

A Reconnaissance Survey of the Distribution of Tin, Copper, Zinc and Arsenic in the Sediments of the Rivers to the South of the St. Austell Granite Mass, Cornwall

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SYNOPSIS

THE minus-80-mesh (B.S.S.) fractions of c. 300 sediment samples, collected at intervals of generally not more than 0.5 mile from the streams and estuaries to the south of the St. Austell granite mass, have been analyzed for Sn, Cu, Zn and As by semiquantitative calorimetric means.

The plotted results reveal all known lode-mining areas intersected by the drainage systems and indicate the general nature of the mineralisation.

In addition, a metal-rich 'belt' has been delineated between the lode belt and the sea, and it is tentatively concluded that there the metals investigated occur not in lodes but as trace components of the slate.

Of the metals determined only arsenic permits certain differentiation to be made between samples from estuaries associated with rivers draining lode-mining areas and those from estuaries fed by rivers draining areas devoid of mines.

Finally, the study emphasises the importance of assessing the nature and degree of pollution of the sediments by past and present human activities if geochemical surveys of the type described are to be usefully applied in the search for ore in areas such as the one investigated.

Introduction.

The work described in this paper was the outcome of one of the exercises undertaken by final-year and post-graduate students of the Camborne School of Mines, under the direction of one of us (K.F.G.H.) during the 1965 Prospecting Camp which was held in the St. Austell area of Mid-Cornwall.

The study, which included collection of samples, analyses of the material collected in a temporary laboratory, and plotting of the results, occupied five days.

The prime object of the work was to give students practice in the organisation and running of a sizeable applied geochemical

survey and in the relevant field and laboratory procedures. It also aimed at establishing to what extent the distribution patterns of certain metals in the stream sediments of the area reflected the presence of known lodes and indicated the existence of hitherto unknown mineral deposits. In addition, it was hoped that the results might reveal to what degree extensive stream pollution, such as is due to china clay mining and to other causes, militated against the successful employment of geochemical methods involving the analyses of stream sediments in the search for ore deposits. Finally, it was expected that the study might contribute somewhat to the question as to what extent the trace element content of estuarine sediments reliably reflected the geologic nature of the hinterland.

Previous Geochemical Studies in the Area.

Previous geochemical studies in the area have been of a limited nature. Ostle's (1954) pioneer work deserves special mention. He, by determining the uranium content of water samples taken at various points on the River Fal (River 1 on maps 2-6) established that there was a marked increase in this element in samples taken immediately below the point where the river intersected the South Terras uranium lode and associated mine workings, and that the uranium contents of the waters of this river were markedly anomalous, at least as far as the estuarine tract which commences near Ruan Lanihorne.

Hosking (1959) by analyzing the finer fractions of samples of grass-covered pebbly alluvium overlying the South Terras lode, showed that the presence of the latter was indicated by anomalous concentrations of copper and arsenic but not of uranium, and he concluded that in such an acid environment any uranium which was liberated from the lode for the most part migrated in solution along the bed-rock surface into the adjacent river.

Field and Laboratory Work.

Samples were collected from the middle of streams at intervals generally not greater than half a mile, and from the mud and sand banks fringing the estuaries. These were stored in resin-impregnated envelopes and transported to the field laboratory where their cold-extractable copper was determined before they were dried, etc., by the usual dithizone method. (For reasons of convenience these determinations were not made, as is usual, at the spots where the samples were collected.)

The samples were then dried in aluminium trays over Calor gas stoves and screened through nylon 80-mesh (B.S.S.) screens. The minus-80-mesh fractions were used for the subsequent analyses.

Tin was determined by the modified gallein method (Stanton and MacDonald, 1961-62), copper and zinc by dithizone methods,

having first fused the samples with bisulphate, and arsenic by the modified Gutzeit method (Hy Almond, 1953).

The plotted results appear on maps 2-6.

General Geology of the Region. (Map 1.)

Considerable uncertainty still exists concerning the stratigraphy and structure of the study area, but basically the region consists of Devonian, essentially non-calcareous, rudaceous, arenaceous and argillaceous sediments which are highly folded and faulted and which locally contain basic effusive and intrusive masses of pre-granite age. In Permo-Carboniferous times the South-West was invaded by a granitic magma which consolidated as an circuate batholith with a corrugated surface and which extends from Dartmoor to the Scilly Isles. Many of the high spots on this batholith were uncovered by the end of the Mesozoic, and the St. Austell granite mass, which is one of these, is the source of several of the streams investigated during the study under discussion.

The batholith, which possesses a complex developmental history which is only now beginning to be unravelled, thermally and chemically metamorphosed the invaded rocks adjacent to it.

Generally following the emplacement of the batholith, granitic dykes (the elvans) were developed, probably more-or-less parallel to ridges on the surface of the major intrusive.

Precisely when the first of the ore-deposits was formed in mid-Cornwall is uncertain, but at Castle-an-Dinas, immediately to the north of the St. Austell granite mass, the wolframite/loellingite/quartz lode clearly pre-dates the granite tongue with which it is closely spatially related. Certain other hypothermal lodes of the region, which possess the anomalous N.-S. strike of the Castle lode, may also be early-developed bodies.

Greisen-bordered cassiterite/wolframite veins are, in Cornwall, characteristic of the apices of well-developed granite cusps, though in some instances such cusps have been severely modified by erosion. These vein swarms probably developed early from residual agents which collected within each cusp as it crystallised, and they probably pre-date the large hypothermal lodes, which are often structurally complex, and flank granitic ridges, particularly in the vicinity of cusps. These complex lodes probably developed from large 'pools' of residuum which collected beneath the cusps as the body of the batholith was consolidating.

Typical greisen-bordered veins occur at the Bunny and Beam Mines in the granite, well inside the contact, whilst complex hypothermal lodes are much in evidence in the mineralised belt which lies for the most part to the south of the St. Austell granite and which is also largely confined to the sedimentary rocks *outside* the metamorphic aureole.

However, even the complex hypothermal lodes may vary considerably in age as there is some evidence that at Polgooth Mine certain of the lodes are older than some of the associated elvans (Collins, 1912, p.235).

