The Determination of Trace-Element Patterns in Soils as an aid to mapping Major Lithologic Units

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SYNOPSIS

THE Lizard Peninsula was selected as a study area to determine to what extent the determination of trace-element patterns in soils would facilitate the mapping of the associated major lithologic units. The area was selected primarily because of the widely contracting rock types occurring there and because its flat surface (a portion of the 400 ft. Pliocene platform) is largely covered by residual soil. In addition, a detailed geological map of the area is available.

Determination of Cr, Ni, Co and Cu in the major rock types, in soil samples taken at intervals of 75 feet along traverse lines across selected contacts, and in the minus-80-mesh (B.S.S.) fractions of soil samples taken on a Km-square grid, indicated that whilst the technique was capable, on occasion, of delineating certain sub-outcropping lithologic units it possessed a number of limitations and did not compare well with that other aid to reconnaissance mapping which involves the determination of trace- and minor-element distribution patterns in stream sediments.

However, it is concluded that when the drainage system of an area is inadequate, the judicious use of soil analyses, particularly if the superficial cover is residual, may facilitate the construction of a geological map.

INTRODUCTION.

The data which form the basis of this paper are derived in part from a study of the distribution of certain trace elements in the major rocks and overlying soils of the Lizard area by two of us (K.H. and S.D.) in 1962, and in part from work carried out by post-graduate and final-year students of the Camborne School of Mines, during a four-day period of their 1967 Easter Prospecting Camp under the direction of the senior author.

Whilst the latter study was devised, to no small extent, to give students experience in applied geochemical field procedures, in the

setting up and running of a temporary field laboratory, and in the plotting and interpretation of the analytical results, it was also planned as an extension of the earlier work noted above. Together these were aimed primarily at establishing to what extent the determination of trace-element distribution patterns in residual soils might facilitate the mapping of associated lithologic units, and at 'high-lighting' some of the 'snags' and defects associated with this aid to mapping.

Already trace-element distribution patterns *in stream sediments* have been used, with conspicuous success, as an aid during geologic reconnaissance mapping, largely by Professor Webb, who initiated this technique, and his co-workers (see, for example, Garrett and Nichol, 1967) and to assist in the unravelling of the genesis and structure of some of the Cornish polyphase intrusives (footnote), and frequently, of course, to facilitate the search for sub-outcropping mineral deposits. Obviously, if the area of interest is not well covered by drainage systems, stream sediment studies are of limited use as an aid to mapping, and clearly, in such circumstances, it is well to consider if something of value might be gained by determining trace-element distribution patterns in soils.

Generally, to date, the trace-element content of soil samples has been used to trace extensions of known ore-deposits, or to locate sub-outcropping virgin mineral deposits, either in known ore-fields, or in 'new' areas, often of limited extent, in which there is reason to believe that sub-outcropping mineral deposits might occur. Soil surveys, of the type under review, have not often been carried out by those concerned with the mapping of hard-rock units other than real or potential ore-deposits, although the fact that they might contribute significantly has not been entirely overlooked. Robertson (1955), for example, records that " a recent investigation . . . . shows that concentrations of Zn, Pb, Cu and Mn in soils collected systematically over the structures (in an area in Montana) demonstrate distinct relationships which make it possible to locate the structures where they do not outcrop at the surface but are covered by a residual soil mantle . . . . In the Philipsburg district, the contact between intrusive granodiorite and Palaeozoic limestone is marked by a strong concentration of metals in the limestone over ore and by a small but conspicuous anomaly in a barren area ". Generally, however, perusal of the literature served only to strengthen the view that the topic with which this paper is concerned merited further investigation, and, to anticipate what comes later, it may be said that the results of the present study serve to emphasise the fact that the need for further investigation still exists.

FOOTNOTE :—This, largely unpublished, work on the Land's End, Carnmenellis and St. Austell granites has been carried out by Hosking and others under his direction at the Camborne School of Mines during the past five or six years.

SELECTION OF THE STUDY AREA.

The Lizard Peninsula (fig. 1), of South-west Cornwall, was selected as the study area for the following reasons :—

i. Any part of it can be reached within an hour or so, by car, from the Camborne School of Mines and so, during the 1962 study period, field work could be carried out when the weather was favourable and laboratory work when it was not. Furthermore, additional work, which seemed desirable after the initial analytical results were available, and which involved further field studies, could be done without difficulty.

ii. The area is of 'manageable' size and consists of a considerable number of lithologic units, which vary in composition from ultrabasic to acidic, and which might, therefore, be expected to be covered by soils whose trace element 'patterns' reflect marked changes in the sub-outcropping rocks.

iii. The Peninsula, being a part of the Pliocene 400-ft. marine platform, is flat, and so the thin residual soil which covers most of it should not be displaced to any appreciable extent except on the sides of the valleys of the few rivers which drain the Mass.

iv. There are comparatively few houses, and factories and other industrial centres (such as mines) either active or abandoned, are virtually absent, so that contamination from such sources is of little or no account, and the selection of sampling points is largely unrestricted.

v. The Peninsula possesses wonderful, readily accessible coastal sections which permit hard-rock geochemical studies, etc., to be carried out with ease.

vi. Excellent Ordnance Survey maps, on a number of scales, and an equally excellent coloured, one inch to the mile geological map (produced by the Geological Survey) are available.

vii. The area is also the subject of a comprehensive and reasonably up-to-date Geological Survey memoir.

CHOICE OF ELEMENTS TO BE STUDIED.

