Natural Environment Research Council

Institute of Geological Sciences

Mineral Reconnaissance Programme Report

A report prepared for the Department of Industry

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No. 32

Investigations at Polyphant, near Launceston, Cornwall

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SUMMARY

A geophysical survey was conducted in the vicinity of the Carrock tungsten mine, Cumbria. The object of the survey was to establish an optimum geophysical exploration procedure for the location of the style of mineralisation known at Carrock. The VLF–EM method recorded only weak or indistinct anomalies over much of the known mineralisation but a weak anomaly coincident with the Emerson vein was traced northwards for one km. Several similar linear features were recorded in the area on trends favourable for mineralisation and two, at Poddy Gill in the east and Arm o' Grain in the west, are coincident for part of their strike with exposed mineralisation.

Resistivity measurements indicated that most fault structures have coincident low resistivity zones; a detailed traverse across the Emerson vein showed a minor high resistivity peak within the low zone.

Induced polarisation, magnetic and self potential anomalies were recorded only within the gabbro on the extrapolated positions of the Smith and Wilson lodes. It is concluded that these anomalies are caused by discontinuous near-surface lenses of pyrrhotite which have little VLF response.

The VLF method is identified as the best tool for the location of structures which may carry mineralisation in this environment. Incidentally to the main objectives of the work, three VLF anomalies are identified which appear to warrant investigation by drilling; the Arm o' Grain anomaly, the Emerson vein extension and the Poddy Gill feature.

INTRODUCTION

A study group has been established within the Mineral Reconnaissance Programme to examine well-documented mineral occurrences (including working mines) in order to evaluate and refine exploration methods and interpretation techniques as an aid to the discovery and preliminary assessment of further mineralisation in the same area or similar occurrences elsewhere.

The Carrock Fell tungsten mining area meets the geological requirements of the project. An active mine provides detailed information on the controls and nature of mineralisation. The geology, geochemistry and mineral paragenesis have been the subjects of recent studies, which conclude that the area has definite mineral potential (Appleton and Wadge, 1976, Shepherd et al., 1976). The present report describes the results of a survey which was aimed at establishing the best geophysical exploration procedure to detect and study this style of mineralisation.

REGIONAL SETTING AND GEOLOGY

The Carrock Mine is situated some two miles to the west of Mosedale, Cumbria, in Grainsgill Beck, a tributary of the River Caldew. The area is one of high relief and rugged topography and in the summer months the lower slopes of the steep valleys are heavily vegetated with bracken and heather.

The geology of the area is detailed in the works mentioned above and the mining history is described in Anon (1977). Only a brief summary of the geology is given here and the solid geology is shown in Fig. 1.

The southern part of the area is underlain by the Lower Ordovician Skiddaw Group sediments, which are commonly highly deformed. Fold axes have an east-north-easterly trend. In the north of the area a thick, near-vertical sequence of volcanic rocks strikes east-west and has been correlated with the Borrowdale Volcanic Series. The central part of the area is dominated by two major intrusions. To the north the Lower Palaeozoic Carrock Fell gabbro complex trends roughly along the east-west regional strike and is in steep contact with the surrounding rocks. To the south, separated from the gabbro by a few hundred feet of hornfelsed sediments, lies the northernmost part of the Caledonian Skiddaw Granite. This has been greisenised in the Grainsgill Beck area.

The mineralisation is in the form of quartz veins which strike north-south and dip steeply to the west. The veins carry tungsten as wolframite and scheelite, together with lesser amounts of arsenopyrite, pyrrhotite and pyrite which increase northwards. The mineralisation is closely associated with the greisenisation of the Skiddaw Granite and it is considered that both the tungsten mineralisation and the greisen are the result of circulation of saline fluids through and around the hot granitic intrusion (Appleton and Wadge, op. cit.). The circulation was especially active on the northern margin of the granite where joints and fractures in the gabbro and the granite provided channelways for the fluids. The Skiddaw Group sediments, in contrast, were hydrologically much "tighter", so that circulation was limited in the south.

SURVEY DESIGN

The survey area was geographically defined to include the harder fractured rocks to the immediate north and west of the present workings. The southern area was not tested in detail. The geophysical methods used were selected on the basis of the following considerations:

i The nature of the veins – tight, continuous quartz lodes of 1.5–3 m average width, with fracture controlled orientation – suggested that they would not form good electromagnetic targets in themselves. Thus exploration procedures using EM methods were aimed at their indirect detection by the identification of favourable structures. The VLF–EM method has a history of successful location of faults and fissures in a variety of geological environments (Phillips and Richards, 1975; Coney and Myers, 1977; Telford et al., 1977; Patrick et al., in prep.) and was considered to be the most suitable method of locating fractures in this area.

ii The quartz lodes should have a considerably higher resistivity than the country rocks (see Table 1), and resistivity methods might thus be expected to detect the veins. The small widths, however, would require the use of small array spacing for optimum resolution.

iii Pyrrhotite has been observed within the gabbro close to the veins and this could be expected to produce an

