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Record 1977/24

RESULTS OF THE 1976 ORIENTATION STREAM-SEDIMENT GEOCHEMICAL SURVEY IN NORTH-EASTERN KEPALA BURUNG (BIRDS HEAD), IRIAN JAYA, INDONESIA

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SUMMARY

Orientation studies indicate that stream-sediment geochemistry is a potentially useful exploration technique in the Kepala Burung region of Irian Jaya, Indonesia. Previously located uranium anomalies and small zones of known base-metal sulphide mineralisation, are reflected in anomalous concentrations of these elements in the stream sediments.

Geologists collected 47 stream-sediment samples from an area of about 3500 km^2 in northeastern Kepala Burung. All samples were submitted to AMDEL, where each was analysed for 23 elements.

Cumulative frequency curves have been used to distinguish between background and anomalous populations for 14 of the 23 elements.

Spatial distributions of element concentrations indicate the presence of two geochemical provinces within the region: (1) an eastern province of volcanic rocks characterised by high copper, nickel, and manganese, and low arsenic, uranium, and lead concentrations, relative to (2) a western province of sediments and low-grade metamorphics intruded by granites. The two provinces are separated by a major fault.

Size fraction analysis indicates that future stream-sediment surveys should use the -80 mesh fraction.

Anomalous uranium concentrations associated with granites appear to be derived from uranium-bearing accessory minerals such as zircon, monazite, xenotime, thorite, and allanite (rather than from common ore-forming uranium minerals), and are usually accompanied by high thorium and cerium concentrations. Values for thorium and cerium can thus be used to screen uranium anomalies.

Lead appears to be a useful pathfinder element to copper mineralisation.

Follow-up work within the area is recommended at four localities where either copper-lead-zinc or uranium anomalies occur.

Kepala Burung can be divided into four metalliferous provinces; (1) a northern province of predominantly island-arc rocks, prospective for porphyry copper and possibly volcanogenic base metal deposits; (2) an eastern province of island-arc volcanics, possibly prospective for porphyry copper and volcanogenic base metal deposits; (3) a central province of sedi-

ments and metamorphics intruded by granites, possibly prospective for strata-bound sulphide, epigenetic, and/or pegmatitic deposits; and (4) a southern province of platform sediments, possibly prospective for Colorado plateau-type uranium-copper mineralisation.

Orientation studies should be extended to cover each province before initiating systematic reconnaissance stream-sediment surveys in the region.

INTRODUCTION

Between 15 August and 9 November 1976 a combined field party from the Bureau of Mineral Resources, Geology & Geophysics (BMR) and the Geological Survey of Indonesia (GSI) made a geological and geochemical reconnaissance in the Kepala Burung (formerly Vogelkop, or Birds Head) peninsula of Irian Jaya, Indonesia (Fig. 1). The purposes of this reconnaissance were to familiarise the ge-ologists with the logistic and operational problems of working in Irian Jaya, and to reconnoitre the geology of Kepala Burung before preparing a detailed submission outlining the budgetary, equipment, and manpower requirements for a 10-12-year Australian aid project of regional mapping and mineral exploration in Irian Jaya. Geological and operational aspects of the reconnaissance will be reported in full elsewhere.

The field party consisted of D.S. Trail (Australian party leader, Australian Development Assistance Bureau); G.P. Robinson, R.J. Ryburn, P.E. Pieters, and D.S. Hutchison (BMR); and Harli Sumadirdja (Indonesian party leader), Kastowo, Memed Masria, and Nana Ratman (GSI). The Royal Australian Survey Corps and the Royal Australian Air Force, which were engaged in topographic surveying and aerial photography from a base at Biak, provided logistic support.

The geochemical part of the reconnaissance was an orientation stream-sediment geochemical survey in the northeastern part of Kepala Burung. The purpose of this survey was to define the optimum sampling medium to establish the general background and threshold values for a range of elements, and to provide general guidelines for future stream-sediment surveys in Kepala Burung.

The geochemical survey area was reached mainly on foot and by boat from a base at Manokwari; four-wheel-drive vehicles and light aircraft were also used, to position geologists on a few occasions. Helicopters, however, were not used at all; this severely limited the area that could be covered by the survey, which - as a result - was less systematic than would otherwise have been possible.

The terrain in and around the geochemical survey area is mountainous and rugged - except in the northeast - and rises to a maximum elevation of about 2950 m (Gunning Mebo) 30 km south-southwest of Manokwari (Fig. 2). Within the mountains, streams are deeply incised, generally have steep gradients, and flow swiftly; abundant coarse to very coarse material is common in the stream sediments. In the northeast, low hills, formed by Cainozoic sediments and separated from the mountains by a coastal alluvial plain (Prafi-Warjori Plain) up to 15 km wide, were excluded from the geochemical survey area.

The area has a wet tropical climate influenced by the northwest monsoon from November to April and the southeast trade winds from May to October; a short, marked dry season generally occurs during August, September, and October. Mean annual rainfall ranges from less than 1500 mm at Ransiki to more than 3500 mm in places in the mountains. Temperatures and relative humidity are uniformly high; the former decreasing regularly with altitude.

Most of the area is covered by dense primary tropical rainforest of various types. Natural grassland occupies narrow belts along the lower reaches of some large rivers, and man-induced grassland occupies large areas on the Kebar Plain and in the Anggi Lakes area. Subalpine grassland is scattered locally on peaks and ridge crests above 1800 m.

Acknowledgements

I am grateful to Allan Rossiter for helpful discussions about the interpretation of the data. D.S. Trail read the manuscript and provided helpful criticisms.

GEOLOGY

The area covered by the stream-sediment survey was mapped in part by geologists of the Foundation Geological Investigation, Netherlands New Guinea, which made an economic geological survey in northeastern Kepala Burung between 1959 and 1962 (D'Audretsch, Kluiving, & Oudemans, 1966). Figure 3 is based largely on their work but also includes data from a compilation of the geological results of Dutch petroleum exploration in Irian Jaya by Visser & Hermes (1962), and incorporates the results of mapping during the 1976 BMR-GSI reconnaissance. The geology of a large part of the geochemical survey area (Manokwari 1:250 000 Sheet area) will be described in detail by Robinson & Nana Ratman (in prep.).

The bulk of the area is occupied by predominantly low-grade metamorphic rocks of Silurian to Devonian age (Kemum Formation). The main lithologies are slate, phyllite, siliceous argillite, metachert, quartzite, mica schist,

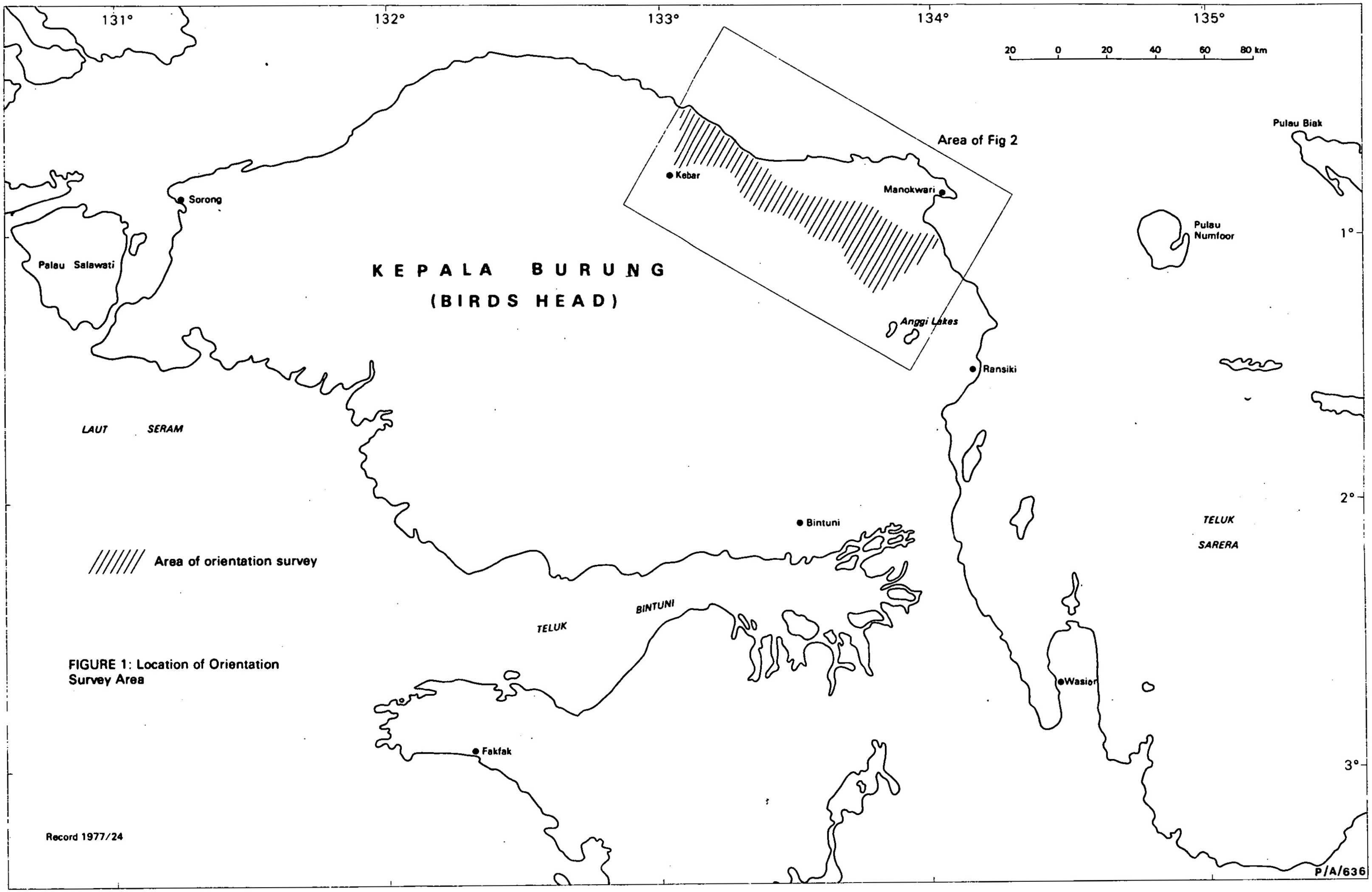

FIGURE 1: Location of Orientation Survey Area

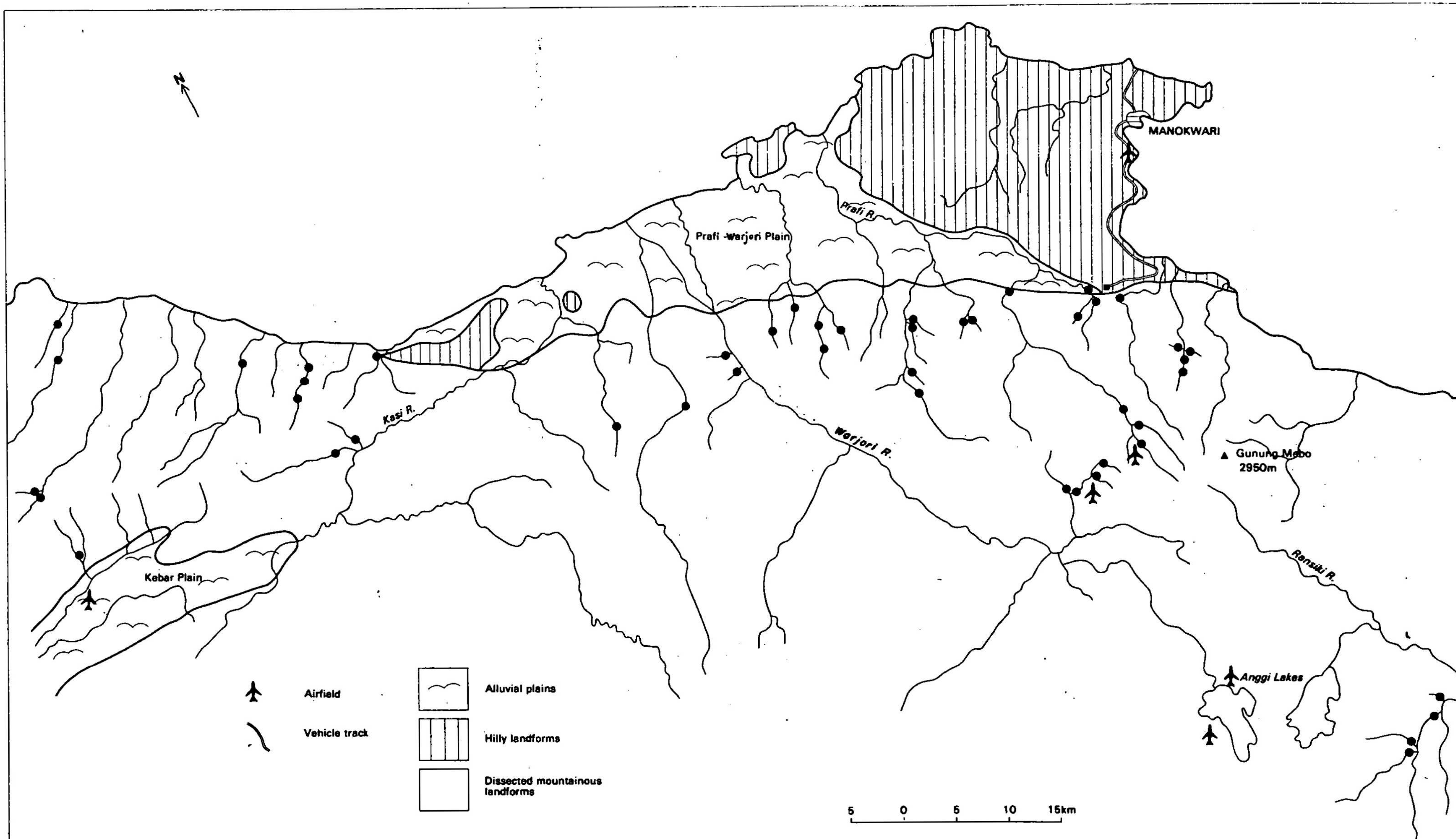

FIGURE 2 Physiography

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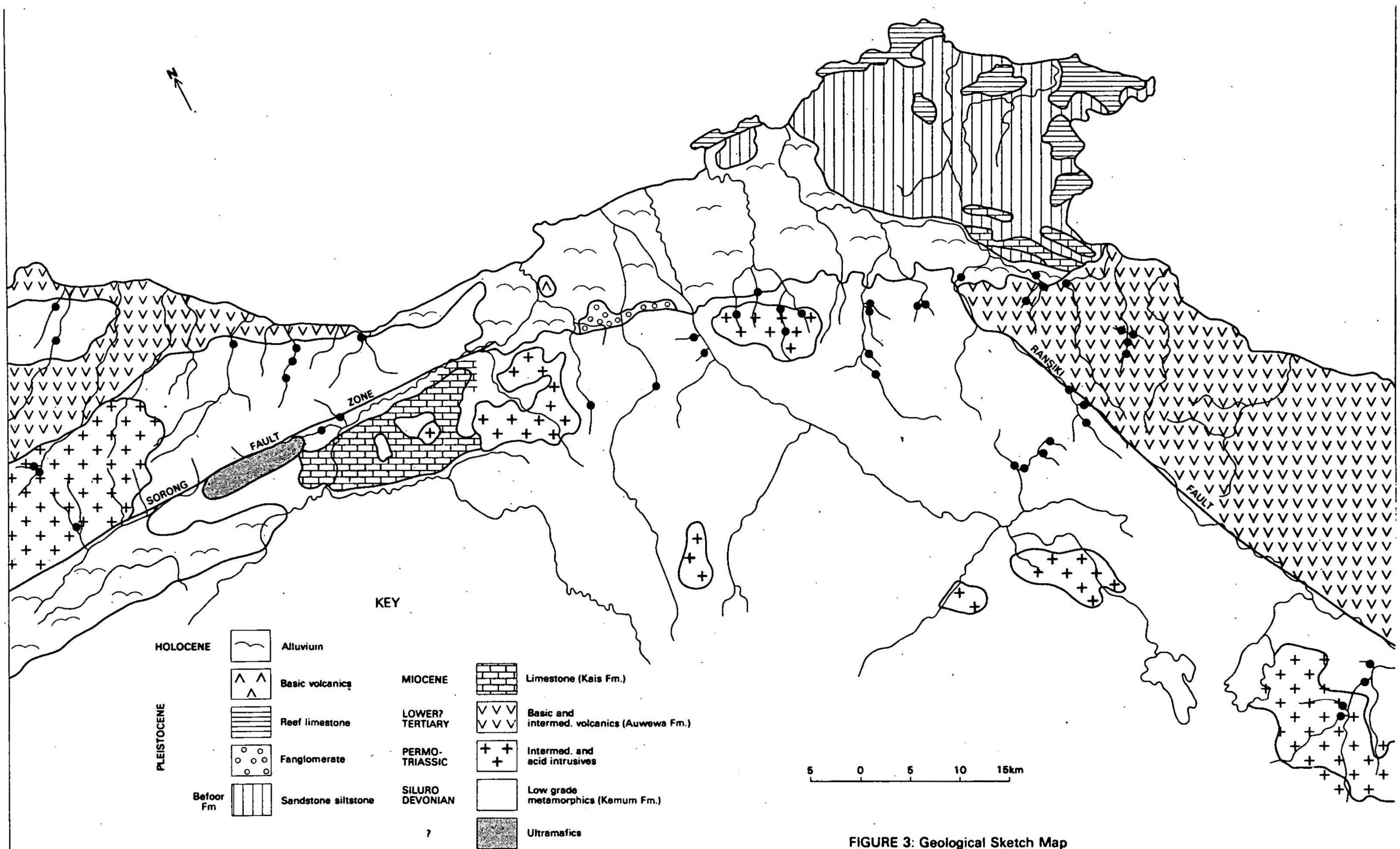

FIGURE 3: Geological Sketch Map

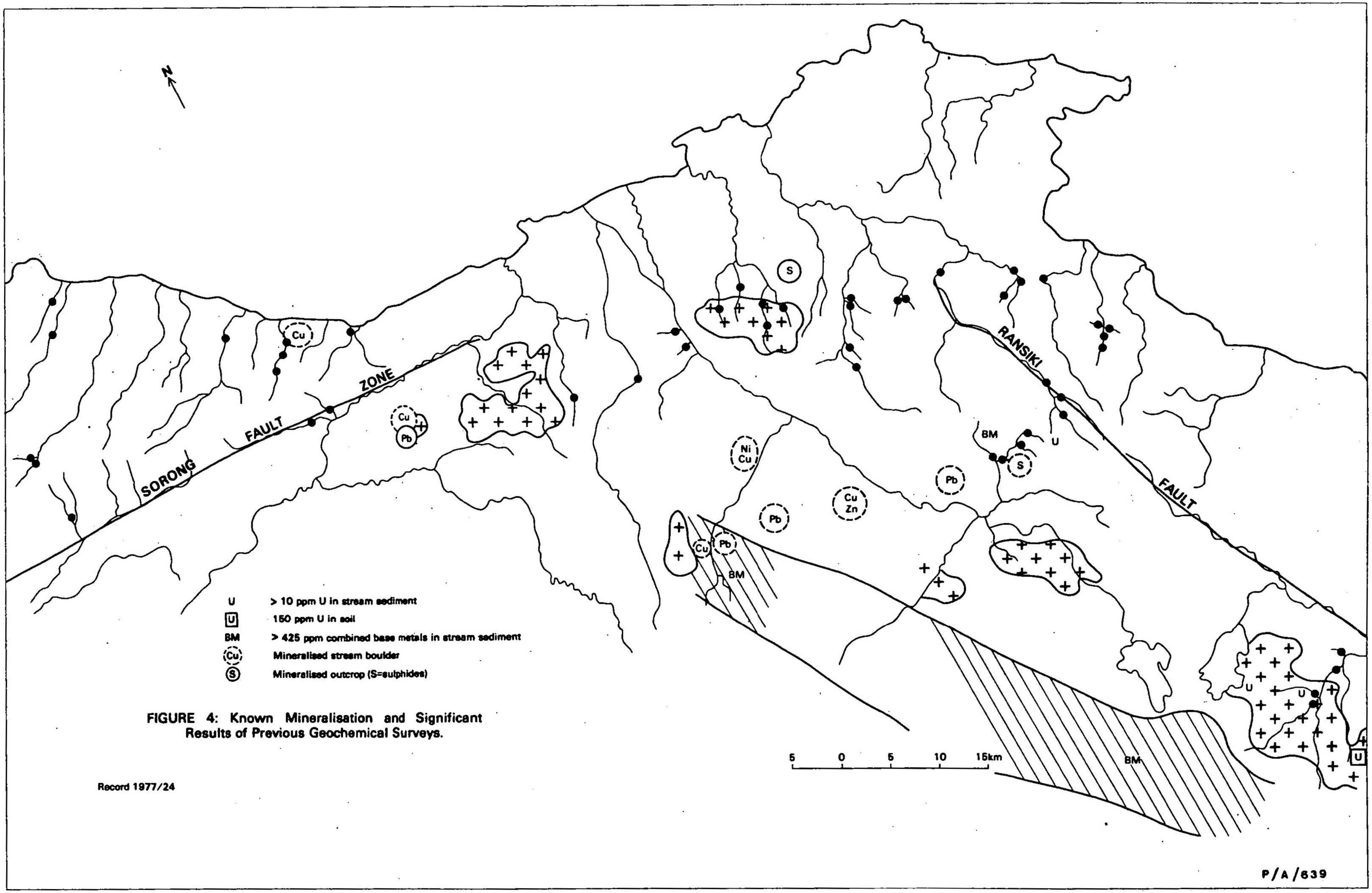

FIGURE 4: Known Mineralisation and Significant Results of Previous Geochemical Surveys.

and (rarely) metamorphosed intrusives. Metamorphic grade increases towards the east, and amphibolite-grade schists (some of which are garnet-bearing) are locally developed adjacent to the Ransiki Fault.

The Kemum Formation is intruded by Permo-Triassic coarse-grained acid intrusive rocks, with associated pegmatitic and intermediate phases. Weak thermal metamorphism of the metamorphic rocks has occurred locally around the margins of some larger intrusions.

To the east a poorly mapped sequence of predominantly basaltic and andesitic volcanic rocks of probable Early Tertiary age (Auwewa Formation) is separated from the metamorphic and intrusive rocks by the large Ransiki Fault.

In the northwest, a second large fault zone - the Sorong Fault Zone - separates a similar sequence of volcanic rocks, metamorphics, and intrusives from the main mass of metamorphic rocks. North of the fault the relations between the various rock types are unclear.

Miocene limestone (Kais Formation) forms elongate southeasterly trending ridges east of the Prafi River, and also crops out in the northwest.

The extreme northeast is occupied by Pleistocene shallow-marine and fluviatile, predominantly coarse-grained clastic sediments (Befoor Formation), and by raised Holocene reef limestone around the coast. Alluvium occupies the Prafi-Warjori Plain.

Mineral occurrences

Known mineralisation in the stream-sediment survey area is restricted to numerous small occurrences of sulphides, in the Kemum Formation and associated intrusives, and is commonly structurally controlled by small faults, shear zones, and fractures, (D'Audretsch and others, 1966). Minerals noted in these occurrences include pyrite, pyrrhotite, ilmenite, chalcopyrite, galena, stibnite, sphalerite, marcasite, arsenopyrite, and covellite.

Anomalous concentrations of uranium occur at several localities associated with the main body of granite in the southeast. However, detailed investigations (by D'Audretsch and others, 1966) of alluvial deposits in-streams draining the granite indicated the presence of alluvial concentrations of accessory minerals bearing uranium and thorium - for example, zircon, monazite, xenotime and thorite; common ore-forming uranium minerals were not identified.

Minor outcropping sulphide mineralisation was found at a few localities during the 1976 BMR-GSI reconnaissance, and stream boulders containing sulphide minerals were found at several localities by both D'Audretsch and others and the BMR-GSI party (Fig. 4).

PREVIOUS GEOCHEMICAL INVESTIGATIONS

D'Audretsch and others (1966) sampled in detail the soil and stream sediments of the area between 1959 and 1962. Initially they attempted to collect soil samples on a grid or along foot-tracks connecting villages. However, both these methods were impracticable, and the survey party then started to collect soil samples from the banks of streams at 100-200 m intervals. This too was found to be impracticable, and finally they collected stream-sediment samples. The results of their stream-sediment sampling are summarised in Figure 4.

The results for base metals are inconclusive, as they list only combined base-metal values in their report. However, there appears to be a narrow northwesterly trending anomalous base-metal zone (particularly in zinc) in the Kemum Formation to the west of the granite bodies. Of the 1662 stream-sediment samples they collected, 172 contained combined base-metal values in the range 345 to 685 ppm, and two contained more than 700 ppm combined base-metal values.

Ground radiometric surveys by the Dutch team located several radioactive anomalies associated with the granite bodies. All of these anomalies were followed up with stream-sediment and soil sampling.

Uranium was not detected in geochemical samples collected at most of the anomalies, which were assumed to be caused by alluvial concentrations of uranium-bearing accessory minerals. Concentrations of 4 to 16 ppm uranium in soil and stream sediments, with rare values up to 30 ppm, were found associated with some anomalies (Fig. 4), and, at one locality in the upper Sivhoe River, up to 150 ppm in soil is associated with the highest-recorded radioactive anomaly of 350-360 counts per second. However, the source of this uranium was not conclusively identified.

SAMPLING AND ANALYTICAL PROCEDURE

During the 1976 survey, geologists collected 47 stream-sediment samples from the active parts of stream channels (Fig. 5). Care was taken to avoid contamination by collapsed bank material, and, wherever possible, sediment was collected from two or more points in the stream at each sample locality.

Nineteen samples were wet-sieved to -50 mesh* in the field; the remainder were collected as 2 to 4 kg bulk samples. All samples were stored in cloth or plastic sample bags.

The nineteen samples sieved to -50 mesh in the field were submitted to the Australian Mineral Development Laboratories (AMDEL) for analysis without further preparation. The remaining samples were dried and them submitted to AMDEL, where eight were dry-sieved to -80 mesh, eight were dry-sieved to -50 mesh, and from the remainder (12) the -80, -50 + 80, and -20 + 50 fractions were recovered for size-fraction analysis. This resulted in a total of 71 separate fractions to be analysed.

All samples were analysed for copper, lead, zinc, cobalt, nickel, chrome, manganese, silver, molybdenum, gold, and lithium by atomic absorption spectrometry; arsenic, barium, bismuth, cerium, niobium, tin, antimony, thorium, uranium, and tungsten by X-ray fluorescence; beryllium by emission spectroscopy; and fluorine by a special specific-ion electrode method.

RESULTS

Presentation of data

The concentrations of elements at each sample locality have been plotted on maps of the same scale as the locality map in Figure 5. Wherever possible values for the -80 fraction are plotted on these maps, but, where no -80 fraction values are available, values for the -50 fraction are given.

Histograms and cumulative frequency curves have been prepared for 14 of the 23 elements (Appendix 2). Because of the small number of samples collected, values for both the -80 and -50 fractions (as plotted on the maps)

* Mesh sizes conform to British Standard wire mesh sieve series BS.410

have been combined in the cumulative frequency curves. In the histograms the combined -50 and -80 fractions are compared with the -80 fraction alone; apart from higher background values in the -80 fraction for some elements, using the combined -50 and -80 fractions seems to make little difference to the statistical calculations.

In order to differentiate anomalous concentrations from background concentrations, threshold values for each element have been calculated using wherever possible the 'break in slope' method on the cumulative frequency curves* (e.g., Lepeltier, 1969; Rossiter, 1976). Where only background populations have been sampled (as indicated by a single population line or curve in the cumulative frequency diagrams) the value corresponding to mean + 2 standard deviations is taken as an approximate threshold value. Background values, corresponding to the mean of the background population, have also been calculated for each element.

Geochemical provinces

The spatial distributions of element concentrations, as shown on the maps in Appendix 1, suggest that two geochemical provinces can be distinguished in the area. One province corresponds to the basic and intermediate volcanic province east of the Ransiki Fault; the other corresponds to the province of low-grade Siluro-Devonian metamorphic rocks and Permian-Triassic granites west of the fault.

The geochemical distinction between the two provinces is summarised in Table 1. The eastern geochemical province is distinguished from the western geochemical province by lower concentrations of lead, arsenic, uranium, lithium, thorium, cerium, niobium, fluorine, and barium, and higher concentrations of manganese, cobalt, copper, and possibly nickel.

The volcanic rocks in the northwest (north of the Sorong Fault Zone) are not readily distinguished on the geochemical maps; their presence is apparently masked by the abundance of nearby metamorphic and intrusive rocks.

Because of the very small number of samples (12) collected from the eastern province, only those samples collected from the western province have been treated statistically. Approximate background values only have been calculated for the eastern province.

*Logarithmic probability curves have been plotted for some elements in an attempt to show a more clearly defined threshold.

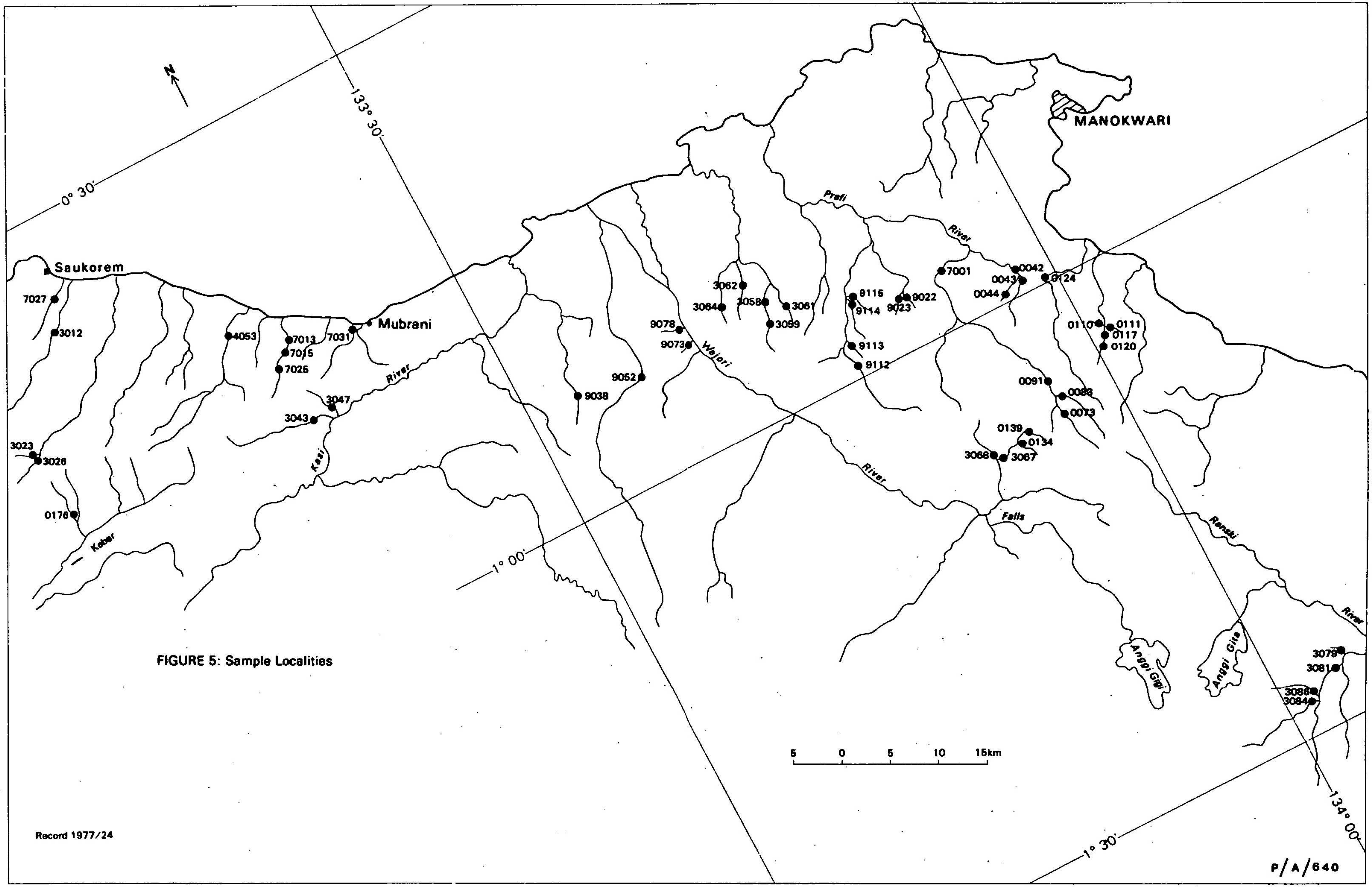

FIGURE 5: Sample Localities

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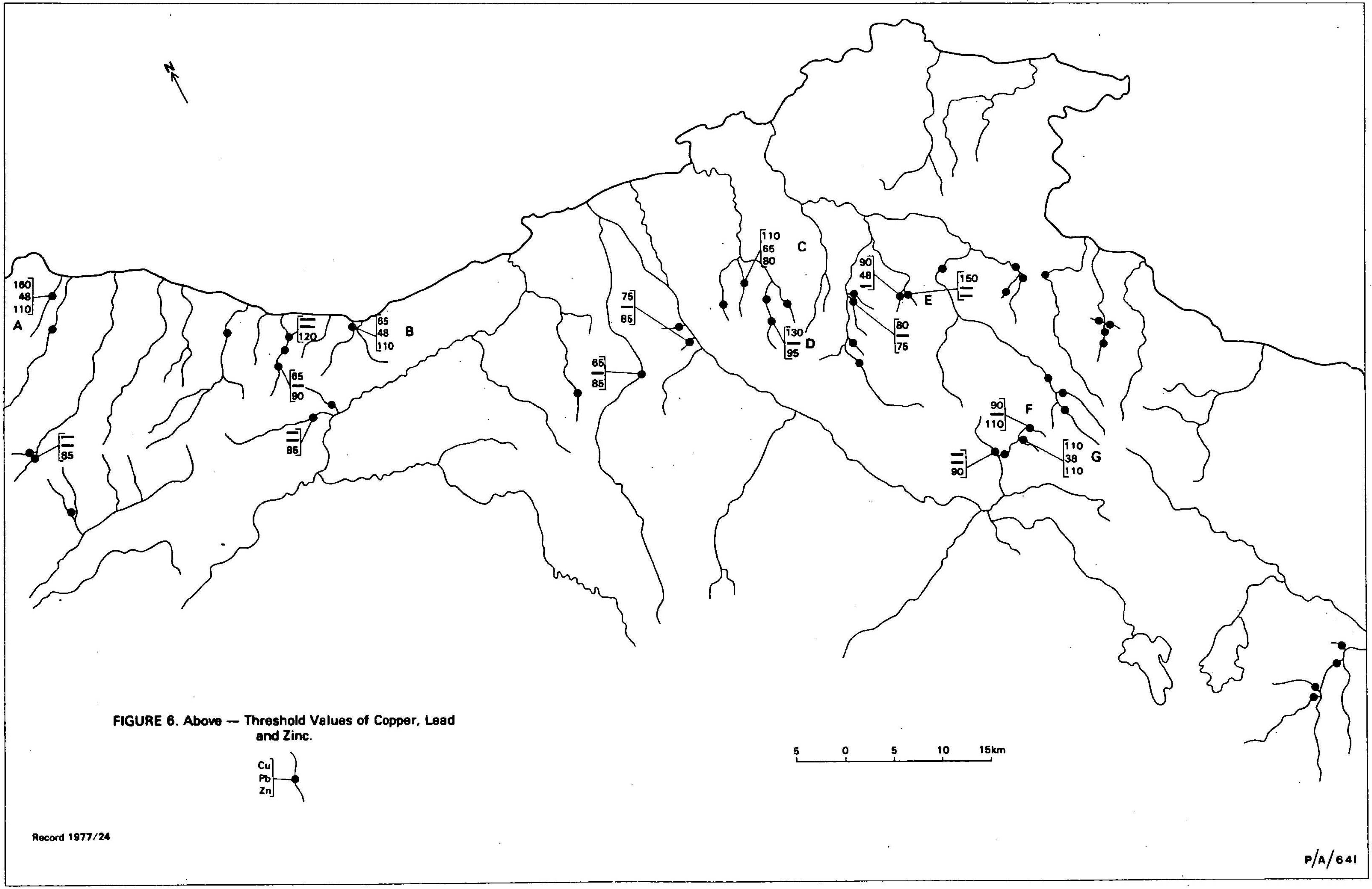

FIGURE 6. Above — Threshold Values of Copper, Lead and Zinc.

