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MINERAL INVESTIGATIONS IN THE NORTHUMBERLAND TROUGH: PART 2, NEWCASTLETON 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

Interest in mineral exploration within the Solway-Northumberland basin developed since the discovery of the world-class Navan Zn-Pb deposit in Ireland in 1970 (Andrew, 1993). Recognition of the broad similarities in the geological and tectonic history of the Lower Carboniferous sedimentary basins of east-central Ireland and northern England/southern Scotland prompted MRP exploration interest in the Solway-Northumberland basin in the early 1970's. Two of the most important criteria for the formation of major SEDEX Irish-style deposits, the presence of syn-depositional faulting in a Lower Dinantian basin and a geothermal system over a zone of high heat flow in the crust, are recognised in the Solway-Northumberland basin. The presence of mafic lavas, the Birrenswark lavas, and possible associated mineralising hydrothermal activity are considered to further increase the economic potential of the area.

Previous research and selection of survey area

A rapid stream sediment reconnaissance survey of the post-Silurian unconformity between Hawick and Dumfries showed anomalous Pb and Zn values which were subsequently traced to an outcrop of galena-bearing sandstone in a stream bed south-west of Langholm, Dumfriesshire (Haslam, 1972). Detailed investigations carried out by the MRP (Gallagher et al., 1977), involving regional panned concentrate sampling over a 20 km^2 area, overburden geochemistry, and geophysics, identified several other major geochemical anomalies in the general area of this discovery extending over a 4 km strike length of the Lower Carboniferous / Lower Palaeozoic boundary. Further evaluation of these prospects by shallow core drilling (13 holes to depths of 20 to 60 m), revealed the presence of sporadic Pb-Zn-Cu mineralisation with combined grades of 0.1-0.3 % over 1-2 m of thickness. Sulphides (galena and sphalerite) occur in disseminations and dolomitic veins in porous sandstones and cementstones, usually in close proximity to the contact of the basal Carboniferous Birrenswark lavas and the overlying 'cementstone' facies of the Lower Border Group. Mineralised breccia zones within the lavas carry chalcopyrite and pyrite, and both styles of mineralisation appear to be emplaced along north-easterly trending normal faults and cross faults.

In 1976 a more extensive panned concentrate survey was carried out to the north-east of Langholm, covering a 40-50 km strike length at the northern margin of the Northumberland basin and the north-western part of the Bewcastle anticline. The most prominent feature of the geochemical data is the consistently high concentration of Zn extending in a strike parallel zone from the Green Burn-Black Burn catchments west and north-west of Newcastleton respectively to the Bonchester Bridge-Carter Bar area in the north-east. High lead values are also clustered, but to a lesser extent than Zn, in the Green Burn-Black Grain catchment (west of Newcastleton), whereas Ba anomalies are most strongly developed further to the west in the Tarras Water catchment. Follow-up investigations to trace the source of the high base-metal values were not carried out at the time, but in the period 1981 - 85 a systematic stream sediment survey of southern Scotland, carried out as part of the BGS Geochemical Baseline Survey of the Environment (G-BASE), identified the presence of anomalous base-metal zones close to the basin margin (British Geological Survey, 1993). The G-BASE data confirm, with particular clarity, the regional pattern of coincident Zn and Pb enrichment and the major Ba anomaly associated with basin boundary faults in the Newcastleton district, although detailed comparison of the patterns for base-metals and Ba in stream sediments and panned concentrates indicates a generally poor degree of spatial correlation (Colman et al., 1995).

A multidisciplinary study into the analysis of spatially-related (geochemical, geophysical and geological) datasets and mineral deposit modelling for carbonate-hosted mineral deposits in northern England (Plant, J A and Jones, D G., 1991; Jones et al., 1994) also emphasised the high base-metal prospectivity of the Solway-Northumberland basin. The report suggests that particularly favourable sites for mineralisation occur where the northern basin-margin synsedimentary faults cut Courceyan-Chadian rocks at <0.5 km depth. Zones of fault intersection can result in areas of dilation and structural disruption which may provide potential pathways for mineralising fluids.

Based on these concepts and the high incidence of base-metal geochemical anomalies a new MRP project aimed at stimulating mineral exploration interest in the northern margin of the Northumberland-Solway basin was instigated in 1992. Four principal targets areas considered prospective for stratabound (Irish-style) and/or epigenetic (Pennine-style) base-metal mineralisation were examined. This report describes the results of follow-up investigations in the area immediately to the north and west of Newcastleton. Several of the suite of north-east trending sub-parallel, *en echelon* basin margin faults, mentioned above, are present in the project area, intersecting rocks varying in age from Silurian (Wenlock) to Carboniferous (Holkerian).

PHYSIOGRAPHY

The district lies in the foothills of the Southern Uplands and is characterised by smooth, rounded hills rising to a maximum of 568 m OD near the northern margin of the study area (Figure 1). Roan Fell together with Hartsgarth Fell and Millstone Edge, forms a long north-south trending ridge of elevated moorland with a general slope to lower ground in the south. Kirk Hill (282 m OD) forms the only prominent hill in the southern part of the area which otherwise ranges from 150 m to 260 m south of the Newcastleton - Langholm road.

Three principal stream catchments, the eastward flowing Black Burn (Hog Gill, Rough Gill, Long Gill) and Hartsgarth Burn (Thief Sike), and the southward flowing Black Grain - Green Burn (Stanygill Burn, Dow Sike, Thackie Sike), are all west bank tributaries of the Liddel Water which has developed along the strike of the Carboniferous strata following a north-north-east course through Newcastleton. The direction of minor drainage has been controlled to some extent by glacial drainage channels. The greatest concentration of these channels is seen on the eastern slopes of Roan Fell, where the upper parts of Rycdale and Hartsgarth burns flow southwards in shallow incised channels before breaking through with a sharp change of direction to follow the natural pre-Glacial drainage direction to the south-east.

Apart from the more deeply incised stream courses and the high moorland formed by the east facing flank of Roan Fell, which is littered with sandstone debris derived from numerous low sandstone scarp-features, bedrock exposure is scarce. Even where stream drainage is sufficiently energetic to cut through the glacial overburden, outcrop is only intermittently developed due to the deposition of recent alluvium. The best exposures in stream sections include the middle reaches of the Black Grain - Stanygill Burn catchment, and the upper reaches of Black Burn, Hog Gill and Rough Gill. A higher than normal degree of rock exposure also exists at major fault intersections with stream channels. In Hartsgarth Burn and Thief Sike, for example, the Tarras Fault has resulted in abrupt steepening and disruption of the strata and the formation of a number of small waterfalls.