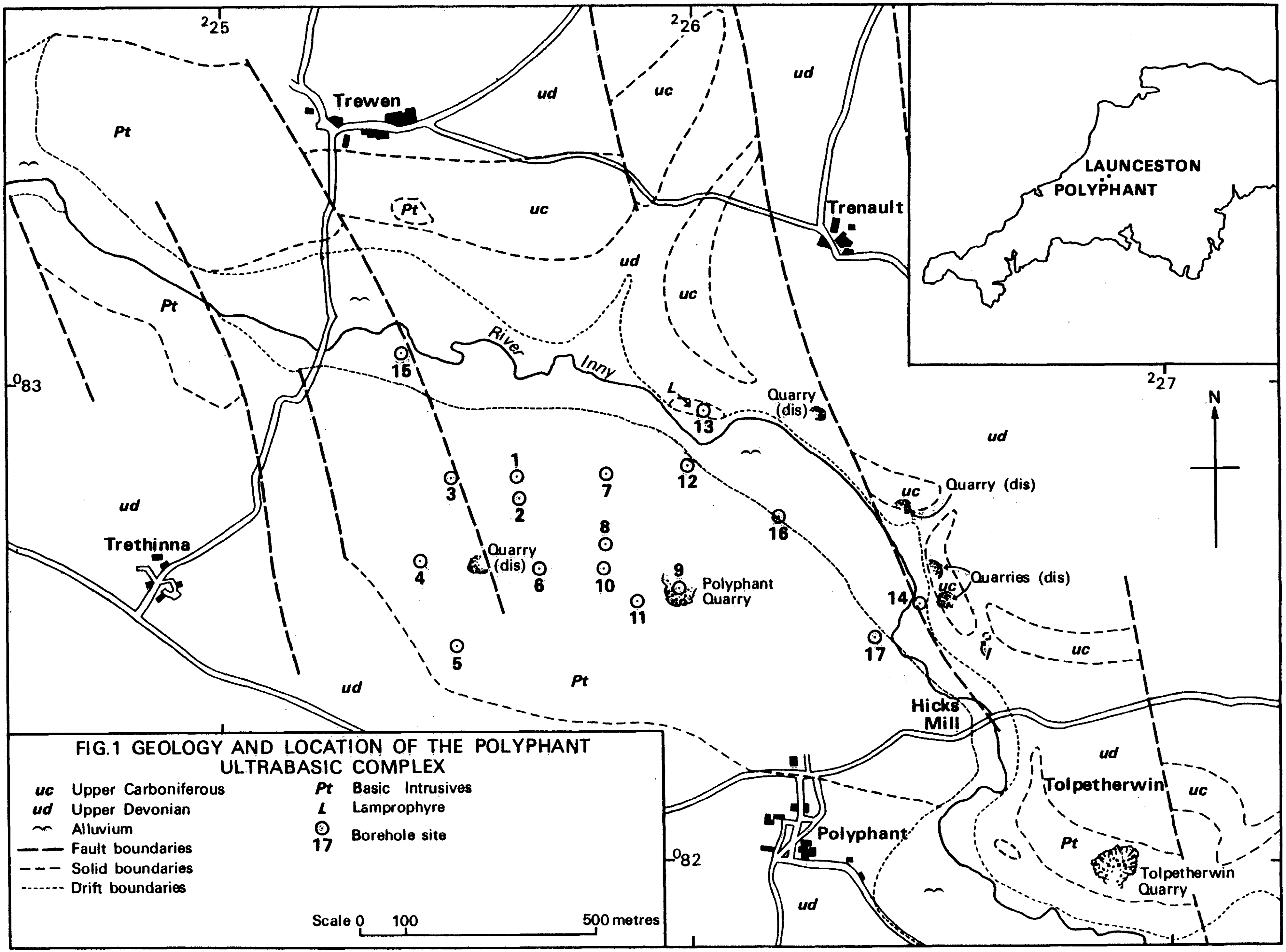

FIG.1 GEOLOGY AND LOCATION OF THE POLYPHANT ULTRABASIC COMPLEX

pyroxene tends to have an interstitial relationship with the olivine. Despite the apparent freshness and hardness of the rock, deuteric uralitisation is ubiquitous and, in Borehole No. 17 (see Fig. 1), progressive replacement of peridotite by dolomite was observed below a depth of 29.50 m.

Adjacent to the two quarries there are outcrops of a fine-grained gabbro consisting chiefly of titanaugite, oligoclase and uralite with accessory biotite, magnetite, ilmenite, epidote, apatite and pyrite. The ilmenite and magnetite are in varying states of alteration and chloritic alteration of both the pyroxene and the uralite is evident.

A coarse-grained gabbro, seen as scree on the wooded river bank north of Trethinna [SX 2485 8320], differs from the fine-grained variety only in its lack of opaque ore minerals.

Relationships between these varying phases are nowhere clearly demonstrable in exposures, though Dewey (in Reid and others, 1911) noted that gabbro (minverite) and peridotite (picrite) were "so intimately associated as to be inseparable in the field". In the exposures to the west of Trewen, however, there is a suggestion of macroscopic layering, and alternations of gabbro and peridotite were observed by I.G.S. in borehole cores. McDonald (1970) suggests that the mass is both macrospically and microscopically layered, features she attributes to a combination of polyphase intrusion, gravitational mineral settlement and the variable conditions under which the body cooled.

From the drilling carried out in 1969 (Fig. 1, Table 1) it was concluded that the upper contact of the intrusion dips moderately steeply in a northeasterly direction below the Devonian slates and limestones in the area north of the River Inny. These sedimentary rocks are part of a thrust slice driven from the south and now covering a part of the ultrabasic body.

Much research remains to be done at Polyphant to elucidate the form of the ultrabasic mass, its relationship to the dolerites and lavas, its age and the significance of its location within a belt of major thrust movement. The petrographic variations within the mass, the distribution of alteration types and their significance are largely unexplored. In view of this, it is possible only briefly to outline the geological history of the area, there having been no justification for detailed studies from the results of the investigation under review.

Polyphase folding of the Upper Devonian slates and lavas, placed by Dodson and Rex (1971) at about 350 Ma, appears to have preceded the intrusion of the ultrabasic mass though, by comparison with other areas in Cornwall, it may have involved some or all of the dolerite (greenstone) sheets. It is possible to speculate that the ultrabasic intrusion is related to the regional thrusting which involves Upper Carboniferous strata and, therefore, cannot be earlier than Permo-Carboniferous in age. Whether the lamprophyres are coeval with the peridotite, are cut by it or transect it at depth, remains uncertain but it seems probable that two such deep-seated igneous intrusions may be closely related in both age and origin. Such considerations would place the age of the peridotite at about 260 Ma, or perhaps a little earlier, but in any case close to the isotopic ages quoted for the Bodmin Moor Granite (Edmonds and others, 1969). The fault which separates the two peridotite outcrops may be one of the wrench structures to which Dearman (1964) ascribes a Tertiary age.

GEOCHEMICAL INVESTIGATIONS

A geochemical investigation of the Polyphant ultrabasic complex, conducted during the summer of 1976, was based on the collection of 250 soil samples from 14 traverse lines. The traverses varied in length between 160 m and 740 m, and samples were collected at 20 m intervals. Sample depth varied between 0.3 m and 1.0 m depending on soil cover, the maximum obtainable depth being south in an attempt to obtain a true 'C' horizon sample. Approximately 150 g of sample were collected at each site.

Ten traverse lines (Figs. 2-6) were centred on the major outcrop of ultrabasic rocks south of the River Inny, with one across the outcrop immediately to the north of the river, west of Trewen. Traverse G passed over a small lamprophyre outcrop in interbedded Upper Devonian limestones and slates, whilst traverse H passed from the interbedded succession into predominant slates. Traverse J*, approximately 350 m west of Laneast, crossed a band of spotted slates and pillow lavas and was located in an attempt to identify the source of the chromium anomaly in the River Inny [SX 225 835], discovered during a regional stream sediment survey carried out in 1971.

All the samples were dried, disaggregated in a mortar

*This is not shown in any of the figures but runs from [SX 2233 8405] to [SX 2208 8350].

Table 1. Location and other features of vertical boreholes near Polyphant.

Borehole No.	Nat. Grid. Ref. (SX)	1" Geol. Map	General location *	Collar elevation (m)	Final depth (m)
1 †	2566 8280	337	818 m at 314°	140	31.70
2	2566 8275	"	782 m at 310°	145	33.83
3, 3A, 3B	2551 8278	"	960 m at 306°	147	3.20, 5.64, 6.32
4	2546 8261	"	869 m at 296°	178	43.13
5	2552 8245	"	745 m at 287°	192	17.37
6	2570 8259	"	654 m at 303°	183	38.71
7	2584 8280	"	704 m at 324°	136	54.25
8	2585 8264	"	581 m at 317°	160	43.28
9	2598 8256	"	425 m at 322°	149	26.67
10	2585 8260	"	544 m at 314°	169	12.93
11	2591 8252	"	443 m at 312½°	181	31.78
12	2601 8282	"	645 m at 339°	128	58.37
13	2606 8292	"	727 m at 345°	128	59.13
14	2648 8253	"	402 m at 253°	122	29.26
15	2540 8304	"	1175 m at 313°	131	46.94
16	2619 8270	"	494 m at 039°	128	50.29
17	2640 8247	"	311 m at 032°	125	46.85

All boreholes are located in the area of the 1:50 000 sheet 332.
* Locations are reckoned from Polyphant Chapel.
† Position may be inaccurate as borehole log does not correspond with geological surface map.