Consideration of published data (particularly by Rankama and Sahama (1952)) of the average concentrations of elements present in trace and minor amounts in rock types similar to those encountered at the Lizard, suggested that Cr, Ni, Co, and Cu, were amongst those whose concentrations were most likely to differ appreciably from rock type to rock type, and these elements were, therefore, selected for investigation. The choice was also, at the outset, limited by the fact that only rapid semi-quantative colorimetric methods were to be used. It cannot, however, be stressed enough that in such a study, and regardless of the nature of the analytical methods to be used to examine the bulk of the samples, the maximum reward for the work done is most likely to be forthcoming if, at the outset, representative samples of the major rock

types, at least, can be subject to spectrographic analysis. The results of this preliminary work will indicate which elements are likely to be the most useful during the subsequent work, that is, which elements show the most marked variation in concentration from one rock unit to another. A similar variation is likely to occur between the soil overlying one rock unit and that overlying another, although the difference in the concentration of an element between two soils, each overlying a different rock type, may be equal to, greater, or less than that between the rocks. Furthermore, if soil sampling is carried out on a grid, and provided the sample point interval is correct (a topic discussed later) the greater the number of elements determined, the greater the chance of accurately delineating the sub-outcropping lithologic units, however in any given study many of the elements are not worth determining as they assist only very little: the initial spectrographic analysis, noted above, will, of course, reveal all this.

ANALYTICAL METHODS, ETC., USED.

Rock samples of c. 1 lb. weight were collected for analyses, and in the laboratory these were scrubbed with soap and water, then washed several times in metal-free water, dried, and crushed to an impalbable powder. Samples of the powder for analysis were obtained by the " coning and quartering " method.

Soil samples were dried in their resin-impregnated plastic containers, screened through a Nylon 80-mesh (B.S.S.) screen, and representative samples of the undersize were analyzed.

The following analytical methods were employed :—

Chromium	—	Chromate/diphenylcarbazide.
Cobalt	—	Tri-n-butylamine.
Nickel	—	α-furildioxime.
Copper	—	Dithizone (bisulphate fusion).

THE 1962 WORK.

The following were the main objects of this phase of the work :—

i. To determine the range of concentrations, and the average concentration, of the four selected elements in each of the major rock units of the Lizard.

ii. To determine, in certain instances, the relationship between the concentrations of each of the chosen elements in the various soil horizons and in the underlying rock.

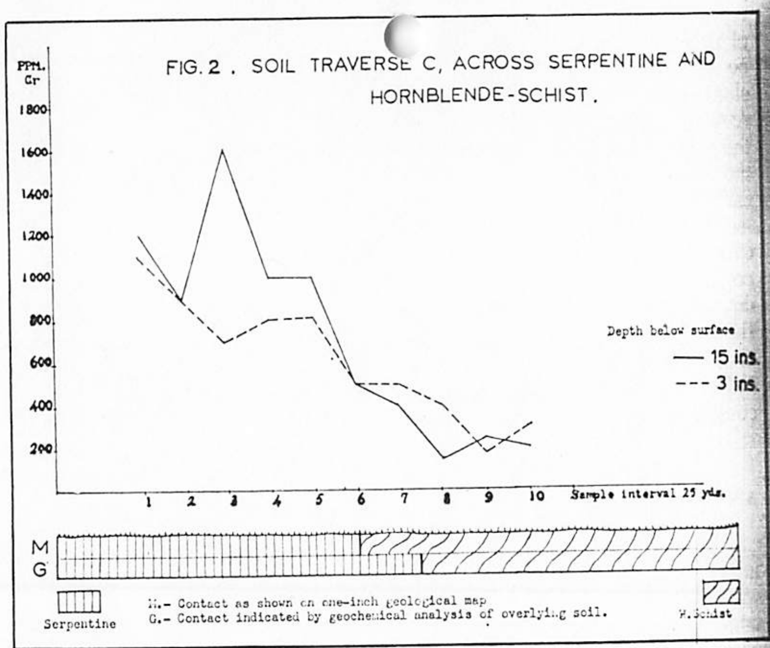

FIG. 2. SOIL TRAVERSE C, ACROSS SERPENTINE AND HORNBLENDE-SCHIST.

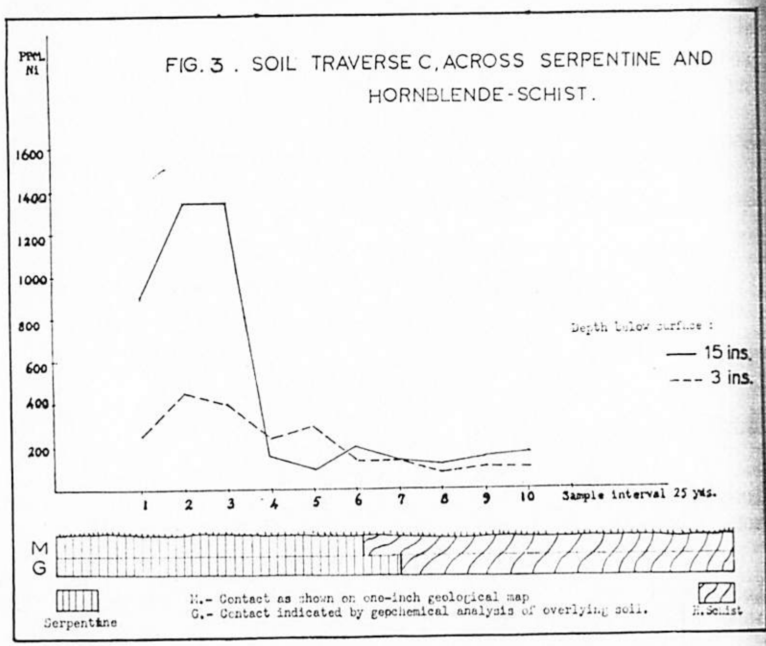

FIG. 3. SOIL TRAVERSE C, ACROSS SERPENTINE AND HORNBLENDE-SCHIST.

iii. To determine the possibility of establishing the contact between the serpentine and various other lithologic units by studying the concentrations of the selected elements in the overlying soils, and, in particular, to 'high-light' any difficulties which might be encountered in the use of this technique.

iv. To investigate the possibility of mapping the sub-outcrops of small lithologic units, particularly narrow dykes, by soil studies of the type noted above.

RESULTS.

A summary of the results of the rock analyses appear in table 1 and need no comment.

