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. 41

Metalliferous mineralisation near Lutton, Ivybridge, Devon

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Metalliferous mineralisation near Lutton, Ivybridge, Devon

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SUMMARY

To the north-west of Slade Hall localised uranium and base metal mineralisation has been traced by radiometric and geochemical soil surveys. It is confined to two narrow structures in a fault zone trending NW—SE and at surface it has a strike length of no more than 200 m. Percussive drilling down to the shallow water table indicated persistence of the secondary metalliferous minerals but narrow diameter cored drilling failed to intersect any recognisable well-mineralised structure at a depth of only 50 m. It remains uncertain whether a small ore shoot exists below the surface anomalies; if so, it must be presumed to pitch south-eastwards.

Only oxidised, and possibly enriched, mineralisation has been sampled; this yielded a little cassiterite, sphalerite, pyrite, pyrrhotite and covellite, abundant hydrated iron and manganese oxides with adsorbed uranium, lead, bismuth, zinc, copper and arsenic, and flakes of secondary uranium and silver minerals. Radiometry confirmed gross uranium disequilibrium.

HISTORICAL BACKGROUND

A car-borne radiometric survey, conducted in 1971 on behalf of the United Kingdom Atomic Energy Authority, located a significant anomaly in a sunken lane about 0.5 km south of the village of Lutton [SX 595 594] * in South Devon (see Figure 3). It was associated with an outcrop of uraniferous gossan in the north bank of the lane which gave readings of 400 μR/hr on a hand-held scintillation meter. Analysis of outcrop samples by rapid scan X-ray fluorescence (XRF) showed values of 3% Cu, 1% U, 1% Bi, 0.5% As and 500 ppm Ag. A reconnaissance radiometric survey north of the lane failed to locate any anomalous radioactivity but southwards readings above 20 μR/hr could be traced for 40 m along a NW—SE trend (Bowie and others, 1973).

Such metal values and the persistence of a discrete radiometric anomaly, located in an area hitherto unmined and assumed as devoid of significant mineralisation, were considered worthy of further investigation. Under the auspices of the Mineral Reconnaissance Programme radiometric mapping and geochemical sampling were initiated, followed by percussive drilling and a cored drill hole.

* All grid references quoted in this Report fall within the 100 km National Grid square SX

LOCATION AND GEOLOGY

The area investigated covers a succession of fields lying immediately north-west of Slade Hall [598 585] on either side of the narrow lane south from Lutton village (Figures 1 and 2). Although only 7 km from Ivybridge [635 565] and close to the main rail line, dual carriageway trunk road and bus route to Plymouth, the area is one of quiet rural isolation served by a network of hedged narrow lanes and minor roads. The ground slopes gently south-eastwards and more steeply eastwards to the Piall River, a tributary of the River Yealm, and is wholly devoted to mixed arable and stock farming.

The geology of the site area (Figure 2) is imperfectly known, there being little exposure and an ubiquitous covering of head debris; the district was last surveyed in 1894 and is described in the Ivybridge and Modbury Memoir (Ussher and Barrow, 1912). Between Slade Hall and the gossan outcrop the ground is underlain by grey Upper Devonian slates which are poorly exposed in the sunken lane. North of the lane the bedrock is mainly of moderately coarse greenstone and tough, fine-grained volcanic rock, both varieties being well represented as large float fragments. The contact between igneous and sedimentary rocks is ill-defined though, from regional structural considerations, it had been assumed that the greenstone overlies the slates, both dipping northwards. A further outcrop of volcanic rock, mapped around a quarry exposure south-east of Slade Hall, is of tough, fine-grained agglomeratic tuff. Its connection, if any, with similar rocks in the north of the area is not determinable. To the east the solid rocks are covered by the alluvium and terrace deposits of the Piall River.

The site lies within an embayment in the Dartmoor Granite outcrop and the granite margin lies about 2 km to the west-north-west, 3 km to the north and 2 km to the east. Although mapped as within the thermal aureole, the slates are only slightly and variably metamorphosed. Some fragments are well spotted, others unaffected, and some appear to have original mineral spots (pyrite or chlorite?) replaced by earthy iron oxides. The greenstone locally exhibits greater evidence of

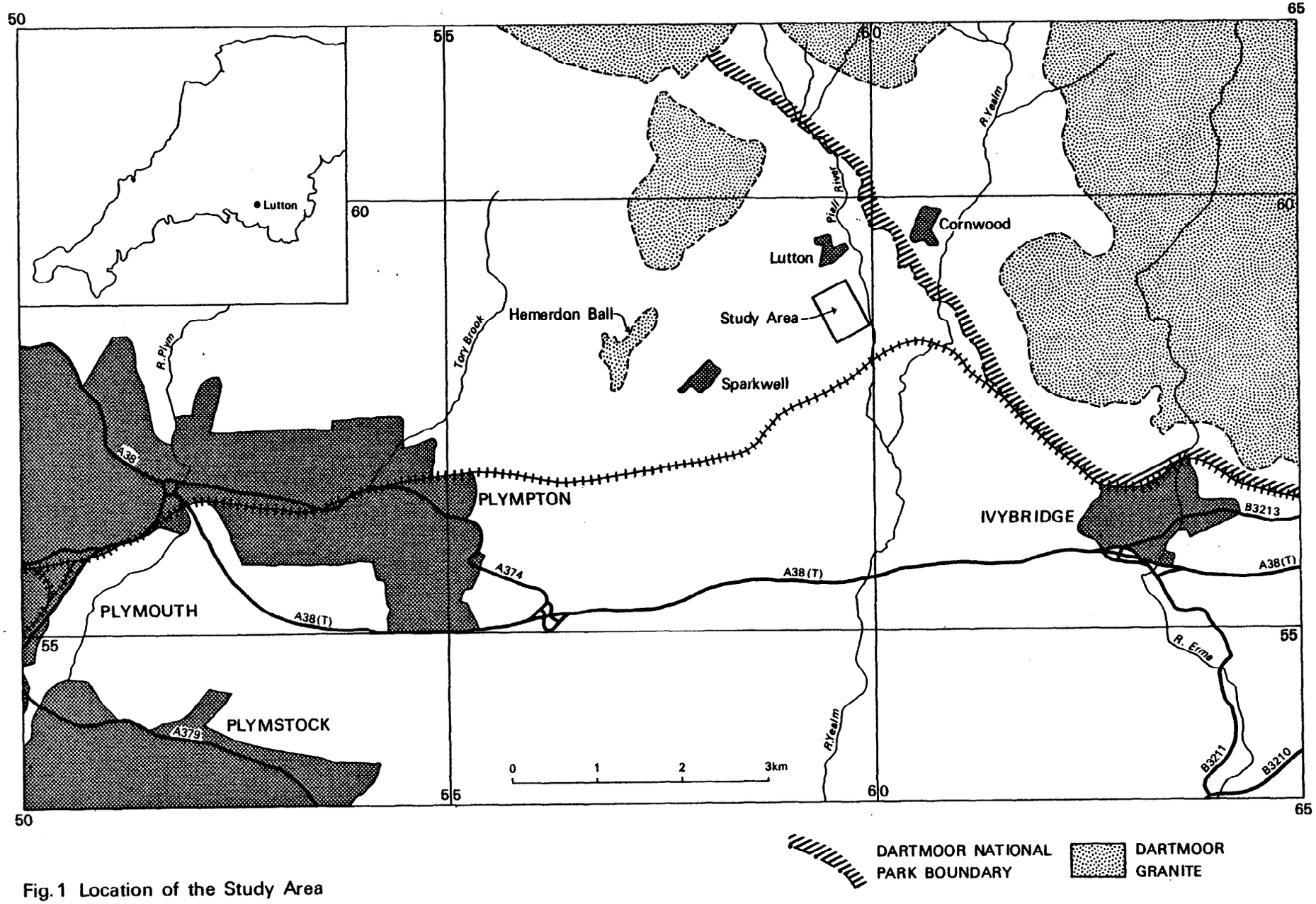


Fig. 1 Location of the Study Area

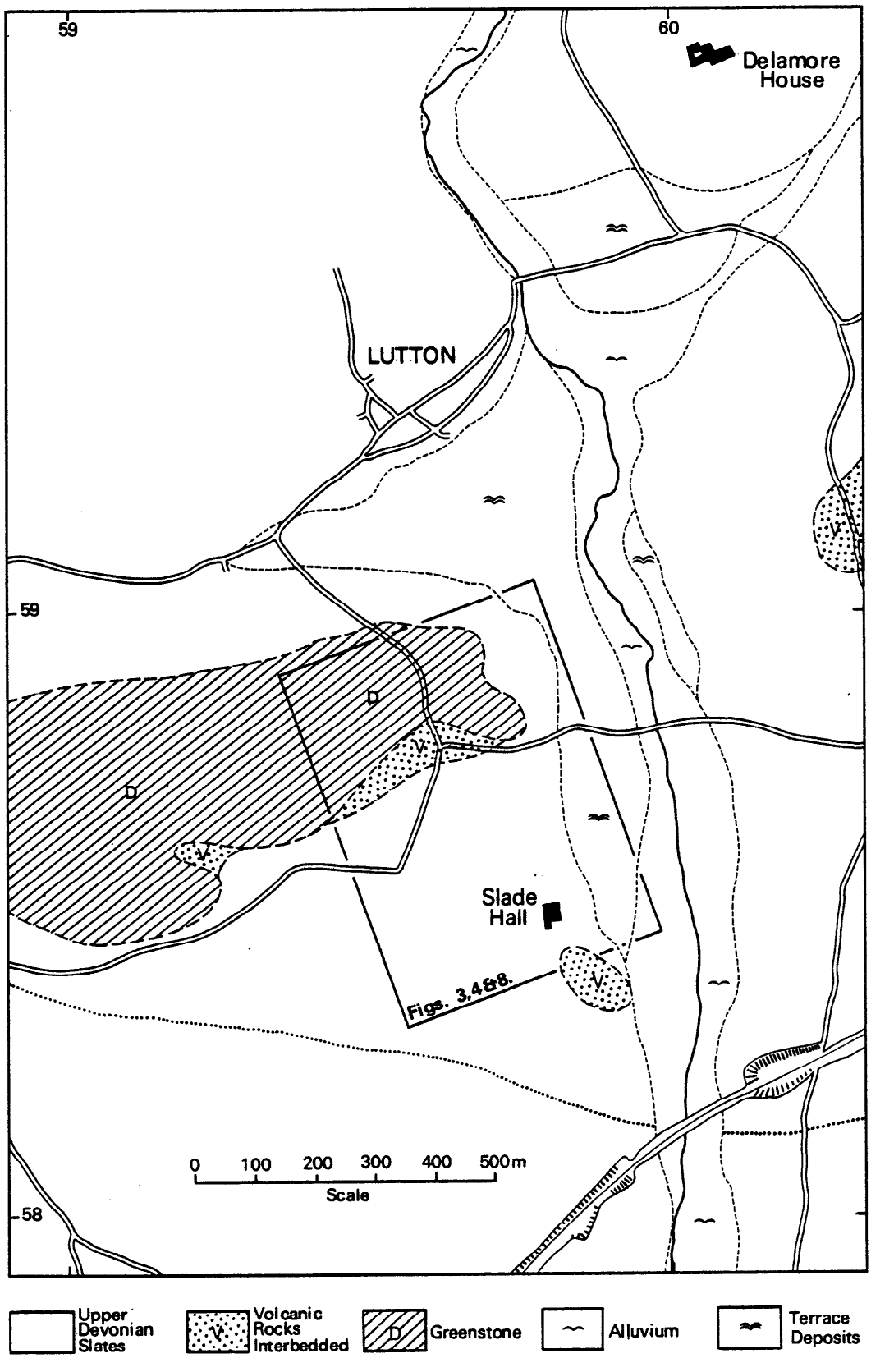


Fig. 2 Geology of the Lutton District (After W.A.E. Ussher, 1899)

thermal alteration, becoming fine-grained, siliceous and containing fine tourmaline. Close to the greenstone outcrop some slate fragments have a more indurated and siliceous appearance which is assumed to reflect metasomatic alteration by the basic intrusion.

Head deposits cover the entire area. In the north it consists of a brown clay containing abundant fragments, both large and small, of the underlying greenstone and volcanic rocks. To the south it is a more variable light greyish brown or yellowish brown clay with fewer stones, most of which are white vein quartz.

MINERALISATION

There is neither physical evidence nor local information to suggest that metalliferous minerals have been sought underground in the vicinity of the site. Although most of the streams draining southern Dartmoor have been tried for alluvial cassiterite, the Piall River near Slade does not appear to have been worked by the 'tinners'.

The nearest mine workings are those on and around Hemerdon Ball [570 582] and the Ivybridge Consols (Fillham Silverlead) Mine [647 550], about 2 km south-east of Ivybridge (Dines, 1956). The former worked east-west lodes for tin and tungsten, the latter a north-south vein of galena, sphalerite and fluorite.

In the tract between Lutton and Hemerdon Ball one anomaly was recorded during an airborne radiometric survey commissioned by the United Kingdom Atomic Energy Authority in 1959. This occurrence [584 588], near Houndall Farm north-east of Sparkwell village, was examined by Hawkes (1960) who identified the source as narrow north-north-west and west-north-west fracture fillings of iron oxides with torbernite within greenstone. Pyrite and chalcopyrite were the only associated metallic sulphides recorded and XRF analysis showed a little arsenic.

RADIOMETRIC INVESTIGATIONS

Detailed radiometric measurements were made with a hand-held scintillation meter over the fields north and south of the lane outcrop to determine the extent of the anomaly. Readings were taken at 2 m intervals along east-west lines spaced 10 m apart. Against a radiometric background of 10–12 μR/hr, contouring at 15 μR/hr suggested a linear causative structure extending north-west and south-east from the lane outcrop (Figure 3). The maximum reading, other than at the outcrop, is of 28 μR/hr and occurs in the lowest field adjacent to the river.

With an Ekco radon monitor, measurements of radon gas in soil were taken at 5 m intervals along three traverses (Figure 3) in an attempt to define the full lateral extent of the anomaly. Anomalous radon readings were confined to the area within the 15 μR isorad, suggesting no appreciable widening of the radon source at depth. Spot readings taken in the river alluvium showed no south-eastern extension of the radiometric anomaly.

GEOCHEMICAL SOIL SAMPLING

Initial geochemical investigations were based upon 42 sampling sites aligned along four traverses (A–D) south of the lane outcrop, three of which had been used for radon measurements (Figure 4). Along lines A and B sampling sites were spaced at 5 m intervals, along lines C and D at 10 m intervals. Two samples were taken at each site, an 'A' horizon sample from 0.05 or 0.10 m depths and a 'C' horizon sample from depths varying from 0.33 to 0.97 m. The 'A' horizon sample was collected to investigate the possibility of silver being concentrated in the upper organic soil layers.

North of the outcrop, three soil traverses (E, F, G) were subsequently collected, samples being taken from the 'C' horizon only. Along lines E and F sampling sites were 5 m apart, along line G they were at 10 m intervals.

All the samples were dried, disaggregated in a mortar and pestle and sieved at 60 mesh BSS size. The undersize fraction was then analysed by atomic absorption spectrophotometry for Cu, Pb, Zn and Ag and, for the A, B, C and D traverse samples, by neutron activation analysis for U. The results are illustrated in Figures 5, 6 and 7 and are discussed below; analytical data are given in Appendix I.