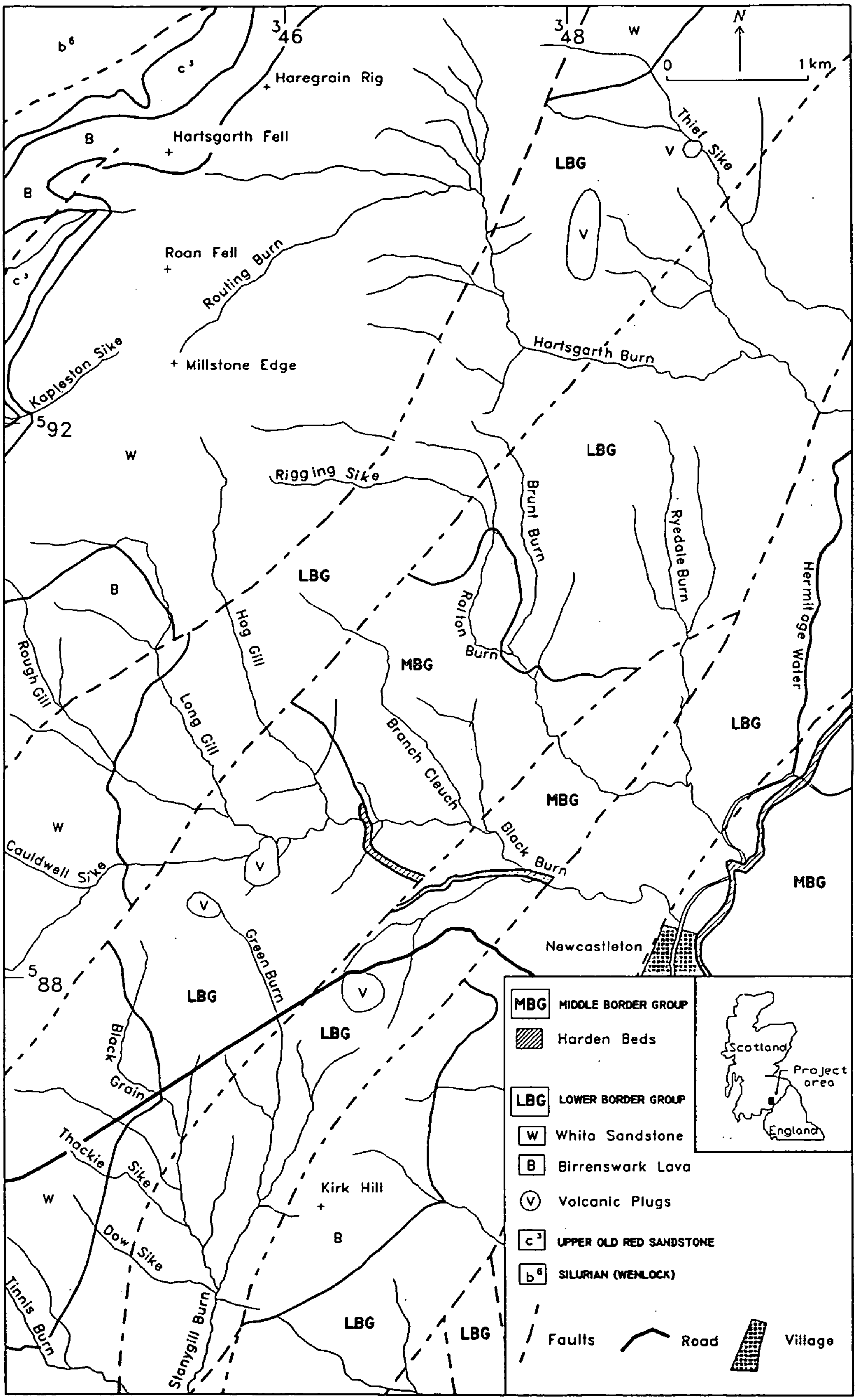

Figure 1 Locational and simplified geological map of the survey area

PLANNING AND DEVELOPMENT FRAMEWORK

The area occupies about 60 km^2 of upland grass and heather moor lying between the village of Newcastleton (3 km east) and the small town of Langholm (9 km west-south-west). (Figure 1). Road communications are good with a network of minor roads and the main A7 trunk road at Langholm linking Carlisle and Edinburgh. Carlisle (30 km south) and Dumfries (50 km west) are the nearest main towns. Population elsewhere is generally sparse, especially over the wider expanses of upland to the north and the heavily forested areas to the east of the project area. Commercial forestry, rough grazing, and grouse shooting are the main land uses.

Coal was worked on a small scale at Rowanburn to the south of Newcastleton from the early 1800's until 1922 and, the existence of a major concealed coalfield near Canonbie was proved in the 1960's by boreholes sunk by the former National Coal Board. Within the last few years the Canonbie coal deposits have also been the subject of economic feasibility and environmental impact studies for the development of a potential open-cast coal working. Apart from an active aggregate quarry south of Newcastleton and a number of small, disused, roadstone, building stone and limestone quarries there are no other commercial mineral workings in the area. The principal landowner in the district is The Buccleuch Estates Limited.

The detailed follow-up area in the Black Grain - Green Burn catchment lies immediately to the south and east of a large Site of Special Scientific Interest (the Langholm-Newcastleton Hills SSSI) which was first notified in 1974 on the basis of its geological, ornithological and botanical importance. All of the high moorland north of the Langholm-Newcastleton road in the northern half of the reconnaissance area (Figure 1) falls within this SSSI.

GEOLOGY

The Lower Carboniferous rocks in the area of interest form part of an almost continuous south-west - north-east trending outcrop at the northern margin of the Northumberland basin. They occupy all but the north-west corner of the project area (Figure 2) where they are underlain by rocks assigned to the Upper Old Red Sandstone which in turn, rest with marked unconformity upon an irregular Lower Palaeozoic surface. The stratigraphical succession is summarised in Table 1.

Lower Palaeozoic

The oldest rocks of the area which outcrop only in the far north-west corner of the study area (Haregrain Rig [NY 457 943]) are the Riccarton Group of Silurian (Wenlock) age. These rocks comprise a thick sequence of steeply dipping, east-north-east striking, greywackes, shales and mudstones deposited by turbidity currents in a deeply subsiding elongate basin. The succession is folded, faulted and affected by low-grade metamorphism which accompanied Caledonian tectonic events. Petrographical and lithological studies (Lumsden et al., 1967) indicate that quartz is the predominant mineral in the greywackes accompanied by subsidiary amounts of feldspar, chlorite (derived from earlier ferromagnesian minerals), muscovite and accessory amounts of apatite, zircon and tourmaline.