Cu
Pb
Zn

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TABLE 1 - COMPARISON OF MEAN VALUES OF FOURTEEN ELEMENTS IN THE EASTERN AND WESTERN GEOCHEMICAL PROVINCES

ELEMENT	WESTERN PROVINCE		EASTERN PROVINCE
	-80 Mesh	-50 Mesh	-50 Mesh
Cu	64	40	74
Pb	26	19	Detected at two localities only
Zn	84	71	67
Co	16	13	24
Ni	42	20	31
Mn	452	354	786
As	4.8	6.5	Detected at two localities only
U	6.9	4.5	Detected at 3 localities only
Li	37	35	8
Th	23	16	Very low or not detected.
Ce	137	106	Very low or not detected.
Nb	10	7.1	Very low or not detected.
F	219	206	85
Ba	506	474	61

Optimum-size fraction

Bulk samples from twelve sites scattered throughout the western province were sieved into -80, -50 + 80, and -20 + 50 size fractions.

Examples of the distribution of Cu, Pb, Zn, Co, Ni, Cr, As, U, Th, Ce, Ba, Nb, Li, and Sn in each fraction are shown in Appendix 3. For almost all these elements there is an increase in concentration in the finer-size fractions. Although for most elements the increase is not marked for the background range of values, some anomalous samples show a distinct increase in concentration in the finest fraction.

One clear exception is barium, which shows a marked increase in concentration in the coarser fractions. Arsenic appears to be more highly concentrated in the -50 + 80 fraction.

It can be concluded that, unless barium is being sought, future geochemical surveys in the region should use the -80 fraction.

Copper

*Threshold - 60 ppm

Above-threshold values of copper, lead, and zinc are given in Figure 6. Anomalous copper values were recorded at several localities scattered throughout the western province. At four of these localities (marked A, B, C, and G in Fig. 6) the anomalous copper is associated with both anomalous lead and zinc, and at seven other localities anomalous copper is associated with either anomalous lead (one locality) or anomalous zinc (six localities).

Boulders of intrusive rock containing chalcopyrite, from which rock-chip samples yielded up to 1000 ppm copper, lie in one of the streams sampled between anomalies A and B (Fig. 4); similar chalcopyrite-bearing boulders are known from several streams draining the volcanic rocks to the west of this locality. Therefore, anomaly A with 160 ppm copper warrants more detailed follow-up sampling.

Anomalies C and D are in an area where outcropping propylitic alteration and sulphide mineralisation has been observed (near anomaly D), and both should be investigated further.

Large iron-stained boulders containing some sulphides occur downstream from anomalies F and G; these streams should also be sampled in more detail. Of the other anomalies none are considered to warrant follow-up work, except possibly anomaly E with 150 ppm copper.

Lead

Threshold - 30 ppm

Slightly anomalous lead concentrations were detected at only five localities in the western province. At each locality, lead is associated with anomalous copper concentrations. Apart from where follow-up work in relation to copper is recommended, further investigation for lead appears unwarranted.

Lead was detected at only two localities in the eastern province.

* All threshold values are for the western geochemical province only.

Zinc

Threshold - 70 ppm

Although more than sixty percent of the zinc population in the western province appears to be anomalous, no significant zinc anomalies were detected. Some of the higher concentrations are associated with copper anomalies and others can be correlated with higher manganese concentrations (e.g., 120 ppm Zn west of anomaly B, Fig. 6), suggesting possible Mn scavenging. No follow-up work is warranted in relation to zinc anomalies alone.

Manganese

Threshold - 500 ppm

Anomalous concentrations of manganese in the western province are mostly in the northwest, probably reflecting the exposures of basic and intermediate volcanics in this area. Some of the higher base-metal values in the northwest are possibly due to manganese scavenging, but this is considered unlikely as the manganese anomalies are very subdued.

Manganese values in the eastern province are roughly twice those in the western province, reflecting the abundance of basic volcanic rocks in the eastern province.

Uranium

Threshold - 16? ppm

Owing to the small number of samples containing detectable uranium, resulting in breaks in the cumulative frequency curve, the threshold value for uranium could not be easily determined. However, the log-probability curve suggests that the upper limit of the background population is probably in the range 12-16 ppm. For the purpose of this report the upper value is taken as the threshold value.

Anomalous concentrations of uranium were detected at four localities in the western province (Fig. 7). In the southeast, uranium values of 18 and 20 ppm associated with high thorium and cerium values were recorded at two localities within a large mass of granite (Anomalies C and D). D'Audretsch and others (1966) discovered anomalous levels of radioactivity in the same area, but attributed this radioactivity to alluvial concentrations of uranium-bearing accessory minerals in the stream beds. The association of high thorium and cerium values with high uranium in these samples suggests that accessory minerals such as zircon, monazite and allanite are the source of the uranium (A. Rossiter, pers. comm. 1977). This supports D'Audretsch's conclusions, and these anomalies are not considered worth further investigation.

The uranium concentration associated with anomaly B is only slightly anomalous (20 ppm), but, as associated thorium and cerium values are low, uranium ore minerals may be the cause (rather than common accessory minerals) and, further investigation is warranted.

The highest detected concentration of uranium in the western province (30 ppm) is associated with high cerium but low thorium values, and, because anomalous concentrations of lithium, fluorine, niobium, and tin were recorded in the same sample, more detailed follow-up work is recommended.

Uranium was detected in only three samples from the eastern province, in contrast to the western province, where it is widespread.

Thorium

Threshold - 40? ppm

In common with uranium the cumulative frequency curves for thorium give inconclusive results for the threshold value. However, the values above 40 ppm appear to define a second population, and, for the purpose of this report, 40 ppm is taken as the threshold value.

Anomalous concentrations of thorium were recorded only in the southeast, associated with granite. Elsewhere, values are below threshold.

Thorium was not detected in any samples from streams which exclusively drain the eastern volcanic province.

Cerium

Threshold - 150 ppm

Anomalous concentrations of cerium are generally associated with anomalous concentrations of uranium and thorium, particularly in the southeast where radioactive anomalies occur; this suggests that the source of the uranium is accessory minerals such as zircon, monazite, and allanite.

In common with uranium and thorium, cerium is only in scattered low concentrations in the eastern province.

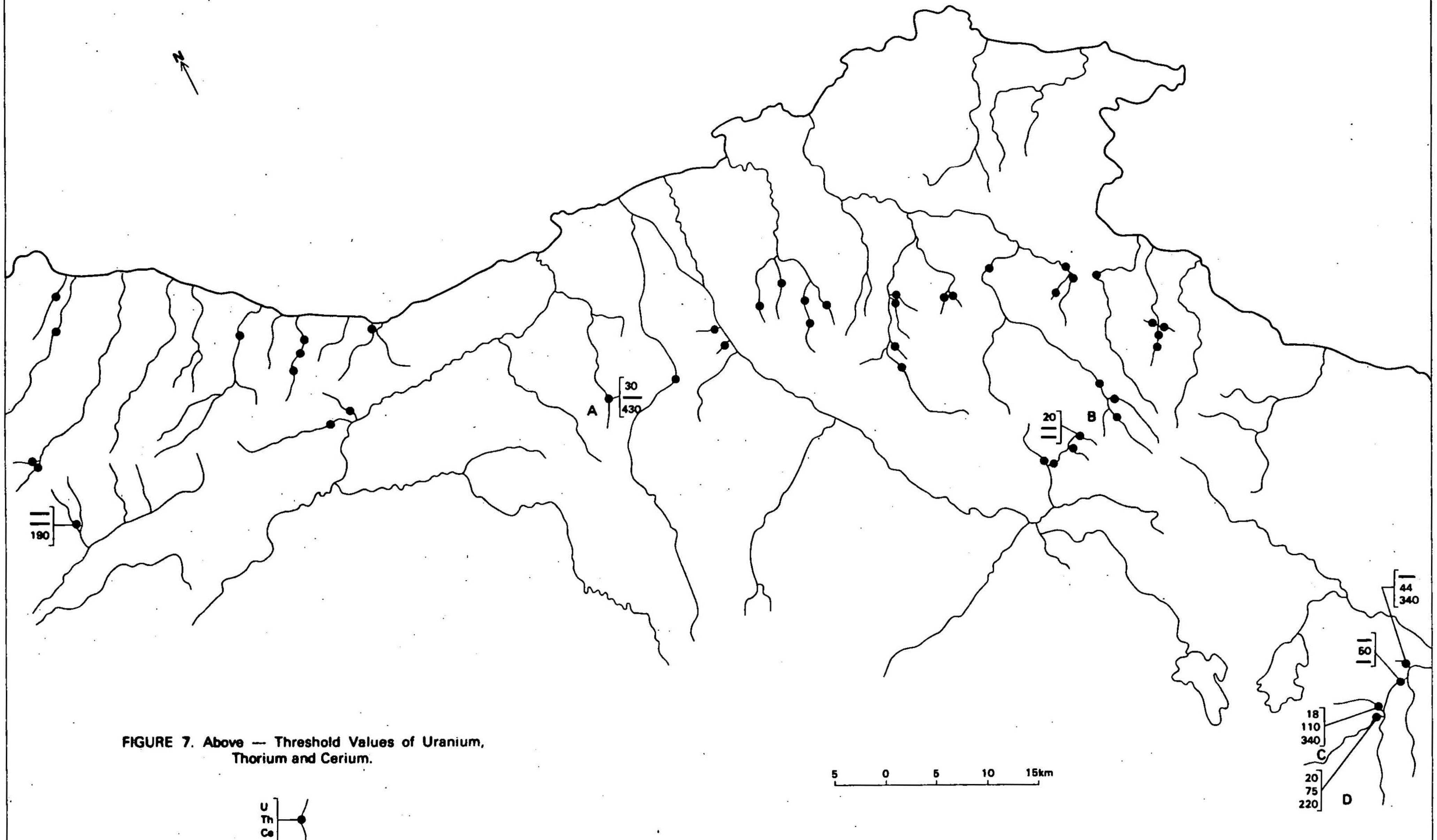

FIGURE 7. Above — Threshold Values of Uranium, Thorium and Cerium.

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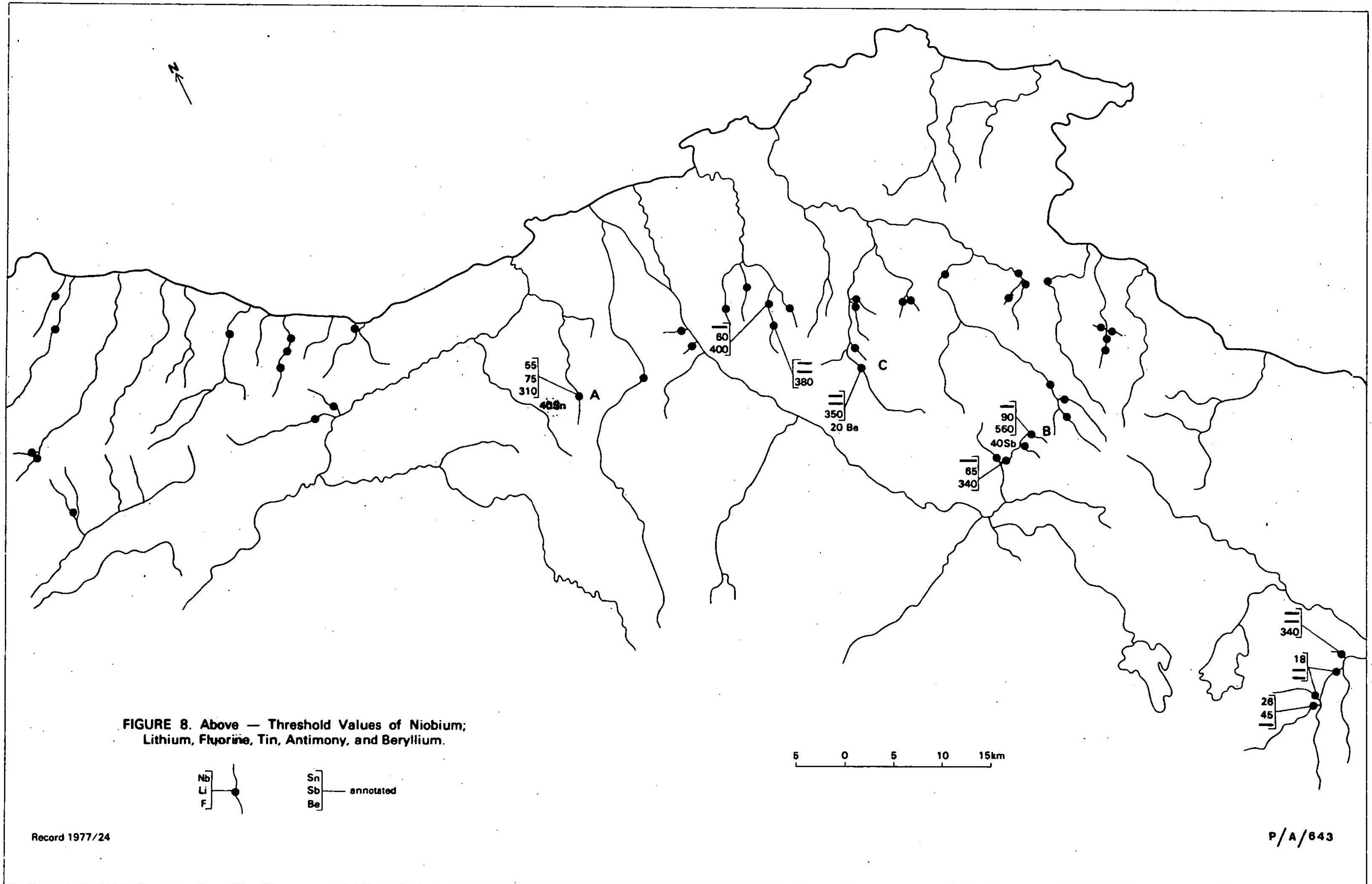

FIGURE 8. Above — Threshold Values of Niobium; Lithium, Fluorine, Tin, Antimony, and Beryllium.

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Niobium, lithium, fluorine, beryllium

Threhold: Nb - 15 ppm, Li - 40 ppm, F - 250 ppm, Be - ?

In an attempt to define areas of pegmatitic rocks (as potential hosts of economic mineralisation), all samples were analysed for niobium, lithium, fluorine, and beryllium. Anomalous concentrations of these elements are shown in Figure 8. Niobium was also sought as a possible indicator of tin deposits.

As would be expected, most samples containing anomalous concentrations of niobium, lithium, or fluorine are from streams draining areas of coarse-grained acid intrusives and associated pegmatites.

Anomalous concentrations of niobium, lithium, and fluorine, either singly or in various combinations, were recorded at ten localities. At one of these (anomaly A) all three elements accompany anomalous tin, uranium, and cerium, and this anomaly should be investigated in more detail.

Of the other anomalies none is considered to be worth further investigation, except for anomaly B, where anomalous lithium and fluorine accompany anomalous uranium, copper, zinc, and antimony. This anomaly should be sampled in more detail.

Anomalous concentrations of beryllium (20 ppm in the -50 + 80 fraction) were detected at one locality only (anomaly C).

All four elements are either absent or in very low concentrations in the eastern province.

Cobalt, nickel, chromium

Cobalt, nickel, and chromium were determined as indicators of ultramafic rocks - potential hosts for copper-nickel, chromium, and platinum mineralisation.

The cumulative frequency curves for cobalt and nickel (chromium was not treated statistically) indicate that, apart from one locality, only the background populations have been sampled.

At one locality in the northwest, anomalous concentrations of 32 ppm cobalt, 380 ppm nickel, and 150 ppm chromium indicate that ultramafic rocks are probably exposed somewhere in the catchment area of this stream. The high cobalt value also suggests that nickel sulphide mineralisation may be present.

Arsenic

Arsenic commonly occurs as a pathfinder element in association with base-metal sulphide and gold deposits, and is also known to occur in association with uranium mineralisation (e.g., Rossiter, 1976).

The cumulative frequency curves for arsenic indicate that only the background population has been sampled. No anomalous values were detected anywhere in the survey area, but higher concentrations (14-24 ppm) are associated with some of the base-metal and/or uranium anomalies.

Arsenic was detected in only two samples in the eastern province.

Barium

Threshold - 700 ppm

The cumulative frequency curves for barium indicate that three populations may be present, with two possible threshold values of 500 ppm and 700 ppm. The upper value is taken as the threshold value, as only 20 percent of the total values are above 700 ppm.

Slightly anomalous barium concentrations were detected at three localities in the western province, two of them in association with base-metal anomalies. The cause of the barium anomalies is probably the presence of felsic igneous rocks.

Barium concentrations in the eastern province are markedly lower than those in the western province.

Tin, tungsten, antimony

The presence of acid igneous rocks in northeastern Kepala Burung, and the geological similarities of central Kepala Burung to the Tasman Fold Belt of eastern Australia, suggest that Kepala Burung might have potential for tin, tungsten, and antimony mineralisation. All three elements were detected at only a few scattered localities. However, 40 ppm tin at one locality, and 40 ppm antimony at another, are associated with uranium and uranium/base-metal anomalies respectively (Fig. 8). Both anomalies should be investigated further.

Molybdenum

Molybdenum concentrations in the range 3-4 ppm were detected at only a few scattered localities in both provinces.

Silver

Silver was not detected in any samples.

Gold

Gold was detected in one sample only, at a concentration of 0.15 ppm.

Bismuth

Bismuth occurs in only scattered low concentrations (up to 6 ppm) in both provinces.

Correlation coefficients

In order to determine possible pathfinder elements, Spearman's correlation coefficients were calculated for all data (Table 2). These coefficients attempt to quantify the interrelation between two or more elements. However, because of the small number of samples collected any correlations inferred from Table 2 must be considered tentative.

Copper displays strong correlation with lead in both size fractions, and lesser correlations with zinc in the -50 fraction and cobalt in the -80 fraction. Apart from its correlation with copper, lead is moderately correlated with zinc and cobalt.

Zinc displays moderate correlation with copper, lead, and nickel, and is also correlated with cobalt in the -80 fraction and with lithium and flourine in the -50 fraction. This suggests that zinc anomalies are related to several different types of lithologies and/or mineralisation.

Cobalt displays moderately strong correlation with manganese in both size fractions. Nickel is also moderately correlated with manganese in the -80 fraction.

TABLE 2 - SPEARMAN'S CORRELATION COEFFICIENTS FOR WESTERN PROVINCE DATA

-50 mesh

	Cu	Pb	Zn	Co	Ni	Mn	Th	Li	F	Be	Ce
Cu	1.00										
Pb	.71	1.00									
Zn	.50	.57	1.00								
Co				1.00							
Ni			.63		1.00						
Mn				.70		1.00					
Th							1.00				
Li			.76					1.00			
F			.57					.61	1.00		
Be							.65			1.00	
Ce							.85				1.00

-80 mesh

	Cu	Pb	Zn	Co	Ni	Mn	Th	Ba	Li	Be	F
Cu	1.00										
Pb	.89	1.00									
Zn			1.00								
Co	.62	.53	.56	1.00							
Ni			.70		1.00						
Mn				.68	.55	1.00					
Th							1.00				
Ba								1.00			
Li									1.00		
Be							.62			1.00	
F								.85	.64		1.00

Elements which were not detected in most samples have been omitted.
Correlation coefficients of .49 or less have also been omitted.

Thorium is moderately correlated with beryllium, and is strongly correlated with cerium in the -50 fraction only. As would be expected lithium and fluorine are moderately correlated, and barium is strongly correlated with fluorine in the -80 fraction only.

CONCLUSIONS

The significant results of the 1976 orientation stream-sediment survey are summarised in Table 3. Because of the small number of samples collected during the survey, the statistical results and conclusions drawn from them must be considered tentative.

Stream-sediment geochemistry appears to be a very useful exploration technique in Kepala Burung. Previously known uranium anomalies and small zones of known base-metal sulphide mineralisation are reflected by anomalous concentrations of these elements in the stream sediments.

Two geochemical provinces can be distinguished in the survey area. These provinces reflect the regional geology and comprise:

(i) an eastern province of predominantly basic and intermediate volcanic rocks characterised by high copper, nickel, cobalt, and manganese, and very low arsenic, uranium, lead, fluorine, barium, lithium, thorium, cerium, and niobium concentrations;

(ii) a western province of low-grade metamorphic and intermediate to acid intrusive rocks characterised by low manganese, moderate copper, lead, and uranium, and high lithium, cerium, thorium and fluorine concentrations.

Stream-sediment size-fraction analysis indicates that future stream-sediment geochemical surveys in Kepala Burung should use the -80 mesh fraction for all elements except barium, for which the -20 mesh fraction should be used.

Anomalous concentrations of uranium associated with uranium-bearing accessory minerals such as zircon, monazite, xenotime, thorite, and allanite are usually accompanied by anomalous concentrations of thorium and cerium. As anomalous uranium concentrations in stream sediments derived from common ore-forming uranium minerals (e.g. uraninite, coffinite) should be accompanied by low thorium and cerium concentrations, this would appear to be a potential method for screening uranium anomalies.

TABLE 3 - SUMMARY OF RESULTS
(Western geochemical province data)
(values in parts per million)

Element sought	Range of values	Mean of sample population fraction -50	Mean of sample population fraction -80	Mean of background population	Threshold	Potential pathfinder elements
Cu	8-160	40	64	25	60	Pb
Pb	9-65	19	26	20	30	Cu
Zn	38-120	71	84	55	70	Pb?
U	4-30	5	7	4.5	*16(-50) 22(-80)	
Ni		20	42	20	*34(-50) 186(-80)	

NB. 1. Mean of background population is taken as mid-point of background population curve in cumulative frequency diagrams.
2. Threshold values are obtained by 'break-in-slope' of cumulative frequency curve, except where marked by asterisk (*), in which case values are taken as mean + 2 standard deviations of sample population.

Follow-up work is recommended on anomalies at four localities within the area of the orientation survey (Fig. 9): copper-lead-zinc at A and B; uranium-cerium-tin at C; and copper-lead-zinc-uranium-antimony at D. Follow-up work should consist of resampling the initial sampling points, more detailed sampling upstream and in all side streams above the initial sampling points, and detailed mapping aimed at locating any outcropping mineralisation.

Spatial element associations and Spearman's correlation coefficients suggest that lead is a useful pathfinder to copper mineralisation. Data are too few for the other elements to permit meaningful assessments of element associations.

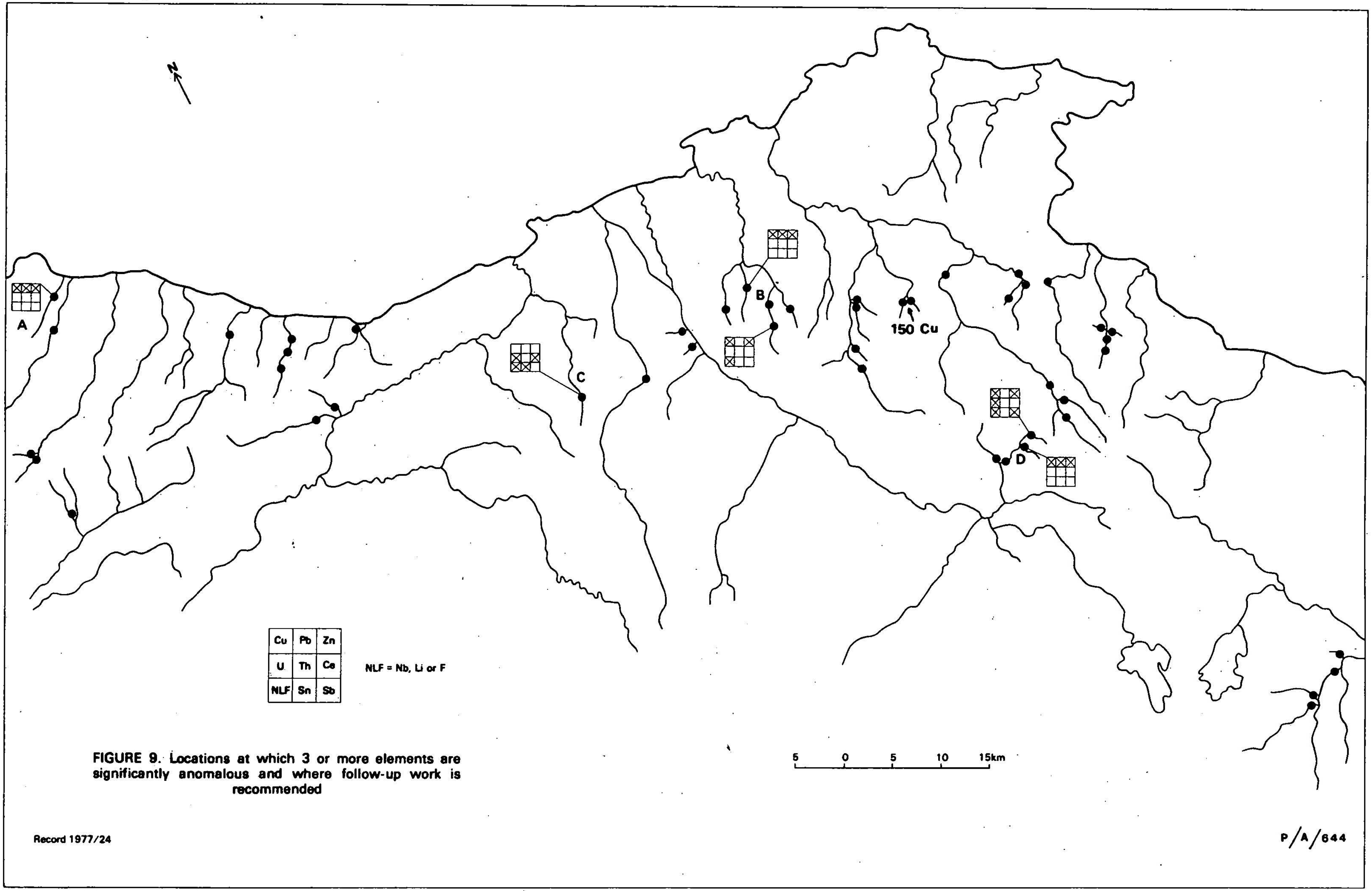

FIGURE 9. Locations at which 3 or more elements are significantly anomalous and where follow-up work is recommended

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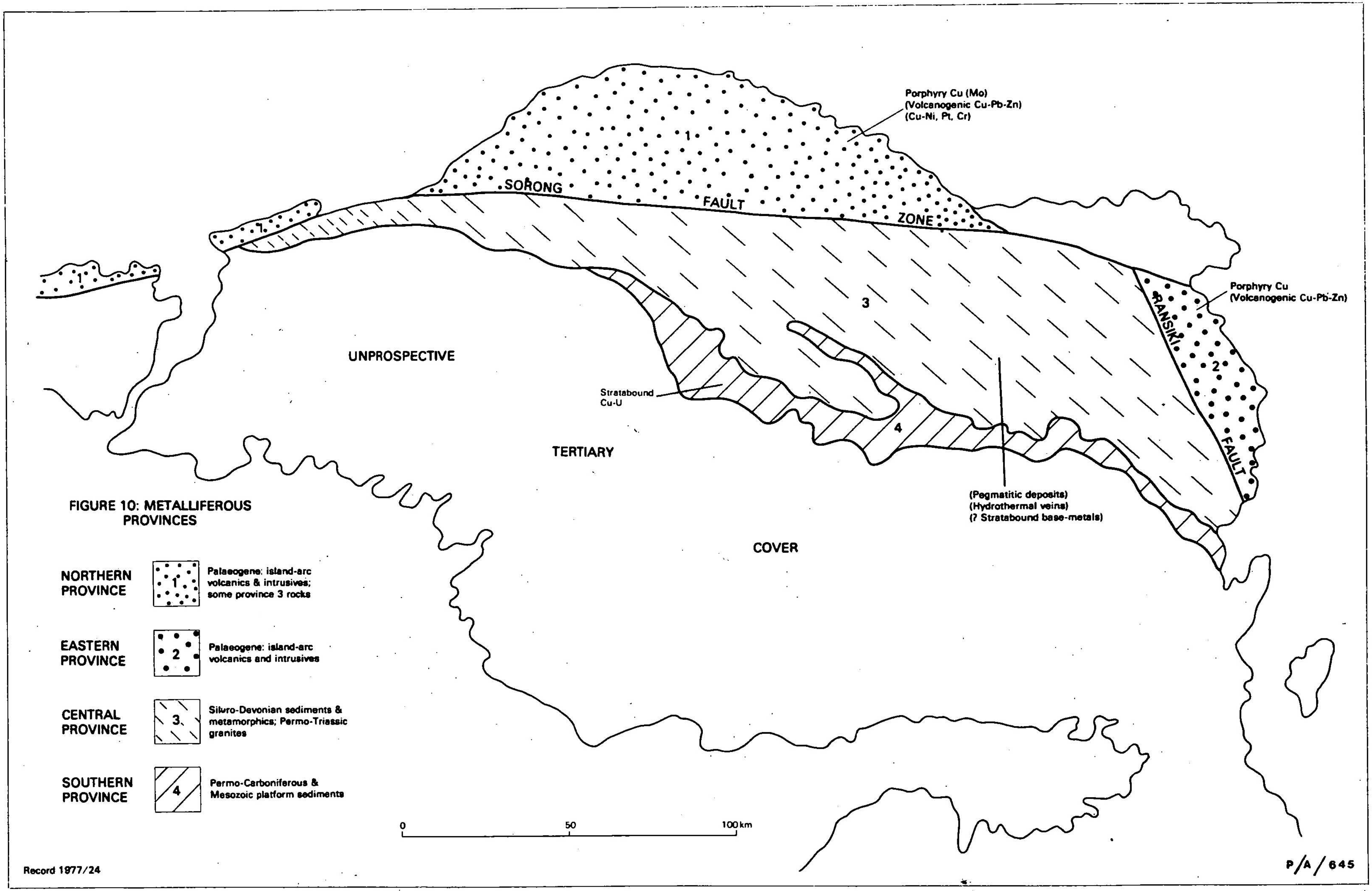

FIGURE 10: METALLIFEROUS PROVINCES
Porphyry Cu (Mo)
(Volcanogenic Cu-Pb-Zn)
(Cu-Ni, Pt, Cr)
SORONG
FAULT
ZONE
1
1
1
3
2
4
RANSIKI
FAULT
Porphyry Cu
(Volcanogenic Cu-Pb-Zn)
UNPROSPECTIVE
TERTIARY
COVER
Stratabound
Cu-U
(Pegmatitic deposits)
(Hydrothermal veins)
(? Stratabound base-metals)
NORTHERN PROVINCE
Palaeogene: island-arc volcanics & intrusives; some province 3 rocks
EASTERN PROVINCE
Palaeogene: island-arc volcanics and intrusives
CENTRAL PROVINCE
Siluro-Devonian sediments & metamorphics; Permo-Triassic granites
SOUTHERN PROVINCE
Permo-Carboniferous & Mesozoic platform sediments
0
50
100 km
Record 1977/24
P/A/645

RECOMMENDATIONS FOR FUTURE RECONNAISSANCE STREAM-SEDIMENT GEOCHEMISTRY IN KEPALA BURUNG

With respect to mineral exploration, Kepala Burung can be divided into four broad metalliferous provinces (Fig. 10). These are:

(i) a northern province of basic and intermediate island-arc volcanics and intrusive rocks with potential for porphyry-copper and possibly volcanogenic-type base-metal sulphide mineralisation, and nickel-chromium mineralisation associated with ultramafic rocks;

(ii) an eastern province of predominantly basic and intermediate island arc volcanic rocks with potential for porphyry copper and possibly volcanogenic base-metal mineralisation;

(iii) a central province of low-grade metamorphic and sedimentary rocks intruded by granites with some potential for pegmatitic and hydrothermal mineralisation (such as U, Sn, Sb, W), and possibly stratabound base-metal sulphides within the sedimentary-metamorphic sequence.