The greisen-bordered veins consist essentially of varying amounts of cassiterite, wolframite, arsenopyrite, quartz, secondary micas, tourmaline and topaz, whilst the complex hypothermal lodes contain, in the main, varying amounts of cassiterite, pyrite, copper-bearing sulphides and high-temperature sphalerite, together with quartz, tourmaline, chlorite and hematite.

The hypothermal phase was followed by a period, or possibly more than one period, during which lodes containing mesothermal species, such as pitchblende, cobalt-bearing sulphides and sulpharsenides, siderite and galena were formed. These bodies commonly, but not invariably, possess strikes which differ by about 90 degrees from those of neighbouring hypothermal lodes.

Some degree of primary zoning is apparent in the study area in that locally lodes which are copper-bearing near the surface become predominantly tin-bearing at depth, and lodes within the granite are essentially tin and tungsten bearing — a fact which in part might be explained by assuming that originally overlying sulphide zones had occurred there but they have since been eliminated by processes of erosion.

Throughout the Mesozoic the area was land, but in Pliocene times marked submergence occurred so that only an archipelago of essentially granitic islands, fringed with sands, that locally must have been markedly stanniferous, remained. Emergence in stages followed and continued into Quaternary and Recent times causing the generation of a series of marine platforms, of which the so-called 400 ft. one is the most prominent, and eventually elevating the land some 40 ft. above that which it stands at present. Finally the land was depressed about 30 feet.

These elevations caused the rivers to excavate their channels rapidly and to effectively concentrate near the bedrock any cassiterite which had been liberated from intersected lodes or which had been carried into the drainage systems as a component of the periglacial solifluction product, known as Head of Rubble, during interglacial and immediate post-glacial times. The final depression resulted in marine invasion of the peat and forest covered lower reaches of the river and the deposition of estuarine and marine sediments over these organic beds so that any alluvial cassiterite occurring there, as at Pentewan, could only be exploited by removing some twenty to thirty feet of overburden. In consequence, also, of the nature of the comparatively recent geologic events, the valleys are steep sided and comparatively immature, a fact which locally militates against the easy collection of sediment samples.

In order to adequately assess the geochemical analytical results a few further brief comments need to be made about the Devonian sedimentary rocks and the Permo-Carboniferous granite.

The distribution of some of the major lithologic sedimentary units may be important: of particular note is a large tongue of essentially argillaceous sediments, which points eastward, and whose northern boundary strikes c. E.-W. whilst its southern one is c. N.E.-S.W. (parallel to the local coast line) and which is fringed by sediments which are essentially arenaceous and rudaceous in character.

The St. Austell granite mass, which has been recently described in some detail by Exley (1959) probably consists of two intrusions. The earlier, which occupies the eastern third, is a porphyritic biotite muscovite granite, whilst the later, due to magmatic differentiation, consists of early porphyritic lithionite granite which is separated in the area to the south of St. Dennis by a belt of non-porphyritic lithionite granite enclosing a comparatively small area of fluorite granite which was the latest differentiate to crystallise.

According to Exley (op. cit., p.225) all the granites were locally subject to tourmalinisation and greisenizing before the development of fissures, and subsequent to the formation of the latter further tourmalinisation and marked kaolinisation occurred. Kaolinisation was confined essentially to the later intrusive and was more or less limited to albite, potash feldspar having previously been largely converted to quartz and secondary mica.

Sources of Sediment Contamination.

It is well known that effluents from domestic and industrial sources may effect marked pollution of rivers. The effluents from domestic sources in any given region are unlikely to vary markedly, from a qualitative point of view, from one area to another. In Britain they may contain considerable concentrations of ionic copper and zinc, (derived from taps and other domestic appliances composed of these elements) which are in part in solution and in part adsorbed on colloids. In addition, considerable copper and other metals occur in raw sewage as organo-metallic complexes which have been eliminated by man (and animals) in excreta and urine. Some idea of the concentrations of certain metals which may occur in urine and tap water may be obtained from the following table which is extracted from certain unpublished studies of one of us (K.H.) concerning the possible relationship between heavy metals and certain diseases. (It is relevant to note subject A is suffering from multiple sclerosis.)

The Zn/Cu/Pb Content of the first Tap Water drawn in the morning in a Camborne house and of the first Voided Urine of two of its Occupants.

	Zn		Cu		Pb	
	Concentration in $\mu\text{g/litre}$	Absolute amount voided (in μg)	Concentration in $\mu\text{g/litre}$	Absolute amount voided (in μg)	Concentration in $\mu\text{g/litre}$	Absolute amount voided (in μg)
Subject A	1,500	234	1.5	0.2	54.0	8.4
Subject B	266	133	10.0	5.0	9.0	4.5
Tap Water	86.0	—	12.5	—	10.0	—

The nature of industrial effluent entering the rivers may vary markedly from region to region and from area to area within a given region. In the study area, for example, some of the streams receive considerable quantities of solids from the clay recovery plants whilst others are fed by liquids and solids charged with heavy metals and derived from debris, etc., round and about abandoned tin, copper, uranium, etc., mines. This subject will be returned to later.

The distribution patterns of domestic- and industrial-derived 'effluent metals' in the natural drainage system of a given region, such as the one under review, is likely to be quite complex and to depend on many factors such as the location of adit and sewage outlets, the disposition of mine dumps, the nature of the ore in the mines, the time of the year, etc.

In order to appreciate the pollution problem fully from the point of view of the geochemical explorationist working in the area to the south of the St. Austell mass it is necessary to consider, in further detail, not only the nature, etc., of the pollution due to the clay and mining industries but also the characteristics of pollution which may be caused as a result of farming and of activities associated with the maintenance of boats in the estuaries.

