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MINERAL INVESTIGATIONS IN THE NORTHUMBERLAND TROUGH: PART 1, ARNTON FELL AREA, BORDERS, SCOTLAND

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This data package relates to work carried out by the British Geological Survey on behalf of the Department of Trade and Industry

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INTRODUCTION

Recognition that the tectonosedimentary environment of the Solway-Northumberland basin is broadly similar to the Lower Carboniferous base-metal province of the Irish Midlands prompted the BGS Mineral Reconnaissance Programme to initiate a drainage survey over the post-Silurian unconformity in southern Scotland in the early 1970's (Haslam, 1972). A follow-up survey in the area to the south-west of Langholm in 1975 traced anomalous Pb and Zn values to a small outcrop of sandstone containing disseminated galena within the 'cementstone' facies of the Lower Border Group close to the contact of the basal Carboniferous Birrenswark lavas. Subsequently, soil and deep overburden studies followed by diamond drilling identified sub-economic base metal concentrations in Lower Border Group rocks extending along 4 km of regional strike (Gallagher et al., 1977).

Reconnaissance panned concentrate sampling continued in 1976 to the north-east of Langholm, successfully identifying a number of mainly Zn, Ba and minor Pb anomalies indicative of further mineral occurrences along the northern margin of the basin, but detailed investigations to trace these anomalies to source was not undertaken at that time. A systematic drainage survey of southern Scotland as part of the BGS Geochemical Baseline Survey of the Environment (G-BASE) in the period 1981 - 85, provided high-quality stream sediment data for the area which identified the presence of anomalous base metal zones close to the basin margin (British Geological Survey, 1993).

In 1992 a new MRP project aimed at stimulating mineral exploration interest in the northern margin of the Northumberland-Solway basin was instigated. It was prompted by the completion of a multidisciplinary study into the analysis of spatially-related datasets and mineral deposit modelling for carbonate-hosted mineral deposits in northern England (Jones et al., 1994). An evaluation of MRP panned concentrate data and G-BASE stream sediment data in conjunction with geological and geophysical information revealed the presence of distinct patterns of metalliferous element enrichment partly coincident with north-east trending Dinantian growth faults developed along the northern basin margin. Comparison of the regional patterns for Pb, Zn, Cu and Ba in the two sample media (Colman et al., 1995), concluded that panned concentrates were the preferred sample type for tracing the source of base-metal mineralisation. Several areas prospective for stratabound base-metal mineralisation were identified, and the results of follow-up investigations in the first and most northerly of these target areas, are presented in this report.

The project area is situated in the Roxburgh District of the Scottish Borders, 15 - 20 km north-east of Newcastleton and about the same distance south-east of Hawick. It lies within the Ordnance Survey 1:50,000 map sheet 80 (The Cheviot Hills), and British Geological Survey 1:50,000 map sheet 17E (Jedburgh). Mature coniferous plantations cover the entire area apart from a narrow east-west strip of land separating Forestry Commission in the north from private forestry in the south. The relief is moderate to steep, rising from about 200 m in the valley bottoms to nearly 600 m on Peel Fell at the eastern edge of the area. Extensive deposits of peat, generally 1 - 2 m thick, overlie glacial deposits which mainly comprise a clay-rich, grey-brown till averaging 3 m in thickness, but locally exceeding 6 m on the lowest ground. The headwaters of two river systems, the Liddel Water (- Peel Burn - Wormscleuch Burn) and the Jed Water (- Raven Burn) catchments, drain to the south and north respectively from a central watershed at Wheelrig Head [NT 615 015] (Figure 1). Outcrop is sparse being limited mainly to the upper reaches of the more deeply incised stream sections, forestry tracks, and one or two small quarries and other excavations for local road stone supplies.

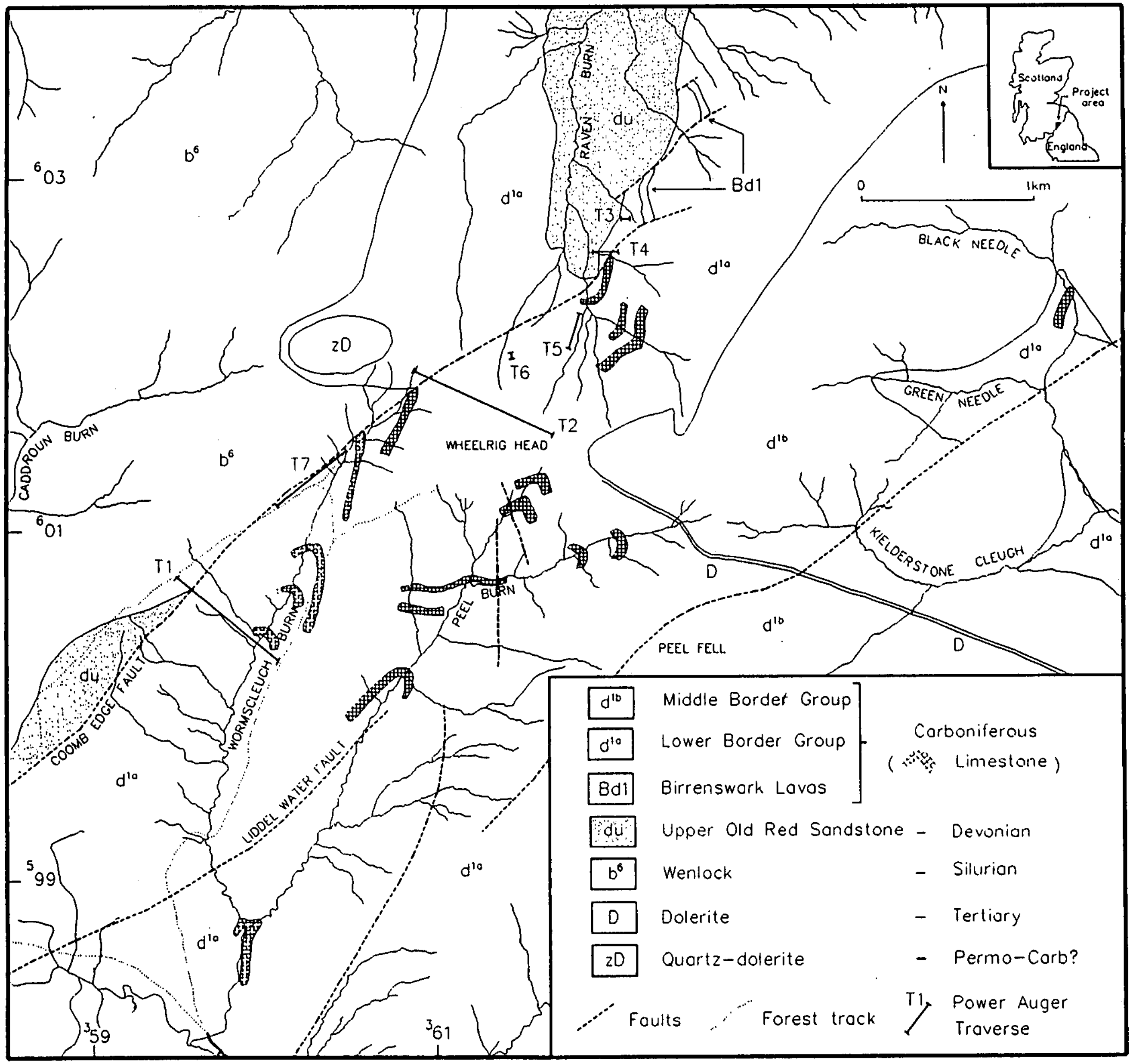

Figure 1 Location and simplified geology of the survey area

PLANNING AND DEVELOPMENT FRAMEWORK

Since the area comprises almost 80% coniferous forest plantation, population density is very low and limited to one or two road-side farms. Within the follow-up area land ownership is divided roughly equally between the Forestry Commission and a private sector forestry company. The only known planning constraint is a site of Special Scientific Interest (SSSI) which includes the unforested Black Needle and Green Needle catchments, 2 - 3 km east of the principal target. Access to some parts of the forested area is restricted for a limited period during early summer to prevent disturbance to nesting birds of prey. The road network in the area consists of minor (B - class) tarmac roads linking (via Hawick) to the A7 in the west and (via Kielder) to the A68 in the east. An extensive system of vehicle tracks provides easy access to most of the forested ground subject to consent of the landowners.

GEOLOGY

Lithostratigraphy

Locally the geological succession (Figure 1) comprises a basement of Silurian (Wenlock) turbidites containing mainly grey fissile shales, green-grey mudstones and occasional massive greywacke bands. This succession, which forms the Riccarton inlier at the western side of the project area, is overlain with marked unconformity by red fluviatile sandstones and siltstones with subsidiary calcareous nodules (cornstones) of Upper Old Red Sandstone (UORS) age. Intermittent exposures of UORS are seen on the eastern flanks of the Riccarton inlier and also in an elongate inlier in Raven Burn. They, in turn, are overlain by alkali olivine-basalt lavas, the Birrenswark Lavas, which mark the base of the Lower Carboniferous succession and are considered to be related to rift-basin formation and tensional fracturing along the main basin faults (Leeder, 1974). As a consequence of late Carboniferous faulting, the lavas are now represented by a few small, isolated outcrops along the north eastern and south western margins of the area. Exposures of the lavas in Dawston Burn just beyond the south western corner of Figure 1 indicate that their thickness within the project area is likely to be of the order 10 - 15 m consistent with an overall directional thinning from south-west to north-east observed by Lumsden et al., (1967).

The lavas are succeeded stratigraphically by sedimentary rocks of the Lower Border Group, characterised by a great diversity of lithologies with alternating thin beds, usually less than 1 m in thickness, of sandstones, siltstones, mudstones and impure limestones which together constitute a fining-upwards cycle. On lithostratigraphic grounds, Leeder (1974) assigns the rocks of this area to the 'Arnton Fell Formation', traceable along the east side of the Kirk Hill Fault in the Newcastleton area for some 20 km along strike. The formation is considered to exceed 200 m in thickness and to be the broad time equivalent of the basal third of the Whita Formation, which represents the earliest rocks of the Lower Border Group in the Langholm area (Leeder, 1974). However the present study indicates that lithology is so variable and the degree of exposure so poor in the interfluve areas that only very tentative correlation of the strata across the district is possible.

Clastic rocks account for the greatest proportion of the sedimentary sequence, but limestones and associated carbonate lithofacies collectively account for about 20% of the total outcrop and are most abundant in the eastern part of the area. For example, in the upper reaches of Peel Burn, beds of hard, light brown to orange-weathering silty and sandy dolomite ('cementstones') up to about 0.5 m thick form a series of small but prominent waterfalls and a distinctive downstream train of boulders identifiable for some 500 m. The dolomite is usually highly ferroan sparite, resulting upon oxidation, in the general orange colouration. Considerable local lithological variations are evident as indicated by frequent internal laminations caused by variable amounts of clastic detritus. The presence of sharp tops and bases of many beds suggest a primary origin for the original, possibly aragonitic, sediment which was subsequently dolomitized. Rarer, irregular nodular cementstones may be diagenetic in origin (Leeder, 1975). Many of these features indicate deposition in ephemeral lacustrine water bodies in areas of poor drainage and high water table.

Several beds of dark fossiliferous limestone, some containing algal bands, have also been noted in Peel Burn. These are indicative of marine-like conditions of deposition and comparable with the upper part of the Lower Border Group to the west and south west of Newcastleton. Pyrite and marcasite, probably of late diagenetic origin, frequently occur as fine-grained disseminations and replacements of microfossils in the carbonate-facies rocks. Pyrite also occurs as patches of irregular or radiating bladed crystals sited in the margins of carbonate veins and as coarse blebs, streaks, joint and fracture coatings associated with intense carbonate veining in cementstones and limestones. Lithofacies studies have indicated deposition in a coastal plain fluviatile environment with poorly-drained flood basins containing ephemeral lakes fed by occasional marine incursions (Leeder, 1974).

Apart from the Birrenswark lavas, the only igneous rocks are represented by a north-north-west trending dolerite dyke (1 - 3 m wide) of probable Tertiary age located on the north side of Peel Fell, and a dolerite plug of Lower Carboniferous age comprising fresh medium-grained plagioclase-pyroxene-iron ore at Needs Law [NT 605 023]. The latter forms an oval-shaped mass over 500 m long which has been extensively quarried as a local source of road metal. Contacts with the Carboniferous sedimentary rocks are sharp and there is no evidence of associated hydrothermal alteration or mineralisation.

Structure

The outcrop of the Silurian rocks is influenced by two major folds of Caledonian age, the Caddroun Burn Syncline, to the north of Arnton Fell summit lying at the western edge of the project area, and a complimentary anticline, the Catscleuch Anticline, to the south. Both are asymmetrical structures with fold axes trending north east. Exposures of strongly cleaved Silurian mudstone on the south limb of the Caddroun Burn Syncline show vertical or steeply inclined inverted beds in contrast to gently dipping strata on the north limb.

A prominent north-east trending normal fault downthrowing to the south east, the Coomb Edge Fault, truncates the eastern margin of the inlier throwing the Silurian against the Lower Border Group (Figure 1). This is one of a major, north-east trending series of *en-echelon* basin margin growth faults of Lower Carboniferous age. Field evidence for this structure is represented by an intense, but narrow (<2 m) zone of brecciated and hematised greywacke mudstone exposed in a small stream [NT 6043 0146] and very disturbed Silurian strata in several track side exposures 100-400 m to the south. Attempts to trace the fault north-eastwards into the headwaters of Raven Burn were unsuccessful, but this may reflect forestry activities which have obscured many of the exposures present during the original mapping. Further eastwards, the Liddel Water Fault, another of the major north-east trending basin margin normal faults, has an estimated throw to the south-east of at least 100 m, intersecting the middle reaches of Peel Burn, and cutting out considerable thicknesses of the Lower Border Group succession.

The existence of these faults of probable Courceyan-Chadian age (Chadwick et al., 1993, 1995), coinciding approximately with the position of the postulated oblique plate collision boundary in late Silurian times (the Iapetus suture), invites close comparison with the structural setting of the Navan orebody at the faulted margin of the Longford-Down Inlier.

There is little evidence locally of the Variscan deformation, the beds dipping consistently and gently to the south-east. A few small-scale folds with north-easterly oriented axes occur in the Lower Border Group and Upper Old Red Sandstone successions. Dips are of small magnitude suggesting that these folds are no more than gentle undulations. Close to the principal north-east trending faults however, there is a general upturning of the strata giving rise to steeper dips to the north or north-west and opposed to the regional dip.

MINERAL OCCURRENCES AND ROCK GEOCHEMISTRY

There are no historical records of mineralisation in the project area. However, during the course of the drainage survey reported here, detailed outcrop inspection resulted in the discovery of minor sulphide mineralisation at the localities described below. Rock sampling of these occurrences was undertaken to establish base metal concentrations and provide mineralogical/petrographical information on the style of mineralisation. Geochemical data and relevant observations for 33 outcrop and 11 float boulder samples are presented in Table 1.

1) Raven Burn and Wormscleuch Burn headwaters. Intensely veined dolomicrites contain pyrite as fine disseminations and pyrite/marcasite as coarse aggregates infilling fracture veinlets. The results of detailed rock sampling undertaken in the headwaters of Raven Burn (see Table 1, samples BFR 6160-6178, at [NT 61890 02420] to [NT 61881 02420]) indicate minor base metal enrichment as well as several percent of iron sulphides associated with the net veining. Weakly disseminated galena was present in an apparently undisturbed, 0.3 m thick, sandstone unit (BFR 6160 at [NT 61890 02420]), but the low Pb content of this rock (153 ppm), although the highest of the sample suite, makes this occurrence of doubtful significance. Ba values (up to 6265 ppm) suggest that baryte is locally present, probably as epigenetic fracture fillings associated with the calcite veinlets or in irregular replacement pockets. Thin, orange-weathering cementstones in the upper reaches of Wormscleuch Burn (BFR 7049-7082, at [NT 60525 01482] to [NT 60635 01585]) contain a similar style of mineralisation, consisting of networks of carbonate veins with the development of pyrite and marcasite along vein margins succeeded by calcite and/or dolomite suggesting episodic growth. Only Ba shows any evidence of mineralisation (up to 1.7% Ba in BFR 7079) in the analysed rocks, base metals being uniformly low in all samples from this stream section.

2) Forest track exposure on the west side of Wormscleuch Burn. A 3 m wide zone of hematite - calcite cemented breccia occurs in Silurian mudstones associated with the Coomb Edge Fault [NT 6043 0146] at the eastern margin of the Riccarton inlier. A few coarse grains of chalcopyrite and pyrite were observed in the breccia, but the analytical data suggest that the mineralisation is weak (Table 1, BFR 6074 at [NT 60430 01455]).

3) The headwaters of Peel Burn. Dark fossiliferous limestones (dolomicrites) up to 0.6 m thick contain pyrite thinly disseminated throughout the dolomite mosaic. Rare crystals of relatively coarse sphalerite were observed in spheroidal, calcite or dolomite-lined vugs, 1 to 2 cm across (BFR 6097-6100 at [NT 61860 00865]), and also in steeply dipping dolomite veins (BFR 5925 at [NT 61770 00870]) together with more abundant iron sulphide. Maximum Zn values of 298 ppm and 3556 ppm respectively were

obtained for bulk samples from these two contrasting styles of mineralisation. The immediately overlying and underlying sandstones and mudstones are unmineralised, suggesting that lithology exerts a primary control on mineralisation. Sulphides thus appear to have crystallised only with dolomite in fractures and cavities in hard, compact limestones and cementstones.