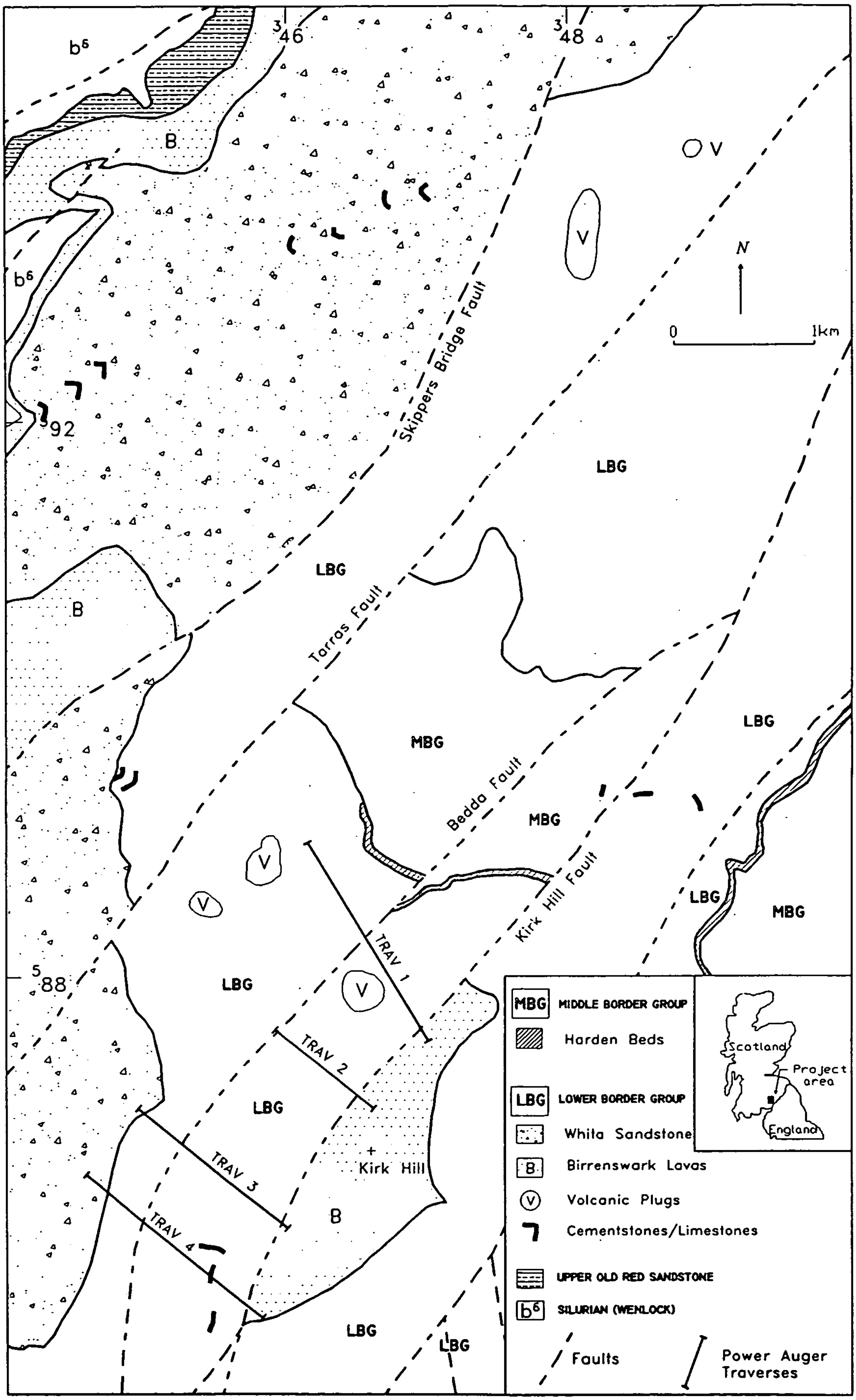

Figure 2 Detailed geological map showing position of deep overburden traverses

Table 1 Stratigraphical succession

SUPERFICIAL DEPOSITS			Thickness
	RECENT	Peat	0.2 - 3 m
		Alluvium	<5 m
	PLEISTOCENE	Glacial sand and gravel	<2 m
		Till	1.5 - 6 m
CARBONIFEROUS			
	DINANTIAN	Middle Border Group (Holkerian)	<400 m
		Harden Beds (at base)	<5 m
		Lower Border Group (Courceyan-Arundian)	<300 m
		Birrenswark lavas (at base)	<60 m
OLD RED SANDSTONE			
UPPER OLD RED SANDSTONE		*Undivided*	<50 m
		unconformity	
SILURIAN			
	WENLOCK	Riccarton Group	>500 m

Upper Old Red Sandstone

Overlying the Silurian with marked unconformity are a thin sequence of red sandstones and siltstones with subsidiary calcareous nodules (cornstones) of probable Upper Old Red Sandstone (UORS) age. Like the Silurian, their outcrop is confined to a relatively small area on Haregrain Rig [NY 457 943]. Some uncertainty exists over their stratigraphic age and in a reappraisal by Lumsden et al., (1967) it is suggested that they may represent a distinctive reddened facies of the Lower Carboniferous. They are of fluviatile origin and palaeogeographical evidence indicates that they were probably part of an interior drainage system with predominant current flow to the north-east (Leeder, 1973).

Carboniferous; Lower Border Group

The lowermost rocks of the Lower Border Group define the base of the Carboniferous system in the area and comprises all the strata from the base of the Birrenswark lavas up to the base of the Harden beds.

Birrenswark lavas

Extensional subsidence was very rapid during Courceyan-Chadian times resulting in marked palaeogeographical changes and destruction of the internal UORS drainage system allowing the sea periodic access to the basins. Locally, alkali olivine-basalt extrusion accompanied rift-basin formation and tensional fracturing along the main basin faults (Leeder, 1974). The basalts, which mark the base of the Lower Carboniferous succession, are known as the Birrenswark lavas, and their petrography and mineralogy are described in detail by Pallister (1952) and Elliott (1960). They are comparable to the Lower Carboniferous basalts of the Midland Valley of Scotland (MacDonald, 1975); being dominantly microporphyritic feldspar-rich types.

In the project area, the lavas are represented by two connected outcrops on the western margin and in the north-west corner and, by a separate, large outcrop forming Kirk Hill near the southern margin (Figure 2). The rocks are vesicular and rich in amygdales particularly in the upper parts of flows, but their most striking feature is their alteration by deuteric activity and the effects of intense atmospheric weathering producing a distinctive spheroidal weathering surface. Hematite is commonly present, but pyrite and chalcopyrite, which were seen as common constituents of calcite-dolomite breccia veins and as patchy disseminations in lavas west of Langholm, have not been observed in the study area. Chloritisation and calcitisation are widespread, the former resulting from alteration of mafic silicates. Amygdales are commonly filled by calcite, accompanied by chlorite, clay minerals, quartz, and chalcedonic silica. Calcite also forms the matrix of breccia-veins noted in outcrop a short distance west of the project area [NY 4014 9146], and in borehole cores west of Langholm (Gallagher et al., 1977). The network of coarsely brecciated calcite veins at the former locality is observed to break across earlier flows, a phenomena considered by Lumsden et al. (1967) to possibly result from a small feeder of a later lava cutting across an earlier flow.

Whita Sandstone Formation

The earliest Lower Carboniferous sedimentary rocks of the area are represented by a thick sequence of fluviatile and deltaic distributary sandstones collectively called the Whita Sandstone (Nairn, 1956; 1958; Lumsden et al., 1967; Leeder, 1974). Palaeocurrent results (Leeder, 1974) indicate derivation from a north or north-western source. Compositionally the sandstones are orthoquartzitic, with quartz forming more than 95%, chert and feldspar <2%, and heavy minerals (mainly ilmenite, zircon, and rutile) <0.05% of the total rock. The deposit achieves maximum thickness (~ 300 m) on Whita Hill near Langholm. North-eastwards on Roan Fell (Figure 1) its outcrop gives rise to a distinctive rolling moorland topography strewn with blocks of sandstone and with numerous parallel, low-scarp features formed by the weathering of individual beds of sandstone. Although the sequence is dominantly arenaceous, increasing numbers of thin cementstones and siltstones occur at progressively lower levels in the succession in a north-easterly direction (e.g. Routing Burn, [NY 464 934]). This probably indicates periods of reduced sediment deposition due to weaker currents and the occasional development of wide estuarine flats submerged in almost static water.

Black Burn Formation

Towards the top of the Whita Formation the more massive sandstones grade into a sequence of thinly bedded alternating sandstones, mudstones, siltstones and cementstones up to 200 m thick. Leeder (1974) refers this assemblage to the Black Burn Formation, lying between the downthrow side of the Tarras Fault (Figure 2) and the base of the Harden Beds which crop out in Black Burn [NY 4640 8912]. However, stratigraphic correlation is precluded by discontinuous exposure, rapid along-strike facies changes and lack of marker beds. Farther to the south-east downstream of the volcanic vent in Black Burn and in the lower reaches of Black Grain there are fewer cementstones and a greater number of limestones. They are more fossiliferous and several algal bands have been reported in them. Conditions of deposition in these areas were probably transitional between estuarine flats and more marine conditions existing to the east of the Kirk Hill Fault.