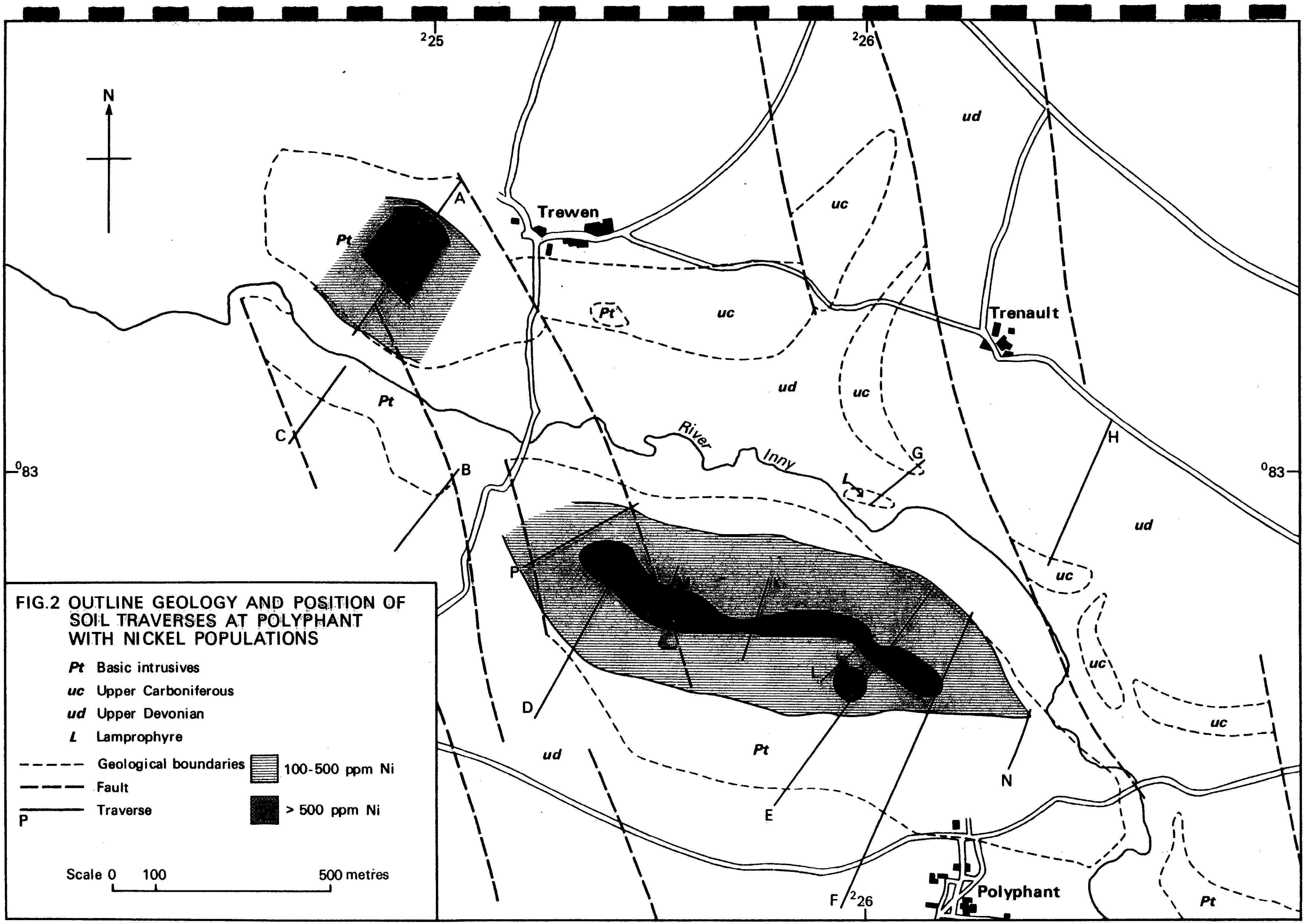

FIG.2 OUTLINE GEOLOGY AND POSITION OF SOIL TRAVERSES AT POLYPHANT WITH NICKEL POPULATIONS

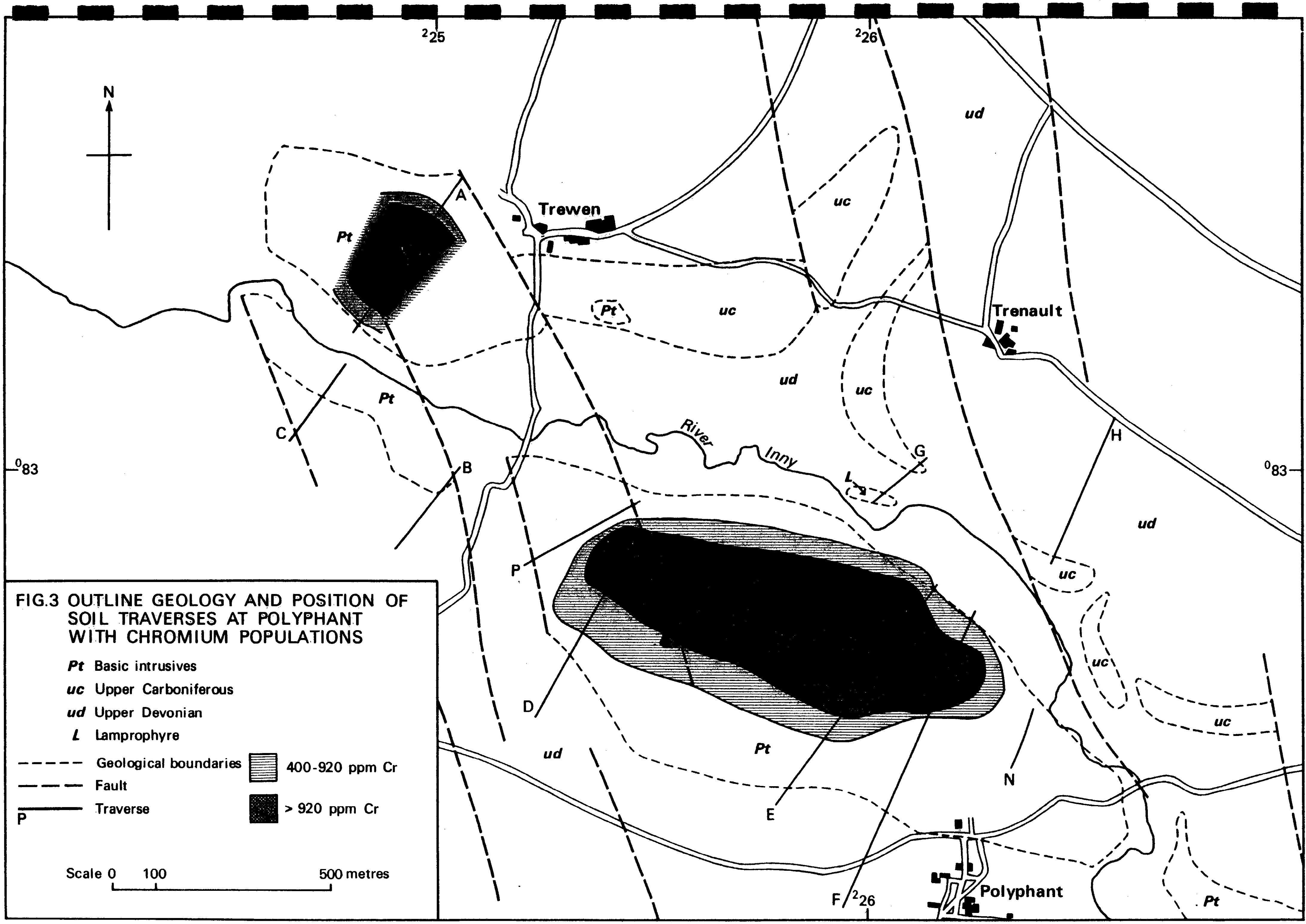

FIG.3 OUTLINE GEOLOGY AND POSITION OF SOIL TRAVERSES AT POLYPHANT WITH CHROMIUM POPULATIONS

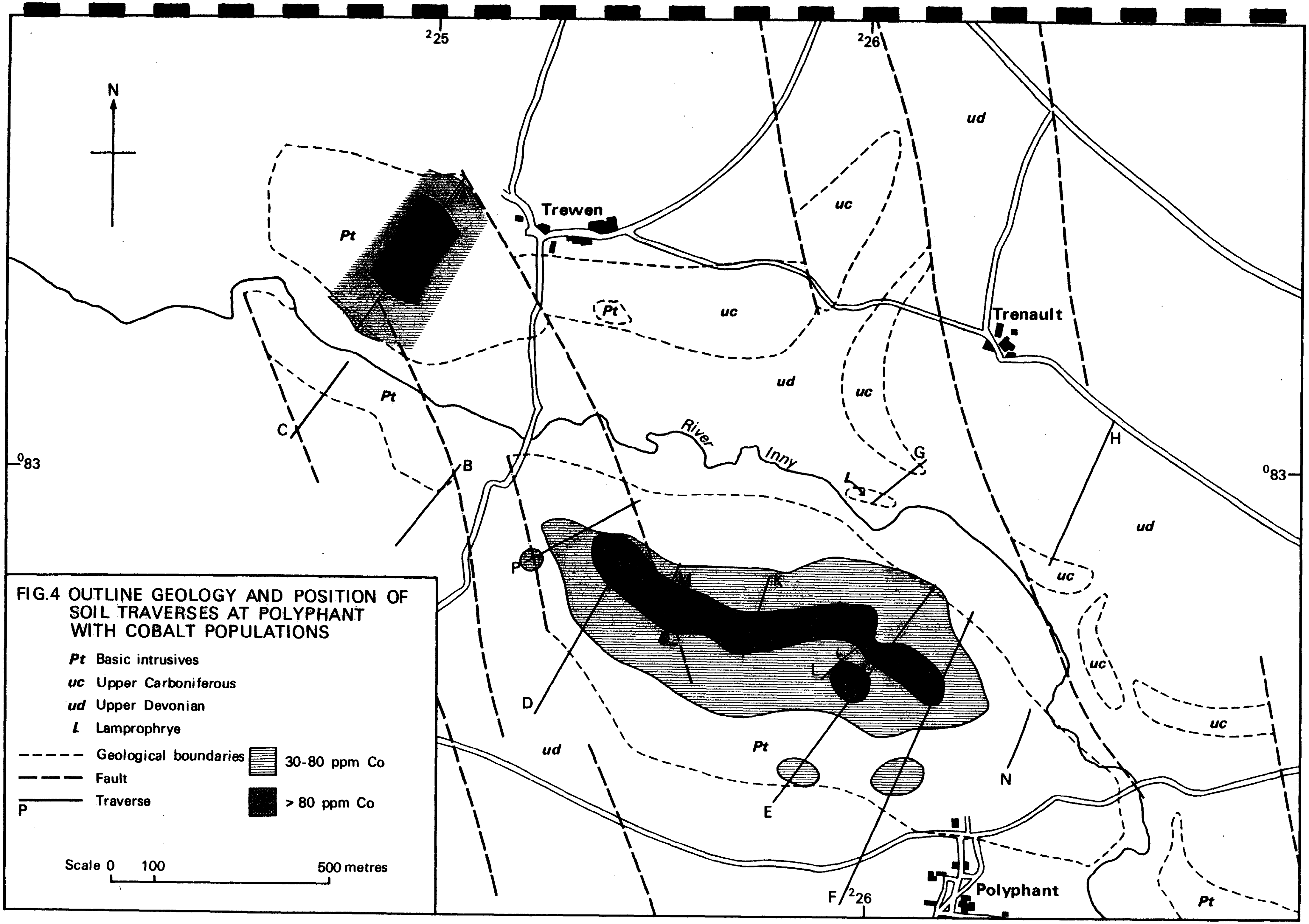

FIG.4 OUTLINE GEOLOGY AND POSITION OF SOIL TRAVERSES AT POLYPHANT WITH COBALT POPULATIONS

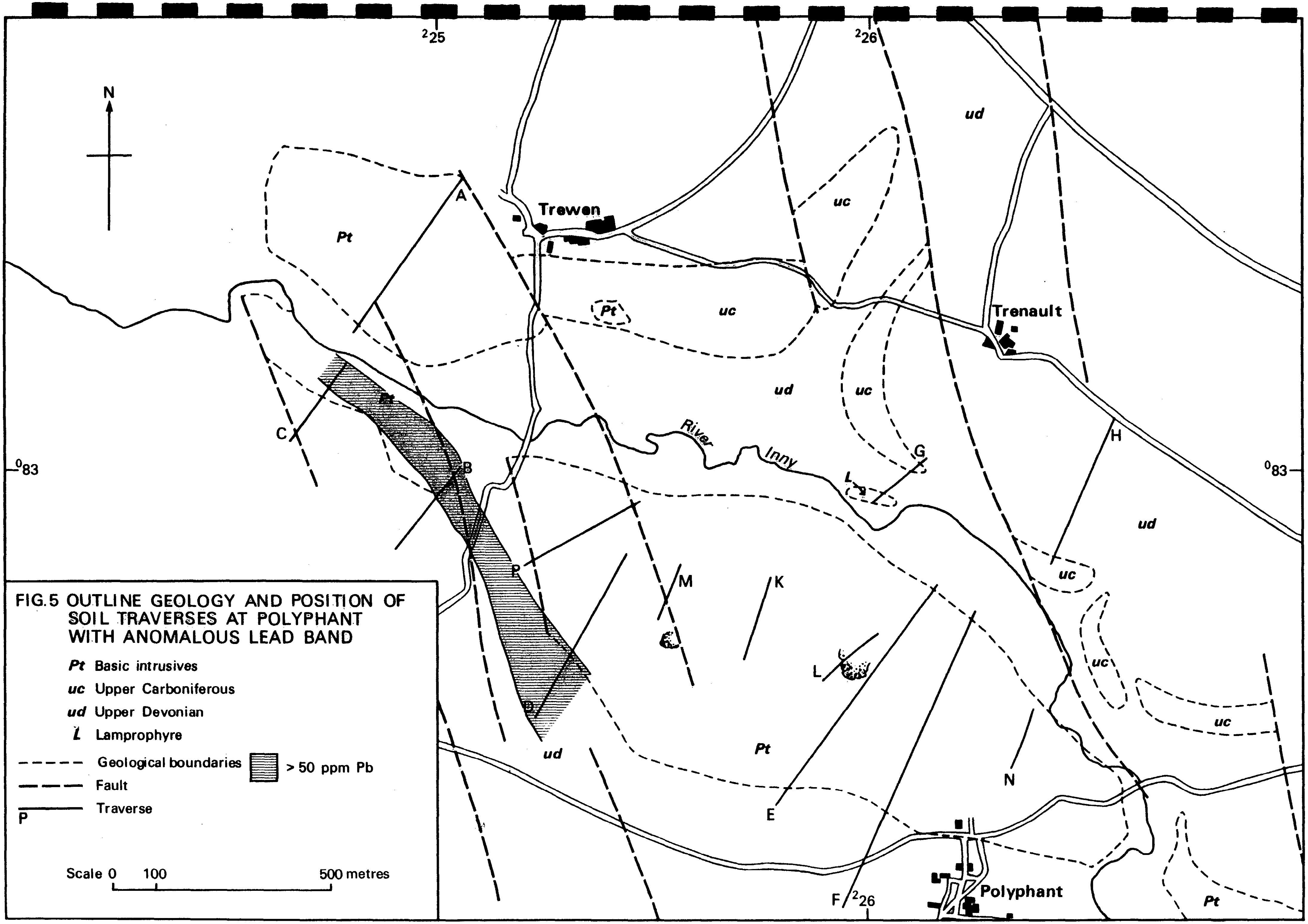

FIG. 5 OUTLINE GEOLOGY AND POSITION OF SOIL TRAVERSES AT POLYPHANT WITH ANOMALOUS LEAD BAND

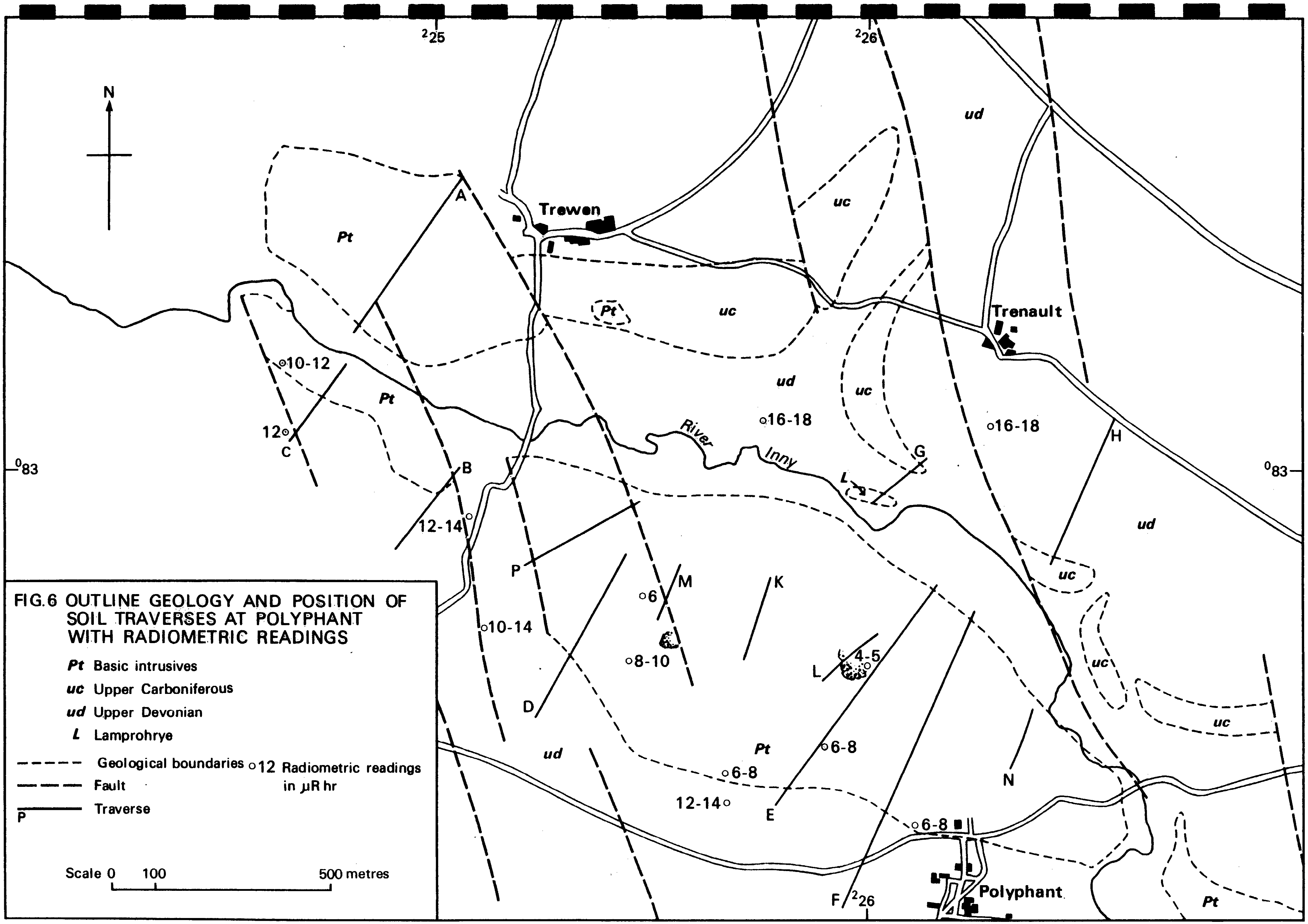

FIG.6 OUTLINE GEOLOGY AND POSITION OF SOIL TRAVERSES AT POLYPHANT WITH RADIOMETRIC READINGS

and pestle and sieved to 60 mesh BSI. The undersize was then analysed for Cu, Pb, Zn, Co, Ni and Ag by atomic absorption spectrophotometry, and for Cr by X-ray fluorescence.

Results
Cumulative frequency graphs were plotted for each element in order to distinguish sample populations. The results are summarised below:

Nickel (Fig. 2): Three distinct sample populations were identified, with values of 0-100 ppm, 100-550 ppm and >550 ppm Ni. The intermediate and higher populations are confined approximately to the mapped boundary of the peridotite, with a slight downhill displacement on traverses E and F. The maximum value of 1040 ppm occurs on traverse A near the mapped boundary of the smaller peridolite outcrop, 230 m west of Trewen.