DRAINAGE GEOCHEMISTRY

Reconnaissance panned concentrate sampling carried out in the 1970's revealed particularly high levels of Zn accompanied by modest enrichment of Ba, Pb, and Cu in several streams in the project area. Geochemical orientation studies conducted in the Langholm area (Gallagher et al., 1977) demonstrated that panned concentrates were the most effective sample media for detecting base metal mineralisation under conditions of thick, clay-rich drift. Follow-up sampling to trace the source of the anomalies was therefore based on the collection of panned concentrates at intervals of 250-400 m along stream sections in conjunction with the examination and sampling of rock outcrop and float boulders.

Heavy mineral concentrates were obtained by wet screening an initial volume of 4 litres of -2 mm stream sediment and panning to a final volume of about 25-30 ml. Analysis for Cu, Zn, Pb, Ba, Ni, Fe, Sn and Sb was performed on 12 g of milled sample by X -Ray fluorescence spectrometry (XRF) at the BGS Analytical Geochemistry Group laboratories. The analytical data for 45 reconnaissance (1976) and 53 follow-up (1993/94) samples, also determined by XRF at the BGS laboratories, are shown in Table 2 and plotted in Figures 2 - 5. The results of optical examination and semi-quantitative XRF analysis of unground excess material from a small number of anomalous samples are presented in Appendix.

Zinc levels show extreme variation (<5 to >4500 ppm) in the panned concentrates, with the highest concentrations clustered over Lower Border Group rocks in the middle reaches of Wormscleuch and Raven Burn headwaters, and the lowest levels over Silurian mudstones on the west side of the area (Figure 2). Sphalerite was observed in many of the anomalous concentrates as coarse, orange to brown, resinous fragments, and mineralogically confirmed as an abundant phase in the +500 -2000 μm fraction (Appendix). Much of the sphalerite is fresh and uncorroded, suggesting local derivation. However, it is difficult to account for such high levels on the basis of the small number of known mineralisation occurrences and the moderate levels of enrichment in rock samples. In Raven Burn headwaters, for example, three consecutive sample sites extending over 300 m of the stream channel, contained Zn values in excess of the upper calibration limit of 4500 ppm (BFP 6778, 6779, and 6781). Despite a relatively high degree of rock exposure (up to 50%) and the presence of a major mapped fault (Figure 1), a detailed search upstream revealed only minor amounts of sphalerite in two calcite-veined cementstone outcrops, which yielded a maximum concentration of 513 ppm Zn (BFR 6092 at [NT 61940 02210]). Other cementstone units in the vicinity contained abundant fracture-bound pyrite-marcasite, but no evidence of ore metals. Near the eastern margin of the area, in the Green Needle and Black Needle catchments, a search for the source of similarly high Zn (and Ba) in-concentrate values (BFP 4696, 2495 ppm Zn at [NT 63760 01905] and BFP 4492, 3710 ppm at [NT 64580 01880]) failed to reveal in-situ mineralisation, although several boulders of extensively veined cementstone comparable to those outcropping in Raven Burn were observed a short distance upstream of the anomaly.

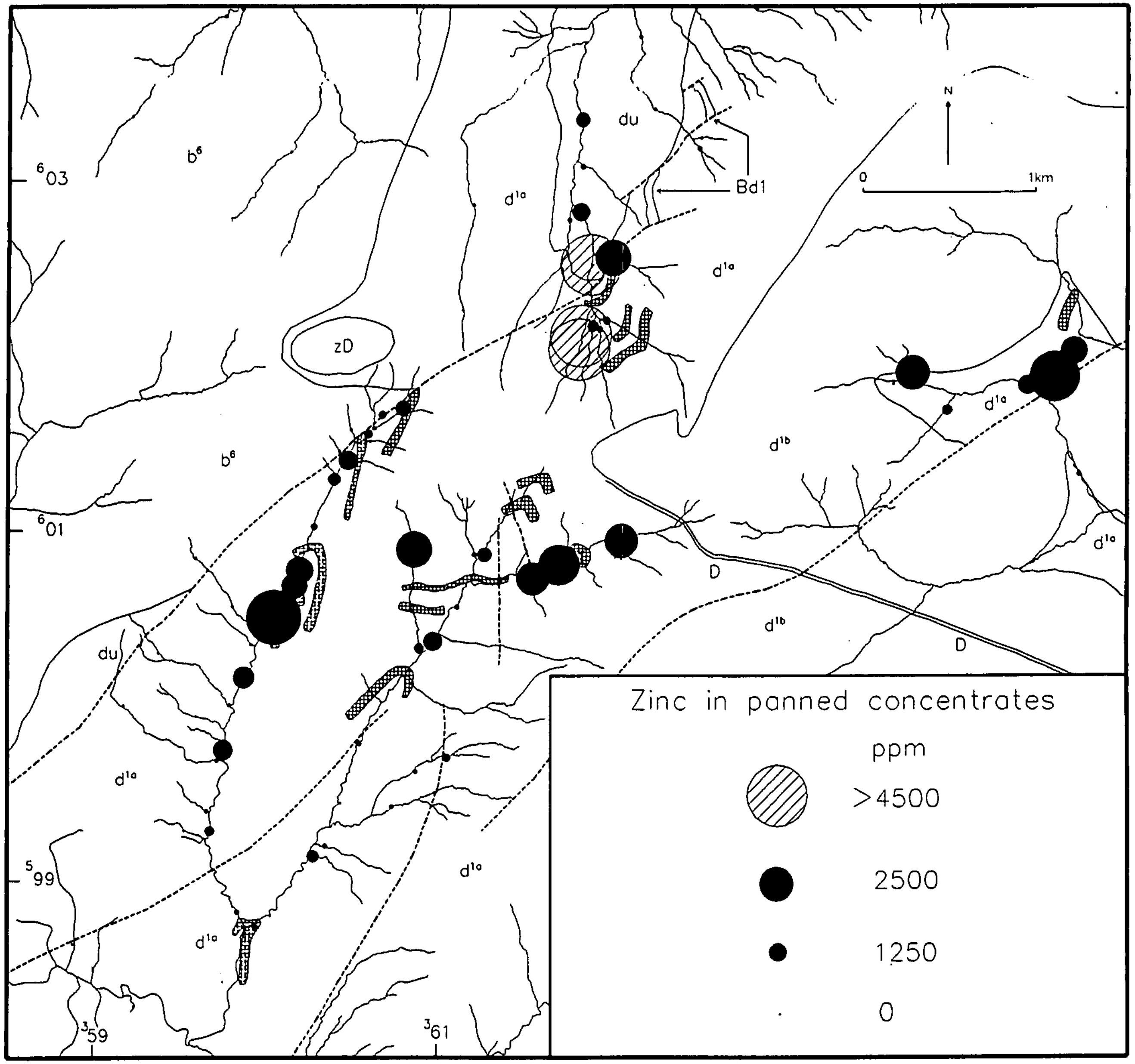

Figure 2 Zinc in panned concentrates

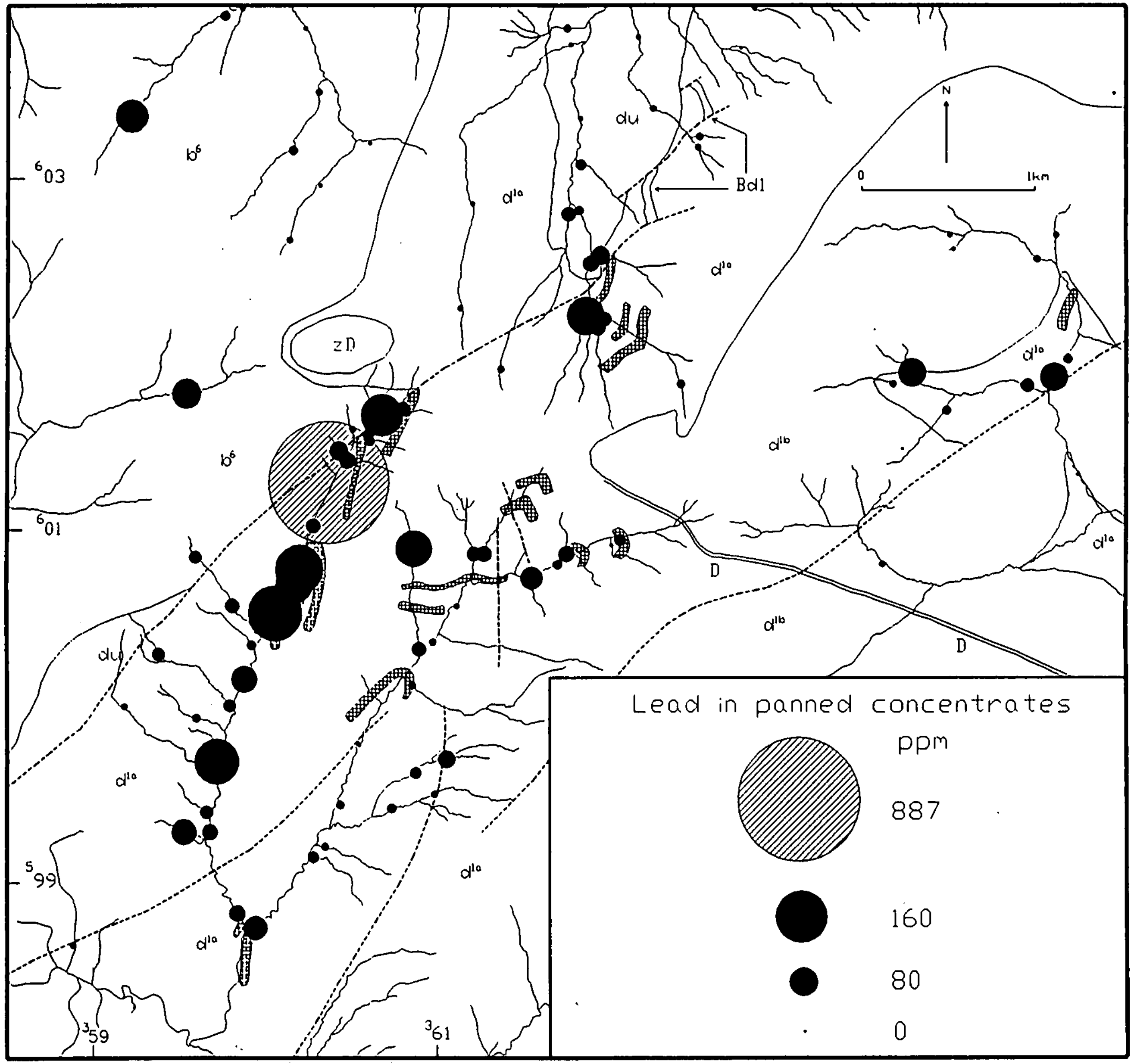

Figure 3 Lead in panned concentrates

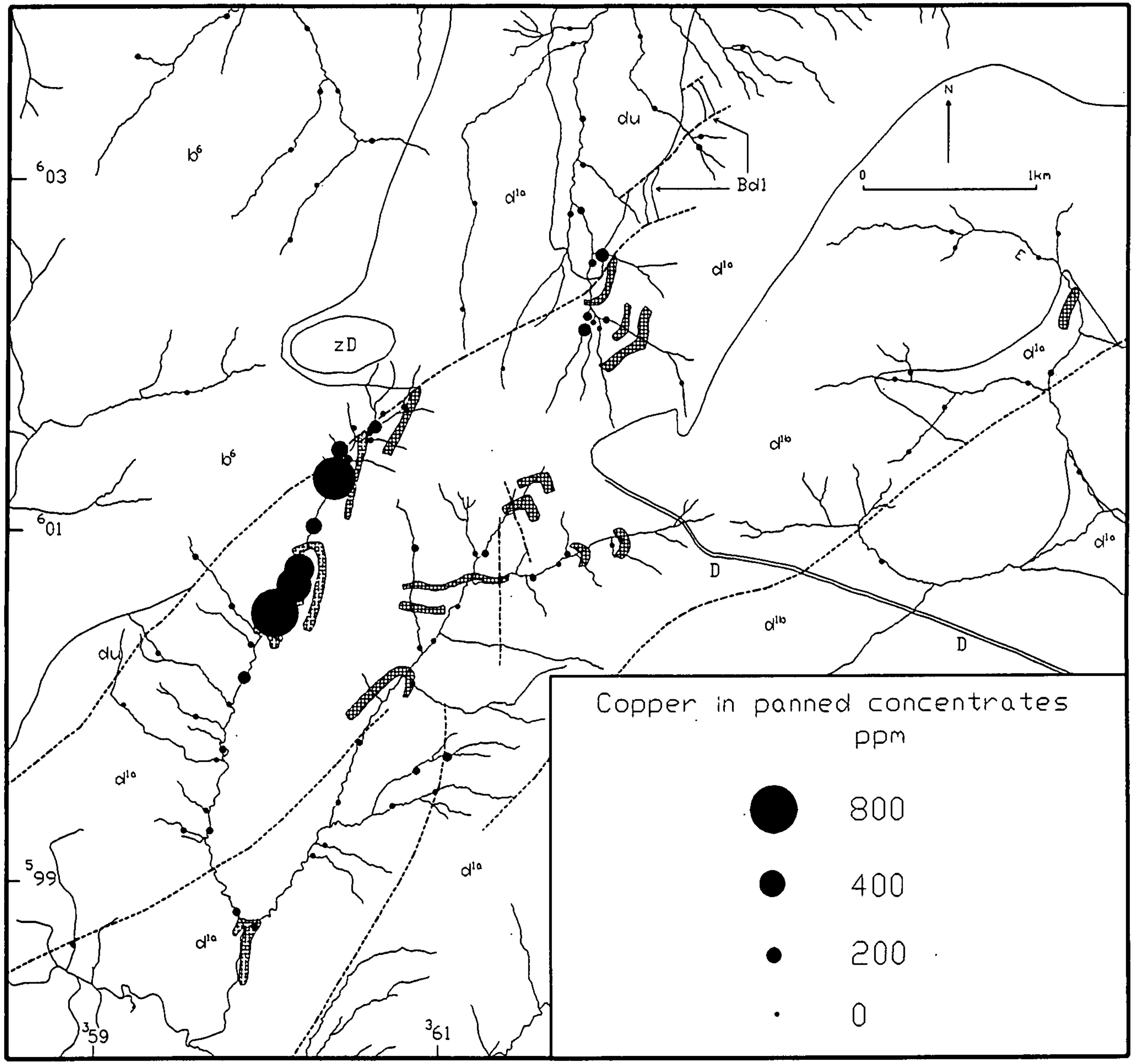

Figure 4 Copper in panned concentrates

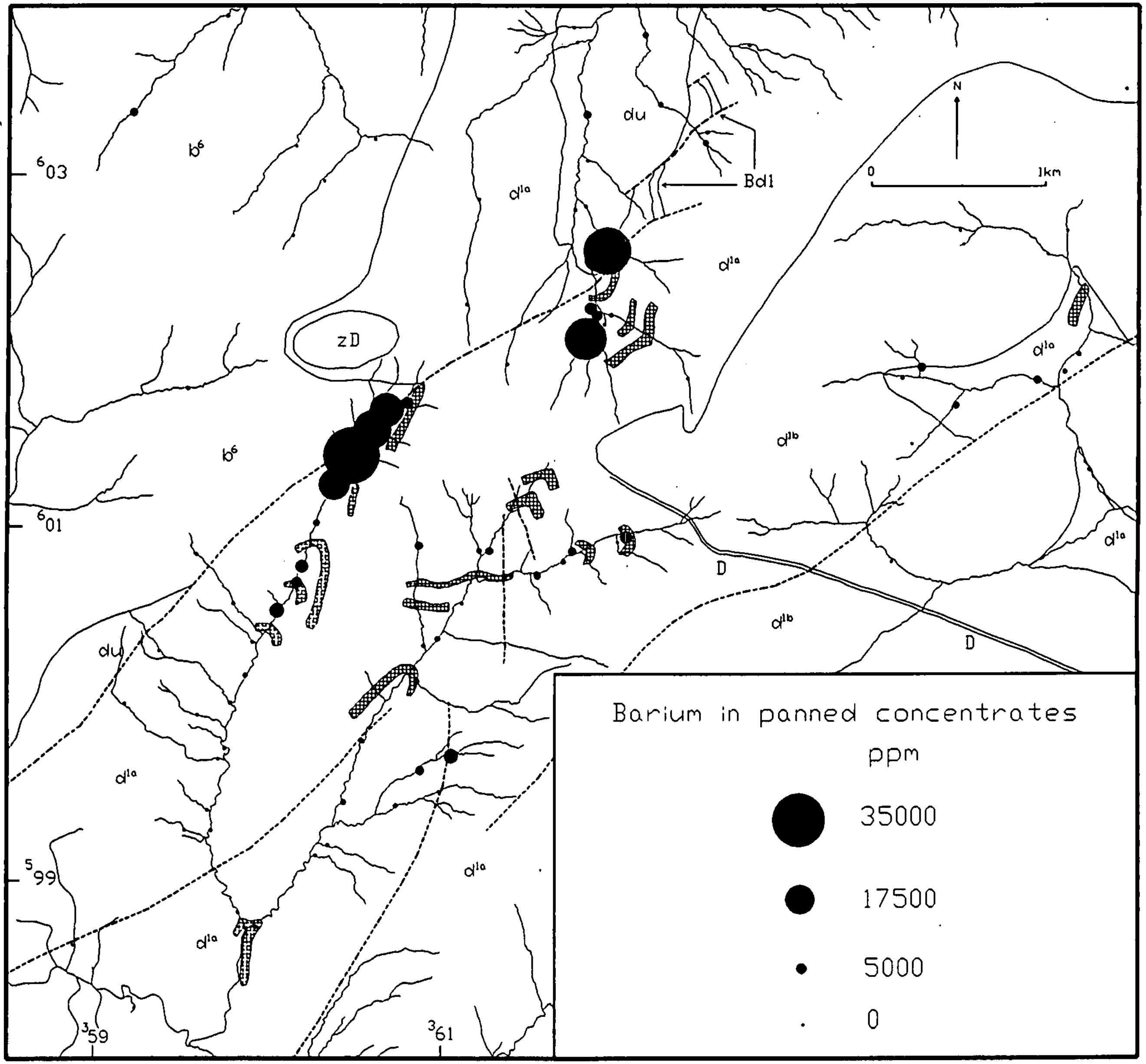

Figure 5 Barium in panned concentrates

In contrast to zinc, lead values show a more restricted concentration range (1 - 887 ppm), the highest value occurring in the upper reaches of Wormscleuch Burn [BFP 6755, at NT 60400 01290] (Figure 3) coincident with a substantial Cu anomaly (710 ppm). Mineralogical work showed that abundant, coarse (+500 μm -2000 μm), irregular fragments of galena and chalcopyrite were the primary cause of the anomaly (Appendix) which appears to originate close to the stream intersection with the Coomb Edge Fault. Although lead values decrease rapidly downstream they remain moderately anomalous (74 - 218 ppm) for a distance of 1.3 km. Downstream of the principal anomaly, finer (-500 μm) oxidised galena was identified in three other anomalous samples, and in one of these (BFP 6763), small amounts of the Pb-As mineral, mimetite were also noted (Appendix). Elsewhere no Pb concentrations >108 ppm were recorded indicating the probable dominance of Zn mineralisation.

