A Reconnaissance Survey of the Distribution of Antimony and Certain Related Metals in North Cornwall

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SYNOPSIS

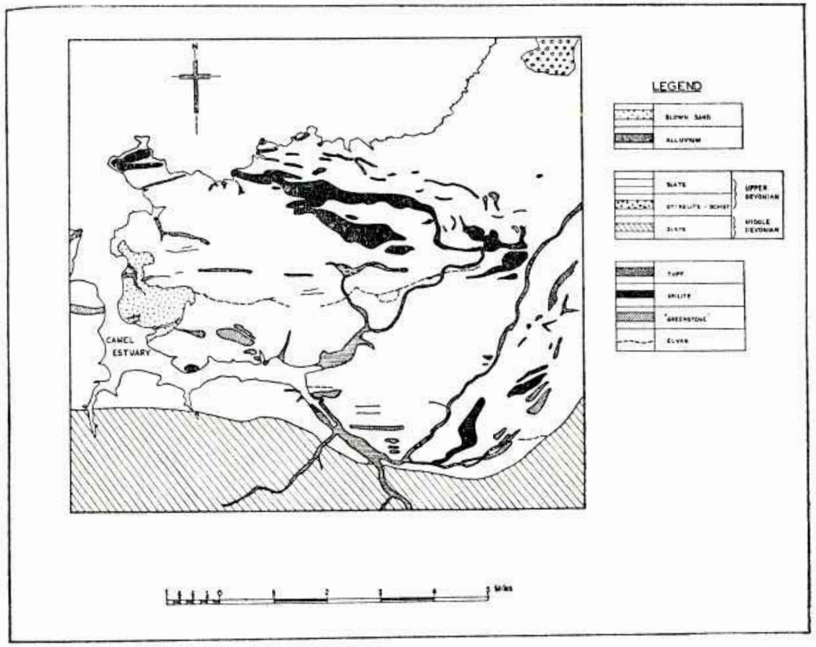
ANTIMONY, lead and arsenic have been determined in several hundred samples of stream and estuarine sediments and soils from the antimony area of North Cornwall which is approximately 70 square miles in extent. In addition, a number of sediments have been analysed for copper and zinc, and the total-heavy-metal content of the river waters has been determined at numerous points.

The work has revealed all the known areas of mineralisation but no new ones of any importance, and it has indicated that geochemical soil studies in the vicinity of known deposits might well lead to the discovery of new lodes.

The study has also given further reason for believing that on occasion a study of the trace element content of estuarine deposits during regional geochemical reconnaissance surveys of little investigated difficult areas might facilitate exploration by indicating, broadly, the disposition and nature of any mineralisation within the areas drained by the rivers feeding the estuary : particularly if the rivers are of limited length.

During the Easter of 1963 final year and research students of the Camborne School of Mines spent a week in the field, in North Cornwall, carrying out various types of prospecting. This paper is based on the results of one of the studies, which was carried out under the guidance of the writers, and involved the analysis of 391 sediment and soil samples for antimony, lead and arsenic and 38 sediments for copper and zinc in a temporary field laboratory, and the determination of 'total-heavy-metals' in water at about 200 sampling points. The work occupied four 11-hour days and the area investigated was approximately 70 square miles.

The major objects of the work were to determine and interpret the distribution of antimony, and certain associated metals in the fluviatile and estuarine deposits of Cornwall's only important antimony field, which lies, for the most part, just to the north of the Camel Estuary, in the parishes of St. Minver, St. Endellion, St. Kew and St. Teath ; to ascertain the characteristics of the metal anomalies in the soil over a known antimony zone, and to enable the students to gain experience in applied geochemical field work and in the establishment and running of a temporary laboratory.



MAP 1. THE MAJOR GEOLOGICAL FEATURES OF THE STUDY AREA

General Geology (Map 1).

The area is occupied by the E.-W.-trending St. Mabyn syncline of Upper Devonian slates with which are associated greenstones and spilites of pre-granite age. An elvan dyke, which, in common with the other igneous rocks, trends approximately E.-W., also occurs : this is probably related to the Permo-Carboniferous Bodmin Granite which outcrops about two miles to the east of the study area.

About a dozen mines — all small — have been worked for antimony in this region and at least a further half-dozen have been lead producers. (Map 2.) Many of these are quite old, and Borlase (1758, p.129) records that antimony was mined at Roscarrock, in Endellion, where it occurs with copper and lead.

Because most of the mines are old and all were small and had a very limited working life, details concerning the nature of the lodes, etc., are very imperfect, and in some cases virtually all the available information has been obtained by examination of dump material.

The antimony deposits are commonly associated with spilites which leads one to contemplate the possibility of a genetic relationship between them. It seems unlikely, however, that such a relationships exists because even in the area of interest antimony occurs where there are no spilites, as at Penhale Mine, St. Breock, and, in addition, it is found elsewhere in Cornwall in a spilite-free environment. Also, the presence of the elvan suggests that the area may be underlain by a tongue of the granite batholith, and so the ore-deposits, which mineralogically possess epithermal characteristics, are probably related to this buried mass. If this is so, the spilites are simply favourable host rocks: perhaps because channel-ways for the ore-forming agents developed most readily in them.

The antimony bearing veins are rarely more than two feet in width and of limited strike length, and, on occasion they are little more than a series of metal rich lenticles joined by narrow veinlets. Ore bearing veinlets sometimes also occur in the wall-rocks adjacent to the main vein. Some of the major lodes trend N.-S. whilst others possess E.-W. strikes. Members of both systems may occur in the same mine (as at Roscarrock) and when this happens rich pockets of ore are often found at the intersections.

