	35	24	58	0
2087	NR8828.4589	173	453	3	4	21	174	13
2088	NR9175.3653	61	419	6	9	16	26	0
2089	NR9294.3140	8	287	0	2	5	54	5
2090	NS0158.3916	119	1046	0	29	40	55	2
2093	NR9314.3356	74	368	3	0	33	254	16
2094	NR8953.3675	85	1594	3	29	22	69	5
2095	NR9525.4725	50	46	0	2	34	36	0
2096	NR8925.4723	238	447	0	2	43	135	249
2098	NR8890.4067	1072	567	0	36	26	29	0
2100	NR9173.4278	72	10	4	0	14	21	0

APPENDIX (cont.)

Sample	Ca	Ni	Fe	Mn	Ti	Ag	U	Rb	Th
XPP2083	3270	27	51850	1350	3790	2	0	94	10
2084	4170	2	25340	450	15310	0	31	106	122
2085	3340	11	33020	600	5570	0	3	82	31
2086	2240	0	17510	280	3490	0	7	106	33
2087	16270	47	75140	1140	6030	4	0	116	17
2088	6680	9	20970	290	1790	2	0	71	7
2089	1260	5	28320	260	3750	3	2	27	4
2090	22200	18	56790	540	4470	4	0	40	11
2093	13930	39	117600	1360	19230	4	0	57	13
2094	3480	13	30110	610	3150	3	2	86	19
2095	4860	2	18720	180	1810	0	6	140	17
2096	16000	25	56950	970	5400	0	4	94	17
2098	4060	2	12910	260	9870	0	16	110	81
2100	1070	0	5990	80	470	0	4	100	10

APPENDIX (cont.)

Sample	Nb	Sr	Zr	Y	Mo	As	W	Bi
XPP2083	12	84	176	17	0	13	3	0
2084	285	42	1904	172	6	0	22	2
2085	46	122	486	47	0	1	5	0
2086	70	13	580	78	1	0	10	0
2087	29	162	283	51	1	18	5	0
2088	13	171	132	18	0	5	6	0
2089	11	22	408	12	0	0	2	0
2090	22	303	308	26	0	12	3	0
2093	22	116	413	37	2	5	5	0
2094	27	131	426	48	0	1	8	0
2095	20	10	216	35	0	0	7	0
2096	30	171	238	45	0	4	1	1
2098	189	43	1073	105	1	0	11	1
2100	16	3	111	34	0	0	6	0