(iv) a southern province of upper Palaeozoic and Mesozoic shallow-marine and terrestrial platform sediments with potential for Colorado plateau-type stratabound copper and/or uranium mineralisation.

The present orientation survey should be extended to broadly cover all four provinces, and to establish background and threshold values for each element within each province. As in the 1976 survey, all 23 elements should be analysed for in the extended orientation survey.

On completion of the orientation survey, a systematic reconnaissance survey, with a sample density of one sample per 25 km^2 or better, should be made of each province. Copper, lead, zinc, cobalt, nickel, manganese, and silver should be routinely determined for all samples in each province. In addition to these elements, molybdenum and chromium should be determined in the northern and eastern provinces; uranium, thorium, cerium, niobium, lithium, tin, and tungsten in the central province; and uranium, thorium, and cerium in the southern province.

In addition to stream-sediment sampling, panned-concentrate sampling should also be done in each province. Samples should be collected at a density of about one per 50-100 km^2, and, after removal of magnetite by hand magnet and optical examination for gold, should be analysed routinely for cobalt, copper, lead, zinc, molybdenum, and nickel. In addition to these elements chromium should be determined in the northern and eastern provinces, and cerium, tin, tungsten, and zirconium in the central province. The panned-concentrate technique should be compared with the stream-sediment technique to evaluate the former's potential as an exploration technique in the region.

The ideal method of conducting a geochemical survey (i.e., initial orientation survey followed by a full systematic survey) may not always be possible, and the form, extent, and thoroughness of geochemical surveys made in conjunction with the Irian Jaya regional mapping project will be dictated by year-to-year operational requirements.

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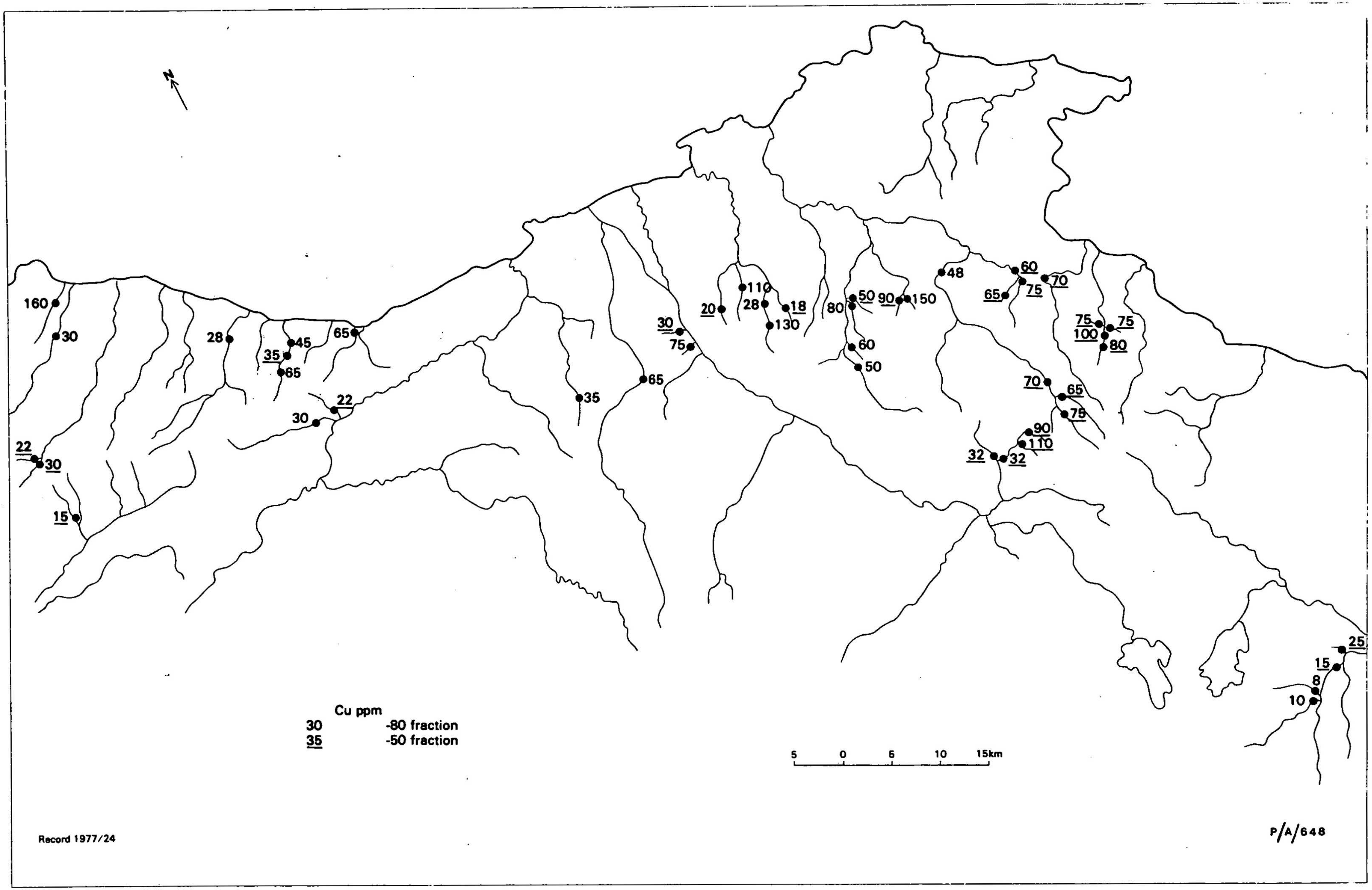
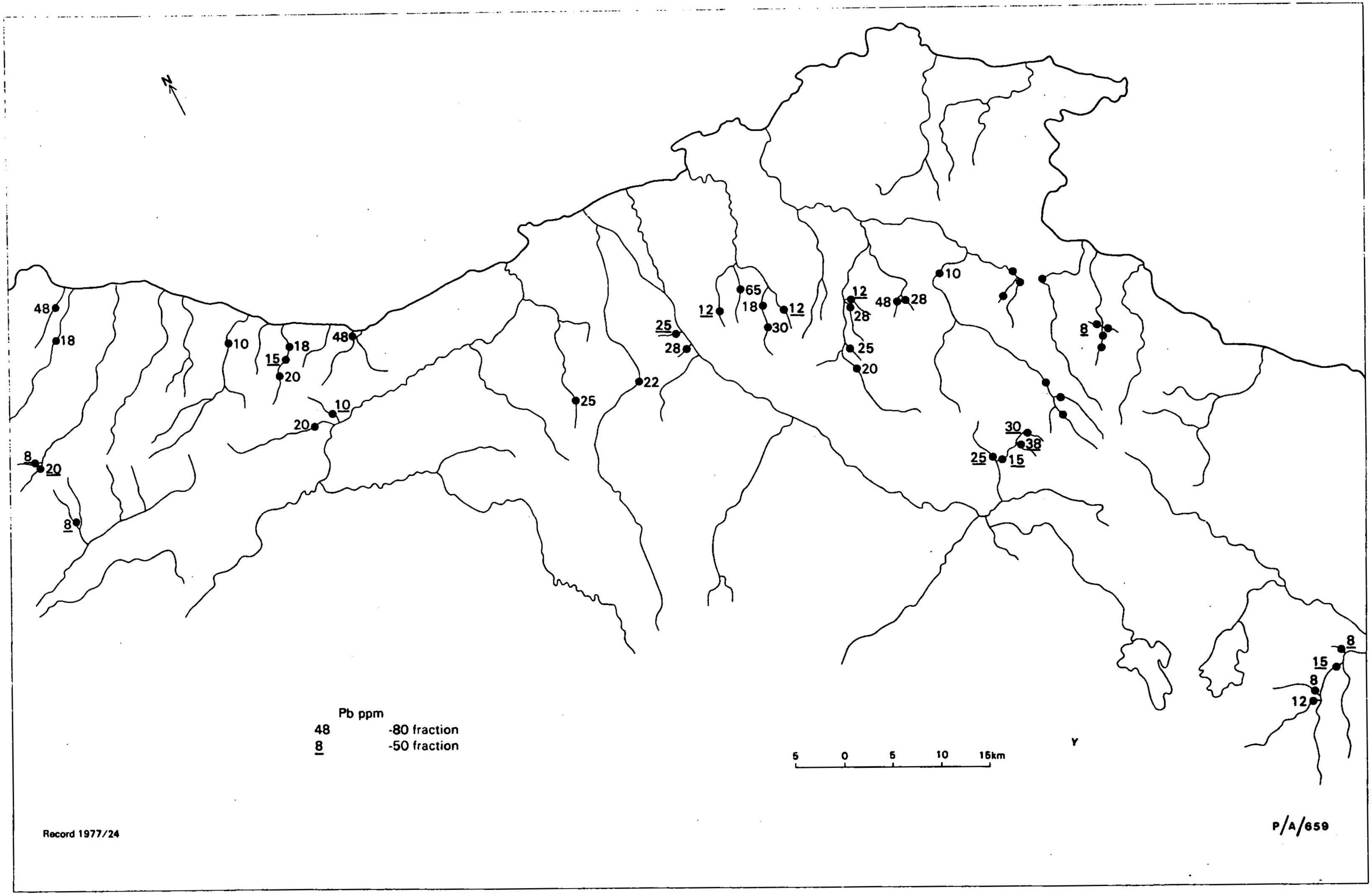
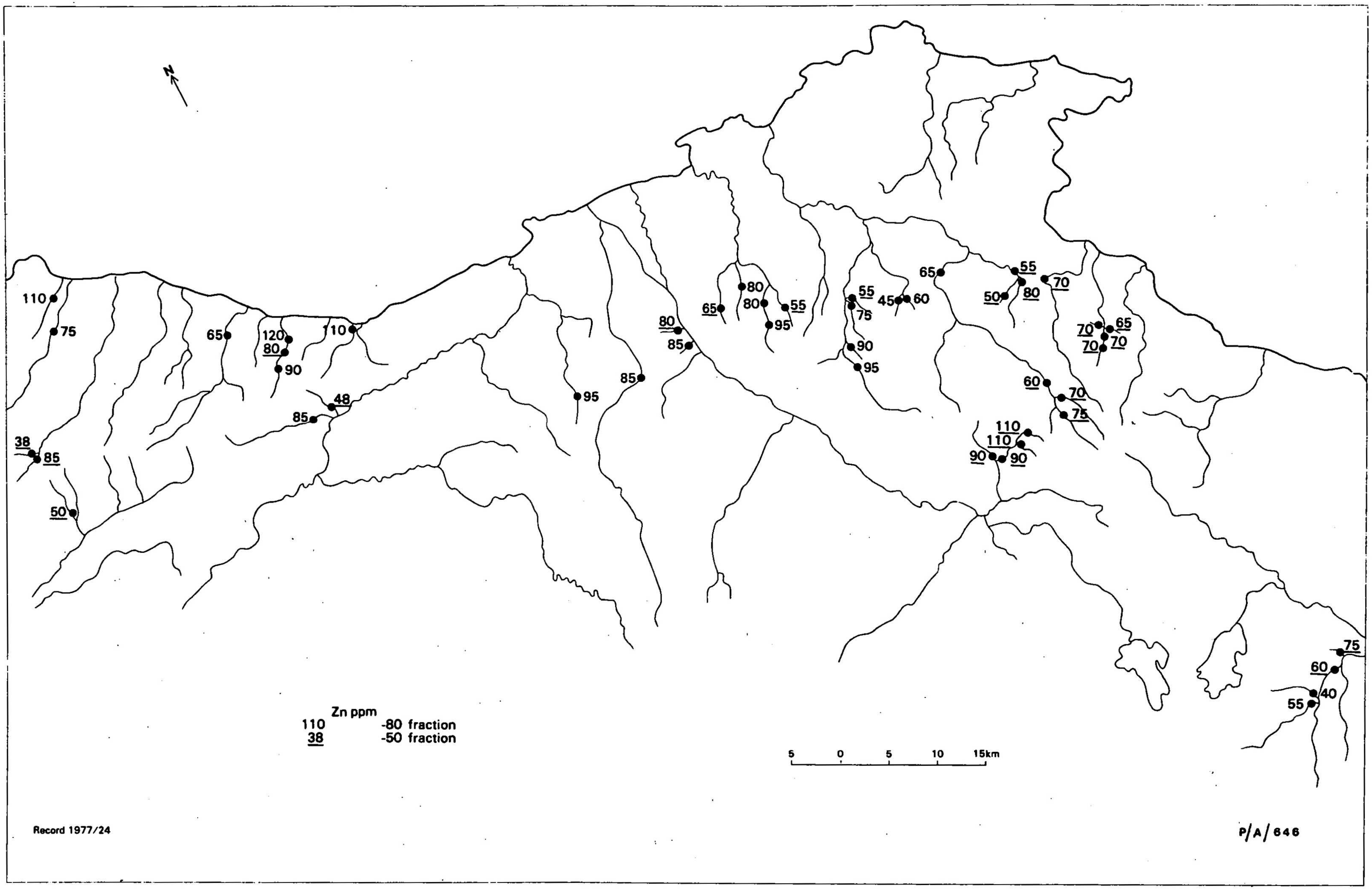
APPENDIX 1

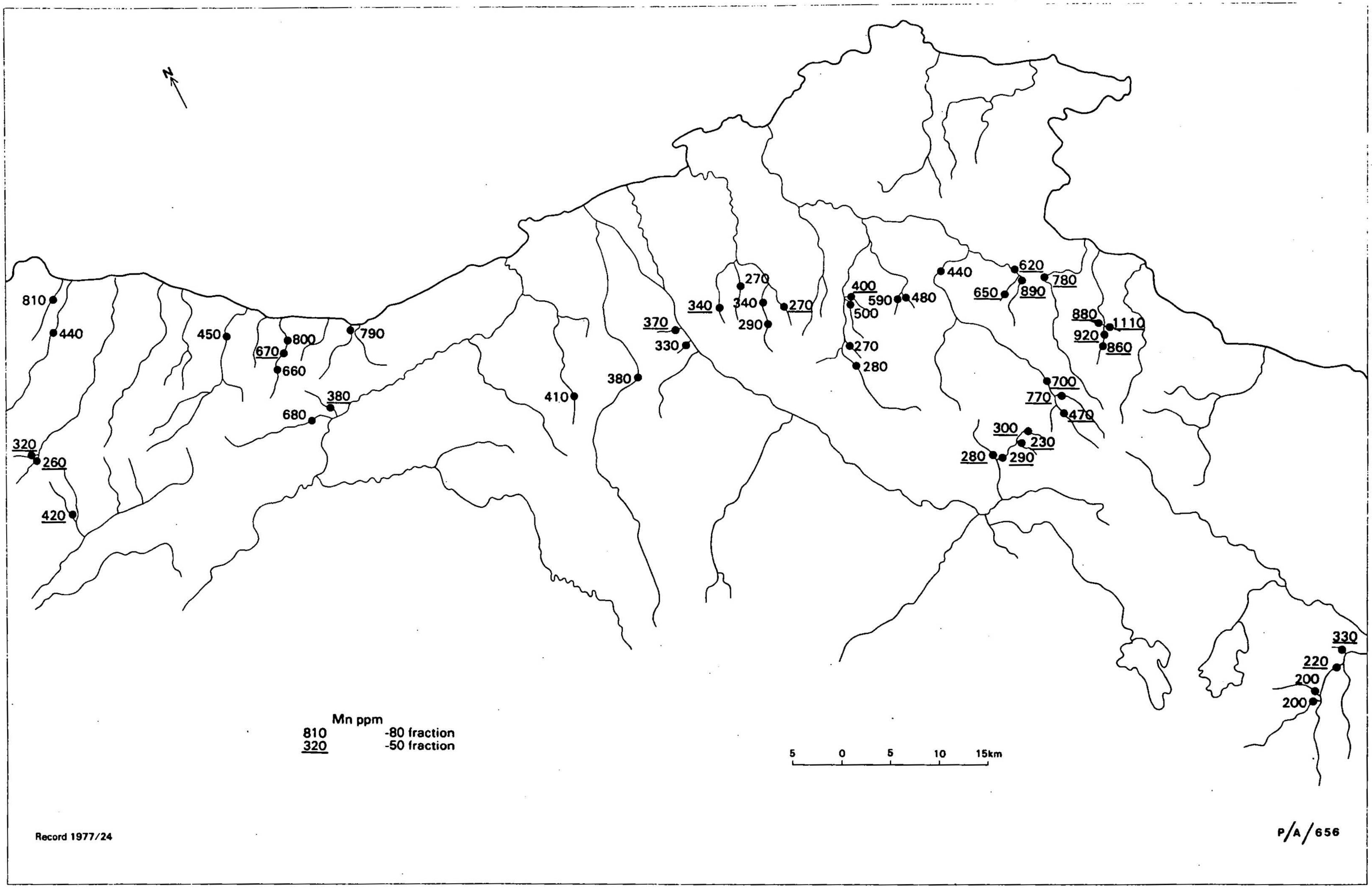
ELEMENT CONCENTRATIONS AT SAMPLE LOCALITIES


N
160
30
22
30
15
28
35
45
65
65
22
30
35
30
75
65
20
110
28
18
130
80
50
90
150
60
50
48
60
65
75
70
75
75
100
80
70
65
75
90
110
32
32
25
15
8
10
Cu ppm
30 -80 fraction
35 -50 fraction
5 0 5 10 15km
Record 1977/24
P/A/648



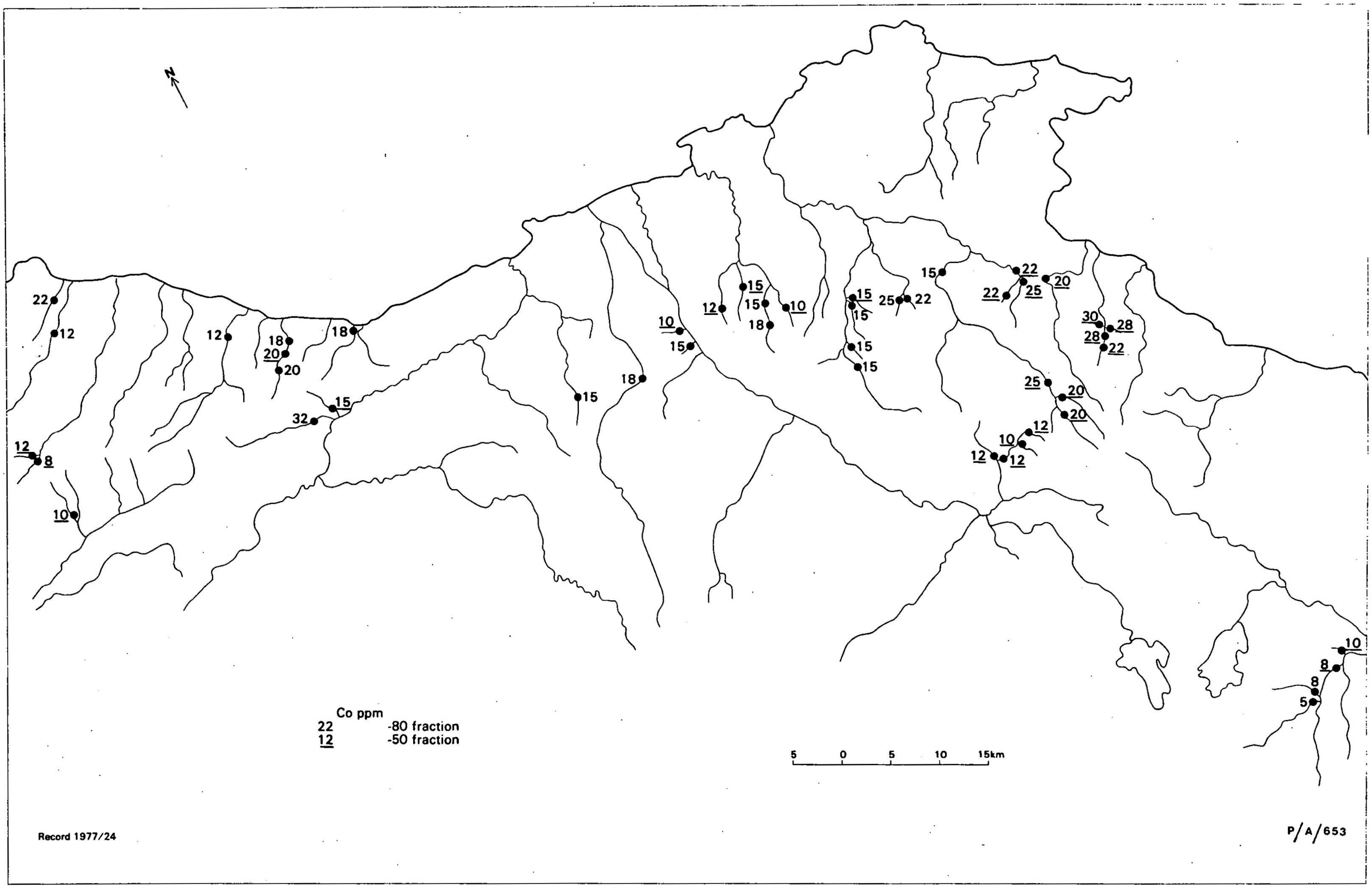
N
Pb ppm
48 -80 fraction
8 -50 fraction
5 0 5 10 15km
Y
Record 1977/24
P/A/659