Certain of the rivers in the area are white due to their heavy load of china clay which has been lost during the beneficiation of this material in the vicinity of the southern contact of the St. Austell granite. These dispersion trains extend along the entire lengths of the affected rivers and beyond into the estuaries or into the sea. In the estuarine tract of the River Fal (River 1 on the maps), near Ruan Lanihorne, for example, not only is the river milky, but the saltings, including the vegetation on them, are also coated with clay which is deposited during periods of spring tide. In such an environment marked deposition of clay occurs, particularly in the distributary channels, due to flocculation, whilst other coarser particles settle

due to marked deceleration. The washing of the mud banks by rising and falling tides also effects concentration of the denser components by an operation akin to wet tabling processes used in a mill. Such dense components may be in part derived from lodes and mine dumps transected by the rivers but it is likely that a certain amount of extremely fine cassiterite might also be a component of the material lost by the china clay companies: certainly minute crystals of cassiterite can occur, for example, along cleavage planes of secondary micas. Tourmaline, also, is likely to be transported from the china clay centres and to be concentrated in the estuaries, and this is of some relevance to the applied geochemist as it may also contain appreciable concentrations of tin within its lattice.

It must also be appreciated that where a clay-bearing stream is locally decelerated clay is likely to be deposited and so blanket local sediments derived from, say, a lode intersected by the river. Thus, it seems likely that the analyses of active, superficial sediments collected from such sources might not reveal the presence of a nearby orebody. However, should the orebody liberate, via natural or man-made channels, metal-charged water into the stream, it seems possible that the clay might facilitate the establishment of a metal dispersion train in the superficial sediments by virtue of the fact that its colloidal components might rapidly and effectively strip the feed water of its metals by adsorption. The validity of these arguments will be returned to when the analytical results are discussed.

The nature and degree of stream pollution by metal mining activities is dependent on many factors. It will depend on the nature of the ore mined as this will govern the nature of the tailings which passed into the streams, the character of the waste dumps and the metal content of the adit waters, which in the present as well as during the time when the mines were operating, continue to contribute metals to the drainage systems. The shape and size of the mine dumps, the nature of their components, their disposition with respect to the rivers, and sewage, all determine to what extent they contribute 'heavy metals' at the present to the natural drainage. Certain rivers not directly associated with mines may, nevertheless, be polluted by mineral matter because, in the past, small mills and smelters, to treat transported ore, were on occasion erected in valleys where, for example, there happened to be an abundance of clear water: today there may be little or no obvious indication, on the ground, of their former presence.

In the past many of the stream beds were pitted in the search for alluvial cassiterite and where the search was successful intensive mining completely disarranged the natural sequence of the unconsolidated sediments. However, as the recovery methods were far from efficient considerable cassiterite excavated from just above bed-rock was eventually lost to the superficial deposits of the streams, and probably the richer the deposit the greater the loss. Hence the location of buried but once worked stanniferous placers may be

revealed during a study of the type described in this paper. It is perhaps relevant to note that in the area in question the most famous alluvial workings occurred at Pentewan and that certain rivers, as for example that draining the Polgooth district, have, in more recent times, been the centres of streaming operations aimed not at recovering natural alluvial cassiterite, but that which had been lost to the rivers as tailings from the mines.

In the estuaries of the Fal and St. Mawes (rivers 1 and 3 respectively) it is likely that the sediments may become contaminated with certain metals as a result of activities associated with boats. Considerable copper contamination, in particular, might accrue from the common practise of painting the undersides of vessels with copper-containing anti-fouling paint. Barnacles, etc., attaching themselves to surfaces covered with such paint gradually assimilate a toxic amount of copper and become detached. Obviously the copper in anti-fouling paint is not readily removed by sea-water and this is a fact of some importance when considering the occurrence of this metal in estuarine sediments.

Although farming activities can promote stream pollution, as a result of the local addition of farm-yard waste products and the transference of artificial fertilizers and fungicides (e.g. Bordeaux Mixture) to the valleys by wind and water, it is thought that these are not of major importance in the area in question.

DISCUSSION OF THE ANALYTICAL RESULTS (Maps 2-6.)

When maps 2-6 are considered the following facts concerning the distribution patterns of the various elements emerge:—

1. **Copper** (Maps 2 and 3).
 - a. **Cold-extractable** (or "On-the-spot" copper).

The area is characterised by comparatively few locations where the sediments contain distinctly anomalous concentrations of cold-extractable copper; they are, in fact, limited to rivers 1, 2, 3, 10 and 11. Those in the upper reaches of rivers 1 and 10 can be related to the presence of copper-bearing lodes.

The slightly anomalous values associated with the middle and lower reaches of river 10 cannot be entirely due to the presence of a copper-bearing lode near the source of the main channel as many of the high results occur on tributary streams. The cause of these anomalous values and of the isolated one on river 11 is unknown, but perusal of the other metal maps will show that this middle belt contains distinctly anomalous concentrations of the other elements studied and so the patterns may *not* be due to pollution, but to the presence of local sediments which are richer than their neighbours

in certain trace elements, or to the occurrence of mineralised veins perhaps associated with a buried granite ridge striking approximately parallel to the southern margin of the St. Austell granite. Of the two possible natural causes of the anomalies the writers prefer the former as work on the slates of Mid and West Cornwall by one of us (Hosking. Unpublished Studies.) has demonstrated that even in lode-barren areas they are remarkably rich in the elements of present interest.

The occurrence of slightly anomalous concentrations of cold-extractable copper in the essentially estuarine tracts of rivers 1, 2 and 3 may be largely due to the flocculation of colloidal material with adsorbed copper which has been derived largely from sewage but possibly in part from the remains of creatures which had been in contact with anti-fouling paint.

b. Total Copper.

Marked dispersion trains occur in rivers, 1, 10, and 15 which can be related to copper-bearing lodes and to mining operations on these ore-bodies. However, in the N.E.-S.W.-trending central belt of the region the tributaries of rivers 1 and 10, and rivers 5, 8, 9, 11, 12 and 13 locally contain distinctly anomalous, though not exceedingly high, concentrations of total copper. In the writers' view these probably reflect the presence of the comparatively metal-rich slate tongue to which attention was drawn earlier.