Table 1
Average Trace-Element Contents of the Major Rock Types of the Lizard.

Rock	No. of analyses	Parts per million Cr	Ni	Co	Cu
Hornblende schist ...	7	450	52	8	16
Mica schist	2	37	70	9	7
Serpentine					
Bastite type	26	1,790	1,630	76	20
Dunite type	2	1,830	1,730	57	8
Tremolite type... ...	5	1,680	2,040	46	12
Chromite type	5	6,200	2,520	80	9
Gabbro and gabbro pegmatites ...	13	304	124	11	13
Dolerites	10	215	182	23	27
Granitic rocks	13	58	130	15	6

In table 2 are indicated the ratios of the trace-element content of certain bed-rocks to those of the soils derived from them. It will be observed that the concentrations of metals in the soils depend on the character of the parent rock essentially, and that those soils derived from serpentines are readily differentiated from the others recorded in the table by their trace-element content. From the same table it may be concluded that the B horizon usually contains greater concentrations of the metals under examination than the A and that, in particular, there is a markedly greater concentration of Cr and Ni in the B horizon of the 'serpentine' soil than in that of the A.

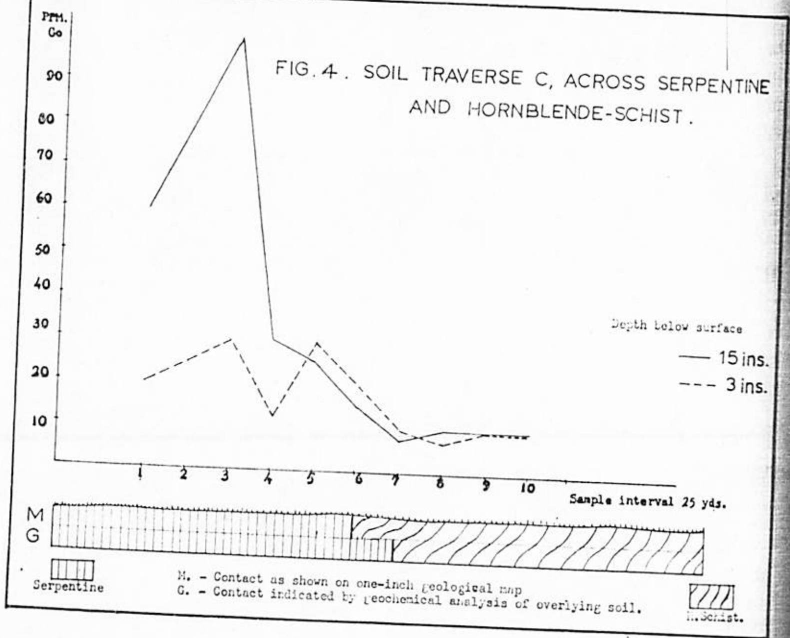

FIG. 4. SOIL TRAVERSE C, ACROSS SERPENTINE AND HORNBLENDE-SCHIST.

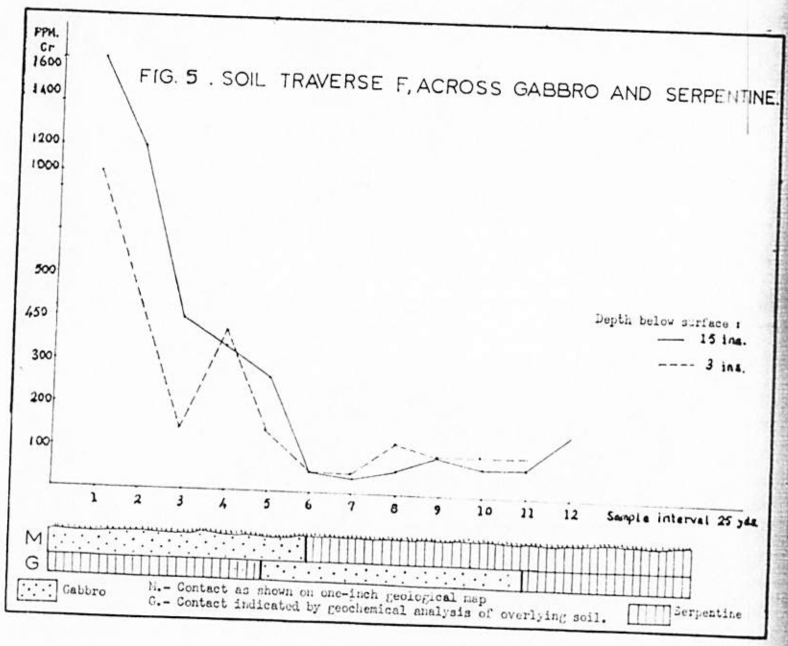

FIG. 5. SOIL TRAVERSE F, ACROSS GABBRO AND SERPENTINE.

Table 2

Ratios of the Trace-Element Contents of certain Bed-rocks to those of the Soils derived from them.

Element	Bedrock	Average in rock (p.p.m.)	Average in Soil (p.p.m.) A horizon	B horizon	Ratio Rock/A	Rock/B
Chromium	Serpentine ...	1,926	802	1,157	2.40	1.66
	Hornblende schist ...	450	162	119	2.77	3.78
	Gabbro ...	304	172	218	1.76	1.39
Nickel	Serpentine ...	1,729	288	809	6.00	2.13
	Hornblende schist ...	52	64	95	0.81	0.55
	Gabbro ...	124	82	127	1.51	0.97
Cobalt	Serpentine ...	78	26	55	2.10	1.40
	Hornblende schist ...	8	9	11	0.88	0.73
	Gabbro ...	11	10	10	1.10	1.10

Figures 2—7 indicate that there is no difficulty in determining, with considerable confidence, sub-outcropping contacts between serpentine and certain other rocks, by analyzing soil samples taken along a traverse, if the ground is comparatively flat, the cover is residual, and the sample point interval is fairly small (in the study under review it was 25 yards). Furthermore, it is probable that under such circumstances the contact established by geochemical means is, on occasion, more reliable than that arrived at by means of the classical mapping procedures, as in this area, the usual 'aids', such as outcrops, are often lacking. Indeed, on one occasion the geochemical results suggested that the published geological map was locally in error and this was confirmed by the examination of air photographs on which the sub-outcropping serpentine masses are usually readily 'picked out' because of the lack of cultivation on them and because of the peculiar character of the vegetation which they support.