Strong enrichment of copper is apparent over the entire 1.3 km zone containing anomalous Pb in Wormscleuch Burn (Figure 4). Values reach a maximum concentration of 806 ppm Cu (BFP 6762 at [NT 60060 00520]) 1 km downstream of the maximum Pb value. Three of the minor west bank tributaries of Wormscleuch Burn, which drain across the Coomb Edge Fault, also contain elevated Cu levels suggesting contributions of mineralised material from several sources along the main stream channel. Elsewhere in the project area Cu values show little variation, except for a few moderate values (up to 166 ppm) associated with the major Zn-Ba anomalies in Raven Burn (Figures 2, 4 and 5). As no copper minerals were identified in concentrates from this stream, the Cu is probably incorporated into euhedral fine-grained pyrite which is a particularly abundant phase in several samples, forming an estimated 5 - 10 % of the total heavy mineral component.

Other metalliferous minerals confirmed by optical examination and microprobe analysis from the anomalous zone in Wormscleuch Burn included small amounts of cinnabar in two samples, and fine (-63 μm) gold in three samples, one of which contained at least 26 grains (BFP 6762 at [NT 60060 00520]). Morphologically similar gold was also identified in one sample from Raven Burn (BFR 6781 at [NT 61870 02220]), a short distance downstream of the projected intersection of the Coomb Edge Fault. The marked degree of angularity exhibited by all of the separated gold grains indicates a short transport distance from a local source(s).

The distribution of high Ba values (> 0.5%) corresponds closely with the relative abundance of coarse, angular grains of white and pink baryte observed in the concentrates at the time of sampling (Figure 5). Like Zn, many of the Ba anomalies occur in the upper reaches of Raven, Wormscleuch and Peel burns consistent with the observation of fracture-bound baryte mineralisation associated with carbonate-pyrite-sphalerite veining in cementstones and micritic limestones in these catchments. Occasional thin veinlets and joint / slickenside coatings of baryte were also seen in the same lithologies. The distinctive cluster of high values in Wormscleuch Burn could also indicate a contribution from undiscovered baryte mineralisation related to the Coomb Edge Fault although none was seen in the fault breccia or in float boulders in the stream section.

OVERBURDEN GEOCHEMISTRY

In an attempt to clarify the source of drainage anomalies and trace the extent of mineralisation in the interfluve areas, fifty two bulk tills were collected using a portable mechanical auger to sample at 50 m intervals along 6 widely spaced traverses (Figure 1). Because of difficult access in the heavily forested ground, traverse lines were sited mainly along fire breaks (traverses 1, 3, 4, 5, and 6). The two longest traverses (traverses 1 and 2), were sited to intersect the faulted Silurian-Carboniferous boundary, approximately at right angles to the regional strike. At each site 6-8 litres of till, collected from the basal 1-2 m of the hole, was wet screened to remove clay and fine silt, and the remaining -2 mm fraction (normally 0.5-1.5 litres) reduced by panning to yield a concentrate of about 30 ml (BFU samples in Table 3). An additional sample from the maximum attainable depth was collected, and after drying and dissaggregation, sieved at 150 μm to produce a fine till fraction (BFT samples in Table 4). The lithology and morphology of clasts recovered during the wet screening operation was recorded to provide an indication of provenance, and transport distance.

The average penetration depth of the power auger at 49 sample sites was 3.3 m (< 1 to 6.4 m), but some exposures of overburden seen in stream banks in the middle reaches of Wormscleuch and Peel burns exceed 8 m and it is therefore doubtful whether the material sampled from some holes represents true lodgement till. Compositionally the drift over most of the area is a very compact grey or grey-brown clay or silty clay till containing numerous large boulders and pebbles of mainly local Carboniferous and Silurian origin. However, from the lithological variety and rounded shape of some clasts recorded in the upper 1-2 m of profiles, transport distances of 20 km or more are indicated. A distinctive red sandy till recovered from the lowermost sections of two holes drilled near the northern end of the project area (Traverse 4) confirms the mapped presence of underlying Upper Old Red Sandstone in an area of very poor exposure.

The concentrations of base metals and Ba are generally low in both the panned till (Table 3) and fine till fractions (Table 4), contrasting strongly with the recorded levels in drainage concentrates which are up to an order of magnitude higher. In part, this is explained by the clay-rich composition of the tills resulting in small initial volumes of washed -2 mm material (average of <1 litre) relative to drainage samples (average of 4 litres). Panned tills thus contain a smaller proportion of heavy minerals and consequently lower abundances of all metalliferous elements.

High Cu values (maximum 348 ppm in panned till and 88 ppm in -150 μm till) occur in samples collected over the projected surface trace of the Coomb Edge Fault (Figure 6), probably reflecting an extension of the weak mineralisation noted in the fault breccia nearly 1 km to the north east. Mineralogical examination revealed the presence of chalcopyrite and two grains of gold in the panned till, providing additional evidence that mineralised material dispersed downhill from the fault is the primary cause of the drainage anomalies in Wormscleuch Burn (Appendix).

Although no major anomalies in Zn or Pb are recorded, coincident weak enhancement occurs in a small number of instances. These lie mainly within 100 - 200 m of the projected fault on traverses 2, 4 and 5 (Figures 7 and 8). Two consecutive sample sites on traverse 2 for example, contain Zn anomalies in the panned sample (BFU 6663 and 6665) and a Pb and Zn anomaly in one of the corresponding -150 μm till samples (BFT 6664). Much fine dodecahedral pyrite together with several coarse grains of sphalerite was separated from BFU 6665 and similar amounts of pyrite from BFU 6663 indicating that sulphide mineralisation may be present in the underlying rocks. Sphalerite has also been identified in other samples having comparable levels of Zn (e.g. BFU 6685 from the Raven Burn area). Here, the mineral assemblage also includes fresh chalcopyrite and framboidal pyrite, several course angular grains of baryte and one fine, irregular grain of gold, all indicating limited glacial dispersion and a local source of mineralisation (Appendix).

A further 11 till concentrate samples (Table 3, Traverse 7) were collected from till exposures in the forest track on the north west side of Wormscleuch Burn. Sampling was conducted at 50m intervals close to the trace of the Coomb Edge Fault to trace the source of the gold and base metal anomalies