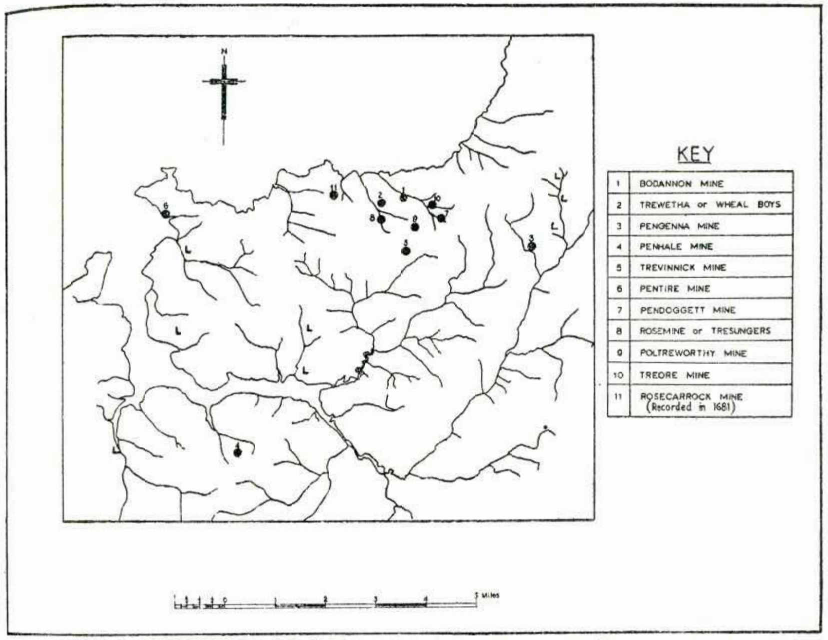
The antimony occurs in the unoxidised parts of the orebodies primarily as stibnite and jamesonite, and Dewey (1920, p.52) notes that " it has been observed by the manager of Poltreworgey Mine and of several others in the district that the lodes coarsing north and south carry stibnite, whereas those running east and west yield jamesonite as the principal antimony ore ". In a few mines the antimony-bearing sulphide bournonite is also prominent. Varying amounts of pyrite, chalcopyrite, arsenopyrite, galena and sphalerite are found with the antimony-bearing species (and in antimony-free lodes), and there is a common tendency for the antimony lodes to change, in depth, to lead lodes. A little gold has been reported from the Trerore and Trevinnick deposits. The non-metallic gangue consists of quartz and siderite.

On oxidation the primary antimony species alter to stibiconite and bindheimite, whilst the galena gives rise to cerussite, and locally pyromorphite and linarite. The major oxidation product derived from arsenopyrite is scorodite.

The area is a portion of the so called 430-ft. Pliocene Platform and as the rivers draining it are comparatively young they are generally fairly fast flowing and their valleys gorge-like. As might be expected, some stretches of stream beds contain very little sediment of any sort, a fact that militates somewhat against geochemical studies.

On the plateau surface the residual soil cover is about two foot thick and is a brown earth with an ill-defined A horizon a few inches thick. It is very fertile and virtually all of it is farmed.

The Camel Estuary, which is locally fringed by raised beaches and sand dunes, has a quite complex history, a discussion of which is beyond the scope of this paper. However, as a series of sediment



MAP 2. DISTRIBUTION OF THE MAJOR ANTIMONY MINES (FILLED CIRCLES) AND SOME OF THE LEAD MINES (L) IN NORTH CORNWALL

samples were taken from it, primarily with a view to determining to what extent an examination of its metal content revealed the distribution of mineralised zones in the hinterland, the following description of its superficial deposits is relevant :—

Within the inter-tidal environment of the estuary there are a number of sub-environments which are reflected by the presence of mature (vegetated) marsh, mud flats, mid-estuary sand banks and tidal channels whose dispositions are shown on Map 9, and which are described below.

Mature marsh deposits :—These occupy the higher parts of the estuary and small sheltered coves leading into the main estuary channel. The deposits are finely-laminated mud laid down during the high slack-tide periods when current action is at a minimum. The thick cover of vegetation facilitates deposition of clay particles in suspension by behaving as a filter : it also reinforces the mud and so reduces the rate at which it is eroded during storms.

Mudflat deposits :—These are developing in front of the marsh, particularly on the northern side of the estuary. They consist of well laminated sand and silty mud. The mud is deposited from suspension when currents are weak, whilst the sand collects under less tranquil conditions. These deposits are highly populated by burrowing annelids and molluscs (Nereis sp. and Scrobicularia sp. respectively) which, by churning up the sediments, disrupt the normal sedimentary structures. Locally their activity has been so intense that the original lamination has been almost completely destroyed.

Mid-estuary sand banks :—These consist largely of clean medium to coarse sands. The abundant ripple and mega-ripple marks covering their surfaces indicate that strong current and wave action play a considerable part in their formation. These deposits are populated by the annelid Arenicola marina and a mollusc which is a species of Cardium (probably edule). The former burrows to as much as eighteen inches and forces sand up on to the surface to form distinctive casts, thus allowing the sediment to be continually reworked by the waves and currents.

Creeks :—A large number of tidal channels meander over the whole estuary. These are constantly changing their course and so are largely responsible for the reworking of all the sediments laid down. Their effects are probably most pronounced in the middle and lower parts of the estuary where ebb- and flood-current velocities are greatest. The floors of these channels are covered by thick mats of mollusc shells.

Field Work.

The field work involved the collection of stream sediments at critical points in each drainage system and the determination of the pH of the water and its 'total-heavy-mineral' content, by the usual dithizone method, at each sampling point. (The results of the 'on the spot' investigations are shown on Map 3.)

Within the estuary traverses were made during the low tide period and 'surface' samples were collected from all the sub-environments discussed above. Locally the 'total-heavy-metal' content of the water, and its pH, were determined.

Finally, soil samples were collected from the B horizon, at approximately one foot below the surface, at points 10 foot apart along three traverse lines which were laid out to intersect the assumed position of the roughly N.-S. coursing antimony and lead lodes at Trevinnick, St. Kew. The ground slopes gently to the east and on the hilltop there are two small shafts. One of these is 11 fms. deep and, according to Dines (1956, p.575) is sited on a north-south, west-dipping lode, 1½ to 2 ft. wide, containing quartz, siderite, chlorite, galena, sphalerite and pyromorphite. At the end of a cross-cut 6 fms. S.E. from the shaft bottom there is a winze 3 fms. deep to the adit which thence runs eastward to its mouth, 100 yds. W.N.W. of Lower Trevinnick farm. " Antimony ore was discovered in a surface excavation close to the shaft, and later in a drive south-westwards from the inner end of the adit. It occurred in scattered lenses up to 2 ft. long and containing up to several hundredweight of ore, in a crush zone, and consisted mainly of jamesonite . . . . The lenses were connected by cracks stained with antimony ochre."

Laboratory Work.

The samples were dried and the minus 80-mesh (B.S.S.) fraction of every sample was analysed for lead, antimony and arsenic. In addition, the minus 80-mesh fractions from the Portgaverne and Port Isaac streams (A and B on the accompanying maps) were analysed for copper and zinc. (Because these streams drained a number of antimony mines, they were sampled more intensively than the others and the samples were subject to this additional analytical treatment.)

Copper, lead and zinc were determined by the bisulphate/dithizone method, arsenic by a modified Gutzeit method, and antimony by the Brilliant Green method of Stanton and McDonald (1961-62). The results of the analyses are indicated on Maps 3-12.

Discussion of Results.

Total-heavy-metals in Water. (Map 3.)