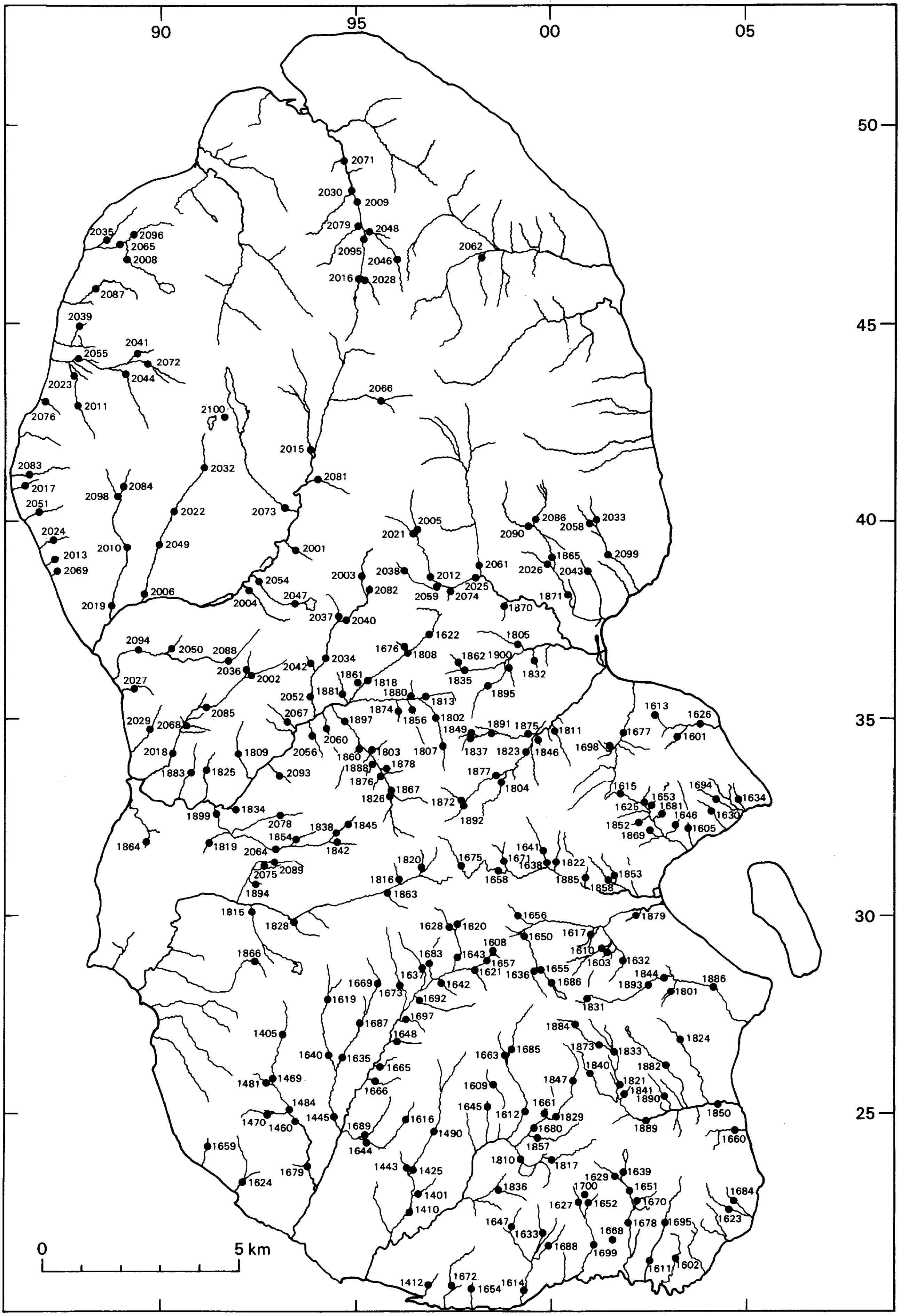

Figure 1 Location of samples

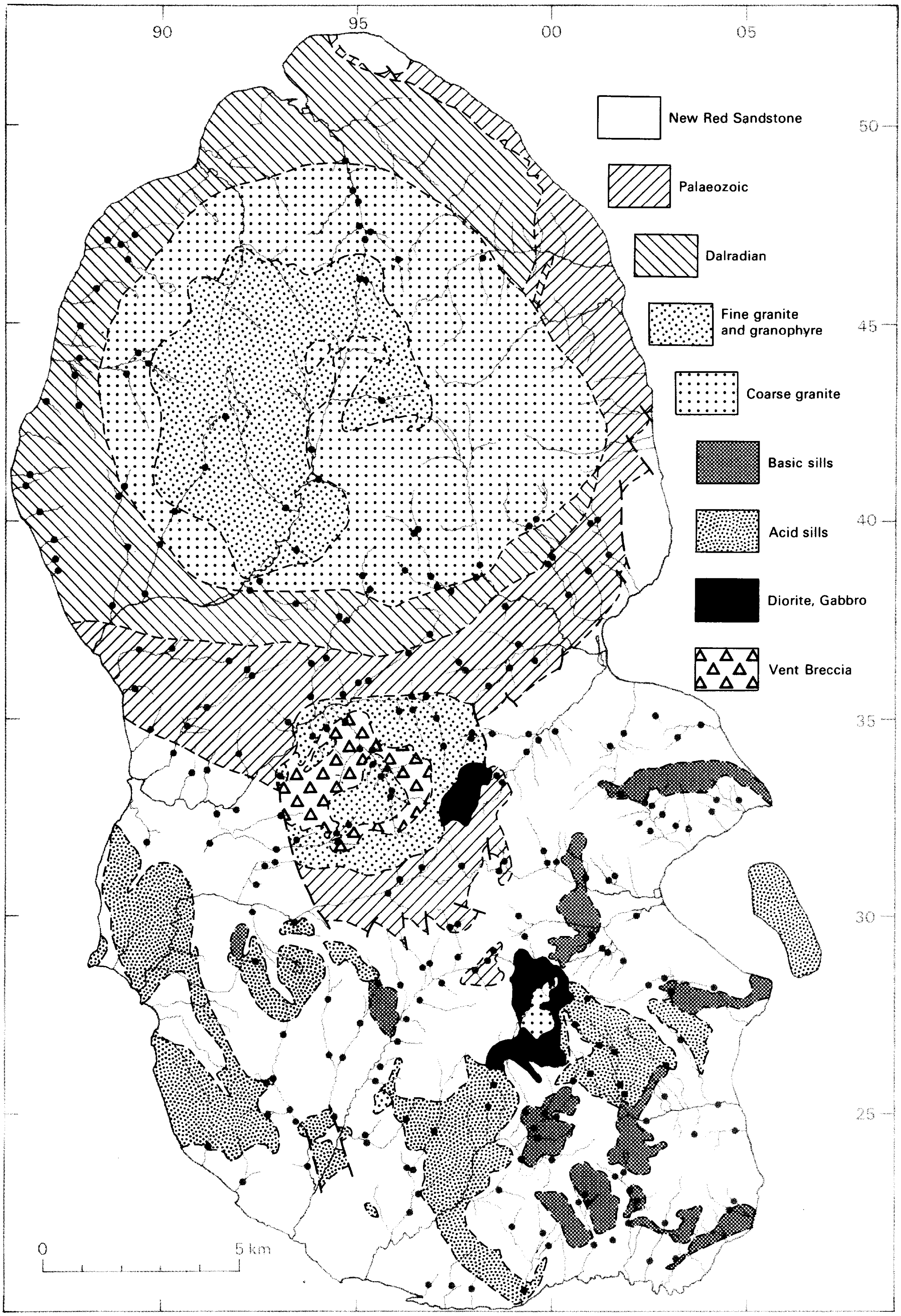

Figure 2 Generalised geology

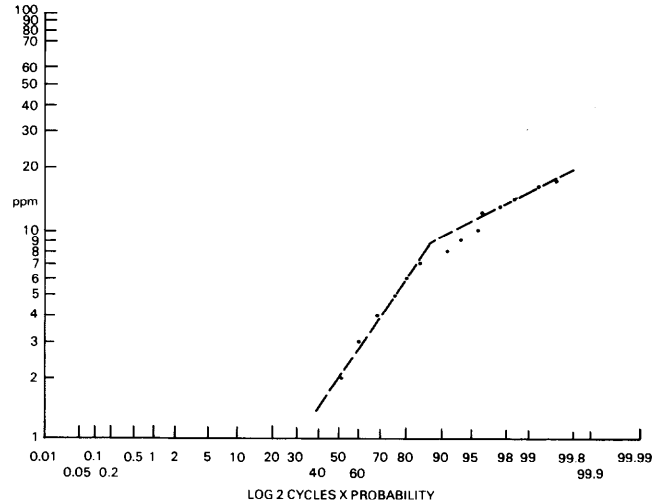

Figure 3 Log-probability plot for Ag

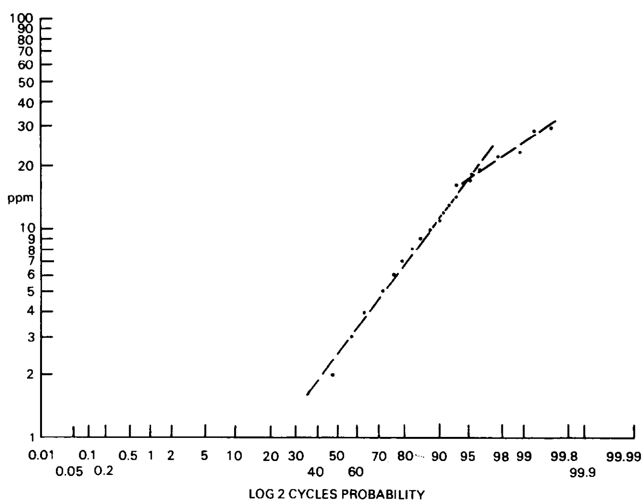

Figure 4 Log-probability plot for As

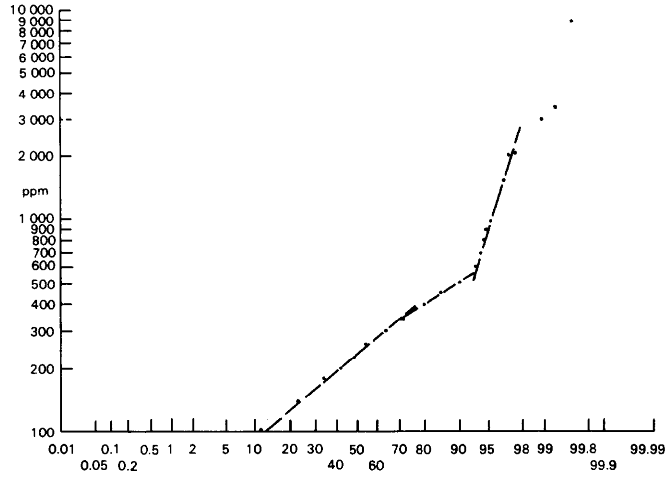

Figure 5 Log-probability plot for Ba

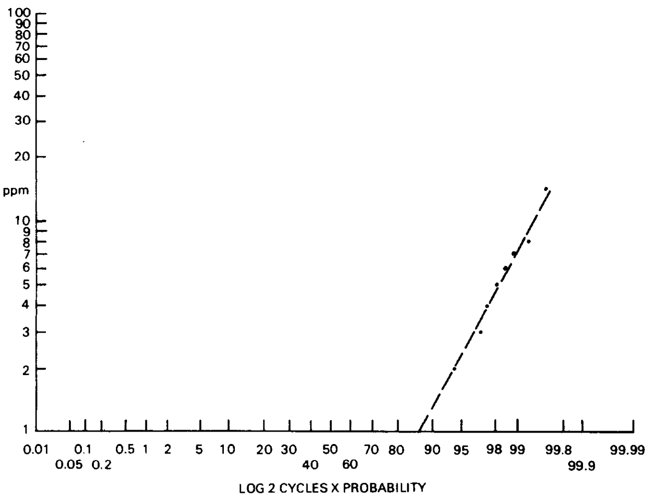

Figure 6 Log-probability plot for Bi

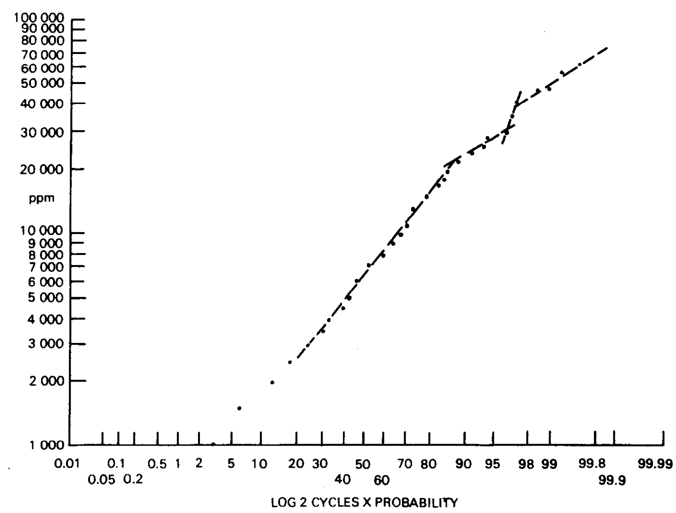

Figure 7 Log-probability plot for Ca