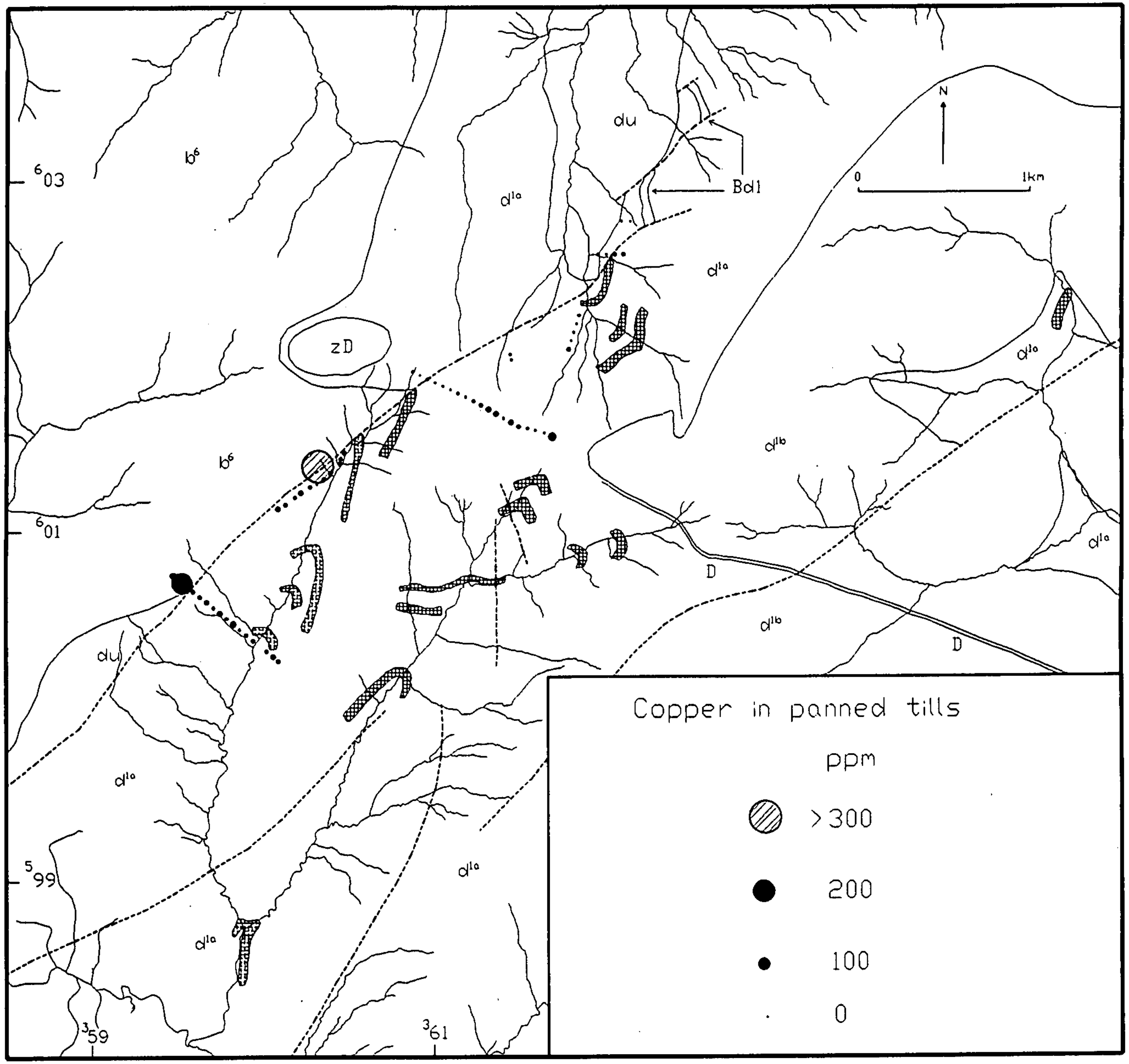

Figure 6 Copper in panned tills

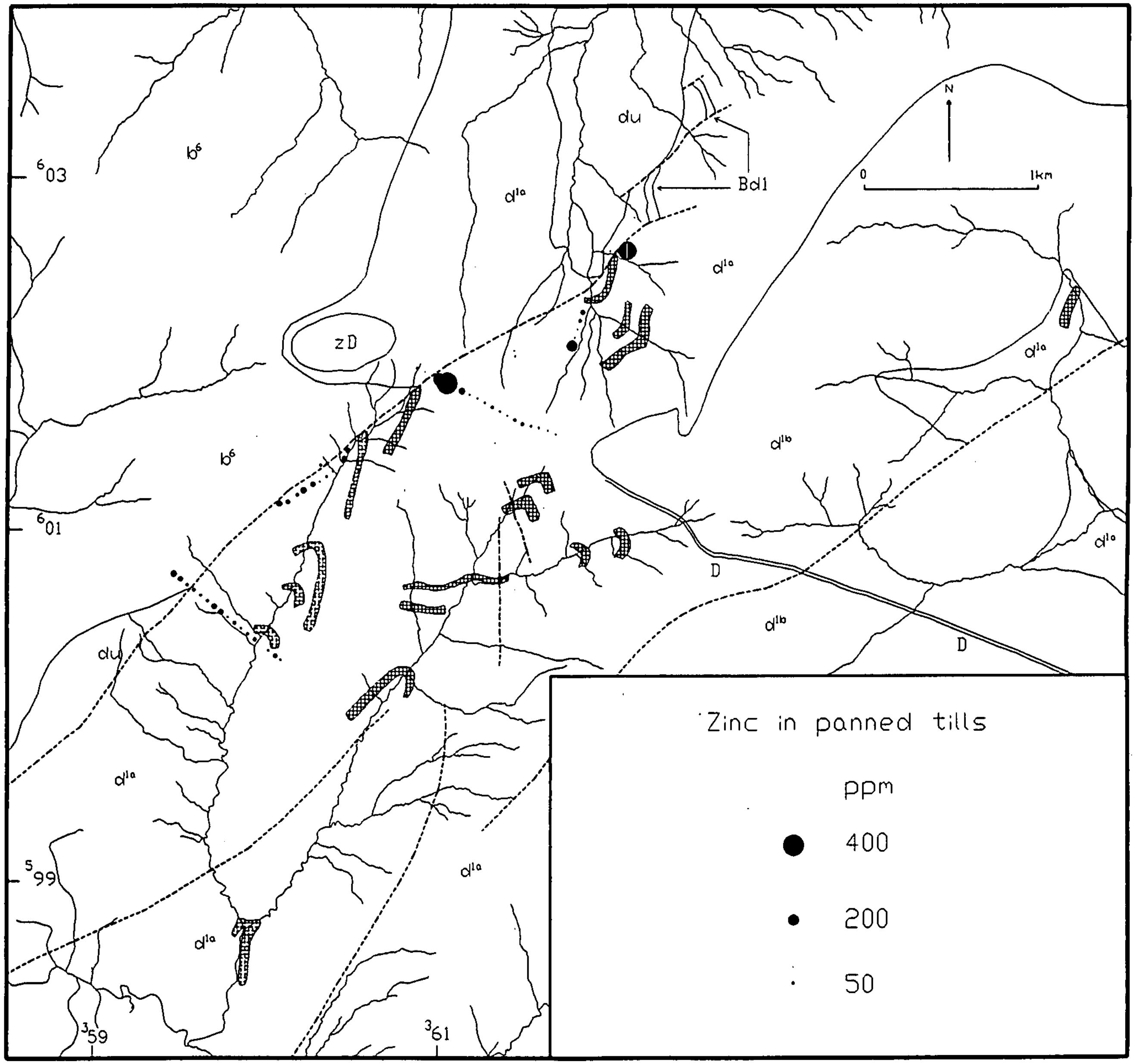

Figure 7 Zinc in panned tills

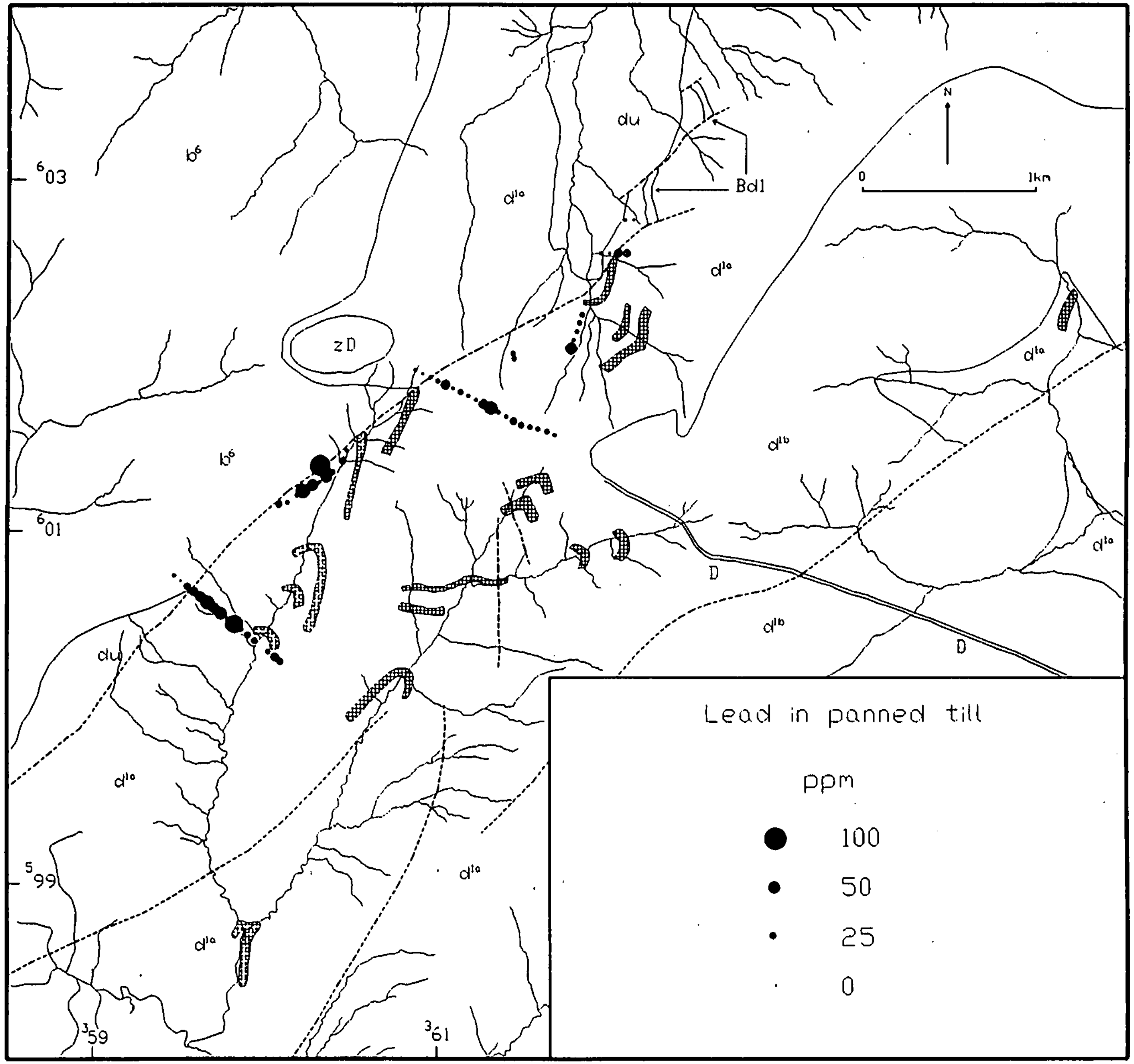

Figure 8 Lead in panned tills

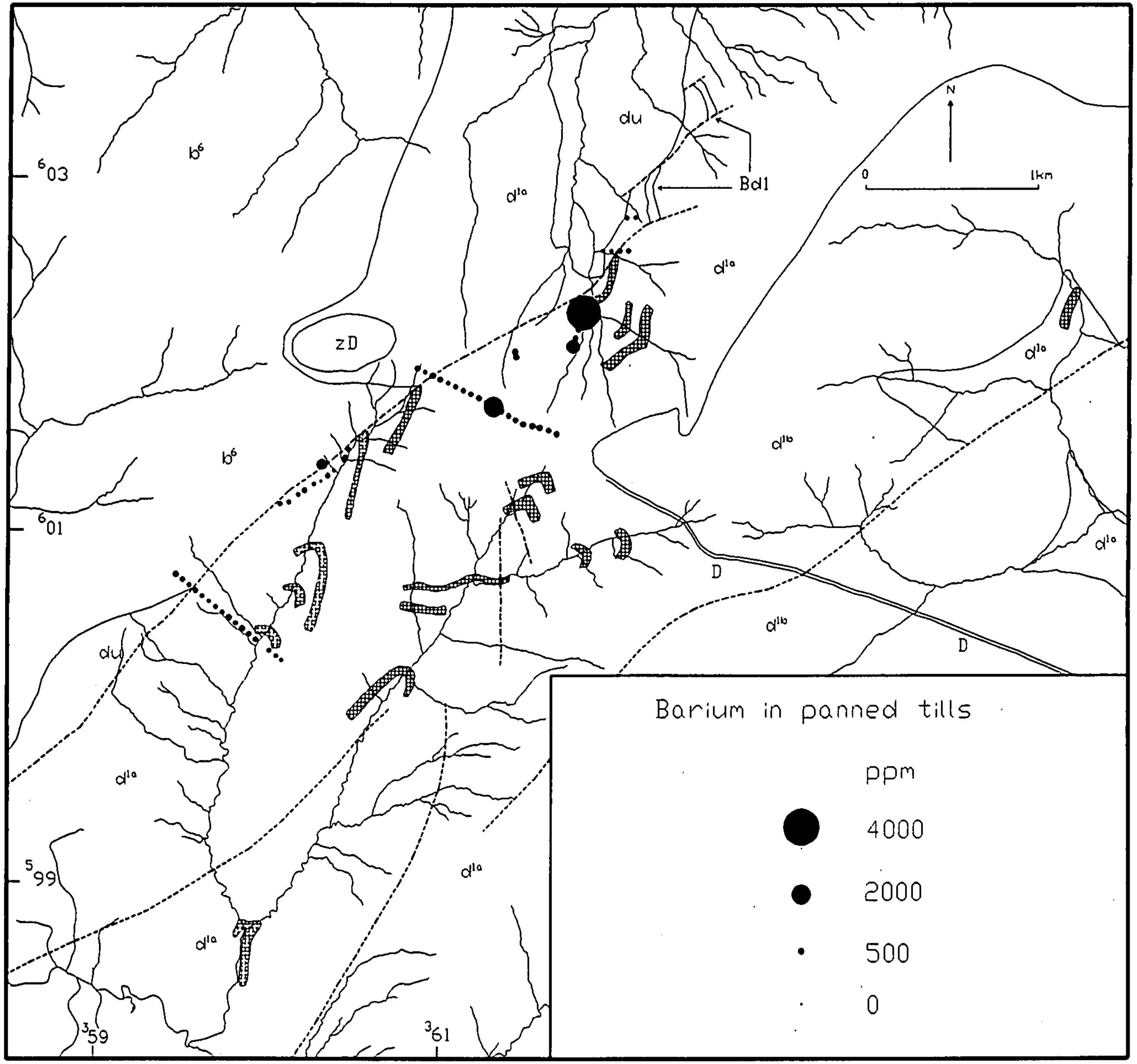

Figure 9 Barium in panned tills

seen in the drainage samples. The results failed to indicate enrichment in Au or Zn, although a prominent Cu anomaly in sample BFU 7281 is accompanied by weakly anomalous Pb and Ba (Figures 6, 8 and 9). Both Fe and Ni, and to a limited extent, As values, are enhanced relative to samples collected over Carboniferous rocks further to the east. The highest concentrations of these elements correlate with the observation of a strong red coloration in several concentrate samples, probably reflecting the presence of hematite similar to that recorded in the fault breccia exposed 140 m to the north east. Apart from iron oxides and the occasional grain of pyrite no heavy metallic minerals were observed in these samples.

Two test holes were drilled with a Cobra percussion drill about 50 m west-south-west of the fault breccia sampled in BFR 6074 (at [NT 60430 01455]). The holes, 50 m apart (Table 4) straddled the projected line of the fault structure. Basal till samples from both holes showed the same distinctive reddening observed in the breccia outcrop, and also enrichment in Cu (and Ni) consistent with the panned till data from Traverse 7.

GEOPHYSICS

Introduction

Reconnaissance geophysical surveys including magnetic (total field) and VLF magnetic field, were undertaken to ascertain if these methods could detect the position of potentially mineralised faults beneath drift cover and to delineate possible sub-outcrops of down-faulted Birrenswark lavas.

In the vicinity of the Wormscleuch Burn-Peel Burn catchments, evidence for continuation of the Coomb Edge Fault is obscured by an almost continuous spread of boulder clay. Geophysical traverses were located to intersect the projected line of this fault in unexposed interfluve areas including the head of the Wormscleuch-Raven Burn catchment.

Out of a total of nine across-strike traverses, seven are located within the Wormscleuch Burn catchment, an eighth in the unexposed watershed area at Wheelrig Head, and the ninth immediately south-east of the Raven Burn headwaters (Figure 10). The traverses average 1 - 1.5 km in length and span approximately 3 km of inferred strike-length. Due to difficult terrain conditions and impenetrable forestry, access to the north-eastern part of the area, in which two small fault-bound blocks of Birrenswark lavas have been mapped, was precluded.

Survey methods

The ground magnetic data were collected with a Scintrex IGS-2 system configured to observe total magnetic field and the VLF magnetic field sequentially. Magnetic observations were made at measured intervals of 10 m along approximate north-west/south-east oriented firebreaks in the forest cover. Total field observations were made using the backpack-mounted bottle for convenience with the concurrent VLF measurements. All total field magnetic data were related to base station observations made at several sites. The base stations were linked together and corrections for diurnal change have been applied.

VLF magnetic field data were collected sequentially with the total field magnetic data using the transmitters at Maine, U.S.A (24.0 kHz) and Rugby, UK (16.0 kHZ) since these were the only transmitting stations to offer a detectable signal. Neither station is, however, particularly suited to the identification of north-east bearing structures since Maine and Rugby are directed to the west and south of the study area respectively. All VLF measurements were made using a back-mounted receiver coil and facing towards the transmitter stations.

Magnetic data

There is little or no published magnetic susceptibility data for the Birrenswark lavas although a recent interpretation of the BGS national aeromagnetic survey of the UK clearly indicates that the lavas are associated with a 40 km long elongate belt of low-amplitude magnetic anomalies (Smith and Royles, 1989, Colman et al., 1995). Ground magnetic surveys conducted in the Langholm area as part of an MRP base-metal survey also detected zones of perturbed magnetic field over thinly buried or suboutcropping Birrenswark lavas (Gallagher et al., 1977). Given the rapid attenuation of magnetic response with depth and the extensive spread of thick overburden throughout the project area, it is unlikely that weakly magnetic sources will be detected unless they lie within 5 - 10 m of the surface.

The total field magnetic data are shown in Figure 10. Magnetic gradients are, for the most part, gentle and there are no zones of perturbed magnetic field to indicate the presence of suboutcropping Birrenswark lavas or other basic igneous rocks. Most pronounced and strongest magnetic variations were recorded along traverse 8, where measurements were taken along a forest track strewn with blocks of basaltic material taken from a local quarry. Traverse 9, located to the north-east, exhibits virtually no magnetic relief, which suggests that the weakly magnetic Birrenswark lavas are either absent in the sub-surface or deeply buried. The other traverses display markedly different magnetic profiles, the nature of which, in part, can be explained by the variable distribution of basalt boulders throughout the study area. These effects are most pronounced over the southernmost segments of traverses 5 and 6 for example, where measurements were taken along forest tracks reinforced with basaltic quarry material.

However, some of the magnetic variations cannot be accounted for by the presence of basaltic road metal, and these may represent the presence of Birrenswark lavas in the sub-surface, especially in the vicinity of traverses 1-4. Additionally, traverses 6 and 7 exhibit narrow anomalies along the course of Wormscleuch Burn suggesting the likely presence of a magnetic dyke.

It is evident that the magnetic method is not successful in mapping the extent of the Birrenswark lavas or the projected line of the Coomb Edge Fault across the study area, due either to the absence of magnetic material or its depth of burial.

VLF data

The VLF in-phase data are shown in Figures 11 and 12. They provide no evidence for the projected trace of the Coomb Edge Fault, most probably due to a lack of contrast in conductivity either side of the fault. Generally, the data appear very noisy, indicative of a variably thick and conductive overburden. No coherent anomaly pattern is apparent apart from a strong in-phase (Rugby) anomaly observed along the course of Wormscleuch Burn which is interpreted as topographic in origin.

Figures 13 and 14 show the Fraser Filter operator applied to the in-phase VLF data. They reinforce the noisy character of the data and the absence of a traceable VLF anomaly along the line of the Coomb Edge Fault.

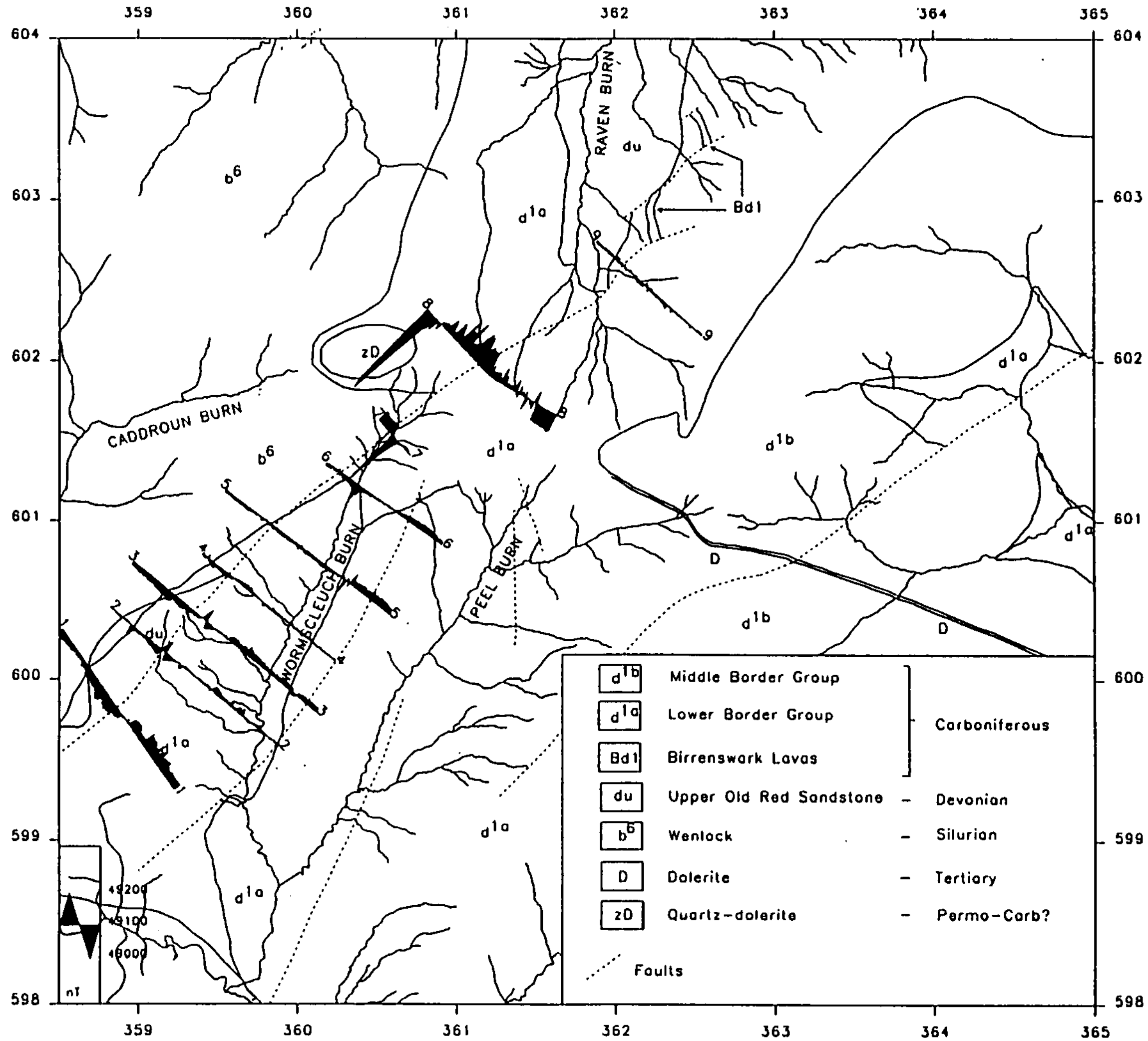

Figure 10 Total field magnetic field profiles, Wormscleuch Burn. All data corrected for diurnal change.