With few exceptions the stream waters of the area contain very low concentrations of heavy metals. This is due to the following :—

(i) The area is not heavily mineralised and such lodes as there are contain comparatively small concentrations of zinc and copper — the two elements which are almost entirely responsible for high total-heavy-metal concentrations in natural waters. Lead, which is much more abundant in the area contributes but little as it is immobilised in various insoluble minerals during oxidation of the ore-bodies.

(ii) Because the lodes are small they have only supported very small mines, hence the adits in the area are very limited in number and extent. Consequently the waters emerging from them have not had the opportunity of collecting much metal. In addition, the dumps of waste material are also small and comparatively poor in " metal " so that contamination of the stream waters by material derived from these is also generally slight.

The heavy metal content of the waters of rivers T and M are exceptional. The former drains the Pentireglaze lead/antimony mine, which probably contained appreciable quantities of sphalerite, and the M (i.e., the River Allen) — which contains distinctly anomalous concentrations of heavy metals in its water throughout its course — owes this particular characteristic to the presence of the comparatively large Treburgett Mine, whose lodes contain lead, copper, zinc and antimony and whose adit feeds the river in question.

Antimony, etc., in Stream Sediments.

Antimony. (Map 4.)

The concentration of antimony in some of the sediments of streams A, B, T, and M is distinctly anomalous and can be fairly well related to known antimony deposits. However, the high value (160 p.p.m.) at the mouth of stream A, and that of 130 p.p.m. in its middle reaches may be indicative of hitherto unknown deposits. On the other hand they may be due to local accumulations of material which have been transported from known up-stream sources.

The distribution of antimony in the sediments of M (the River Allen) is interesting. The material has probably been derived from the Pengenna Mine by lode erosion, and as a result of material being washed into the river by adit water and by run-off from the antimony-rich slag dumps at Watergate, near the adit mouth. Southward from Pengenna antimony appears to concentrate whenever the branches of the river coalesce, and distinctly anomalous values are encountered over the five miles to the south of the mine.

In barren areas the streams contain not more than 2 or 3 p.p.m. antimony, and when samples containing two or three times this concentration are encountered in a stream there are probably one or more antimony-bearing lodes in the catchment area. This is strongly suggested by the metal content of the sediments of river R which contain up to 7 p.p.m. antimony, and 1,000 p.p.m. lead. On the other hand, for obvious reasons, examination of stream sediments is unlikely to reveal all the antimony deposits of the area. Indeed, the antimony lode of the Penhale Mine, which lies within the fork of river Z has not caused anomalous amounts of antimony to report in the sediments, but the high concentrations of lead (up to 12,500 p.p.m.) and arsenic (up to 75 p.p.m.) indicate that the area is lode bearing.

Lead. (Map 5.)

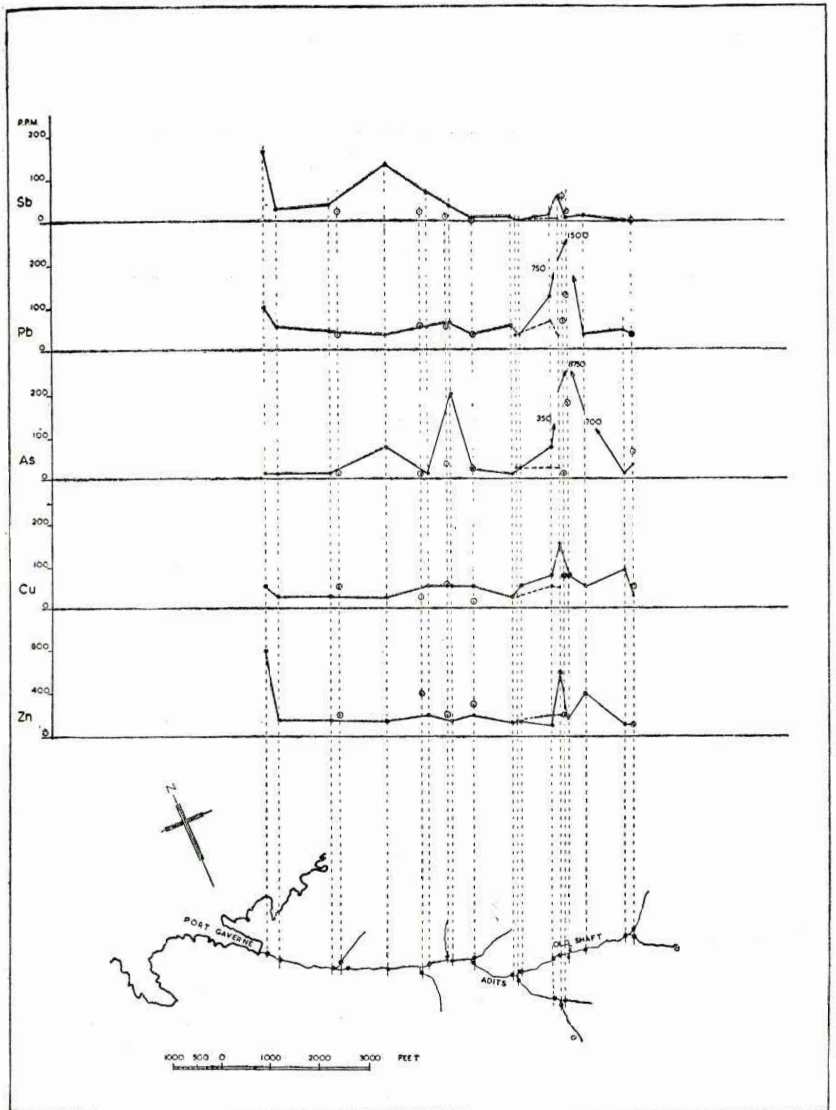
Distinctly high concentrations of lead occur in all the rivers examined excepting F, G and H, and testify to the fact that many lead lodes (albeit usually of little economic importance) occur in the study area. All the high concentrations can be related to known deposits.

The River Allen (M) is again particularly interesting as strongly anomalous lead values occur in its sediments for five miles below the primary source of the metal.