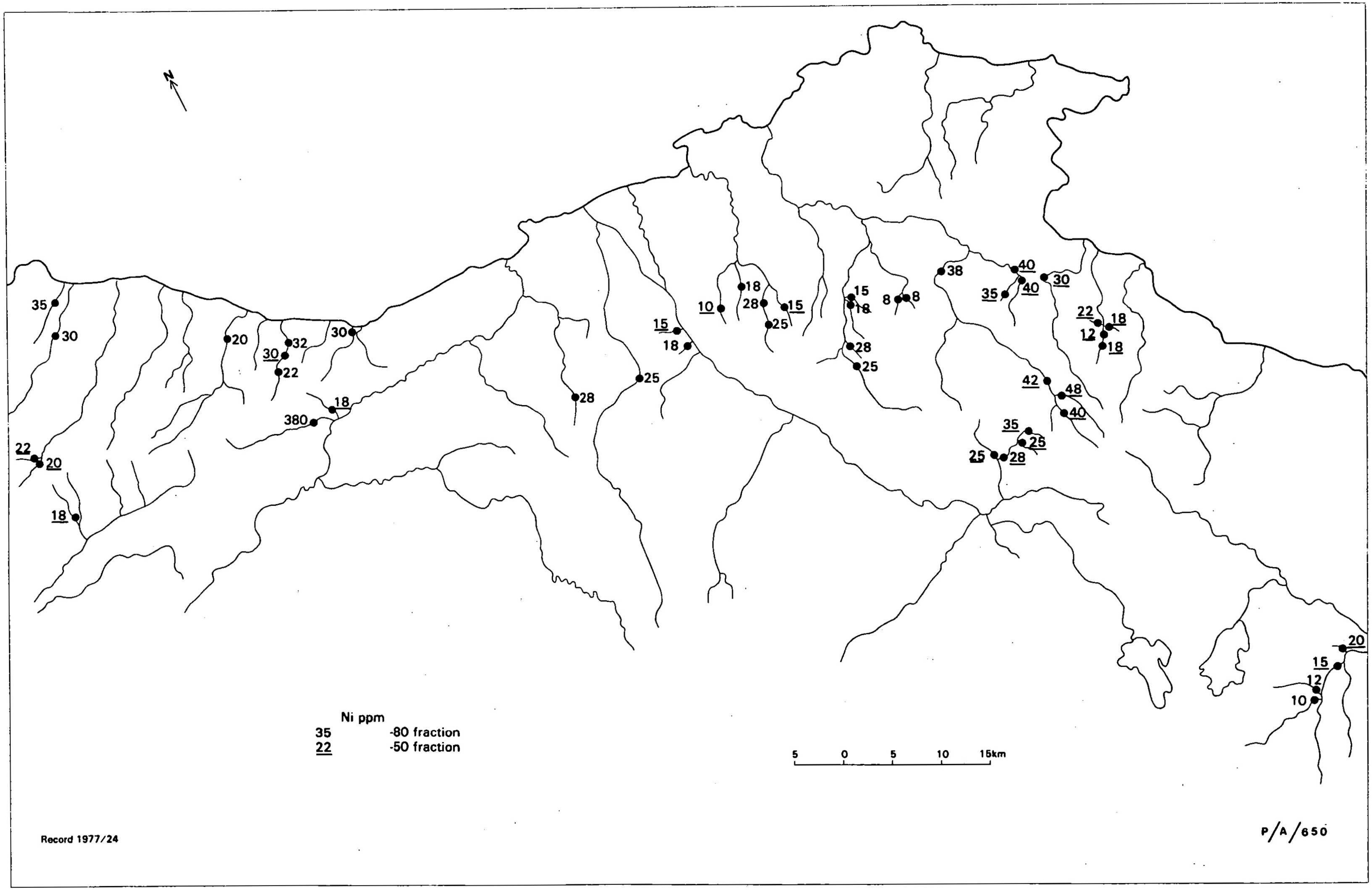

N
Zn ppm
110 -80 fraction
38 -50 fraction
5 0 5 10 15km
Record 1977/24
P/A/646

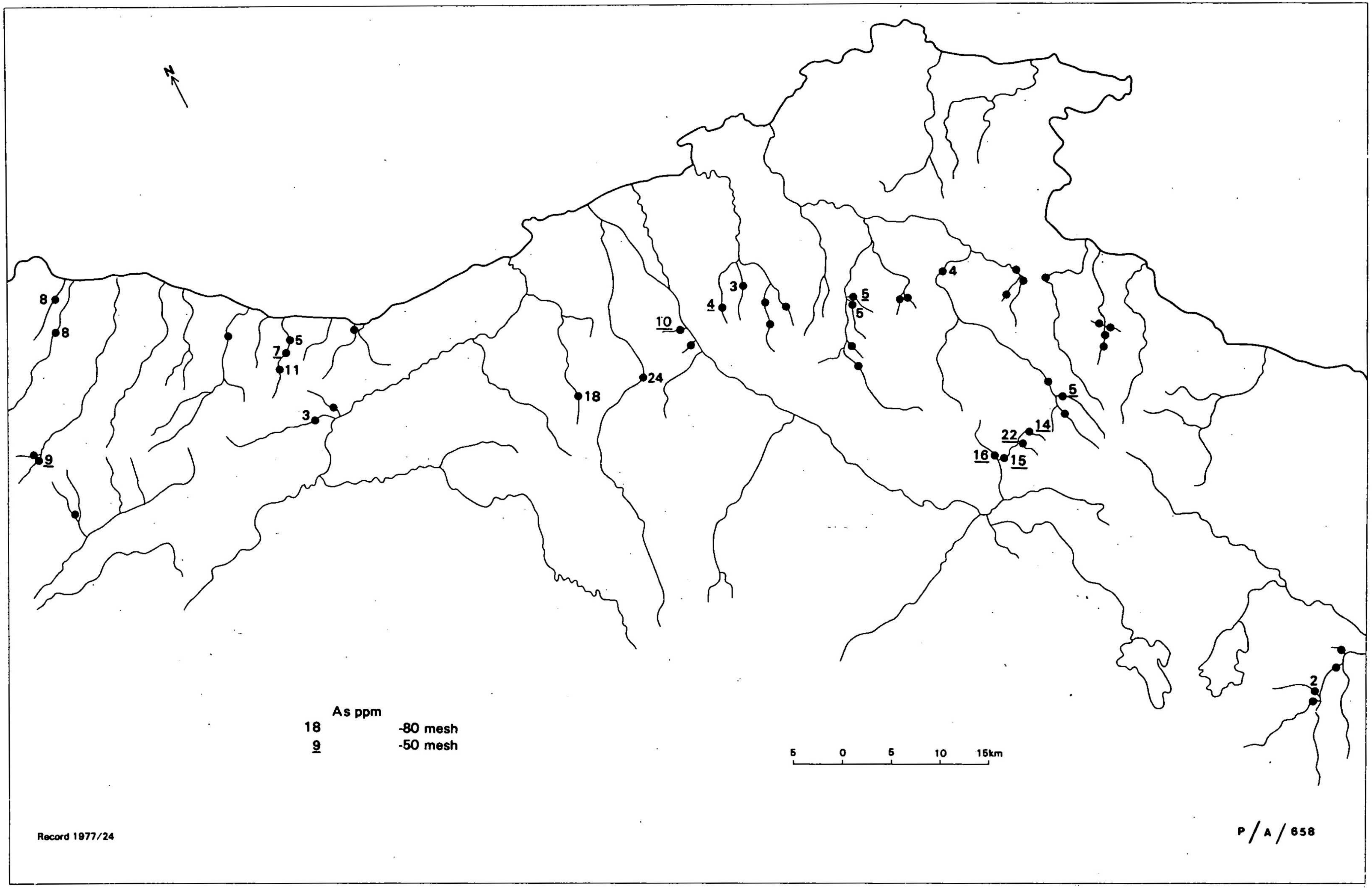


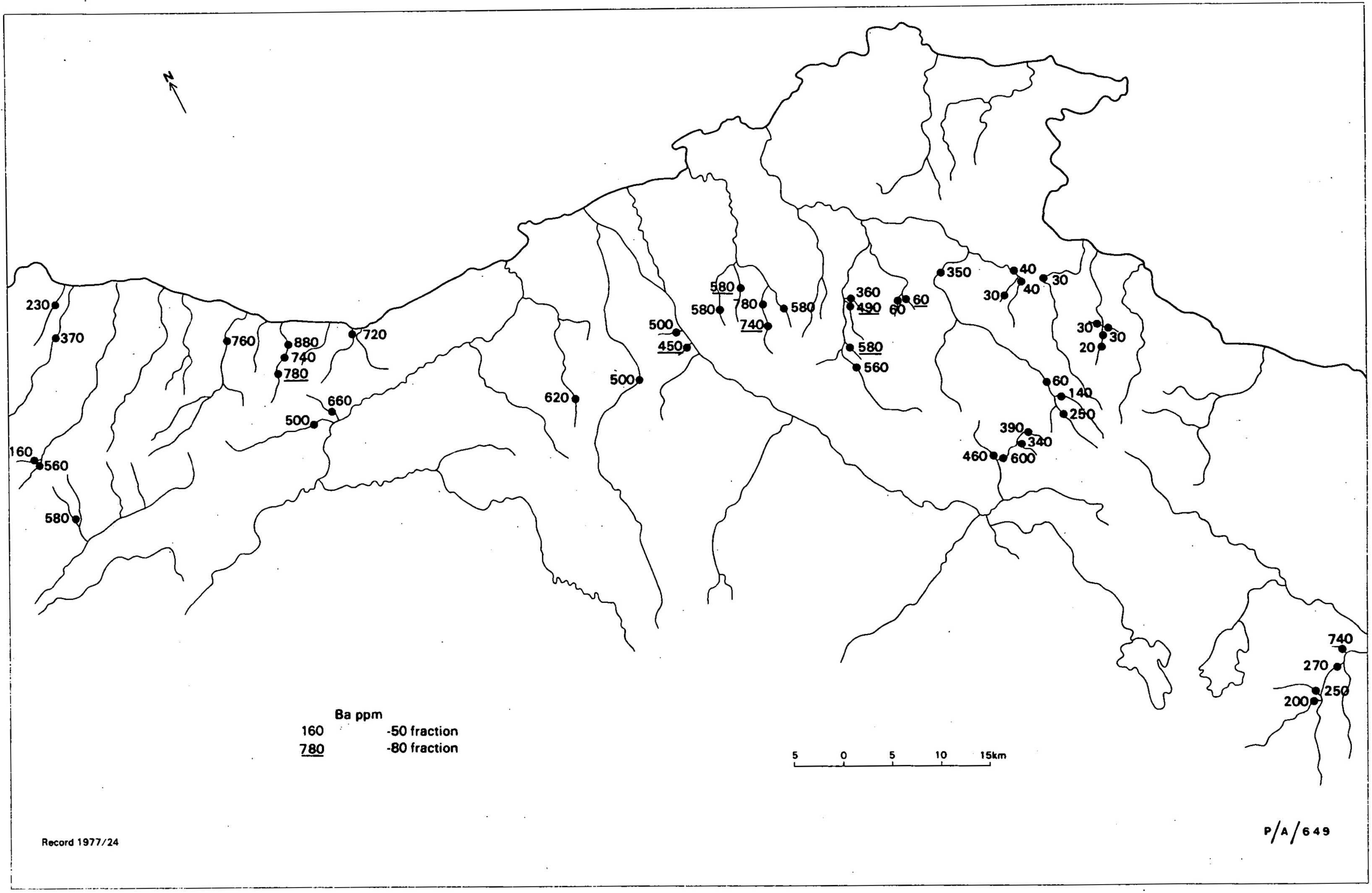
Record 1977/24

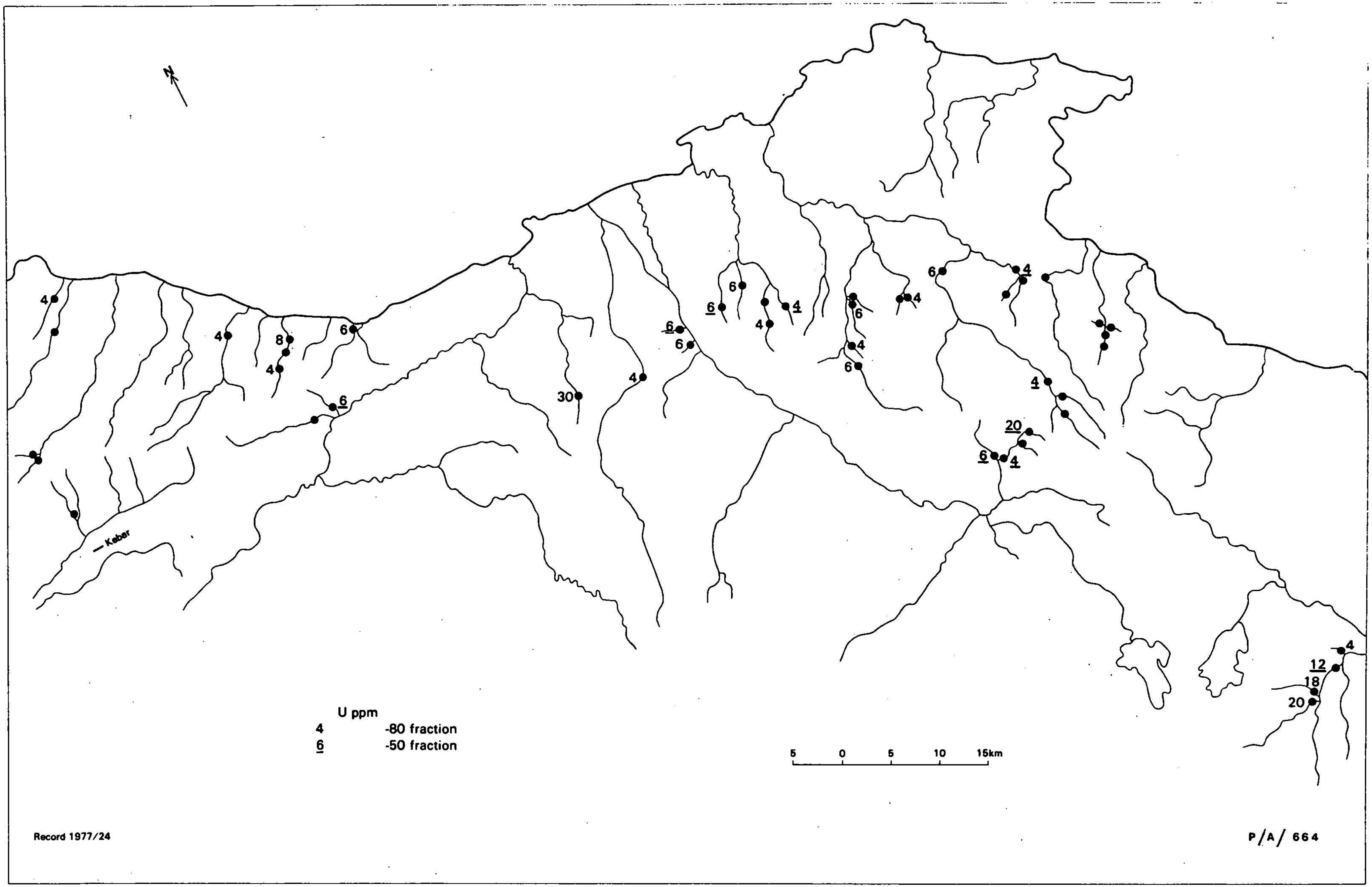
P/A/656


N
22
12
12
8
10
12
18
20
20
18
15
32
15
18
10
15
12
15
15
18
10
15
15
15
15
25
22
15
22
22
25
20
30
28
28
22
25
20
20
12
10
12
12
10
8
8
5
Co ppm
22 -80 fraction
12 -50 fraction
5 0 5 10 15km
Record 1977/24
P/A/653


N
Ni ppm
35 -80 fraction
22 -50 fraction
5 0 5 10 15km
Record 1977/24
P/A/650

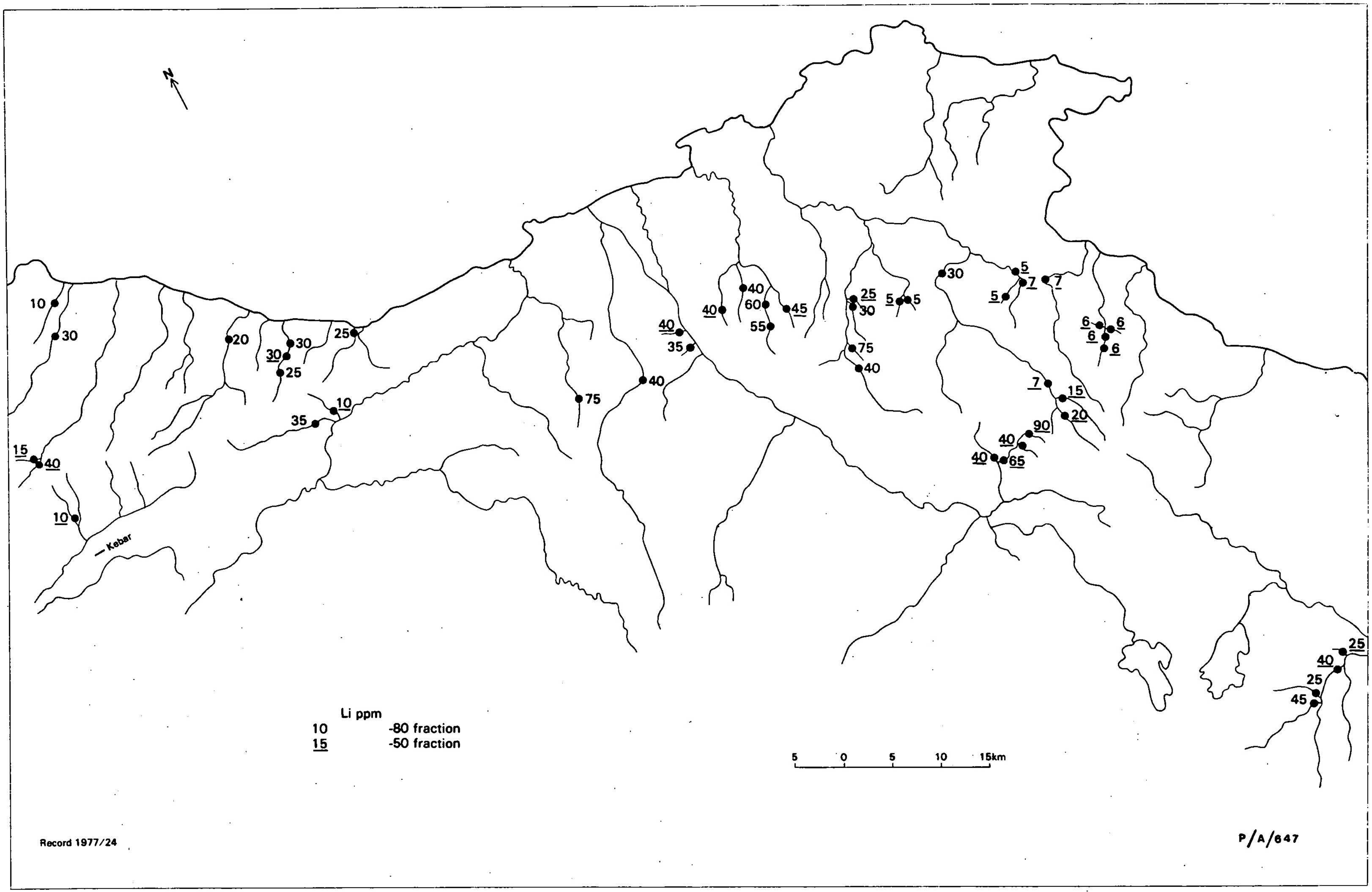

N
8
8
9
5
7
11
3
3
18
24
10
4
3
5
5
4
5
14
22
16
15
2
As ppm
18 -80 mesh
9 -50 mesh
5 0 5 10 15km
Record 1977/24
P/A/658

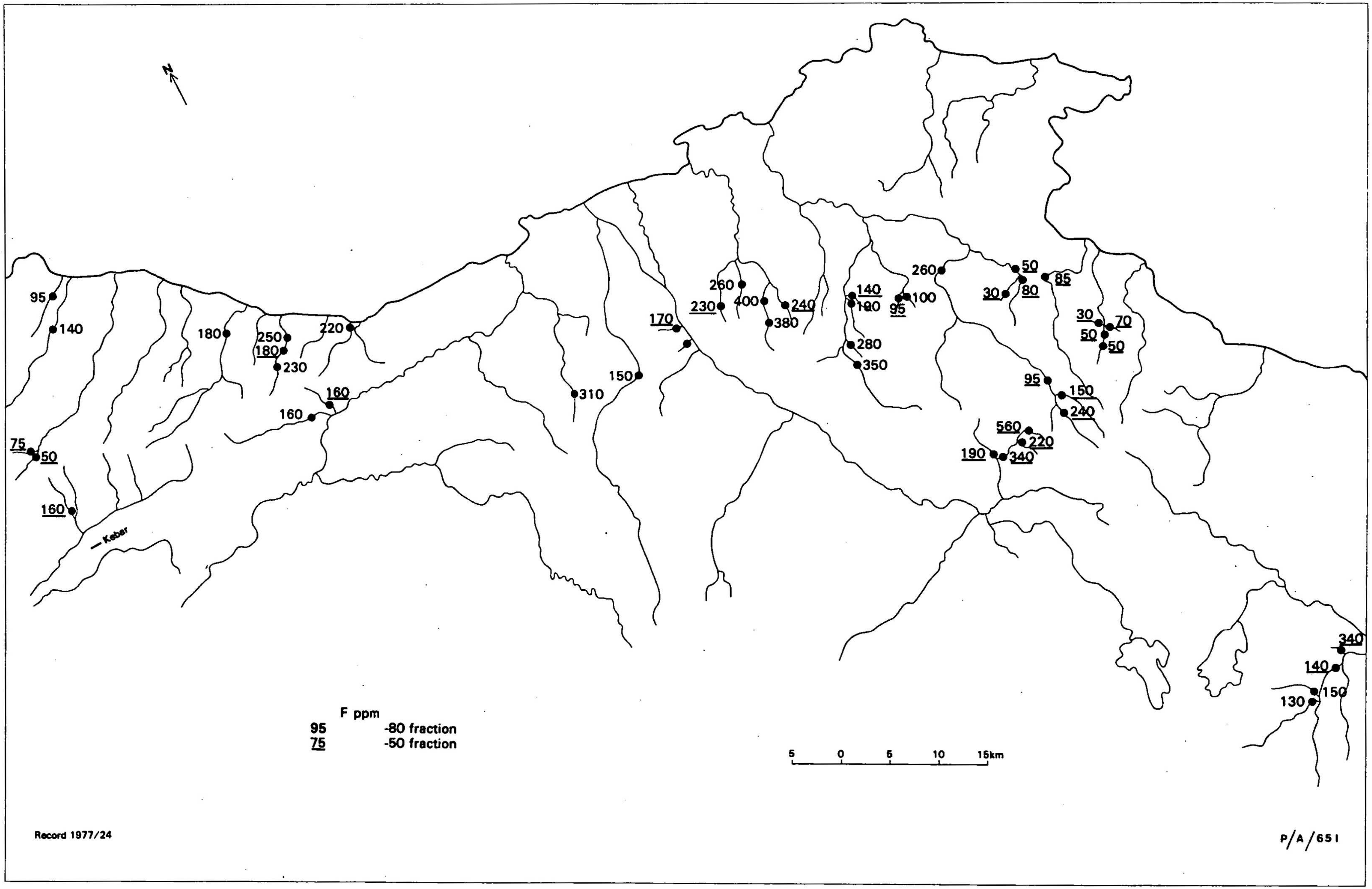

N
230
370
760
880
740
780
720
660
500
160
560
580
620
500
500
450
580
580
780
740
580
360
490
60
60
580
560
350
40
40
30
30
30
30
30
20
60
140
250
390
340
460
600
740
270
250
200
Ba ppm
160 -50 fraction
780 -80 fraction
5 0 5 10 15km
Record 1977/24
P/A/649



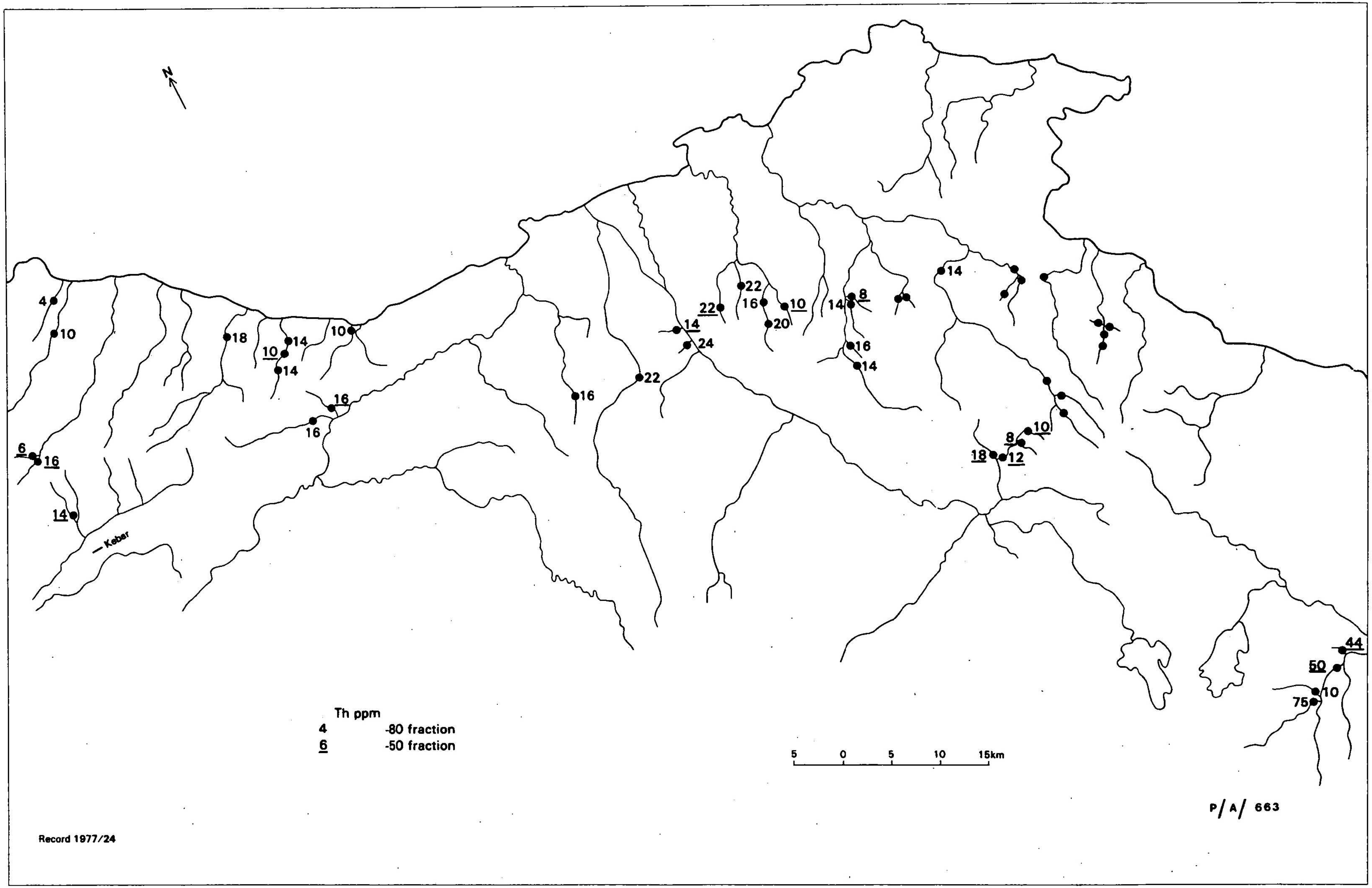
Record 1977/24

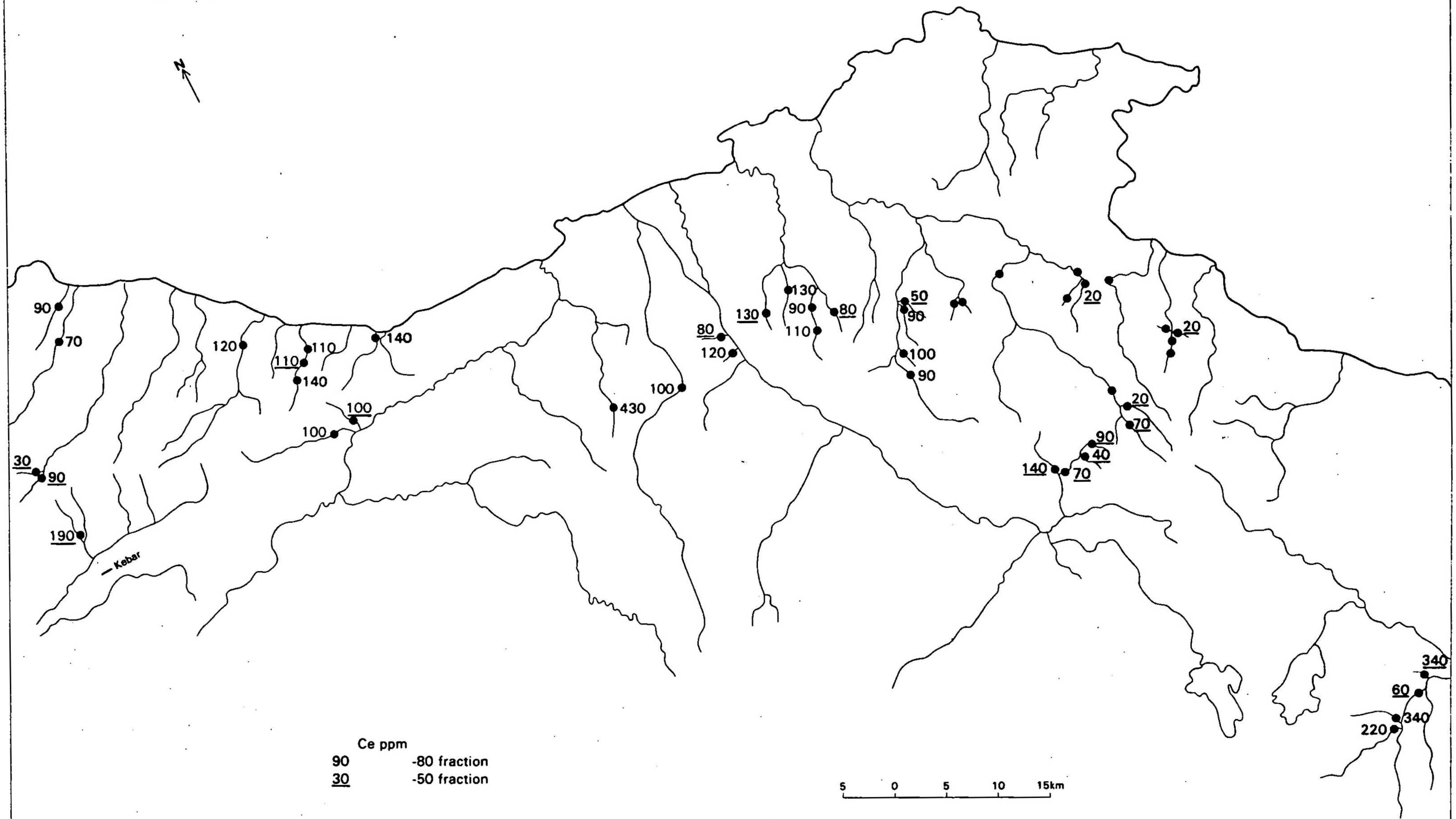
P/A/664


N
Kebar
Li ppm
10 -80 fraction
15 -50 fraction
5 0 5 10 15km
Record 1977/24
P/A/647



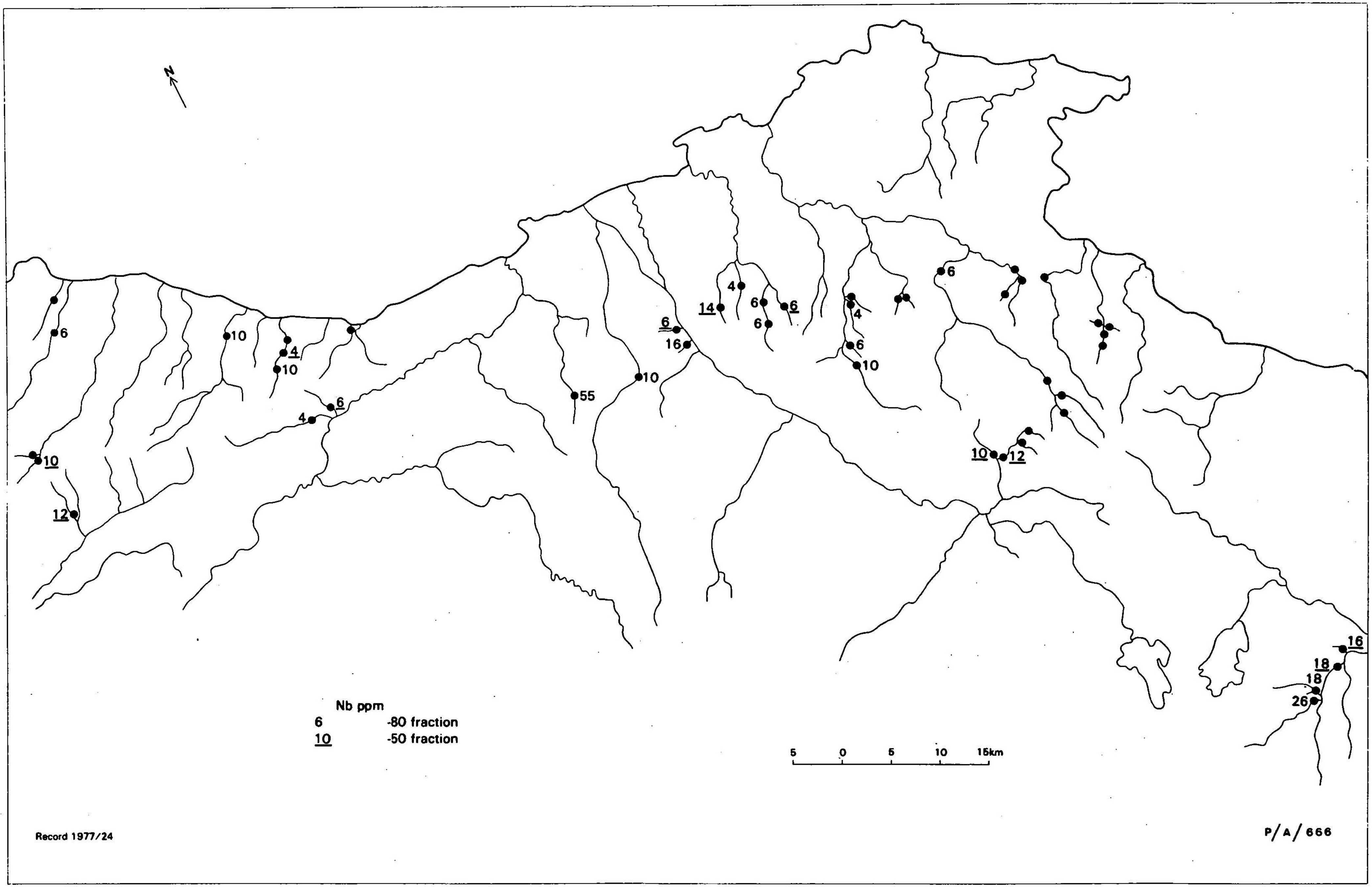
N
95
140
180
250
180
230
220
160
160
75
50
160
Kebar
310
150
170
230
260
400
380
240
140
280
350
95
100
260
50
30
80
85
30
70
50
50
95
150
240
560
220
190
340
340
140
150
130
F ppm
95 -80 fraction
75 -50 fraction
5 0 5 10 15km
Record 1977/24
P/A/651

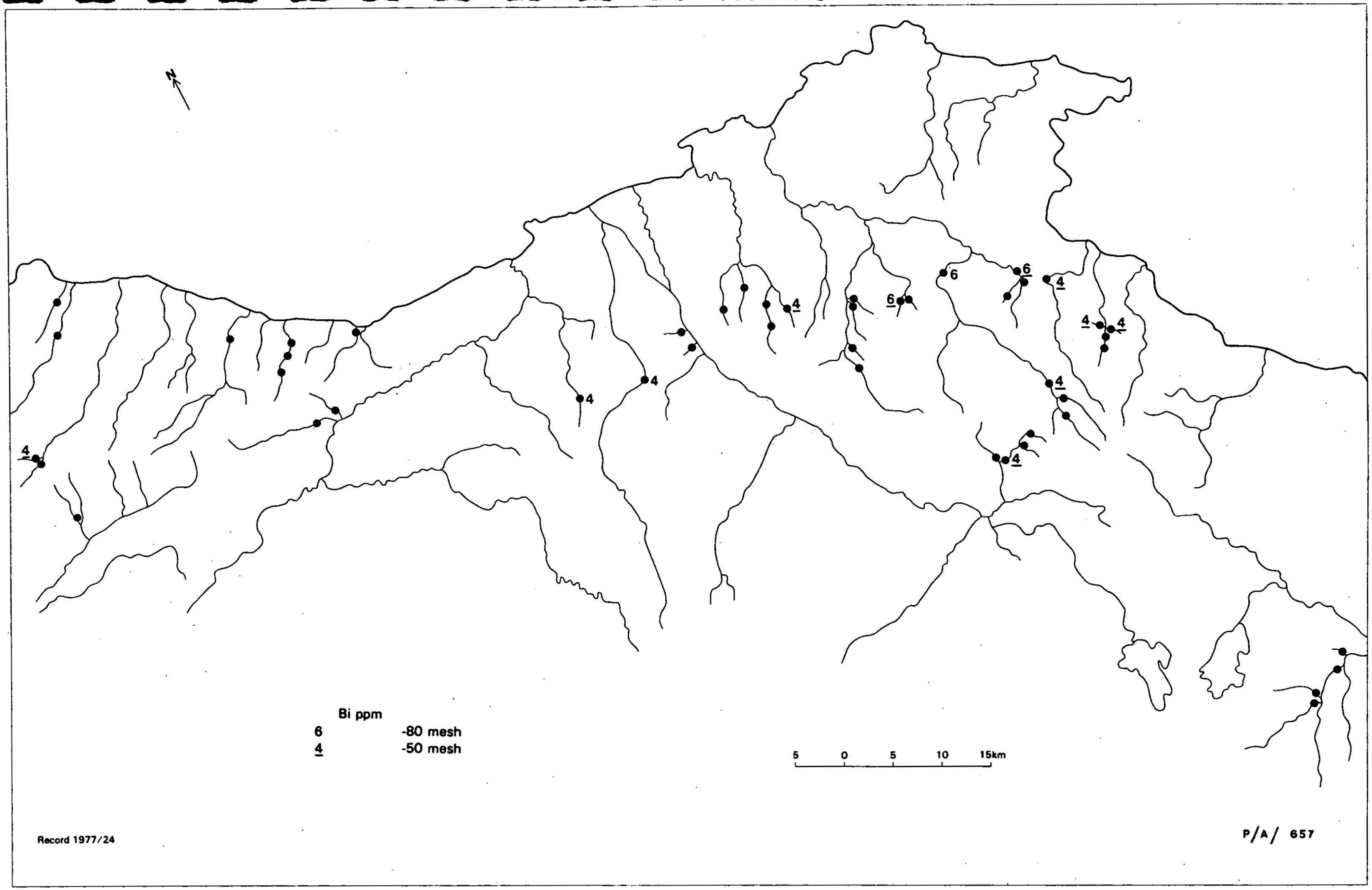

N
Keber
Th ppm
4 -80 fraction
6 -50 fraction
5 0 5 10 15km
P/A/ 663
Record 1977/24