Figure 8 demonstrates that difficulties in establishing a sub-outcropping contact by soil analysis may be encountered when the contact lies within a valley because of the mixing, by creep, of soil from one rock type with that from another.

Figure 9 shows the concentration patterns of the four elements studied in the thin soil overlying certain granitic dykes in serpentine at Kennack. The results clearly show that even when samples are

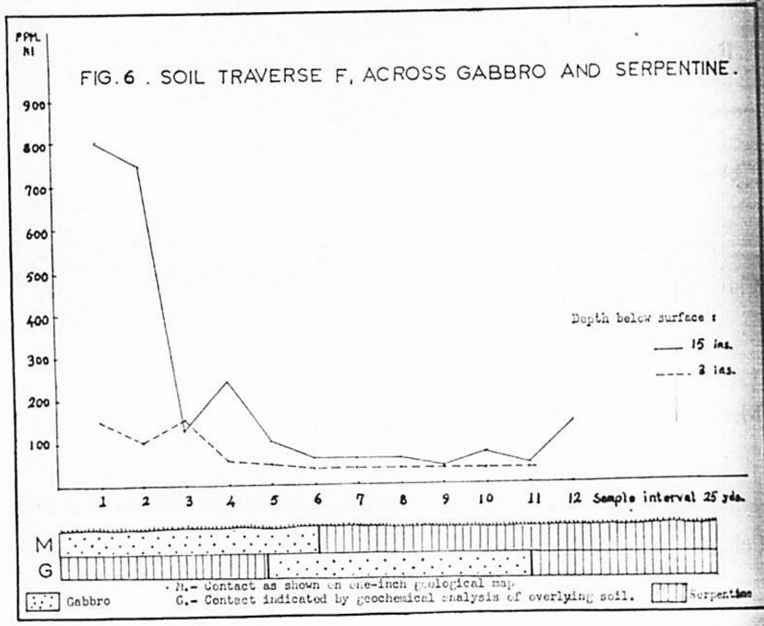

FIG. 6 . SOIL TRAVERSE F, ACROSS GABBRO AND SERPENTINE.

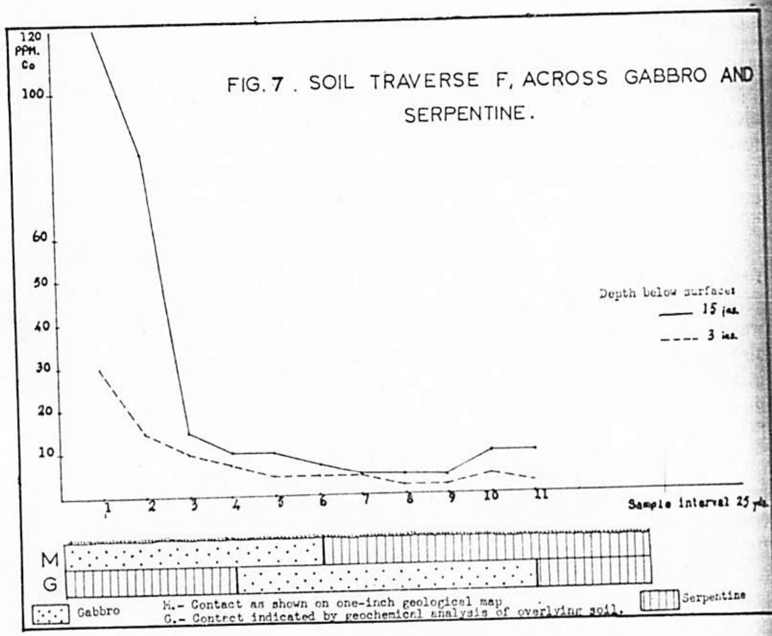

FIG. 7 . SOIL TRAVERSE F, ACROSS GABBRO AND SERPENTINE.

taken at intervals of one yard no clear indication of the presence of the small acidic units is obtained. This is in part due to the mixing, by physical and biological agents, of the soil, despite the fact that the ground along the traverse was not far removed from the horizontal, and it is also in part due to the migration of serpentine elements into the granite. This latter fact is established by the mineralogical character of the dykes and was confirmed by analyzing samples, for Cr, etc., taken along a traverse across the ultrabasic and acidic components.

In all the work the results make it clear that the Cr and Ni distribution patterns in the soil are superior to the Co, and much superior to the Cu, when the object is to delineate the sub-outcropping contact between serpentine and other lithologic units.

THE 1967 WORK.

During this brief study period B horizon soil samples were taken by groups of students from as near as possible to the points of intersection of the kilometer square grid lines printed on the various maps. It was pointed out, however, that samples should not be taken from the bottoms or sides of valleys in view of the results of the earlier study.

The results (figs. 10—14) indicate that the work only permitted the serpentine masses to be delineated with any degree of precision. It is not surprising that sampling on such a large grid failed to indicate, or, in any case, to delineate, the smaller lithologic units such as many of the granites. On account of their similar chemical composition it is also not surprising that differentiation between the hornblende schist, the spilite and the gabbro was not achieved. (It may well be, however, that there are significant trace element differences between these three units, and if they exist, they would be revealed, as stated earlier, by spectrographic analysis ; and so it is quite possible that a study of the distribution of other elements in the soils might permit each of these three units to be mapped correctly.) It may be, perhaps, surprising that the work did not allow the sedimentary units to be mapped en bloc with some degree of confidence : this, however, is largely due to the fact that the sedimentary rocks of South-west Cornwall contain unusually high concentrations of the 'heavy' metals (a fact confirmed repeatedly by research workers at Camborne during the past six or seven years), but to some extent it is also due (at least in the northern belt of the study area) to the complex spatial relationship existing between sedimentary units and small igneous ones.