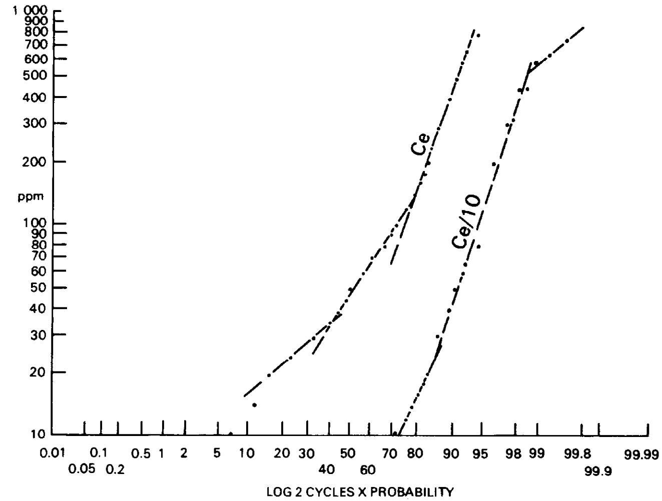

Figure 8 Log-probability plot for Ce

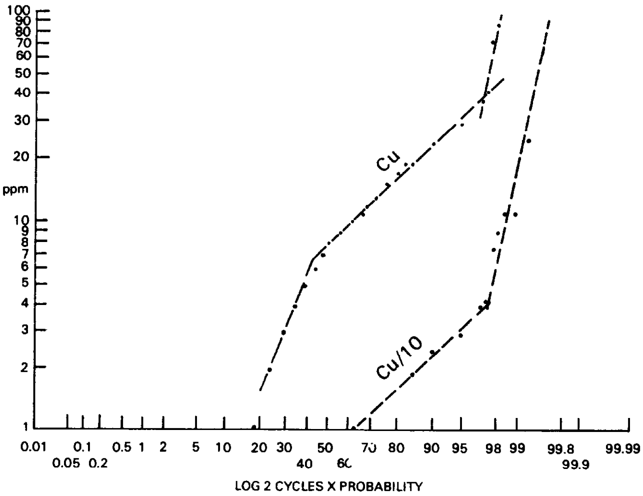

Figure 9 Log-probability plot for Cu

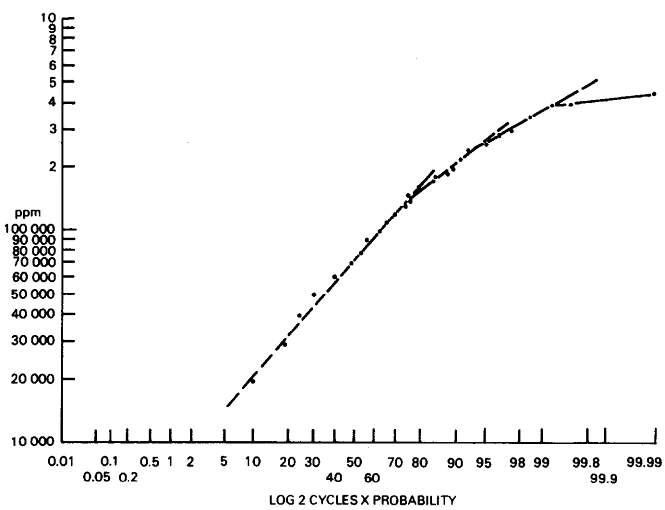

Figure 10 Log-probability plot for Fe

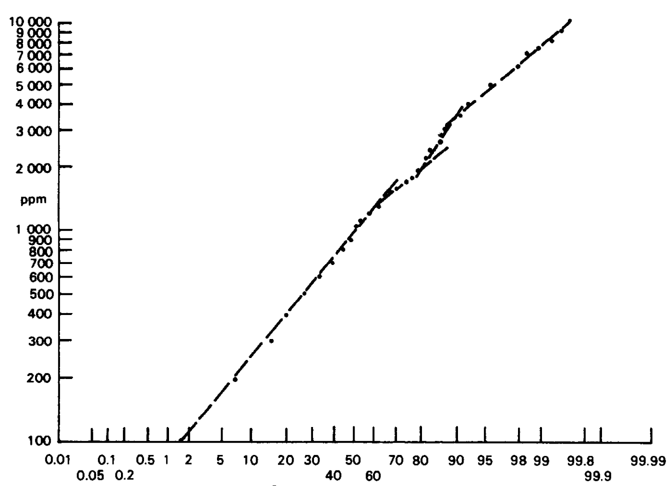

Figure 11 Log-probability plot for Mn

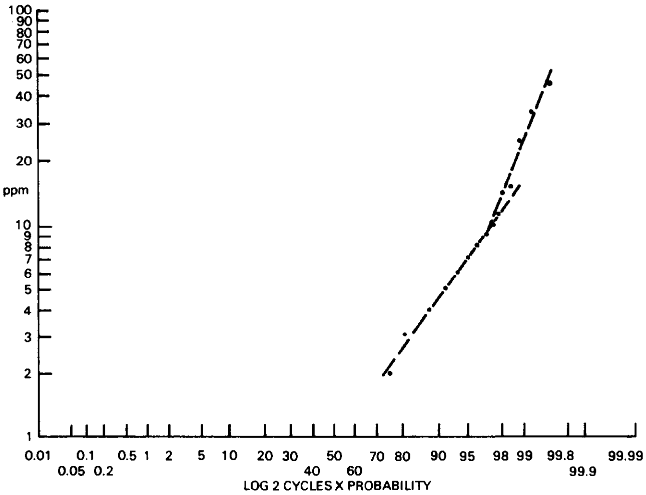

Figure 12 Log-probability plot for Mo

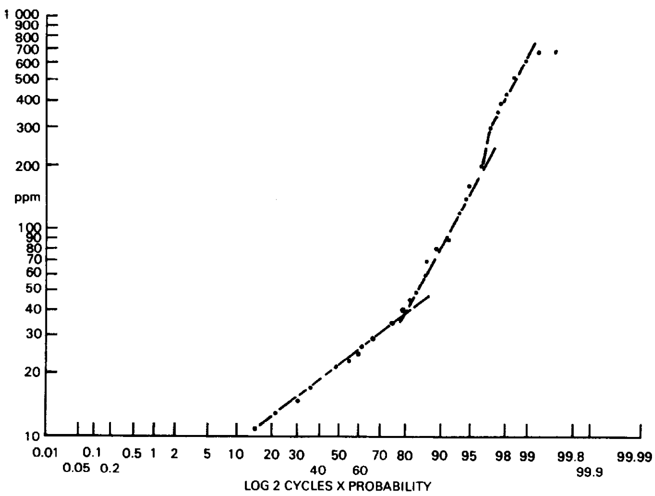

Figure 13 Log-probability plot for Nb

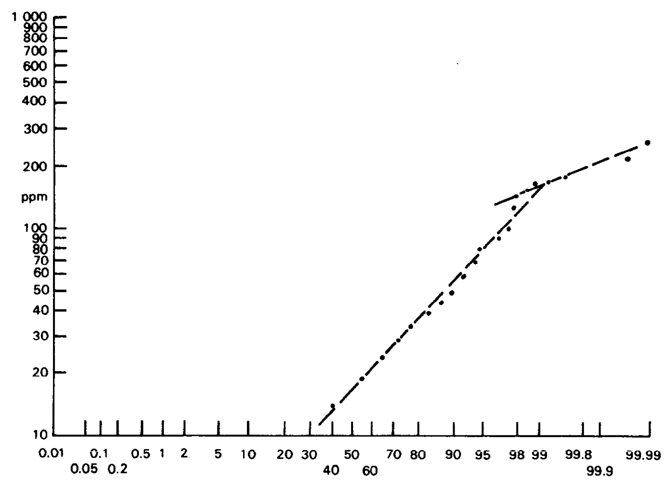

Figure 14 Log-probability plot for Ni