Values lying within the higher sample population are confined to traverses D,M,K.L,E and F of those traverses taken across the major peridotite outcrop and identify an anomalous band within the ultrabasic body of 50 m to 100 m in width, with a WNW-ESE strike of approximately 900 m. In traverse A values within the higher population occur over a width of 200 m.

Chromium (Fig. 3): Cr shows a close correlation with Ni and similarly has three sample populations, with values of 0-400 ppm, 400-920 ppm and >920 ppm Cr. As with Ni, the intermediate and higher opulations are confined essentially to the mapped boundaries of the ultrabasic intrusives, although again showing downhill creep on traverses E and F. The contoured area of intermediate population corresponds very closely with that of the intermediate Ni population, but the band of higher anomaly is wider than that for Ni, varying between 200 and 350 m, though of a similar strike length. A maximum value of 2000 ppm Cr occurs as the northernmost sample on traverse D.

Cobalt (Fig. 4): As with Ni and Cr, Co values fall into three sample populations, having values of 0-30 ppm, 30-80 ppm and >80 ppm Co, with the intermediate and higher populations again being roughly confined to the ultrabasic bodies. The Co values show a much closer correlation with those of Ni than with Cr and the area enclosed by the lowest contour of the higher population closely corresponds to the band of higher Ni values. The maximum value of 150 ppm Co occurs on traverse A, 20 m along line from the Ni maximum.

Copper: The Cu values are generally low and have a normal Gaussian distribution. There is no clear correlation between Cu variations and underlying rock types but, compared with the slates, the intrusive rocks show slight copper enrichments at levels of 15-20 ppm Cu. The maximum value of 95 ppm, however, occurs in the northernmost sample from traverse G on ground mapped as underlain by Upper Devonian sediments.

Lead (Fig. 5): The Pb results fall into two distinct sample populations of 0.50 ppm and >50 ppm Pb. The anomalous population occurs in a band 120 m to 150 m wide at the northern end of traverses B and C, widening to approximately 300 m at the southern end of traverse D. A maximum value of 150 ppm Pb reports from the northernmost sample of the enriched band on traverse D.