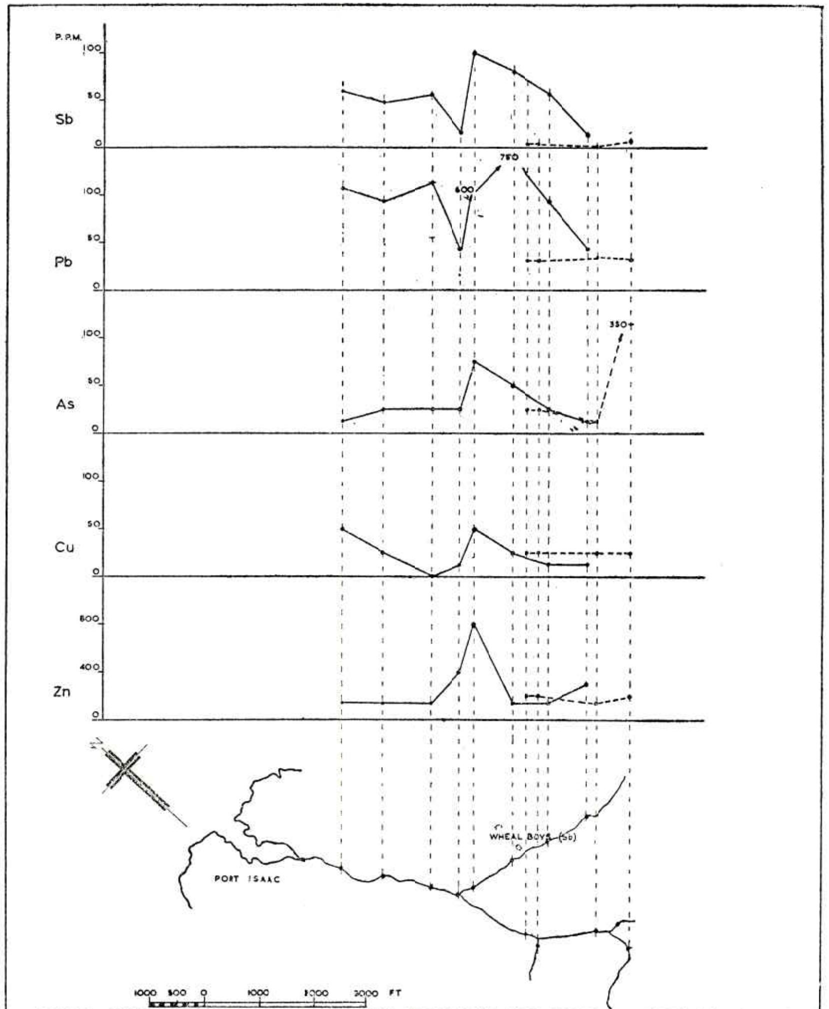
Arsenic. (Map 6.)

Arsenic-bearing minerals are not recorded in descriptions of the ore from many mines in this area, but they are undoubtedly present in most of them, though often in comparatively limited amounts. By virtue of the comparatively small amounts of arsenic present in most of the lodes the sediments are correspondingly generally poor in the

element. It is probably fair to assume that any samples containing 25 or more p.p.m. arsenic are indicative of the presence of lodes in the catchment area, but the latter may contain lodes when the sediments are very much poorer in the element.



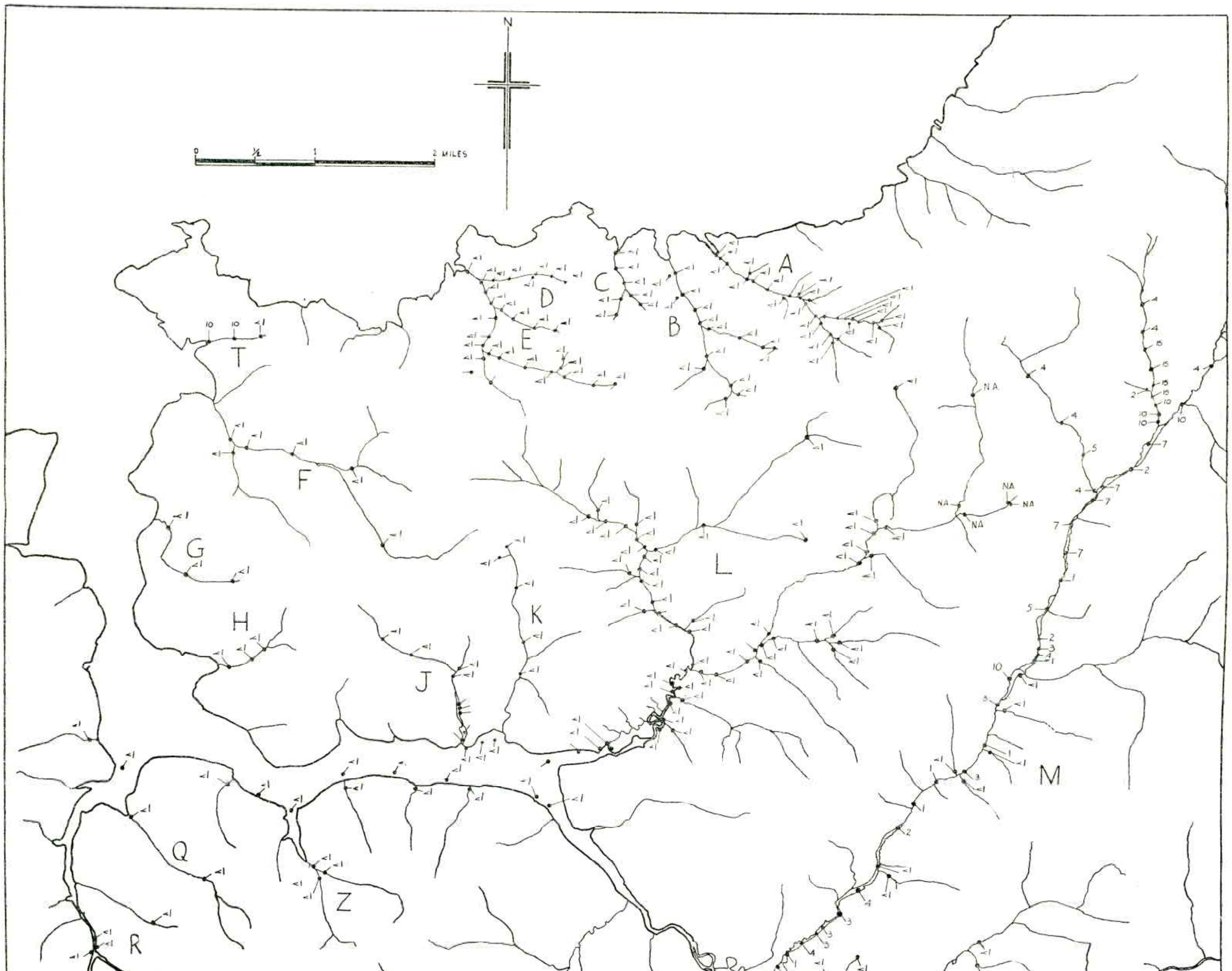
MAP 7. THE DISTRIBUTION OF CERTAIN METALS IN THE MINUS-80-MESH FRACTIONS OF THE SEDIMENTS OF THE PORT GAVERNE (A) STREAM



MAP 8. THE DISTRIBUTION OF CERTAIN METALS IN THE MINUS-80-MESH FRACTIONS OF THE SEDIMENTS OF THE PORT ISAAC (B) STREAM

The Metal Content of the Sediments of Streams A and B. (Maps 7 and 8.)