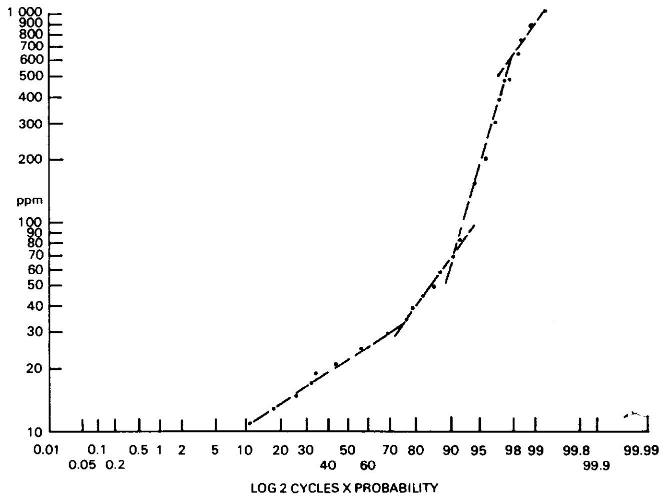

Figure 15 Log-probability plot for Pb

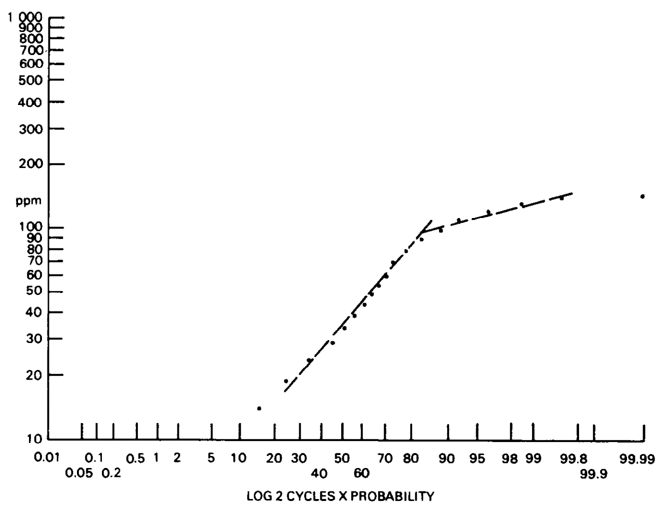

Figure 16 Log-probability plot for Rb

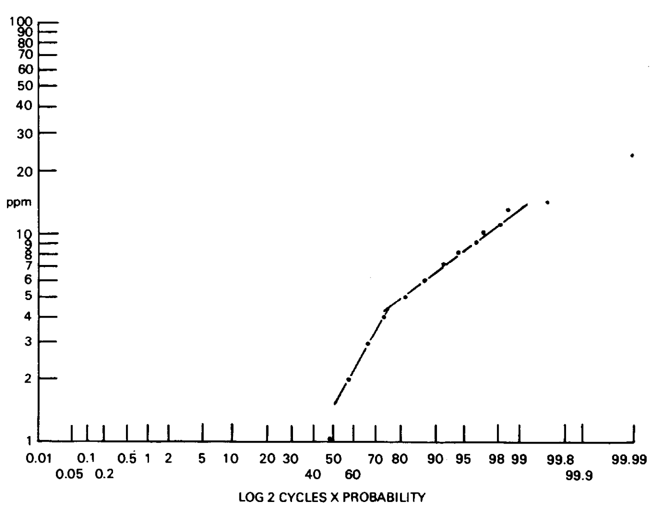

Figure 17 Log-probability plot for Sb

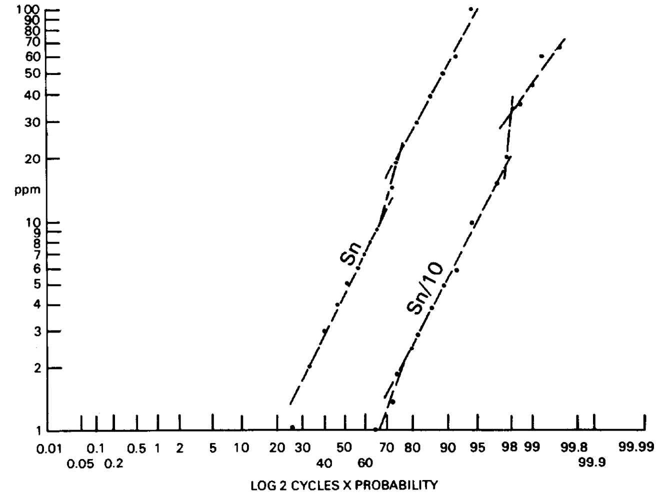

Figure 18 Log-probability plot for Sn

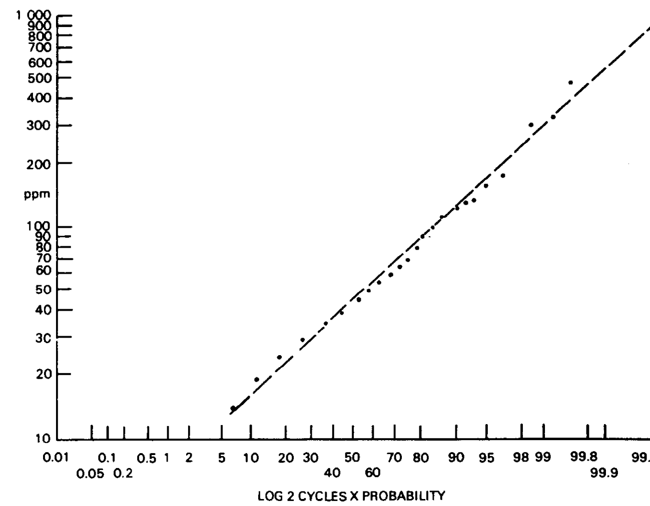

Figure 19 Log-probability plot for Sr

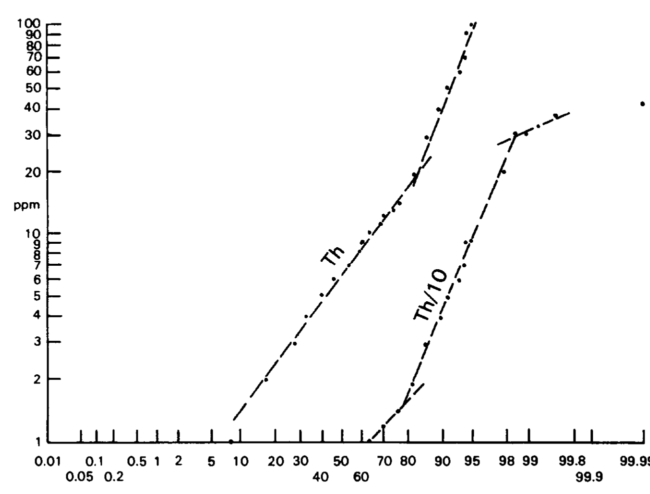

Figure 20 Log-probability plot for Th

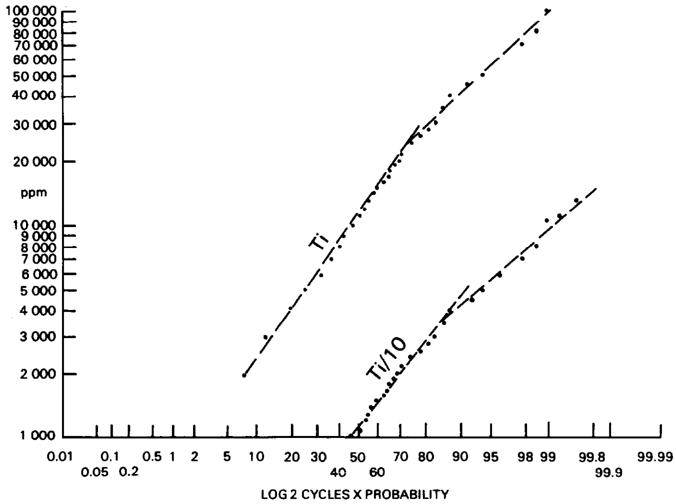

Figure 21 Log-probability plot for Ti