Zinc: Zinc values give a normal Gaussian distribution with differing values seemingly unrelated to lithological variation. The maximum value of 410 ppm Zn, however, occurring in the southernmost sample of traverse N, is distinctly anomalous and may be the result of local contamination.

Radiometric survey
Surface radiometric readings are shown in Fig. 6.

GEOPHYSICAL INVESTIGATIONS

Background
Inspection of the 1:63 360 aeromagnetic maps for southwest England shows the Polyphant complex to lie within a zone of high magnetic relief north of the Bodmin Moor Granite, and to exhibit a significant positive anomaly. The belt of magnetic anomalies skirting the northern margins of the Dartmoor and Bodmin Moor Granite outcrops has been variously interpreted but it is generally agreed to indicate strong remanent magnetisation of the source. Within this belt to the west of Dartmoor, Cornwell (1967) attributes magnetisation of Lower Carboniferous sediments and dolerites to metasomatic pyrrhotite formed during emplacement of the granite and thermally remagnetised during its consolidation.

Creer (1966) concluded that the albite-dolerites (green stones) of southwest England were intruded prior to the main Hercynian folding episodes and remagnetised during late Carboniferous or early Permian times. Their very low intensities of magnetisation (10^{-5} to 10^{-6} gauss) are a reflection of minor magnetite contents and explain the absence of magnetic anomalies over many of them. In contrast, the ultrabasic body at Polyphant contains abundant magnetite (albeit not necessarily primary) and gives intensities in the range of $139.5-189.5 \times 10^{-6}$ gauss.

Measured values of mean direction of magnetisation (D) and its inclination to the present horizontal (I) for two Polyphant samples ($D = 184^\circ, 204^\circ; I = +27^\circ, +69^\circ$) suggested to Cornwell (1967) an earlier magnetisation than that of the greenstones; probably Upper Devonian or Lower Carboniferous. This might represent either the age of intrusion or that of alteration of mafic minerals (mainly olivine) to produce magnetite. Such an early date would imply that metamorphic heating by the granite was insufficient to remagnetise the magnetite (curie temperature = 578°) at Polyphant but capable of remagnetising pyrrhotite (curie temperature = 310°) in the dolerite at Two Bridges Quarry [SX 305 817].

Little is known about possible deformation of the peridotite since its intrusion, though parts of the mass show the effects of intense shearing, and it is possible that variance from the Permian means of D and I (202° and +7°) may still be consistent with a Lower Permian magnetisation and subsequent deformation. Furthermore, modelling techniques may be limited by the significant anisotropy of susceptibility to be expected in a layered igneous complex; Cornwell (1965) records a susceptibility of $5.528 \pm 2.315 \times 10^{-3}$ gauss oersted^{-1} for the Polyphant New Quarry.

Magnetic surveys
An aeromagnetic survey was flown for IGS in 1958 along north-south flight lines with a mean separation of 400 m and a mean terrain clearance of 152 m. The strong positive anomaly of the Polyphant complex lies within a larger zone of positive magnetic anomalies trending WNW-ESE associated with the regional structure. This positive zone is flanked by negative zones to the southwest and northeast.

Cornwell (1965) indicated remanence to be significant in the Polyphant complex (Koenigsberger ratio Q, up to 0.4). Model interpretations of the aeromagnetic anomaly incorporating remanence and using intensities of magnetisation in the range 500-1000 nT, can explain 95% of the anomaly in terms of a shallow magnetic body (less than 200 m deep) with a northerly dip of less than 20° to its lower contact.

Ground magnetic traverses by McDonald (1970) (traverses M1-M36) and by IGS (traverses M101-M103) are shown in Fig. 7 and two of the profiles are illustrated in