The presence of appreciable concentrations in the estuarine deposits of river 1 might be interpreted as being due essentially to primary and secondary, comparatively insoluble copper species derived from mine tailings and which have been reconcentrated on the mud banks by gravity-processes, were it not for the fact that the estuary of river 3, which, so far as is known, drains a lode-barren area, also contains distinctly anomalous concentrations of the element in question. It seems reasonable to conclude therefore that the total copper, which is largely in a form not extractable by comparatively innocuous reagents, has been primarily derived from anti-fouling paint and sewage. It is probable that the copper from the former source is largely firmly fixed in organic complexes within the remains of barnacles and other creatures which tend to attach themselves to bottoms of boats, whilst that from the latter source, which was probably initially adsorbed, and so loosely held, on colloids, has, by ageing processes, been incorporated into comparatively insoluble products of unknown composition. (In the latter connection it may be added that it is well known that as stream and other sediments dry the amount of readily extractable copper in them decreases.)

2. Zinc. (Map 4.)

As in the case of total copper, zinc dispersion trains occur in the upper reaches of certain rivers (particularly 1, 10, 13 and 15)

which can be directly related to zinc-bearing lodes and mining activities. Also, as in the case of copper, these trains are largely due to losses sustained during mineral beneficiation and reflect the presence of grains of sulphide (which are far more stable in the active sediment zones of drainage systems than is generally appreciated). In addition, the concentration of zinc in the tributaries of rivers 1 and 10, and in rivers 5-9 and 11-13, reflects the presence of the N.E.-S.W.-trending metal-high belt noted earlier.

The lack of a marked concentration of zinc in the estuaries of rivers 1 and 3 is worthy of comment and confirms the observation of one of us (Hosking. Unpublished Studies.) which was based on work on the distribution of trace metals in the sediments of the Helford, Hayle and Gannel estuaries, that zinc is much less prone to concentrate in such an environment than copper, and when concentration does occur it reaches a maximum to the seaward of the copper-rich zone.

3. Arsenic. (Map 5.)

Arsenic dispersion trains occur in rivers 1 and 10 which can be related to known arsenic-bearing lodes and to mining activities associated with these, and it is probable that most of this arsenic occurs as arsenopyrite which was lost during milling operations.

The remarkably high concentration of arsenic in the lower reaches of the valley of rivers 13 and 14 (i.e. in the Pentewan area) may be in part due to arsenic brought to the surface during the working of the true stanniferous alluvials there, but it is probably largely caused by the accumulation of arsenical tailings which were produced during comparatively recent streaming operations in the valley in the general vicinity of Polgooth Mine.

The occasional sample containing a slightly anomalous concentration of arsenic which was collected from the tributaries of streams 1 and 10, and from streams 5, 6 and 12, again points to the presence of the already repeatedly referred to mineralised 'central' belt.

It is of some considerable interest to note that arsenic has concentrated in the estuarine deposits associated with river 1 but not in those associated with river 3. There is little doubt that the arsenic which has accumulated in the estuarine deposits is material lost during milling operations in the upper stretches of the river and in all probability much of it was transported as the comparatively dense arsenopyrite and concentrated on the mud banks by natural gravity processes akin to tabling. Although some of the arsenopyrite may have oxidised to iron arsenate such as scorodite, as reducing conditions prevail almost immediately below the surfaces of many of the mud banks it is probable that most of the sulpharsenide has not been so altered. In this area arsenic is the only element studied which clearly differentiates between the estuary which is associated

with a river draining a known lode area and that which is associated with a river draining an area which, from all the available evidence, is barren of lodes. Whether this differentiation could be made had no mining taken place and had no tailings been added to river 1, is uncertain. However, as arsenates are, as a group, insoluble compounds and reasonably dense it is possible that those liberated from lodes by natural processes would be eventually concentrated in the estuaries. Quantitatively, the arsenic concentrated in a comparatively short span of time, equal to that between the period of active mining and the present, is certain to be small by comparison with that due indirectly to mining, and so the difference in the arsenic content between the estuarine deposits of rivers 1 and 3 would, without the intervention of man, have been far more subtle than it is — perhaps not detectable with any degree of certainty.

4. Tin. (Map 6.)

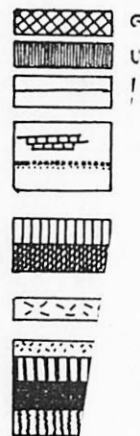
At the outset it must be said that distinctly anomalous concentrations of tin are so common in the sediments of all the rivers of the area that the metal distribution pattern is exceedingly difficult to interpret with any degree of certainty. The first reaction is to doubt the validity of the analyses but this can be set aside as numerous blank and check samples were interspersed with the unknowns during the work.

The high concentrations, particularly in the upper reaches of rivers 1, 10, 13 and 14 offer no difficulty: they reflect the presence of known tin lodes and of associated mining and milling operations. The tin in these sediments is largely in the form of cassiterite.

The high tin content in the lower reaches of rivers 13 and 14 may be in part due to cassiterite lost during true alluvial operations there but in all probability is largely the result of losses sustained during the much more recent up-valley streaming operations referred to earlier.

The concentration of tin in those main and tributary streams which do not drain known lode areas again suggests the presence of a metal-high central belt which broadly coincides with the slate tongue referred to earlier; and the wide dispersion of tin-high sample points suggests that the metal in question was derived from the slate rather than from discrete lodes or veins. This leads to many interesting speculations, not least is that concerning the origin of the tin and other metals in the known lodes of the region. Could these metals have been obtained from granitisation, in depth, of slate of the type discussed above?