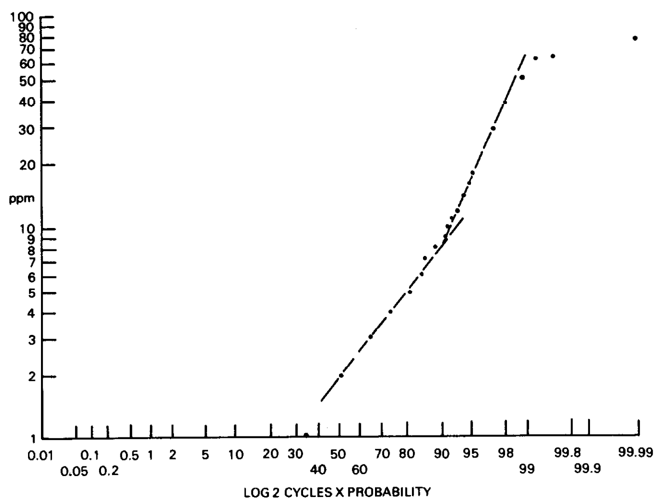

Figure 22 Log-probability plot for U

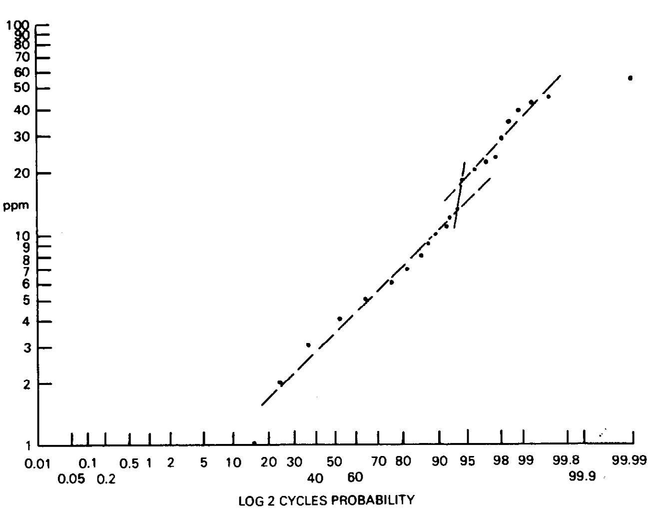

Figure 23 Log-probability plot for W

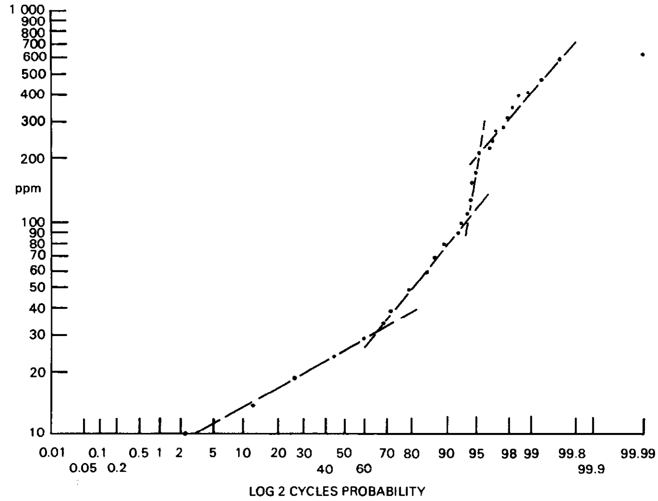

Figure 24 Log-probability plot for Y

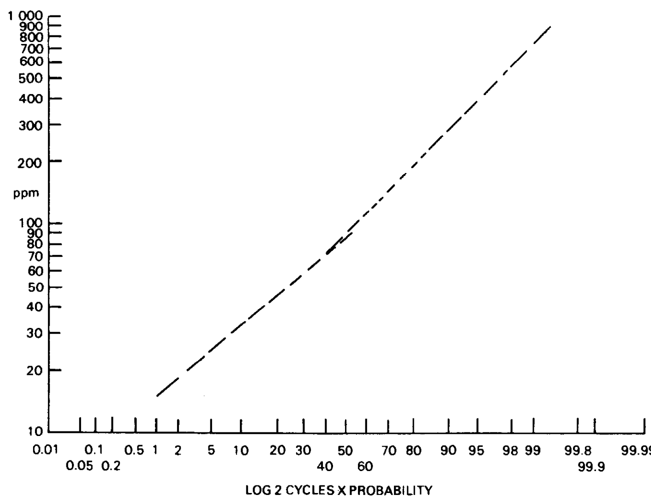

Figure 25 Log-probability plot for Zn

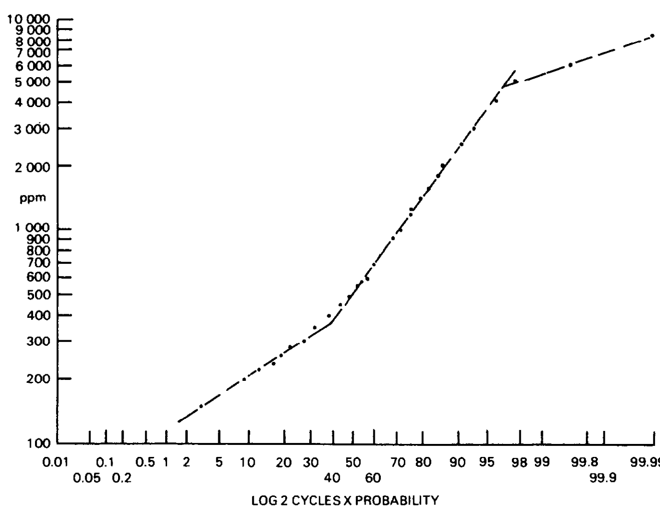

Figure 26 Log-probability plot for Zr

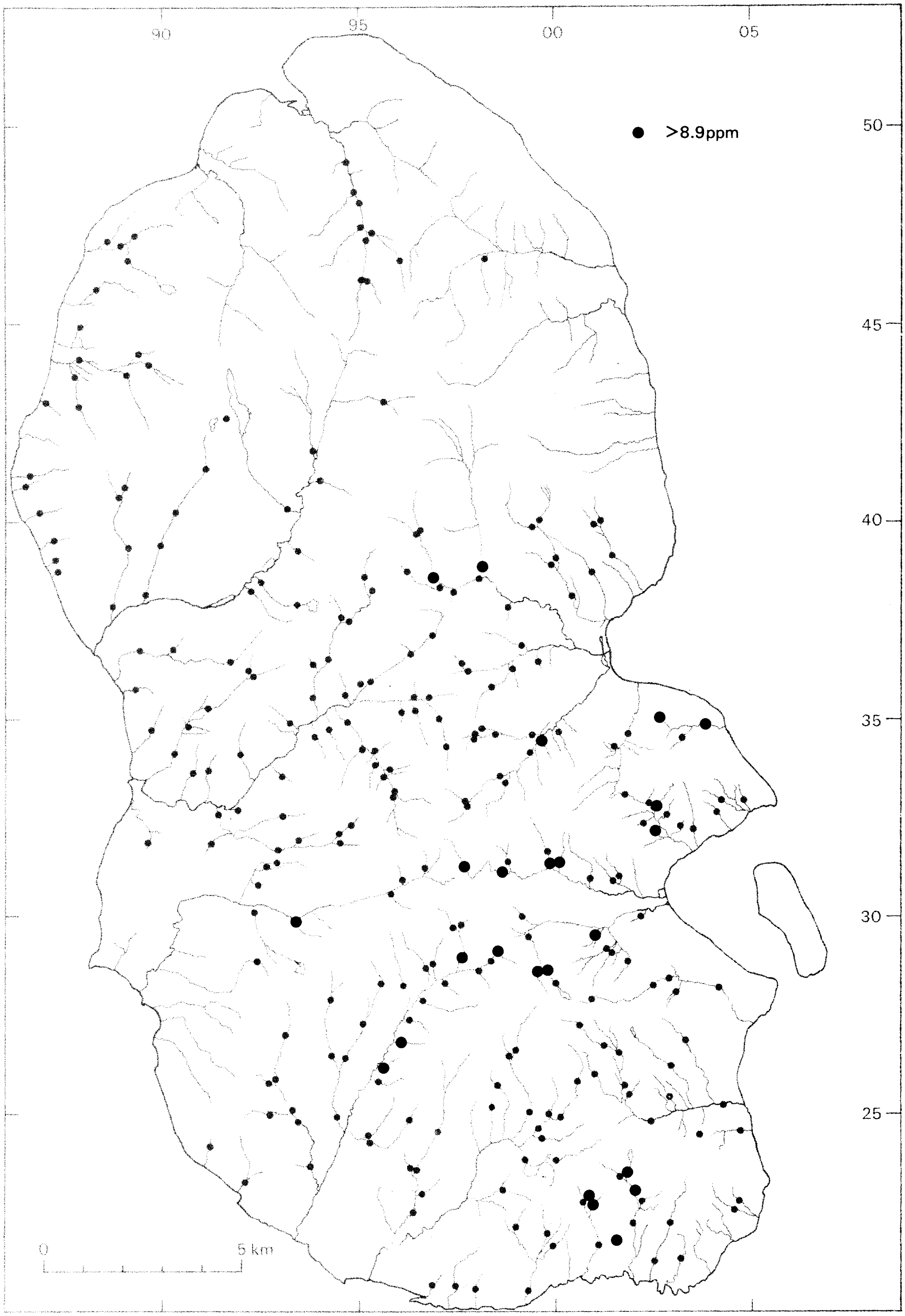

Figure 27 Distribution of silver anomalies

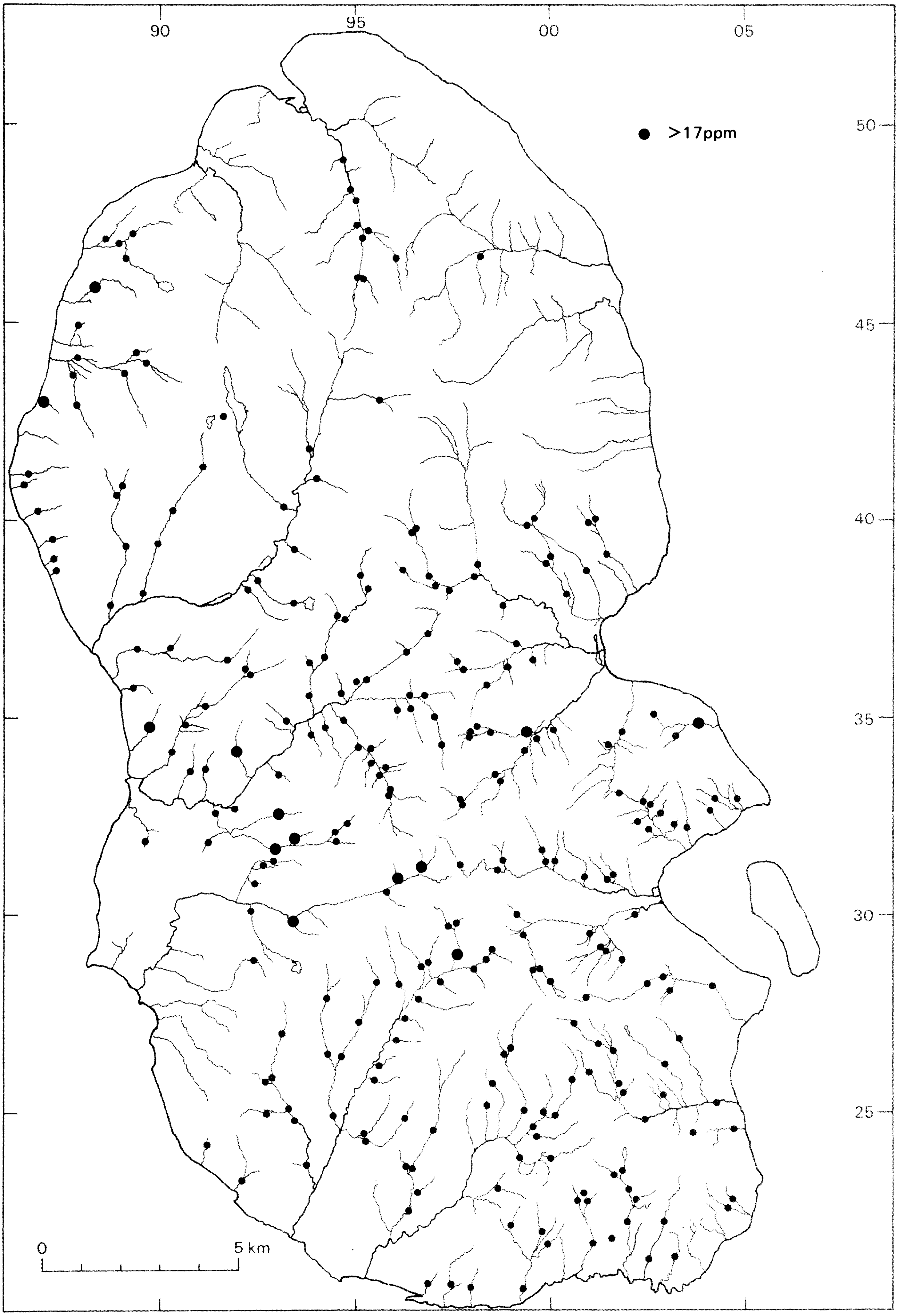