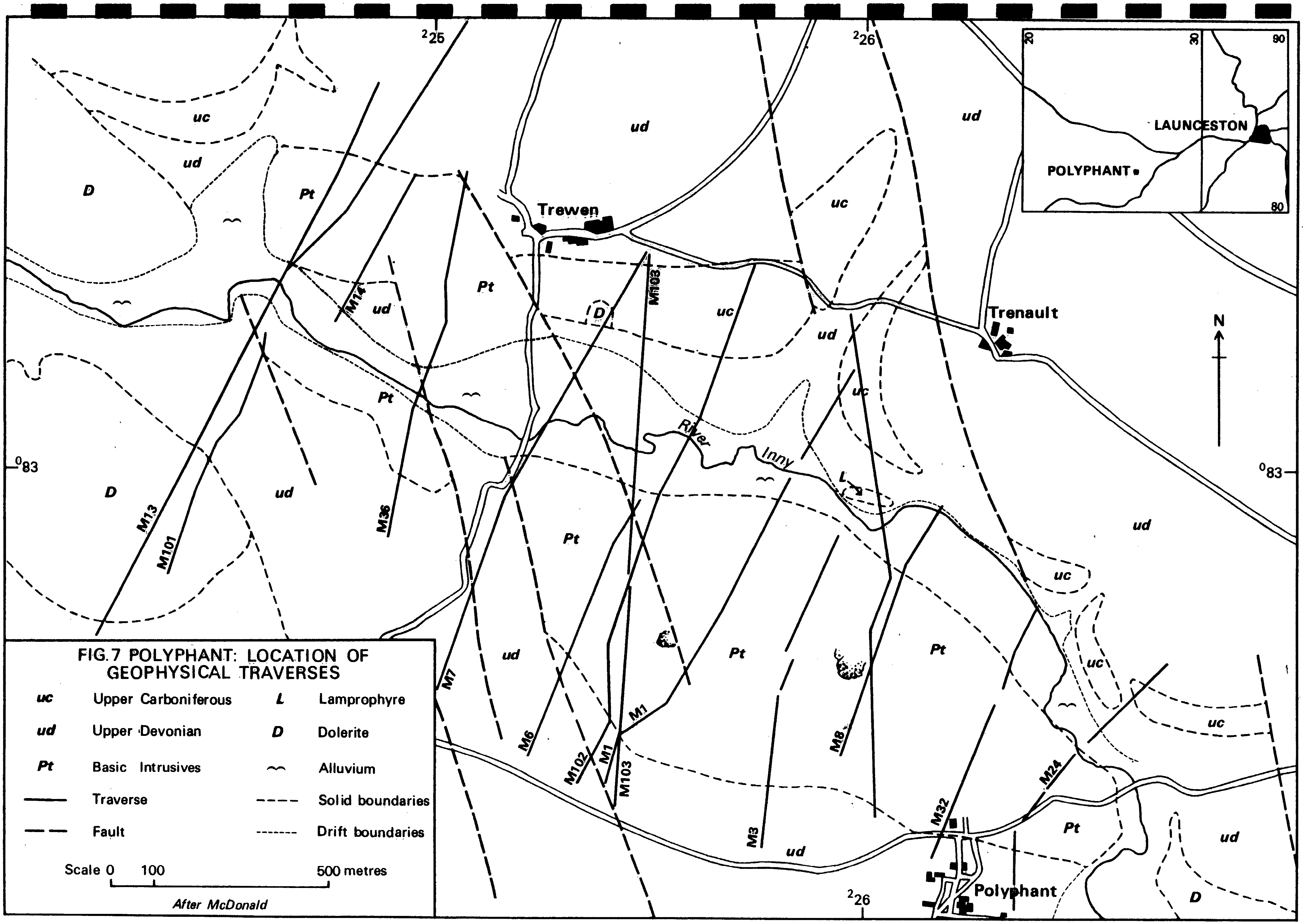

FIG.7 POLYPHANT: LOCATION OF GEOPHYSICAL TRAVERSES

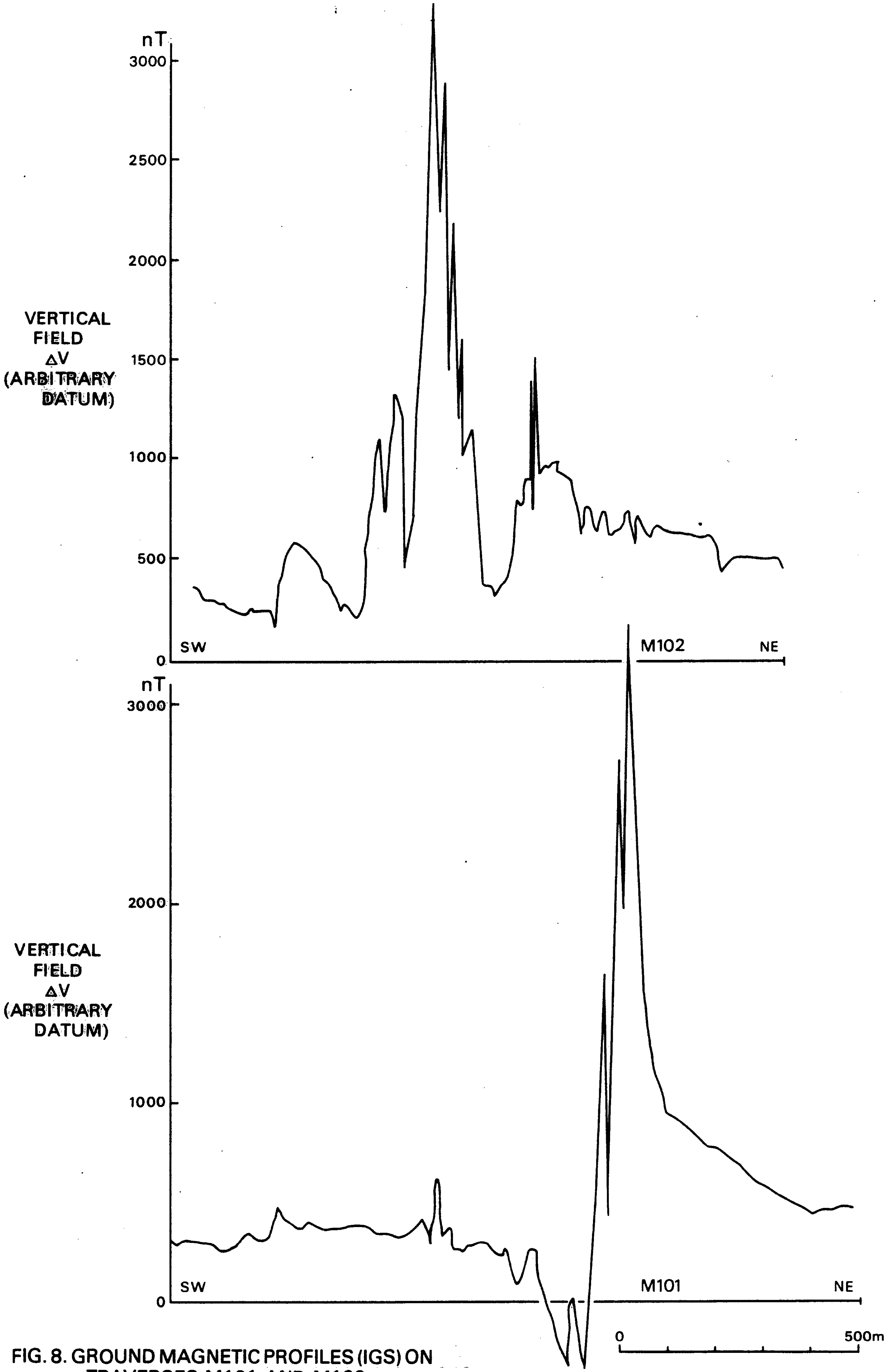

FIG. 8. GROUND MAGNETIC PROFILES (IGS) ON TRAVERSES M101 AND M102

Fig. 8. Observations (by McDonald) were not standardised, so only qualitative interpretations are possible. The ultrabasic body shows magnetic lineations attributable to mineral layering; in some parts (eg the southwest outcrop) the rock appears to be poorly magnetic and this may reflect increased grain size as well as low contents of magnetic minerals. Anomalous zones can be plotted as magnetic lineaments whose orientation pattern suggests several phases of deformation since consolidation. Overall the pattern indicates a clockwise rotation of the western ends of the outcrops and this may be associated with the emplacement of the Bodmin Moor Granite. The southwestern outcrop of coarse gabbro, over which there is no significant magnetic anomaly, may represent a slice detached from either the Trewen outcrop or the main body. If the latter is the case, the lack of magnetic anomalies might be due to the magnetic lineations being parallel to the traverse directions.

Induced polarisation survey

A reconnaissance profile was surveyed across the main peridotite outcrop with a dipole length of 50 m and separations of up to 250 m (penetration of $n = 5$). A Huntec Mark III IP instrument was used with a duty ratio of unity, a delay time of 120 ms and a sample time of 60 ms. Chargeabilities were measured over the period 120-1020 ms after switch off, using a 2 s polarising pulse.

The results show a range of apparent resistivities of 200 to 1000 ohm metres with maximum values towards the south and minimum values over the peridotite. High chargeability values are a feature of the peridotite margins, especially the southern one. Drilling of the northern contact intersected no mineralisation but it is possible that minor sulphide concentration at the southern margin (not drilled) might explain the chargeability maximum.

CONCLUSIONS

The Polyphant ultrabasic mass exhibits a marked variation in composition, with two types of peridotite and two of gabbro seen in shallow boreholes. Internal layering of the igneous rocks is apparent in the drill cores and is suggested in the western outcrops but in neither case is there evidence of significant concentrations of magnetite, chromite or sulphides. Distribution plots of Ni, Co and Cr in soils convey an impression of macro-layering within the peridotites but seem not to differentiate between the two variants of this rock type.

Geological interpretation of the structure of the mass is hampered by the paucity of exposure but drilling has indicated that the northern contact is intrusive, the southern contact being unexplored. Aeromagnetic data indicate a sheet-like body less than 200 m thick with a northerly dip of 20°. An Upper Devonian to Lower Carboniferous age is tentatively suggested but the alternative age of Lower Permian for the magnetisation cannot be ruled out.

The pattern of magnetic lineations suggest post-magnetisation deformation of the body with a clockwise rotation of the western end of the outcrop which may be an effect of the intrusion of the Bodmin Moor Granite.

Levels of Ni, Co, Cu and Cr concentration are normal or low for soils overlying peridotites and gabbros. With the exception of some IP data indicative of minor sulphide enrichment at the southern margin of the complex, there is no evidence of anomalous metal concentration due to mineral settling or wall rock reaction and it is concluded that the complex holds no potential for the discovery of workable deposits.