The Portgaverne (A) Stream — This stream drains the areas occupied by the Bodannon, Treore and Pendoggett antimony mines (Map 2) and from each of these areas Sb, Pb, As, Cu and Zn have been transported by man's activities and natural causes into the stream. On Map 7 the disposition of shafts and adits in the vicinity of the stream is indicated and their locations are reflected very well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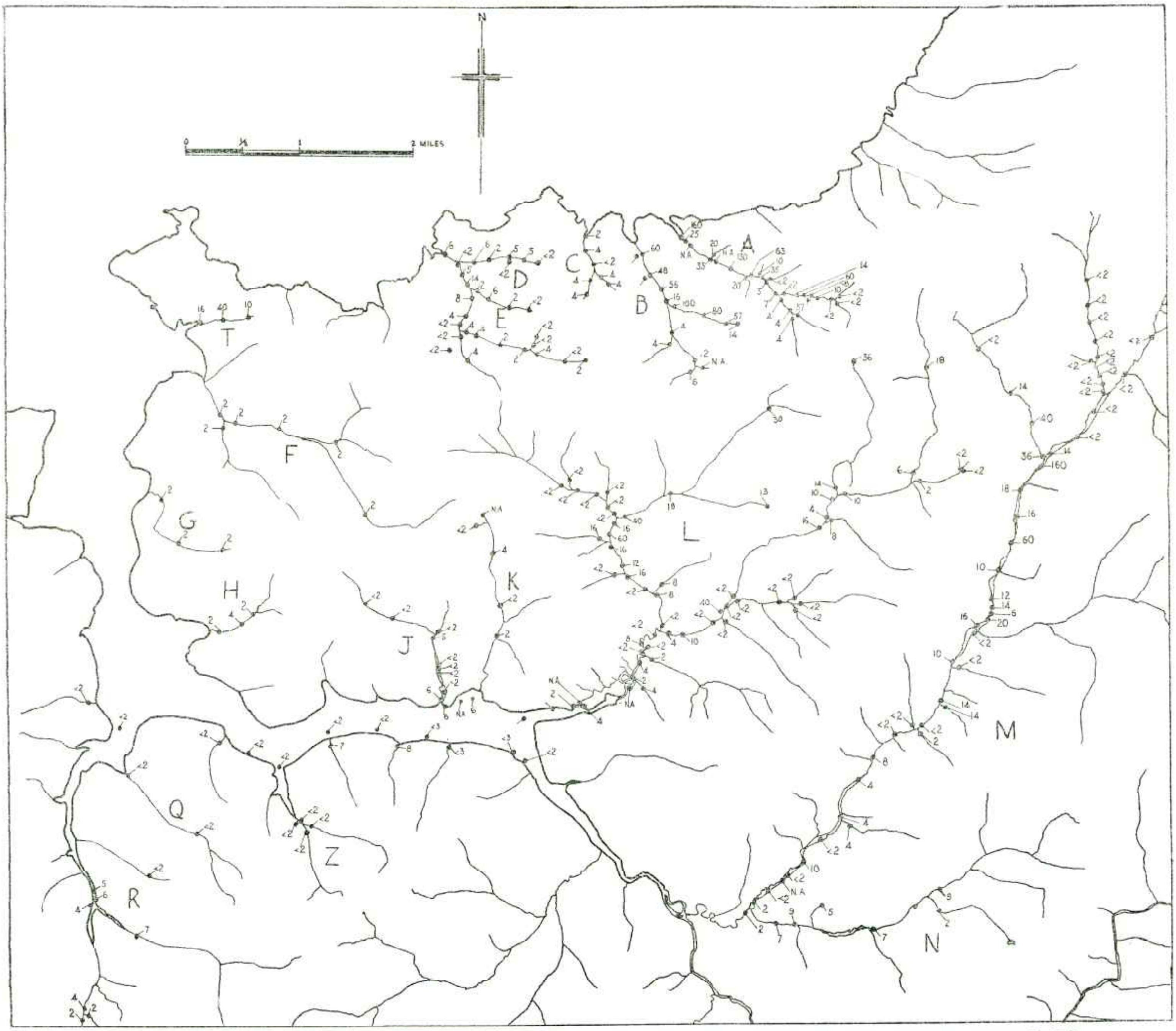
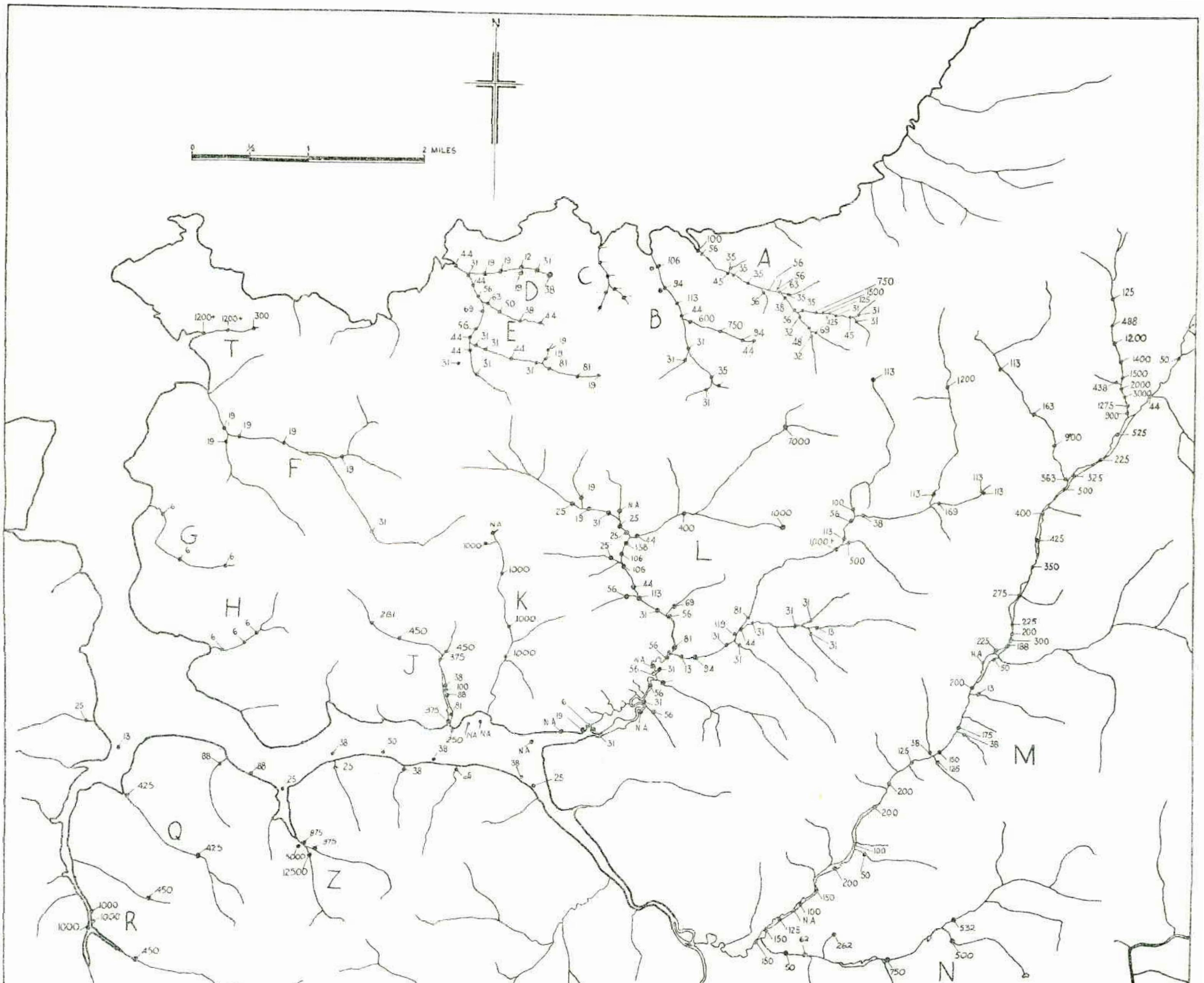
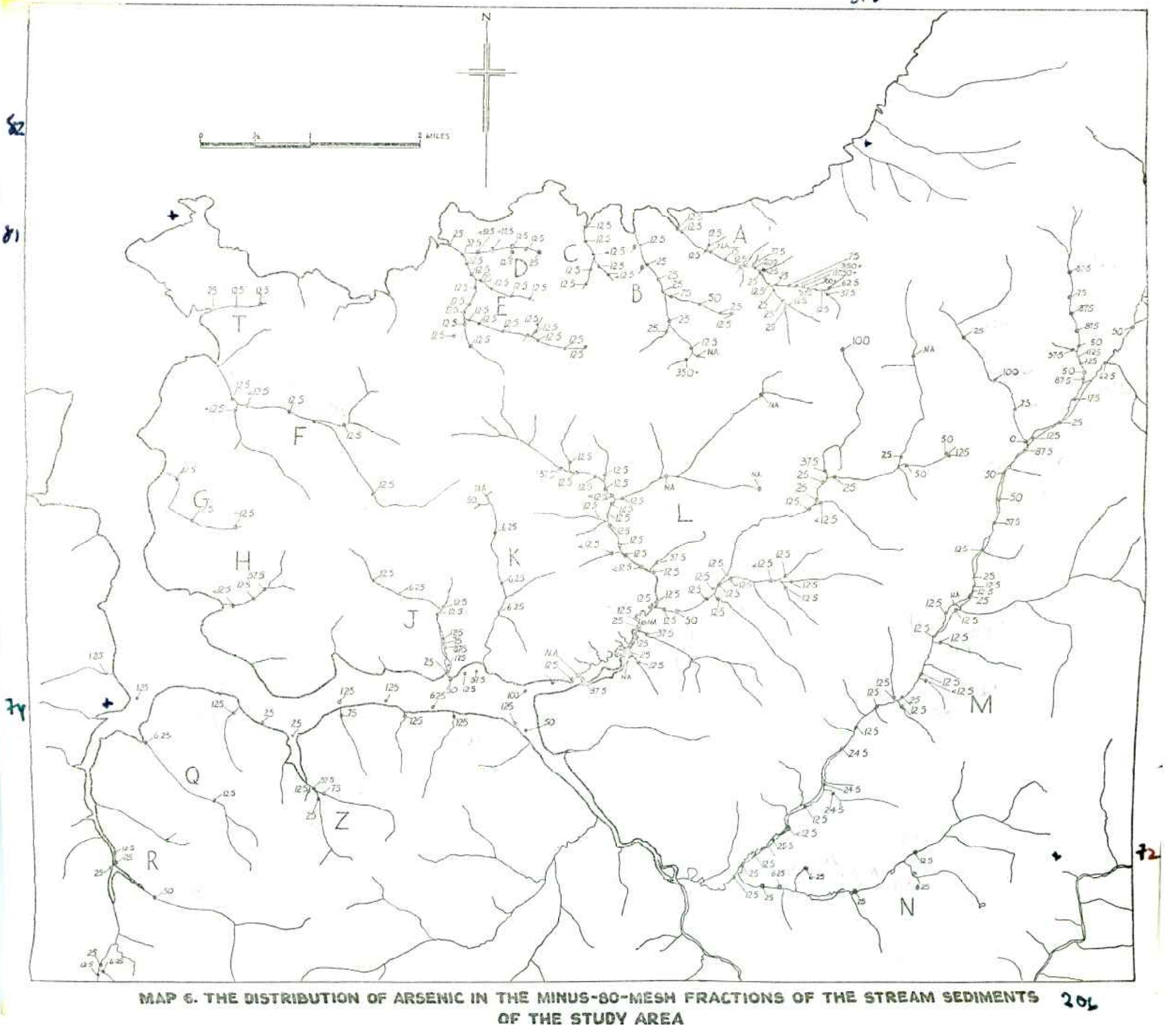