Figure 28 Distribution of arsenic anomalies

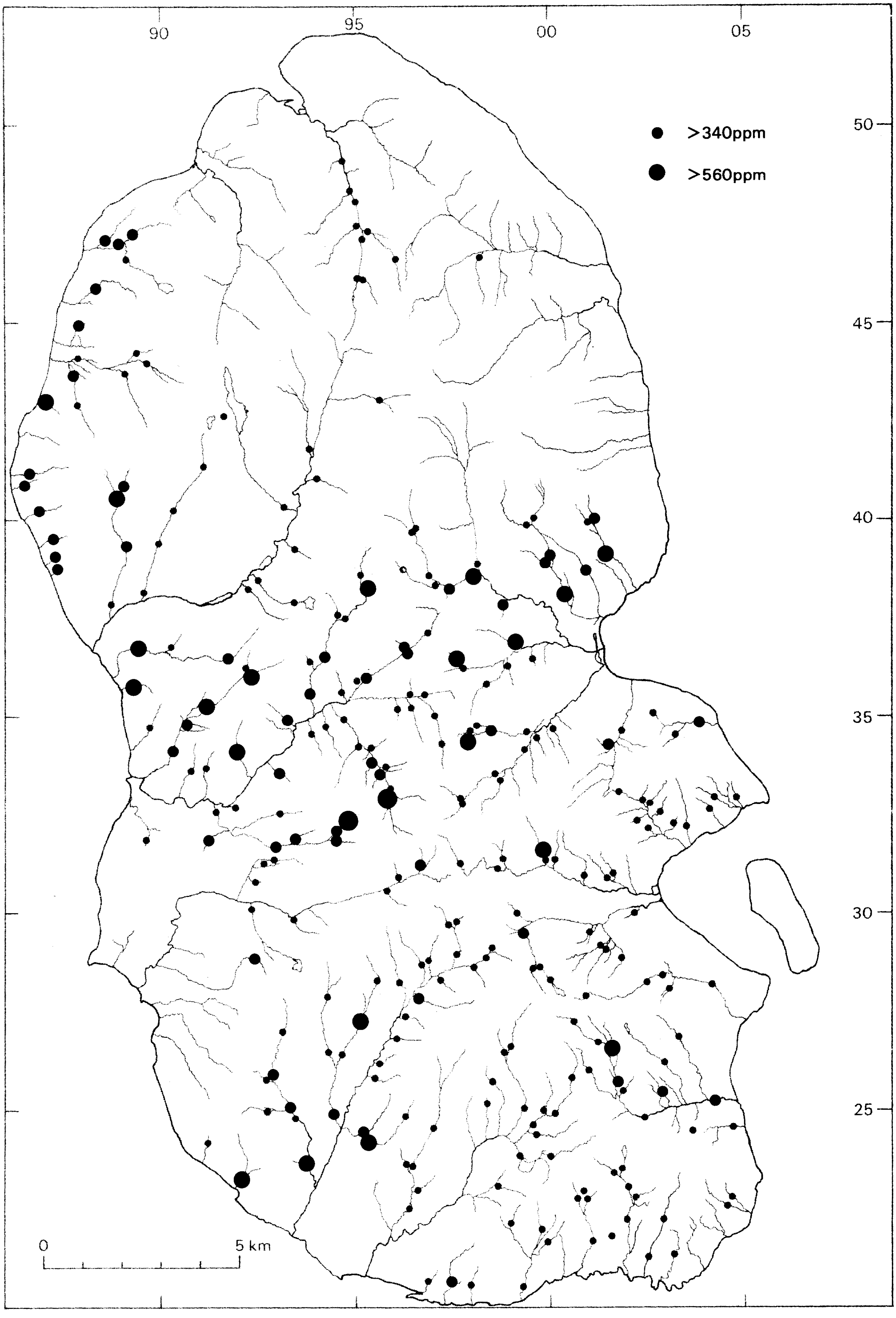

Figure 29 Distribution of barium anomalies

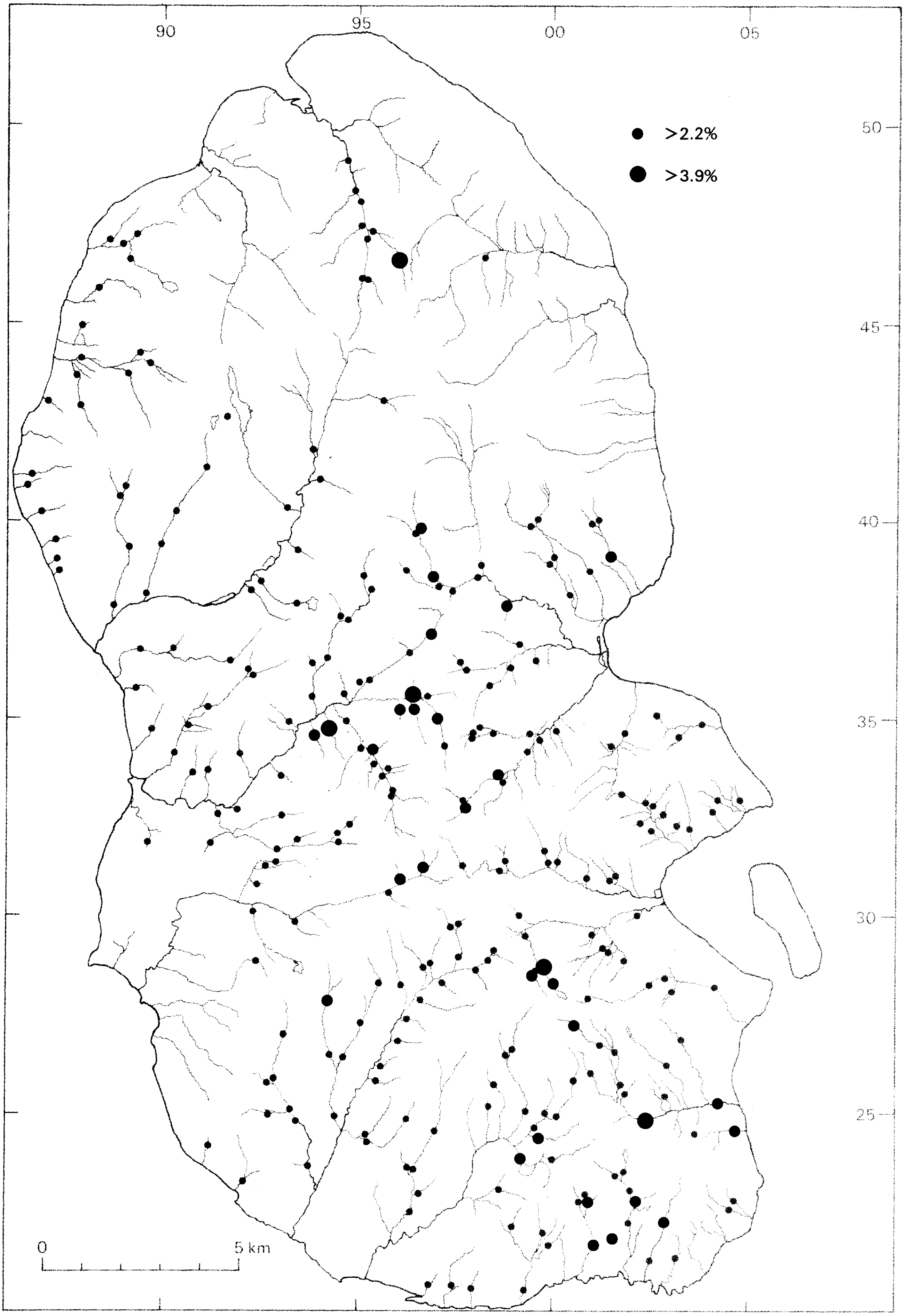

Figure 30 Distribution of calcium anomalies

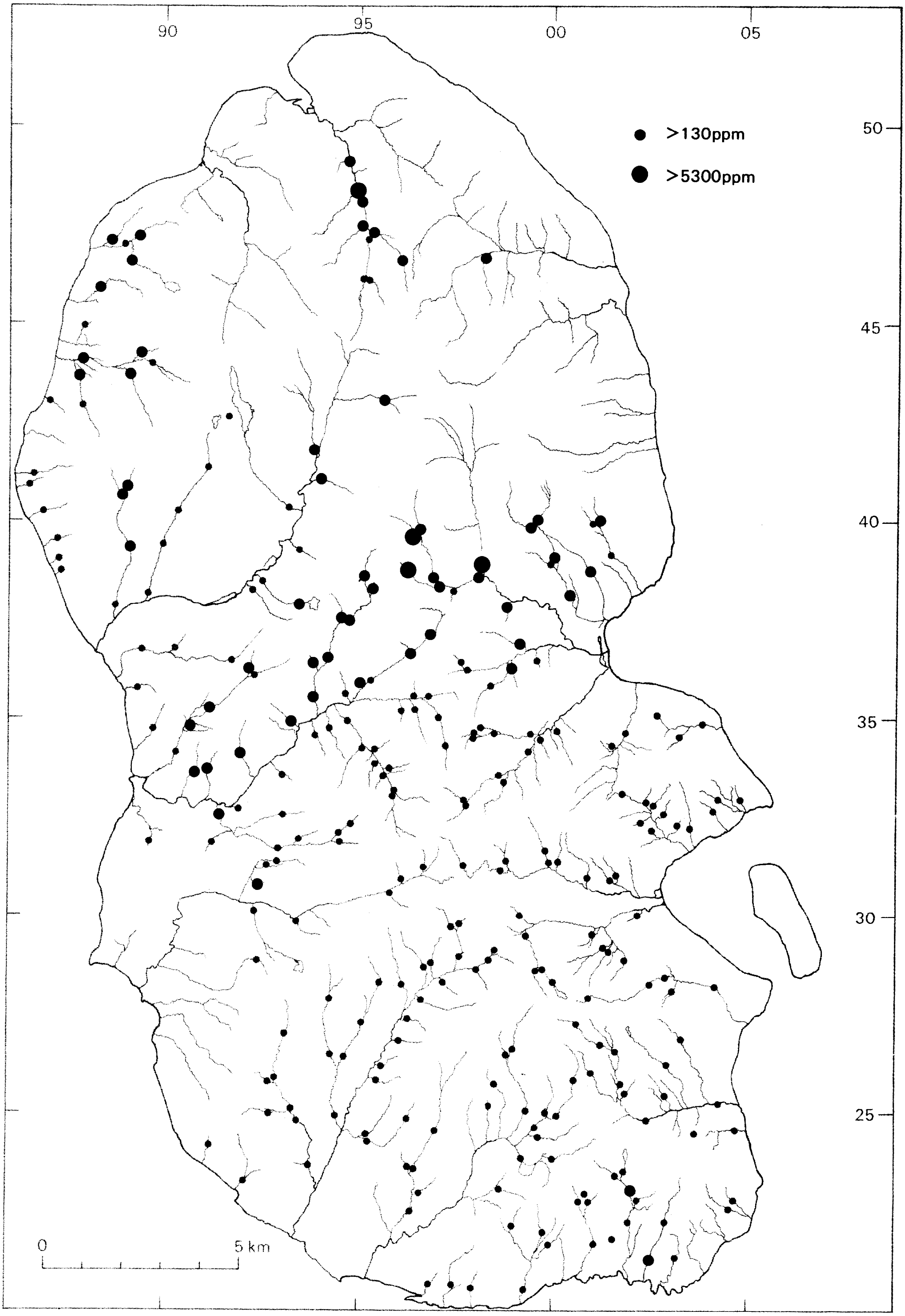

Figure 31 Distribution of cerium anomalies

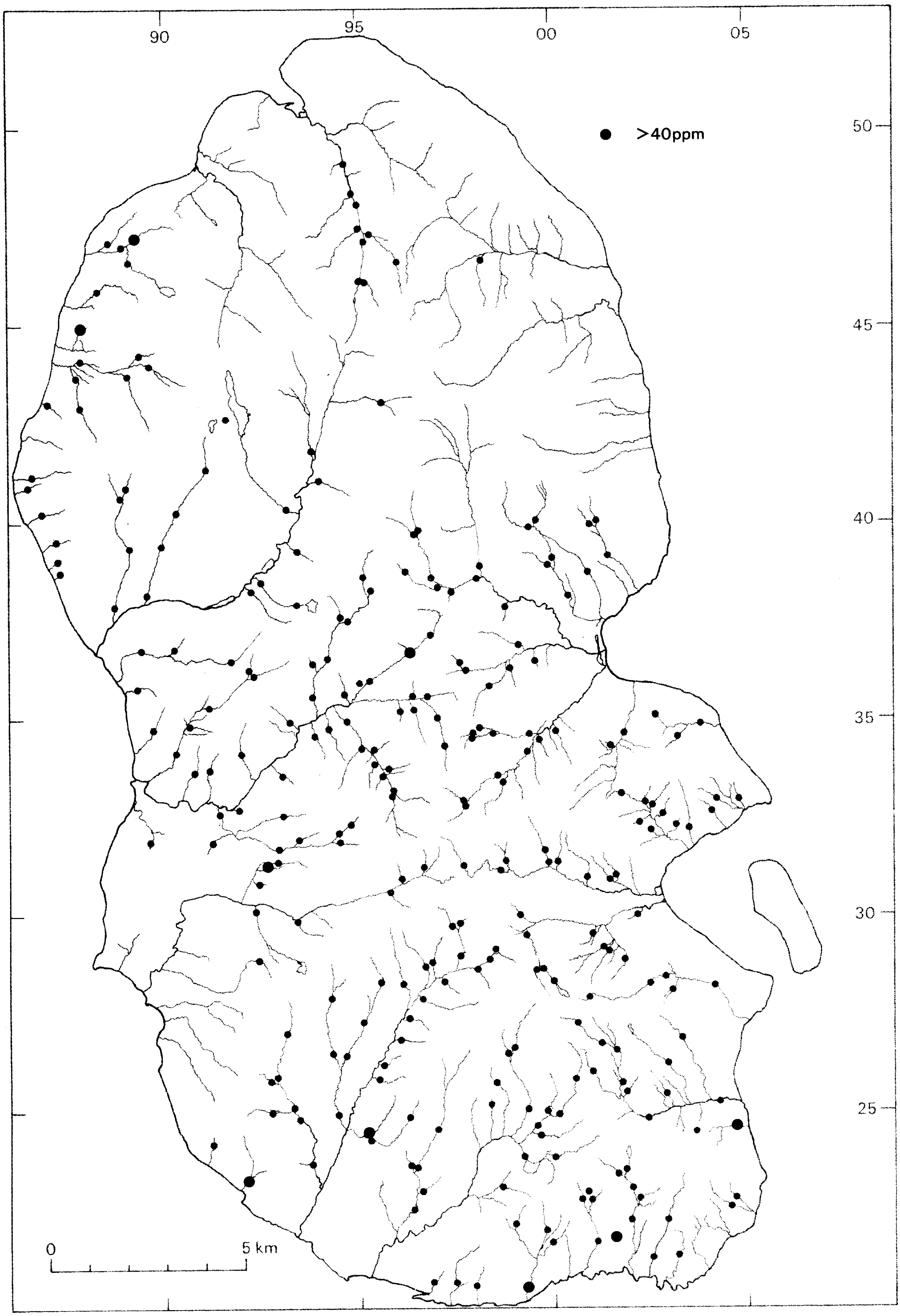

Figure 32 Distribution of copper anomalies

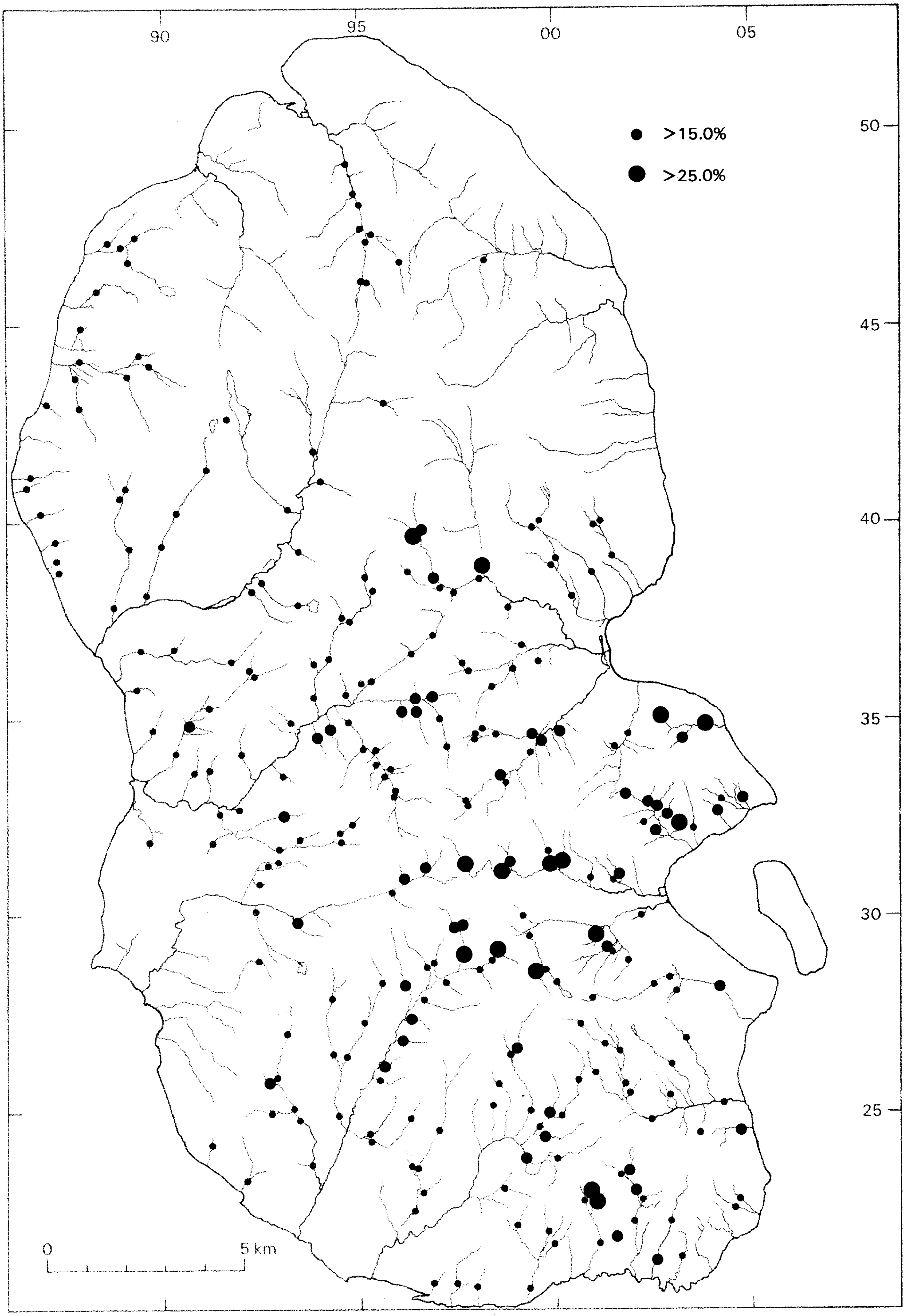

Figure 33 Distribution of iron anomalies

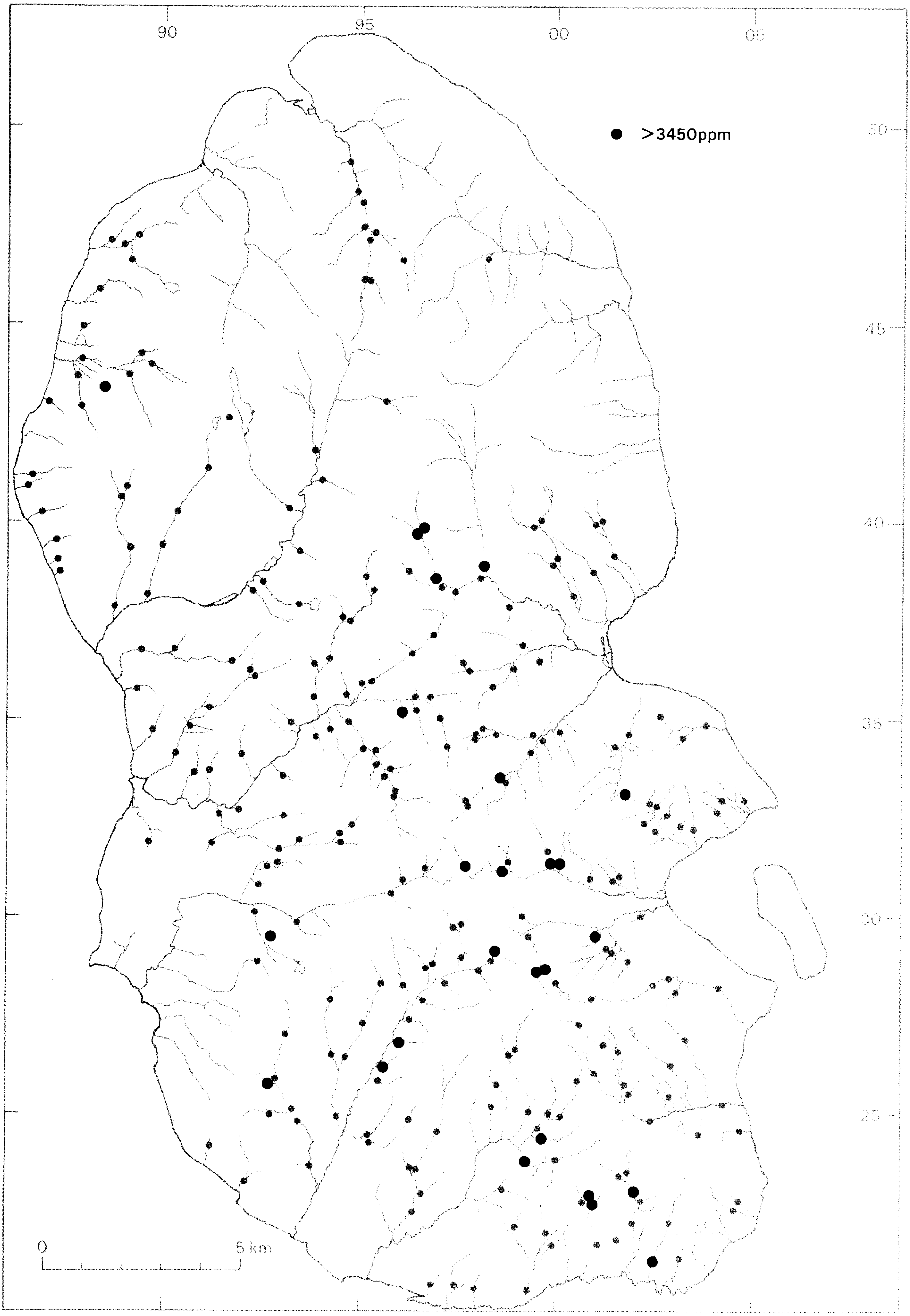

Figure 34 Distribution of manganese anomalies