The results of the 1967 work also serve to emphasise the following :—

The degree of accuracy characterising the plan form of a given lithologic unit as determined by soil analyses varies broadly with the number of sample points falling over the unit. This is, of course,

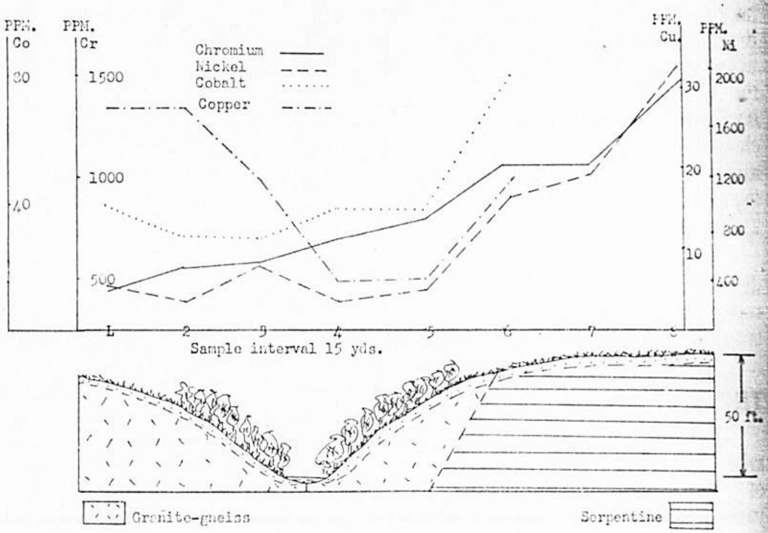

FIG. 8. Distribution of chromium, nickel and cobalt along traverse G across Granite-gneiss and serpentine.

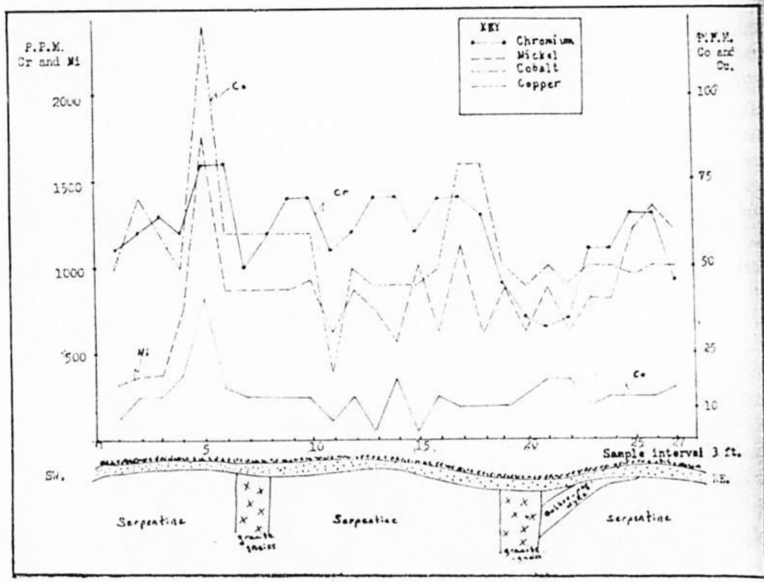

FIG. 9. Distribution of chromium, nickel, cobalt and copper in the soil over the cliff, W. of Kennack.

'a glimpse of the obvious', but it must always be borne in mind when planning a geochemical soil survey which is aimed at facilitating the production of a geological map. Obviously, sampling on such a large grid as was employed at the Lizard could, at best, only hope to broadly delineate the larger lithologic units.

One is also reminded by this study that the distribution of rock units, as established by the geochemical technique under discussion, may differ from that arrived at by the classical methods of mapping because of one or more of the following causes :—

i. The taker of the samples mis-read the map so that the sample point he recorded on the map was not, in fact, the spot from where the sample was taken. This probably happens much more frequently than one cares to admit : in featureless areas (such as parts of the Lizard Peninsula) it is quite easy to make such a mistake.

ii. The sample was taken over a sub-outcrop which was not recorded on the geological map, either because the former was too small to record in this way or because it was missed by the geologist who did the mapping. On the Lizard Peninsula many small patches of Crousa-type gravels are known which are not recorded on the one-inch Geological Map. In addition, the fact that the area is a marine platform, indicates that outcrops are limited, so it would be surprising if those who mapped the area succeeded in locating *all* the small sub-outcropping units. Perhaps some of the chromium-low soil samples from the serpentine areas reflect the presence of small unmapped granite masses, but there may be other reasons, which are noted below, for these apparent anomalies.

iii. The sample was taken on a stope covered by transported material.

iv. The maker of the geological map locally mapped a major contact incorrectly : an example of this has been noted earlier.

v. Some of the geochemical analyses were incorrect. Although during analysis great care is taken to ensure that all apparatus is clean and all the reagents are of the correct strength, and although blanks and check samples are analyzed with the unknowns, such precautions do not completely eliminate the possibility of errors creeping in. Three or four test-tubes in a rack may, for example, be contaminated, whilst the rest, including those holding checks and blanks, are clean. The analyst, too, may become less careful towards the end of a day's work. Of course, when a result does not appear to 'fit', the sample should be re-analyzed : a difficulty arises when a result which appears reasonable is, in fact, incorrect. In the 1967 study a considerable number of analyses were repeated and, had time been available, still more analyses would have been checked. It was felt, however, that despite the fact that the validity of some of the results was suspect, collectively they were still worth publishing in map form as they serve to illustrate very well many