Copper

The 'A' and 'C' horizon samples do not differ significantly in their copper contents except for those from 10 m along traverse B where the high value (245 ppm) in the 'C' horizon is not reflected in the 'A' horizon. Values range from 30 to 245 ppm in 'C' horizon and 55 to 130 ppm in 'A' horizon; the 'C' horizon mean value is 75 ppm and the standard deviation 30 ppm. A cumulative frequency plot of 'C' horizon values shows a distribution which is close to log normal. As well as the sharp anomaly 10 m along traverse B there is a small anomaly 15 m from the eastern end of traverse A and a broad zone of slightly elevated copper values in the eastern half of traverse G; the latter undoubtedly partly reflects the in-situ weathering of greenstone.

Lead

There is considerable variation between the lead contents of the 'A' and 'C' horizon samples (Figures 5 and 6) and little consistency in the relationship between values in the two layers. In

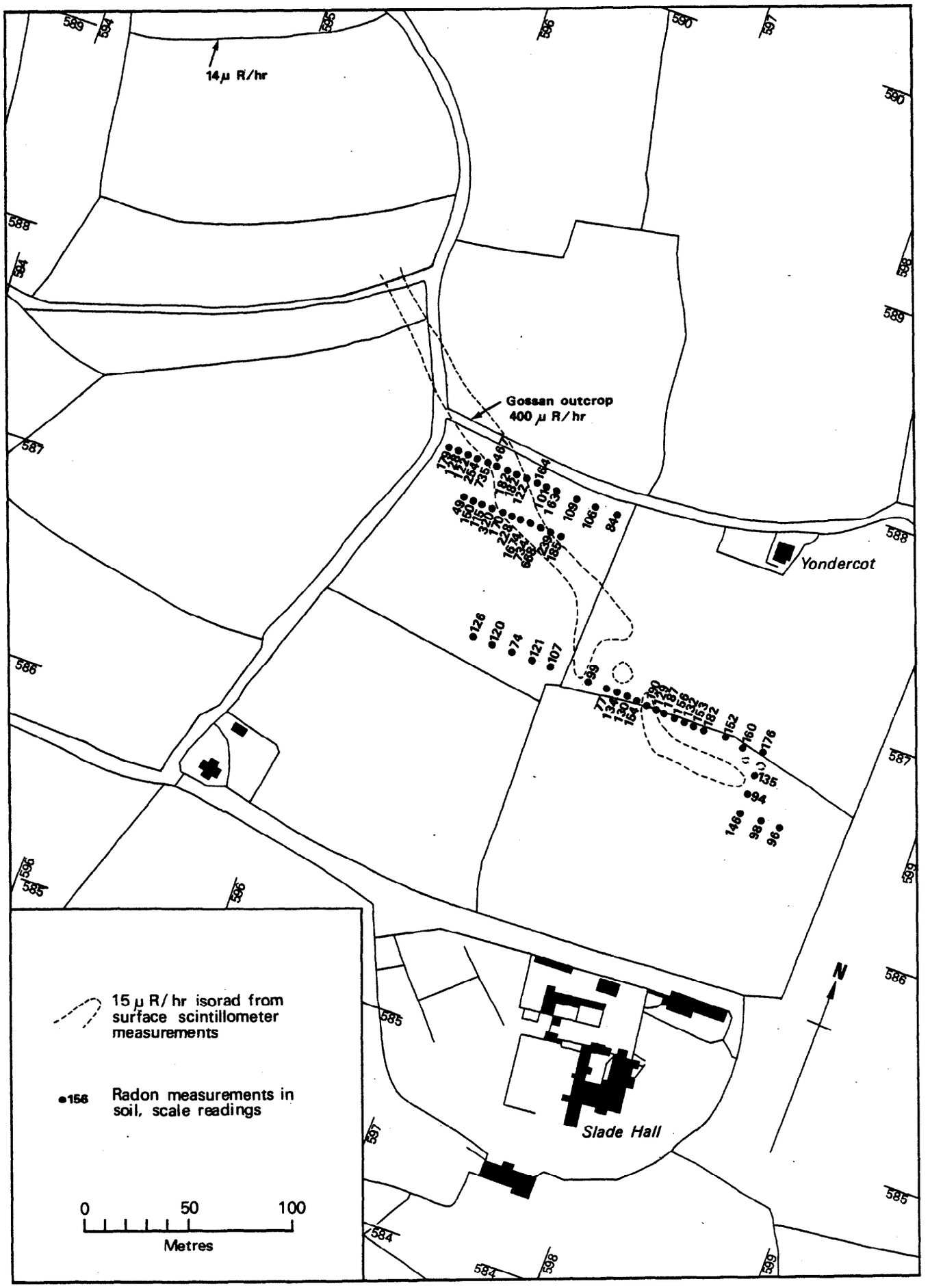


Fig. 3 Radiometric anomaly

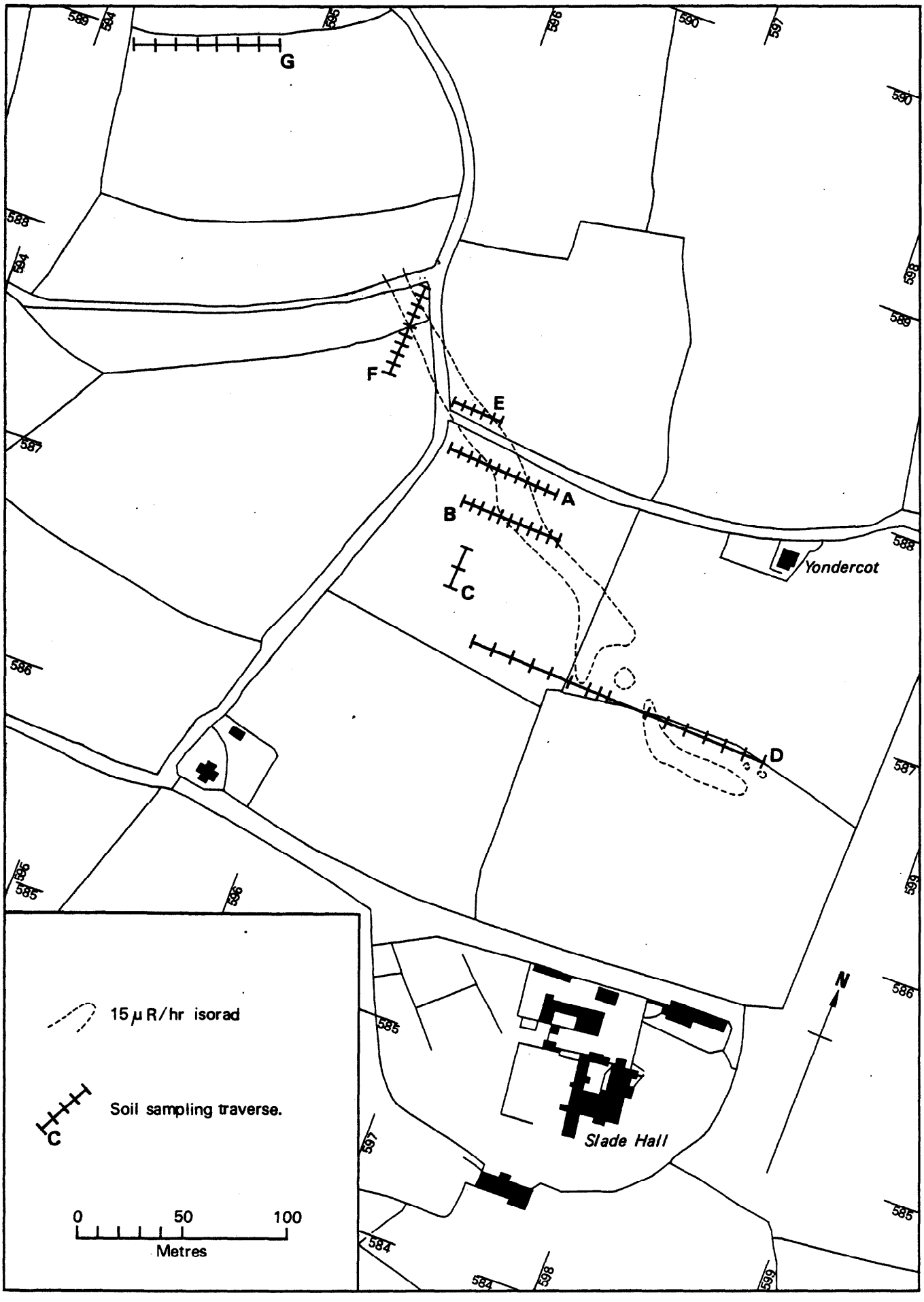


Fig. 4 Soil Traverses

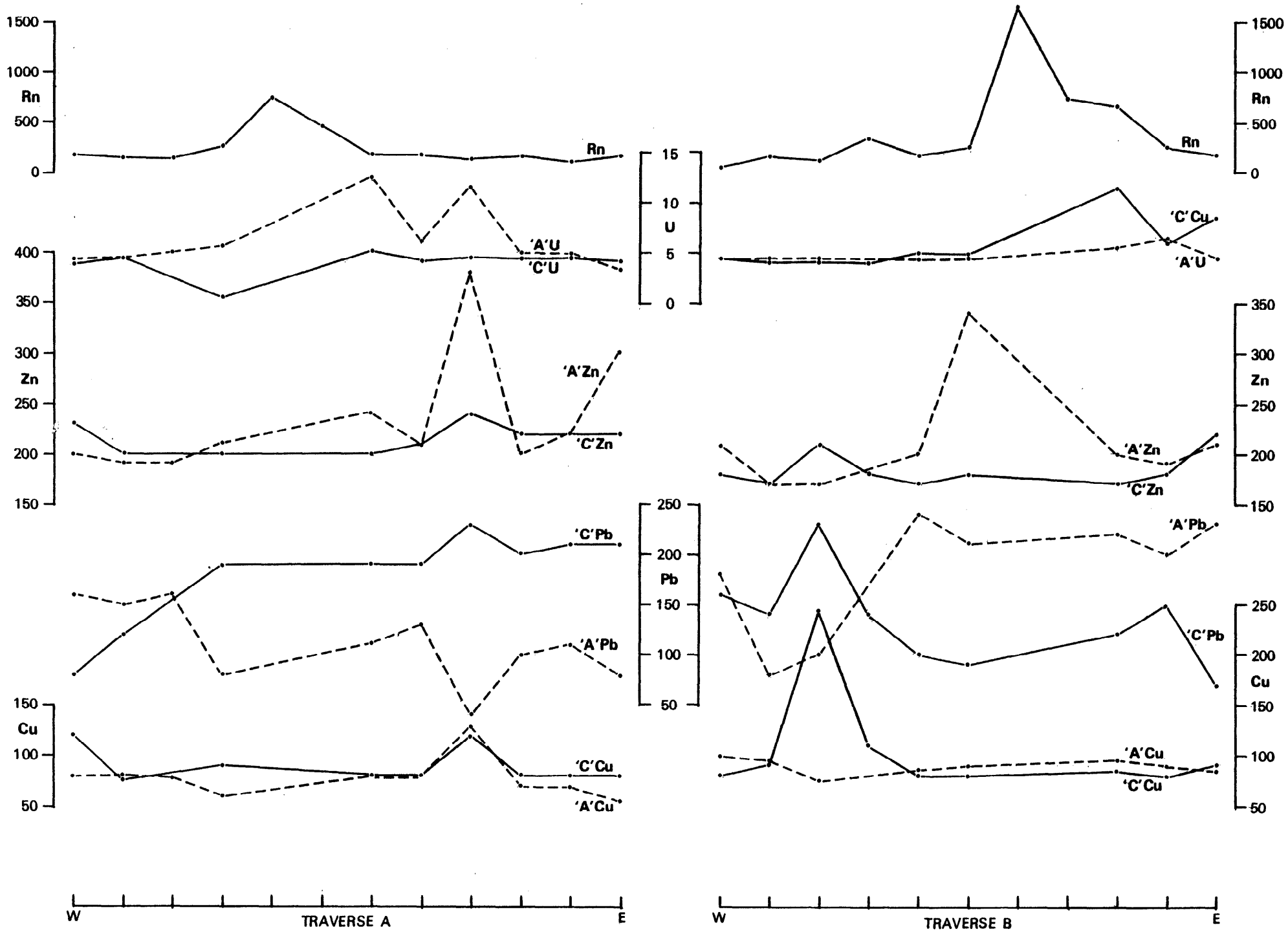


Fig.5 Geochemical Results : Traverses A and B

Metals in ppm, Radon in meter readings. Horizontal scale 1:500

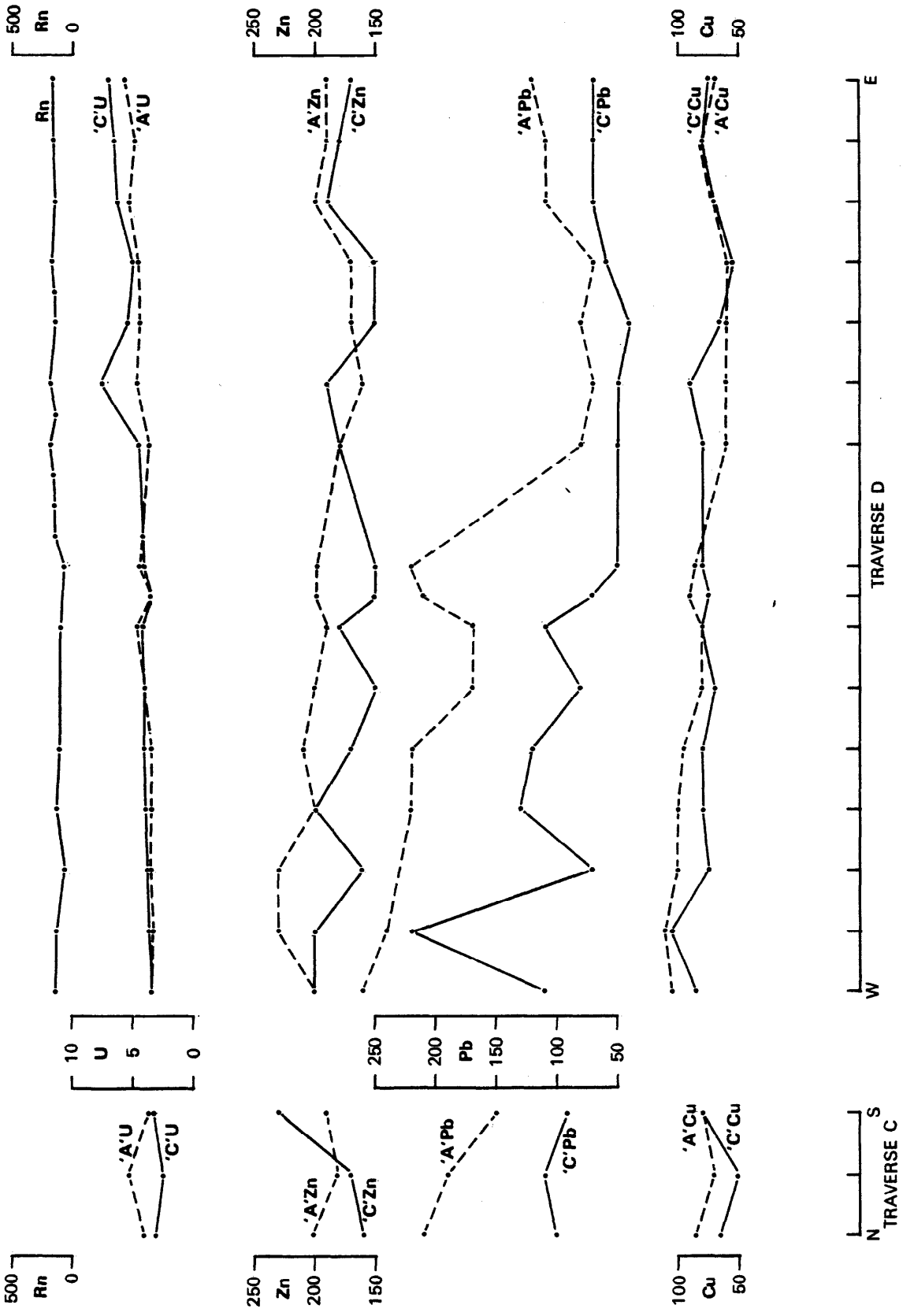


Fig. 6 Geochemical Results : Traverses C and D

Metals in ppm; Radon in meter readings. Horizontal scale 1:1000

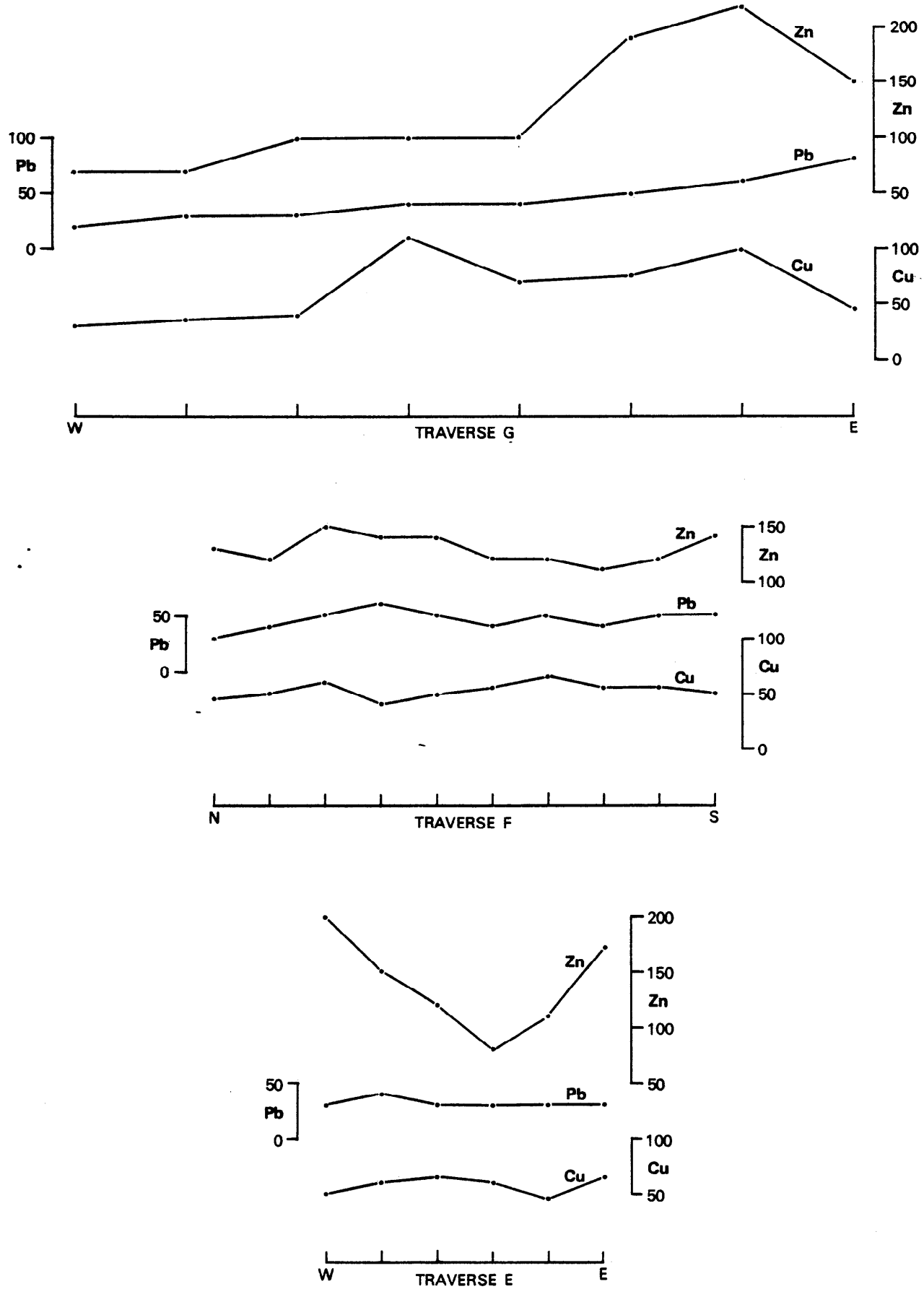


Fig.7 Geochemical Results : Traverses E,F and G

Metals in ppm; Horizontal scale 1:500

traverse D (Figure 6) the 'A' horizon values are higher than those for the 'C' horizon but elsewhere there is a general inverse correlation between the deeper and shallower samples. No obvious geological, pedological or hydrological reason can be advanced for this curious behavioural pattern, nor can agricultural contamination provide a satisfactory explanation.

The range of lead values is not dissimilar in the two horizons, 20 to 230 ppm in the 'C' and 40 to 260 ppm in the 'A', but the mean values are markedly different, 90 and 154 ppm respectively. Both show a standard deviation of 60 ppm. A cumulative frequency plot of the 'C' horizon values indicates two sample populations with a point of reflexion at 195 ppm.

Anomalous 'C' horizon lead values coincident with anomalous copper and zinc levels are located near the eastern end of traverse A and the western end of traverse B. There is also a sharp lead anomaly 10 m along traverse D, but this is not associated with other metals. In the northern traverses lead levels are uniformly low in the soils, reaching only 80 ppm.

Zinc

Variations in the zinc levels between 'A' and 'C' horizons are irregular; traverses A and B each show a peak in 'A' horizon values significantly greater than the equivalent rise in 'C' horizon values, whilst in traverse D the two values are commonly antipathetic.

'C' horizon values exhibit a total range of 70 to 240 ppm with a mean value of 165 ppm and a standard deviation of 41 ppm. A cumulative frequency plot indicates two sample populations with a reflexion point at 195 ppm. By comparison the 'A' horizon values range from 160 to 380 ppm, have a mean value of 209 ppm and a standard deviation of 44 ppm.

The best defined zinc anomalies occur in traverse B, coinciding with copper and lead peaks and in the eastern part of traverse G where the soils are derived from underlying greenstone. A smaller anomaly in traverse A also coincides with elevated copper and lead values.

Silver

With only two exceptions, all samples have a silver content of 1 or 2 ppm. The exceptions, both bearing 3 ppm, occur in the 'C' horizon at 10 m from the eastern end of traverse B and in the 'A' horizon at 30 m along traverse A. Significantly, both samples also contain anomalously high levels of uranium (11.4 and 12.4 ppm, respectively). There is no apparent preferential concentration of silver in the upper, organic soils.

Uranium