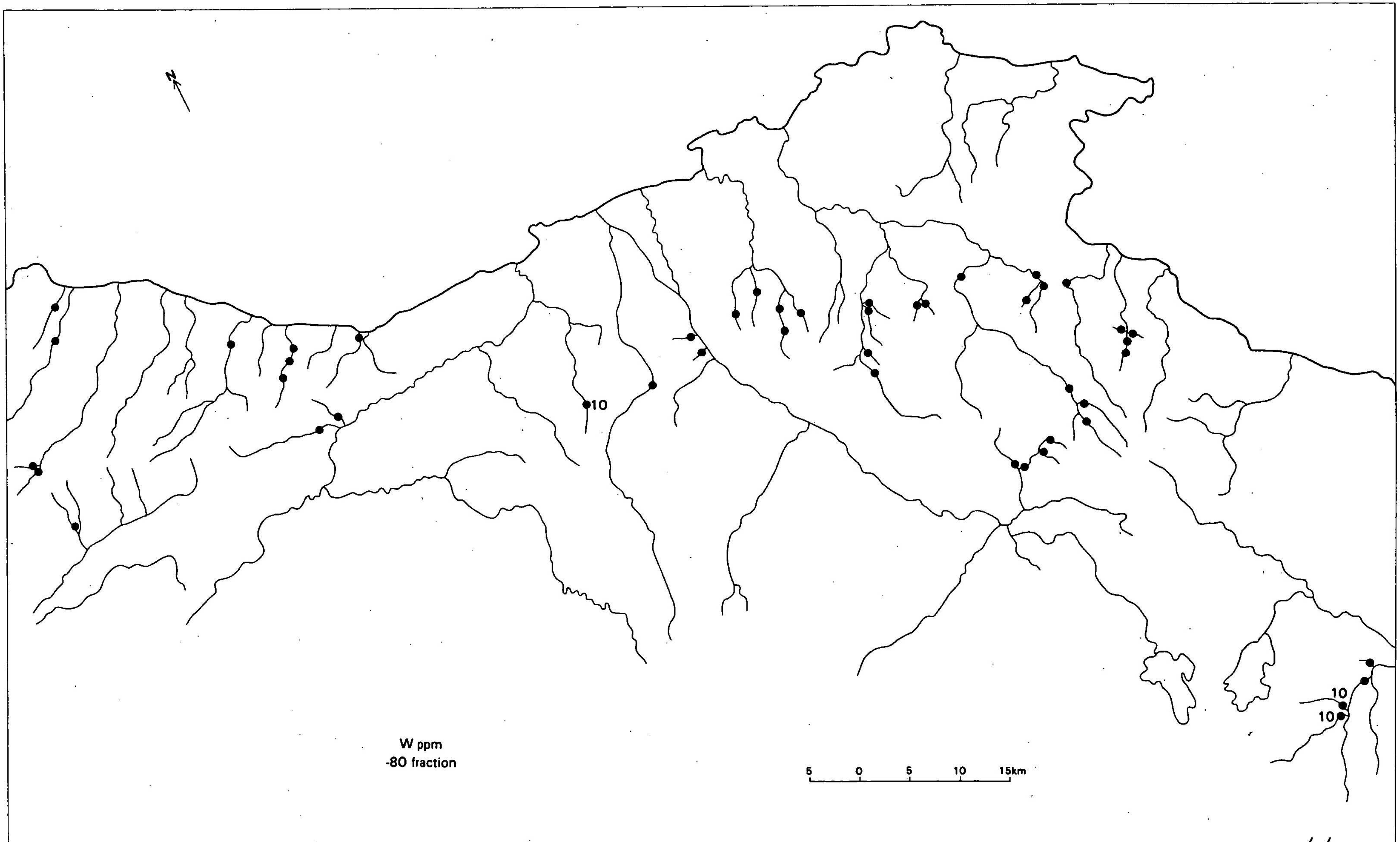


Record 1977/24

P/A/ 655

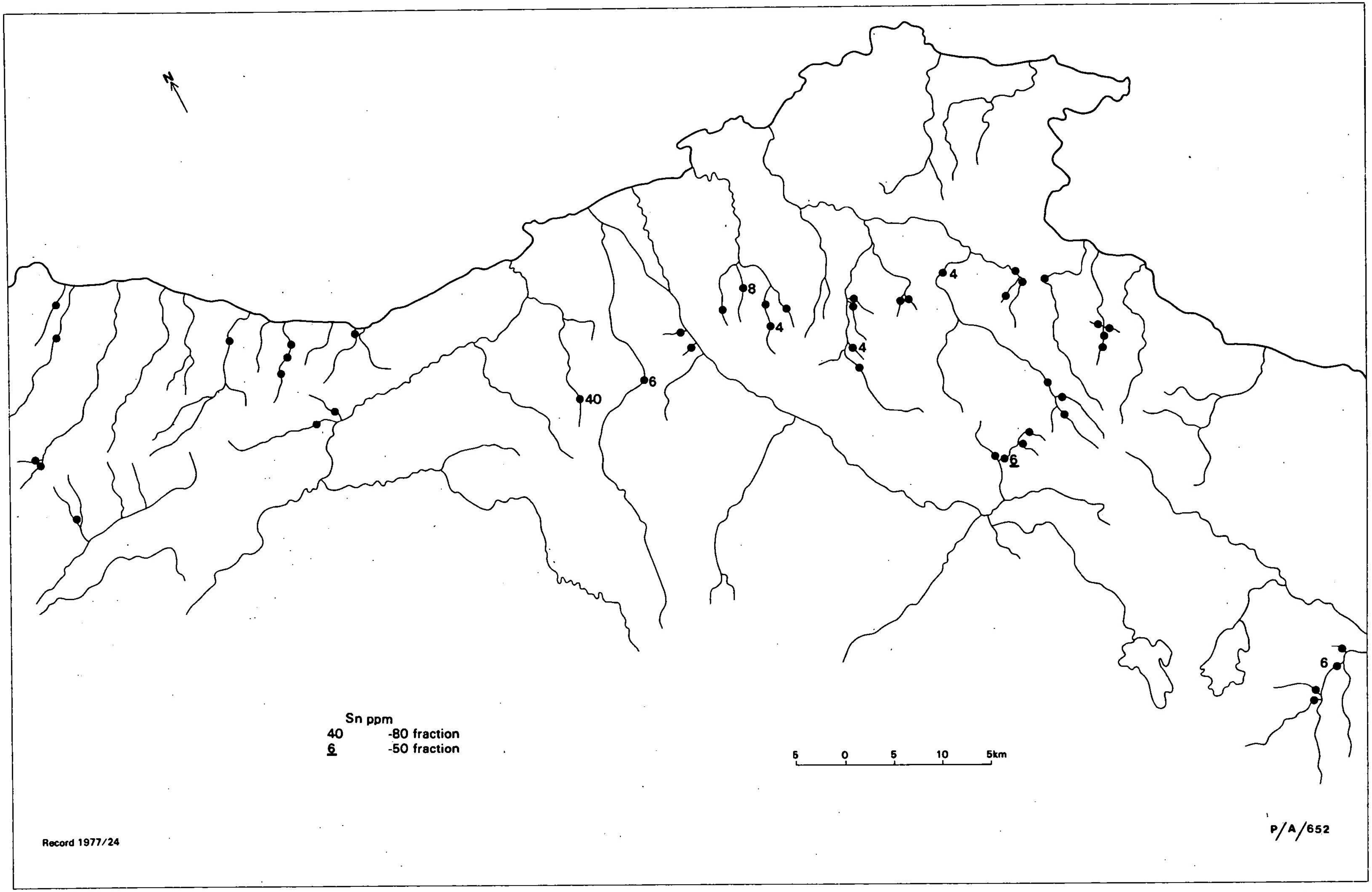

N
6
10
4
10
6
4
6
10
12
6
16
10
55
14
4
6
6
6
4
6
10
6
10
12
16
18
18
26
Nb ppm
6 -80 fraction
10 -50 fraction
5 0 5 10 15km
Record 1977/24
P/A/666

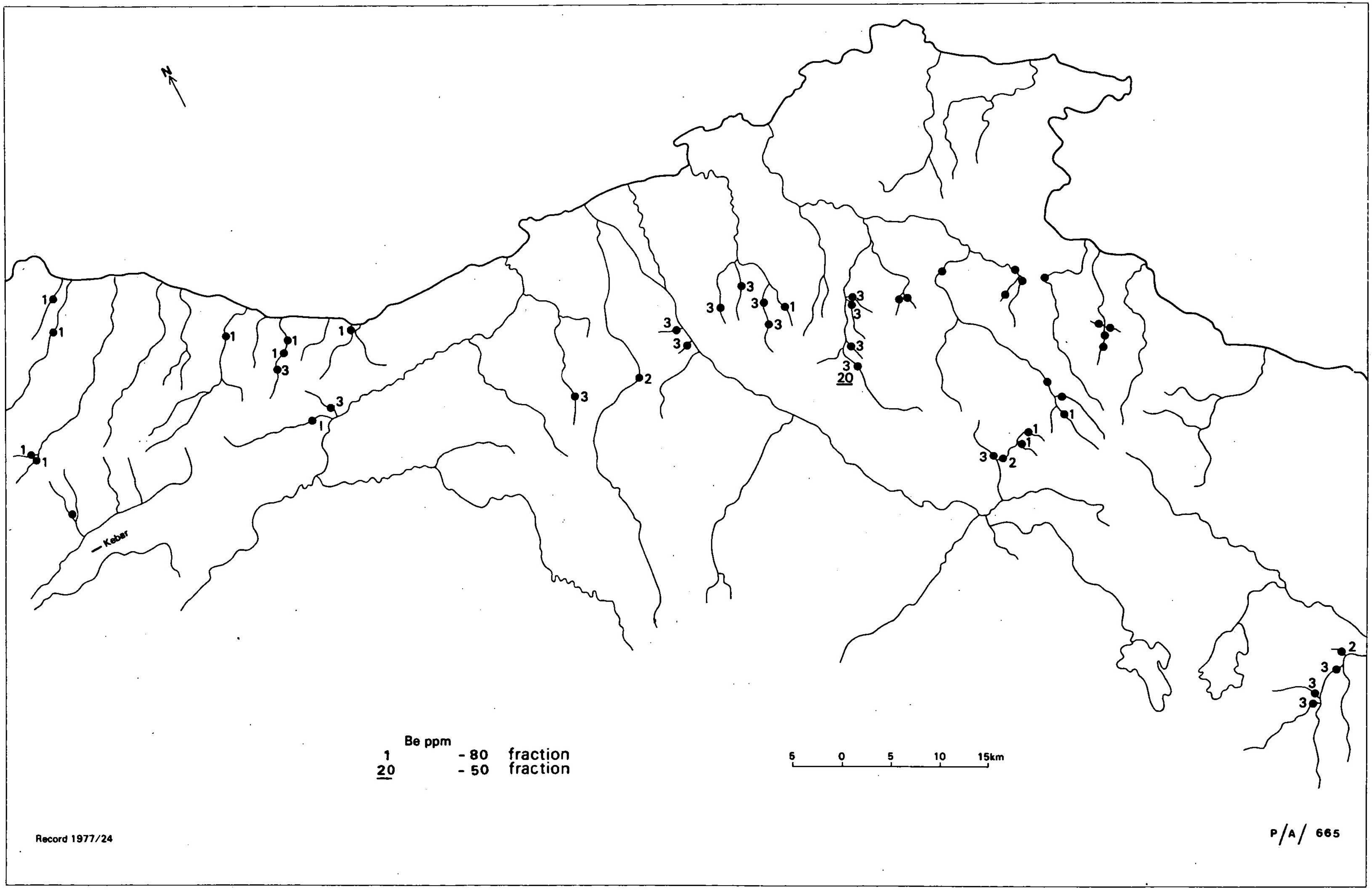

N
Bi ppm
6 -80 mesh
4 -50 mesh
5 0 5 10 15km
Record 1977/24
P/A/ 657

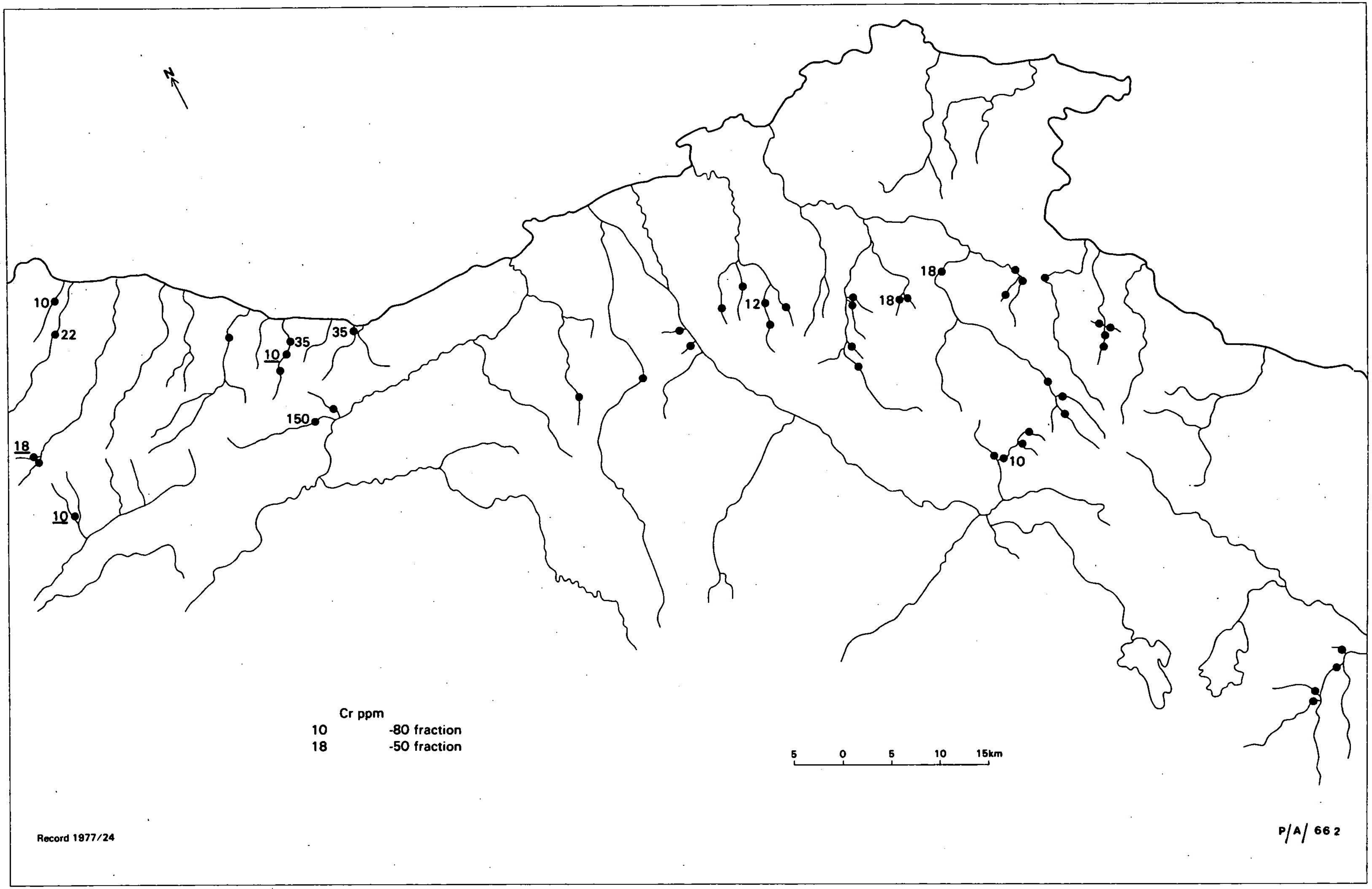


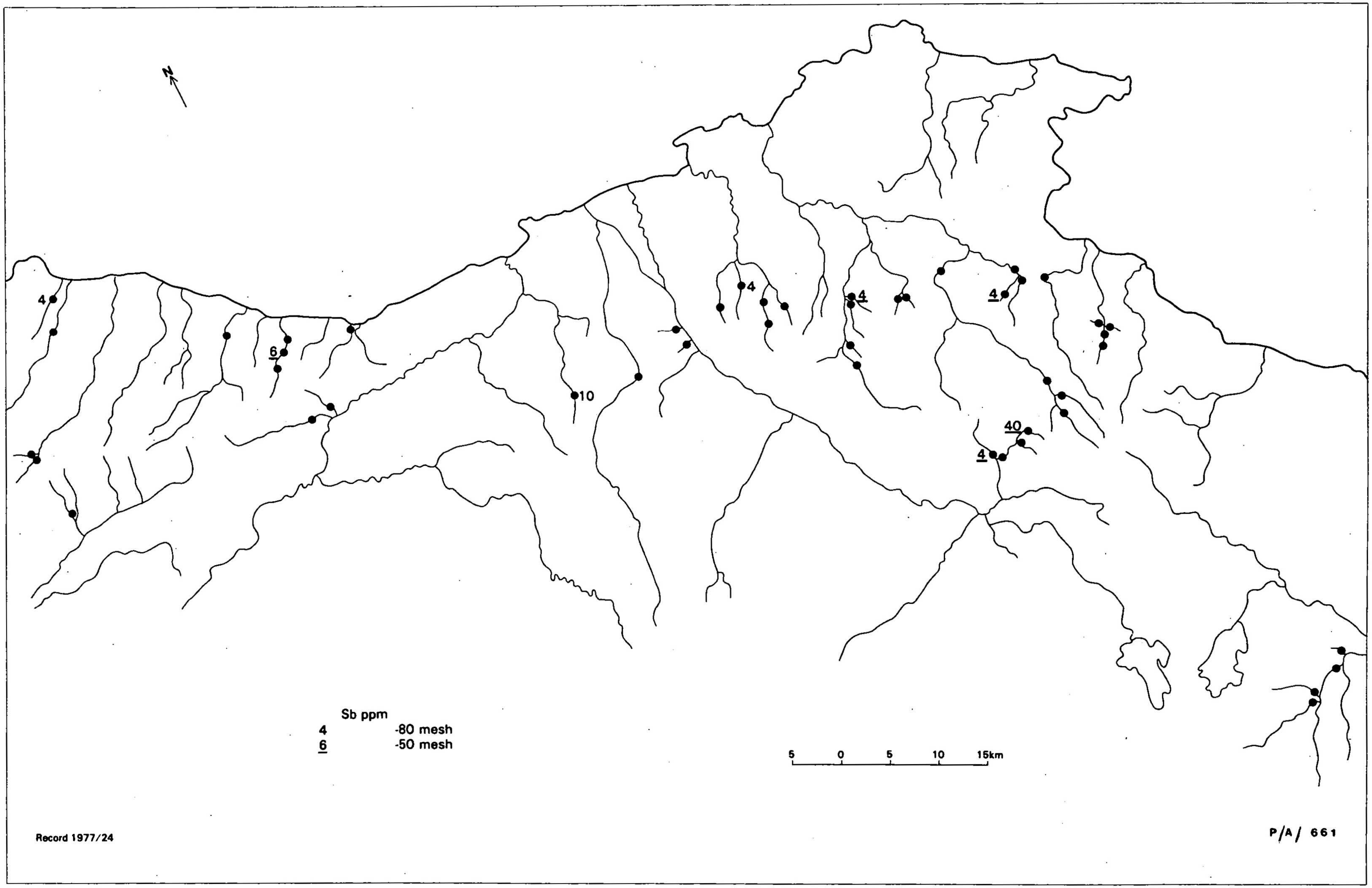
Record 1977/24

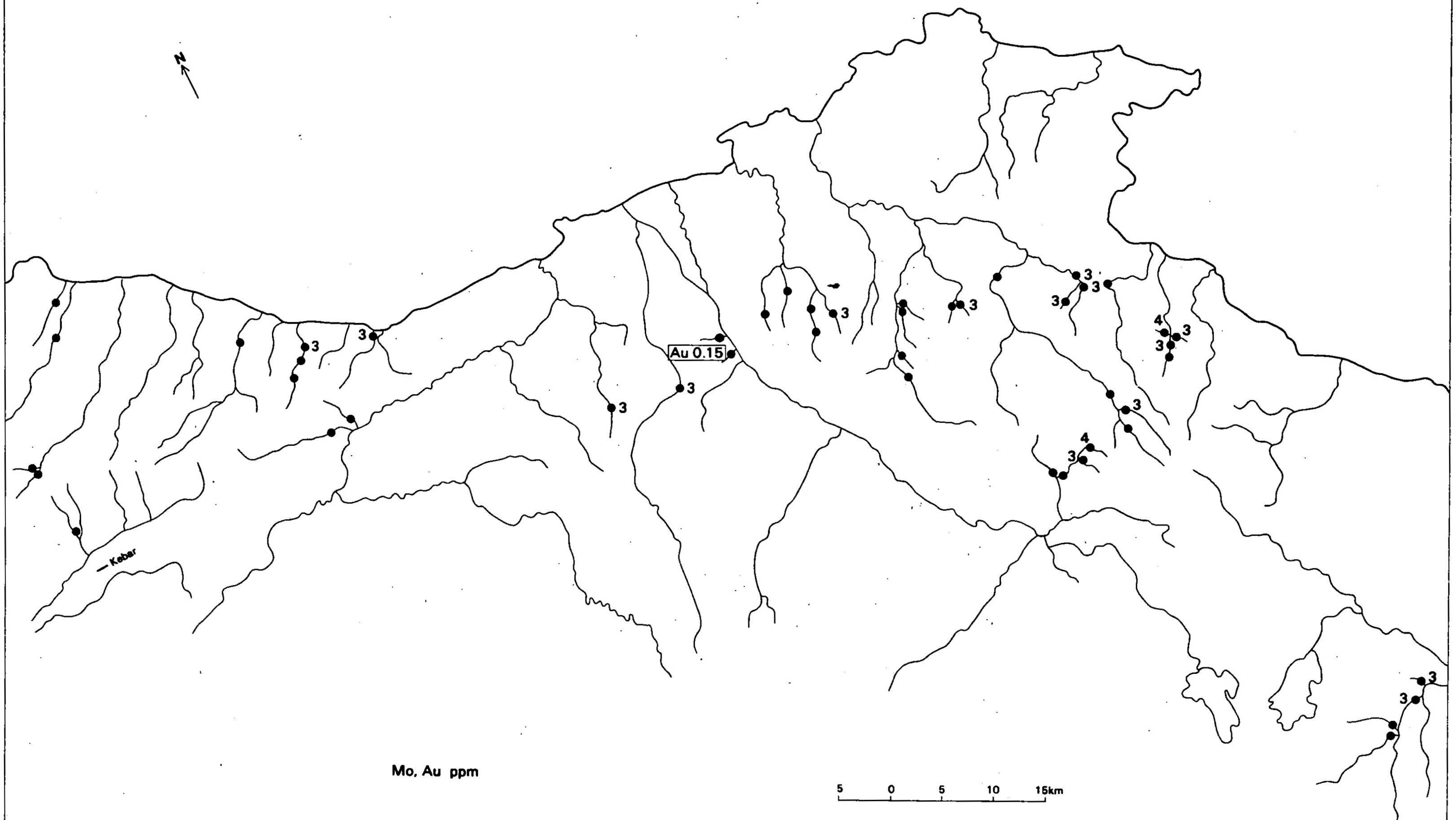
P/A/660


N
8
4
4
4
4
6
40
6
6
6
Sn ppm
40 -80 fraction
6 -50 fraction
5 0 5 10 5km
P/A/652
Record 1977/24


N
Keber
Be ppm
1 - 80 fraction
20 - 50 fraction
5 0 5 10 15km
Record 1977/24
P/A/ 665


N
10
22
35
10
35
150
18
10
12
18
18
10
Cr ppm
10 -80 fraction
18 -50 fraction
5 0 5 10 15km
Record 1977/24
P/A/ 66 2


N
4
6
10
4
4
4
40
4
Sb ppm
4 -80 mesh
6 -50 mesh
5 0 5 10 15km
Record 1977/24
P/A/ 661
[redacted]



Mo, Au ppm

Record 1977/24

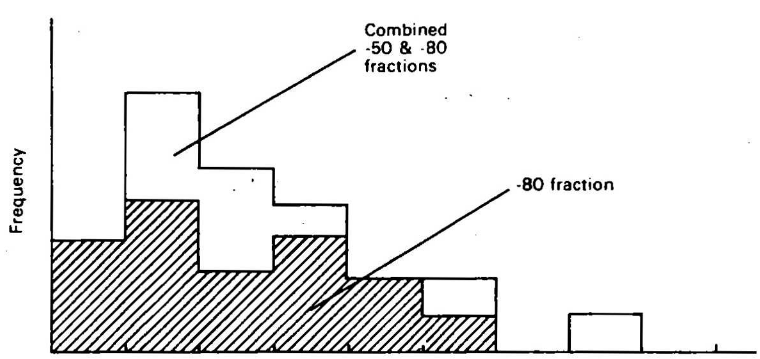
P/A/654

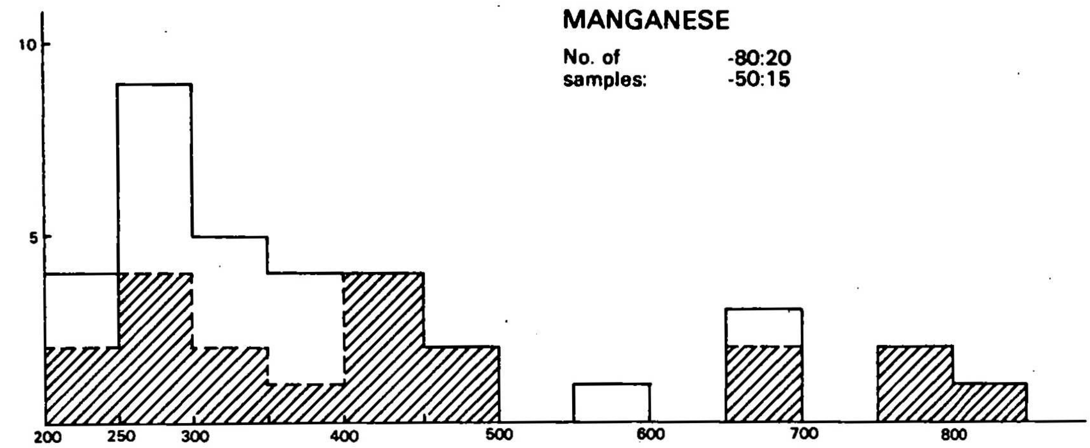
APPENDIX 2

HISTOGRAMS AND CUMULATIVE FREQUENCY CURVES FOR

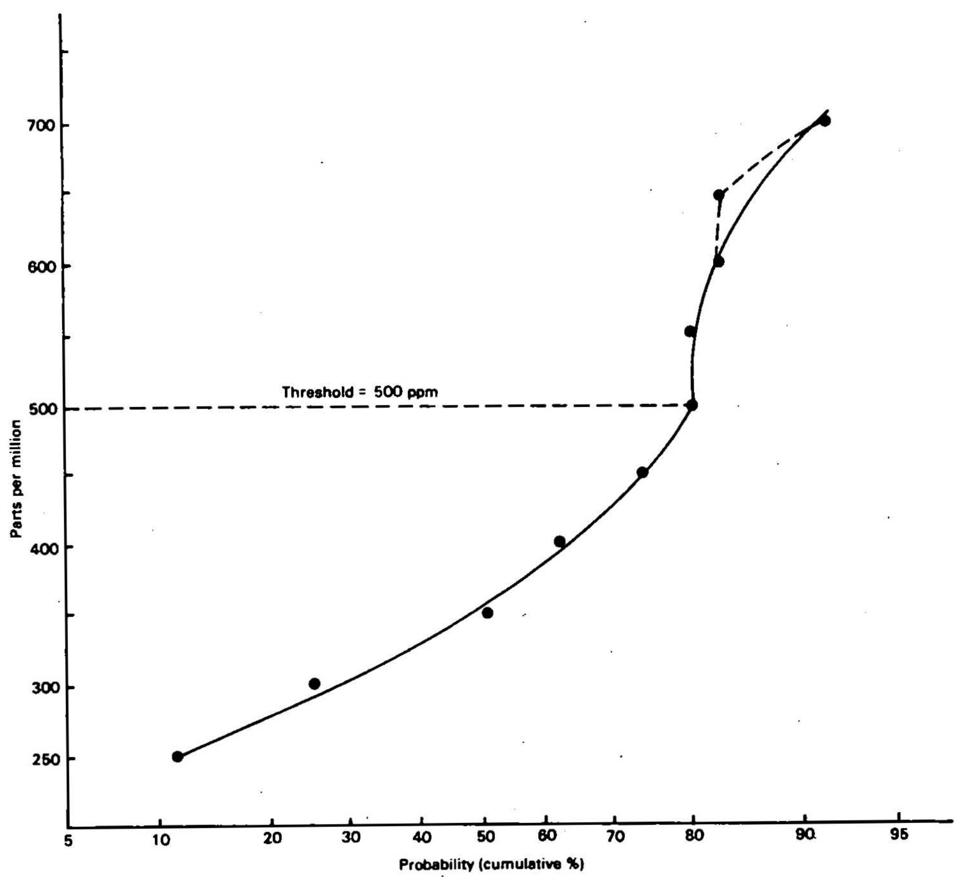
Cu, Pb, Zn, Mn, U, Th, Ce, Nb, Li, F, Co, Ni, As and Ba.

KEY TO HISTOGRAMS

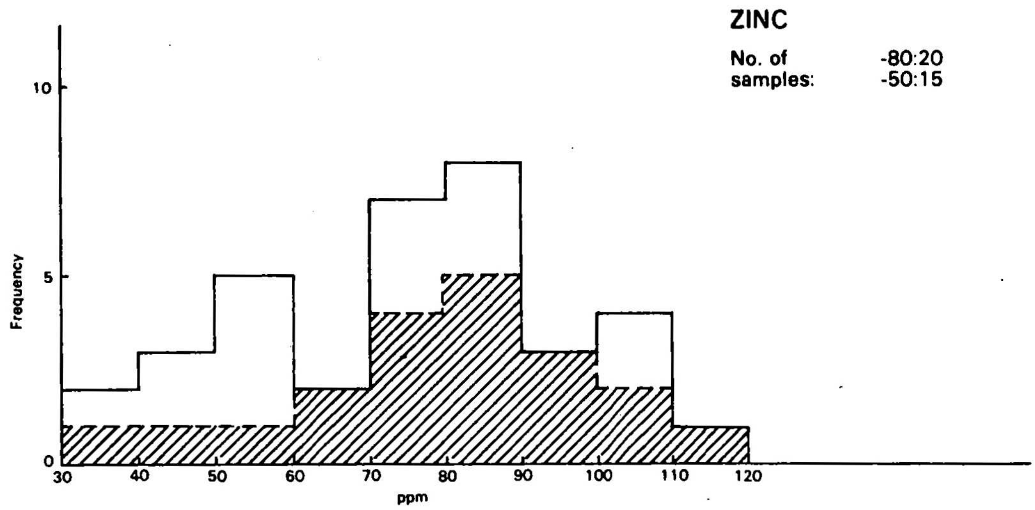


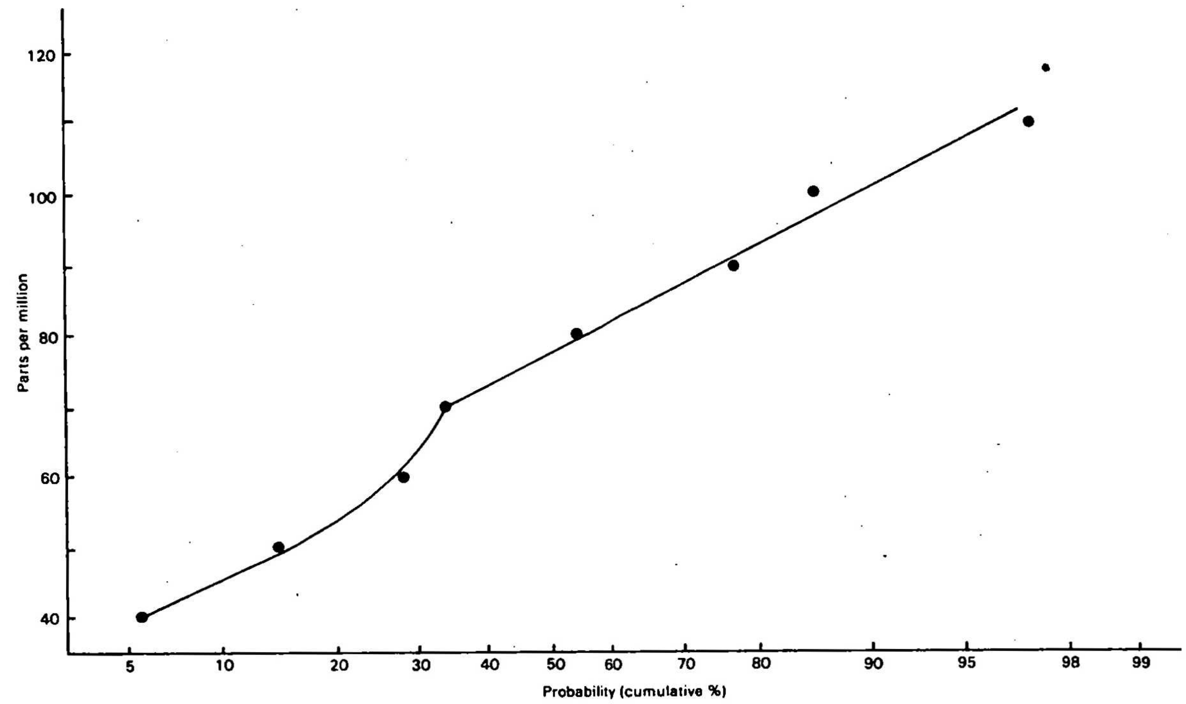


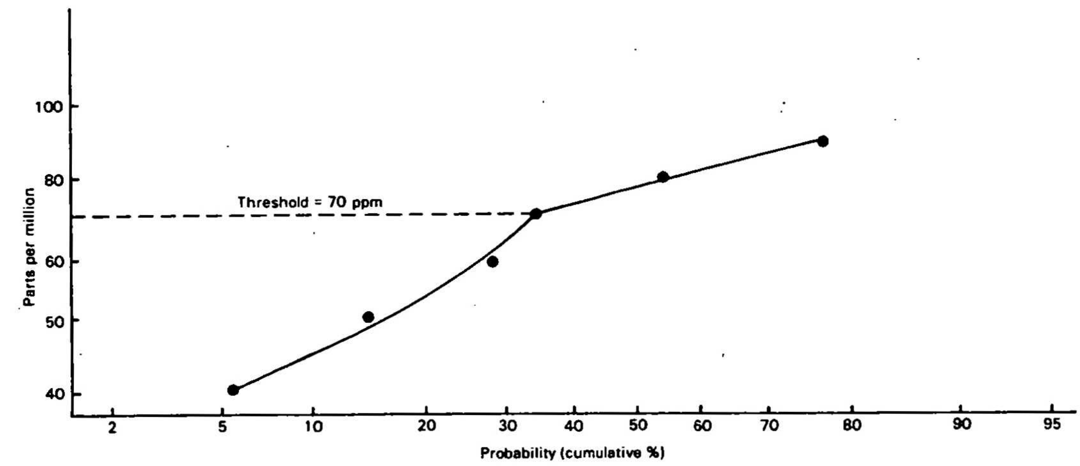
MANGANESE
No. of samples:
-80:20
-50:15
10
5
200
250
300
400
500
600
700
800