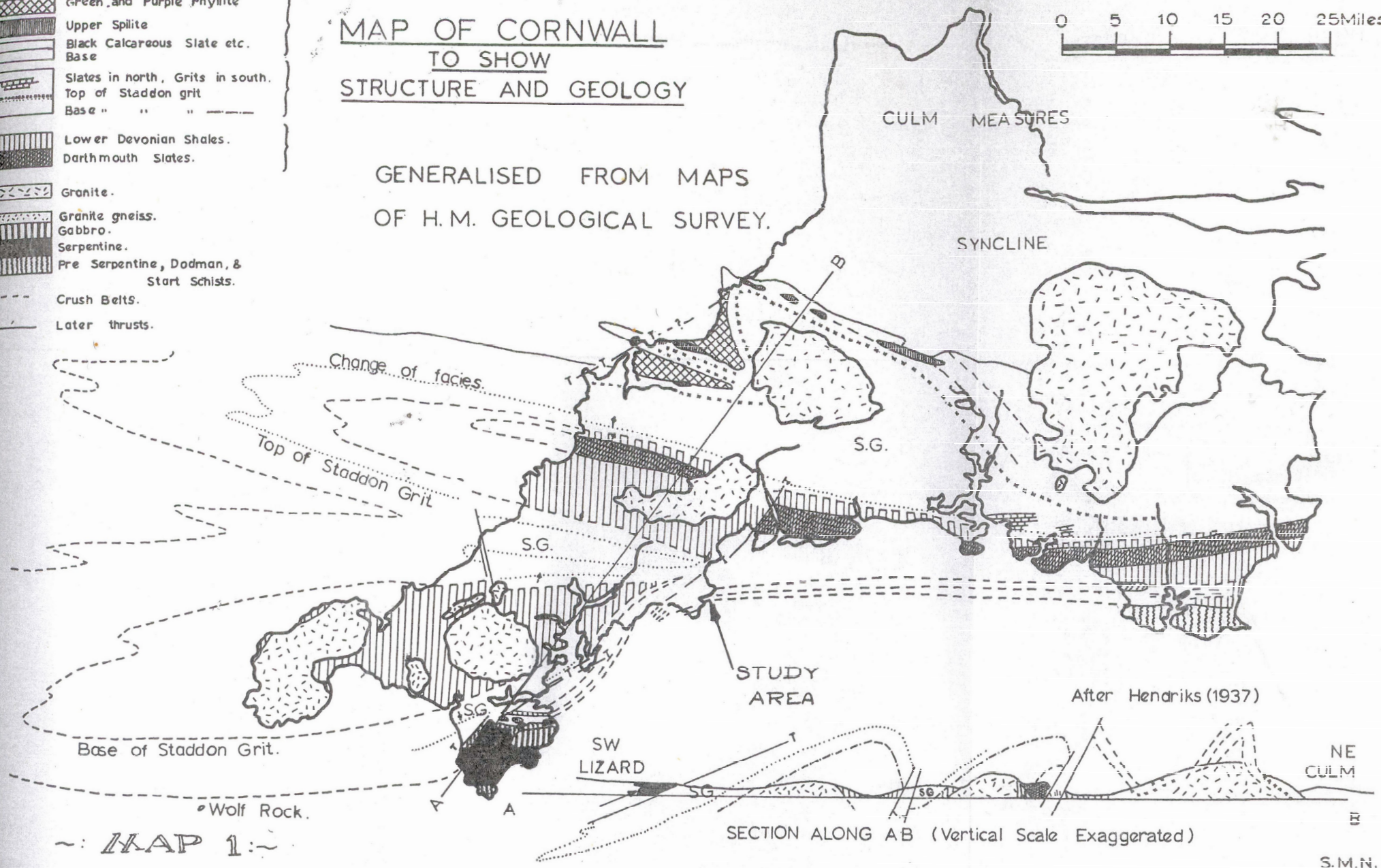
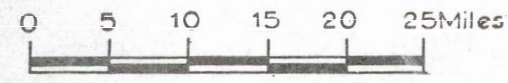
The high tin content of the sediments of the most southerly of the tributaries entering river 1 from the West is worthy of comment: it may be due to the presence, in the past, of a mill or smelter erected to treat ore transported to it, but this is at present unknown.



-  Green and Purple Phyllite
-  Upper Spilitic
-  Black Calcareous Slate etc. Base
-  Slates in north, Grits in south. Top of Staddon grit
-  Base " " "
-  Lower Devonian Shales. Dartmouth Slates.
-  Granite.
-  Granite gneiss. Gabbro. Serpentine. Pre Serpentine, Dodman, & Start Schists.
-  Crush Belts.
-  Later thrusts.

MAP OF CORNWALL TO SHOW STRUCTURE AND GEOLOGY

GENERALISED FROM MAPS
OF H. M. GEOLOGICAL SURVEY.



MAP 1:-

The concentration of tin in the mud banks of estuary 1 is about twice that found in similar situations in estuary 3, and is, doubtless, due to the mining activities which were carried out in the valley of river 1. However, the surprising fact is not that samples from the former contain the higher concentrations but that they do not contain concentrations many times higher than those of the latter.

THE EFFECT OF CHINA CLAY IN CERTAIN RIVERS

In the previous sections devoted to an interpretation of the metal distribution patterns no mention has been made of the possible modifying effects occasioned by the presence of appreciable quantities of china clay in certain of the rivers (see footnote). The reason for this is that thought it was thought that the presence of clay might have far-reaching effects, in fact, it seems that this is not so. Although the clay must locally strongly dilute sediments derived from other sources it has not obscured the dispersion trains of the metals examined and so has not prevented the presence of known mineralised areas from being revealed by analysis of the stream sediments. This is probably due to marked mixing of local sediments and the clay as a result of turbulence in the fairly shallow rivers which, particularly during the wetter seasons of the year, are fairly fast flowing.

Although it was thought that the clay might strongly adsorb both copper and zinc there is very little evidence in support of this. In fact, had strong adsorption occurred, much higher concentrations of cold extractable copper would be expected in the china clay-rich upper reaches of the estuarine tracts of river 1 than do, in fact, occur, and the zinc content, at least of the seaward extensions of these deposits, would be expected to be appreciable.

Conclusions.

The results of the reconnaissance study recorded in this paper serve to emphasise the fact that geochemical anomalies are all too frequent and that the main task in all such work is to discover the reasons for each one. Particularly in an old mining area such as the one under review, all anomalies cannot be satisfactorily explained without an intimate knowledge of its geography and history, and without a detailed knowledge of the local industries.

Were this area to be subject to a further search for ore deposits then, in order to make full use of the geochemical data at present available, records, old newspapers, etc., would have to be examined for information relating to past streaming activities and the location

FOOTNOTE : Clay contaminated rivers are indicated on map 2.

of mills. Information would have to be sought from the clay processing groups for details of any metal-containing chemicals which they might employ, and the extent to which farmers use copper-containing fungicides in fields adjacent to streams would locally need to be investigated. Streams, not draining known lode areas whose sediments contain high concentrations of tin would have to be searched for the presence of old mills and early smelters. Finally, the possibility of lodes existing in the vicinity of carefully chosen portions of rivers would need to be tested, in the first instance, by geochemical soil surveys.