Arnton Fell Formation

East of the Kirk Hill Fault (Figure 2), the base of the Arnton Fell Formation (Leeder, 1974) rests conformably on the Birrenswark lavas, the easterly limit being drawn along the Ettleton Fault. It is exposed to a limited extent in the streams on the eastern side of Kirk Hill, but because the streams flow on a dip-slope no great thickness of strata is exposed. The formation is characterised by alternating bands of flaggy sandstones and micaceous shales with cemenstones and limestones up to 1 m thick. In the lower reaches of Black Burn, Ralton Burn and Ryedale Burn (Figure 1), strata somewhat higher in the sequence are exposed. These comprise mostly shales and limestones (up to 2 m thick), some displaying prominent algal bands and a more abundant and diverse fauna than is evident to the west of the Kirk Hill Fault.

Carboniferous Middle Border Group

Harden Beds

At the base of the Middle Border Group (MBG), the Harden Beds form a thin (3 - 5 m) sequence of marine shales and limestones with a distinctive, rich marine fauna containing an abundance of the diagnostic fossil, *Syringothyris* cf. *Cuspidata.* The only exposure of the Harden Beds positively identified within the project area is in Black Burn at the junction with Mouly Sike [NY 4666 8913], (Figure 2). Elsewhere in the Black Burn catchment *Syringothyris* cf. *Cuspidata* has not been observed and the boundary between the Middle and Lower Border Groups is therefore conjectural and based on a notable increase in the proportion of calcareous lithologies. Only intermittent exposures in the lower part of the overlying MBG sequence are seen in the project area notably in Ralton Burn and Branch Cleuch. These consist of about 50 - 70 m of thinly-bedded shales with numerous thin limestones and cementstones, indicating dominantly marine conditions with only limited fluvio-deltaic input.

Volcanic Vents

Several small volcanic plugs containing agglomerate and/or intrusive material occur in the Black Burn and Hartsgarth Burn catchments (Figure 2). While no direct genetic link has been established, it is likely that the vents acted as feeders for the Birrenswark lavas or the Glencartholm volcanic beds at the top of the Middle Border Group (not represented in the project area). Blocks and fragments of sedimentary debris in the agglomerate-filled necks include dolomite and chert of probable Upper Old Red Sandstone age, The principal igneous component is olivine-basalt, but unusually a block of carbonated, serpentinized peridotite has been recorded in the Black Burn-Rough Gill vent (Lumsden et al., 1967). Apart from small amounts of pyrite, no sulphide mineralisation has been noted in or at the margins of the vents.

Structure

The regional structure of the post-Silurian strata is relatively simple, being dominated by a north-easterly strike, dip to the south-east, a few folds with mainly north-south orientation and a system of normal, *en echelon* north-easterly faults downthrowing predominantly to the south-east. This structural pattern, which is largely the result of deformation during the end-Carboniferous to early Permian, Variscan Orogeny, probably reflects reactivation of older Caledonian structures within the underlying basement (Chadwick and Holliday, 1991).

Recent seismic interpretation and outcrop studies (Chadwick et al., 1993; 1995) in the Solway Basin has indicated that normal faulting, near the basin margins was the result of rapid extensional subsidence during the early Dinantian and that continuing movement on these syn-depositional faults accompanied deposition of the Lower, and to a lesser extent, the Middle Border groups.

Of the six major north-easterly faults represented in the project area (Figure 2) only the Kirk Hill Fault throws down to the north-west, causing repetition of the succession at crop. In Stanygill Burn and its tributary Green Burn, a belt of strata about 1.6 km long and about 200 m wide is seen to be steeply upturned on the downthrow side with dips ranging from 45 to 75 degrees to the north-west. The fault follows a prominent scarp feature over most of this section, but its extension northwards to join the Arnton Fault is largely based on palaeontological evidence.

A syncline oriented parallel to the Kirk Hill Fault is probably the result of upturning of the strata against the fault. Zones of concentrated small folds and minor faults, most apparent in Black Burn and Ryedale Burn, may also be related to the proximity of major faults. Evidence of larger-scale folding is, however, scarce. An asymmetrical anticline at [344000 585780] with north-south orientation and plunge to the south, and a complimentary synclinal axis with similar trend was observed 4 km to the north-east [347290 589140].

The structures display no obvious sequence of events, although folding, which shows evidence of truncation by the major faults, probably took place prior to, or at the latest, contemporaneously with, the faulting.

Superficial deposits

Glaciation during the Pleistocene produced extensive tracts of boulder clay (till) and outwash sands and gravels, though the latter are mainly restricted to a small area around Woolhope [347400 589400] and to the lower ground south and east of the area shown in Figure 1. These deposits together with alluvium in the river and stream valleys, and peat which is thickest and most extensive on the highest ground, effectively mask all, but a very small proportion (<0.1%) of the outcrop.

Over much of the area the deposits are dominated by grey or grey-brown lodgement tills characterised by unsorted, internally structureless material containing abundant clasts of locally derived pale sandstone with lesser amounts of siltstone, shale, and basalt lava. From the presence of well rounded and quite abundant granodiorite clasts seen in the upper parts of till exposures, it is evident that a component of the glacial material was transported over at least ten's of kilometres, probably originating in south-west Scotland or the Cheviot Hills.

Tills encountered during the overburden survey have very variable thickness (<2 to 8.6 m), generally showing an increase towards the lower ground in the south where some stream exposures (e.g. Stanygill Burn) indicate depths of up to 15 m . Compositionally the finer matrix material comprises between 30 and 40% sand fraction, with clay-grade material and silt making up the balance in the proportion of about 2:1.

DRAINAGE GEOCHEMISTRY

Geochemical sampling of panned concentrates in the Newcastleton area was originally undertaken in 1976 as part of a more extensive MRP reconnaissance survey of the northern margin of the Northumberland Trough. The results of this work, which are included here, supplement the stream sediment data collected as part of the G-BASE regional geochemical coverage of southern Scotland (BGS, 1993). Both datasets revealed the presence of high levels of Zn accompanied by modest enrichment of Pb, Ba and Cu in several streams in the project area. However, comparison of data for the two sample media indicated improved anomaly contrast and much higher concentration levels in the panned concentrates. Visual inspection of the panned concentrates also identified small amounts of sulphide minerals and baryte in many samples confirming that the geochemical anomalies were related to mineralisation rather than the effects of anthropogenic contamination.

A limited programme of follow-up panned concentrate sampling was undertaken in 1994 mainly in the Black Grain - Green Burn catchment in an attempt to trace the source of major geochemical anomalies. At the same time, inspection and sampling of rock outcrops and float boulders was undertaken mainly from stream exposures and from a small number of road and track sections.

Sampling and analysis

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, Sb and Mn was performed on 12 g of milled sample by X -Ray fluorescence spectrometry (XRF) at the BGS Geochemical Division laboratories in London (1976 reconnaissance samples, n = 140) and Keyworth (1994 follow-up samples, n = 33). The analytical data from both surveys are shown in Table 3 and plotted in Figures 3 - 6. The results of optical examination and semi-quantitative XRF analysis of the remaining unground excess material from a small number of the anomalous samples from the 1994 survey are described in Mineralogy and Petrology, Short Report MPSR/95/18C, (Bland, 1995).