Uranium values in the 'A' and 'C' soils show an inconsistent pattern of behaviour. In traverses C and D they correlate reasonably closely, although in traverse C the 'A' values are somewhat higher than those in the 'C' horizon, whilst in traverse D they are slightly lower. Traverse A and the eastern part of traverse B exhibit marked variations between the uranium contents of the two horizons. Most of the uranium results are less than 5 ppm, the range being 0.5 to 11.4 ppm for 'C' soils and 3.2 to 12.4 ppm for 'A' soils. The 'C' horizon results give a log-normal cumulative frequency plot, a mean value of 4.7 ppm and a standard deviation of 1.8 ppm.

No significant pattern of distribution can be discerned and there is no clear correlation of uranium content, in either horizon, with the surface radiometric anomaly nor with the radon content of the soils (Figures 5 and 6).

Discussion

The distribution of base metals in the soils shows no clearly defined pattern which can be related either to the surface radiometric anomaly or to the subsurface geology. The coincidence of elevated Cu, Pb and Zn contents in the 'C' horizon samples at points on traverses A and B, however, suggests that there may be localised small concentrations of base metal ores within the slate sequence close to its contact with the greenstone. Although it would be an effective exploration criterion to be able to anticipate that any ore mineral concentration of the Lutton type would contain base metals and uranium in close association, the soil geochemistry provides no supportive evidence for this. Indeed, the two Cu-Pb-Zn peaks lie outside the radiometric and radon anomalies, that in traverse A being to the east and that in traverse B to the west of the radiometric anomaly. This lack of geochemical coincidence seems to belie the analytical evidence from the gossan outcrop, where copper, silver and uranium are all present in significant quantities.

PERCUSSION DRILLING

Poor correlation of the geochemical and radiometric anomalies leaves unresolved the possibility that base metals and uranium are associated in a north-westerly fracture filling which follows the rectilinear outline of the radiometric contours. To test this concept, however, ten inclined air-flush percussive boreholes were drilled immediately south (PH 1–3), farther south (PH 4–5) and well to the north (PH 6–10) of the lane outcrop (Figure 8), to intersect the postulated trend of mineralisation. All the holes were inclined at 45° except PH2 (60°) and carried down to the water table, the depth of which varied considerably from spot to spot. Dust and chippings, and in some cases wet slurry, were collected at regular intervals and checked for uranium content with a scintillometer and for copper, tin and barium with a portable

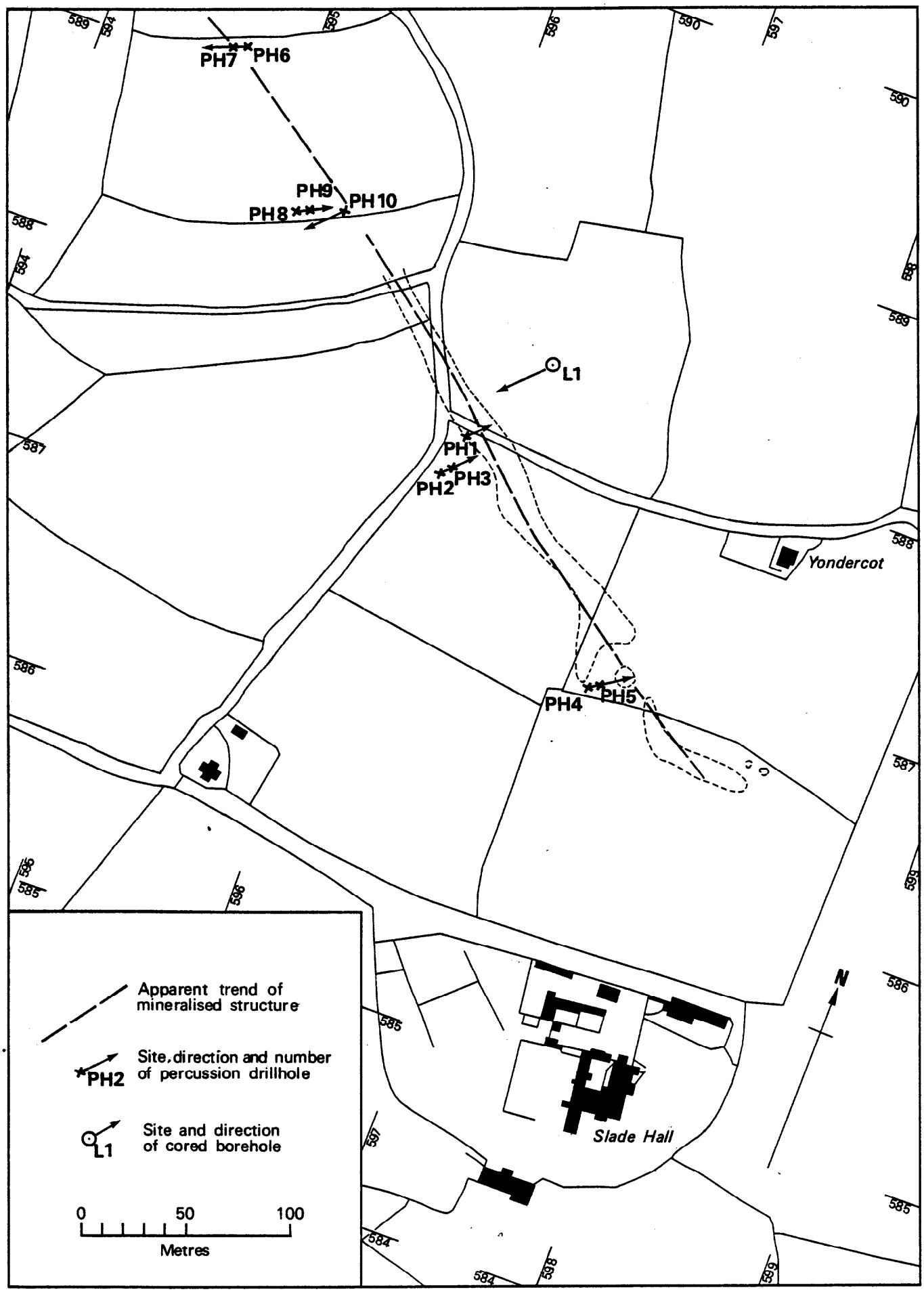


Fig. 8 Drilling Sites

Table 1 Percussion hole parameters

Hole No.	*Nat. Grid. Ref.*	*Azimuth*	*Inclination*	*Downhole length (m)*
PH 1	SX 59629 58772	048°T	45°	22.25
PH 2	SX 59624 58752	048°	60°	27.43
PH 3	SX 59629 58758	048°	45°	41.15
PH 4	SX 59725 58681	058°	45°	28.04
PH 5	SX 59730 58685	058°	45°	24.08
PH 6	SX 59471 58915	248°	45°	28.04
PH 7	SX 59462 58911	248°	45°	27.13
PH 8	SX 59519 58850	064°	45°	37.34
PH 9	SX 59526 58852	064°	45°	21.95
PH 10	SX 59540 58857	225°	45°	21.64

X-ray fluorescence meter. Particularly interesting samples were submitted for rapid XRF analysis and mineralogical examination. The completed holes were radiometrically logged using a slim diameter GM probe connected to a calibrated spark recorder.

The drilling equipment employed was a Holman's Vole Drill mounted on a crawler tractor chassis and towing its own air compressor. Compressed air provided power for the tractor base, rotation and hammer percussion for the drill bit and transport for the rock dust chippings, which were directed through a hood into the collecting sack. Tungsten carbide chisel or button bits were used. The hole diameter was 3½ inches (90 mm) and each 5 ft (1.5 m) length produced about 10 to 11 kg of sample.

In most instances the hole was stopped on penetrating damp rock (i.e. water table) in order that the sides of the hole were kept clean. On standing, the bottom of the hole usually filled with water. Where the hole proceeded further (e.g. PH 3) the return consisted of a clay slurry which coated the hole walls, probably invalidating the radiometric down-hole log (Figure 10).