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Congratulations

WE congratulate Dr. Edward K. E. Williams of the Mineral Engineering Department of the Henry Krumb School of Mines at Columbia University on the award of his D.Sc. in Engineering on June 11. His thesis was entitled "Rate Determining Mechanisms in the Flotation of Very Fine Hematite with Oleic Acid and Mineral Oil".

He obtained his M.Sc. degree for a thesis entitled "Some Hydrodynamic Aspects of Flotation Conditioning and Scale-up Correlation", and intends to do further research on a flotation process for fine diamond separation.

Report on the Use of a Raise Climber at Bralorne Pioneer Mines Limited, British Columbia, Canada

G. R. GRIFFITH

THE purpose of this paper is not just to give the technical facts about raise climbers but to show how the different makes of machine compare with each other and with conventional methods, and how and why the management at Bralorne reached their decision to use one.

Raise climbers were first introduced into Canada in 1959. An Alimak machine was used at Levack (Falconbridge Nickel Mines, Ontario) and the Joy Craig Raise Machine was also first used in this year.

Bralorne Pioneer Mines Limited became interested in raise climbers as soon as they were introduced, and their file on the subject contains articles and memoranda dating back to June, 1959.

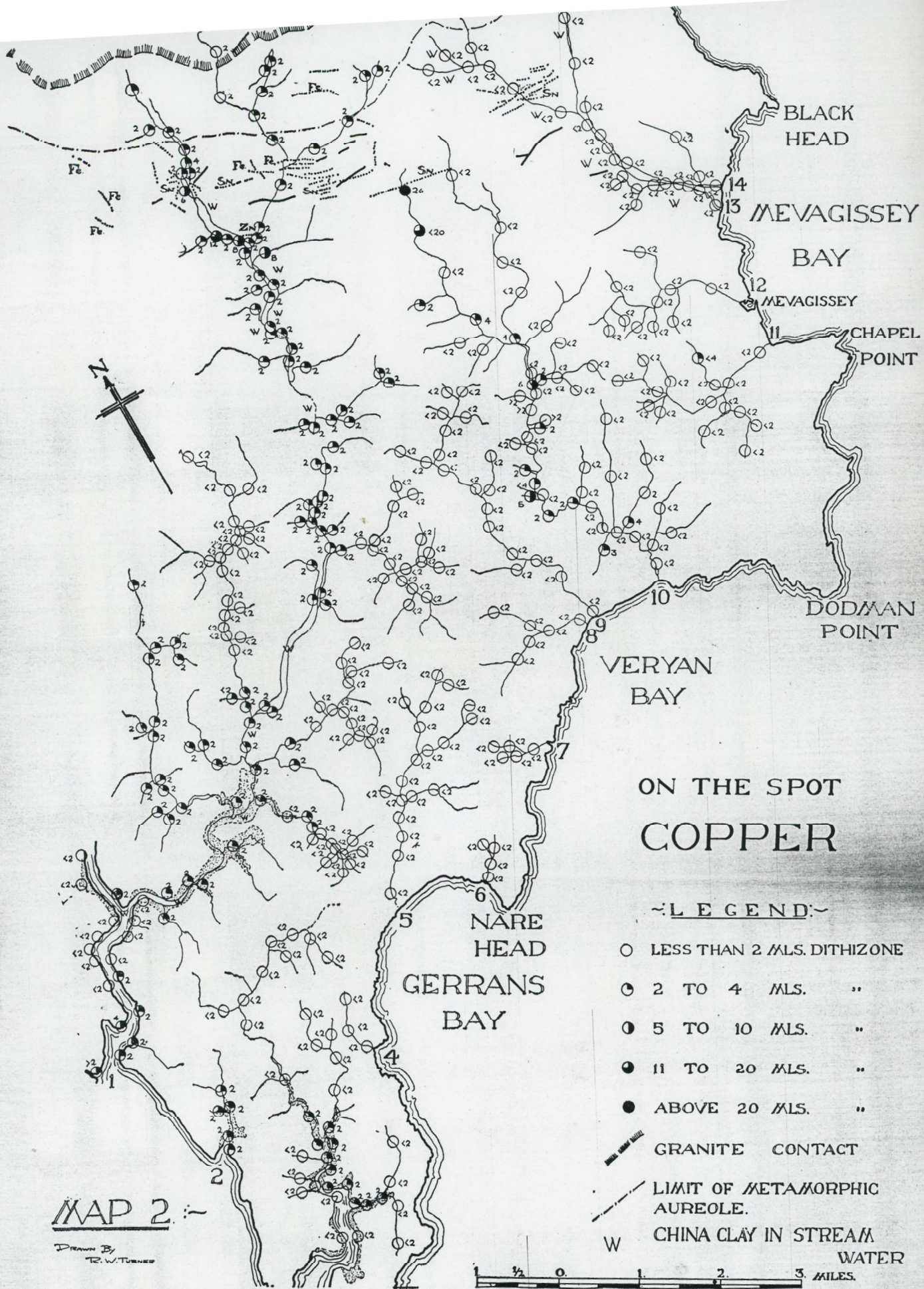
After some discussion between the engineers, the Superintendent and the Manager, The Mine Equipment Company of Canada was asked for, and supplied, a proposal for an Alimak Raise Climber for driving a raise at some angle greater than 65° to a height of 165 feet.