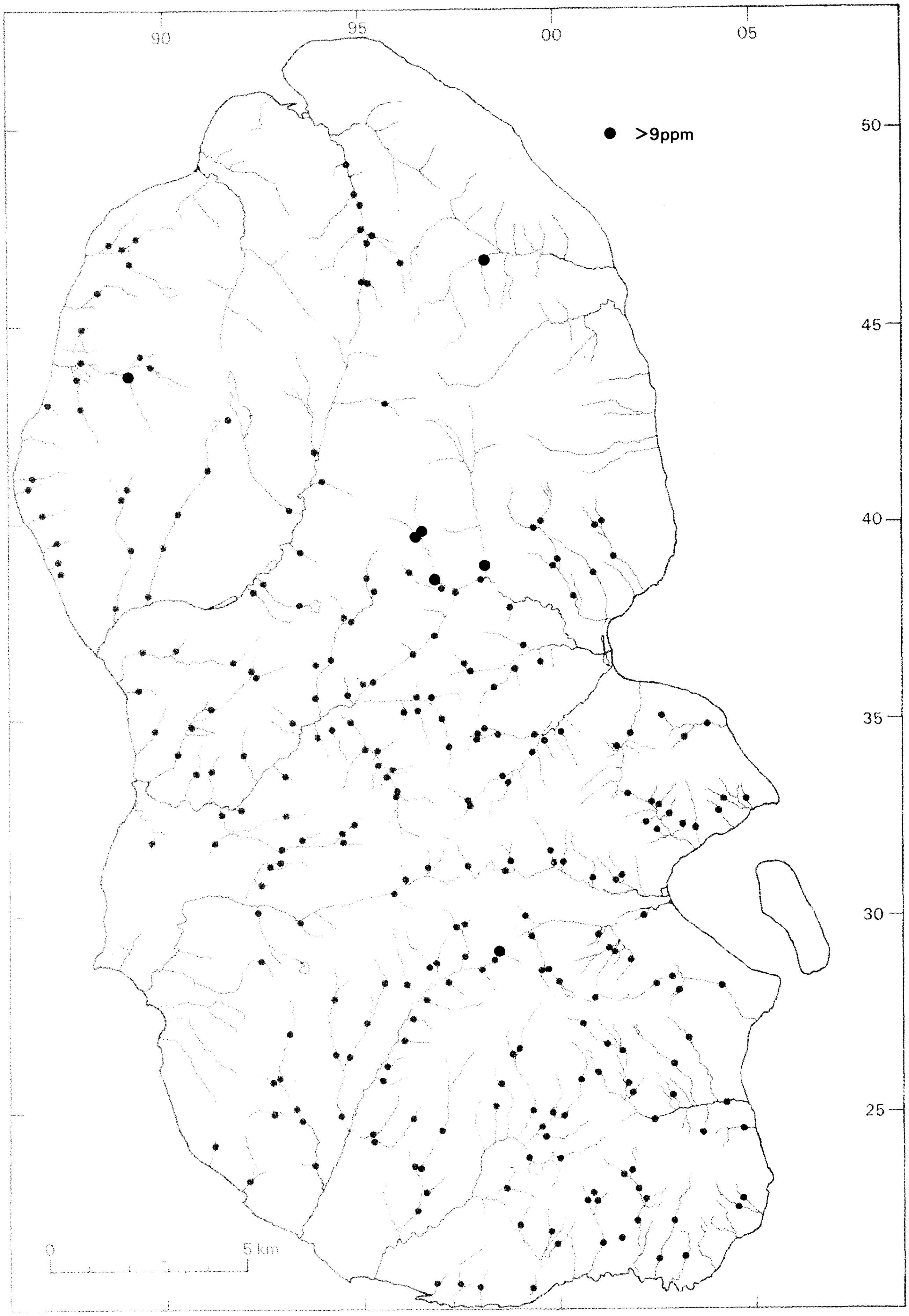

Figure 35 Distribution of molybdenum anomalies

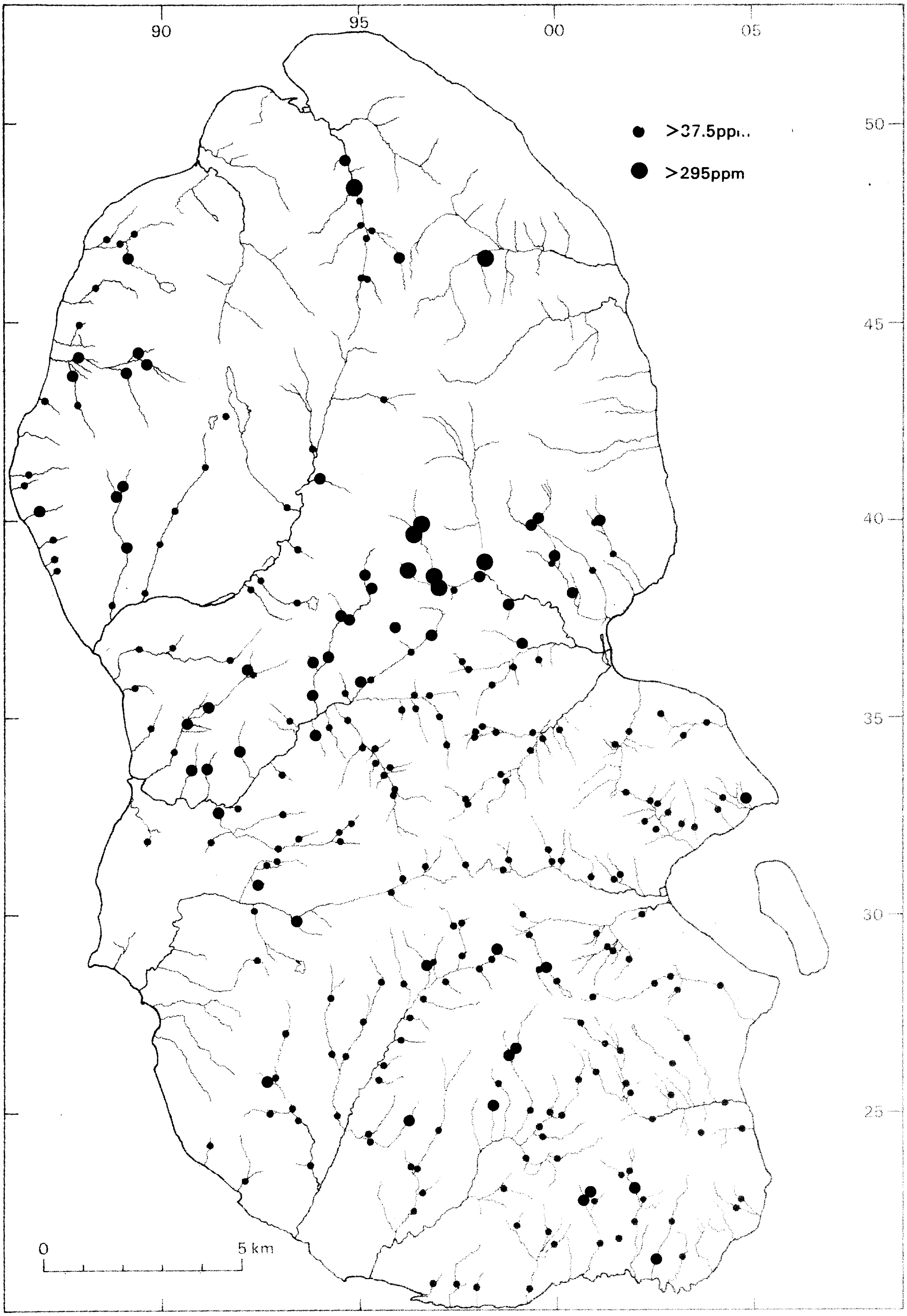

Figure 36 Distribution of niobium anomalies

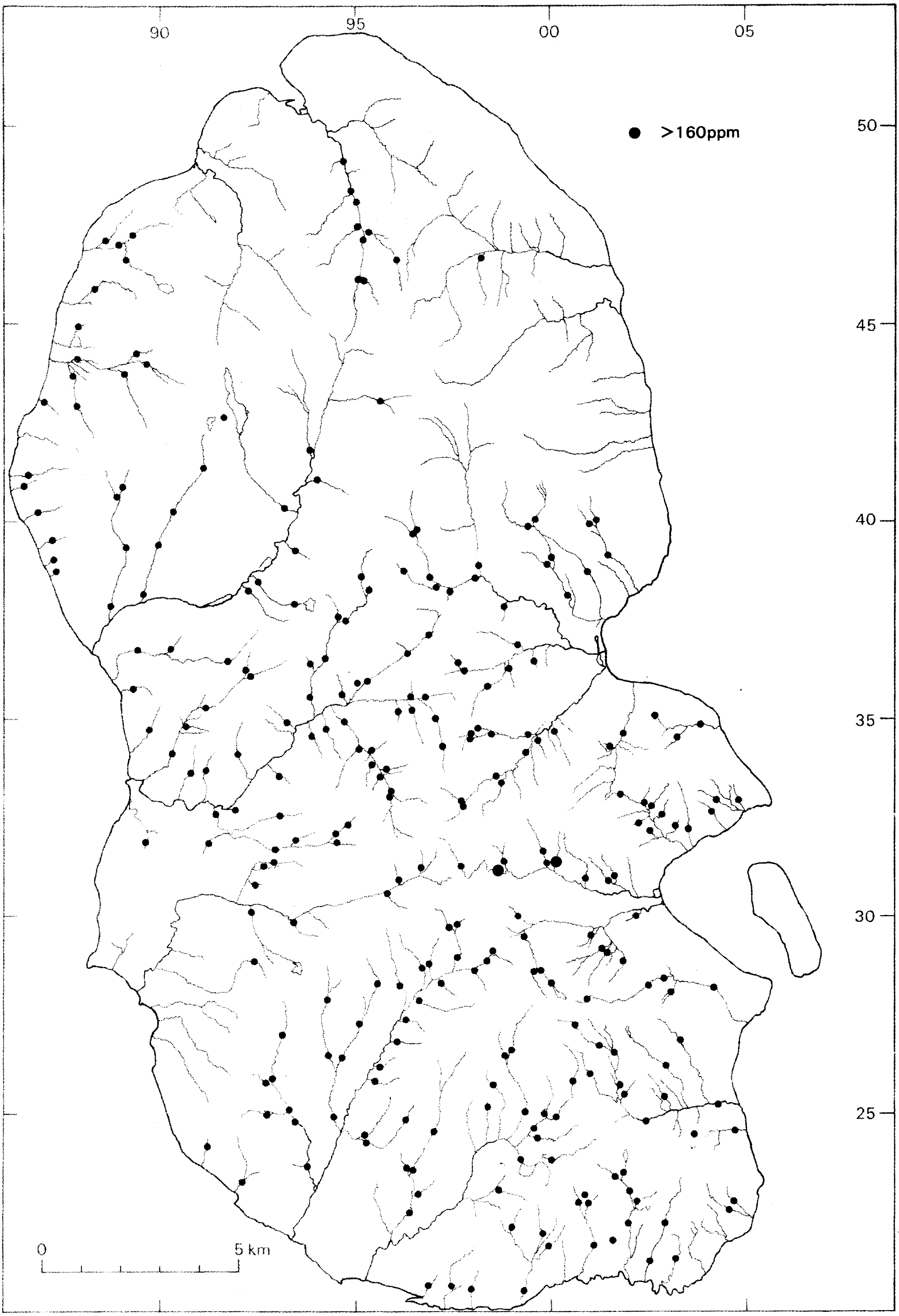

Figure 37 Distribution of nickel anomalies

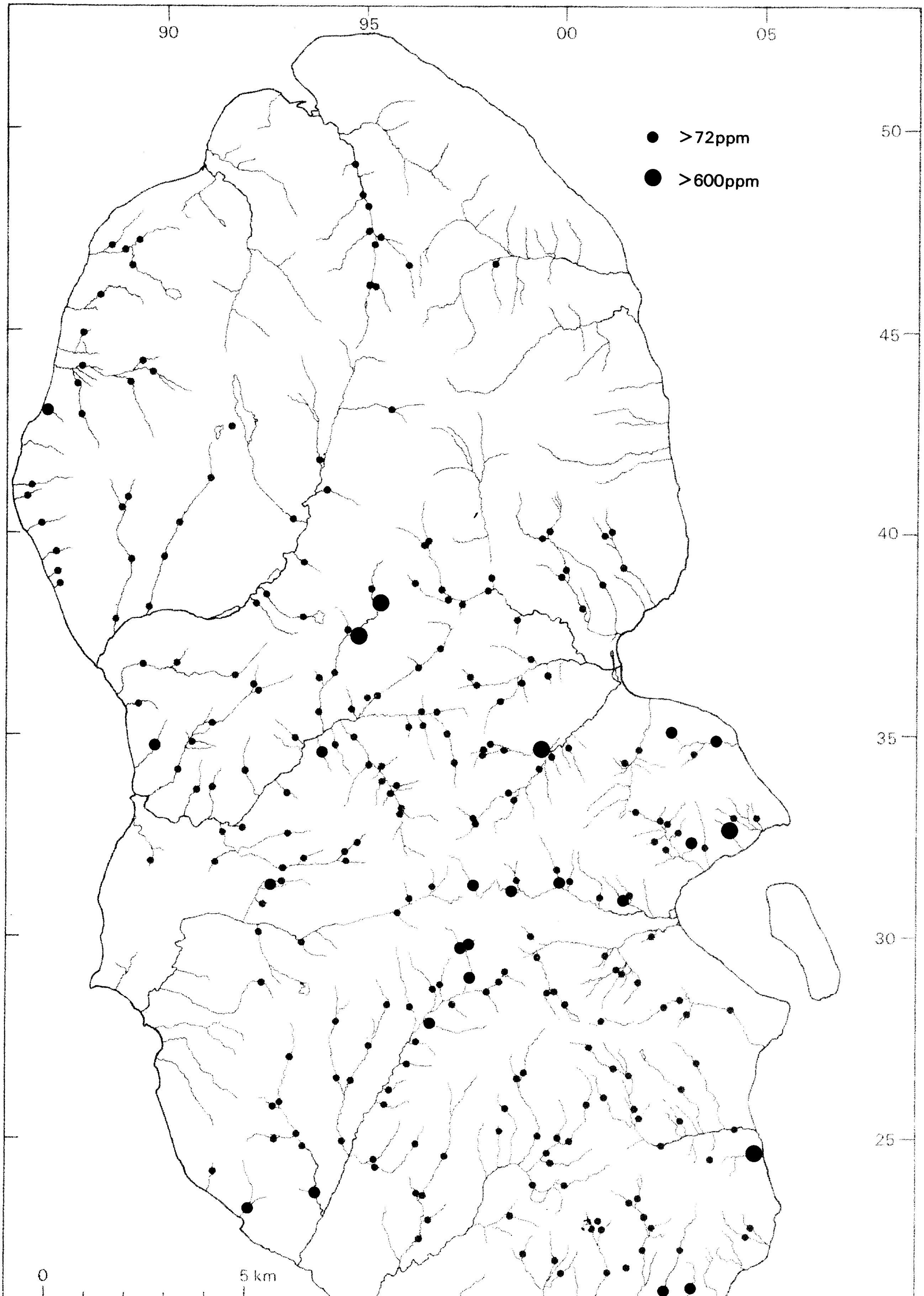

Figure 38 Distribution of lead anomalies

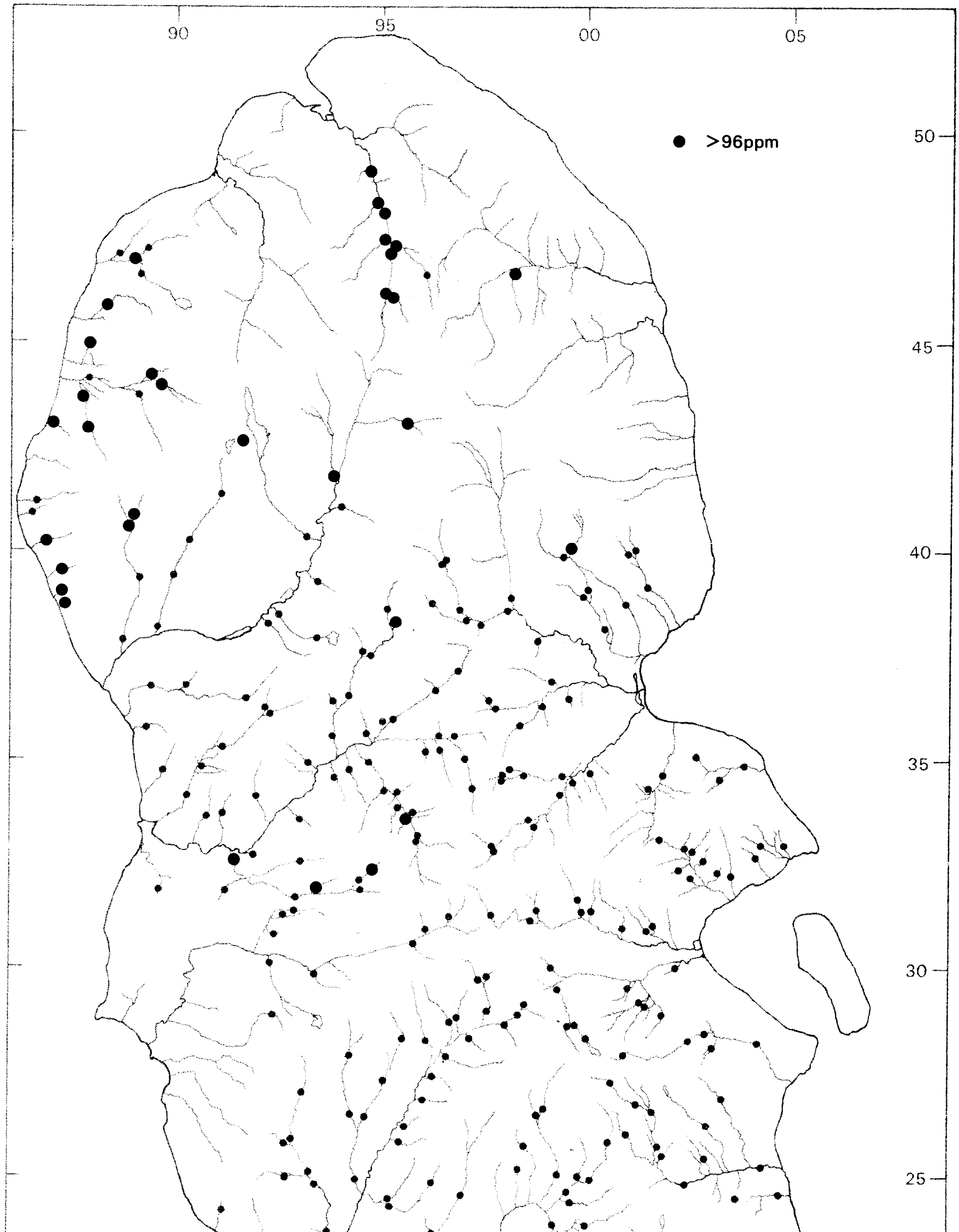

Figure 39 Distribution of rubidium anomalies

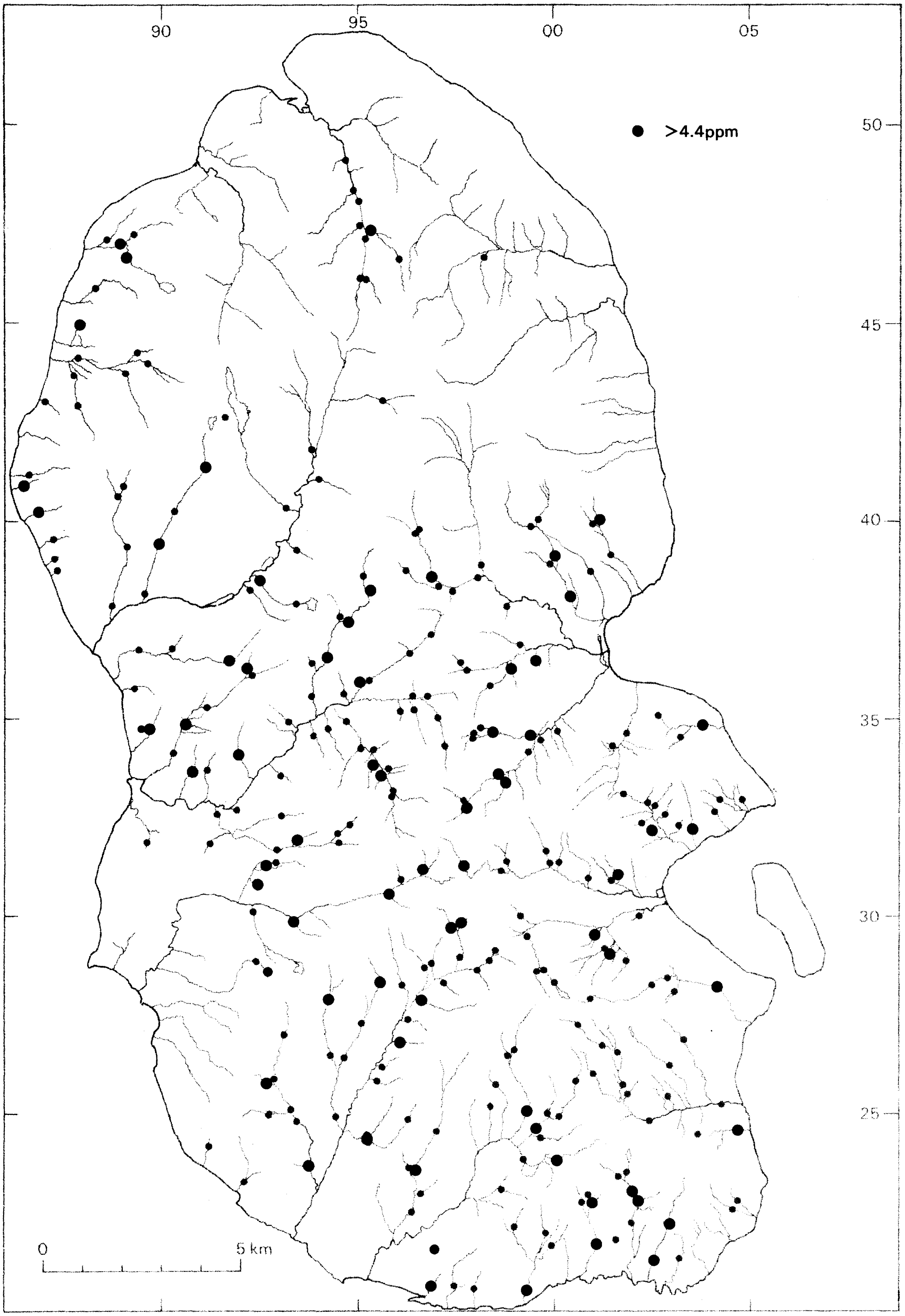

Figure 40 Distribution of antimony anomalies

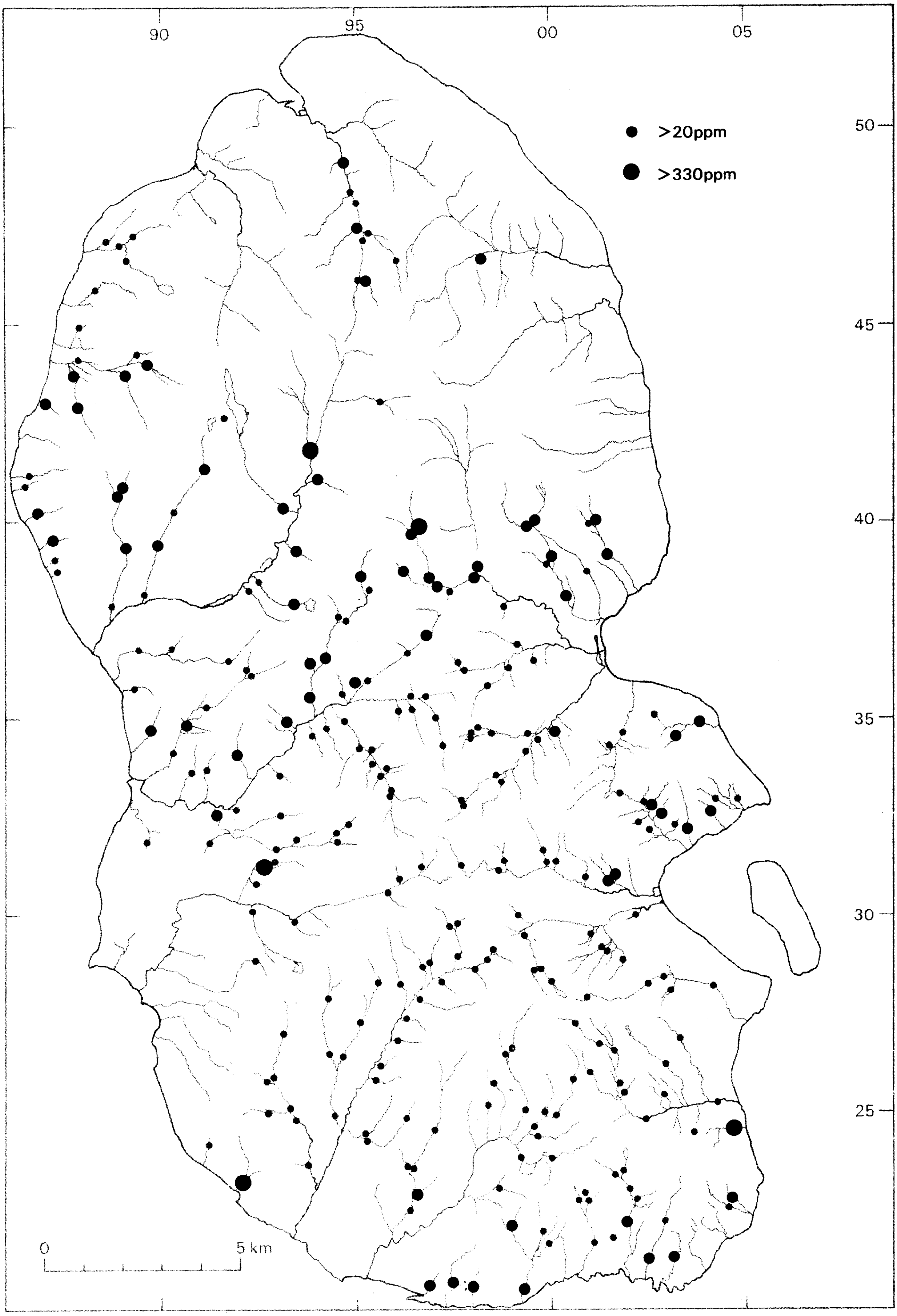