DISTRIBUTION OF MAJOR PANNED CONCENTRATE ANOMALIES

Zinc

High levels of Zn are the most prominent feature of panned concentrate analyses throughout the project area (Table 3, Figure 5), levels being considerably higher than those reported from other exploration surveys over Lower Carboniferous rocks in northern Britain (Bateson et al., 1983; Cooper et al., 1991), but comparable to those recorded in other parts of the Solway-Northumberland basin (Colman et al., 1995; Smith et al., 1996). Mineralogical examination of the superpanned fraction from samples containing as little as 200 ppm Zn identified coarse (mostly >500 μm) euhedra of resinous, glassy sphalerite varying in colour from yellow to brown or occasionally orange/red. Some samples with >1000 ppm Zn contain several hundreds or even thousands of sphalerite grains. Unusually in sample BFP 2548 from [348620 590680], with the highest Zn value of the dataset (4629 ppm), the sphalerite forms the most prominent constituent of the heavy fraction, other sulphides, with the exception of a little fine pyrite, being absent. Most frequently, sphalerite is the most abundant sulphide phase, but it is normally accompanied by small amounts of galena, pyromorphite or secondary Pb-minerals and variable amounts of baryte, chalcopyrite, euhedral pyrite, and spherulitic marcasite. The presence of these minerals explains the generally close association of Zn with elevated concentrations of Pb, and to a lesser extent, Ba and Cu.

A few of the high Zn values (>1000 ppm) north of Newcastleton (Figure 5) are closely related to mineralised structures containing visible sphalerite. This is most clearly demonstrated by the presence of major Zn anomalies in Hog Gill (1268 ppm in BFP 2255 at [346290 589210]) and Thief Sike (3307 ppm in BFP 4106 at [349200 593450]) a short distance downstream of faulted limestones containing abundant sphalerite-carbonate veining.

However, the relationship between high Zn values and geological and structural controls is not always evident. For example the conspicuous clustering of high Zn values in the Black Grain - Green Burn -