PH 1–5 were drilled essentially in slates, though thin bands of harder material (volcanic beds?) were encountered. For the most part the slates were grey and somewhat silty with a near-surface oxidation which was brown and ferruginous. In PH 2 a thin black slate was penetrated but this was not seen in PH 3. PH 6–10 were all sited in greenstone, usually hard and fresh but with thin zones of softer alteration, presumably around joints. Parameters of the percussion holes are given in Table 1.

PH 1

Between about 12 and 16 m inclined depth this hole penetrated a rather soft, highly ferruginous zone containing lenses or veinlets of broken quartz in which small specks of yellow sulphide ores were present. Both quartz and slate fragments showed scattered flakes of a green secondary uranium mineral. The vein zone is clearly defined as a sharp peak in the down-hole radiometric log (Figure 9) in which the maximum radioactivity occurs at 13.8 m and represents a content of 16% equivalent ^{238}U. Measured at half peak-height (about 7% eq. ^{238}U) the anomaly is 1.72 m wide, extending from 12.99 to 14.71 m. Being derived from within the zone of secondary alteration, the radioactive content is grossly out of equilibrium and quantitative XRF analysis of the rock powder shows only 0.13% U with associated Pb, Zn, Cu and As (Tables 2 and 3). Although the Bi, Se and Ag contents are somewhat low, they also seem to accompany the uranium.

Mineralogical examination of the rock powder and fragments showed an abundance of iron and manganese oxides and hydroxides carrying adsorbed U, Pb, Zn, Cu, As, Sb and Bi. Uranium was also present as flakes of metatorbernite. Sulphide grains include pyrite, arsenopyrite, chalcopyrite and sphalerite usually associated with quartz or quartz-chlorite vein material. Cassiterite is seen as fine prisms in compound lithic fragments of chloritised slate or quartz-chlorite vein material. The Ag content is contained mainly in ductile flakes of a mineral of the bromargyrite–chlorargyrite series. No lead minerals were observed.

This mineralisation, intersected at a vertical depth of about 10 m, correlates well with the surface radiometry. From such coincidence it can be assumed that the structure has a steep to vertical attitude.

PH 2

At an inclined depth of 18.0 m the hole intersected a structure similar to that penetrated in PH 1; the chippings recovered were again of ferruginous material with a little quartz and somewhat more conspicuous pyrite. The mineralised zone was distinctly narrower, its true width being about 1.0 m and extending from 18.0 to 20.0 m inclined depth.

In the down-hole radiometric log (Figure 9) the

Table 2 XRF analyses of loose rock powder from percussion holes

Hole No.	*Depth sampled (m)*	*Cu*	*Pb*	*Zn*	*As*	*Sn*	*Bi*	*Se*	*Ag*
PH 1	11.58–13.11	1000	400	1000	1000	200	30	30	20
	13.11–14.63	1100	1000	1200	1500	200	200	100	100
	14.63–16.15	700	150	400	1700	100	ND	50	20
PH 2	17.98–19.51	1100	400	1100	500	500			
	19.51–21.03	700	100	1300	400	200			
PH 4	13.41–14.93	400	320	300	3200	600			
	14.93–16.46	400	200	200	2800	700			
PH 8	4.27– 5.79	500	50	300	300	ND			
	5.79– 7.32	600	100	300	400	ND			
	7.32– 8.84	500	50	200	300	ND			
	8.84–10.36	500	ND	100	200	ND			

All values are semi-quantitative and are quoted in ppm. ND = not detected.

Table 3 XRF analyses on pressed discs of percussion hole rock powders

Hole No.	*Depth sampled (m)*	*U*	*Th*	*Pb*	*Bi*	*W*
PH 1	11.58–13.11	120 (130)	20	350 (300)	30	50
	13.11–14.63	1330 (1210)	10	1070 (950)	350	70
	14.63–16.15	373 (370)	20	230 (200)	60	30
PH 2	17.98–19.51	84 (100)	20	280 (250)	10	20
	19.51–21.03	23 (20)	20	40 (30)	10	10

All results are quantitative and expressed in ppm; figures in parentheses are repeats. Tungsten results are suspect owing to use of tungsten carbide components in drilling and grinding.

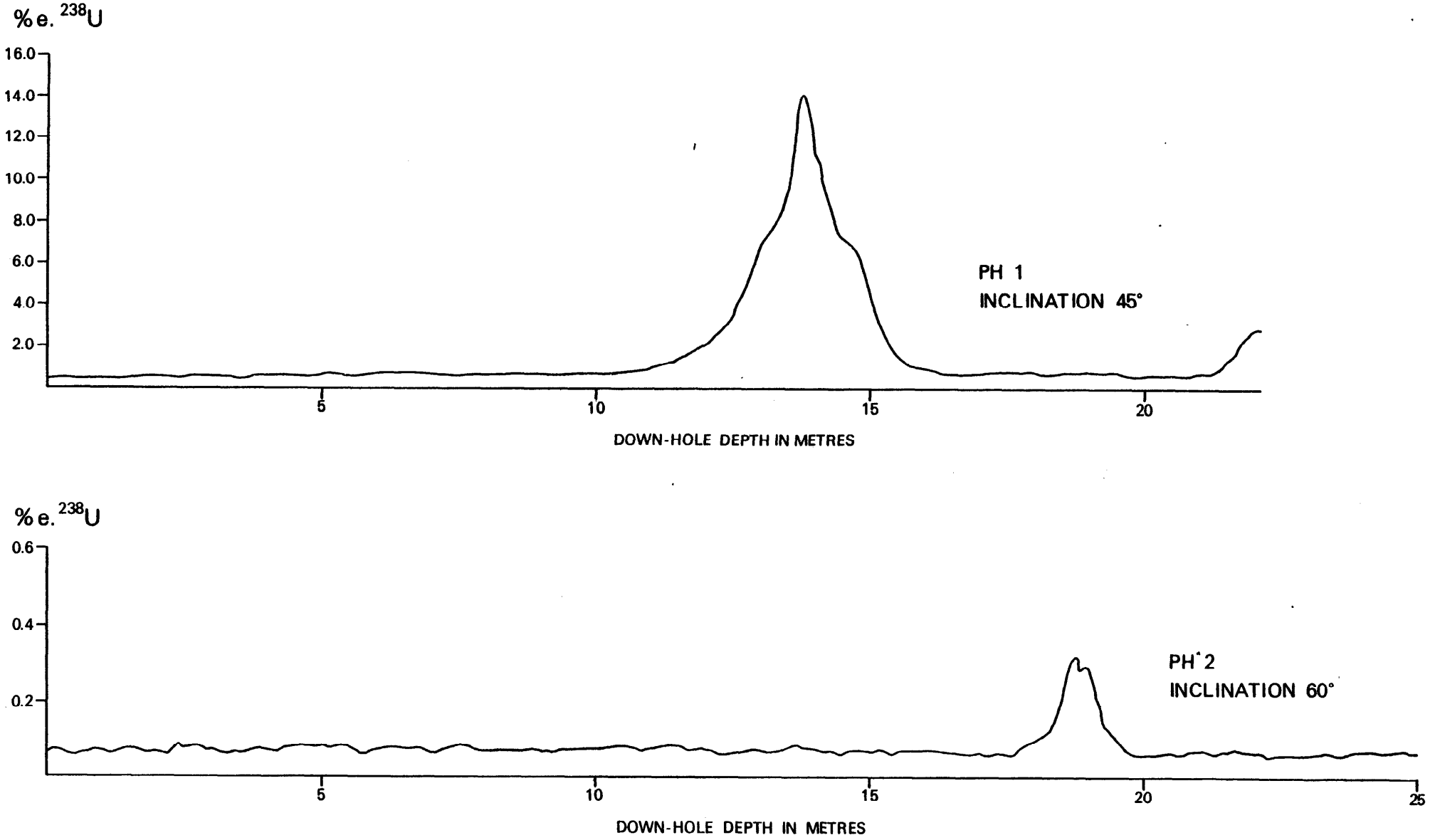
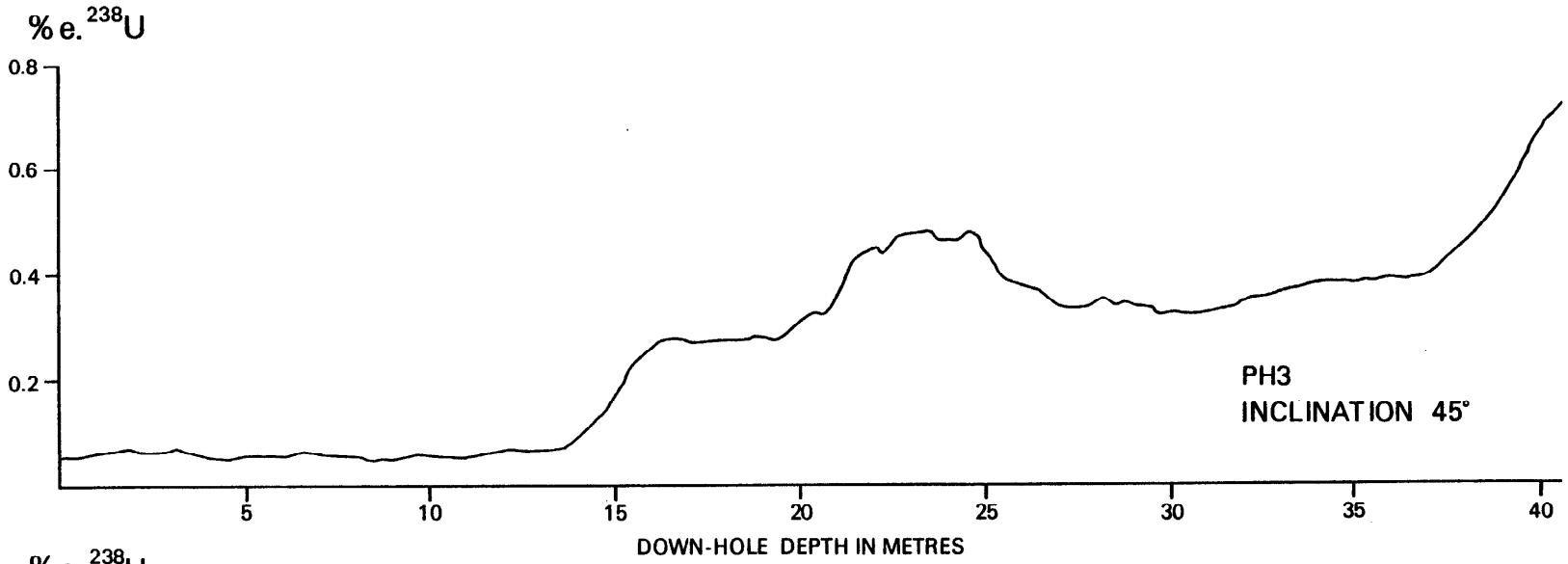


Fig. 9 Geiger-Müller logs of percussion holes : PH 1 and PH 2



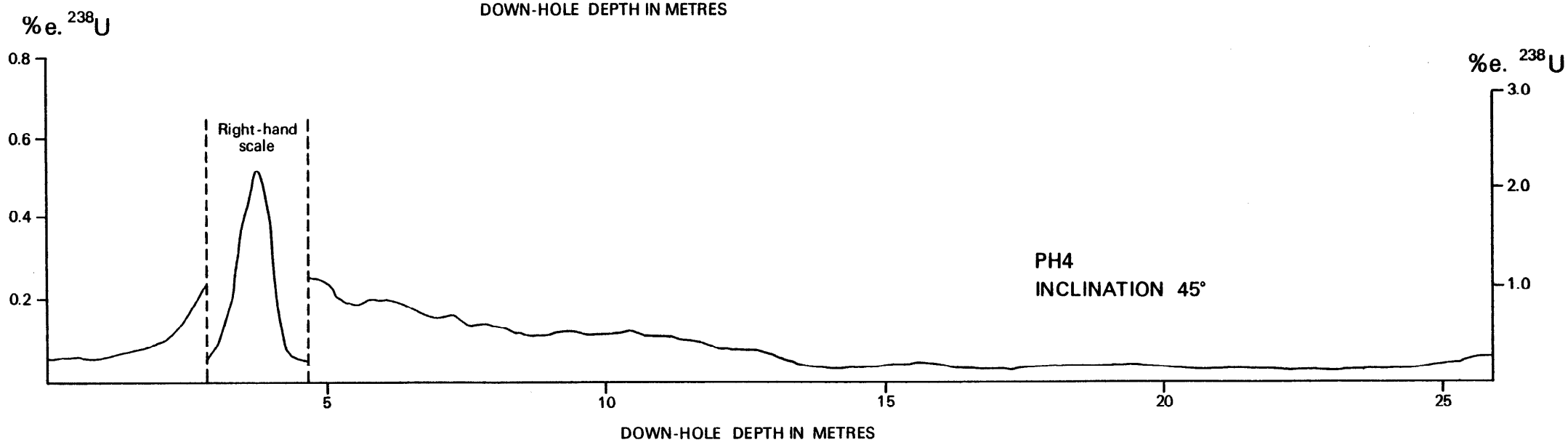


Fig. 10 Geiger-Müller logs of percussion holes : PH 3 and PH 4

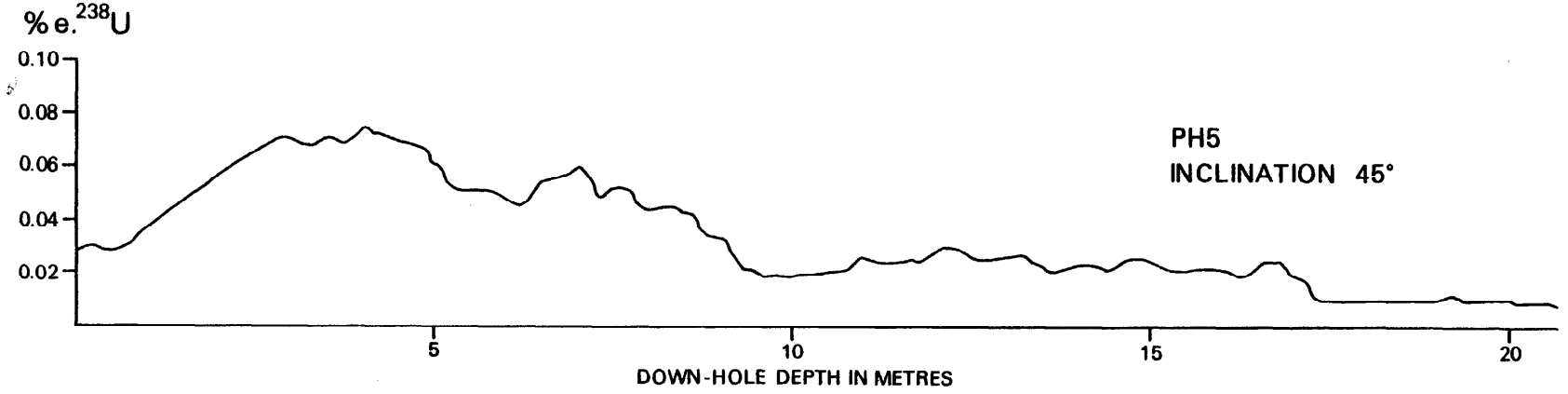


Fig. 11 Geiger-Müller logs of percussion holes : PH 5

structure is marked by a sharp peak between 18.3 and 19.5 m, corresponding to an equivalent ^{238}U content of 0.32%. At half-peak height the indicated width of uranium mineralisation is 0.8 m. As in PH 1, there is gross radioactive disequilibrium owing to a significant deficiency in uranium or an enrichment in gamma-emitting daughter elements.