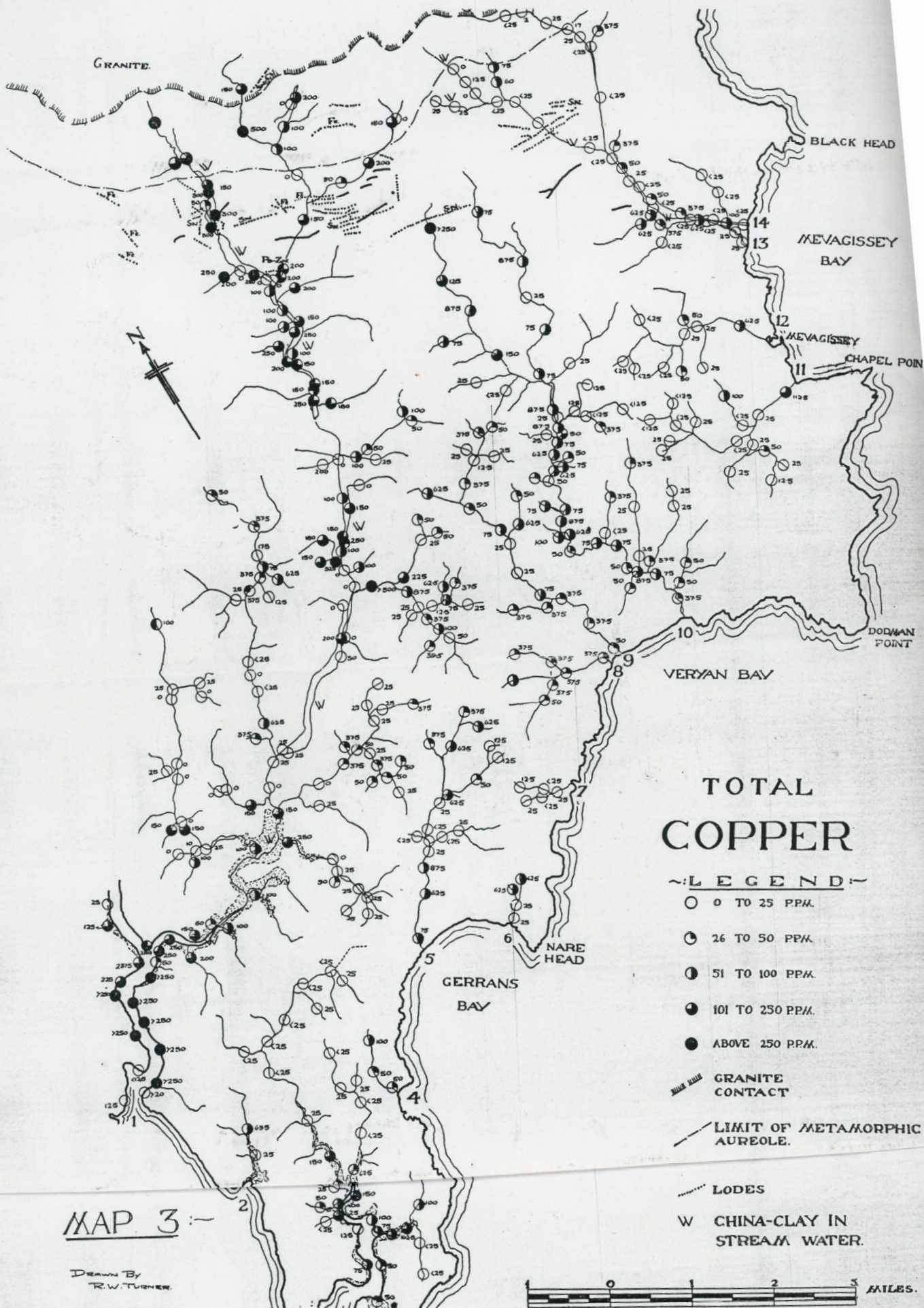
The Joy Manufacturing Company also supplied information and a proposal early in 1960.

It is necessary to include here a very brief description of conditions at Bralorne so that the background against which the following points were discussed may be known and the reasons for some of the decisions understood.

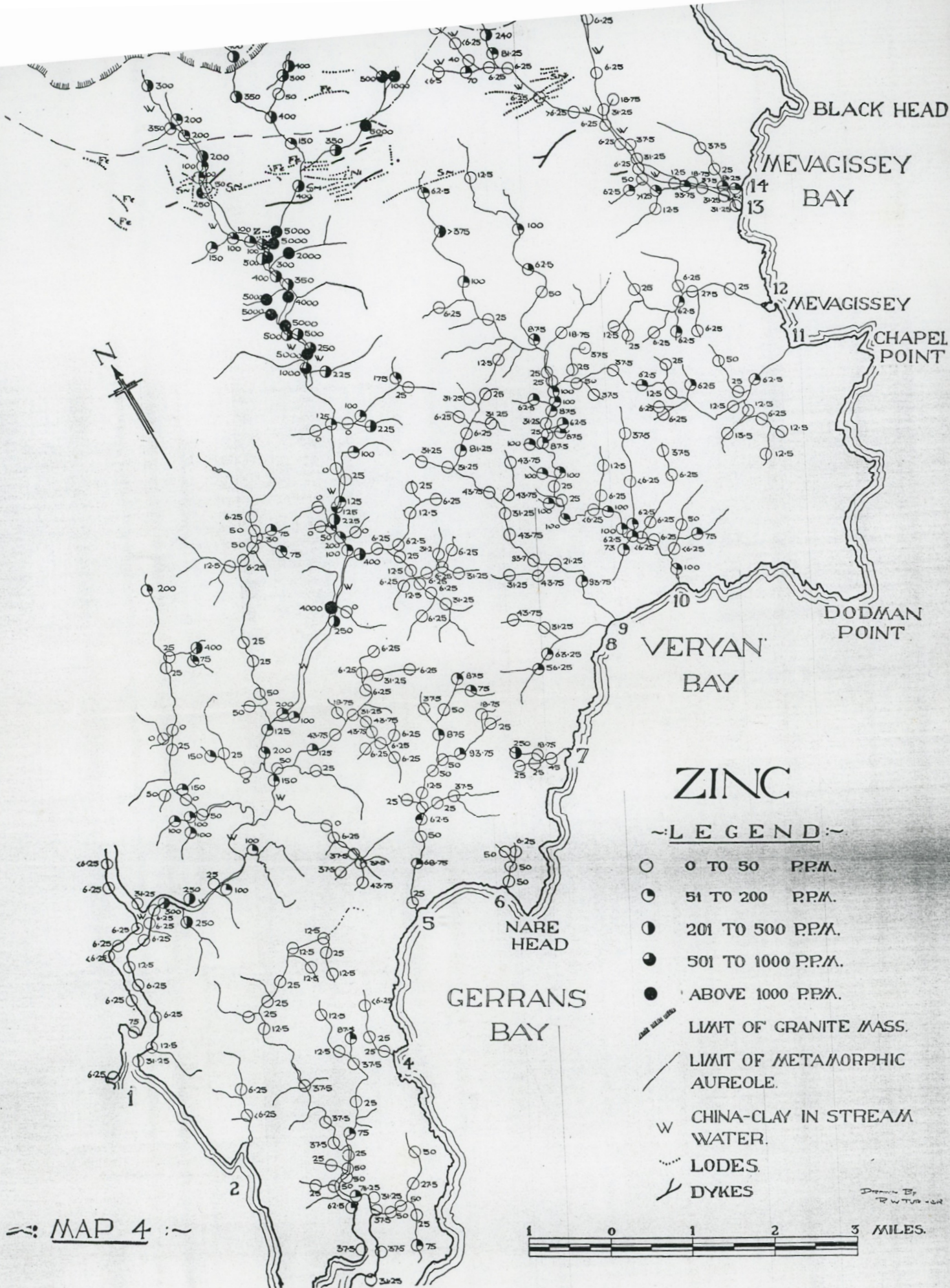
Bralorne is a gold mine and the main working areas are now in the region of 5,000 feet in depth. Although the rock is fairly strong, the depth does produce 'flaking' of the workings, especially on new faces, and this produces a support problem which is most acute during development. The mine is hot, rock temperatures sometimes reaching 120° F., and the ventilation system is not highly efficient. Ground water, and the use of hydraulic fill, make the atmosphere humid. The ore is in a series of roughly 70-80° dipping veins which vary in thickness and are not of regular dip. Although the veins are roughly parallel in strike, their rather wide separation prohibits large-scale mining methods and a hydraulic cut and fill method is used, the development and stopes closely following the veins wherever possible.