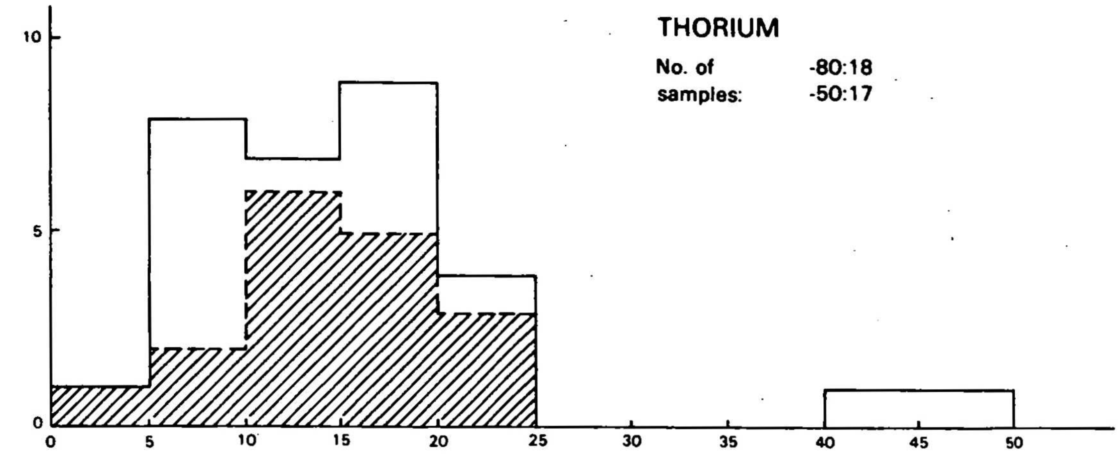


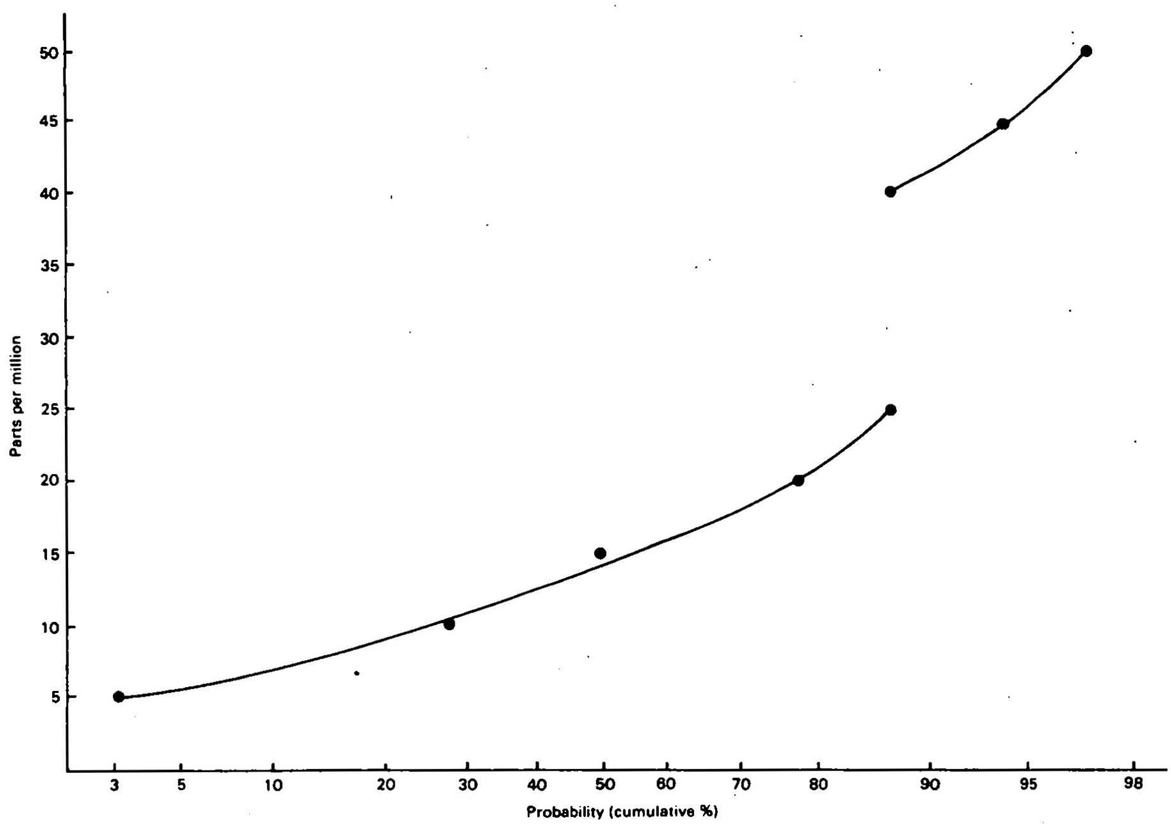
700
600
500
400
300
250
Threshold = 500 ppm
Parts per million
5
10
20
30
40
50
60
70
80
90
95
Probability (cumulative %)

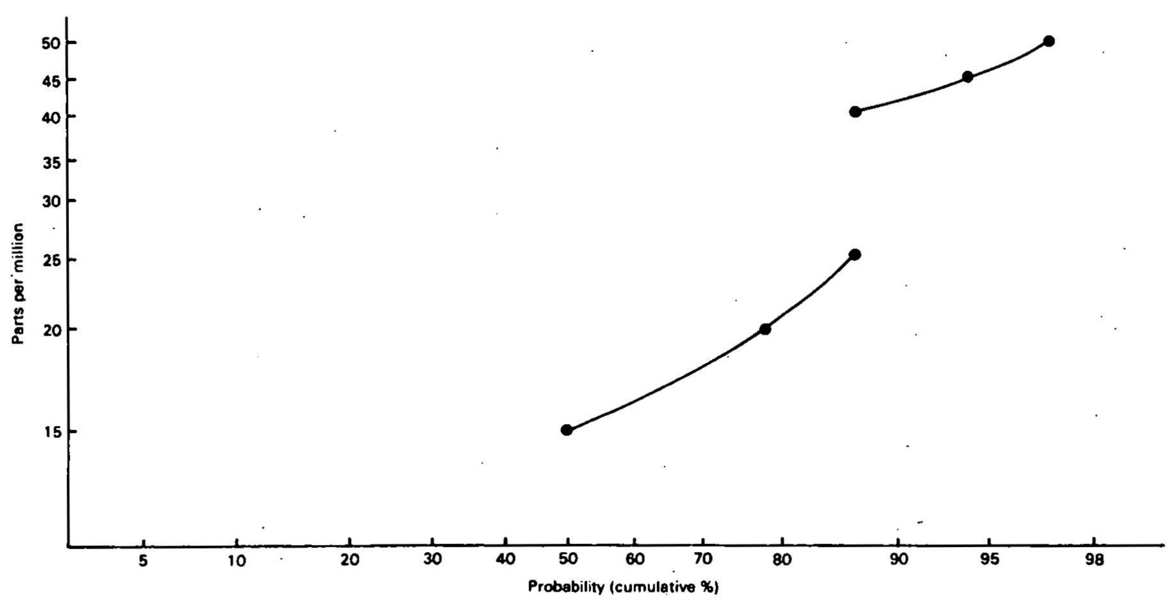

ZINC
No. of samples: -80:20
-50:15
Frequency
0
5
10
30
40
50
60
70
80
90
100
110
120
ppm

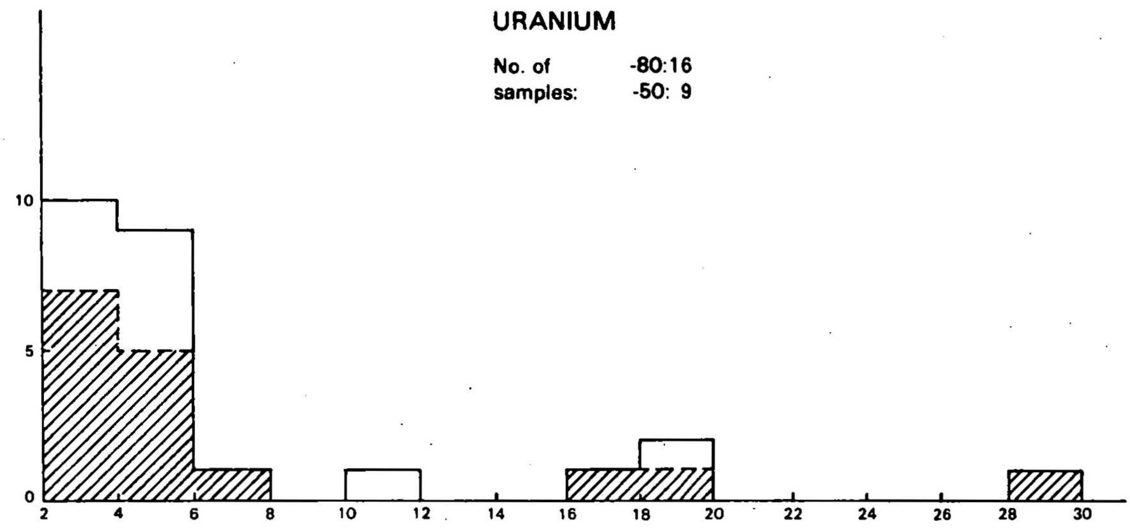

Parts per million
40
60
80
100
120
5
10
20
30
40
50
60
70
80
90
95
98
99
Probability (cumulative %)

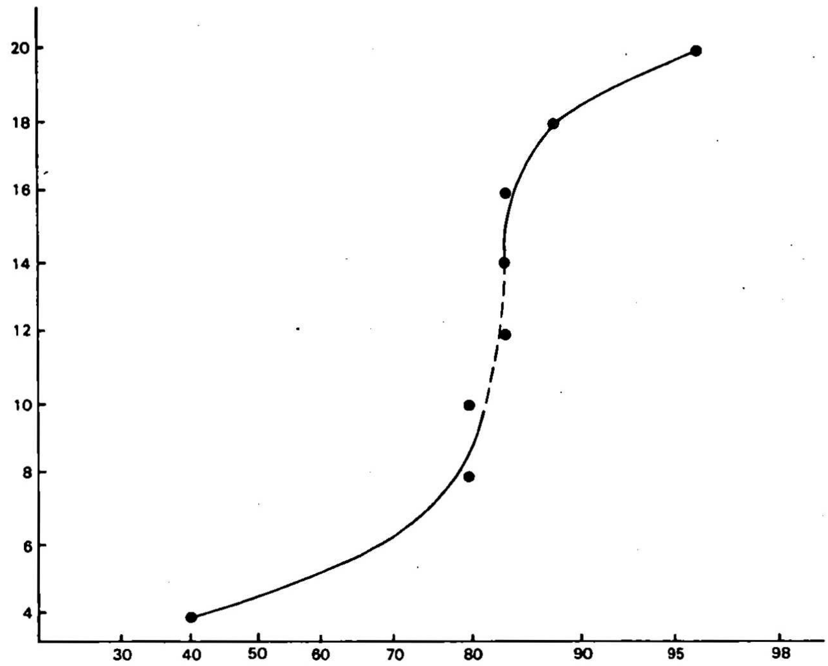

Threshold = 70 ppm
Parts per million
40
50
60
80
100
2
5
10
20
30
40
50
60
70
80
90
95
Probability (cumulative %)

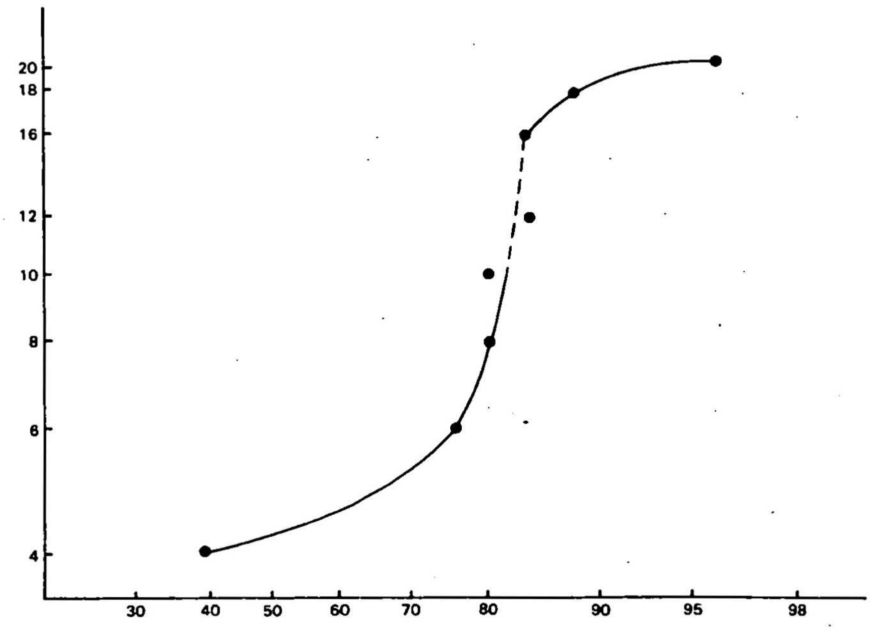

THORIUM
No. of samples:
-80:18
-50:17
0
5
10
15
20
25
30
35
40
45
50

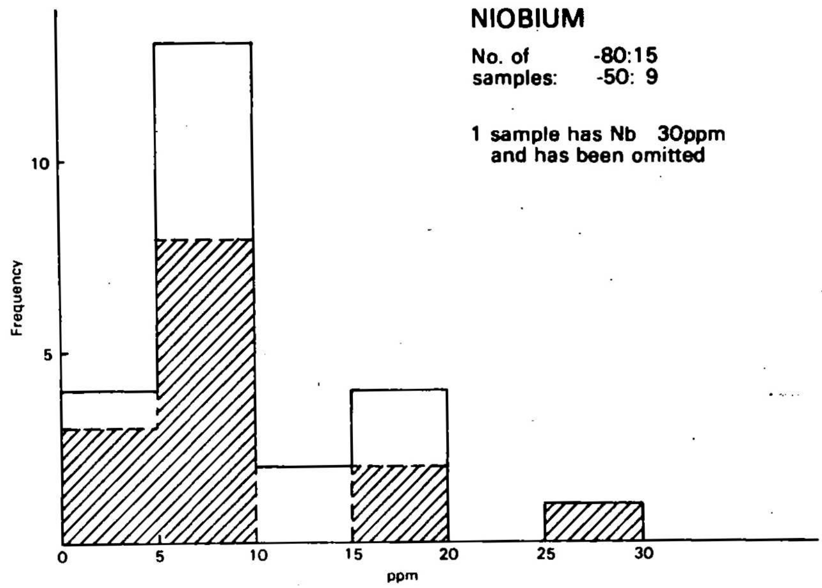

Parts per million
5
10
15
20
25
30
35
40
45
50
3
60
70
80
90
95
98
Probability (cumulative %)

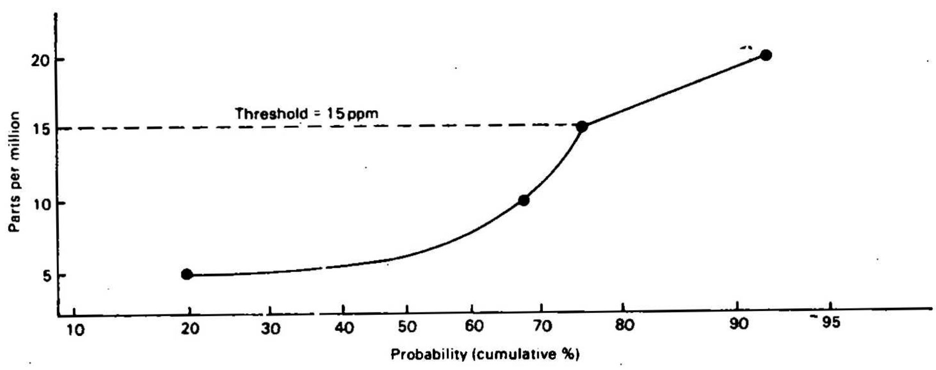

Parts per million
15
20
25
30
35
40
45
50
5
10
60
70
80
90
95
98
Probability (cumulative %)

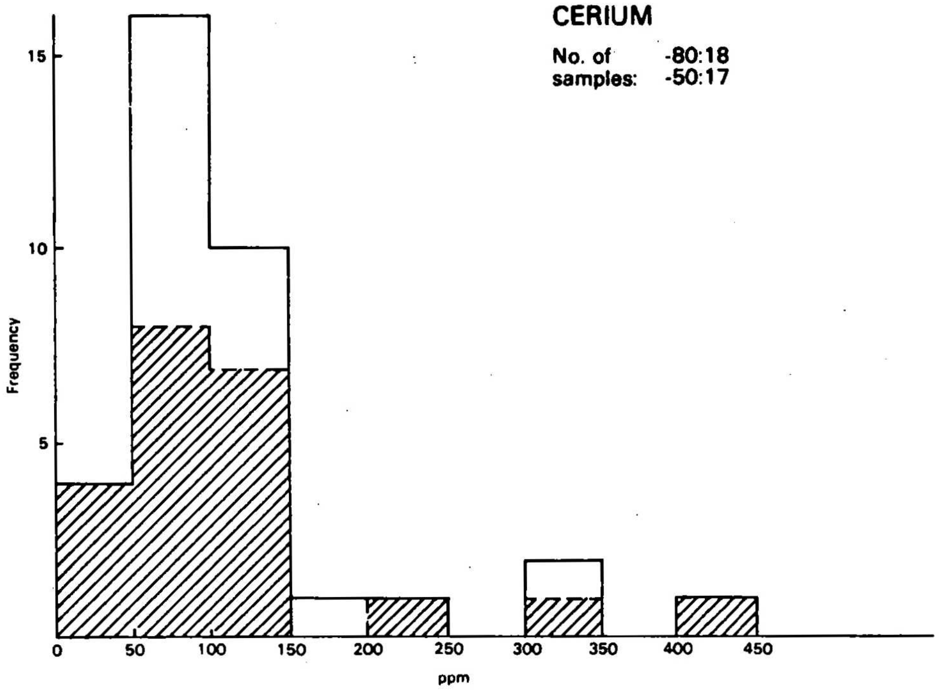

URANIUM
No. of samples: -80:16
-50: 9
10
5
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30


20
18
16
14
12
10
8
6
4
30
40
50
60
70
80
90
95
98

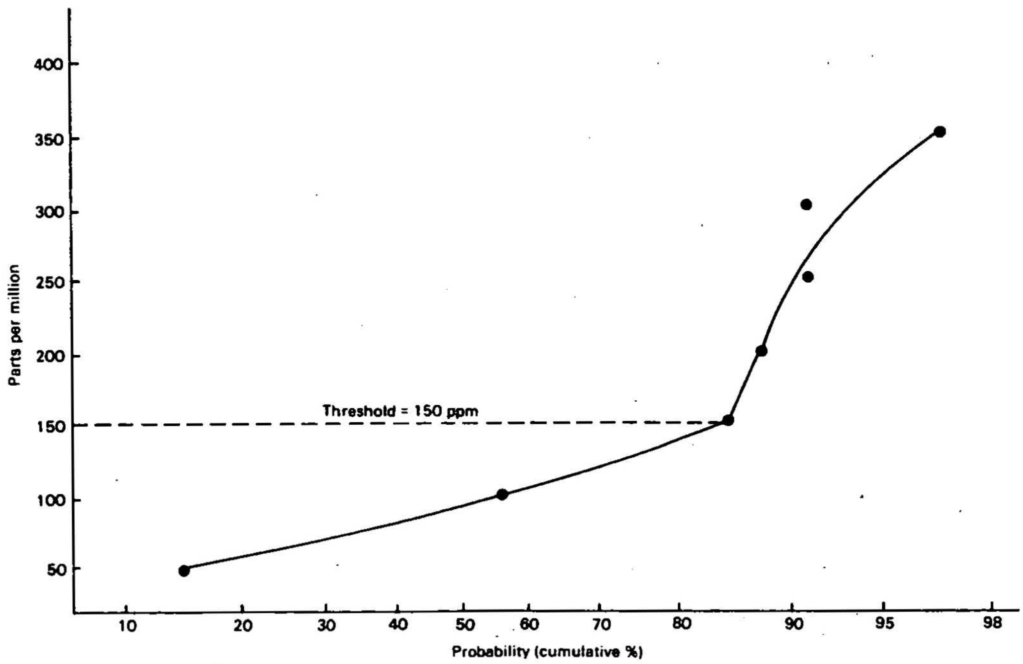

20
18
16
12
10
8
6
4
30
40
50
60
70
80
90
95
98


NIOBIUM
No. of samples: -80:15
-50: 9
1 sample has Nb 30ppm and has been omitted
10
5
Frequency
0
5
10
15
20
25
30
ppm

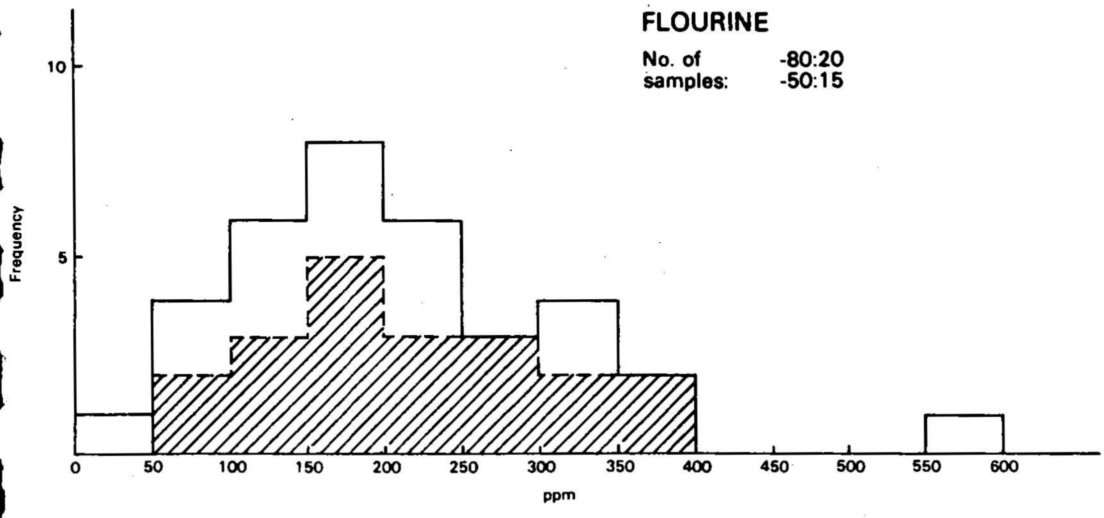

20
15
10
5
Parts per million
Threshold = 15 ppm
10
20
30
40
50
60
70
80
90
95
Probability (cumulative %)

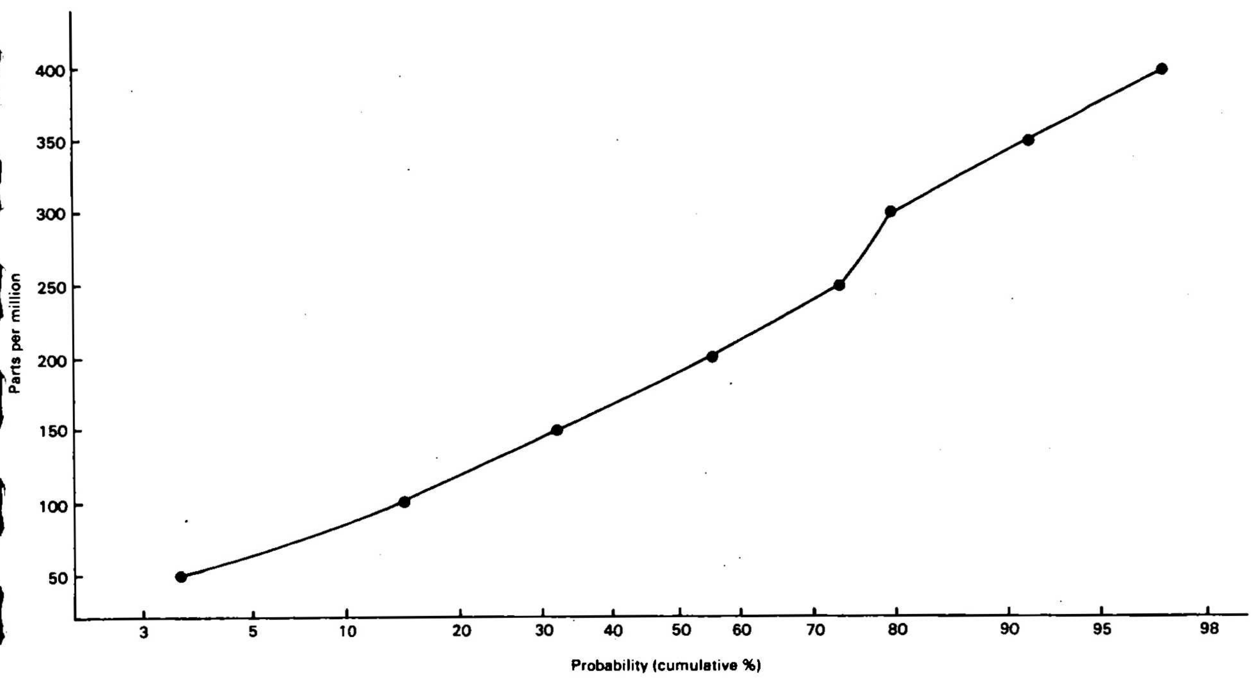


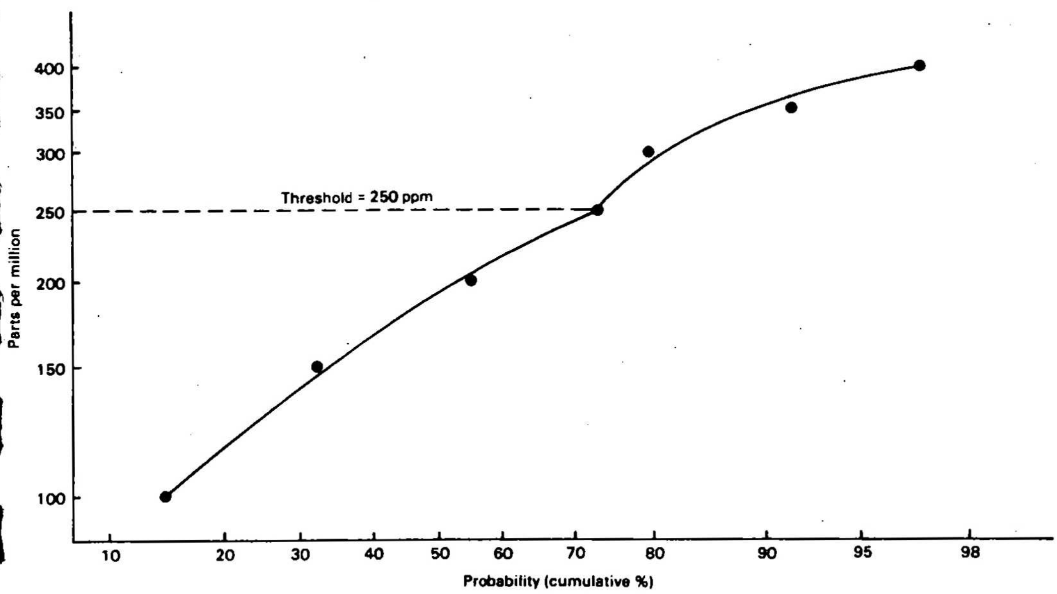
CERIUM
No. of samples: -80:18
-50:17
Frequency
15
10
5
0
50
100
150
200
250
300
350
400
450
ppm

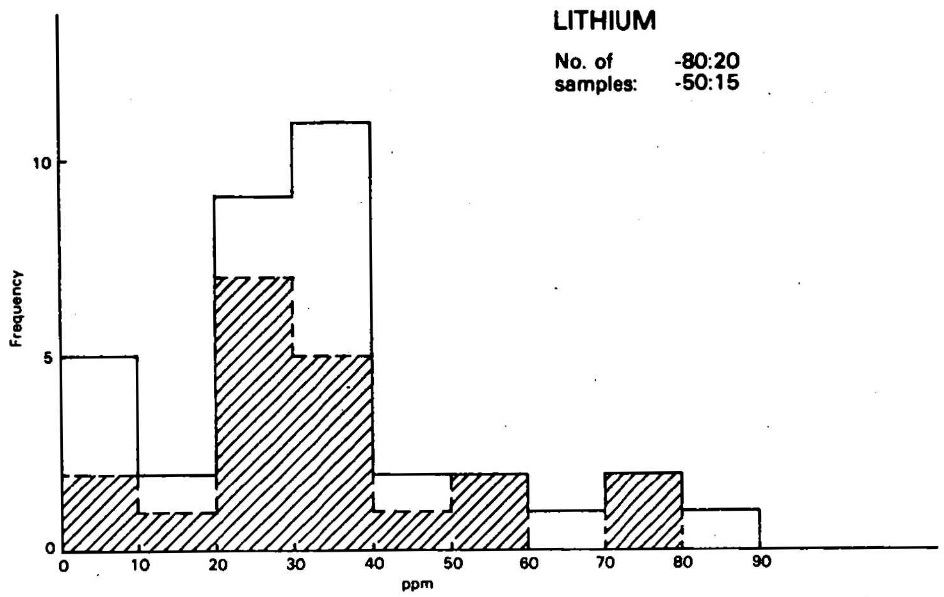


Parts per million
400
350
300
250
200
150
100
50
Threshold = 150 ppm
10
20
30
40
50
60
70
80
90
95
98
Probability (cumulative %)

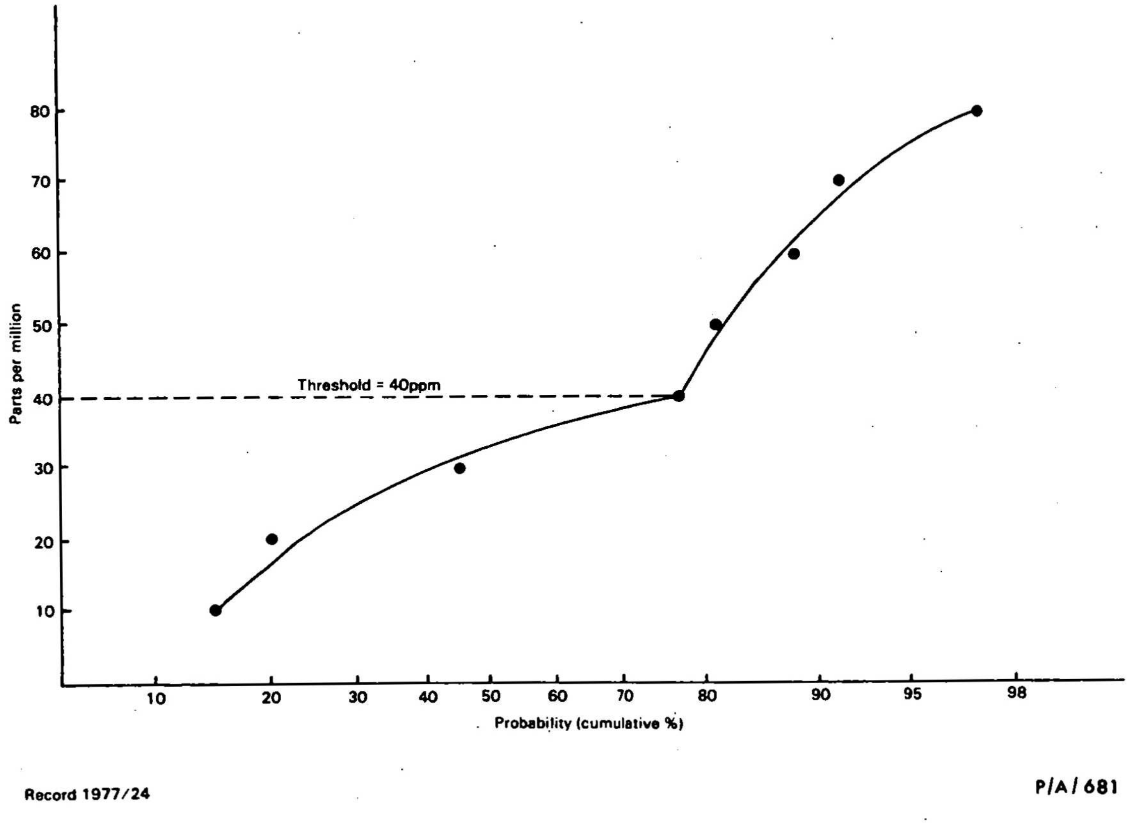

FLOURINE
No. of samples: -80:20
-50:15
Frequency
10
5
0
50
100
150
200
250
300
350
400
450
500
550
600
ppm