Rock chippings indicate a mineralogy similar to that in the PH 1 structure but with less metatorbernite and appreciably more pyrite. Sphalerite, enclosing blebs of chalcopyrite and rimmed by covellite, is common. There is a little pyrrhotite and some plumbogummite. No silver minerals were detected.

This mineralised structure does not correlate with the surface radiometry but lies well to the west of the 15 μR/hr isorad. Presumably it does not reach to surface.

XRF analysis of the rock powder (Tables 2 and 3) shows Cu and Zn levels similar to those in the PH 1 structure but much lower U, Pb, As and Bi values. Of particular interest is the unexpectedly high Sn content in the uppermost sample. Although cassiterite reports in the heavy mineral concentrates, this tenor is somewhat unusual in association with U—Cu—Ag mineralisation. Even more unusual is the lack of correlation with As.

PH 3

Drilled from a site only 6 m north-east of PH 2 (Figure 8), this hole was expected to locate the near-surface expression of the structure in PH 2 and then to explore below the surface radiometric anomaly. In the event, no radioactive material was returned from the uppermost 13 m but, just below 20 m, the hole penetrated a hard, broken and wet zone from which only fine slurry and quartz chips were recovered. Below this, moist slate gave a poor return of sample until water was struck at 40 m.

The up-hole flow of slurry which coated the walls of the hole has presumably affected the gamma probe measurements (Figure 10), producing an unusual form of trace. Even so, it is apparent that there is a broad peak, perhaps broadened by contamination, between about 21 and 25 m and the suggestion of a further radioactive source at the base of the hole. The uranium value corresponding to the peak height (0.48% equivalent ^{238}U) cannot be accepted without question, especially if the basal anomaly is a genuine reflection of uranium mineralisation. That a radioactive structure occurs at about 23 m is certain, however, and this correlates well with the surface anomaly and the structure in PH 1.

Because of the water problems in this hole no satisfactory samples of chippings were obtained for laboratory and analytical study. Field examination of the washed fragments showed vein quartz in the zone from 5.79 to 8.84 m with much pyrite, traces of chalcopyrite and sphalerite and a few flakes of a green secondary uranium mineral (metatorbernite?). No metalliferous minerals were noted from the lowest part of the hole.

PH 4

Drilled to examine the projected south-eastward continuation of the mineralised zone, this hole penetrated moist slates with only sporadic thin seams of harder, apparently quartz-rich, rock.

The gamma log shows a very sharp peak at 3.8 m (Figure 10), indicative of an equivalent ^{238}U content of 2.2%. At half peak height the indicated width is 0.75 m. This high radioactive level was not reflected in the field assay of the rock pulp nor was any significant content of secondary uranium minerals noted in the ferruginous material recovered. Below this depth the radioactivity drops steadily to background level.

When plotted, the peak lies well west of the surface radiometric anomaly. It may be likened to that in PH 2 but it would be unrealistic to correlate the two over such a distance. The lack of agreement between gamma log and pulp assay is disturbing, even though the latter depends on beta-emission measurements, and suggests that the anomaly source may be recently derived daughter products adsorbed on the ferruginous or clay minerals. Such an explanation may accord with the broad radiometric 'high' recorded in the upper section of nearby PH 5.

Radioisotope XRF field assays of the pulps, for Sn and Cu, demonstrate a sharp peak for both metals around 15 m down-hole (Figure 12), coinciding with a small but marked drop in barium content. Laboratory XRF analysis (Table 2) confirms the high Sn levels, which are associated with high As, but shows the Cu values to be less spectacular. The similarity to PH 2 is again suggested; both zones carry markedly high Sn but they differ sharply in As levels.

Two mineralogical samples taken between 13.41 and 16.46 m exhibit much pyrite, some pyrrhotite and possibly magnetite with secondary iron oxides and hydroxides. The finer fractions, in particular, showed sphalerite, arsenopyrite, plumbogummite, metatorbernite, zircon and appreciable prismatic cassiterite.

PH 5

Although collared only 6 m from the previous hole (Figure 8) and drilled in the same direction to about the same depth, this hole proved to be much wetter than PH 4. In consequence, no samples were collected for laboratory study.

The gamma log (Figure 11) shows somewhat elevated radioactivity levels to a depth of about 9 m, the maximum being equivalent to 0.75% ^{238}U. Thereafter the level drops to background. There is no doubt that the borehole walls were smeared with slurry, but experience in borehole PH 3 suggests that this does not totally invalidate the radiometric measurements. It can, therefore, be accepted that this hole did not penetrate any

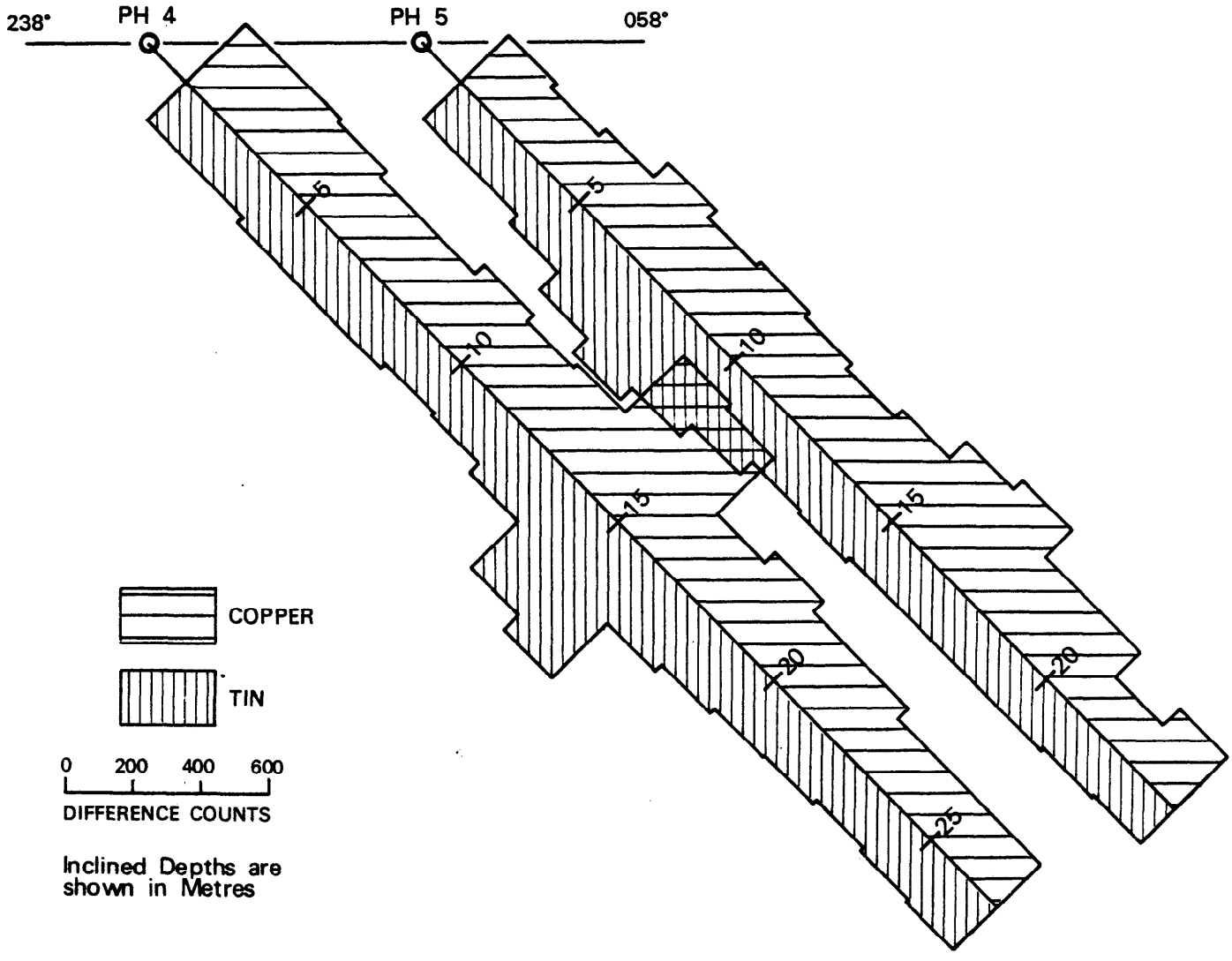


Fig. 12 Portable XRF Measurements on Pulps from PH 4 and PH 5

significant uraniferous structures. Field assay of the chipping returns identified no radioactive material from the upper parts of this hole and, as in PH 4, beta and gamma measurements reflect substantial disequilibrium. It appears that the radioactivity recorded in the upper levels of both holes may be due to the hydromorphic redistribution of daughter elements and their adsorption on the iron oxides and clay minerals of the weathered slates.

Radioisotope XRF analysis of the drilling returns (Figure 12) indicate a small Sn anomaly around 8 m depth and a Cu anomaly at about 15 to 18 m. Although the wet drilling returns may not be wholly representative of the rocks penetrated, field XRF analyses show no evidence of serious contamination in the deeper samples and it is considered that correlation between PH 4 and PH 5 is essentially valid. As shown in Figure 12, such a correlation indicates a stanniferous structure dipping steeply to the south-west, whilst the copper 'peaks' are aligned almost horizontally. It is difficult to explain such an orientation in terms of bedded or intercleavage mineralisation and, in view of the absence of primary copper sulphides in the PH 4 samples, it is considered that both copper anomalies may reflect a secondary (adsorbed?) enrichment related to fluctuations of the local water table.

PH 6 and PH 7

These two holes, 8 m apart and both drilled towards the west-south-west (Figure 8), explored the northern extension of the radiometric anomaly in an area where it was only very weakly defined. Both holes intersected mainly greenstone with occasional layers of dark grey slate; no obvious vein material was returned.

Gamma radiometry down both holes recorded only fluctuations of background radioactivity, equivalent to about 0.03 to 0.04% ^{238}U. Field XRF analysis indicated a slight enrichment in Cu within the upper half of PH 6, correlating with thick greenstone. In PH 7 the distribution of Cu was more erratic, but levels were generally lower than those in PH 6. Sn was consistently low in both holes. In view of the absence of anomalous results, no samples were taken for laboratory study.

It is apparent that there is no recognisable near-surface continuation of the mineralised zone as far north as this location, though the persistence of a weak radiometric signature raises the question of a deeper 'blind' structure which cannot be investigated by this method of drilling.

PH 8, PH 9 and PH 10

To confirm the apparent disappearance of the mineralisation northwards a line of three holes was drilled about midway between PH 6 and PH 1. Two of these (PH 8 and PH 9) were directed towards the north-east, PH 10 was drilled south-west (Figure 8).

As with PH 6 and PH 7, down-hole radiometry recorded only background levels of radioactivity, generally at about 0.03% equivalent ^{238}U. The Sn content of the pulps was expectedly low and, with the exception of PH 8, so was the Cu content. Between 4.27 and 14.94 m in PH 8 the returns showed a Cu enrichment up to more than twice background level and the four richest samples, from 4.27 to 10.36 m contained 500 to 600 ppm Cu, by laboratory XRF analyses. This Cu enrichment is not accompanied by enhanced Pb, Zn or As values and must presumably be attributed solely to the presence of minor amounts of copper sulphides within the greenstone or associated volcanic rocks.

Correlation of percussion hole results

South of the lane outcrop, the percussion hole data indicate the presence of a mineralised shatter zone trending about NW—SE and almost coincident with the surface radiometric anomaly. Within this zone mineralisation is concentrated in one or two, probably discontinuous, narrow fractures which dip steeply, possibly towards the south-west. Because of standing crops, percussion drilling was not possible for 110 m north from the gossanous outcrop and any continuation of the structure in this direction remains untested; certainly there is no clear expression of mineral veining in any of the holes (PH 6—10) drilled farther north-west.

For practical, operational reasons, samples were taken over 5 ft (1.5 m) lengths, so that there was dilution of ore material by unmineralised country rock. Comparison of metal values from the percussion borehole samples with those of the surface material is, therefore, usually unfavourable to the former. The geochemical signatures are closely comparable, however, showing Cu and U associated with As, Bi and a little Ag. Although not determined in the original gossanous sample, Zn and Pb are also present, as may be Se. This elemental assemblage is typical of low-temperature and late mineralisation and it seems anomalous, therefore, that Sn in appreciable concentration should occur in PH 2 and PH 5 samples. The deposition of cassiterite in a structure of NW—SE trend is unusual; almost all the tin-bearing veins in the surrounding areas have an east-west strike, but it seems that the cassiterite occurs in the same structures as the lower-temperature assemblage. The temperature range indicated by this mineralogy implies at least two phases of mineral deposition: an early phase of quartz, chlorite, cassiterite and perhaps associated chalcopyrite, sphalerite and arsenopyrite, and a later infilling of chalcopyrite, arsenopyrite (and sphalerite?) associated with Bi, Ag, Pb and U minerals.

CORED DRILLING

To investigate the depth extension of the mineralisation, four inclined narrow diameter core boreholes were proposed. Because of access difficulties along the narrow lanes around Lutton, a small Diamec 250 drilling rig was employed and BH L1 (59660 58816) was drilled to 92.67 m at an inclination of 45° and on an azimuth of 223°T. Throughout the borehole the strata proved to be intensely jointed and locally soft and friable, causing continuous collapse of the hole walls and necessitating frequent cementing. Because of high operational costs, agricultural inconvenience, difficult ground conditions and the lack of encouraging mineral values in BH L1, it was decided to terminate the investigation.

Instability of the borehole walls ruled out any down-hole geophysical or radiometric logging but the core was checked for radioactivity with a hand held scintillation counter and for anomalous Sn and Cu with a portable XRF meter.

Lithology of the core

Three main lithologies were penetrated in the borehole – greenstone, slate and volcanic tuff. Their distribution and relationships are indicated in the abbreviated geological log at Appendix II.

The greenstone at the top of the borehole, presumed to have been a doleritic sill originally, is identified as a medium to fine-grained epidioritic rock, massive in texture and well jointed. Only a small proportion of the amphibole has been converted to biotite, suggesting that it has been but little affected by thermal metamorphism. Throughout its thickness it has been weathered and some sections are notably friable and ferruginous. Its relationship to the underlying slates is not known, owing to heavy core losses around the contact. The only mineralisation seen within the greenstone was in the basal zone, where disseminated fine pyrite was conspicuous over a thickness (inclined) of 1.75 m. No other greenstone bands were recognisable in the core and this single band would seem to be the southernmost member of a suite of basic intrusions, some of which have been quarried at surface.