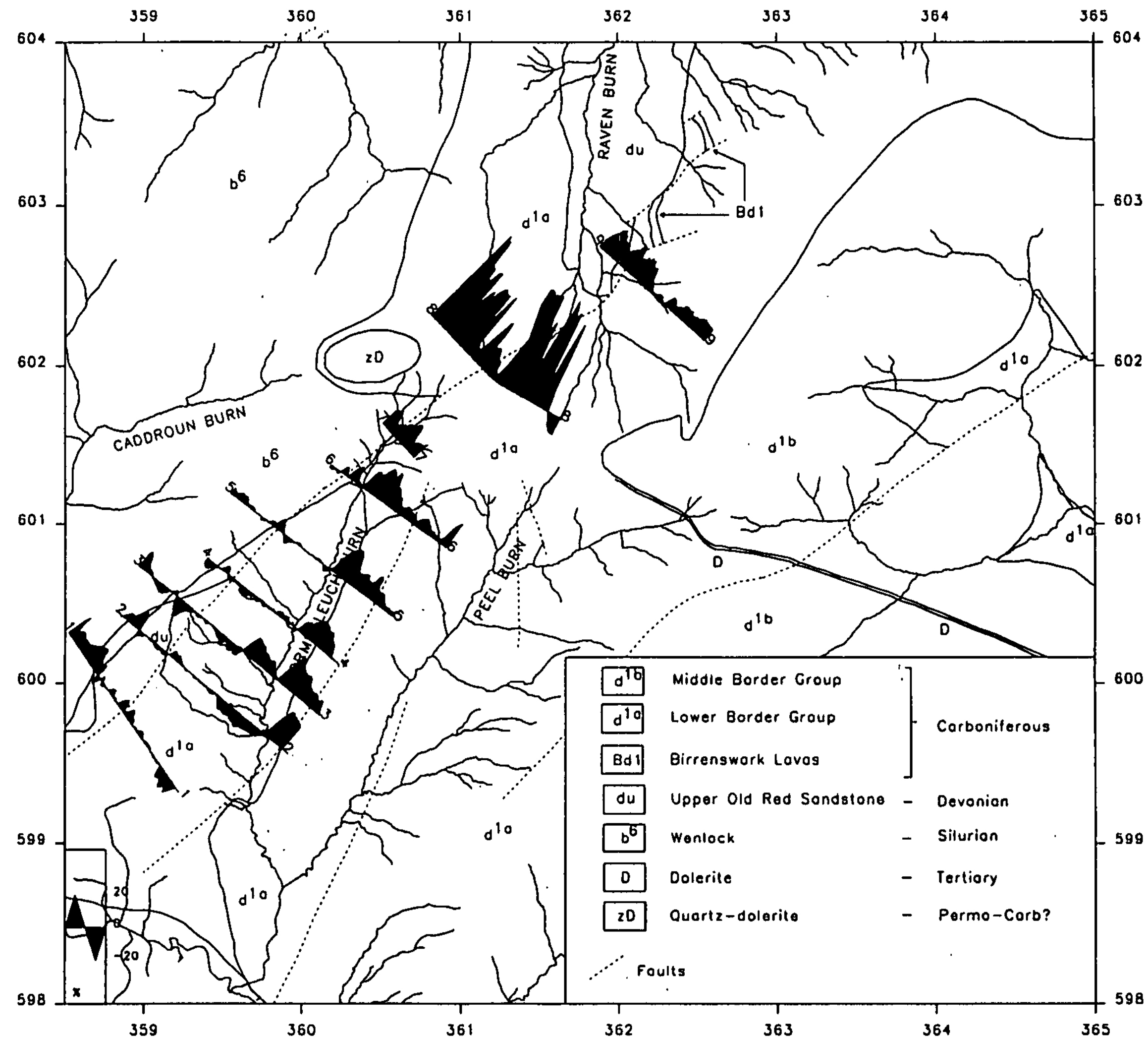

Figure 11 VLF electromagnetic (magnetic field) profiles, Wormscleuch Burn. VLF frequency 16.0 kHz, in-phase component

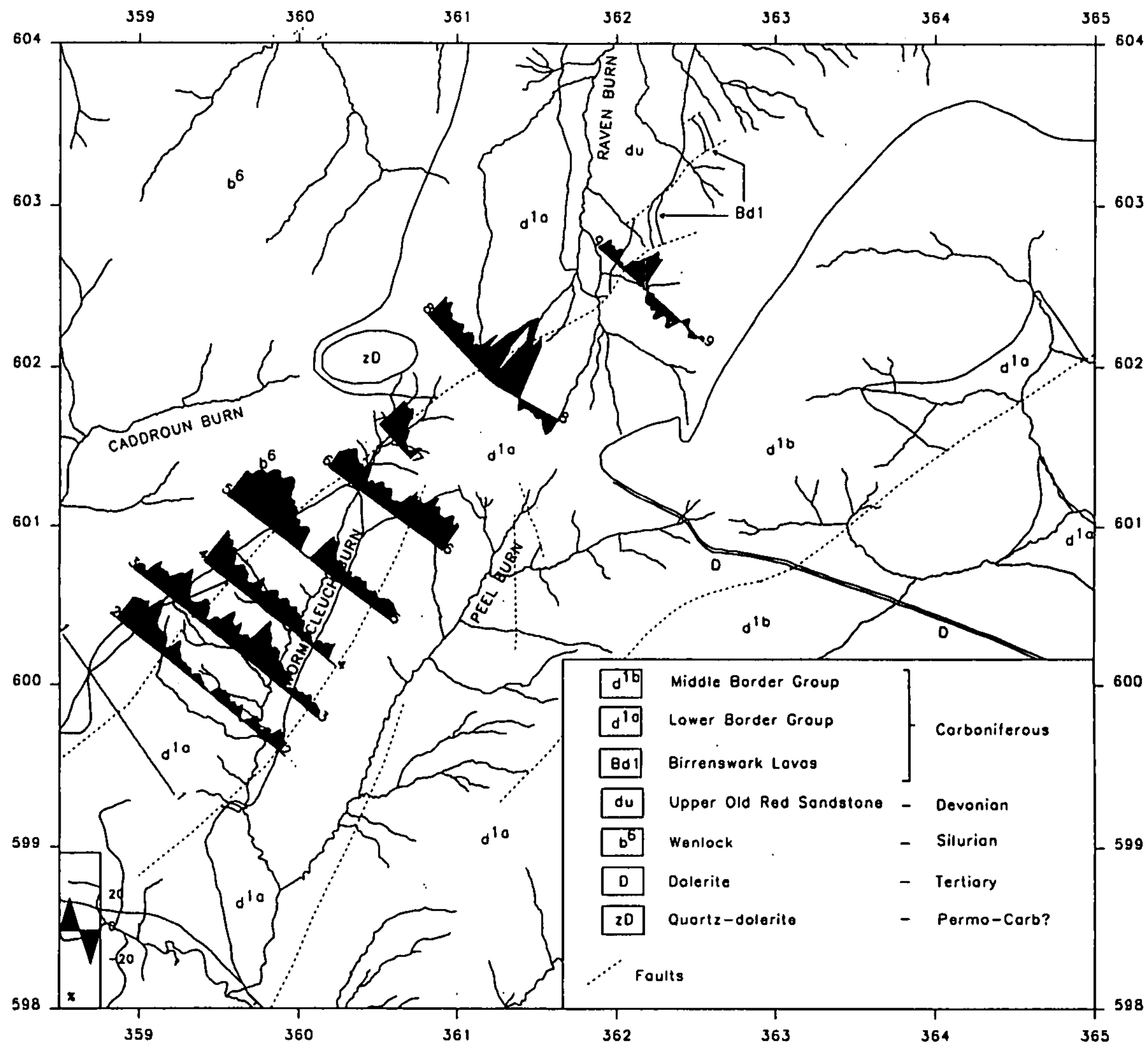

Figure12 VLF electromagnetic (magnetic field) profiles, Wormscleuch Burn. VLF frequency 24.0 kHz, in-phase component.

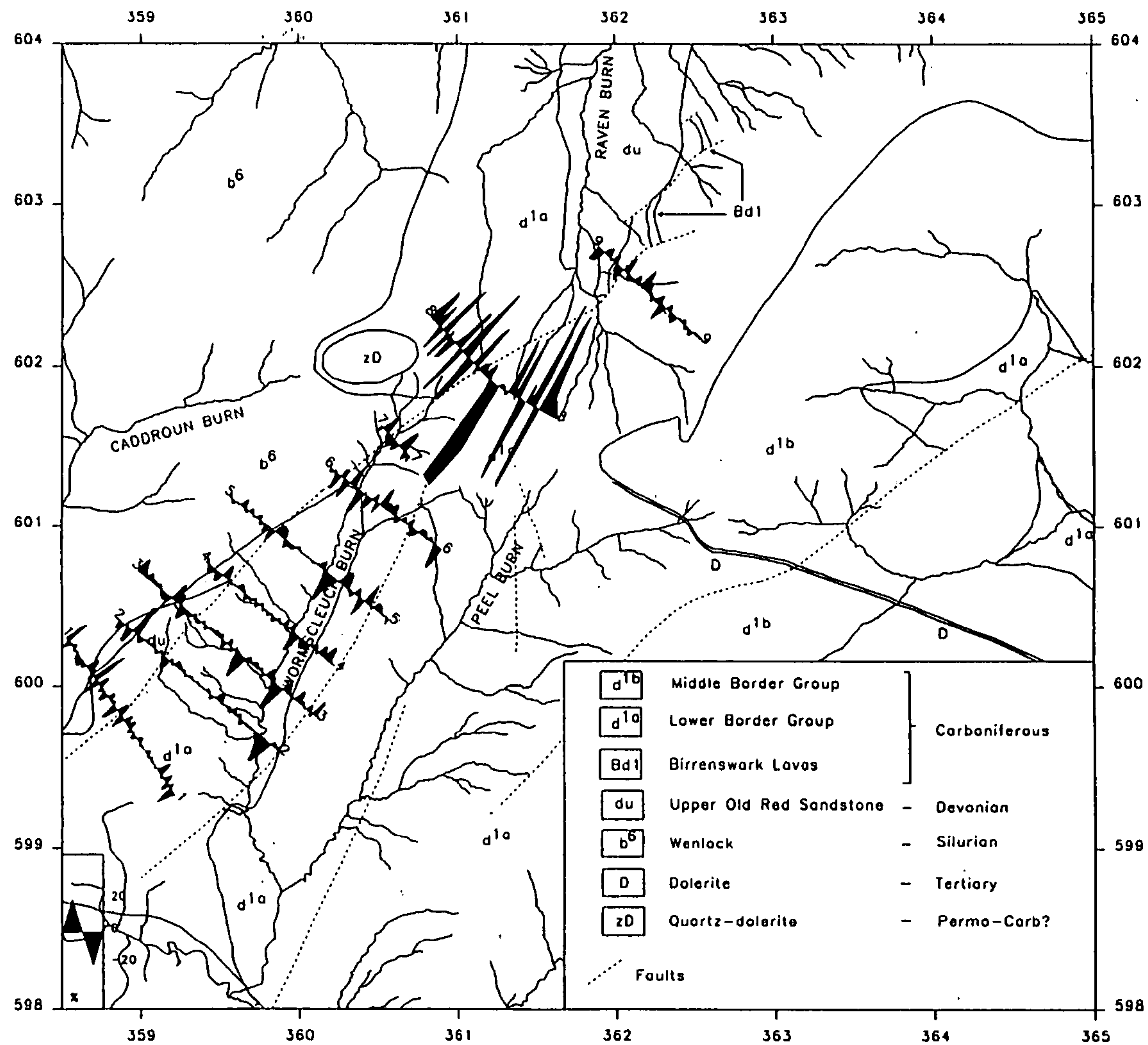

Figure 13 Fraser Filtered VLF electromagnetic (magnetic field) profiles, Wormscleuch Burn. VLF frequency 16.0 kHz.

Filtered from in-phase component.

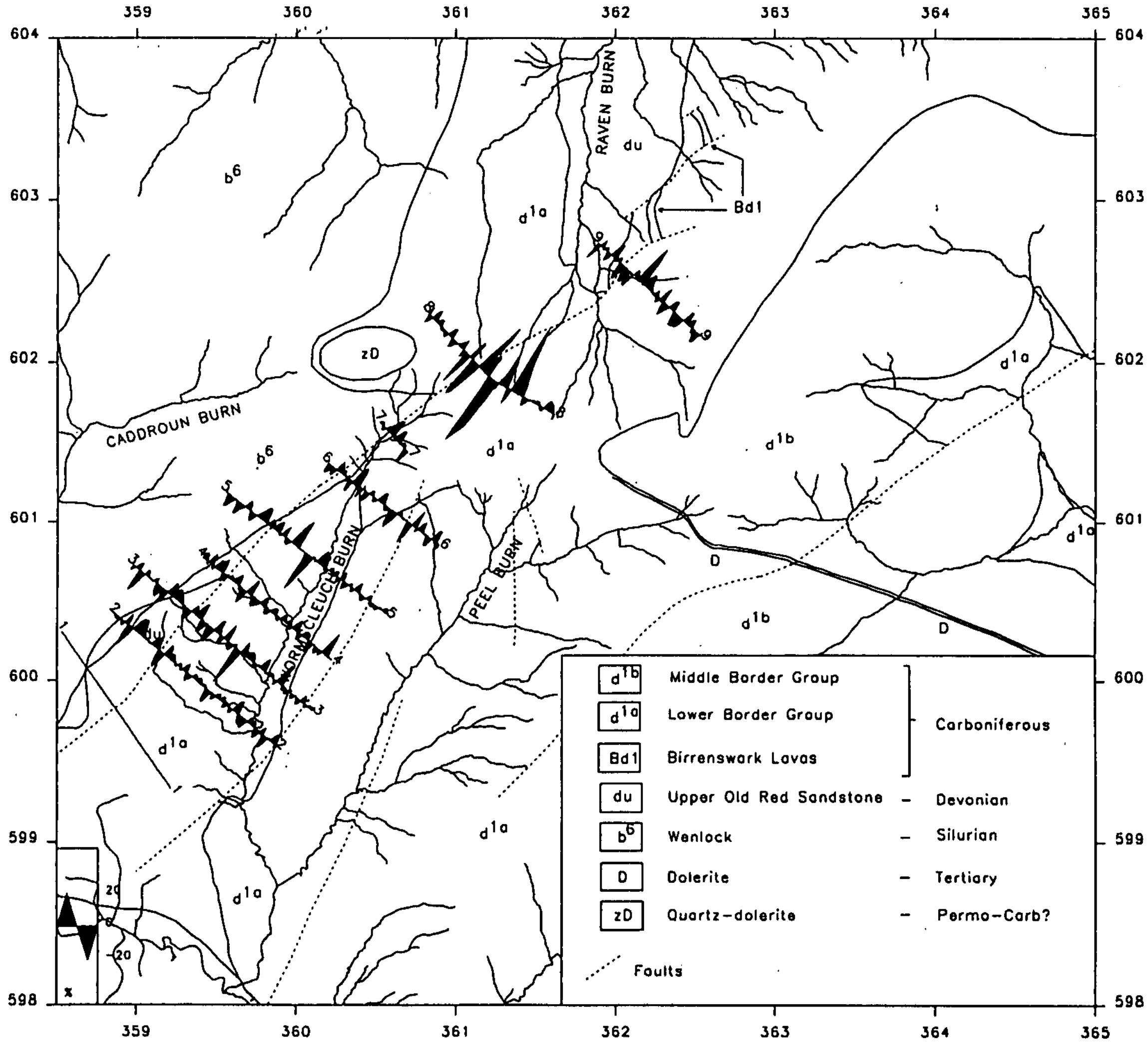

Figure14 Fraser Filtered VLF electromagnetic (magnetic field) profiles, Wormscleuch Burn. VLF frequency 24.0 kHz. Filtered from in-phase component.

DISCUSSION AND ASSESSMENT

Strongly anomalous Cu, Pb, Zn, and Ba levels are present in panned stream sediment samples over much of the project area at concentrations which suggest close proximity to a mineralised source or sources. Mineralogical examination of panned concentrates and electron microprobe studies of selected grains demonstrate that sphalerite is present in substantial amounts, in generally coarse (+500 -2000 μm fraction), untarnished grains indicating only limited distance of transport from a local source. Sphalerite grains separated from panned concentrates collected in the Langholm-Newcastleton area are virtually identical in morphology, size and colour suggesting a common metallogenic origin associated principally with calcite-dolomite-(baryte) vein-networks and fractures in Lower Border Group cementstones in both areas.

However, the small number of minor sphalerite occurrences discovered during the present survey does not adequately explain the magnitude of the geochemical anomalies in the Arnton Fell area, and it is considered likely that further sources of mineralisation of similar style exist beneath the thick drift deposits. The possibility that the minor shows of Zn-mineralisation seen in the area could represent a distal or remobilised expression of Irish-style mineralisation cannot be discounted (Andrew et al., 1986).

Grains of galena, chalcopyrite and gold discovered in the Wormscleuch and Raven Burns are also quite fresh and of undoubted local provenance. Their presence, together with rare grains of mimetite and cinnabar and, in the case of the Wormscleuch catchment, enrichment of As in till and drainage concentrates, points to a Lower Palaeozoic source, possibly lying within or at the faulted margin of the Arnton Fell inlier. This mineralogical association shows certain similarities with the nearest recorded polymetallic mineralisation at the Glendinning mine about 30 km to the west. Here, Silurian greywackes contain stratiform pyrite and weakly auriferous arsenopyrite overprinted by fracture-controlled Pb-Zn-Cu-Sb-As mineralisation (Gallagher et al., 1983). Although not discovered in the mineral veins cinnabar was identified in panned concentrates taken below the old mine workings.

Epigenetic veins in the Lower Palaeozoic rocks of the Lake District adjacent to the southern margin of the Solway Basin often contain several phases of mineralisation each characterised by a distinctive suite of minerals and metals (Stanley and Vaughan, 1982), including all of those noted in panned concentrates from the project area. Recent MRP surveys over the Carboniferous rocks at the southern margin of the basin (Cooper et al., 1991, 1992) reported the widespread presence of cinnabar and gold in panned concentrates and anomalous concentrations of Hg, Cu, As, Pb, and Ba were also recorded in mineralised limestone associated with a complex copper-lead-baryte vein at Threapland [NY 1620 3942]. Apart from the gold, which is present in much smaller amounts than in the project area, and may have been glacially transported from source areas in southern Scotland and the Lake District (Cooper et al., 1991), there is close similarity in the observed pattern of ore metal enrichment between the Carboniferous rocks of the project area at the northern margin of the basin and the Cockermouth area at the southern edge. This suggests a similar style of metallogeny in the two districts which share comparable structural and stratigraphic environments.