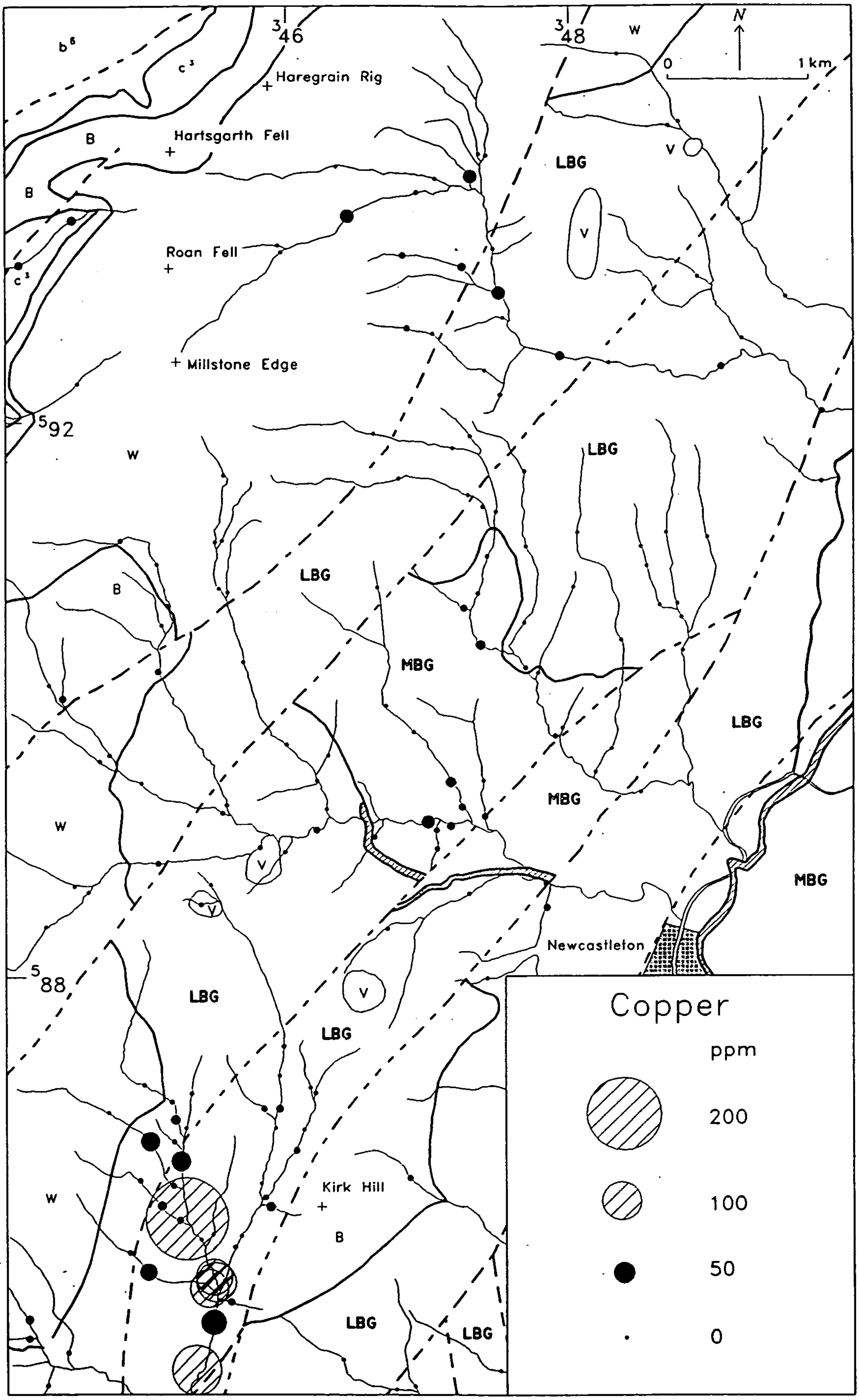

Figure 3 Copper in panned concentrate samples

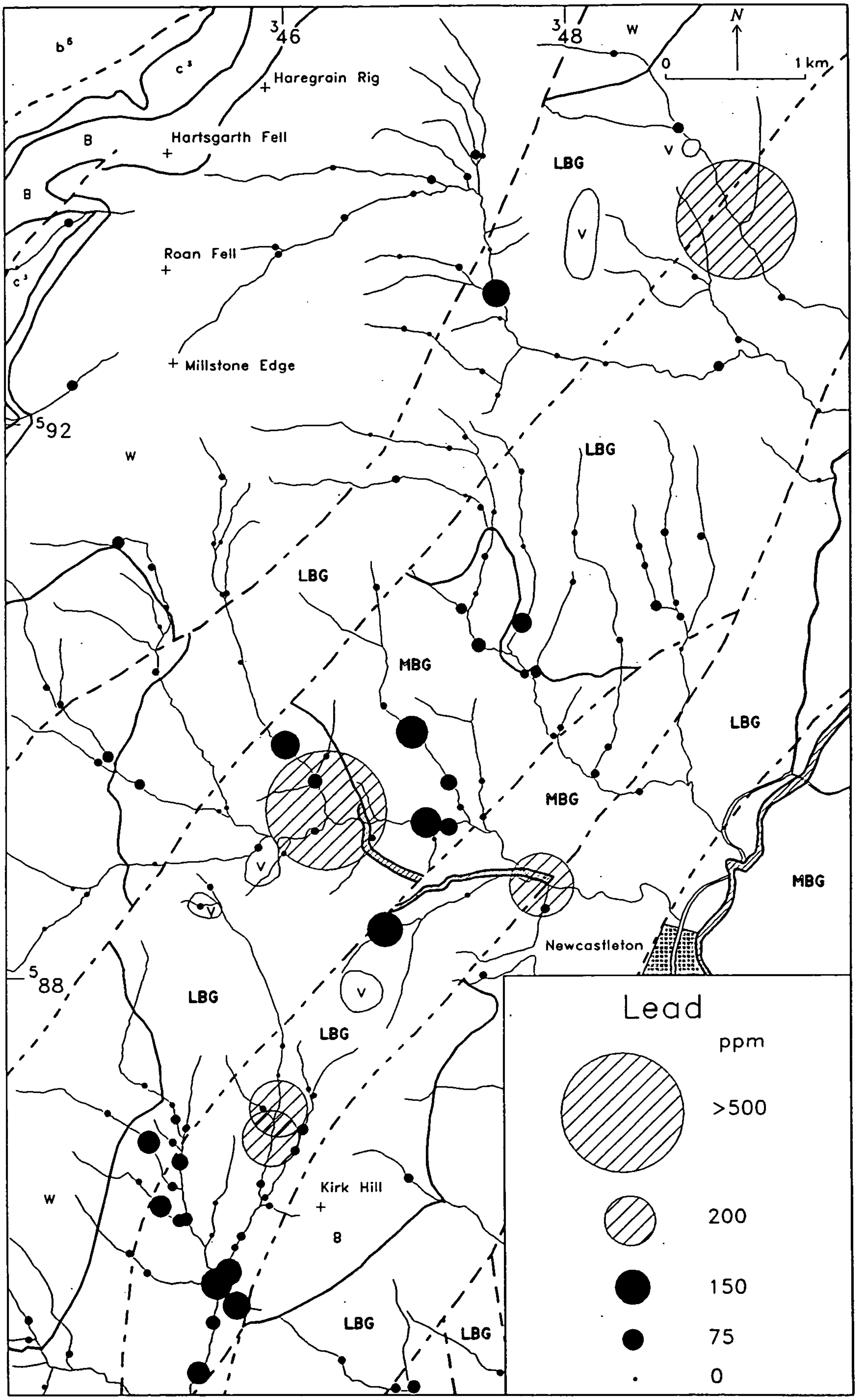

Figure 4 Lead in panned concentrates

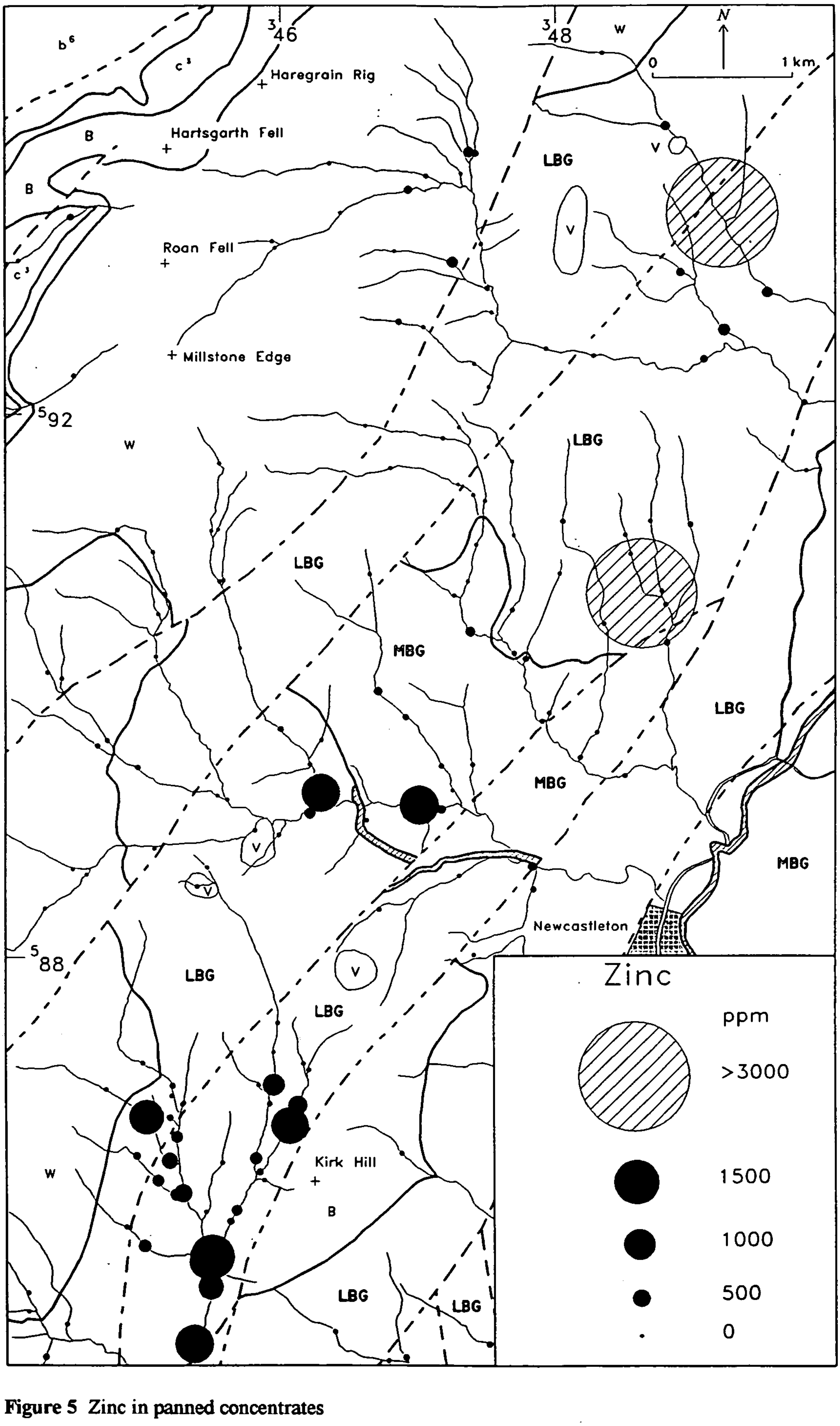

Figure 5 Zinc in panned concentrates

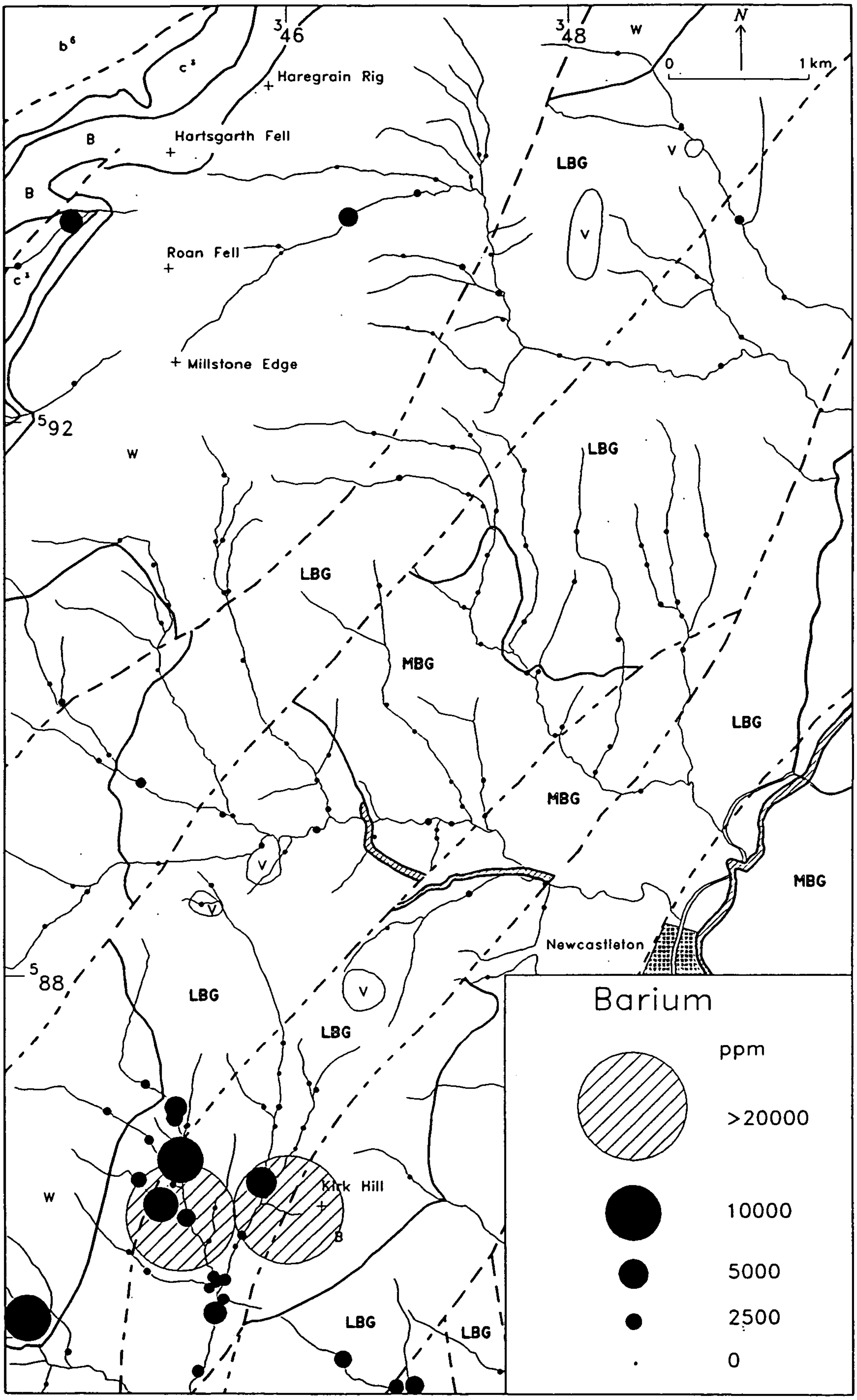

Figure 6 Barium in panned concentrates

Stanygill Burn catchment (Figure 5) occurs midway between the Kirk Hill and Bedda faults in the south of the area. In this zone there are 15 Zn values exceeding 300 ppm, but attempts to relate the highest values directly to in situ mineralisation were unsuccessful. Within this catchment there is little indication of regular downstream decay of the major Zn anomalies, the variation between adjacent sites being sufficiently large to indicate the presence of several sources of Zn within or beneath the drift. Also no evidence of mineralisation could be found to account for the highest Zn value of the dataset (4629 ppm at [348620 590680]) which occurs in a tributary of Ryedale Burn, well upstream of the Bedda Fault.

Lead

Unlike Zn there are comparatively few very high Pb values (Table 3, Figure 4), and little evidence of a coherent pattern. The highest values in Hog Gill (549 ppm in BFP 2255 at [346290 589210]) and Thief Sike (643 ppm in BFP 4106 at [349200 593450]) occur 150 to 200 m downstream of mineralised structures in which coarse galena forms a prominent if minor constituent of calcite (or dolomite) veins in faulted limestones (see Mineral occurrences and rock geochemistry). High Pb values at two consecutive sites in Green Burn (BFP 5194, 230 ppm Pb, and BFP 7513, 226 ppm Pb), are situated well upstream of the nearest recorded galena mineralisation at [345742 586260], but the observation of fresh sulphide in the panned concentrates and the presence of high Zn in BFP 7513 are indicative of a local source. Similarly, in Black Grain just above its confluence with Green Burn, a Pb value of 119 ppm (BFP 2486) is associated with high Zn (and Cu) and several grains of fresh grey sulphide in the pan, suggesting a relatively short distance of transport from a source(s) obscured by drift.

Most other high Pb values (> 100 ppm) are located in the Black Burn catchment where occasional grains of cerrusitised galena were recorded at the time of sampling, and, in one sample containing 117 ppm Pb (BFP 2586), a grain of bright green pyromorphite was mineralogically confirmed (Bland, 1995).

Surprisingly, in view of the number of grouse butts in the area, little lead shot was seen in the panned concentrates and none of the Pb anomalies can be attributed to this or any other contaminant source.

Copper