Below the greenstone an assumed Upper Devonian succession of slates and interbedded volcanic rocks appears to dip generally southwards, though this attitude cannot be satisfactorily defined from a single, inclined borehole. Of the succession penetrated, some 30% is a rather soft, often intensely folded and well jointed, grey or brown slate. Quartz stringers and veinlets are locally abundant but carry no visible sulphide mineralisation. There is a penetrative cleavage universally developed in the slates; its attitude is uncertain but probably is flat-lying and locally horizontal.

Volcanic horizons, designated as tuff in the borehole log, probably represent a wide spectrum of lavas, agglomerates and tuffs, the distinction between each being difficult to appreciate with the naked eye in narrow diameter core. Banding is relatively rare but where present shows clastic grading indicative of a normal succession – major folding, therefore, seems to be absent. Interfingering with slate is apparent at several contacts, indeed the boundaries between tuff and slate are somewhat subjectively defined, and in one horizon there is clear interdigitation with thin chert bands, which probably are also of volcanic association. There is a tendency for the tuffs to become more siliceous with depth and some layers are extremely tough and flinty, being difficult to discriminate from siliceous with depth and layers are extremely tough and flinty, being difficult to discriminate from discoloured cherts. For the most part the volcanic rocks are green or greenish grey, usually very fine-grained, often extensively sheared and always well jointed. Mineralisation is locally conspicuous in the tuffaceous horizons, particularly towards the base of the main bands. It takes the form of both disseminations and fracture fillings of pyrite and arsenopyrite. Chalcopyrite is rare.

Faulting is apparent throughout the section, the major zones being at 60.50 to 66.19 and 70.52 to 70.72 m. Clay bands (fault gouge?) and intense quartz veining are conspicuously developed and some mineralisation is associated with these zones of movement.

Between 71.82 and 73.52 m an apparently vertical band of indurated and comminuted tuff probably represents the vein zone identifiable to the south-east by its surface geochemical signature. Apart from secondary iron oxides, no metallic mineralisation is evident within the vein centre but arsenopyrite, pyrite and minor chalcopyrite occur as fine fracture fillings in both walls.

Geochemistry of the core

Prior to sampling, the core was checked by scintillation counter for U and by portable X-ray fluorescence analyser for Cu and Sn. In neither case was the sample geometry satisfactory, due to the small core diameter, but any major anomalies should have been recorded. In the event no significant Sn or U levels were recognisable and only one small Cu anomaly was registered at about 20.50 m down-hole. Subsequently the entire core was sampled in convenient lengths (maximum of 1 m recovered core), reduced in a jaw crusher to about 6 mm size and split. One portion was further ground in a tungsten carbide mill and by rapid XRF scan the powder was checked for U, Th, Pb, Bi and W, the last figure being checked for gross contamination by Co determination. Two high W values were rechecked by analysis of a further split crushed in an agate mill. These XRF results are quoted in Appendix III. Of particular interest are the elevated Pb and W values in sample 1009, the high U in 1047 and 1048, and the high Bi in 1048. The repeated W analysis of 1045 suggests

that values below 400 ppm are not anomalous but reflect contamination from the crushing equipment at levels varying with the abrasiveness of the sample.

A second split was crushed in a tungsten carbide mill, pelletised and analysed by XRF for Ce, Ba, Sb, Sn, Pb, Zn, Cu, Ca, Ni, Fe, Mn, Ti, As, U, Ag and Mo. Full analytical results are given in Appendix IV with calculated elemental statistics and correlation matrix in Appendix V. The more significant elements are shown graphically in Figures 13 and 14.

Most elements, including the base metals, exhibit a variation which is closely related to lithological units in the borehole but within that correlation there are differences which presumably signify petrogenetic diversities not apparent to the naked eye.

The dolerite is characterised by low Ni, Ba, Pb, Sn, As and Sb, moderate Ca, Mn, Ce, Zn and Cu, and notably high Ti. Neither Cu nor Zn is significantly anomalous in this body. There is a marked geochemical contrast between this dolerite and the underlying volcanic sequence, particularly in terms of trace elements.

Visual examination divides the volcanic rocks into three types: lavas, agglomerates with lava and slate fragments, and tuffs with a highly variable content of slate clasts. Lithological variation and gradation with superimposed subsequent induration renders visual separation difficult but the trace element geochemistry largely confirms the geological log. The upper zones of tuffaceous material are marked by low Ni, Ti, Ca, Mn, Sn, Sb, Pb, Cu and As, moderate Zn and high Ba and Ce. Towards the base of the uppermost zone there is one significant As anomaly, reflecting visible aresenopyrite, with an associated small peak in U values. Some of the variation in elemental content, especially of Ba and Zn, undoubtedly arises from variations in the abundance of slate clasts. In these zones there is no obvious geochemical discrimination between tuffs and agglomerates.

Below about 68 m the volcanic horizons exhibit a totally different signature with considerable variation displayed by most elements. Much of this variation appears to be attributable to the alternation of thin lava horizons and agglomerates, the latter containing many recognisable fragments of lava. Generally these rock types display very low Cu, Pb and Ce values, low to moderate Ba, As, Zn and Sb, and high but variable Ti, Ni, Mn and Ca levels. Sn is particularly variable and, occasionally, unexpectedly high for a lava.

Interbedded cherts and tuffs, just above 50 m depth, exhibit only one diagnostic signature, that of low Ba and Zn. Ce and Mn are variably low, probably reflecting alternations of the two rock types. As is anomalously high at the upper contact of the cherty horizon and U levels are somewhat elevated in this vicinity. The low levels of Ba and Mn are rather unusual as, elsewhere in SW England, similar sequences of chert-volcanic composition commonly host localised concentrations of baryte and manganese oxides.

The Upper Devonian slates yield a distinctive geochemical pattern of low Ca, Mn, Ni, Ce and Sn, moderate Ti, and high Ba and As. Base metal contents are more variable with localised anomalously high values. The heavily quartz-veined slates below 25 m show slight increases in Ca, Mn, Ti and Ni content and marked reductions in Ba and As. Zn is notably high in a 4 m zone below the greenstone, and Pb, Cu, As and, particularly, W show peak anomalies immediately beneath the same body. It is not clear whether this distribution represents remobilisation and preferential concentration during intrusion of the greenstone or entrapment of latter fugitive mineralisation beneath the igneous contact.

Just below 60 m depth an intensely brecciated fault zone of mainly volcanic rocks shows an elemental content different from non-tectonised volcanic material elsewhere in the borehole. Mn, Ti, Ba, Ni and Sn values suggest that the upper part is predominantly of tuffaceous composition with a lower lava-rich portion. Ce levels suggest the opposite case and Ca levels indicate no significant lava content. Within this breccia zone U, Sb and Ag show elevated values reflecting weak pervasive late mineralisation. At such low metal tenors, any correlation with the structures indicated south of the sunken lane must inevitably be tenuous. It seems reasonable to conclude, however, that this zone of breccia may be the north-westerly continuation of the more easterly of the two structures.

If this correlation is correct, the lode structure recorded about 72.5 m down-hole should equate with the more westerly of the near-surface mineralised zones. Such a correlation is even more tenuous on geochemical evidence as the lode zone shows a distinct depletion in Ba, Mn, Sn and As and enrichment in only Ni, Ti and Sb. Anomalously high Mn is registered on either side of the lode.

Levels of Mo are uniformly low throughout the core with the exception of three sharp peaks, one in the middle of the greenstone and the other two in the slate horizon between 75 and 81 m. This distribution makes little sense and arouses fears of contamination from molybdenum-based drilling lubricants.

CONCLUSIONS

Investigation of an earlier discovered radiometric anomaly near Slade Hall, to the south of Lutton village, has revealed the presence of a mineralised structure carrying Cu, U, Pb, Zn, Ag, As, Bi and Sn. Surface radiometry defines a narrow zone of mineralisation trending approximately NW—SE with maximum radioactivity confined to the two fields immediately north of Slade. Shallow percussion drilling confirms the sub-surface

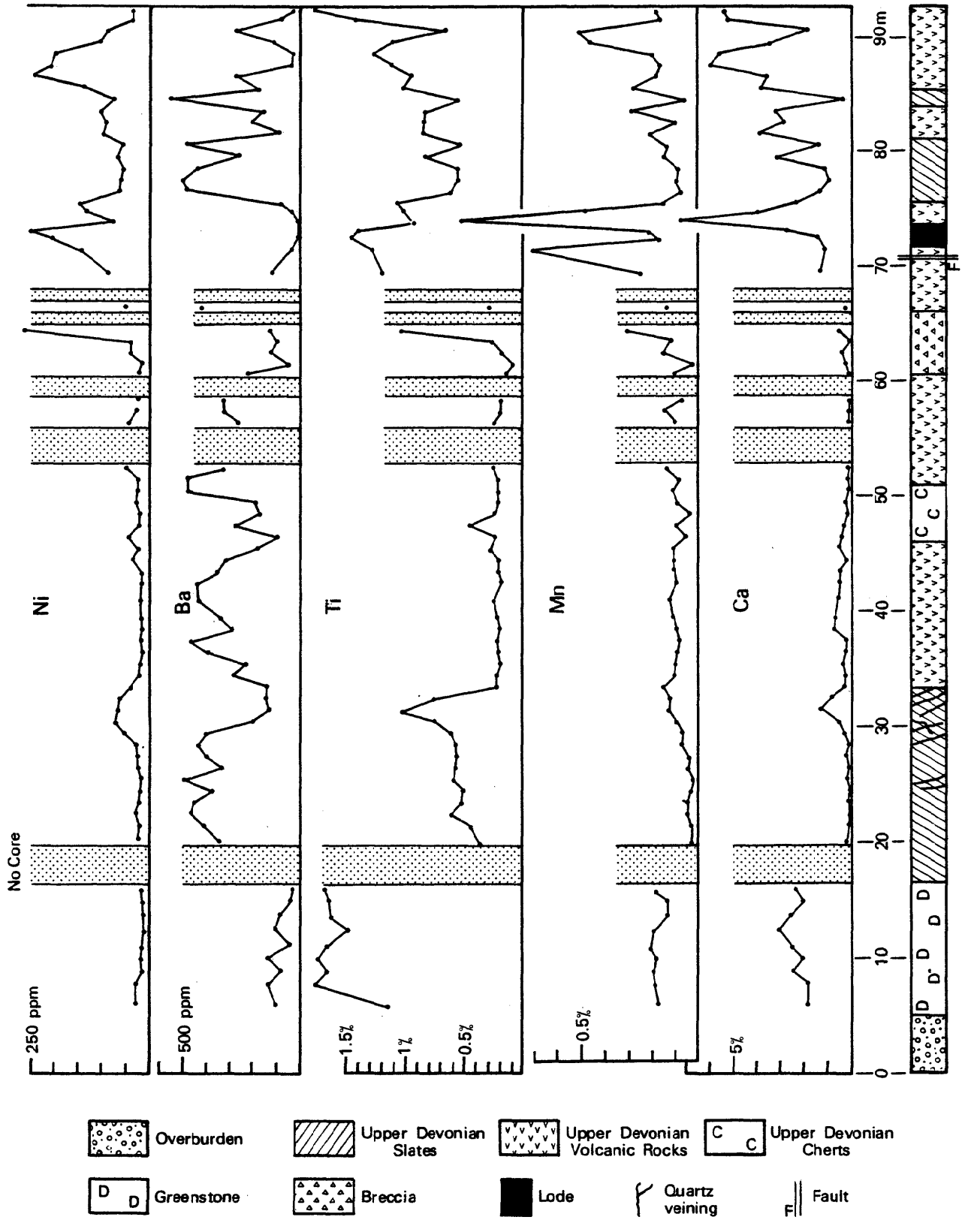
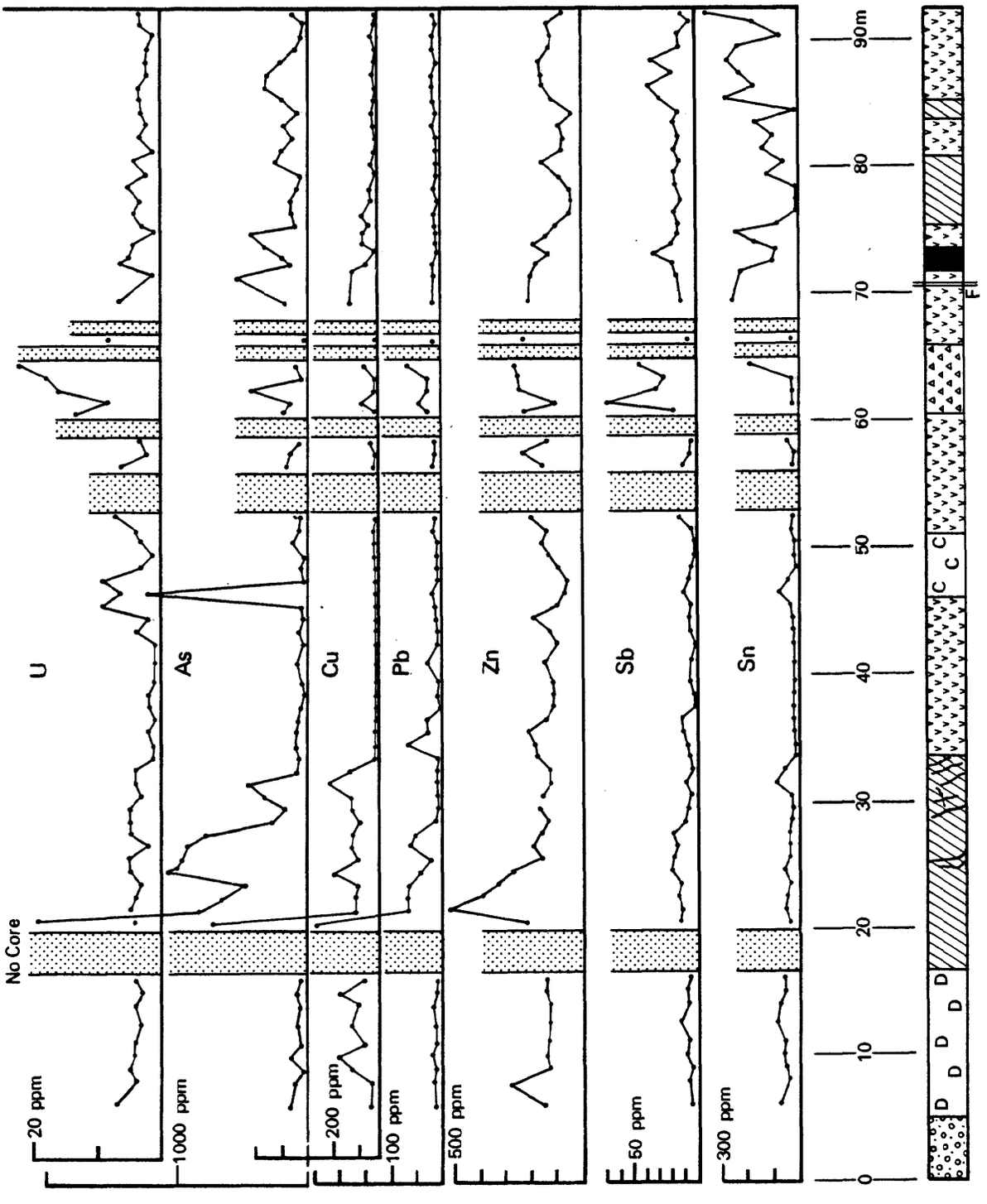


Fig. 13 Geochemistry of borehole L1 : Ca, Mn, Ti, Ba and Ni.