Ground magnetic data (total magnetic field and VLF magnetic field), failed to detect pronounced anomalies indicative of either the position of sub-outcropping Birrenswark lavas or the surface trace of the Coomb Edge Fault. Most probably, this reflects the masking effect of thick overburden and the poor contrast in the geophysical properties of rocks on either side of the fault(s).

The difficulties involved in attempting to locate mineralisation in heavily glaciated terrain using portable deep overburden sampling equipment are also clearly demonstrated by this study. The absence of substantial anomalies in the panned till samples could arise for several reasons, the most likely being that the sub-outcropping mineralised source(s) are of low tenor and/or of very limited extent. However, in the clay-rich, neutral to mildly alkaline tills, typical of those in the project area, the majority of sulphide grains examined have fresh uncorroded surfaces indicating that chemical weathering of sulphides is very limited. Under such conditions glacial dispersion trains are characteristically small in size and therefore difficult to locate geochemically, especially in the upper parts of deep till profiles which contain a higher proportion non-local material. The capacity of the power auger to penetrate dry clay-rich till to depths greater than 5 m was very limited, so that the material collected, may in some instances, have come from well above the base of the till and not be representative of local bedrock.

CONCLUSIONS AND RECOMMENDATIONS

1. The geochemical data, taken in conjuntion with the presence of a major basinal synsedimentary fault and a substantial thickness of Lower Dinantian carbonate-bearing strata, suggests that undiscovered mineralisation may be present concealed either by the thick spread of glacial deposits or by a cover of barren sedimentary rock.

2. Based on evidence from sparse rock exposures and mineralogical work on panned concentrates it seems likely that the mineralisation is predominantly fracture-bound epigenetic in style and may involve both polymetallic veins (Cu, Au, Pb, Hg, ±Ba) associated with Lower Palaeozoic rocks and Zn ± Ba fracture-bound mineralisation associated with Lower Border Group cementstones and limestones. The latter may represent the distal expression of Irish-style stratabound base-metal mineralisation.

3. Further investigations to test this hypothesis are recommended. Because of the almost continuous cover of glacial drift this would require a more extensive overburden sampling programme with equipment such as a reverse circulation or rotasonic drill, capable of penetrating up to 10 m of till and the top few metres of bedrock. Definition of a target for deep drilling would also require geophysical surveys and a structural analysis.

4. The possibility of gold mineralisation being associated with the Coomb Edge Fault merits further investigation. In comparison with the widespread but low abundance of gold over Lower Palaeozoic and Carboniferous rocks of the Cumbria area, gold is present in significantly larger amounts in the project area, and has morphological features suggesting derivation from a local source. The logical next step in exploration would be the use of deep overburden sampling equipment with greater depth and core drilling capacity to sample at close intervals across the projected line of the Coomb Edge Fault and its extension northwards into densely forested ground.

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APPENDIX Mineralogical Examination of Panned Concentrates and Panned Tills from the Arnton Fell area

Reproduced with minor amendments from BGS, Mineralogy and Petrology Short Report MPSR/94/14 (Bland, 1994).

Introduction

Eight panned concentrates from streams and six panned till samples, all collected close to the faulted Silurian-Lower Carboniferous boundary at the east side of Arnton Fell were submitted for mineralogical examination. The samples were selected on the basis of their anomalous base-metal and barium concentrations or because of the observed presence of sulphides and baryte in the pan at the time of sampling.

Laboratory examination

All samples were sieved at 500 microns, the greater than 500 micron material being stored whilst the less than 500 micron fraction was separated into a heavy and light fractions with the superpanner. The heavy fractions were further separated with a Frantz Isodynamic separator into very strong, strong, moderate, weak and non-magnetic fractions. This greatly aids phase identification, when being examined under a binocular microscope.

During the microscope examination a number of grains were attached to a microscope slide with double sided adhesive tape for electron microprobe analysis to confirm their chemical composition and mineral identification.

Results

Examination of the less than 500 micron material showed a distinct lack of some phases relative to that which would be expected from the chemical analyses. In these cases the greater than 500 micron material was first examined, using the Siemens VRS manual XRF, for the element in deficit and then under the microscope. In all cases the 'missing' material was found in the oversize fraction. This was particularly noticeable for zinc and barium, less so for lead as many large sphalerite and barite grains were found but only a few galena grains.

The observations of significant features noticed in the super-panned concentrates are given in Table I. This table also contains the results of optical and XRF examinations of the greater than 500 micron fractions. In the results for the >30 mesh till samples the XRF peaks have been graded very small, small and large as a qualitative indication of the quantity present.

The phase identifications of the grains from the concentrates was made with the Cambridge Microscan Electron Microprobe using the Link Systems (Oxford Instruments) energy dispersive attachment. The results are presented in Table II. Mimetite is $Pb_5(AsO_4)3Cl$ and gahnite, the zinc spinel, is $ZnAl_2O_4$. The silicate grains placed on the slide were not identified as specific mineral types.

A selection of the pyrite, sphalerite, galena, gold, silver and gahnite grains were semi-quantitatively analysed in the microprobe to "quantify" any included arsenic, iron silver, etc. These results are shown in Tables III, IV and V. The totals for these analyses are low in some cases, mainly due to clay coatings on the grain surfaces.

Discussion

The chemical anomalies in the samples have mostly been accounted for in the minerals, sphalerite, galena, chalcopyrite and barite, found in the samples. The exceptions are barium and lead in the till samples which are not completely explained.

In the stream samples the large grain size (up to 2 mm) particularly of sphalerite and galena suggests that the "nugget effect" may have affected the analyses, causing unrepresentative results.

The small grain size and marked degree of angularity of the gold found in the panned stream concentrates indicates an extremely short distance of travel in the stream.

The analyses of the silver rich grains show 10% or more of cadmium. Cadmium is a constituent of several of the alloys used for 'silver-soldering' (Reference 1).This strongly suggests that the grains, which have the appearance of metallic swarf, are 'silver-solder', probably AG1 (Ag 50, Cu 15, Zn 16, Cd 19) which has a liquidus of 640°C. The totals do not add up to 100 and the analyses show variability which are thought to be clay on the surface and segregation of the alloying elements during the 'soldering' process.

Table I Observations during optical and XRF examination.

Sample number	Comment
BFP6562	+30 two galena grains
BFP6563	little true heavy - ?? gold; +30 some sphalerite
BFP6577	abundant zircon, few small galena; +30 some sphalerite
BFP6578	very little fine sphalerite; +30 much sphalerite - some abraded surfaces
BFP6755	+30 much galena
BFP6756	abundant ?hematite; +30 little and nearly all barite
BFP6779	abundant pyrite - both fine grained and crystal fragments; +30 abundant sphalerite
BFP6781	+30 abundant sphalerite, 1 largish galena
BFU6603	very little heavy; +30 no Ba, Pb, Zn, Cu
BFU6663	abundant fine pyrite in dodecahedron, abundant black rutile, abundant garnet (broken fragments); +30 no Ba, Cu very small Pb, Zn
BFU6665	abundant fine pyrite in dodecahedron, abundant black rutile, many small rods and crosses - probably siderite, fresh ilmenite; +30 no Pb, Cu, very small Ba, large Zn
BFU6667	little true heavy apart from little iron oxide and garnet; +30 no Pb, Cu very small Zn, small Ba
BFU6685	abundant fine framboidal pyrite, little garnet, fresh ilmenite; +30 no Pb, Cu very small Zn, large Ba - several large grains of barite
BFU6698	abundant cokey-looking pyrite, little else; +30 no Zn, Cu, small Ba, Pb - abundant bitumen

Table II Electron microprobe identification of selected grains.

Sample	Phase
BFP6755	Cinnabar, Sphalerite, Rutile, Pyrite, Galena, Barite, Silicate
BFP6756	Gold, Barite, Pyrite, Chalcopyrite, Rutile, Silicate
BFP6762	Gold, Cinnabar, Galena, Sphalerite, Pyrite, Barite, Rutile, Silicate
BFP6763	Mimetite, Galena, Sphalerite, Chalcopyrite, Pyrite, Barite, Rutile, Silicate
BFP6777	Galena, Sphalerite, Pyrite, Barite, Rutile, Monazite, Silicate
BFP6778	Galena, Sphalerite, Pyrite, Barite, Monazite, Rutile, Silicate
BFP6779	Sphalerite, Pyrite, Gahnite, Barite, Monazite, Rutile, Silicate
BFP6781	Gold, Galena, Sphalerite, Pyrite, Silicate
BFU6603	Gold, Silver, Chalcopyrite, Rutile
BFU6663	Pyrite, Sphalerite, Gahnite, Iron Oxide, Apatite, Dolomite, Rutile, Silicate
BFU6665	Pyrite, probably Siderite, Rutile, Silicate
BFU6667	Pyrite, Iron Oxide, Dolomite, Silicate
BFU6685	Gold, Pyrite, Sphalerite, Chalcopyrite, IronOxide, Rutile, Apatite, Silicate
BFU6698	Pyrite, Rutile, Silicate

Note The order of the minerals in Table 2A has no significance.

Table III Semi-quantitative electron microprobe analyses of selected ore minerals

Grain No.	Phase	Cu	Zn	Fe	As	Pb	Ag	S	Cd	Total
6755/2	SPHALERITE	0	64.6	0.64	0	0	0	29.4		94.64
6755/3	SPHALERITE	0	64.1	0.68	0	0	0	30.7		95.48
6755/25	SPHALERITE	0	66.4	0	0	0	0	30.8		97.2
6762/28	SPHALERITE	0	67.4	0.43	0	0	0	31.6		99.43
6762/29	SPHALERITE	0	65.5	0.48		0	0	31.9		97.88
6763/5	SPHALERITE	0	65.6	0	0	0	0	30.9		96.5
6763/8	SPHALERITE	0	64.3	0	0	0	0	31.1		95.4
6763/9	SPHALERITE	0	66.6	0	0	0	0	32.2		98.8
6777/9	SPHALERITE	0	68.6	0.3	0	0	0	31.8		100.7
6777/10	SPHALERITE	0	67.2	0	0	0	0	32.1		99.3
6778/3	SPHALERITE	0	66	0	0	0	0	31.2		97.2
6778/10	SPHALERITE	0	65.2	0	0	0	0	32		97.2
6778/11	SPHALERITE	0	67.4	0	0	0	0	32.2		99.6
6779/3	SPHALERITE	0	66.5	0	0	0	0	31.6		98.1
6779/4	SPHALERITE	0	66.4	0	0	0	0	31.9		98.3
6779/5	SPHALERITE	0	64.2	0.3	0	0	0	30.8		95.3
6779/7	SPHALERITE	8.3	49.3	0.8	0	0	0	28.3		86.7
6781/12	SPHALERITE	0	66	0	0	0	0	30.8		96.8
6781/13	SPHALERITE	0	67.3	0	0	0	0	31.8		99.1
6663/9	SPHALERITE	0	62.6	0.4	0	0	0	30.9		93.9
6663/11	SPHALERITE	0	68.9	0	0	0	0	31.8		100.7
6663/12	SPHALERITE	0	66.9	0	0	0	0	32.3		99.2
6663/14	SPHALERITE	0	66.8	0	0	0	0	32.4		99.2
6685/3	SPHALERITE	0	66.1	0	0	0	0	31.5		97.6
6685/4	SPHALERITE	0	67	0	0	0	0	31.3		98.3
6685/5	SPHALERITE	0	66.1	0	0	0	0	31.6		97.7
6685/5	SPHALERITE	0	66	0	0	0	0	31.5	0.7	98.2
6755/12	GALENA	0	0	0	0	83.3	0	11.7		95
6755/13	GALENA	0	0	0	0	86.3	0	11.9		98.2
6755/27	GALENA	0	0	0	0	86.7	0.31	12.3		99.31
6726/27	GALENA	0	0	0	0	91.2	0	12.4		103.6
6763/3	GALENA	0	0	0	0	87	0	12.6		99.6
6777/7	GALENA	0	0	0	0	85.7	0	13.3		99
6777/8	GALENA	0	0	0	0	85.9	0	12.5		98.4
6778/4	GALENA	0	0	0	0	79.6	0	13.2		92.8
6778/5	GALENA	0	0	0	0	86.4	0	12.5		98.9
6781/8	GALENA	0	0	0	0	91.9	0	13.3		105.2
6781/9	GALENA	0	0	0	0	88.2	0	12.5		100.7
6781/9	GALENA	0	0	0	0	83.4	0	12.4	0	95.8
6778/4	GALENA	0	0	0	0	78.7	0	13.2	0	91.9
6778/5	GALENA	0	0	0	0	88.9	0	13.1	0	102
6777/7	GALENA	0	0	0	0	87.1	0	12.5	0	99.6
6755/13	GALENA	0	0	0	0	85.9	0	12.5	0	98.4
6762/32	PYRRHOTITE	0	0	50.2	0	0	0	28.7	0	78.9
6762/33	PYRITE	0	0	47.8	0	0	0	42.8	0	90.6
6756/5	PYRITE	0	0	44.4	0	0	0	48.8	0	93.2
6762/6	PYRITE	0	0	45.2	0	0	0	45.4	0	90.6
6781/4	PYRITE	0	0	46.1	0	0	0	49	0	95.1
6781/5	PYRITE	0	0	45.9	0	0	0	50.2	0	96.1
6685/9	PYRITE	0	0	37.7	0	0	0	43.6	0	81.3
6685/10	PYRITE	0	0	45.1	0	0	0	49.2	0	94.3

Table IV Electron microprobe analyses of precious metal grains

Grain no.	Phase	Au	Ag	Fe	Cu	Zn	S	Cd	Ni	Total
6756/1	GOLD	81.8	1.3	6.4	0	0	0.6			90.1
6756/2	GOLD	57	8.4	17.2	1.2	1	0.6			85.4
6762/26	GOLD	90.6	6.5	0.6	0	0	0			97.7
6762/22	GOLD	92.3	8.1	0	0	0	0			100.4
6762/19	GOLD	77	6.1	8.2	0.7	0	1.9			93.9
6762/15	GOLD	59.3	33.2	3.2	0	0	0			95.7
6762/10	GOLD	69.5	7.4	2	0	0	0.8			79.7
6762/4	GOLD	89.1	6.5	0.7	0	0	0			96.3
6762/2	GOLD	85.3	3.8	0.5	0	0	0			89.6
6781/1	GOLD	86.8	7	3.1	0	0	0			96.9
6781/2	GOLD	81	16.3	0	0	0	0			97.3
6781/3	GOLD	87.4	6.3	2.6	0	0	0			96.3
6603/1	GOLD	89.1	5.8	0.6	0	0	0			95.5
6603/2	GOLD	91	5.7	0	0	0	0			96.7
6685/1	GOLD	84.1	7.3	1.7	0	0	0			93.1
6603/10	SILVER	0	55.8	0	8.1	8.6	0.4	17.4		72.9
6603/11	SILVER	0	45.5	0	20	7.1	0.2	11	0.8	72.8
6603/12	SILVER	0	30.4	0.3	5.1	4.2	1.1	10.7		41.1
6603/13	SILVER	0	49.5	0.7	11.7	6	0	11.7		67.9

Table V Electron microprobe analyses of gahnite grains

Grain No.	Phase	Si	Ti	Al	Cr	Fe	Mn	Mg	Ca	Na	K	Zn	O	Total
6663/29	GAHNITE	0	0	30.4	0	7.2	0.6	1.4	0	2	0	25.5	37.2	104.3
6779/21	GAHNITE	0	0	30.4	0	9.2	0.3	1.9	0	1.6	0	23.6	37.5	104.5