Levels of Cu in panned concentrates are low over most of the project area (Table 3, Figure 3). The six highest values ranging from 62 to 227 ppm Cu occur in a limited area in Black Grain, Dow Sike, and Stanygill Burn. All are located over a narrow 1 km long, north-south zone, associated with variably enhanced levels of Zn, Ba and Pb in the south of the area (Figure 3 - 6). In general, the samples with the highest Cu values were found to contain quite abundant euhedral pyrite, usually heavily tarnished and difficult to distinguish from chalcopyrite, but displaying fresh surfaces when crushed. Most of the copper is probably contained in the pyrite lattice, although not all pyrite is cupriferous, as indicated by the low copper content of pyrite-rich panned concentrates collected from Thief Sike and Hog Gill. Also, in sample BFP 7551 from Thackie Sike, [345290 586265], which returned the highest Cu value (227 ppm), a few grains of chalcopyrite and an iridescent mineral, probably bornite, were identified in the panned concentrate confirming that, in this case, Cu-mineralisation is the cause of the anomaly. A careful search upstream of this site did not reveal a bedrock source.

In the Langholm district, high Cu values in panned concentrates (80-100 ppm) were traced to small amounts of cupriferous pyrite and subsidiary chalcopyrite in carbonate veins in dolomitic cementstones and in underlying brecciated lavas (Gallagher et al.,1977). Although no bedrock Cu-mineralisation was discovered in the Newcastleton area, the pattern of high Cu values in Black Grain and Stanygill Burn, occurs in a closely similar geological environment, within a few hundred metres of a faulted lava-sediment contact (Figure 1). It therefore seems likely that the source of the Cu is the basalt lavas and that localised leaching has occurred in fault zones such as the Kirk Hill Fault, followed by deposition of Cu minerals in carbonate veins and fractures in the adjacent Lower Border Group sedimentary rocks. Alternatively the Cu may have been derived from hydrothermal fluids associated with the lavas, although mineralogical examination of mineralised lavas from the Westwater area, west of Langholm, indicated that the only pervasive alteration present was deuteric in origin

Barium

High levels of Ba in the panned concentrate samples are caused by the presence of relatively coarse (>500 µm) grains of white baryte. As in the case of Cu, most of the high Ba values (>2500 ppm) occur south of the Newcastleton - Langholm road mainly in the Black Grain - Green Burn - Stanygill Burn catchment and in the minor streams draining eastwards from Kirk Hill (Table 3, Figure 6).