Parts per million
400
350
300
250
200
150
100
50
3
5
10
20
30
40
50
60
70
80
90
95
98
Probability (cumulative %)

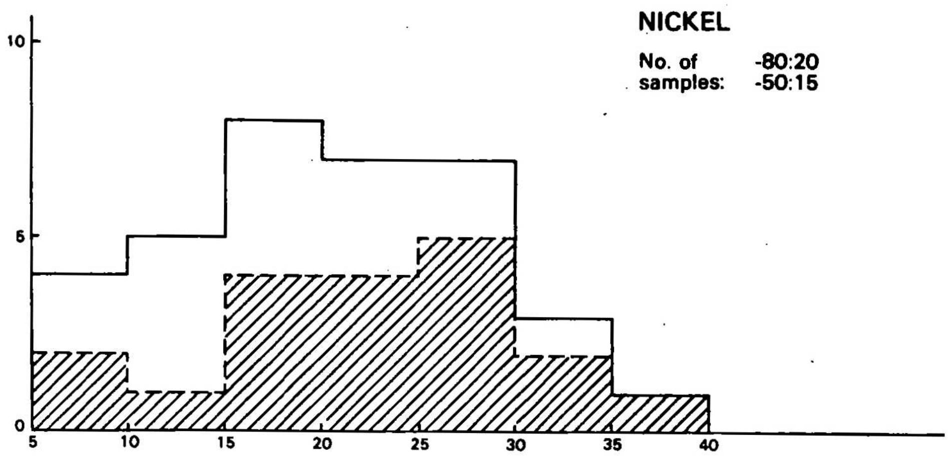

Threshold = 250 ppm
Parts per million
400
350
300
250
200
150
100
10
20
30
40
50
60
70
80
90
95
98
Probability (cumulative %)

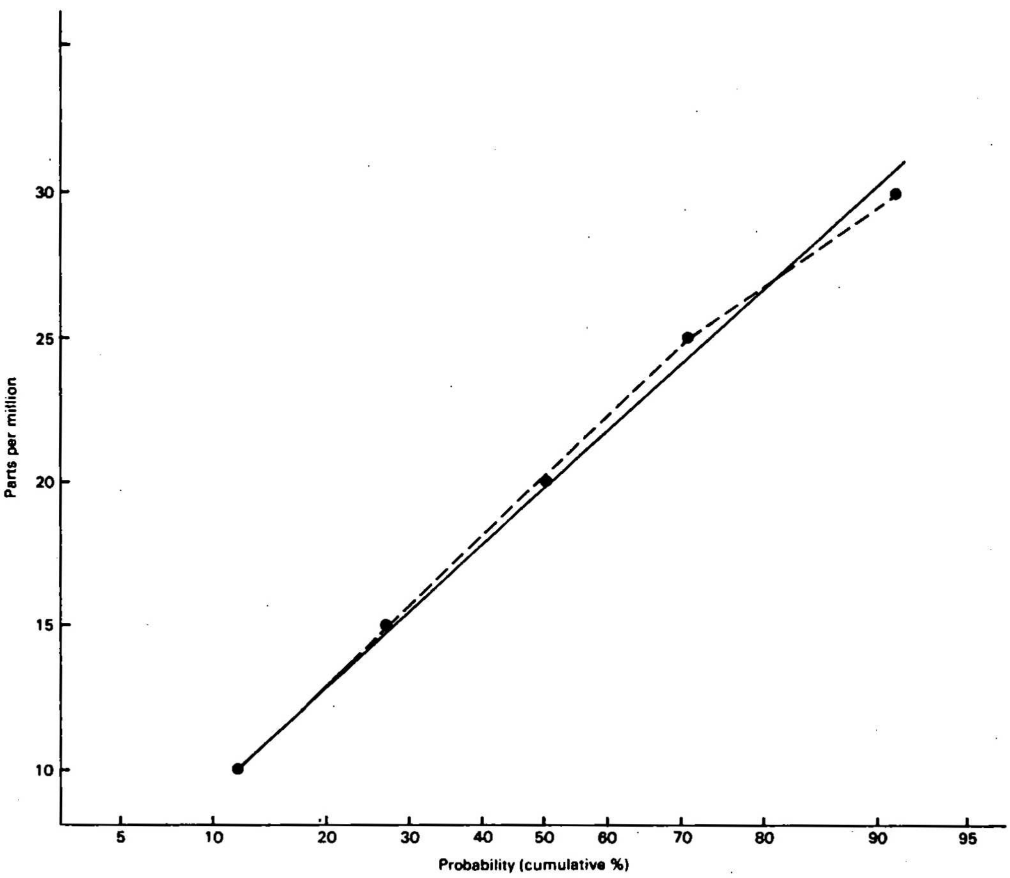


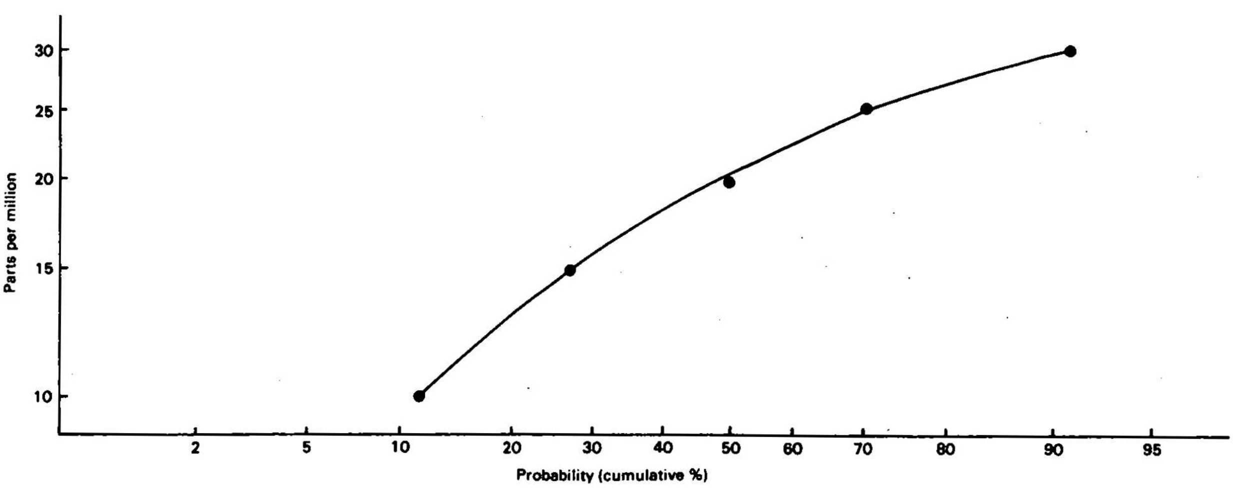
LITHIUM
No. of samples: -80:20 -50:15
Frequency
10
5
0
0 10 20 30 40 50 60 70 80 90
ppm

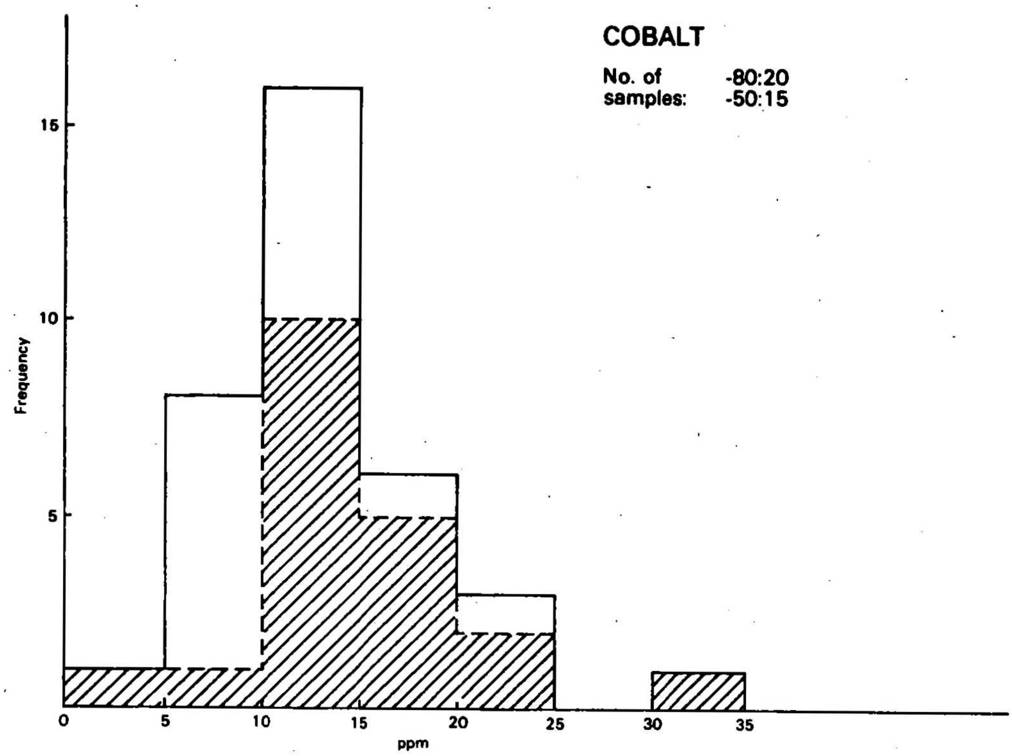


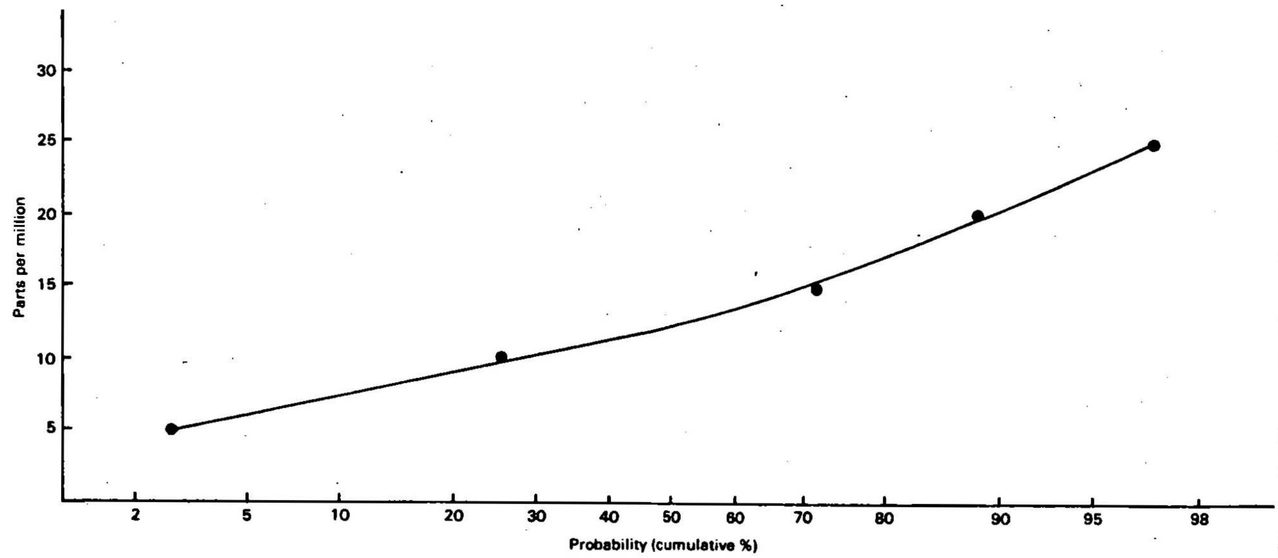
Parts per million
80
70
60
50
40
30
20
10
Threshold = 40ppm
10 20 30 40 50 60 70 80 90 95 98
Probability (cumulative %)

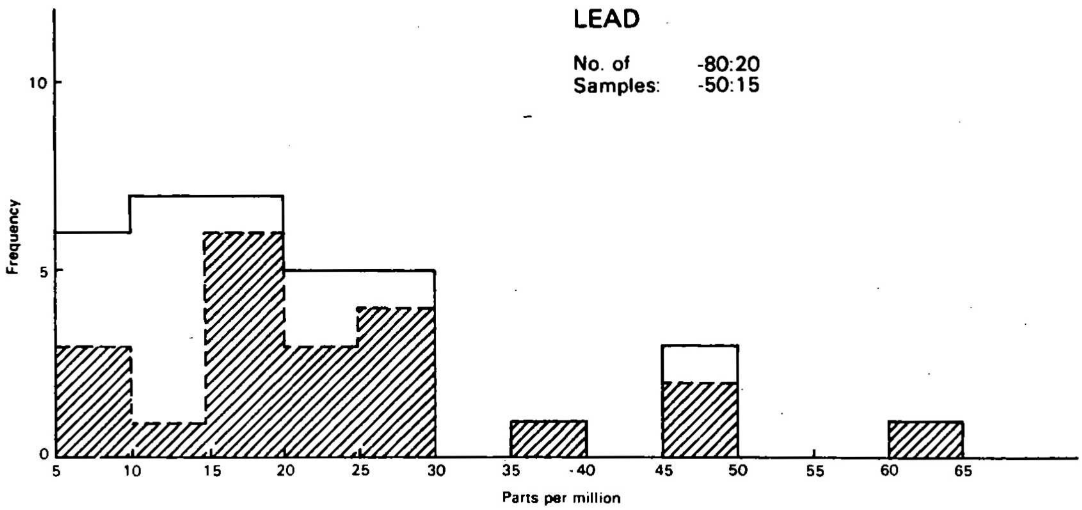

NICKEL
No. of samples: -80:20
-50:15
10
5
0
5
10
15
20
25
30
35
40


Parts per million
30
25
20
15
10
5
10
20
30
40
50
60
70
80
90
95
Probability (cumulative %)

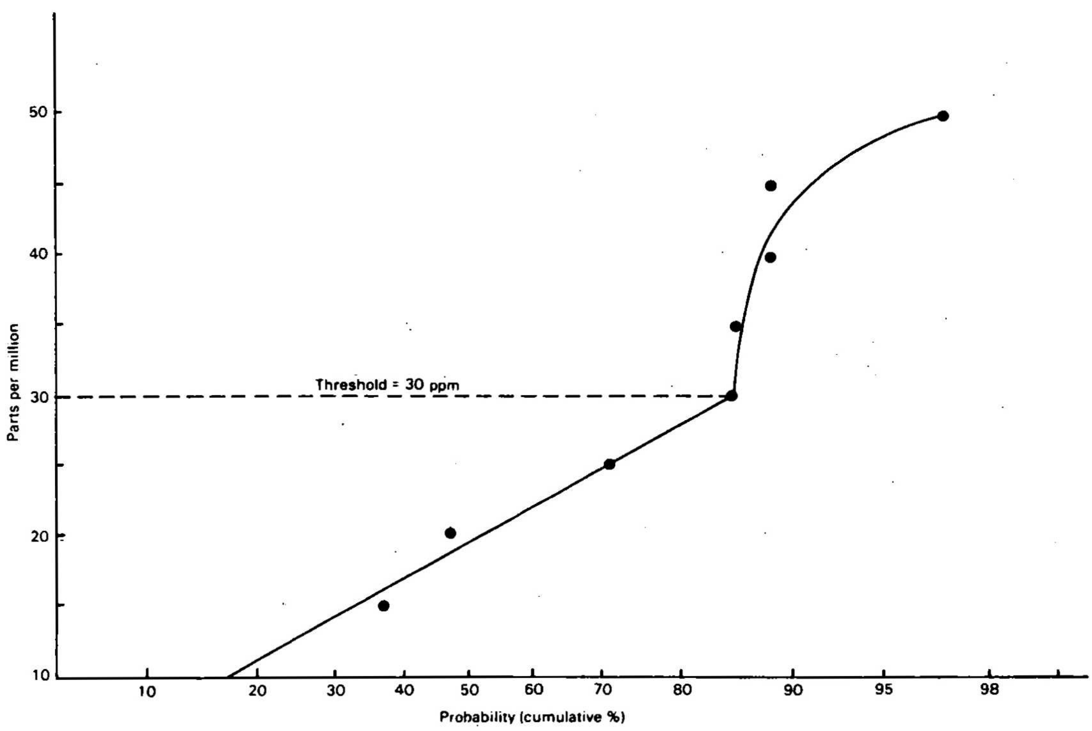

Parts per million
30
25
20
15
10
2
5
10
20
30
40
50
60
70
80
90
95
Probability (cumulative %)


COBALT
No. of samples: -80:20
-50:15
Frequency
15
10
5
0
5
10
15
20
25
30
35
ppm

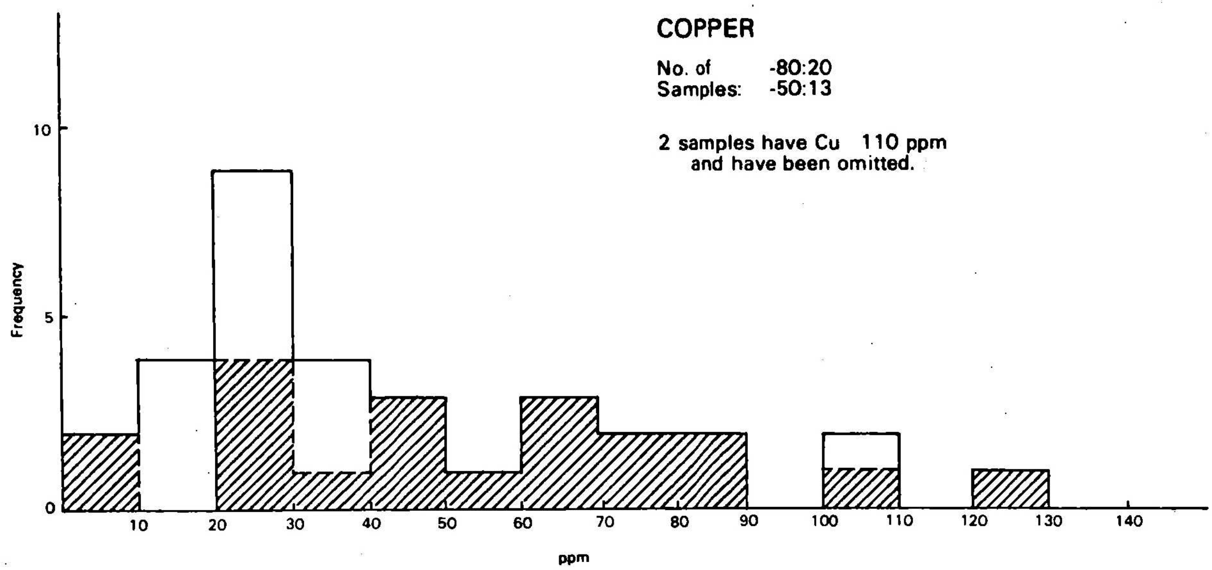

30
25
20
15
10
5
Parts per million
2
5
10
20
30
40
50
60
70
80
90
95
98
Probability (cumulative %)

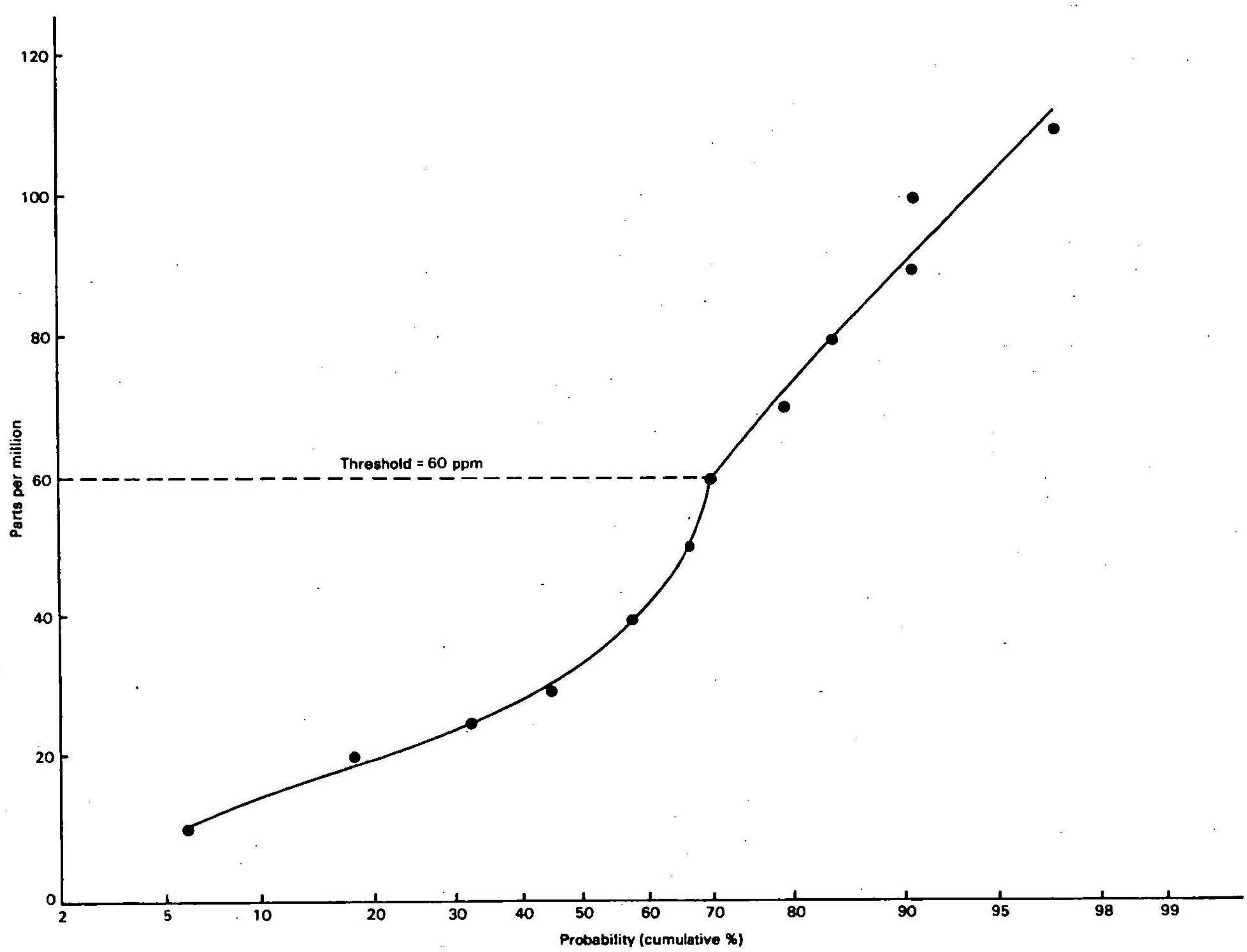


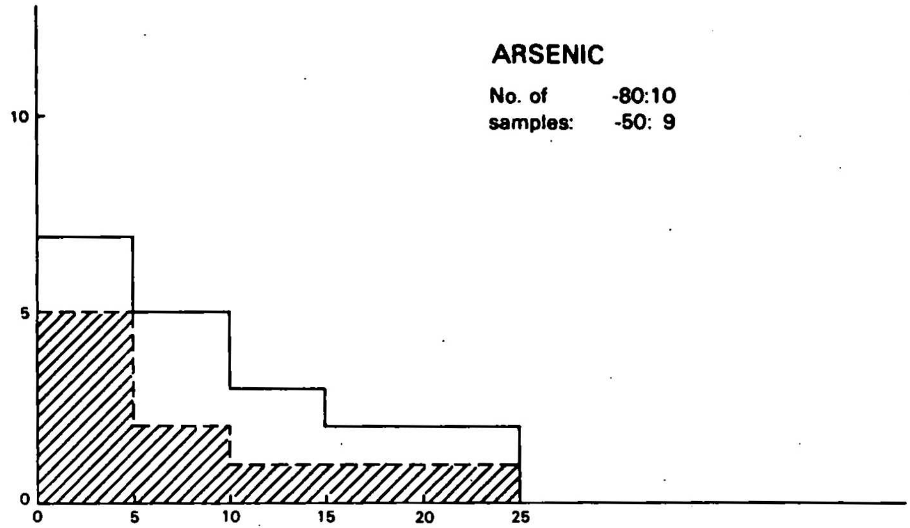
LEAD
No. of Samples: -80:20
-50:15
Frequency
0
5
10
5
10
15
20
25
30
35
-40
45
50
55
60
65
Parts per million



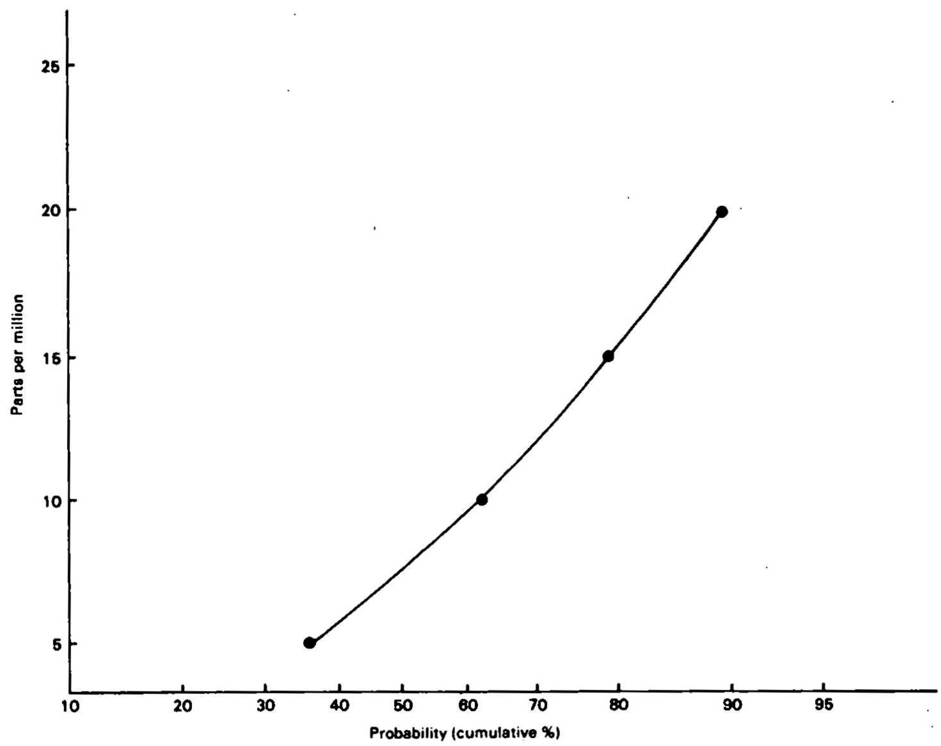
Parts per million
50
40
30
20
10
Threshold = 30 ppm
10
20
30
40
50
60
70
80
90
95
98
Probability (cumulative %)


COPPER
No. of Samples: -80:20 -50:13
2 samples have Cu 110 ppm and have been omitted.
Frequency
10
5
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
ppm

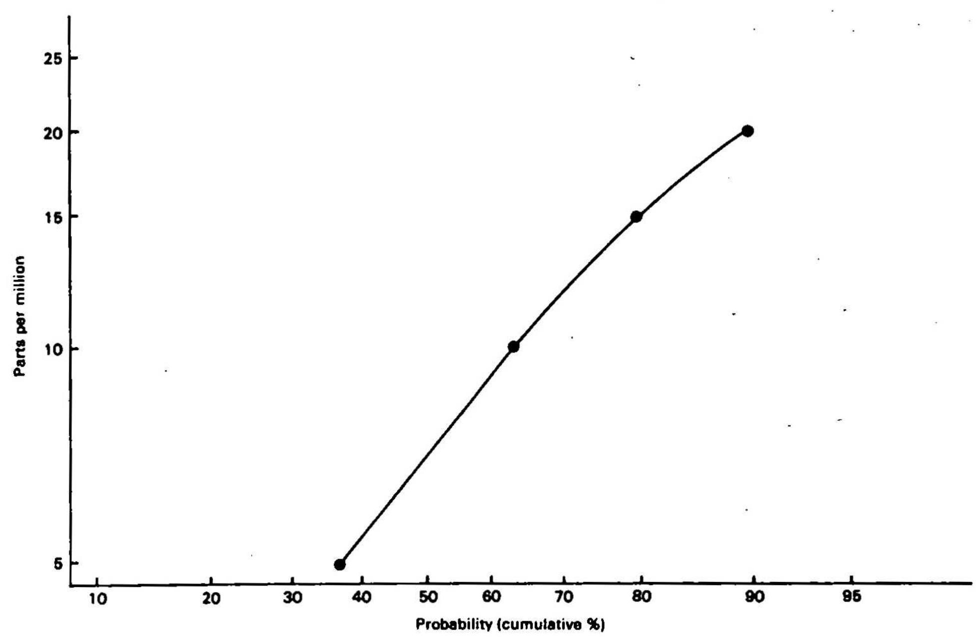

Threshold = 60 ppm
Parts per million
120
100
80
60
40
20
0
2
5
10
20
30
40
50
60
70
80
90
95
98
99
Probability (cumulative %)



ARSENIC
No. of samples: -80:10
-50: 9
10
5
0
0
5
10
15
20
25

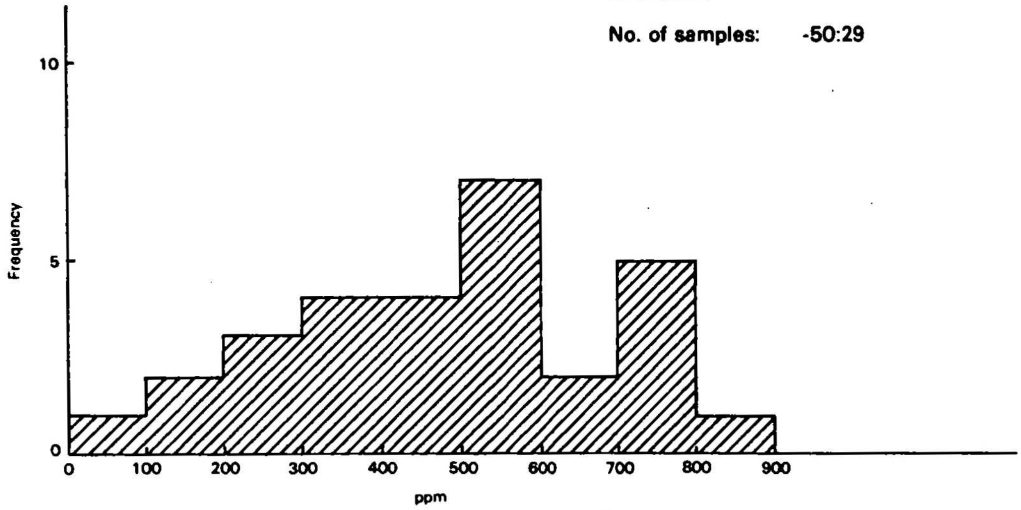


Parts per million
25
20
15
10
5
10
20
30
40
50
60
70
80
90
95
Probability (cumulative %)

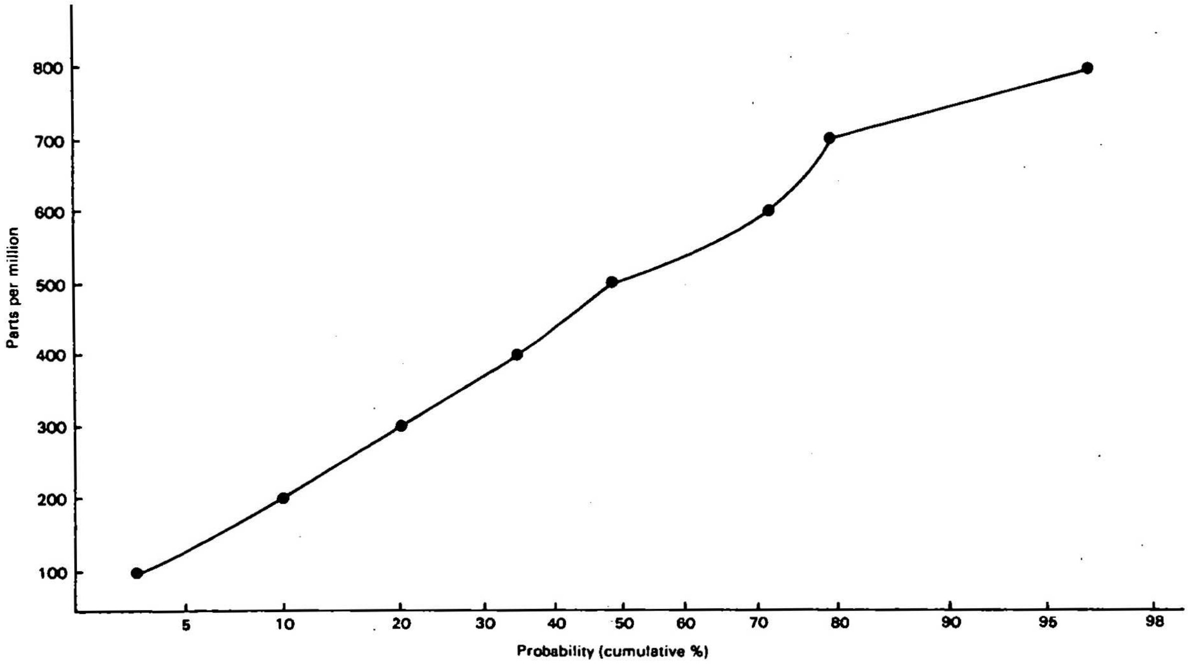


Parts per million
25
20
15
10
5
10
20
30
40
50
60
70
80
90
95
Probability (cumulative %)