Table 1

BRITISH GEOLOGICAL SURVEY
Mineral Reconnaissance Programme

Arnton Fell Rock Data

SAMPLE REF.	EASTING	NORTHING	LOCALITY	COMMENTS
BFR5925	361770	500870	S FLWNG HDWTR TRIB OF PEEL BURN, 50M UPSTM JN.	0.6M THICK DARK LMSTN. UNIT, CSE ZNS IN CARB. VNS.
BFR6067	362170	602500	YELLOW SIKE 5M UPSTM FOREST TRACK, STRM BED O'CROP	? CRUSHED-CAL.VND. FERROAN DOLOMITE-RICH CEMENTSTONE
BFR6074	360430	601455	W BANK H'DWATER TRIB. OF WORMSCLEUCH BURN, 7M UPSTM TRK	HEMATITE-CAL CEMENTED BRECCIA, RARE GRAINS CUFES
BFR6077	360680	601660	WORMSCLEUCH BURN 50M UPSTRM OF FIRST NW BANK TRIB. CONFL.	STREAM CLAST. DARK MINERAL IN VEIN ? SPHALERITE.
BFR6081	360480	601400	WORMSCLEUCH BURN 200M UPSTRM TRACK INTERSECTION	STREAM CLAST. FROM STREAM SITE BFP6760
BFR6082	360420	601450	WEST BANK TRIBUTARY OF WORMSCLEUCH BURN	CARBONATE VEINING & HEMATITE STAINING.
BFR6084	360850	600230	PEEL BURN, 90M DWNSTRM OF JN WITH TURPY SIKE	CARBONATE + BARYTE WITH FEW GRNS PYRITE+ CHALCOPYRITE
BFR6085	360870	600250	PEEL BURN, 80M DWNSTRM JN WITH TURPY SIKE	BARYTE COATING FRACTURES, 90 DEG. TO BEDDING
BFR6086	359960	600340	WORMSCLEUCH INTERSECT. WITH AUGER TRAV. (STRM EXPOSURE)	20CM THICK MICRITE WITH HORIZON OF SOFT WHITE MINERAL?
BFR6088	361960	600905	PEEL BURN, 760M UPSTRM JN WITH MARCH SIKE	? SPHALERITE IN CARBONATE VUGS, 80M UPSTRM OF MAIN LST
BFR6089	361960	600905	PEEL BURN, 760M UPSTRM JN WITH MARCH SIKE	DARK MICRITE WITH IRREG. CALCITE PATCHES/VNS WITH FES
BFR6090	361940	602190	RAVEN BURN HEADWATERS, 15M UPSTRM JN WITH DEEP SIKE	STREAM BOULDER
BFR6091	361940	602170	RAVEN BURN HEADWATERS, 20M UPSTRM JN WITH DEEP SIKE	DARK MICRITE, WITH CARBONATE VEINS
BFR6092	361940	602210	DEEP SIKE AT JN WITH RAVEN BURN	LOOSE BOULDER, SPHALERITE+ CALCITE ON JOINTS
BFR6093	361930	602220	RAVEN BURN HEADWATERS, 40/50M DWNSTRM DEEP SIKE JN.	LOOSE BOULDER, NARROW JNTS/FRACTS. WITH CAL-FES-ZNS
BFR6094	361930	602220	RAVEN BURN HEADWATERS, 40/50M DWNSTRM DEEP SIKE	1M THICK BED SILTY MICRITE WITH ?FINE SULPHIDE
BFR6095	361890	602280	RAVEN BURN HEADWATERS, 100M DWNSTRM DEEP SIKE	1CM CALCITE VN IN MICRITE BRECCIA+ BA ON SLICKS. AT VN MARGINS
BFR6096	361890	602350	RAVEN BURN HEADWATERS, 50M DWNSTRM OF DEEP SIKE JN	0.6M THICK BED WITH JNTS AND THIN VEINS CALCITE +FES
BFR6097	361860	600865	PEEL BURN 680M UPSTRM OF JUNCTION WITH MARCH SIKE	DARK SACCHAROIDAL LIMESTONE WITH SULPHIDES IN CAVITIES
BFR6098	361860	600865	PEEL BURN 680M UPSTRM OF JUNCTION WITH MARCH SIKE	DARK SANDY MICRITE WITH RARE DISSEMINATED SULPHIDES
BFR6099	361860	600865	PEEL BURN 680M UPSTRM OF JUNCTION WITH MARCH SIKE	DARK LIMESTONE WITH CAVITIES CONTAINING SPHALERITE
BFR6100	361860	600865	PEEL BURN 680M UPSTRM OF JUNCTION WITH MARCH SIKE	DARK LIMESTONE WITH RARE DISSEMINATED CUBIC SPHALERITE
BFR6146	361880	602450	RAVEN BURN 130M UPSTRM OF YELLOW SIKE JUNCTION	?BASAL L. CARB. CONGLOM. SST, >10M O'CROP IN STREAM BED
BFR6149	361940	602130	THIRD SW BANK TRIB OF DEEP SIKE, 75M UPST OF CONFL.	CEMENTSTN. WITH CAL+FES ON FRACTURE AND JOINT SURFACES
BFR6150	362080	602530	YELLOW SIKE 70M BELOW TRACK, 1.5M THICK BED, S BANK OF STRM	CALCITE VEINS/BLEBS WITH FES + SPHALERITE AT MARGINS,
BFR6151	362080	602530	YELLOW SIKE 70M BELOW TRACK	CALCITE VEINS WITH ABUN. PYRITE+ ?SPHALERITE
BFR6160	361890	602420	RAVEN BURN HDWATERS E BANK, 140M UPSTRM YELLOW SIKE	SMALL AGGREGATE CRYSTALS OF GALENA IN 0.3 M THICK SSTN.
BFR6171	361881	602420	RAVEN BURN 153M UPSTRM OF CONF WITH YELLOW SIKE	0.4M PALE CEMENTSTN. 1ST O'CROP UPSTRM OF CONGLOM.
BFR6172	361881	602420	RAVEN BURN 153M UPSTRM CONF. WITH YELLOW SIKE	0.45M CEMENTST. EXTENSIVELY CARB. VEINED, OVERLIES BFR 6171

Table 1

Arnton Fell Rock Data

SAMPLE REF.	EASTING	NORTHING	ROCK TYPE	STYLE	MINERALS	Cu (ppm)	Pb (ppm)	Zn (ppm)	Ba (ppm)	Sb (ppm)	Fe (ppm)	Ni (ppm)
BFR5925	361770	500870	MICRITIC LIMESTONE	VEIN	SPHALERITE	9	0	3556	26	2	20300	0
BFR6067	362170	602500	MICRITIC LIMESTONE	VEIN	SPHALERITE	15	10	95	39	1	20842	14
BFR6074	360430	601455	FAULT BRECCIA	FRACTURE	CHALCOPYRITE	69	10	19	666	0	36509	47
BFR6077	360680	601660	MICRITIC LIMESTONE	VEIN	CALCITE	29	12	24	22	4	18045	4
BFR6081	360480	601400	MICRITIC LIMESTONE	VEIN	?CHALCOPYRITE, PYRITE	9	14	28	24	7	40285	7
BFR6082	360420	601450	SANDSTONE	VEIN	CALCITE,	8	2	16	1366	5	42873	20
BFR6084	360850	600230	MICRITIC LIMESTONE	FRACTURE	PYRITE, ?CHALCOPYRITE	34	8	11	370	2	20073	6
BFR6085	360870	600250	MICRITIC LIMESTONE	FRACTURE	BARYTE	9	8	14	511	3	23989	13
BFR6086	359960	600340	MICRITIC LIMESTONE			12	22	25	133	0	25108	18
BFR6088	361960	600905	MICRITIC LIMESTONE	VEIN	SPHALERITE?	17	15	253	11	9	15457	5
BFR6089	361960	600905	MICRITIC LIMESTONE	VEIN	PYRITE	5	38	59	32	0	42733	15
BFR6090	361940	602190	MICRITIC LIMESTONE	FRACTURE	SPHALERITE?, PYRITE	18	22	180	7	0	27067	14
BFR6091	361940	602170	MICRITIC LIMESTONE	VEIN	SPHALERITE, PYRITE	11	18	498	19	0	34690	15
BFR6092	361940	602210	MICRITIC LIMESTONE	FRACTURE	SPHALERITE	14	16	513	92	3	25948	11
BFR6093	361930	602220	MICRITIC LIMESTONE	FRACTURE	SPHALERITE, PYRITE	13	13	471	20	8	20353	10
BFR6094	361930	602220	MICRITIC LIMESTONE	DISSEMINATED	PYRITE	10	29	28	98	5	19793	13
BFR6095	361890	602280	MICRITIC LIMESTONE	VEIN	BARYTE, CALCITE	14	11	160	994	0	17065	5
BFR6096	361890	602350	MICRITIC LIMESTONE	FRACTURE/VEIN	PYRITE, CALCITE	7	15	20	14	3	23290	7
BFR6097	361860	600865	MICRITIC LIMESTONE	DISSEMINATED	SPHALERITE, PYRITE	12	20	298	26	4	22661	11
BFR6098	361860	600865	MICRITIC LIMESTONE	DISSEMINATED	SPHALERITE, PYRITE	10	25	168	76	2	25388	14
BFR6099	361860	600865	MICRITIC LIMESTONE	DISSEMINATED	SPHALERITE	12	23	189	60	2	23640	11
BFR6100	361860	600865	MICRITIC LIMESTONE	DISSEMINATED	SPHALERITE	8	12	213	52	3	14967	7
BFR6146	361880	602450	SANDSTONE			9	5	19	551	0	17485	13
BFR6149	361940	602130	MICRITIC LIMESTONE	FRACTURE	PYRITE	12	9	78	82	6	30634	4
BFR6150	362080	602530	MICRITIC LIMESTONE	VEIN	SPHALERITE, PYRITE	6	16	12	96	4	30284	8
BFR6151	362080	602530	MICRITIC LIMESTONE	VEIN	SPHALERITE, PYRITE	9	20	11	113	2	28745	5
BFR6160	361890	602420	SANDSTONE	DISSEMINATED	GALENA	10	153	69	446	2	13708	13
BFR6171	361881	602420	MICRITIC LIMESTONE			10	3	41	182	0	20353	12
BFR6172	361881	602420	MICRITIC LIMESTONE	VEIN	BARYTE, CALCITE	12	3	30	6265	1	13149	7

Table 1 continued

BRITISH GEOLOGICAL SURVEY
Mineral Reconnaissance Programme

Arnton Fell Rock Data

SAMPLE REF.	EASTING	NORTHING	LOCALITY	COMMENTS
BFR6173	361881	602420	RAVEN BURN 155M UPSTRM OF CONFL. WITH YELLOW SIKE	0.35M THICK CEMENTSTN. ABOVE BFR 6172
BFR6174	361881	602420	RAVEN BURN 158M UPSTRM. CONFL. WITH YELLOW SIKE	0.3M THICK GREY SHALE BETWEEN TWO MICRITES (BFR 6173/6175)
BFR6175	361881	602420	RAVEN BURN 160 M S OF CONFLUENCE WITH YELLOW SIKE	0.35M CALC. SSTN. FRACTURE SURFACE WITH CAL.+ MINOR PBS
BFR6176	361881	602420	RAVEN BURN 163M UPSTRM CONFL. YELLOW SIKE	0.5 M HARD SHALE FRAGS IN CLAY MATRIX. OVERLYING BFR 6175
BFR6177	361881	602420	RAVEN BURN 163 M UPSTRM CONFLUENCE WITH YELLOW SIKE	0.8M THICK SILTY MICRITE WITH DARK CARBONACEOUS WISPS
BFR6178	361881	602420	RAVEN BURN 163 M UPSTRM CONFLUENCE WITH YELLOW SIKE	0.3M THICK, DARK GREY PARTINGS, OVERLYING BFR 6177
BFR7001	360010	600420	WORMSCLEUCH BURN 200M UPSTRM CONFL WITH COOMB SIKE	?SILURIAN GREYWACKE FLOAT SAMPLE
BFR7002	360105	600550	WORMSCLEUCH BURN 200M SW FIRE BREAK INTERSECT.	FLOAT SAMPLE
BFR7003	360140	600610	WORMSCLEUCH BURN 150M SW FIRE BREAK INTERSECT.	FLOAT SAMPLE
BFR7004	360235	600865	WORMSCLEUCH BURN APPROX 400M DWNSTRM OF TRK. INTERSECT.	FLOAT SAMPLE. 4CM IRREG. PINK-BROWN VN WITH ?SULPHIDE
BFR7005	360270	600965	APPROX. 250M DWNSTRM TRACK INTERSECT. WORMSCLEUCH BURN	FLAT BEDDED O'CROP, IRREG.DOLOMITISATION
BFR7049	360525	601482	WORMSCLEUCH APPROX. 280M UPSTM. OF TRACK INTERSECT.	FES IN 0.2CM THICK LAYERS AND REPLACING FOSSILS?
BFR7079	360615	601555	WORMSCLEUCH APPROX 9M UPSTM OF HEAD OF FOREST TRACK	CEMENTSTN. BLDR. WITH BLACK ORG. STREAKS, FES + CA-BA VNLTS.
BFR7080	360625	601575	WORMSCLEUCH (E BANK O'CROP), 9 M UPSTM OFOREST TRACK.	? FINE DISSEM FES IN HARD SANDY, ORGANIC-RICH CEMENTSTN
BFR7082	360635	601585	S DRNG MINOR TRIB OF WORMSCLEUGH 60M NE OF TRACK END	GREEN STAINED CEMENTSTN BOULDER HEAVILY CALCITE VND

Table 1 continued

Arnton Fell Rock Data

SAMPLE REF.	EASTING	NORTHING	ROCK TYPE	STYLE	MINERALS	Cu (ppm)	Pb (ppm)	Zn (ppm)	Ba (ppm)	Sb (ppm)	Fe (ppm)	Ni (ppm)
BFR6173	361881	602420	MICRITIC LIMESTONE			18	12	49	73	2	21681	14
BFR6174	361881	602420	SHALE			15	63	93	368	2	52315	42
BFR6175	361881	602420	SANDSTONE	FRACTURE	GALENA, CALCITE	58	38	51	376	0	13988	12
BFR6176	361881	602420	SHALE			11	49	122	441	0	41195	42
BFR6177	361881	602420	MICRITIC LIMESTONE	FRACTURE/VEIN	SPHALERITE, PYRITE	31	15	40	691	3	15527	9
BFR6178	361881	602420	MUDSTONE			8	33	181	183	1	21821	21
BFR7001	360010	600420	SILTSTONE	VEIN	PYRITE, HEMATITE	17	3	49	340	0	31543	48
BFR7002	360105	600550	LIMESTONE	DISSEM/VEIN	MARCASITE, PYRITE	5	4	8	32	0	21192	6
BFR7003	360140	600610	LIMESTONE	VEIN	PYRITE, HEMATITE,	6	5	13	57	0	8743	9
BFR7004	360235	600865	MUDSTONE	VEIN	SPHALERITE, CALCITE	7	1	31	150	4	24129	31
BFR7005	360270	600965	LIMESTONE	DISSEM	PYRITE	23	1	9	1523	0	19024	5
BFR7049	360525	601482	LIMESTONE	LENS	PYRITE	3	5	23	30	0	14687	4
BFR7079	360615	601555	MICRITIC LIMESTONE	VEIN	PYRITE, BARYTE	4	33	20	17094	0	39306	11
BFR7080	360625	601575	MICRITIC LIMESTONE	DISSEM	PYRITE	6	12	17	242	3	17625	7
BFR7082	360635	601585	MICRITIC LIMESTONE	VEIN	CALCITE, PYRITE	4	5	8	6	0	14058	2

Table 2

Arnton Fell Panned Concentrate Data (Reconnaissance Survey, 1976)

Sample Ref.	Easting	Northing	Cu (ppm)	Zn (ppm)	Pb (ppm)	Ba (ppm)	Ni (ppm)	Sn (ppm)	Sb (ppm)
BFP4088	360550	599780	19	267	3	440	3	0	3
BFP4178	361760	600860	24	1170	40	3689	6	0	0
BFP4182	361120	600560	5	242	10	308	2	2	2
BFP4283	359220	603735	23	33	93	3531	59	3	2
BFP4284	359760	603940	23	117	21	617	62	2	1
BFP4285	359860	603980	22	115	9	270	55	0	0
BFP4295	359540	601782	10	5	83	617	22	0	2
BFP4342	364930	603490	16	39	2	228	5	2	2
BFP4366	361830	602820	48	1230	20	567	11	2	5
BFP4367	361770	602800	31	227	36	537	18	0	0
BFP4368	361840	603080	9	287	25	389	7	0	0
BFP4369	361838	603342	25	971	7	3389	6	2	2
BFP4370	361780	603780	0	24	6	232	12	0	0
BFP4371	361760	603870	0	22	16	249	10	7	4
BFP4372	361140	602260	0	18	11	129	6	4	0
BFP4373	361210	602858	0	140	7	171	13	3	12
BFP4441	361378	601920	0	19	14	322	2	0	5
BFP4446	362423	601840	0	22	19	260	6	0	4
BFP4448	361940	602150	5	303	39	291	10	0	0
BFP4484	363980	602680	0	13	8	17	5	3	3
BFP4485	364000	602602	0	9	6	27	4	5	4
BFP4486	364482	602545	3	11	15	43	6	0	0
BFP4487	364595	602680	0	22	11	149	9	3	0
BFP4488	364980	601660	9	1915	21	1546	14	0	0
BFP4492	364580	601880	26	3710	79	1604	25	3	3
BFP4534	362172	603822	0	122	7	2158	7	5	3
BFP4535	362260	603400	6	117	13	1882	7	0	2
BFP4536	362520	603180	23	188	11	1929	8	0	3
BFP4537	362530	603240	0	52	16	597	4	4	0

Table 2 continued

Arnton Fell Panned Concentrate Data (Reconnaissance Survey, 1976)

Sample Ref.	Easting	Northing	Cu (ppm)	Zn (ppm)	Pb (ppm)	Ba (ppm)	Ni (ppm)	Sn (ppm)	Sb (ppm)
BFP4542	362850	603980	14	104	6	466	3	1	0
BFP4543	362770	603760	1	21	1	224	12	1	4
BFP4609	360140	602650	9	23	12	168	17	2	0
BFP4610	360320	602960	9	33	4	143	18	0	4
BFP4611	360610	603200	16	13	3	163	6	3	0
BFP4612	360430	603217	3	18	0	188	9	0	0
BFP4613	360410	603500	16	70	13	228	36	0	0
BFP4614	360160	603160	9	52	20	185	23	0	0
BFP4615	360230	603870	8	26	6	188	14	1	4
BFP4694	363650	601842	0	45	14	451	19	2	0
BFP4696	363760	601905	0	2495	79	3746	17	0	0
BFP4697	363960	601690	0	629	20	2530	13	0	0
BFP4698	364425	601833	0	1333	35	3438	15	0	1
BFP4699	364720	601320	10	176	3	815	10	2	0
BFP4744	363590	601800	20	63	12	46	8	3	0
BFP4745	363705	601470	0	17	0	15	8	1	0