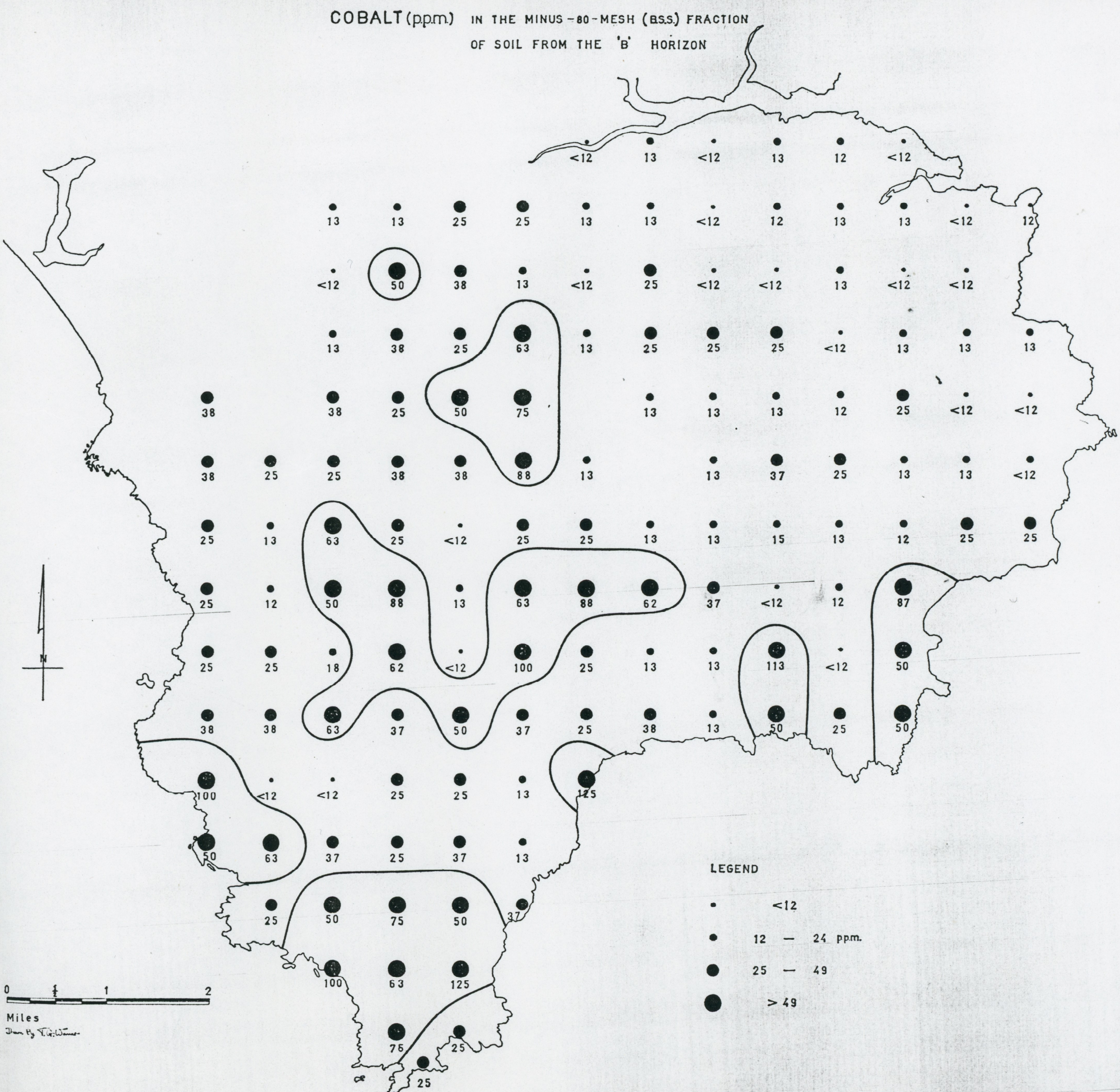
COBALT (p.p.m.) IN THE MINUS-80-MESH (B.S.S.) FRACTION
OF SOIL FROM THE 'B' HORIZON
<12 13 <12 13 12 <12
13 13 25 25 13 13 <12 12 13 13 <12 12
<12 50 38 13 <12 25 <12 <12 13 <12 <12
13 38 25 63 13 25 25 25 <12 13 13 13
38 38 25 50 75 13 13 13 12 25 <12 <12
38 25 25 38 38 88 13 13 37 25 13 13 <12
25 13 63 25 <12 25 25 13 13 15 13 12 25 25
25 12 50 88 13 63 88 62 37 <12 12 87
25 25 18 62 <12 100 25 13 13 113 <12 50
38 38 63 37 50 37 25 38 13 50 25 50
100 <12 <12 25 25 13 125
50 63 37 25 37 13
25 50 75 50 37
100 63 125
76 25
25
N
0 ½ 1 2
Miles
LEGEND
<12
12 — 24 p.p.m.
25 — 49
> 49