MAP 4. THE DISTRIBUTION OF ANTIMONY IN THE MINUS-80-MESH FRACTIONS OF THE STREAM SEDIMENTS



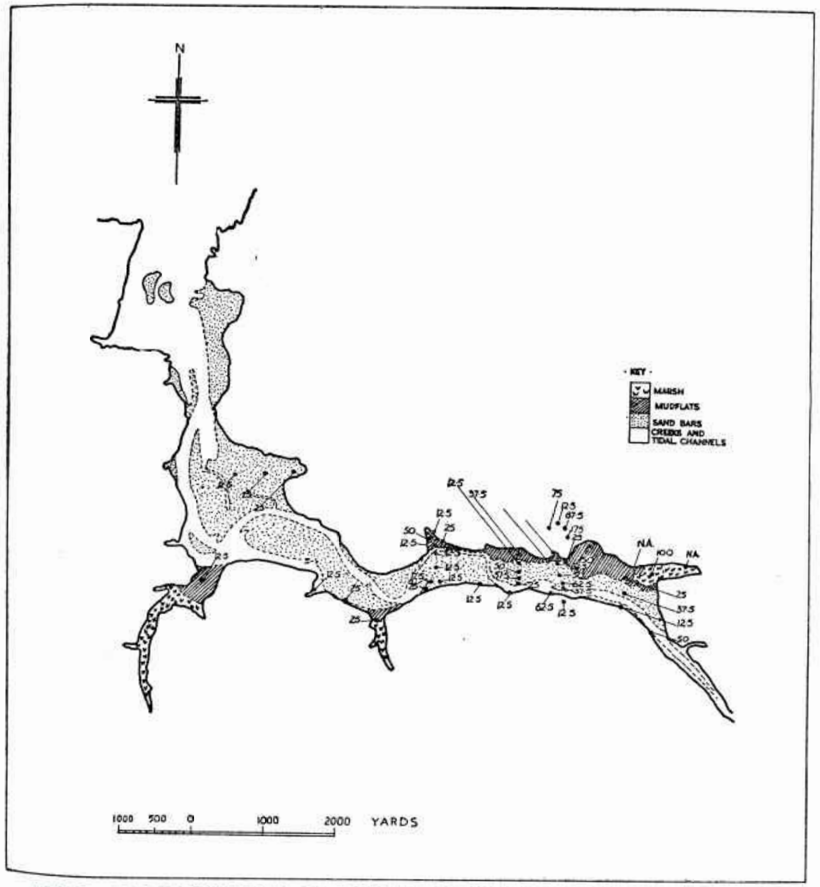
MAP 5. THE DISTRIBUTION OF LEAD IN THE MINUS-80-MESH FRACTIONS OF THE STREAM SEDIMENTS OF THE STUDY AREA



MAP 6. THE DISTRIBUTION OF ARSENIC IN THE MINUS-80-MESH FRACTIONS OF THE STREAM SEDIMENTS OF THE STUDY AREA

by the distribution of Sb, Pb, and As in the sediments along the stream profile. Cu and Zn indicate the mines in the upper reaches but give virtually no indication of the Bodannon adits in the middle portion, presumably because there is a deficiency of these elements in the Bodannon ore. The marked increase in the concentration of all the elements determined except As in the sample taken nearest the stream mouth may indicate the presence of a hitherto unknown deposit or may be due to an accumulation of fine material derived from the upper reaches.

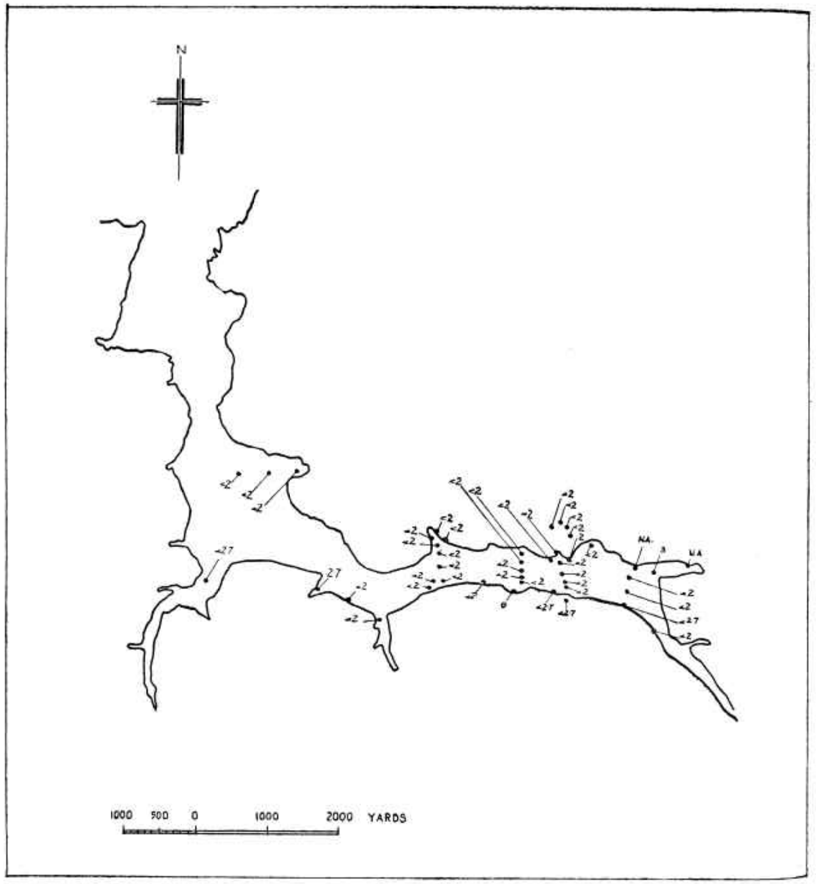
The Port Isaac (B) Stream — Here material derived from the Wheal Boys deposit has caused marked Pb, Sb, As, Zn and Cu anomalies to develop in the stream sediments. The maximum lead



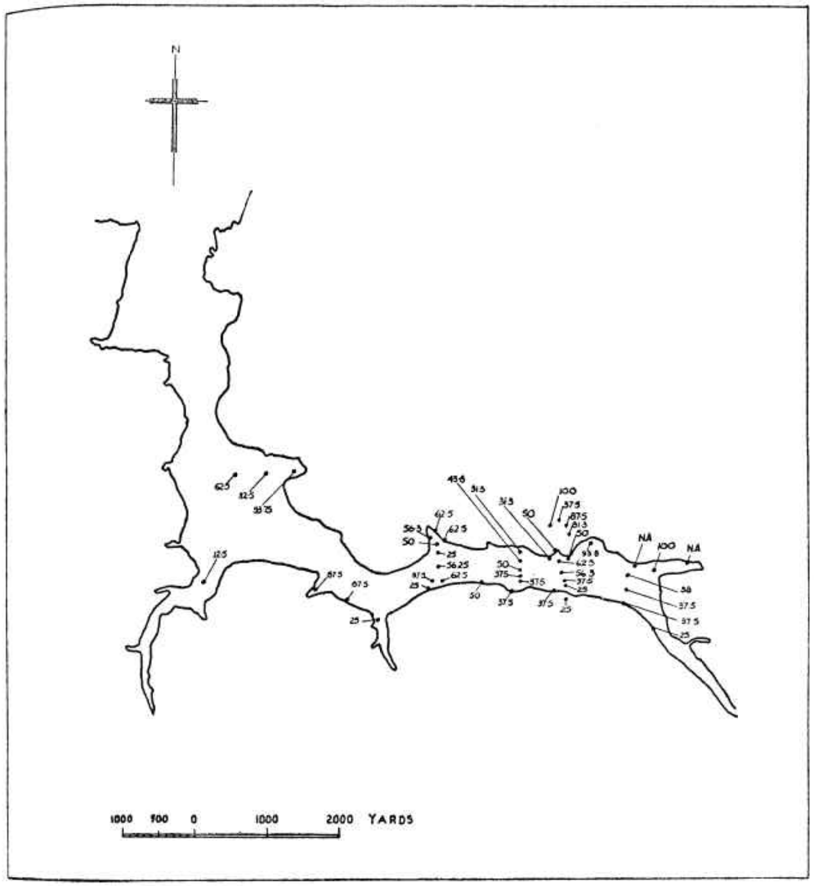
MAP 9. THE DISTRIBUTION OF ARSENIC IN THE MINUS-80-MESH FRACTIONS OF THE SEDIMENTS OF THE CAMEL ESTUARY