For key see Fig. 13

Fig. 14 Geochemistry of borehole L1 : Sn, Sb, Zn, Pb, Cu, As and U.

position of the mineralised zone and indicates that the metallic elements are concentrated in two separate structures which may be discontinuous along strike. From geochemical soil sampling, radon measurements and percussion drilling it is evident that near-surface mineralisation is concentrated in a 60 m strike length immediately south-east of the gossan outcrop located in the sunken lane 160 m west of Yondercot. North-west of the outcrop both radiometric and base metal values decline sharply; south-eastwards anomalous radioactivity and Cu values persist to the margin of the Piall River terrace deposits.

A cored drillhole directed below the gossan outcrop intersected a breccia zone followed by a lode structure at positions which appear to correlate satisfactorily with the near-surface mineralised structures. Neither borehole intersection was significantly mineralised.

From the drilling results it is apparent that there is at least a limited depth continuity of mineralisation south-east from the outcrop, though none below it. It must be concluded, therefore, that any ore-shoot (if the mineralisation is so disposed) must pitch south-eastwards. Continuity of the radiometric and copper anomalies in this direction adds support to this concept.

Sub-surface information upon the distribution of mineralisation is too meagre to allow meaningful speculation about the size of this deposit. The strike length indicated so far can only promise a small tonnage of metals but expansion in depth or the discovery of further mineralised structures could improve the potential of this hitherto unworked and unexplored area.

The metallic assemblage – Cu, As, Zn, Pb, U, Bi and Ag – is indicative of late mesothermal or epithermal sulphide mineralisation. Although only secondary uraniferous and argentiferous mineral species have been encountered it is presumed that at depth primary pitchblende and argentite (or native silver) may be present. In the cored borehole Sn appears to occur preferentially in the lavas and lava-rich agglomerates, not in association with the lode, breccia or quartz veins, and it is not accompanied by arsenopyrite. Its further presence, as cassiterite, in the mineralised sections of two of the percussion holes suggests that it may have been introduced via the shatter zone during an early metasomatic phase.

ACKNOWLEDGEMENTS

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APPENDIX I

XRF ANALYSES OF SOIL SAMPLES

South of lane outcrop; 'A' horizon samples

Sample No.	*Line*	*Eastings m*	*Depth m*	*Cu ppm*	*Pb ppm*	*Zn ppm*	*Ag ppm*	*U ppm*
BTS 2373	A	0	0.05	80	160	200	2	4.1
2375	A	5	0.05	80	150	190	1	4.5
2377	A	10	0.05	80	160	190	2	5.0
2379	A	15	0.05	60	80	210	2	5.5
2381	A	20	0.05	No sample				
2383	A	25	0.05	No sample				
2385	A	30	0.05	80	110	240	3	12.4
2387	A	35	0.05	80	130	210	2	6.1
2389	A	40	0.10	130	40	380	2	11.3
2391	A	45	0.10	70	100	200	2	4.9
2393	A	50	0.10	70	110	220	2	4.9
2395	A	55	0.10	55	80	300	1	3.2
2397	B	0	0.10	100	180	210	2	4.3
2399	B	5	0.10	95	80	170	1	4.3
2401	B	10	0.08	75	100	170	2	4.4
2403	B	15	0.10	No sample				
2405	B	20	0.10	85	240	200	2	4.4
2407	B	25	0.10	90	210	340	2	4.4
2409	B	30	0.10	No sample				
2411	B	35	0.10	No sample				
2413	B	40	0.10	95	220	200	2	5.7
2415	B	45	0.10	90	200	190	2	6.3
2417	B	50	0.10	85	230	210	2	4.7
2419	C	North	0.10	85	210	200	1	4.1
2420	C	Middle	0.10	70	190	180	2	5.2
2422	C	South	0.10	80	150	190	2	3.8
2430	D	0	0.10	105	260	200	2	3.6
2432	D	10	0.10	110	240	230	2	3.6
2434	D	20	0.10	100	230	230	2	3.8
2436	D	30	0.10	100	220	200	1	3.5
2438	D	40	0.10	95	220	210	1	3.4
2440	D	50	0.10	80	170	200	1	4.1
2442	D	60	0.10	80	170	190	2	4.5
2444	D	65	0.10	90	210	200	2	3.6
2446	D	70	0.10	85	220	200	1	4.2
2448	D	90	0.10	60	80	180	1	3.8
2450	D	100	0.10	60	70	160	2	4.8
2452	D	110	0.10	60	80	170	1	4.4
2454	D	120	0.10	60	70	170	2	4.8
2456	D	130	0.10	70	110	200	1	5.3
2458	D	140	0.10	80	110	190	2	5.0
2460	D	150	0.10	70	120	190	1	5.8

Anal. M. Shah

Statistics: n = 37

Range	55—130 Cu	40—260 Pb	160—380 Zn	1—3 Ag	3.2—12.4 U
Mean	82.2	154.3	208.7		4.9
S.D.	15.8	61.3	43.6		1.8

APPENDIX I (contd.)

South of lane outcrop; 'C' horizon samples

Sample No.	*Line*	*Eastings m*	*Depth m*	*Cu ppm*	*Pb ppm*	*Zn ppm*	*Ag ppm*	*U ppm*
BTS 2374	A	0	0.46	120	80	230	2	3.9
2376	A	5	0.43	75	120	200	2	4.4
2378	A	10	0.97	No sample				
2380	A	15	0.81	90	190	200	2	0.5
2382	A	20	0.91	No sample				
2384	A	25	0.76	No sample				
2386	A	30	0.38	80	190	200	2	5.1
2388	A	35	0.76	80	190	210	2	4.1
2390	A	40	0.51	120	230	240	2	4.5
2392	A	45	0.63	80	200	220	2	4.3
2394	A	50	?	80	210	220	2	4.4
2396	A	55	0.43	80	210	220	1	4.1
2398	B	0	0.58	80	160	180	1	4.5
2400	B	5	0.66	90	140	170	1	4.0
2402	B	10	0.61	245	230	210	2	4.1
2404	B	15	0.61	110	140	180	2	4.0
2406	B	20	0.63	80	100	170	2	5.0
2408	B	25	0.56	80	90	180	2	4.9
2410	B	30	0.51	No sample				
2412	B	35	0.58	No sample				
2414	B	40	0.46	85	120	170	3	11.4
2416	B	45	0.76	80	150	180	1	6.0
2418	B	50	0.61	90	70	220	2	8.7
2421	C	Middle	0.51	50	110	170	1	2.5
2423	C	South	0.33	80	90	230	2	3.4
2424	C	North	0.56	65	100	160	2	3.1
2431	D	0	0.51	85	110	200	2	3.5
2433	D	10	0.38	105	220	200	2	3.7
2435	D	20	0.51	75	70	160	1	3.9
2437	D	30	0.41	80	130	200	2	4.0
2439	D	40	0.38	80	120	170	2	4.1
2441	D	50	0.51	70	80	150	1	4.1
2443	D	60	0.51	80	110	180	2	4.2
2445	D	65	0.76	75	70	150	1	3.6
2447	D	70	0.63	80	50	150	2	4.1
2449	D	90	0.51	80	50	180	1	4.6
2451	D	100	0.51	90	50	190	2	7.7
2453	D	110	0.51	65	40	150	2	5.3
2455	D	120	0.51	55	60	150	2	5.0
2457	D	130	0.51	70	70	190	2	6.3
2459	D	140	0.51	80	70	180	2	6.7
2461	D	150	0.51	75	70	170	2	7.1

Anal. M. Shah

APPENDIX I (contd.)

North of lane outcrop; 'C' horizon samples

Sample No.	*Line*	*Eastings m*	*Cu ppm*	*Pb ppm*	*Zn ppm*	*Ag ppm*
BTS 2663	E	0	50	30	200	2
2664	E	5	60	40	150	1
2665	E	10	65	30	120	2
2666	E	15	60	30	80	1
2667	E	20	45	30	110	1
2668	E	25	65	30	170	2
2669	F	0	45	30	130	1
2670	F	5 N	50	40	120	1
2671	F	10 N	60	50	150	1
2672	F	15 N	40	60	140	1
2673	F	20 N	50	50	140	1
2674	F	25 N	55	40	120	2
2675	F	30 N	65	50	120	1
2676	F	35 N	55	40	110	1
2677	F	40 N	55	50	120	1
2678	F	45 N	50	50	140	1
2679	G	0	45	80	150	1
2680	G	10	100	60	220	2
2681	G	20	75	50	190	1
2682	G	30	70	40	100	1
2683	G	40	110	40	100	2
2684	G	50	40	30	100	1
2685	G	60	35	30	70	1
2686	G	70	30	20	70	1

Anal. B. P. Allen

Statistics:

	S. of outcrop (n = 37)	N. of outcrop (n = 24)	Total (n = 61)
Range Cu	50–245 ppm	30–110 ppm	30–245 ppm
Mean Cu	86.1	57.3	74.8
S.D.	30.0	18.0	29.5
Range Pb	40–230 ppm	20–80 ppm	20–230 ppm
Mean Pb	121.4	41.7	90.0
S.D.	57.1	13.1	59.7
Range Zn	150–240 ppm	70–220 ppm	70–240 ppm
Mean Zn	187.3	130.0	164.8
S.D.	25.1	37.3	41.4
Range Ag	1–3	1–2	1–3
Range U	0.5–11.4 ppm		
Mean U	4.7		
S.D.	1.8		

APPENDIX II

ABBREVIATED GEOLOGICAL LOG OF BOREHOLE L1

Location SX 59660 58816
Azimuth 223°T
Inclination 45°
Hole diameter 45 mm
Core diameter 35 mm

	Thickness m	*Depth m*
Overburden Fragments of weathered greenstone	4.92	4.92
Greenstone Weathered and well jointed greenstone. Some of the joints show marginal development of secondary amphibole and many are filled by ferruginous clay. Disseminated pyrite is conspicuous in the basal 1.75 m	11.58	16.50
Upper Devonian		
Slate Major core loss between 16.50 and 20.52 m contains the greenstone-slate contact. Below the latter depth the slates are greyish brown and intensely folded with numerous joints filled with clay and occasionally lined by amphiboles. Some joints have bleached walls. Quartz stringers and veinlets are common between 24.82 and 25.42 m and below 27.92 m but there are no visible sulphides	16.82	33.32
Tuff Banded greenish grey fine-grained tuffs and agglomeratic tuffs, the latter with an abundance of slate clasts and small fragments of lava. Distinctly brecciated in the uppermost 3.35 m and the lowest 1.00 m. Local graded bedding suggests that the sequence is right way up	12.70	46.02
Tuff and chert Interbedded or interfingered greenish tuffs, commonly agglomeratic, and cherts. At 46.92 m arsenopyrite fills minor movement planes and vughs within chert bands	5.28	51.30
Tuff Fragmented or highly fractured, and locally altered, agglomeratic tuffs. Parts of the section are intensely hematitic and there is a considerable development of clay in many fractures. Minor arsenopyrite occurs at 57.50 m and pyrite is associated with a clay-filled joint at 58.85 m	9.20	60.50
Fault zone The uppermost 0.12 m is of fragmented tuff cut by quartz-amphibole veinlets. Between 60.62 and 62.72 m the agglomeratic tuff is well brecciated and indurated, the fragments being cemented by banded crystalline quartz. The rock has a striking red and green mottled colour. The main fault line is represented by 0.28 m of red clay containing fragmented tuff. This is succeeded by shattered, hematitic tuff heavily veined by thin quartz seams	4.50	65.00
?Fault No core recovered; may be a further fault	1.19	66.19
Tuff Greenish grey tuffs which are sheared throughout and contain many slickensided surfaces. Joints are clay-filled. The tuffs become increasingly silicified with depth. Minor pyrite is disseminated throughout the rock and some pyrite veining occurs around 70.50 m in tuffs which bear hematitic vugh fillings	3.33	70.52
Fault The upper half consists of red clay containing small fragments of tuff. The lower part is grey to green rubble	0.20	70.72
Vein zone? Wallrock Leached tuffaceous rock cut by narrow veinlets bearing hematite, pyrite and arsenopyrite	1.10	71.82
Veinstuff Grey to black rock with a texture not unlike fine greenstone. Appears to consist of highly indurated tuff particles. Hematite and epidote occur at 73.00 m. Dips at 45° to the core length; probably vertical in attitude	1.70	73.52
Wallrock Silicified volcanic rock with numerous fractures filled by veinlets of pyrite, chalcopyrite, arsenopyrite and amphibole. These veinlets are never more than 4 mm in width	0.80	74.32
Tuff Less silicified, partially altered, banded tuffs	1.37	75.69
Slate Grey, well folded slate with a cleavage at 25° to the core axis and general dip parallel to that axis. There is some minor faulting. Occasional vughs of pyrite and hematite	5.38	81.07
Tuff Green agglomeratic tuff, usually well banded and with large fragments of foreign igneous rock (lava?). Cleaved at 45° to core axis	2.90	83.97
Slate Grey to brown slate dipping parallel to the core axis and cleaved at 45° to that axis. The lowest 10 cm is a green clay and may represent a zone of movement	1.35	85.32
Tuff Grey volcanic rock, locally tinged with green. Brecciated strongly at 88.88 to 90.02 m and at 90.56 m. Two slate bands, at 90.02 to 90.32 and 90.62 to 91.22 m, are interbedded with the tuffs. From 91.22 m to the base of the hole the rock is vesicular, the vesicles being filled by a green (chloritic?) mineral	7.35	92.67

End of borehole 92.67 m

APPENDIX III

RAPID XRF SCAN OF CRUSHED CORE FROM BH L1

Collection No.	*Depth (metres)*	*Approximate content in ppm*					*% Core Recovery*
		U	*Th*	*Pb*	*Bi*	*W*	
BTD 1000	4.92– 7.32	10	20	30	<10	100	41.7
1001	7.32– 8.32	<10	20	10	<10	50	100
1002	8.32– 9.32	10	20	<10	<10	130	100
1003	9.32–10.62	<10	10	<10	10	20	53.8
1004	10.62–11.62	10	20	<10	10	40	100
1005	11.62–13.32	<10	20	10	10	50	31.8
1006	13.32–14.32	<10	10	<10	<10	40	70.0
1007	14.32–15.32	<10	20	<10	10	100	100
1008	15.32–16.50	10	10	<10	<10	40	67.8
1009	19.72–21.00	10	20	170	10	1430 (1300)	58.6
1010	21.00–22.00	<10	20	40	10	130	70.0
1011	22.00–23.00	10	20	50	<10	60	90.0
1012	23.00–24.00	<10	20	40	10	30	90.0
1013	24.00–25.00	10	20	30	10	90	60.0
1014	25.00–26.00	10	20	10	10	30	80.0
1015	26.00–27.00	10	20	40	<10	60	73.0
1016	27.00–28.00	10	20	30	10	40	100
1017	28.00–29.00	<10	20	<10	<10	20	80.0
1018	29.00–30.00	10	20	<10	<10	20	100
1019	30.00–31.00	<10	20	<10	<10	40	100
1020	31.00–32.00	<10	10	<10	<10	60	80.0
1021	32.00–33.32	10	20	<10	<10	50	75.8
1022	33.32–34.00	<10	30	<10	<10	20	100
1023	34.00–35.00	<10	40	40	<10	20	85.0
1024	35.00–36.00	<10	30	10	<10	30	95.0
1025	36.00–37.00	<10	30	10	<10	10	90.0
1026	37.00–38.00	<10	30	<10	<10	10	96.0
1027	38.00–39.00	<10	30	<10	<10	20	90.0
1028	39.00–40.00	<10	20	<10	<10	50	90.0
1029	40.00–42.00	<10	30	10	10	10	90.0
1030	42.00–43.00	<10	30	<10	<10	20	100
1031	43.00–44.00	<10	30	<10	<10	20	80.0
1032	44.00–45.00	<10	30	<10	10	10	80.0
1033	45.00–46.00	10	30	10	<10	70	40.0
1034	46.00–47.00	10	30	10	10	10	50.0
1035	47.00–48.00	20	20	<10	10	60	45.0
1036	48.00–49.00	<10	20	<10	<10	30	30.0
1037	49.00–50.00	<10	30	<10	<10	20	65.0
1038	50.00–51.00	<10	30	<10	10	30	100
1039	51.00–52.00	10	30	<10	<10	40	100
1040	52.00–53.00	<10	30	10	<10	40	90.0
1041	56.00–57.00	<10	30	10	<10	40	80.0
1042	57.00–58.00	<10	30	<10	10	20	80.0
1043	58.00–58.85	<10	30	<10	<10	40	60.0
1044	60.50–61.00	10	20	10	10	70	56.0
1045	61.00–62.00	10	10	20	10	400 (50)	50.0
1046	62.00–63.00	20	30	20	20	50	60.0
1047	63.00–64.00	30	30	20	10	60	70.0
1048	64.00–65.00	30	20	50	50	70	80.0
1049	66.00–67.00	10	20	10	10	60	100
1050	68.00–71.00	<10	10	10	20	120	28.0
1051	71.00–72.00	<10	10	10	<10	60	60.0
1052	72.00–73.00	10	10	10	<10	40	70.0
1053	73.00–73.52	10	20	<10	<10	70	76.9

APPENDIX III (contd.)