Figure 41 Distribution of tin anomalies

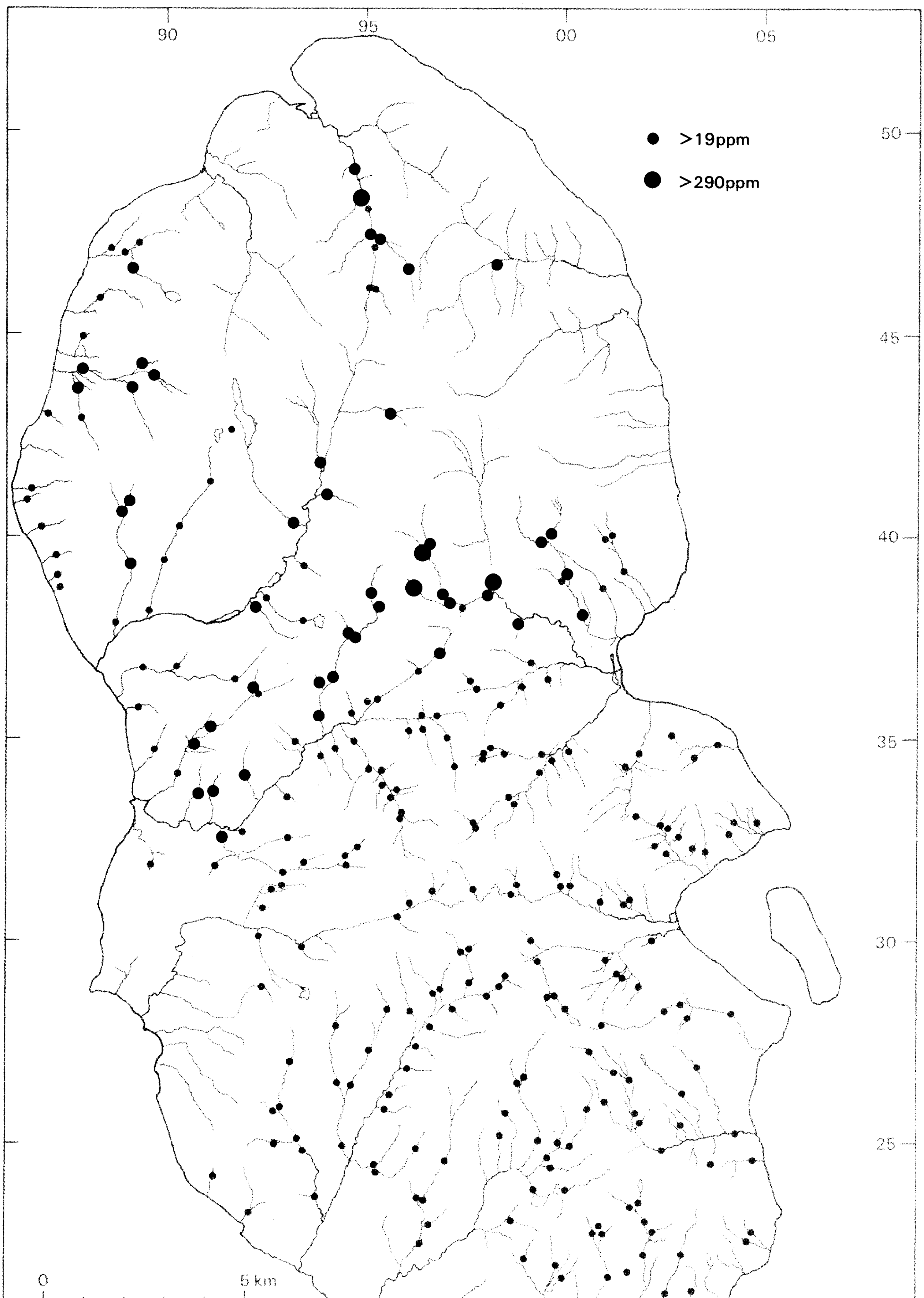

Figure 42 Distribution of thorium anomalies

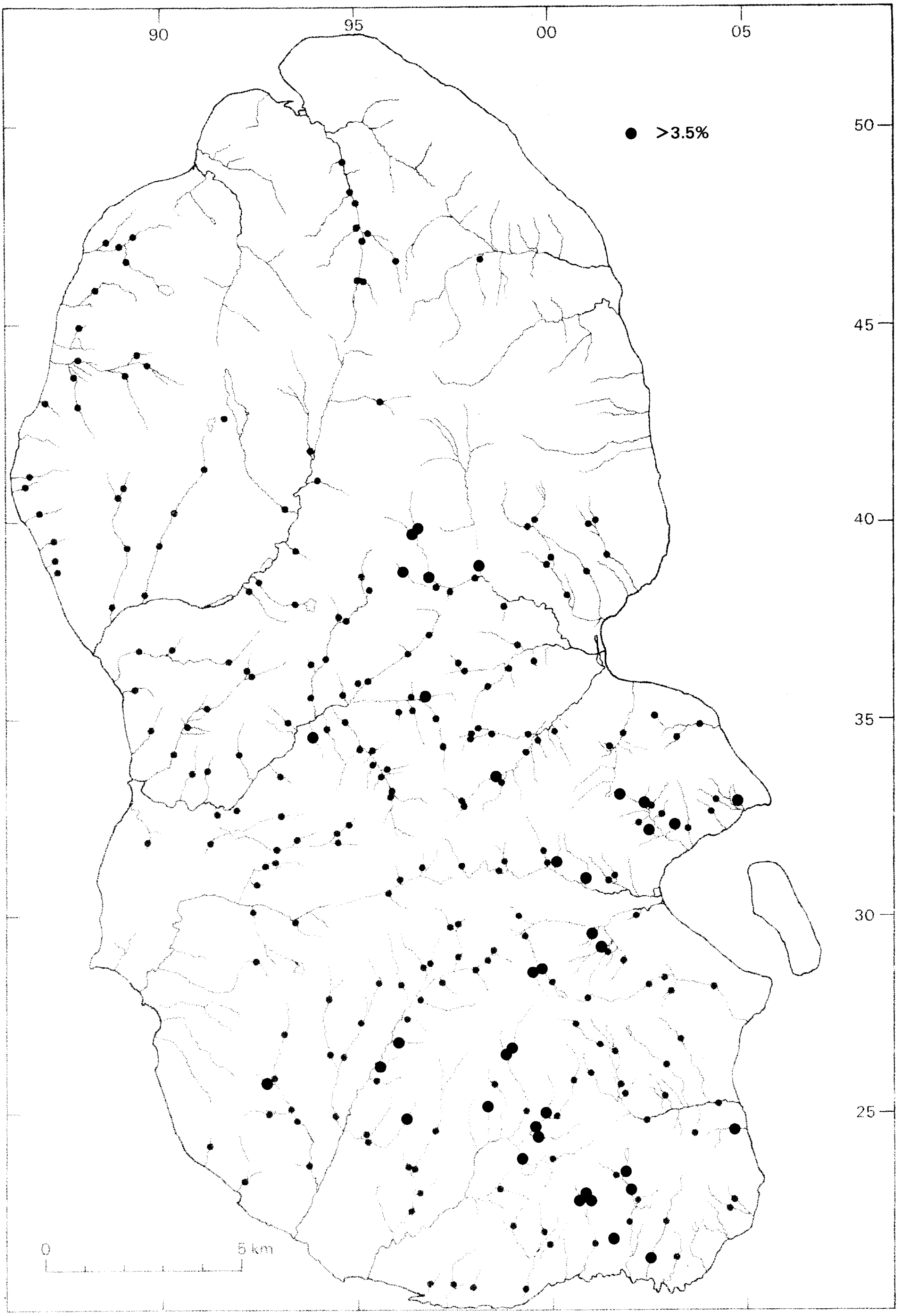

Figure 43 Distribution of titanium anomalies

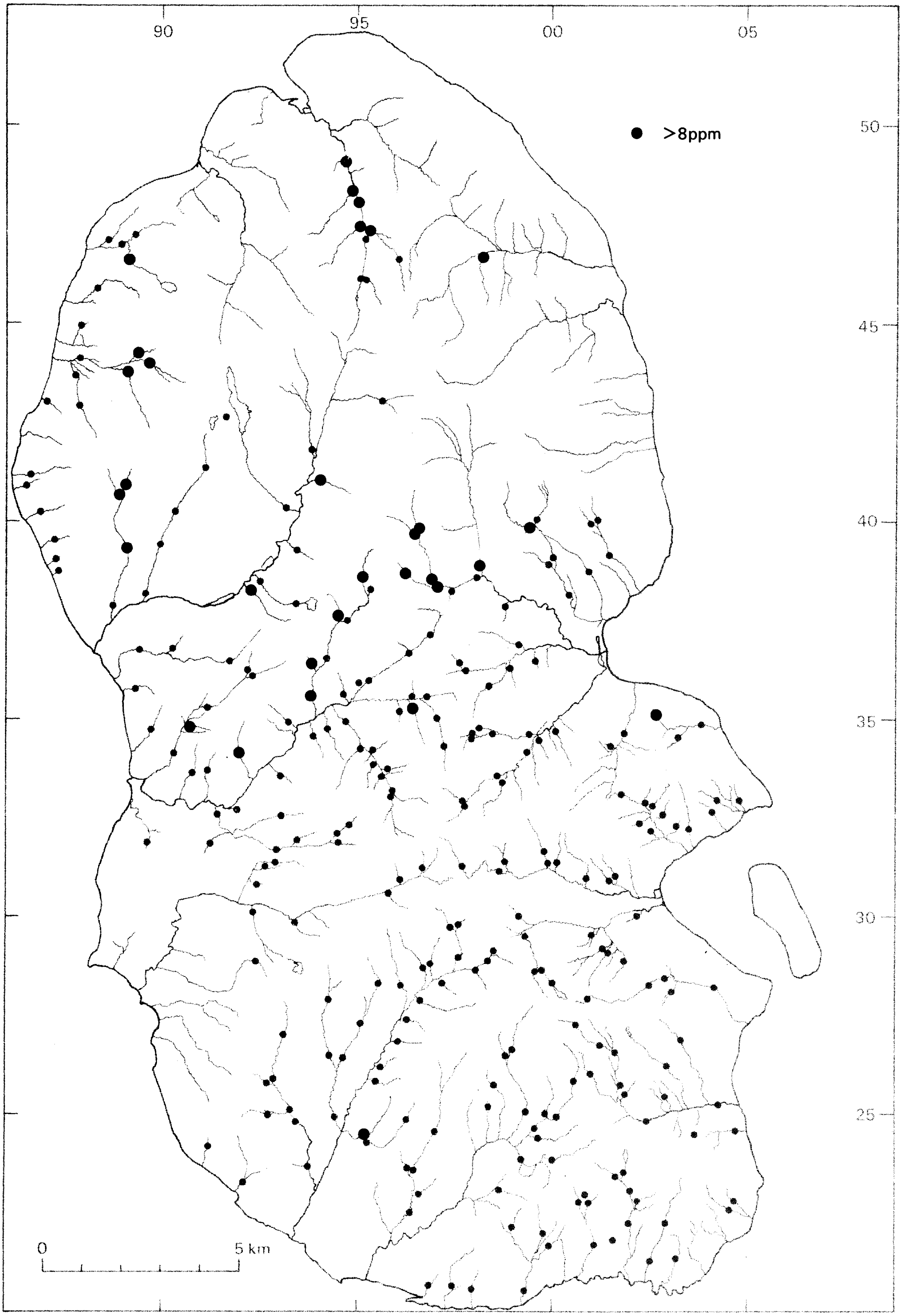

Figure 44 Distribution of uranium anomalies

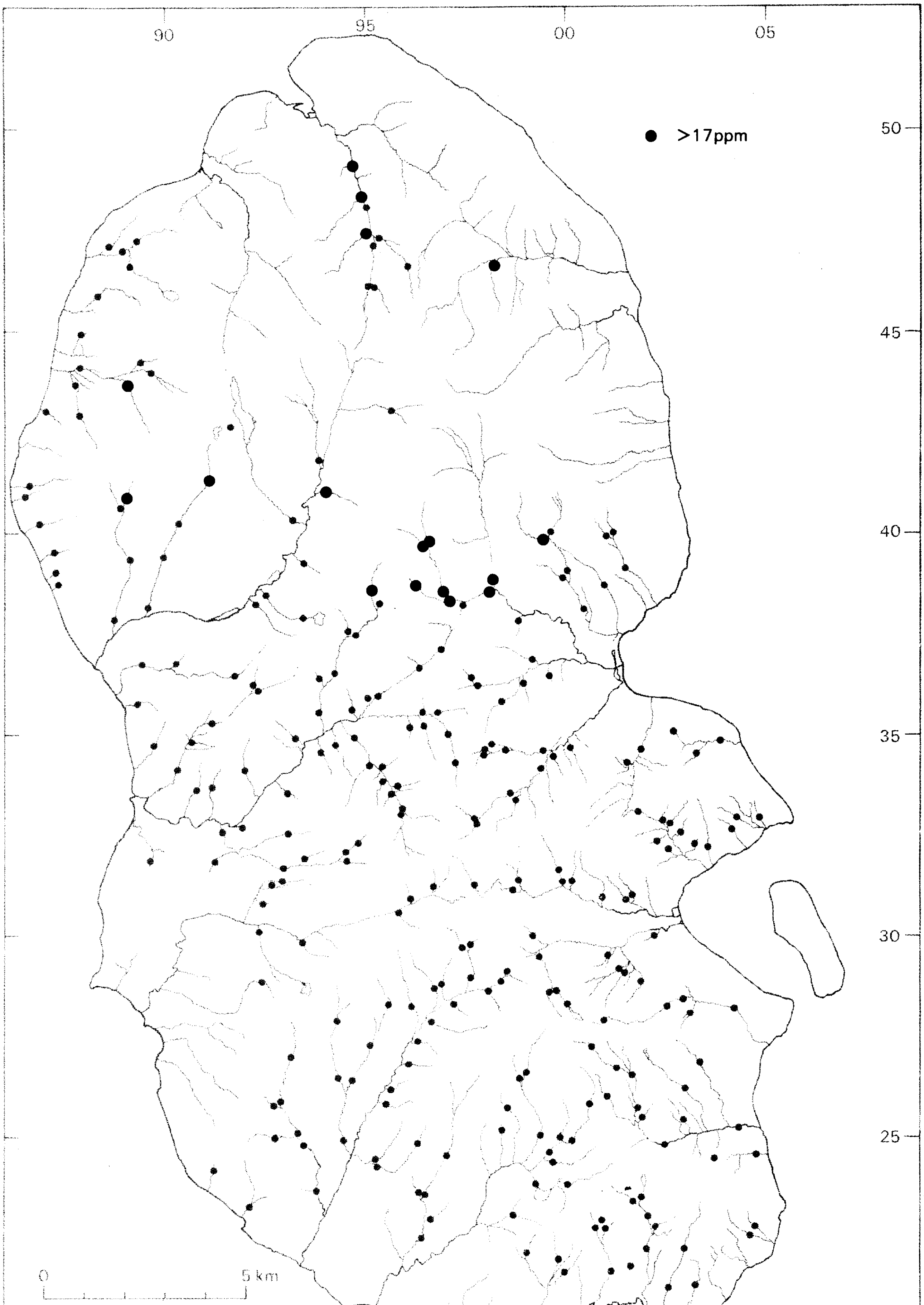

Figure 45 Distribution of tungsten anomalies

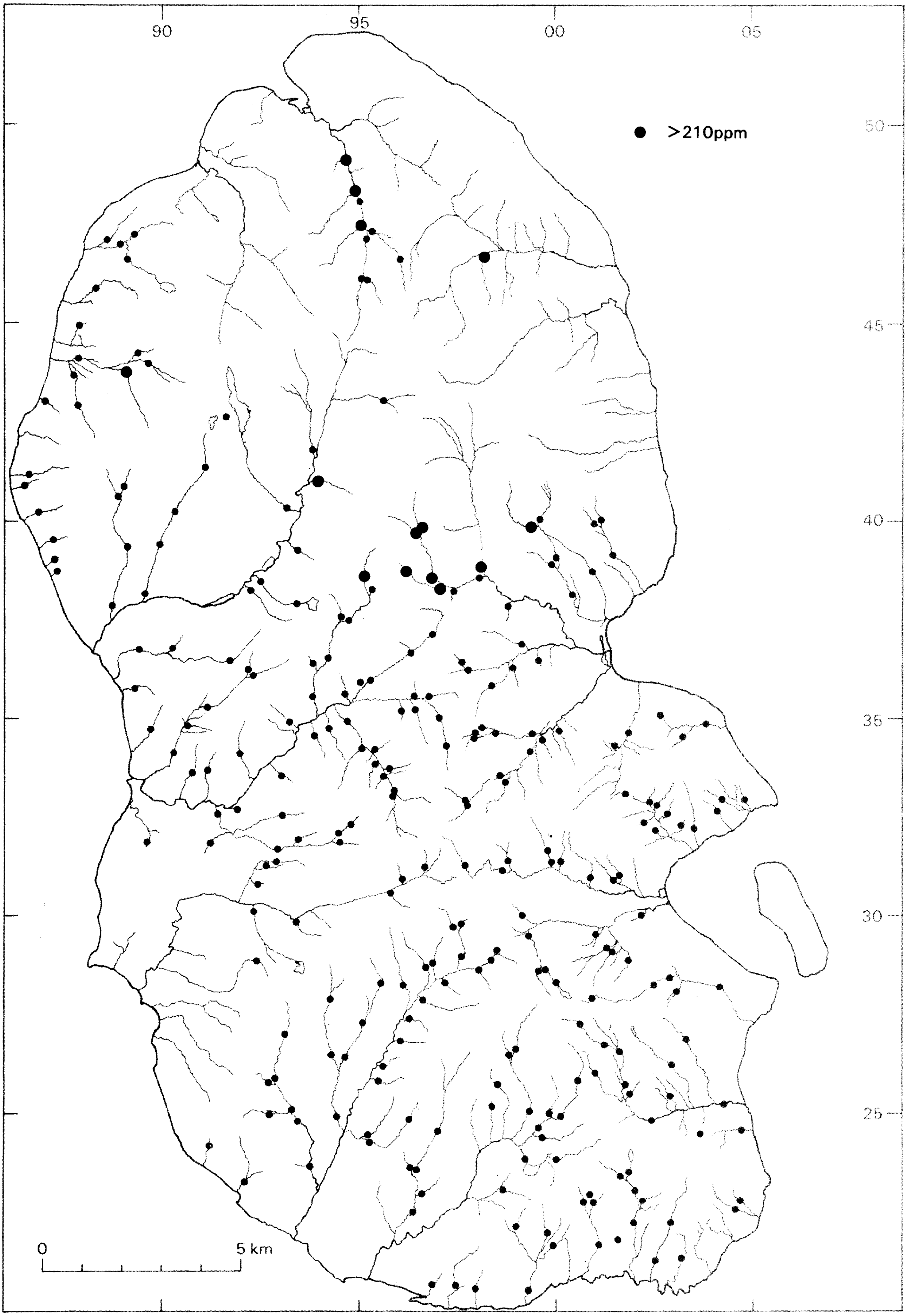

Figure 46 Distribution of yttrium anomalies

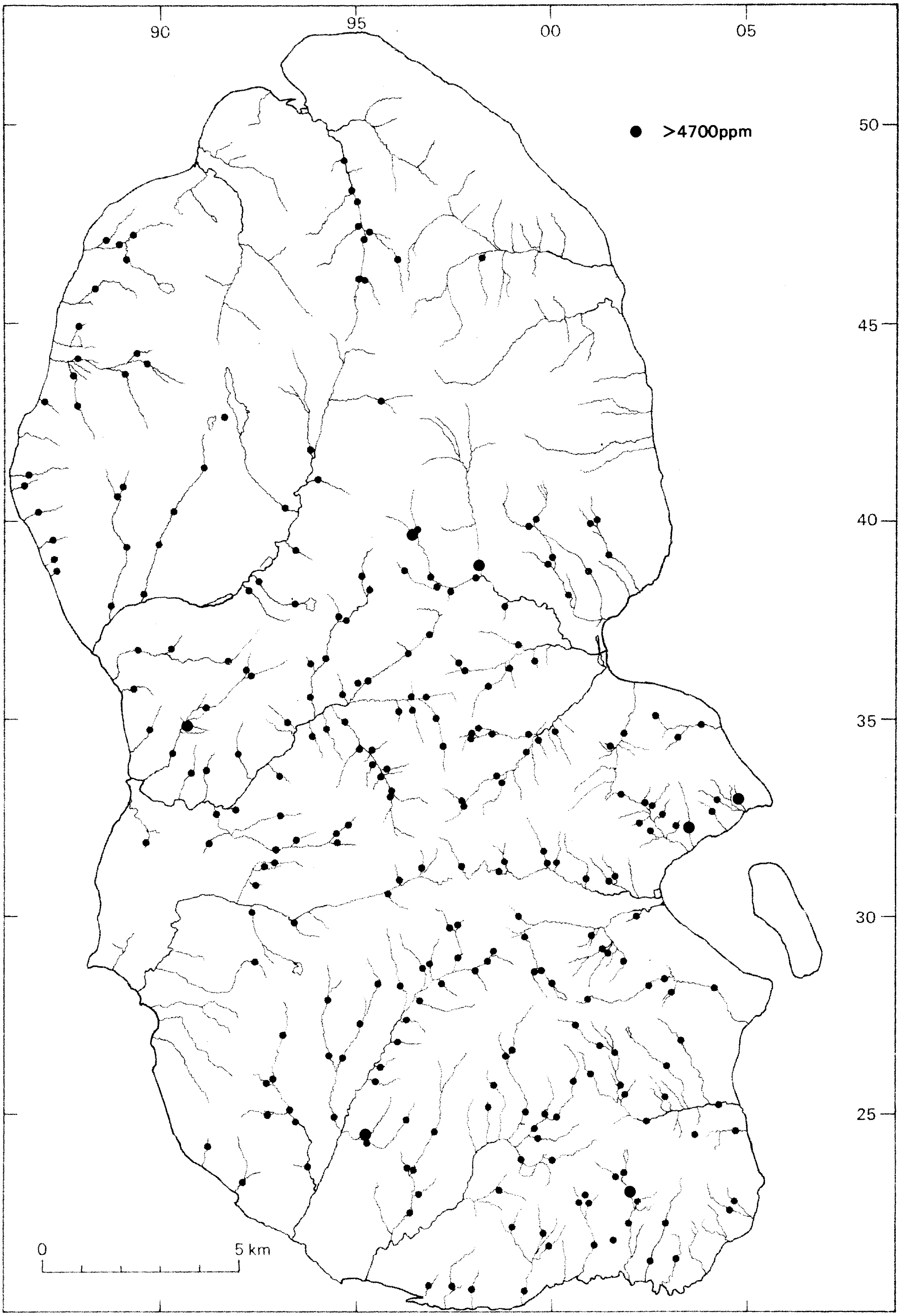

Figure 47 Distribution of zirconium anomalies