FIG. 12

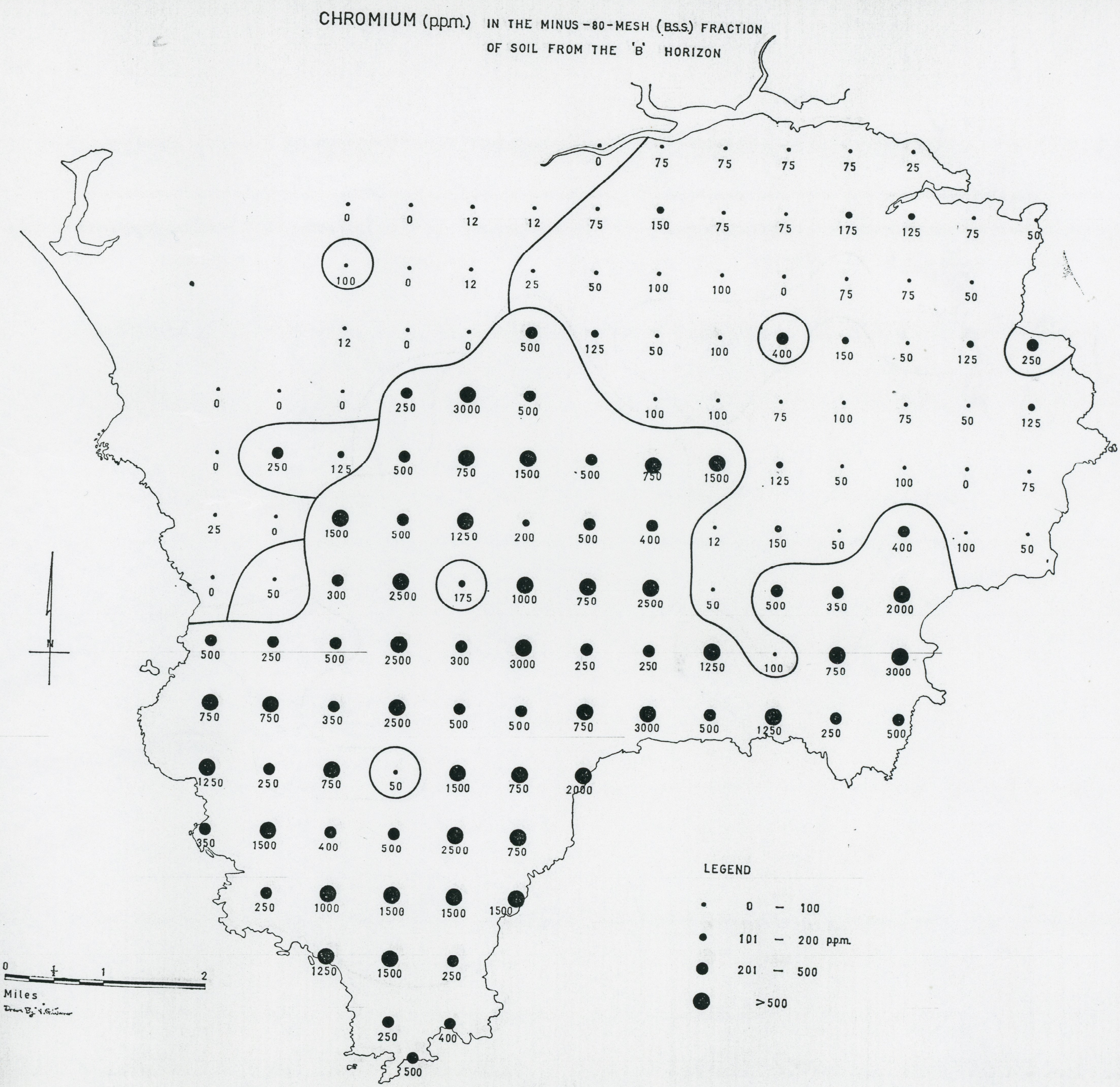
CHROMIUM (p.p.m.) IN THE MINUS-80-MESH (B.S.S.) FRACTION
OF SOIL FROM THE 'B' HORIZON
0 75 75 75 75 25
0 0 12 12 75 150 75 75 175 125 75 50
100 0 12 25 50 100 100 0 75 75 50
12 0 0 500 125 50 100 400 150 50 125 250
0 0 0 250 3000 500 100 100 75 100 75 50 125
0 250 125 500 750 1500 500 750 1500 125 50 100 0 75
25 0 1500 500 1250 200 500 400 12 150 50 400 100 50
0 50 300 2500 175 1000 750 2500 50 500 350 2000
500 250 500 2500 300 3000 250 250 1250 100 750 3000
750 750 350 2500 500 500 750 3000 500 1250 250 500
1250 250 750 50 1500 750 2000
350 1500 400 500 2500 750
250 1000 1500 1500 1500
1250 1500 250
250 400
500
N
0 ½ 1 2
Miles
LEGEND
0 — 100
101 — 200 p.p.m.
201 — 500
>500