Collection No.	*Depth (metres)*	*Approximate content in ppm*					*% Core Recovery*
		U	*Th*	*Pb*	*Bi*	*W*	
BTD 1054	73.52–74.42	<10	10	<10	<10	60	88.9
1055	74.42–75.10	<10	10	<10	<10	100	92.6
1056	75.10–76.00	<10	20	<10	10	50	66.7
1057	76.00–77.00	10	20	10	<10	60	70.0
1058	77.00–78.00	10	20	10	<10	30	100
1059	78.00–79.00	<10	20	<10	<10	30	100
1060	79.00–80.00	<10	10	<10	10	50	87.0
1061	80.00–81.00	<10	20	10	<10	60	90.0
1062	81.00–82.00	<10	10	<10	10	80	100
1063	82.00–83.00	<10	10	<10	<10	80	100
1064	83.00–84.00	<10	10	10	10	60	100
1065	84.00–85.00	10	20	<10	<10	10	100
1066	85.00–86.00	<10	10	<10	<10	40	85.0
1067	86.00–87.00	<10	10	<10	10	40	100
1068	87.00–88.00	<10	<10	<10	10	70	100
1069	88.00–89.00	<10	10	<10	<10	40	100
1070	89.00–90.00	<10	10	10	<10	40	90.0
1071	90.00–91.00	<10	20	<10	<10	60	85.0
1072	91.00–92.00	<10	10	<10	<10	50	100
1073	92.00–92.67	<10	10	<10	<10	70	89.5

Values in parentheses determined on splits crushed in an agate mortar

APPENDIX IV

XRF ANALYSES OF CRUSHED CORES FROM BH L1

Element / Sample No.	Ce ppm	Ba ppm	Sb ppm	Sn ppm	Pb ppm	Zn ppm	Cu ppm	Ca%	Ni ppm	Fe%	Mn%	Ti%	Mo ppm	As ppm	U ppm	Ag ppm
BTD 1000	109	111	5	60	4	143	32	1.789	20	8.523	0.160	1.149	5	102	7	4
1001	124	134	6	29	7	281	32	1.787	20	9.813	0.184	1.754	1	52	4	2
1002	173	70	5	45	5	108	102	2.450	8	10.299	0.187	1.664	3	28	5	1
1003	146	137	8	52	10	136	152	1.978	10	11.553	0.167	1.720	3	102	4	0
1004	173	43	5	48	7	129	48	2.485	9	9.274	0.197	1.649	11	31	4	2
1005	143	99	12	75	7	126	103	3.051	7	10.929	0.181	1.465	23	47	3	1
1006	143	81	6	63	12	124	65	2.490	8	7.461	0.131	1.615	2	37	4	3
1007	175	45	8	47	4	139	151	1.947	9	9.415	0.126	1.610	2	56	3	1
1008	167	37	4	53	4	138	46	2.431	9	8.910	0.174	1.667	3	38	4	1
1009	71	350	11	25	238	204	644	0.107	17	5.099	0.033	0.364	5	>1000	4	1
1010	53	406	10	53	56	516	88	0.035	15	4.991	0.025	0.434	0	807	5	1
1011	74	459	15	43	62	387	85	0.038	21	6.090	0.046	0.605	0	640	4	0
1012	45	452	12	29	56	326	71	0.079	15	5.805	0.045	0.514	2	444	3	2
1013	43	369	20	52	32	264	171	0.049	12	7.481	0.035	0.492	0	>1000	5	2
1014	41	501	19	36	15	152	77	0.162	11	6.390	0.022	0.589	0	952	5	2
1015	56	329	17	33	55	187	105	0.095	18	8.597	0.043	0.568	0	894	2	0
1016	69	399	20	33	45	154	97	0.210	17	7.432	0.042	0.555	1	760	5	2
1017	58	430	8	17	6	138	78	0.083	23	5.873	0.063	0.568	1	222	5	1
1018	84	399	6	12	2	160	102	0.233	48	6.618	0.064	0.604	0	164	5	1
1019	103	200	4	24	3	153	106	0.498	61	8.255	0.083	0.749	2	296	3	2
1020	126	141	9	89	4	121	181	1.307	54	8.977	0.117	1.034	0	424	4	1
1021	143	147	2	52	4	121	98	0.830	55	8.647	0.118	0.745	1	62	4	1
1022	255	143	6	8	0	178	4	0.223	33	10.388	0.144	0.211	4	42	1	1
1023	260	284	7	9	64	179	9	0.195	17	8.269	0.098	0.199	2	79	1	0
1024	248	227	10	12	20	204	6	0.280	14	7.931	0.091	0.180	1	67	2	2
1025	232	395	11	11	21	139	0	0.166	9	8.176	0.086	0.208	0	55	1	2
1026	255	465	0	9	0	109	3	0.154	12	7.585	0.075	0.217	4	33	2	0
1027	256	287	1	8	3	103	4	0.707	10	7.143	0.085	0.192	2	4	2	1
1028	213	336	4	7	1	106	1	0.656	12	7.708	0.104	0.200	0	26	1	1
1029	288	434	3	9	21	146	5	0.498	14	7.965	0.112	0.243	2	48	1	1
1030	277	434	0	7	5	95	6	0.442	9	7.633	0.088	0.177	2	11	1	3
1031	268	352	5	14	5	128	0	0.409	11	8.066	0.098	0.206	1	56	4	3
1032	237	318	5	10	6	184	5	0.190	27	8.843	0.102	0.198	1	28	2	0
1033	149	181	4	26	7	95	3	0.519	16	5.757	0.105	0.279	0	31	9	2
1034	210	96	10	76	14	62	5	0.358	36	4.660	0.052	0.222	2	>1000	6	1
1035	173	281	5	40	2	55	3	0.260	16	4.826	0.084	0.458	1	14	9	0
1036	98	163	4	8	2	85	2	0.108	17	5.193	0.035	0.221	0	31	3	1
1037	230	192	0	7	3	125	7	0.148	23	9.537	0.084	0.198	2	13	1	2
1038	261	480	1	7	0	151	6	0.092	20	8.998	0.106	0.197	0	99	3	1
1039	237	480	3	25	12	138	8	0.093	16	7.036	0.074	0.204	2	66	4	0
1040	175	315	13	12	6	193	1	0.116	44	6.859	0.133	0.251	1	55	7	1

APPENDIX IV (contd.)

Sample No.	Element Ce ppm	Ba ppm	Sb ppm	Sn ppm	Pb ppm	Zn ppm	Cu ppm	Ca%	Ni ppm	Fe%	Mn%	Ti%	Mo ppm	As ppm	U ppm	Ag ppm
BTD 1041	227	255	9	15	10	146	8	0.107	42	6.784	0.093	0.249	0	159	6	1
1042	255	326	3	10	5	224	0	0.094	23	7.884	0.138	0.191	0	124	2	2
1043	286	326	2	42	5	131	26	0.085	19	6.570	0.060	0.184	0	50	3	1
1044	107	222	14	13	23	221	2	0.089	20	9.545	0.101	0.140	0	184	13	5
1045	29	47	69	14	37	96	56	0.156	8	2.926	0.020	0.093	0	133	8	8
1046	220	121	29	17	20	243	7	0.409	31	7.710	0.146	0.183	2	435	16	8
1047	146	97	23	17	20	246	4	0.144	29	7.836	0.113	0.258	2	44	18	4
1048	170	134	43	188	67	253	53	0.500	263	10.649	0.306	1.074	2	96	22	2
1049	201	423	5	21	10	220	0	0.137	46	7.941	0.136	0.290	1	22	8	1
1050	88	117	11	250	11	200	107	1.232	83	8.647	0.246	1.206	4	191	6	1
1051	66	35	12	217	6	196	93	1.069	142	16.989	0.715	1.283	2	575	1	3
1052	114	7	17	93	10	173	41	1.391	205	10.597	0.158	1.457	3	136	6	2
1053	147	ND	31	82	1	135	5	2.705	252	10.869	0.210	1.392	0	200	5	3
1054	32	3	17	168	2	182	49	7.159	76	9.503	1.032	0.948	0	355	4	2
1055	47	32	11	247	2	140	49	3.931	131	11.140	0.482	1.007	2	465	1	2
1056	99	79	11	76	5	91	37	2.343	143	9.790	0.150	1.077	5	80	3	1
1057	79	489	15	4	9	42	53	1.216	57	5.169	0.077	0.607	5	136	4	2
1058	70	503	9	3	0	33	24	0.850	58	5.632	0.090	0.552	18	129	3	0
1059	73	442	13	0	8	45	23	1.043	49	6.259	0.079	0.541	20	92	5	2
1060	58	248	16	133	4	66	5	3.083	61	7.804	0.141	0.843	1	74	2	1
1061	56	494	10	53	5	150	18	1.308	53	5.346	0.136	0.518	31	246	4	1
1062	79	70	15	143	3	78	5	3.892	94	9.520	0.209	0.865	2	211	1	3
1063	85	201	11	92	3	67	1	2.758	88	6.775	0.095	0.837	1	131	3	0
1064	92	148	15	159	11	84	10	3.159	101	9.851	0.291	0.841	2	198	2	2
1065	76	553	11	2	2	35	15	0.233	72	5.974	0.055	0.550	2	101	3	1
1066	63	162	26	287	11	111	6	3.721	134	11.256	0.283	1.027	0	219	3	0
1067	109	ND	34	159	13	152	0	3.478	239	7.050	0.178	0.960	4	347	3	3
1068	72	33	16	227	14	155	9	5.942	203	8.943	0.163	1.111	3	334	2	1
1069	110	25	33	266	3	161	9	5.295	198	11.836	0.197	1.288	4	229	2	1
1070	67	96	10	234	11	129	6	3.443	99	11.812	0.459	1.098	3	116	2	1
1071	67	261	11	62	8	117	19	1.793	82	10.472	0.512	0.679	1	76	1	0
1072	76	78	3	177	4	137	3	5.095	31	10.458	0.159	1.417	2	44	3	2
1073	114	25	8	367	7	69	4	5.397	30	8.670	0.176	1.799	1	128	3	0

ND = not detected

APPENDIX V

ELEMENTAL STATISTICS AND CORRELATION MATRIX FOR BH L1 SAMPLES

Elemental Statistics

Element	*Range*	*Mean Value*	*Standard Deviation*
Ce	29–288 ppm	138	76
Ba	0–553 ppm	233	164
Sb	0–69 ppm	11.7	10.8
Sn	0–367 ppm	69.1	82.3
Pb	0–238 ppm	15.9	30.9
Zn	33–516 ppm	151	78
Cu	0–644 ppm	45.8	84.6
Ca	0.035–7.159%	1.392	1.659
Ni	7–263 ppm	53.9	62.3
Fe	2.926–16.989%	8.206	2.208
Mn	0.020–1.032%	0.154	0.156
Ti	0.180–1.799%	0.715	0.511
Mo	0–31 ppm	2.8	5.3
As	4–2073 ppm*	234	341
U	1–22 ppm	4.3	3.7
Ag	0–8 ppm	1.5	1.6

*Values for As above 1000 ppm subject to imprecision

Correlation Matrix

Ce	1.00															
Ba	0.13	1.00														
Sb	*0.41*	*0.29*	1.00													
Sn	*0.40*	*0.57*	0.27	1.00												
Pb	*0.17*	0.17	0.20	*0.09*	1.00											
Zn	*0.07*	0.09	0.11	*0.06*	0.39	1.00										
Cu	*0.29*	0.04	0.03	*0.05*	0.78	0.20	1.00									
Ca	*0.37*	*0.63*	0.15	0.76	*0.23*	*0.24*	*0.12*	1.00								
Ni	*0.28*	*0.43*	0.48	0.59	*0.07*	*0.04*	0.13	0.46	1.00							
Fe	0.01	*0.54*	*0.03*	0.52	*0.23*	0.03	*0.08*	0.46	0.43	1.00						
Mn	*0.24*	*0.46*	0.11	0.55	*0.17*	0.00	*0.08*	0.58	0.39	0.62	1.00					
Ti	*0.37*	*0.62*	0.06	0.57	*0.16*	*0.08*	0.14	0.67	0.35	0.55	0.37	1.00				
Mo	*0.15*	0.12	*0.04*	*0.04*	*0.04*	*0.20*	0.04	0.10	0.01	*0.06*	*0.01*	0.15	1.00			
As	*0.38*	0.12	0.19	0.06	0.72	0.33	0.71	*0.12*	*0.01*	*0.19*	*0.06*	*0.10*	*0.07*	1.00		
U	*0.02*	*0.12*	0.43	*0.07*	0.15	0.26	0.00	*0.24*	0.12	*0.15*	*0.07*	*0.08*	*0.05*	0.02	1.00	
Ag	*0.07*	*0.28*	0.53	*0.10*	0.01	0.11	*0.08*	*0.06*	0.03	*0.04*	0.04	*0.11*	*0.08*	0.01	0.46	1.00
	Ce	Ba	Sb	Sn	Pb	Zn	Cu	Ca	Ni	Fe	Mn	Ti	Mo	As	U	Ag

Negative correlation factors in italics