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APPENDIX I

BOREHOLE LOGS COMPILED BY THE INSTITUTE OF GEOLOGICAL SCIENCES

Borehole 1

	To depth (metres)
OVERBURDEN *Not cored*	9.75
DEVONIAN SLATES Soft grey slates with cleavage at 20°-48° to horizontal. Minor pyrite along joints	24.08
SHEAR ZONE Sheared and argillised slate, altered to a white clay in part	27.25
SLATE Grey slate with ferruginous veining	29.11
LIMESTONE Dark grey, compact limestone with clay-actinolite-iron oxide joint coatings	31.70

Borehole 2

OVERBURDEN *Not cored*	4.88
PERIDOTITE Alternating layers of hard and softer peridotite. The harder variety is fresh and dark green in colour resembling the 'Polyphant Stone', whereas the softer peridotite has been highly altered, being talcose in part with abundant veinlets of fibrous asbestos	33.83

Borehole 3

OVERBURDEN *Not cored*	1.63
PERIDOTITE Fresh, tough, dark green fine-grained rock	3.20

Hole abandoned: redrilled as 3a

Borehole 3A

OVERBURDEN *Not cored*	5.18
PERIDOTITE Fine-grained, tough and very dark rock	5.64

Hole abandoned, redrilled as 3b

Borehole 3b

OVERBURDEN *Not cored*	2.74
PERIDOTITE Hard, dark peridotite with some thin asbestos and calcite stringers	6.32

Borehole 4

	To depth (metres)
OVERBURDEN *Not cored*	6.40
GABBRO Medium-grained igneous rock, highly altered near surface but becoming harder and fresher with depth. The amphiboles remain unaltered and some iron oxide is present below 13 metres	23.77
GABBRO Coarser grained, intensely altered igneous rock. No apparent ferromagnesian minerals intact. Iron oxide fills small cavities. Occasional bands of less altered gabbro occur, with abundant feldspar and some unaltered amphibole	40.74
Finer-grained, lighter grey, feldspathic gabbro, becoming coarser in depth	43.13

Borehole 5

OVERBURDEN *Not cored*	6.40
PERIDOTITE Intensely altered, fine-grained, highly ferruginous rock. Cut by a white massive quartz vein at 7.34 to 8.03 metres	17.37

Borehole 6

OVERBURDEN *Not cored*	4.27
PERIDOTITE Medium-grained, dark bluish green peridotite. Occasional joint fillings of calcite, actinolite and chlorite. Moderately hard throughout but softer and rather more altered towards the base	33.73
GABBRO Intensely altered cellular rock, consisting predominantly of a yellow ferruginous clay	37.34
Fine-grained, spotty gabbroic rock composed of white feldspar, chlorite and dark pyroxene or amphibole	38.71

Borehole 7

OVERBURDEN *Not cored*	14.94
PERIDOTITE Dark green, medium-grained rock with some lighter carbonate spots. Considerably altered and cut by irregular white dolomite veins with some quartz. Sheared from 27.74 metres to the base	28.65
GABBRO Pale green, coarse-grained rock with abundant feldspar and some secondary quartz	30.22
PERIDOTITE Broken and sheared in the upper metre. Thereafter it is altered with chlorite and talc minerals along joints and dolomitic carbonate at 39.32 metres. Pyrrhotite is seen throughout and pyrite, carbonate and quartz form vein associations at 46.50-47.0 metres	54.25

Borehole 8

OVERBURDEN *Not cored*	2.74
PERIDOTITE Very fine-grained, black peridotite, unaltered near surface but displaying a little deuteric alteration with depth. Some calcite, chlorite or asbestos joint fillings	36.42

	To depth (metres)
GABBRO Spotted feldspathic rock with whitish grey feldspars and some ferro-magnesian minerals. Occasional calcite veins	43.28

Borehole 9

OVERBURDEN *Not cored*	2.36
PERIDOTITE Greyish green 'Polyphant Stone'. Fairly soft with talcose, chloritic or carbonate joint fillings. A ferruginous alteration which is patchy near surface becomes very marked towards the base	22.86
GABBRO Medium-grained, feldspathic rock which is very variably altered	26.67

Borehole 10

OVERBURDEN *Not cored*	1.22
PERIDOTITE Greyish green, fine-grained rock, altered principally to chlorite. Frequent joints carry some calcite. Occasional disseminated pyrrhotite	10.06
As above but more altered with a few small calcite veins but no pyrrhotite seen	12.93

Borehole 11

OVERBURDEN *Not cored*	4.57
GABBRO Green and white mottled rock of moderately fine grain. Weathered at surface to a brown clayey rock. Below 9.14 metres it is rich in white feldspar, amphibole and pyroxene with a completely altered ferromagnesian mineral. A vague banding dips at 40° to the horizontal. Towards the base, the rock is more altered and heavily jointed	31.78

Borehole 12

OVERBURDEN *Not cored*	3.96
DEVONIAN SLATE Grey slate with a cleavage at 0 to 25° to the horizontal. Iron staining on joint faces. Some small vertical calcite veins	24.38
LIMESTONE Fine-grained, calcareous rock with abundant chlorite	25.30
SLATE Grey slates with cleavage from 30° to 50° to the horizontal. Many small calcite veins cut the slate and disseminated pyrrhotite is seen around 49 metres	50.75
LAMPROPHYRE Light grey rock composed largely of dolomite with fine-grained margins and a coarser central zone	52.73

	To depth (metres)
SLATE Grey to black slate with a cleavage from 30°-45° to the horizontal	53.95
PERIDOTITE Altered igneous rock containing several thin calcite veins	58.37

Borehole 13

OVERBURDEN *Not cored*	2.44
DEVONIAN SLATES Grey, argillised slate showing iron staining on joint surfaces. Cleavage varies from 0 to 15° to the horizontal. Infrequent quartz veins throughout the slates	20.57
LIMESTONE Very fine-grained, light grey limestone bearing a few irregular quartz veins	21.64
SLATES Uniform, grey slates with infrequent quartz veins. Cleavage varies from 0 to 15° to the horizontal. Occasional calcareous bands occur	58.22
LIMESTONE Light grey limestone cut by quartz-calcite veins bearing a little pyrrhotite	59.13

Borehole 14

OVERBURDEN *Not cored*	2.29
DEVONIAN LIMESTONE Fine-grained, light grey limestone with surface cavities	3.20
SLATES Light grey, argillised slate cut by many quartz and calcite veins. The cleavage varies from 10°-50° to the horizontal. Pyrite seen on joint facies at around 16.0 metres	28.96
GABBRO Fine-grained, fresh rock showing an ophitic texture. Consists mainly of feldspar and amphibole	29.26

Borehole 15

OVERBURDEN *Not cored*	6.10
DEVONIAN Grey slates, showing iron staining on joint surfaces. Cleavage varies from 0°-20° to the horizontal. Pyrite appears on joint faces and disseminated through the slate. Occasional quartz veinlets and calcite fragments	41.30
PERIDOTITE Fine-grained, dark greyish green, altered and chloritised ultrabasic rock. The rock shows frequent carbonate veins up to 25 mm wide	46.94

Borehole 16

OVERBURDEN *Not cored*	3.96
DEVONIAN SLATE Grey slates, highly jointed with calcite or clay forming joint coatings. Cleavage varies from 5°-30° to	

	To depth (metres)
the horizontal. Quartz and calcite veins cut the slate and in places are associated with pyrrhotite	39.24
PERIDOTITE Dark greyish green, altered peridotite. Calcite is present in veins and on joint surfaces. Disseminated pyrite may be seen in places	50.29

Borehole 17

OVERBURDEN *Not cored*	4.88
PERIDOTITE Dull green 'Polyphant Stone' with several carbonate veinlets. Iron oxides near surface are distributed as small spots. Below 13.0 metres some pyrite cubes seen	29.49
DOLOMITISED ULTRABASIC ROCK Varying amounts of light mineral in the rock with vague alternations of darker and paler green colours, reflecting the composition. The percentage of dolomite present increases markedly with depth	45.81
QUARTZ VEIN Massive vein quartz and abundant rhombs of creamy coloured dolomite	46.85