FIG. 10

COPPER (p.p.m.) IN THE MINUS-80-MESH (B.S.S.) FRACTION OF SOIL FROM THE 'B' HORIZON

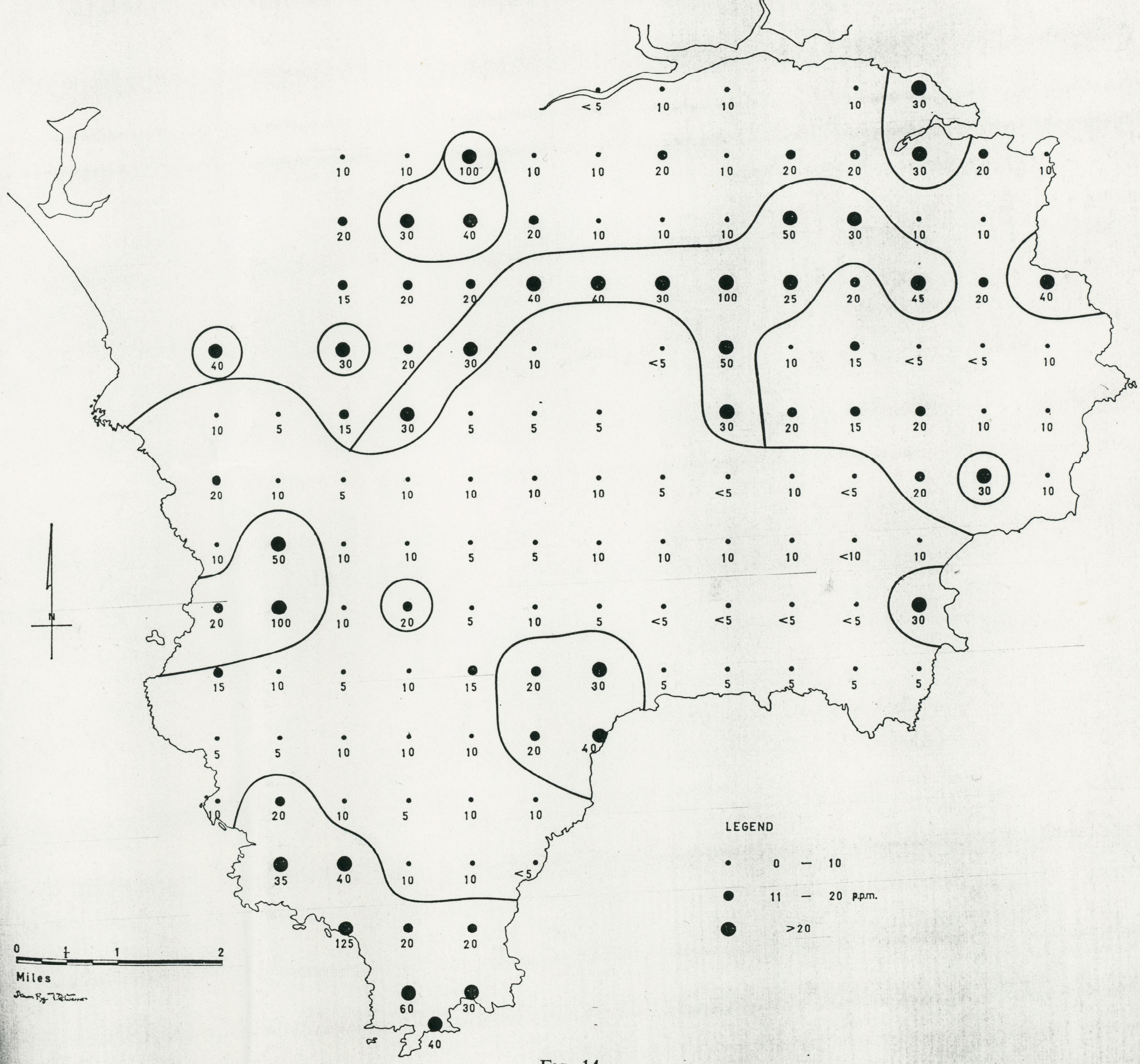

FIG. 14

NICKEL (p.p.m.) IN THE MINUS-80-MESH (B.S.S.) FRACTION OF SOIL FROM THE 'B' HORIZON

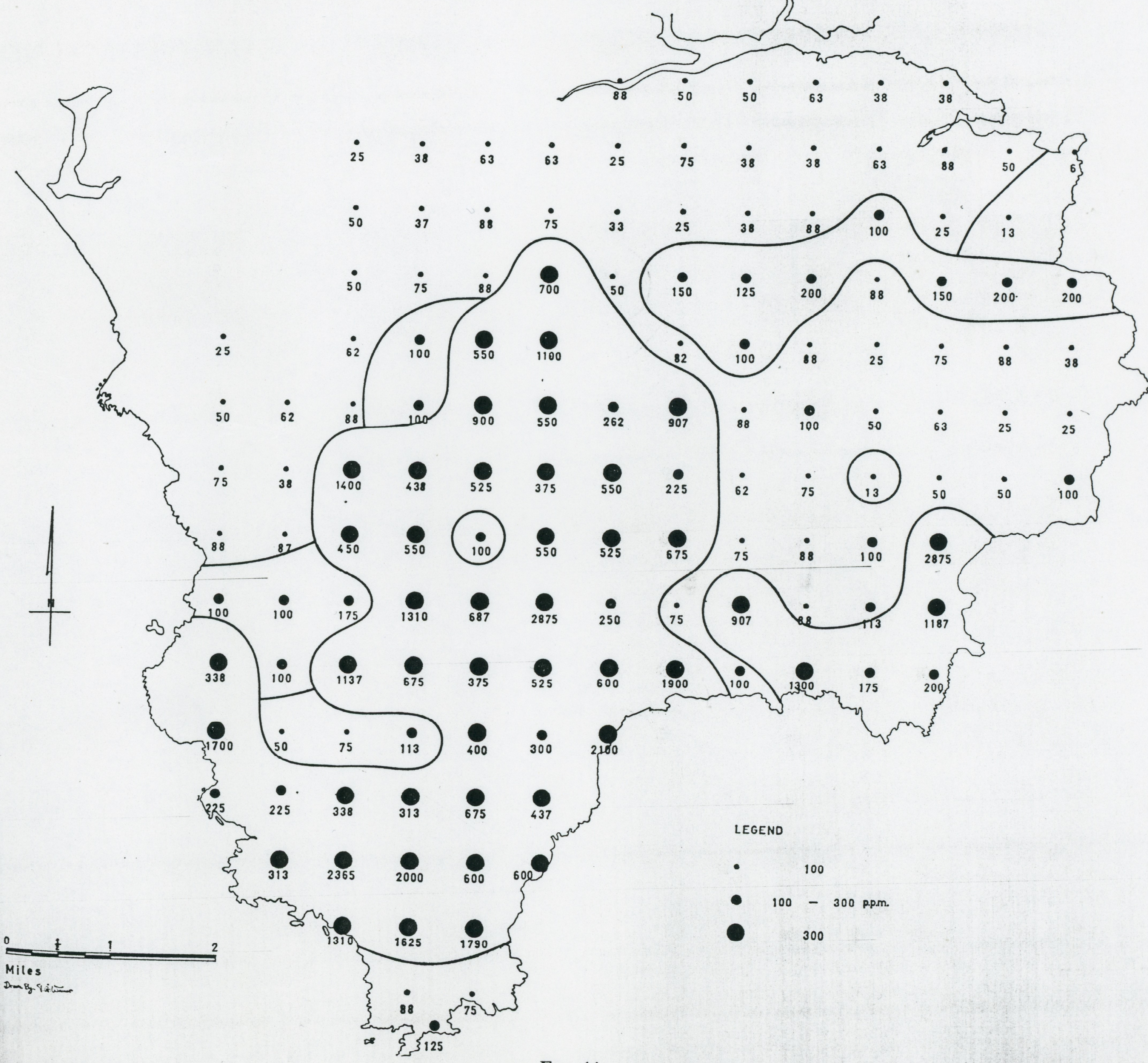

FIG. 11