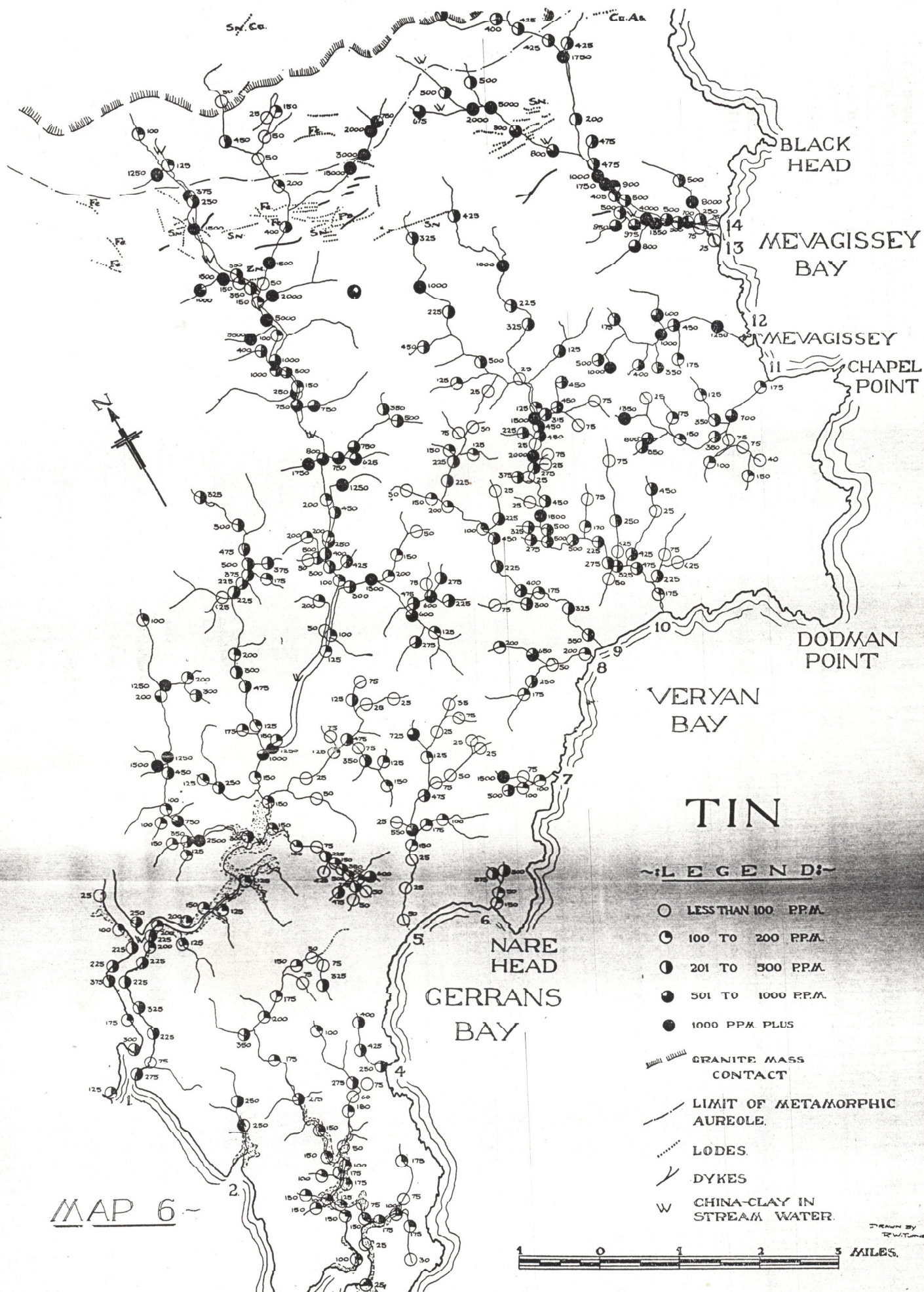
Thus, although there are no really serious problems, there are limiting conditions, and conditions with regard to actual physical











TIN

~LEGEND~

- LESS THAN 100 PPM
- 100 TO 200 PPM
- ⊕ 201 TO 500 PPM
- ⊕ 501 TO 1000 PPM
- 1000 PPM PLUS

- GRANITE MASS CONTACT
- - - - LIMIT OF METAMORPHIC AUREOLE
- LODGES
- DYKES
- W CHINA-CLAY IN STREAM WATER

DRAWN BY
R. W. TUNER

1 0 1 2 3 4 5 MILES