Arnton Fell Panned Concentrate Data (Follow - up Survey 1993/94)

Sample Ref.	Easting	Northing	Cu (ppm)	Zn (ppm)	Pb (ppm)	Ba (ppm)	Ni (ppm)	Sn (ppm)	Sb (ppm)	Fe_2O_3t %
BFP6755	360400	601290	710	829	887	19000	47	2	0	15.62
BFP6756	360430	601455	233	72	51	1452	72	4	1	31.63
BFP6757	360610	601510	21	47	23	2354	25	2	2	4.36
BFP6758	360510	601580	16	82	13	392	63	1	2	8.46
BFP6759	360600	601550	32	519	28	24000	26	0	0	4.62
BFP6760	360480	601400	74	1329	44	36000	26	1	2	6.03
BFP6761	359810	600560	30	95	38	494	55	0	1	7.57

Table 2 continued

BRITISH GEOLOGICAL SURVEY
Mineral Reconnaissance Programme

Arnton Fell Panned Concentrate Data (Follow - up Survey 1993/94)

Sample Ref.	Easting	Northing	Cu (ppm)	Zn (ppm)	Pb (ppm)	Ba (ppm)	Ni (ppm)	Sn (ppm)	Sb (ppm)	Fe_2O_3t %	As (ppm)
BFP6762	360060	600520	806	4090	160	7817	57	2	1	19.35	
BFP6763	360200	600770	477	1958	143	6650	45	16	4	14.07	
BFP6764	360282	601020	218	343	37	2315	33	2	2	10	
BFP6765	359793	600000	15	52	31	388	25	0	5	3.83	
BFP6766	359600	599930	17	36	18	333	13	0	2	1.68	
BFP6767	359720	599682	3	164	131	176	4	2	0	0.86	
BFP6768	360870	600890	53	2652	106	3730	61	7	-1	11.44	
BFP6769	360900	600320	21	604	37	796	29	-4	-5	6.88	
BFP6770	360980	600360	11	1320	15	1763	8	-1	1	2.31	
BFP6771	360680	601660	22	469	123	21000	14	0	-2	3.33	
BFP6772	360802	601700	29	1050	34	5429	11	2	3	4.06	
BFP6773	360820	601678	9	227	21	483	6	2	5	2.24	
BFP6774	359878	600052	150	1492	73	1558	38	3	5	10.13	
BFP6775	359757	599742	48	1389	38	638	34	-1	1	8.1	
BFP6776	359680	599282	40	579	41	524	49	0	-1	6.86	
BFP6777	361955	602565	166	2642	49	30000	11	0	-2	3.45	
BFP6778	361899	602520	59	>4500	42	16000	14	2	-2	3.01	
BFP6779	361879	602202	154	>4500	60	4927	13	2	2	4.4	
BFP6780	361980	602200	39	422	35	1021	12	-1	5	3.15	
BFP6781	361870	602220	80	>4500	108	6260	18	1	0	5.09	
BFP6782	361900	602170	19	717	30	26000	8	-2	-1	1.25	
BFP7201	359920	600340	27	61	21	399	28	2	1	3.29	7
BFP7202	360170	600680	558	1824	107	5178	41	3	0	13.42	34
BFP7501	358883	598640	10	21	11	300	10	4	4	2.29	1
BFP7502	359659	599395	12	176	33	319	12	10	<1	3.53	14
BFP7503	359528	599282	22	31	71	262	16	1	<1	4.56	28
BFP7504	359942	598740	31	277	66	732	21	20	<1	8.06	22
BFP7505	359838	589822	64	261	43	440	35	2	5	10.29	29
BFP7512	360280	599140	11	774	27	451	16	16	<1	4.22	7

Table 2 continued

Arnton Fell Panned Concentrate Data (Follow - up Survey 1993/94)

Sample Ref.	Easting	Northing	Cu (ppm)	Zn (ppm)	Pb (ppm)	Ba (ppm)	Ni (ppm)	Sn (ppm)	Sb (ppm)	Fe_2O_3t %	As (ppm)
BFP7516	360350	599200	8	224	17	592	17	1	<1	2.59	2
BFP7517	360440	599440	9	55	18	1735	11	1	<1	2.49	2
BFP7518	360740	599420	12	207	22	1364	14	35	2	4.2	8
BFP7519	360990	599500	9	26	14	208	11	<1	2	4.4	7
BFP7520	361060	599700	86	466	47	7427	18	<1	<1	4.57	9
BFP7521	360880	599620	57	175	28	4135	13	1	<1	3.2	4
BFP7525	360860	600120	9	102	15	1891	6	<1	1	1.64	6
BFP7526	361560	600720	39	2377	62	3046	8	1	1	3.1	9
BFP7527	361710	600800	11	2983	21	1631	6	1	<1	2.19	5
BFP7528	362020	600910	<1	7	3	57	2	2	4	0.35	2
BFP7529	362070	600940	13	2434	28	6222	15	2	3	2.95	9
BFP7530	361280	600860	49	964	42	3239	29	18	<1	5.82	10
BFP7531	361220	600860	14	210	37	1603	16	1	2	4.33	7
BFP7538	359180	599997	3	10	12	210	6	2	3	1.42	2
BFP7539	359380	600290	8	22	32	244	7	1	<1	2.8	4
BFP7540	359595	600840	28	64	32	404	55	7	3	6.77	21
BFP7541	360635	601585	153	147	37	1434	37	2	5	7.41	16

Table 3

BRITISH GEOLOGICAL SURVEY
Mineral Reconnaissance Programme

Arnton Fell Panned Till Data

Traverse No.	Sample Ref.	Easting	Northing	Depth (metres)	Cu (ppm)	Pb (ppm)	Zn (ppm)	Ba (ppm)	Sb (ppm)	Fe_2O_3t %	Ni (ppm)	Sn (ppm)
1	BFU6602	359475	600745	3.4	48	11	118	533	0	8.84	94	0
1	BFU6603	359514	600714	4.0	191	3	91	452	4	8.36	91	7
1	BFU6604	359553	600682	2.9	26	27	52	355	3	4.67	38	1
1	BFU6606	359592	600651	4.5	27	35	55	430	6	5.33	37	2
1	BFU6608	359631	600620	3.2	28	43	47	347	1	5.06	39	2
1	BFU6610	359670	600589	2.5	35	61	52	314	1	5.40	44	2
1	BFU6612	359709	600557	4.7	18	45	105	351	3	3.09	23	5
1	BFU6614	359748	600526	5.0	39	52	98	355	4	5.60	37	2
1	BFU6616	359787	600495	3.2	20	11	25	537	2	1.81	11	0
1	BFU6618	359826	600463	5.1	45	80	61	367	3	6.79	51	5
1	BFU6620	359864	600432	4.7	13	19	34	512	0	2.96	21	0
1	BFU6622	359903	600401	2.5	23	24	49	430	2	4.19	33	1
1	BFU6624	359942	600369	5.0	26	22	70	425	2	4.89	44	0
1	BFU6627	360020	600307	3.2	25	18	41	338	2	4.27	27	2
1	BFU6629	360059	600276	3.3	37	34	85	343	2	6.41	46	0
1	BFU6631	360090	600251	3.4	28	26	34	290	0	3.14	26	0
1	BFU6633	360450	601390	1.7	24	24	49	360	5	6.52	41	3
2	BFU6635	361688	601545	3.3	64	12	21	477	8	2.61	13	6
2	BFU6637	361643	601565	3.5	8	19	17	453	5	1.11	5	2
2	BFU6639	361590	601580	2.3	10	17	27	549	2	2.62	7	3
2	BFU6641	361545	601590	2.5	18	18	40	509	4	6.65	34	3
2	BFU6643	361493	601600	1.8	31	24	63	491	5	7.15	17	1
2	BFU6645	361449	601624	2.0	39	29	56	442	2	9.03	39	6
2	BFU6647	361406	601648	3.4	12	13	20	435	5	1.90	10	2
2	BFU6649	361362	601673	1.9	39	16	31	531	1	4.52	18	0
2	BFU6651	361318	601697	3.2	41	58	55	2091	1	13.66	36	3
2	BFU6653	361274	601721	3.6	30	39	34	383	1	7.31	31	2
2	BFU6655	361231	601745	3.5	18	11	24	463	2	3.10	17	5
2	BFU6657	361185	601767	2.7	8	12	24	423	0	1.55	12	1

Table 3 continued

BRITISH GEOLOGICAL SURVEY
Mineral Reconnaissance Programme

Traverse No.	Sample Ref.	Easting	Northing	Depth (metres)	Cu (ppm)	Pb (ppm)	Zn (ppm)	Ba (ppm)	Sb (ppm)	Fe_2O_3t %	Ni (ppm)	Sn (ppm)	As (ppm)	Au (ppb)
2	BFU6659	361140	601788	1.9	12	20	115	420	0	10.35	15	0		
2	BFU6661	361096	601809	2.4	7	9	10	363	3	0.44	4	1		
2	BFU6663	361052	601830	4.1	8	40	399	304	3	3.46	8	5		
2	BFU6665	361007	601851	3.0	9	15	228	478	6	2.86	6	1		
2	BFU6667	360963	601872	5.0	15	12	24	513	0	6.88	34	0		
2	BFU6669	360919	601893	5.2	3	5	5	293	3	1.23	5	0		
2	BFU6671	360875	601914	6.4	14	10	41	450	6	6.93	52	0		
3	BFU6673	362140	602770	3.0	3	4	8	260	2	0.24	2	2		
3	BFU6675	362090	602770	0.6	5	9	7	290	3	0.63	0	0		
4	BFU6677	362100	602580	5.9	21	34	345	383	2	3.95	15	0		
4	BFU6679	362050	602580	4.5	21	35	86	436	2	4.40	19	2		
4	BFU6681	362000	602580	4.9	5	5	9	274	5	0.81	3	1		
4	BFU6683	361950	602580	2.4	6	12	12	198	8	1.87	5	0		
5	BFU6685	361780	602040	3.6	29	49	200	1321	5	5.15	20	4		
5	BFU6687	361795	602088	1.6	6	11	15	436	1	0.79	5	3		
5	BFU6689	361811	602135	2.8	11	14	12	519	0	0.42	3	0		
5	BFU6691	361826	602183	2.4	8	18	54	488	2	1.58	6	1		
5	BFU6693	361842	602230	1.3	14	19	85	3734	7	2.48	8	6		
6	BFU6695	361450	601980	3.3	10	18	23	499	6	2.03	16	2		
6	BFU6697	361444	602010	1.9	14	17	21	516	6	2.07	14	3		
7	BFU7224	360315	601270	1.9	6	10	17	118	0	2.72	9	1	6	1
7	BFU7246	360275	601255	2.4	25	47	91	302	1	5.31	36	2	50	1
7	BFU7247	360220	601220	2.2	38	63	119	458	0	7.30	83	3	35	1
7	BFU7248	360185	601195	3.2	19	16	63	343	1	8.85	54	4	16	1
7	BFU7249	360130	601155	4.0	27	14	80	332	2	5.47	60	6	11	1
7	BFU7250	360080	601145	3.6	39	27	111	380	1	7.14	80	3	16	1
7	BFU7279	360355	601300	2.7	18	48	51	430	1	3.67	32	1	17	1
7	BFU7280	360390	601330	2.7	5	23	24	191	0	2.52	12	0	45	1
7	BFU7281	360320	601365	3.1	348	92	48	1020	2	5.31	44	5	22	1
7	BFU7282	360455	601405	2.8	21	10	81	405	1	8.26	95	4	9	1
7	BFU7283	360475	601450	1.6	28	10	94	392	1	8.54	97	4	8	4

Table 4

Arnton Fell Sieved Till Data

Traverse No.	Sample Ref.	Easting	Northing	Depth (metres)	Cu (ppm)	Pb (ppm)	Zn (ppm)	Ba (ppm)	Sb (ppm)	Fe_2O_3 %	Ni (ppm)	Mn (ppm)	Sn (ppm)
1	BFT6601	359475	600745	3.4	49	17	115	606	0	9.25	91	1115	1
1	BFT6600	359514	600714	3.5	68	6	89	609	3	9.07	100	426	0
1	BFT6605	359553	600682	2.5	33	29	95	665	0	7.04	65	620	3
1	BFT6607	359592	600651	3.6	37	33	73	423	0	6.93	58	953	1
1	BFT6609	359631	600620	3.2	35	21	68	371	1	6.77	56	658	0
1	BFT6611	359670	600589	2.5	35	23	67	375	3	6.75	55	565	2
1	BFT6613	359709	600557	4.7	34	58	257	459	0	5.90	47	991	0
1	BFT6615	359748	600526	5.0	30	34	121	475	1	5.98	49	759	4
1	BFT6617	359787	600495	3.2	19	14	59	584	0	4.76	28	364	0
1	BFT6619	359826	600463	5.1	36	33	68	445	2	6.71	56	945	4
1	BFT6621	359864	600432	4.7	17	13	56	558	0	4.87	32	372	0
1	BFT6623	359903	600401	2.3	31	21	80	528	0	5.91	51	705	0
1	BFT6625	359942	600369	5.0	31	24	85	481	0	5.96	50	736	0
1	BFT6626	359981	600338	1.3	21	21	57	479	0	4.03	33	325	0
1	BFT6628	360020	600307	1.8	32	24	77	481	0	6.24	49	558	0
1	BFT6630	360059	600276	3.2	36	24	86	393	5	6.36	49	1200	6
1	BFT6632	360090	600251	3.4	30	25	57	416	3	4.86	41	705	0
1	BFT6634	360450	601390	1.7	35	40	74	486	2	8.70	54	976	3
2	BFT6636	361688	601545	3.3	43	34	34	525	0	3.35	30	232	2
2	BFT6638	361643	601565	3.5	35	104	89	451	0	8.35	24	287	0
2	BFT6640	361590	601580	2.3	36	47	79	590	0	7.02	24	217	2
2	BFT6642	361545	601590	1.8	30	33	51	603	0	11.83	33	1038	0
2	BFT6644	361493	601600	1.8	35	34	95	506	1	8.42	32	1340	2
2	BFT6646	361449	601624	2.0	41	41	84	505	0	8.07	43	519	0
2	BFT6648	361406	601648	3.4	28	26	84	489	3	6.29	35	372	4
2	BFT6650	361362	601673	1.9	17	8	57	579	3	5.56	35	643	3
2	BFT6652	361318	601697	3.2	19	16	35	579	0	7.07	26	2339	2
2	BFT6654	361274	601721	3.6	23	30	41	493	2	5.55	34	891	1
2	BFT6656	361231	601745	3.5	22	10	47	533	2	4.54	30	248	0

Table 4 continued

Traverse No.	Sample Ref.	Easting	Northing	Depth (metres)	Cu (ppm)	Pb (ppm)	Zn (ppm)	Ba (ppm)	Sb (ppm)	Fe_2O_3 (ppm)	Ni (ppm)	Mn (ppm)	Sn (ppm)
2	BFT6658	361184	601767	2.7	24	21	70	539	0	5.12	35	240	1
2	BFT6660	361140	601788	1.9	28	40	203	502	3	10.50	52	550	3
2	BFT6662	361096	601809	2.4	20	18	49	545	2	3.47	21	186	3
2	BFT6664	361052	601830	4.1	27	67	246	400	3	6.20	36	736	2
2	BFT6666	361007	601851	3.0	16	26	93	476	2	4.74	25	1022	7
2	BFT6668	360963	601872	5.0	24	15	39	597	7	7.58	50	914	1
2	BFT6670	360919	601893	5.2	26	16	63	522	2	5.49	55	565	2
2	BFT6672	360875	601914	6.4	20	12	59	506	3	6.02	67	798	5
3	BFT6674	362140	602770	3.5	11	15	121	639	0	2.65	16	170	0
3	BFT6676	362090	602770	0.6	6	17	19	628	4	2.60	7	503	1
4	BFT6678	362100	602580	5.9	28	36	122	491	3	5.70	40	503	5
4	BFT6680	362050	602580	4.5	25	32	84	478	0	5.82	39	519	0
4	BFT6682	362000	602580	4.9	20	14	47	634	1	5.63	30	1169	0
4	BFT6684	361950	602580	2.4	14	12	31	599	0	3.47	15	434	0
5	BFT6686	361780	602040	3.6	27	47	209	572	2	7.11	47	1487	0
5	BFT6688	361795	602088	1.6	10	21	67	570	2	2.95	14	310	1
5	BFT6690	361811	602135	2.8	13	23	132	618	0	3.93	28	341	4
5	BFT6692	361826	602183	2.4	20	28	76	563	0	5.05	29	736	0
5	BFT6694	361842	602230	1.3	21	40	109	579	1	5.67	38	511	0
6	BFT6696	361450	601980	4.5	22	21	79	581	1	4.72	38	457	3
6	BFT6698	361444	602010	1.9	29	24	71	546	0	5.95	48	263	0
Cobra hole	BFT6699	360420	601412	3.6	88	7	34	726	0	7.48	50	1959	0
Cobra hole	BFT6700	360388	601445	5.4	82	5	93	603	2	8.93	99	728	0