concentration occurs a little upstream of all the others. The reason for this is not clear : it may be because appreciable amounts of lead alone are still being added by natural processes to the stream : it may be because the lead-bearing fractions are denser than the rest and so less easily transported. The markedly similar Sb and Pb profiles suggest that these elements are moving together. This is to be expected when the parent is jamesonite, as oxidation produces the lead/antimony species bindheimite.

The high arsenic value in the most southerly sample suggests that there is a mineralised vein in the vicinity, whilst the presence of 50 p.p.m. copper in the most northerly sample also indicates that there may be slight mineralisation there.



MAP 10. THE DISTRIBUTION OF ANTIMONY IN THE MINUS-80-MESH FRACTIONS OF THE SEDIMENTS OF THE CAMEL ESTUARY

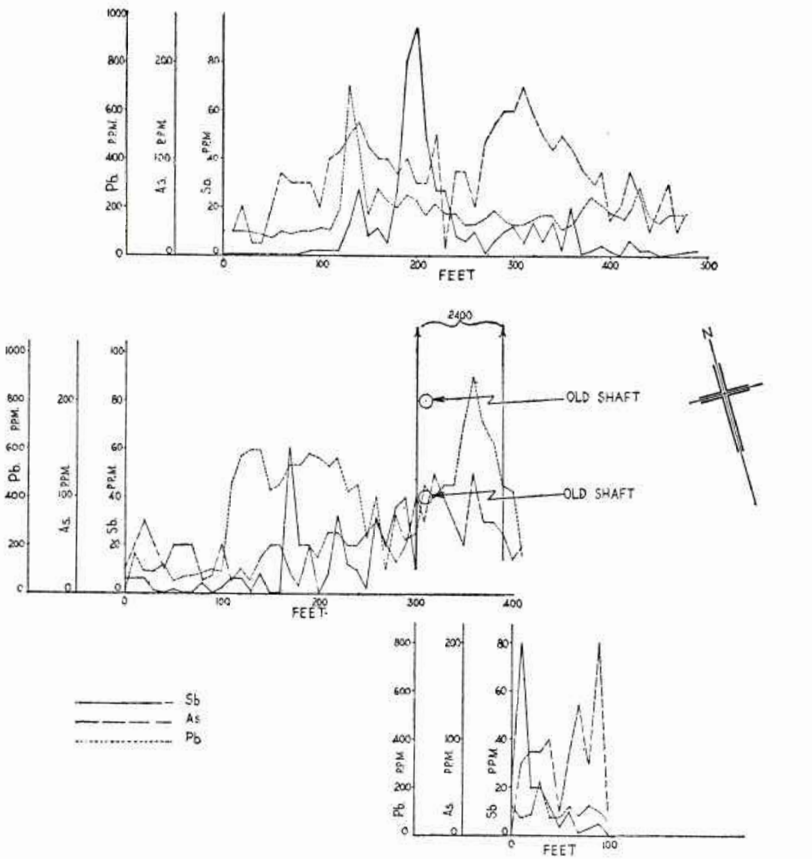


MAP 11. THE DISTRIBUTION OF LEAD IN THE MINUS-80-MESH FRACTIONS OF THE SEDIMENTS OF THE CAMEL ESTUARY

Antimony, etc., in the Estuarine Deposits. (Maps 9-11.)

In all the estuarine samples examined antimony never exceeds 3 p.p.m. and does not indicate, therefore, that the hinterland has an antimony potential. This is largely due to the fact that very small amounts of antimony report in the stream as a whole because the proportion of antimony in the lodes is usually not great and during mining the antimony ore was hand picked so that there were no mill losses.

On the other hand the concentrations of arsenic and lead in many of the samples are such that they clearly indicate that the hinterland contains deposits of these two elements. The arsenic is most concentrated in the muds, whilst lead appears in considerable concentrations in certain mud and sand samples. That lead is locally concentrated in the sands is probably due to the fact that there are a number of lead deposits close to the northern margin of the estuary, whilst the tendency for the highest lead concentrations to occur in the sediments fringing the northern margin suggests that the area to the north of the estuary is likely to have a greater lead potential than that immediately to the south of it.



MAP 12. THE DISTRIBUTION OF ANTIMONY, ARSENIC AND LEAD IN THE MINUS-80-MESH FRACTION OF SOIL FROM THE B HORIZON OVER THE ORE-BODIES OF TREVINNICK MINE

Antimony, etc., in Soils. (Map 12.)

The results obtained by analysing the minus 80-mesh (B.S.S.) fraction of samples of soil from the B horizon over the Trevinnick deposits are recorded on Map 12. They clearly indicate that both

lead and antimony deposits exist there and suggest that the latter becomes impoverished over a comparatively limited strike length. The remarkably high concentrations of lead suggest that this is the dominant metal of the area, whilst its distribution pattern indicates that the richest deposit lies considerably to the west of the shafts and has probably not been mined. The limited amount of work carried out at Trevinnick reveals that the soil background and threshold values of the elements under examination in the study area are approximately as indicated in the following table :—

Element	p.p.m.	
	Background	Threshold
Sb	2	40
Pb	50	200
As	12	50

Conclusions.

The work gives good reason for believing that no unknown mineralised areas of any consequence exist near any of the streams examined, but it indicates that geochemical soil surveys in the vicinity of known deposits might well reveal further lead and antimony lodes. It also gives added support to the view that studies of the metal content of estuarine deposits might be rewarding during the early phases of a regional geochemical survey of a little investigated difficult area because they might yield considerable information concerning the possible economic potential of the hinterland : particularly if the rivers feeding the estuaries were not very long.

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