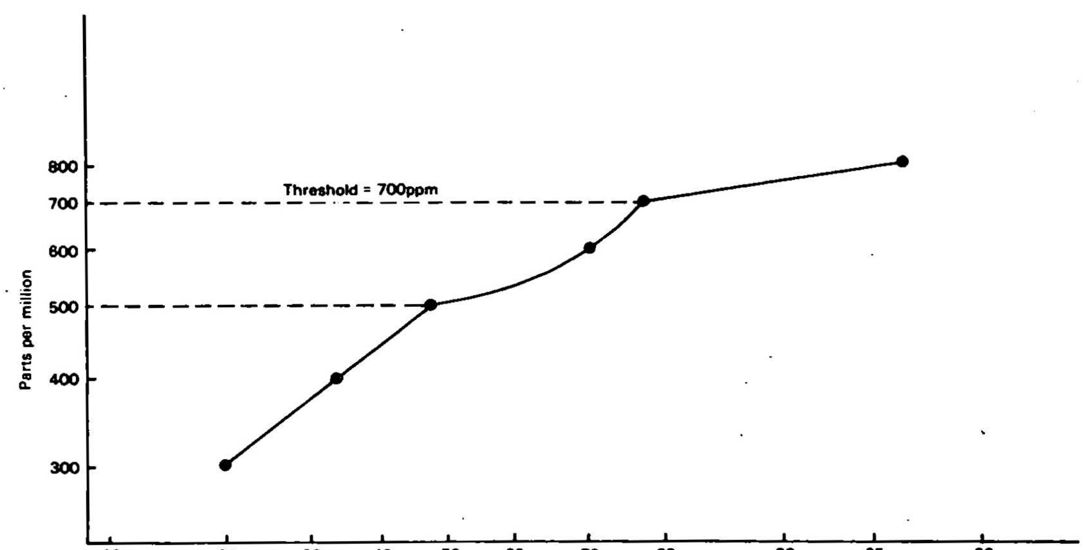
BARIUM



No. of samples: -50:29
Frequency
ppm



Parts per million
Probability (cumulative %)

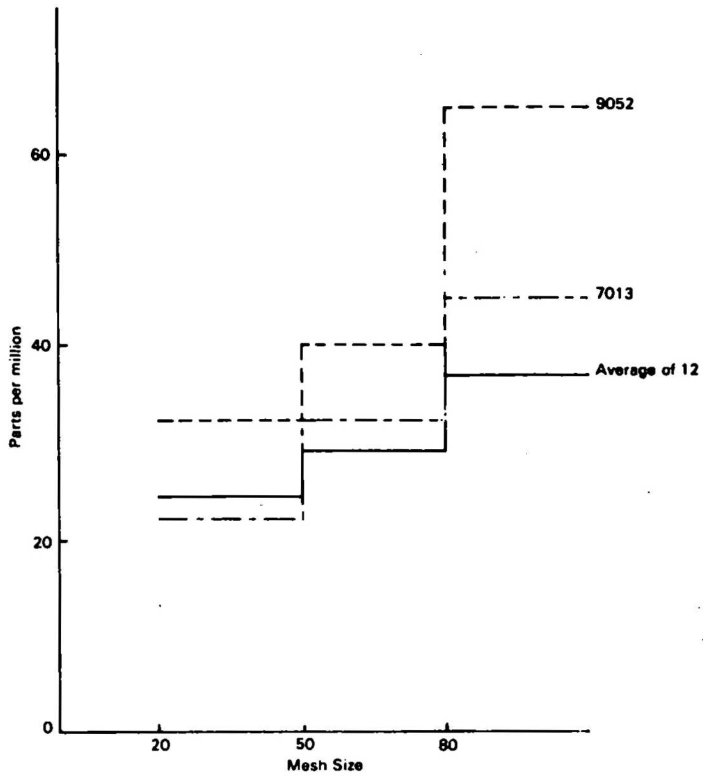


Threshold = 700ppm
Parts per million
Probability (cumulative %)

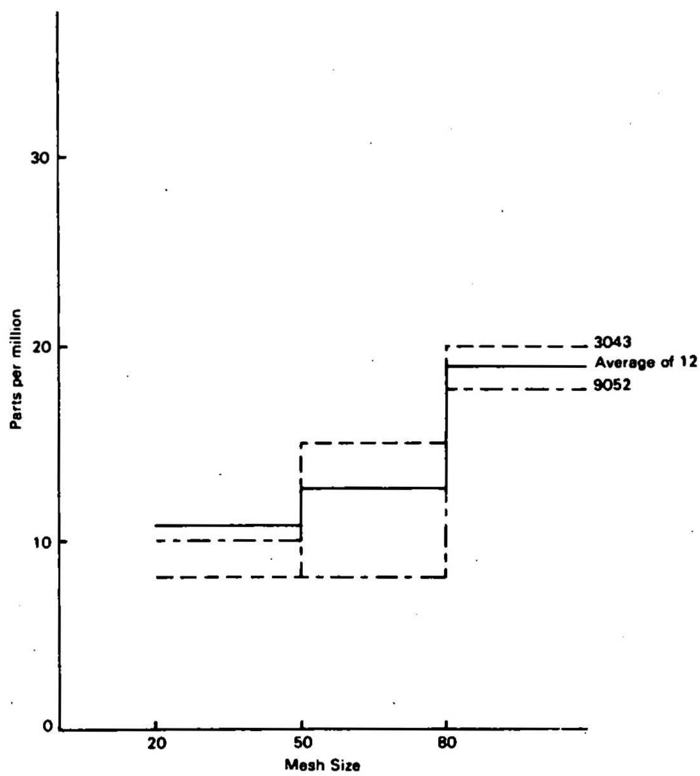
APPENDIX 3

RESULTS OF STREAM-SEDIMENT SIZE-FRACTION ANALYSIS

Copper

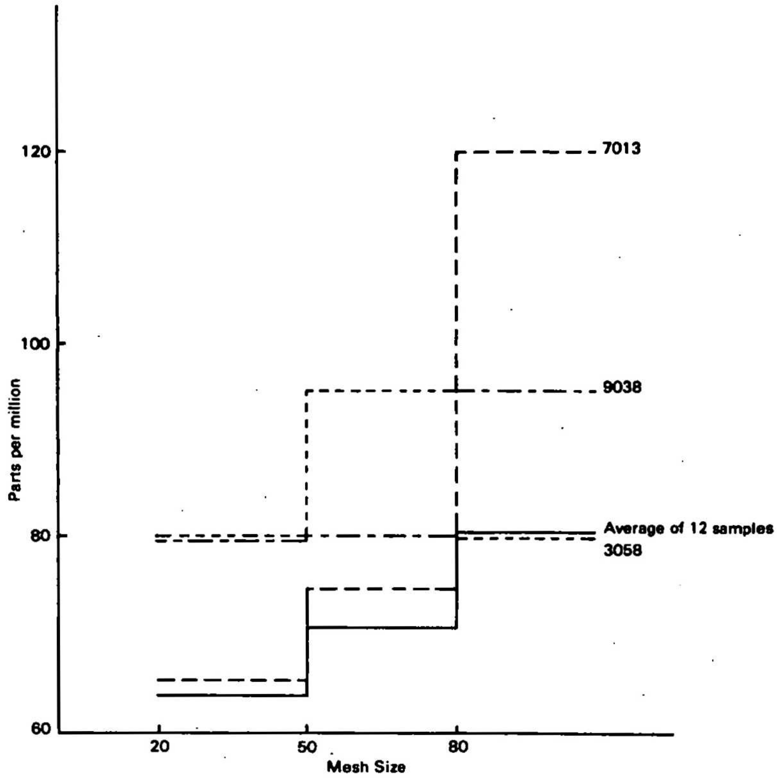


Lead



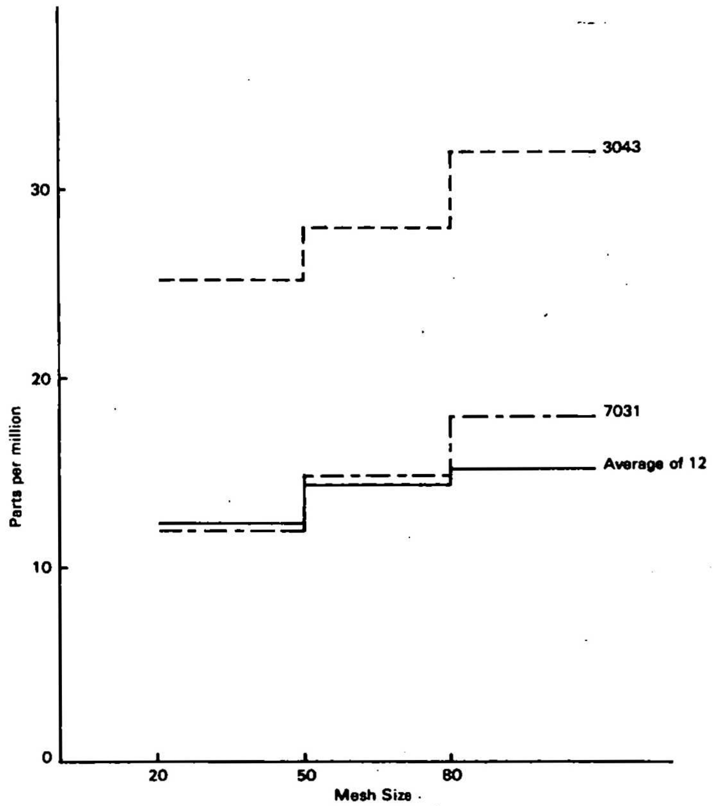
P/A/ 675

Zinc



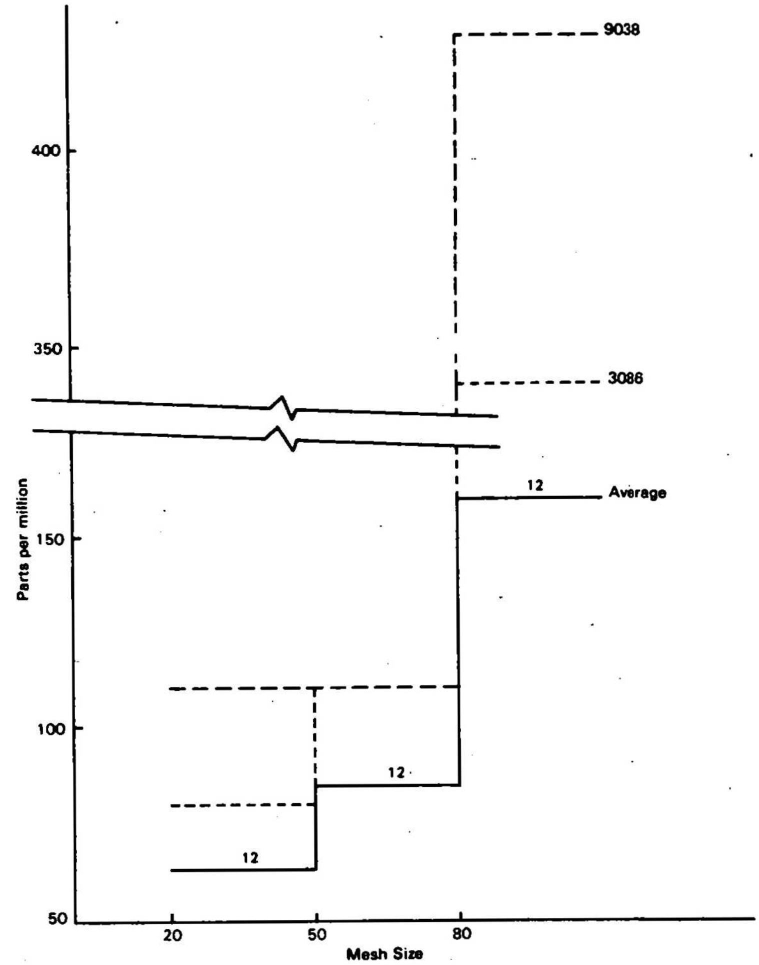
120
100
80
60
Parts per million
7013
9038
Average of 12 samples
3058
20
50
80
Mesh Size

Cobalt

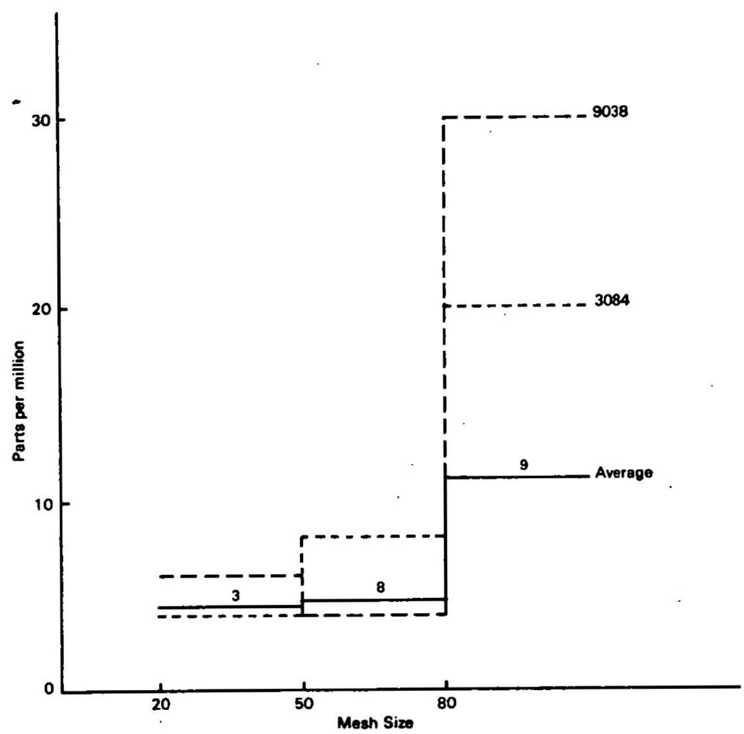


30
20
10
0
Parts per million
3043
7031
Average of 12
20
50
80
Mesh Size

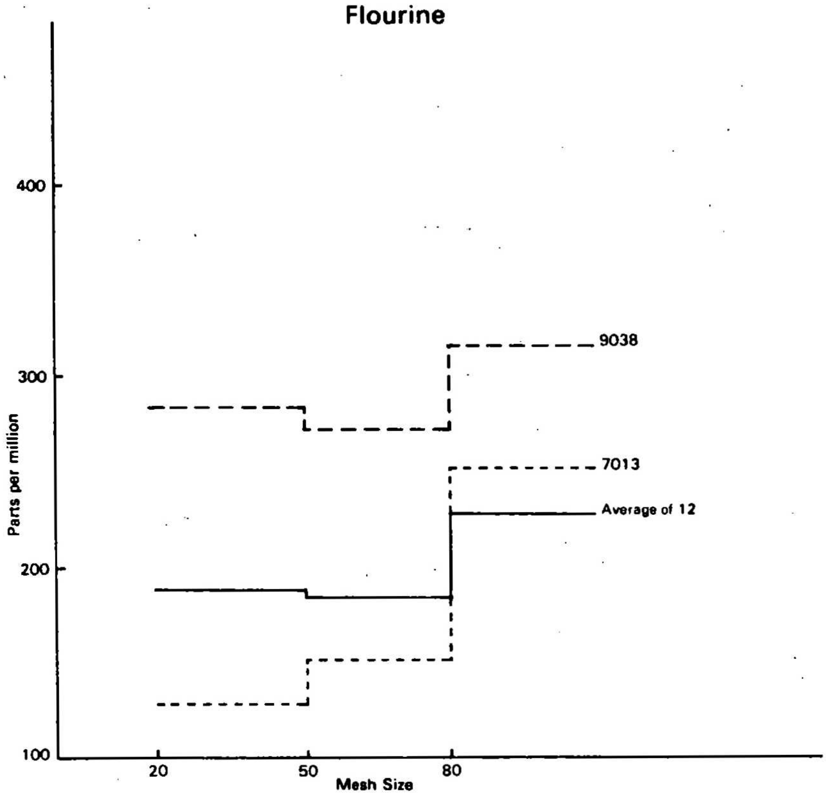
Cerium



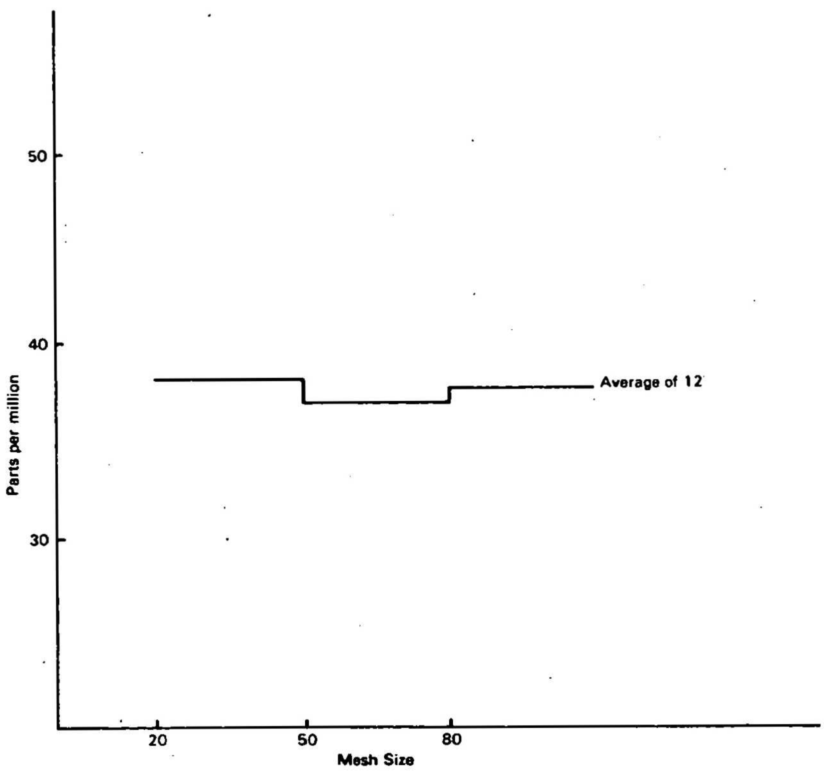
Uranium



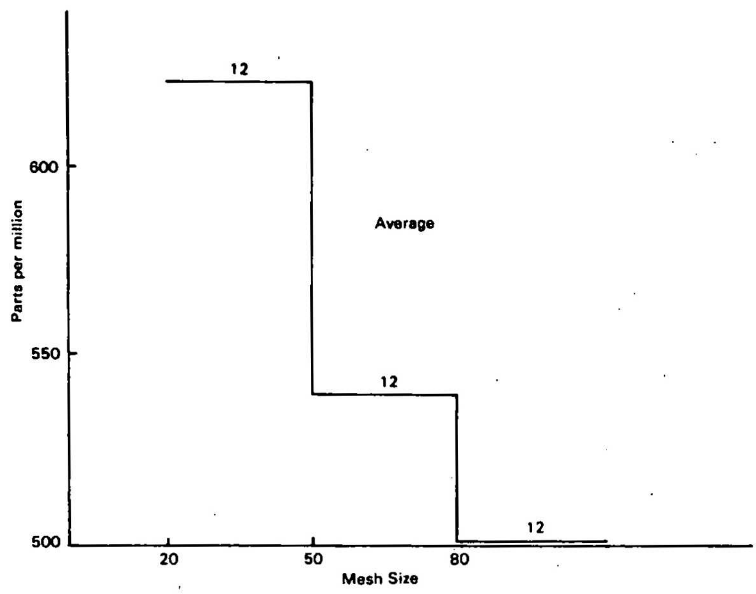
Flourine



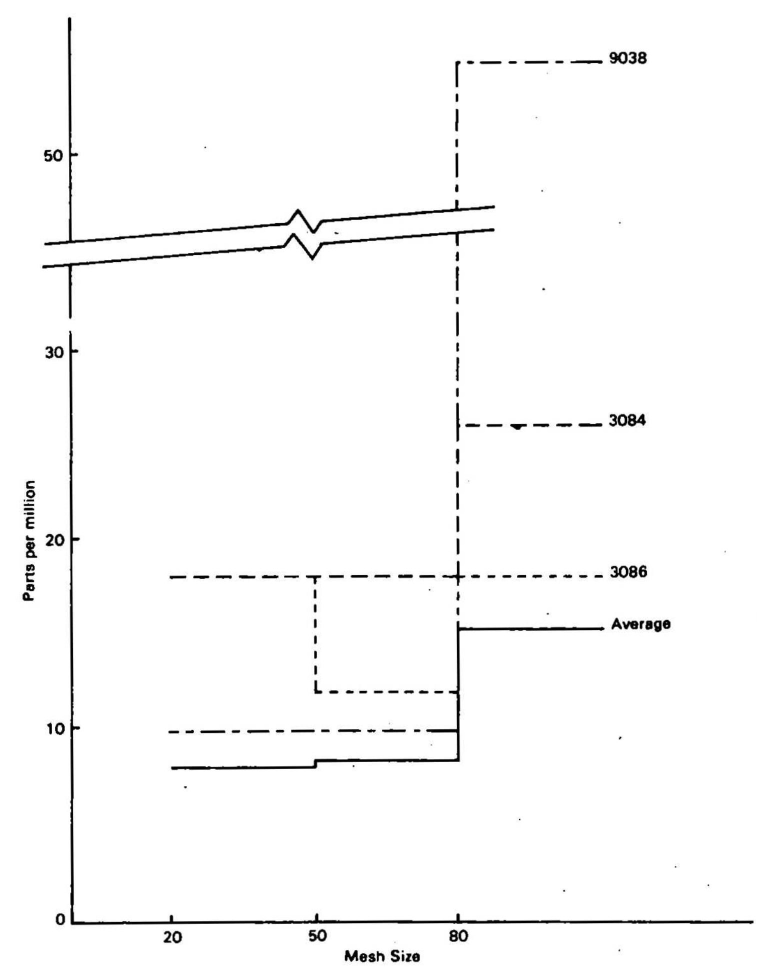
Lithium



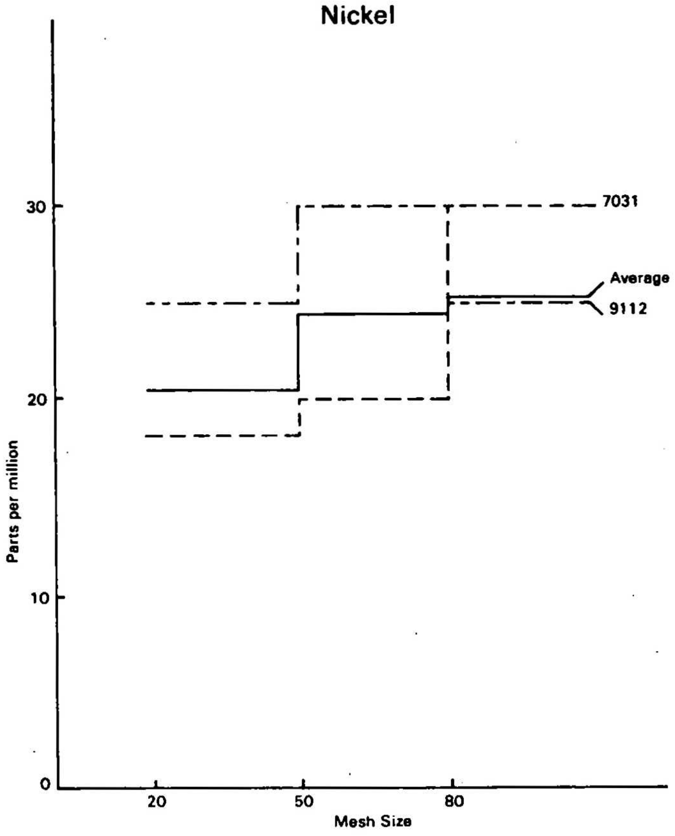
Barium



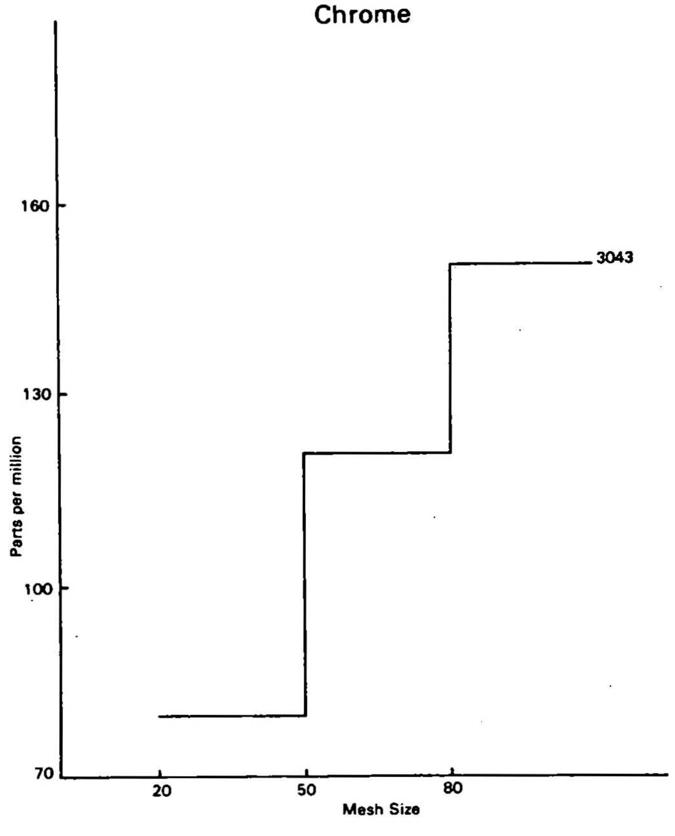
Niobium



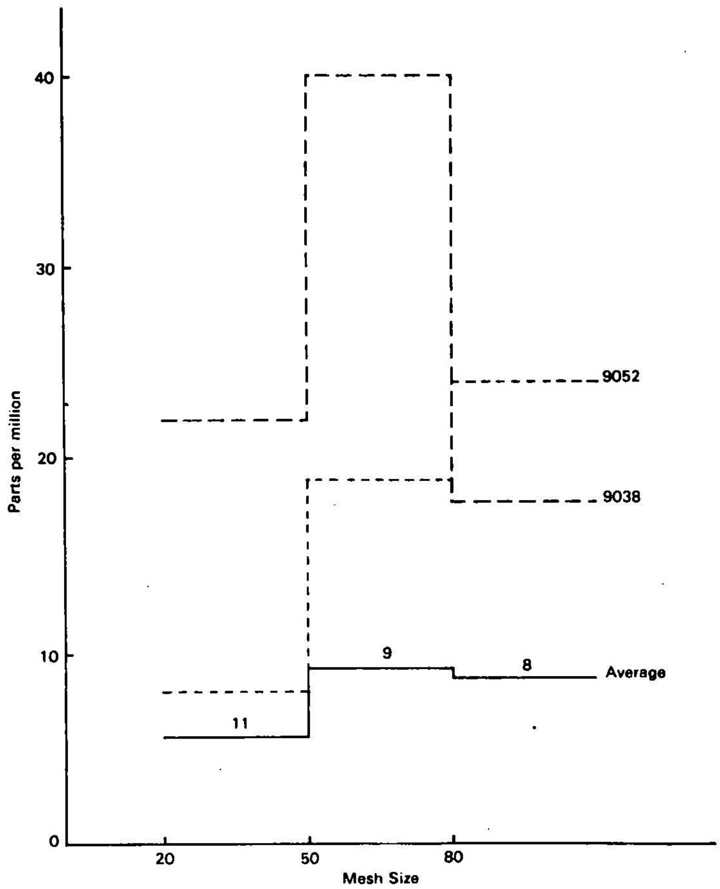
Nickel



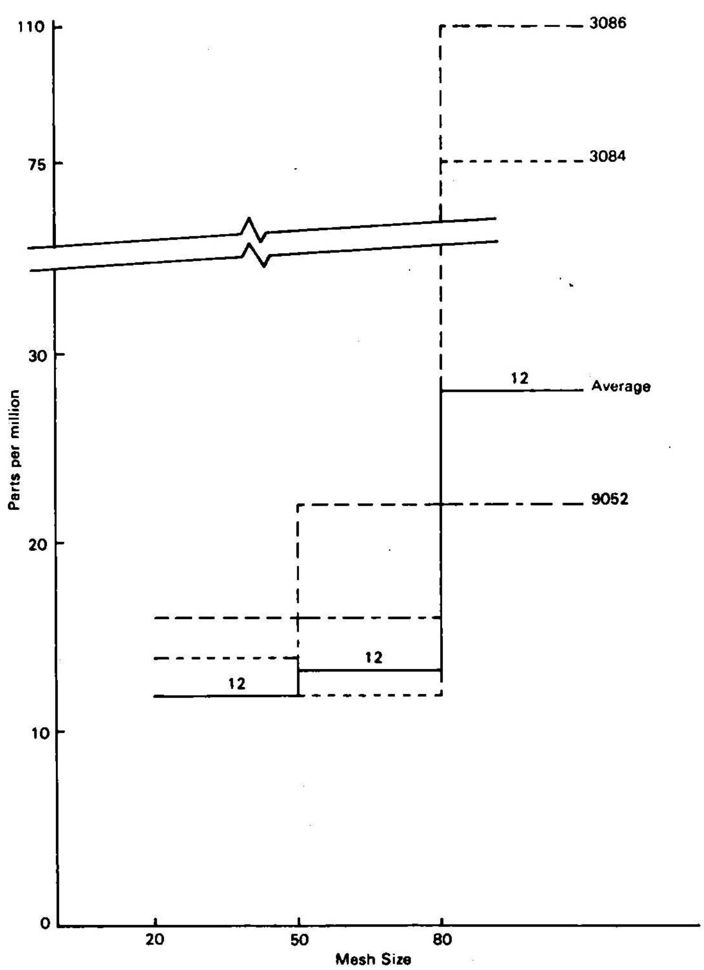
Chrome



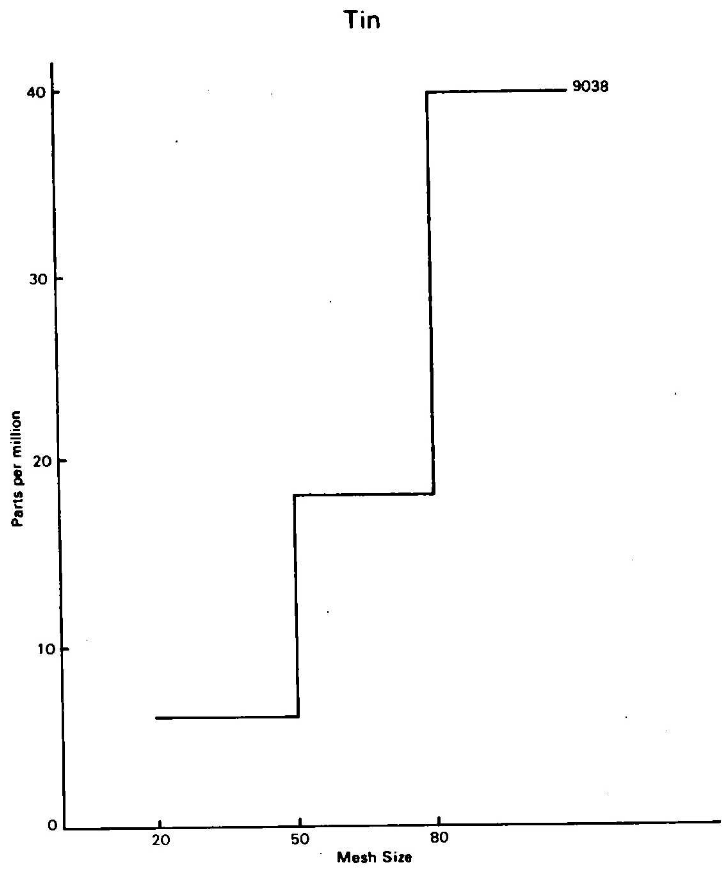
Arsenic



Thorium



P/A/674


Tin
9038
40
30
20
10
0
Parts per million
20
50
80
Mesh Size