Relatively weak Zn (300-500 ppm), accompanied by Ni (20-40 ppm), and in one or two cases by high Cu values (e.g. BFP 7551 at [345290 586265]), were also recorded in these samples. Generally though, the association of high Ba with base-metals is not sufficiently close to indicate a common source of the metals, and in the case of the highest Ba value of the dataset (13%), occurring in a minor stream draining the faulted western margin of the Birrenswark lavas, there is no evidence of base-metal enrichment. Clasts of vein baryte were noted in the stream at the time of sampling and traced to a small gulley a few metres to the south [345900 586350] directly over the trace of the Kirk Hill Fault. Another source of baryte is indicated by the presence of high values (maximum of 2% Ba) recorded at three consecutive sites in Thackie Sike. Again the low tenor of associated base-metal values suggests that the likely cause is minor vein or fracture-bound baryte unrelated to sulphide mineralisation. The only substantial enrichment of Ba in bedrock in the northern part of the area was recorded from the mineralised structure in Hog Gill (BFR 4845), but since there is no evidence of anomalous Ba concentrations in panned concentrates from this stream the baryte mineralisation is assumed to be of very minor and localised extent. The close spatial relationship between Ba anomalies in panned concentrates and the Birrenswark lava outcrop on Kirk Hill is consistent with the regional pattern of high Ba in panned concentrates and stream sediments observed over the Birrenswark lavas south-west of Langholm (Colman et al., 1995) and with the widespread association between baryte veining and Lower Carboniferous lavas in southern Scotland (Stephenson and Coats, 1983).

MINERAL OCCURRENCES AND ROCK GEOCHEMISTRY

Detailed inspection of outcrops and float material was routinely undertaken during the drainage survey leading to the discovery of several new occurrences of sulphide and baryte mineralisation. Rock samples (2 - 3 kg) were collected from these occurrences to establish base-metal concentrations and provide mineralogical/petrographical information on the style(s) of mineralisation. The samples were analysed by X-ray fluorescence (XRF) for the same range of elements as the drainage, till and soil samples (see Sample Preparation and Analysis, p 8). Field observations and geochemical data for 56 outcrop and 28 float boulder samples are presented in Table 2A and 2B respectively.

There is no history of metalliferous mining in the area and only one documented occurrence of an old lead trial, located on Roan Fell (Milne, 1843). According to Lumsden (1967) no trace of the workings or the associated heaps of slag and cinders reported by Milne (*op. cit.*) were found during remapping of the district. However, in the course of the present survey an east-north-east trending adit, 1 m wide and 7 m long was discovered in heavily fractured Birrenswark lavas in the east bank of Long Gill [NY 4514 9049]. The objective of the excavation appears to have been a 20 - 30 cm wide zone of steeply inclined chalcedonic quartz-limonite veins, but no evidence of galena or other sulphides was found and chemical analysis of the vein material (Table 2B, BFR 4947) failed to reveal their presence. Individual veins up to 5 cm wide contain abundant limonite in cavities both within, and at the vein margins. This mineralisation, together with a 30 cm wide limonitic fault gouge about 25 m upstream of the adit are associated with the major north-east trending Skippers Bridge Fault which is marked by several fractures and a zone of considerable disturbance over a 30-40 m section of the stream channel.

All the new occurrences are located in stream sections in three distinct areas, collectively forming a north-north-east trending zone bounded by the Tarras Fault in the north and the Kirk Hill Fault in the south. Most of the mineralisation occurs in networks of carbonate veins or in and adjacent to narrow breccia zones in cementstones and limestones. Individual veins are thin, rarely exceeding 1 cm and commonly only 3 to 5 mm in width. Mineralogically the occurrences are simple; in decreasing order of abundance the ore minerals are pyrite/marcasite, sphalerite, galena, and rare chalcopyrite. Baryte is present locally in small amounts, while ore-stage gangue minerals comprising ferroan dolomite and calcite, are greatly in excess over metalliferous phases. Often pyrite occurs as fine disseminations in micritic limestones or as clusters of tiny crystals grown along vein margins, but occassionally forms more massive groups of crystals or radiating rosettes replacing the carbonate matrix. It is evident from the extent of veining and the increased abundance of base-metals in proximity to faults that most of the mineralisation is fracture-controlled and epigenetic.

1) The Black Grain - Green Burn catchment.

In Black Grain upstream from its confluence with Green Burn and in the lower reaches of its west bank tributaries, Dow Sike and Thackie Sike, mineralisation is present intermittently in outcrops of carbonate (dolomite)-veined cementstones and micritic limestones over at least a kilometre of stream section (Table 2A, BFR 5234 - 6008, 6103 - 6111, 7070 - 7075, and 7104 - 7106). Outcrops of these rocks and their down-stream dispersion trains of boulders and smaller clasts are readily identifiable from the distinctive orange-brown weathering surface caused by oxidation of the iron-bearing carbonate minerals, ferroan dolomite and ankerite, which together account for a high proportion of the matrix material. However, individual carbonate beds rarely exceed 0.7 m in thickness and the cumulative thickness of mineralised strata is estimated to be no more than 15 m over the entire section. Most of the mineralised occurrences are associated with faults trending either north-eastwards parallel to the major basin-bounding faults, or to the north-west, probably representing later cross-faults with throws of only a few metres. In some instances, for example at [345300 586250], minor faults are seen to cut the crests of small anticlinal structures, both structures pre-dating later cross-cutting carbonate-baryte-pyrite veinlets (e.g. BFR 6003).

Only the most competent rocks show evidence of veining, the softer interbedded mudstones and shales being essentially barren. Many of the cementstones and micrites carry irregular sparry patches and calcite-lined cavities up to about 3 cm in diameter, both of likely diagenetic origin. Pyrite forms occasional coarse crystals in the cavities, but more commonly occurs as aggregates of blade-like crystals intergrown with marcasite in radiating rosette structures up to about 1.5 cm across. In many of the cementstone samples, including veined and unveined varieties, small amounts of evenly disseminated fine-grained pyrite and/or marcasite are present. This is presumably of diagenetic origin.

In sample BFR 5235, which contains the highest in-situ Zn - Pb levels in the Black Grain catchment (Table 2B), sphalerite is present as irregular groups of small crystals within the carbonate veins and galena forms either isolated subhedral to euhedral crystals, usually favouring sites at the margins of calcite veins, or plate-like crystals (galena bloom) grown along joint surfaces. About 400 m downstream, a lithologically similar sample of mineralised stream float (BFR 6051) containing very high Pb (>11200 ppm) and Zn (>4500 ppm) values may have been derived from the same outcrop.

Two mineral localities situated in Green Burn close to the Kirk Hill Fault are also worthy of note: a) coarse radiating bladed barytes accompanied by small crystals of pyrite form thin coatings on two orthogonal, vertical joint faces in a thin (0.3 m) bed of sandy micrite (BFR 6167 and 6168). Slickensides are conspicuous on the major north-west - south-east joint faces indicating that the baryte mineralisation is probably fault controlled. About 200 m to the south-east [345900 586350] in a small gulley lying directly over the Kirk Hill Fault, more substantial vein mineralisation is indicated by the presence of numerous fragments of monomineralic baryte up to 3 cm across. b) In an outcrop of ochreous weathering dark limestone 4 m wide by 10 m long, abundant vertical calcite veins striking north-south contain coarse crystals of euhedral galena and sphalerite. The best sulphides (up to 0.16 % Pb and 0.57 % Zn) were seen in breccia zones up to 10 cm wide containing fragments of dolomitic wall rock set in a carbonate cement (BFR 6169 and 6170). Within the mineralised outcrop a sheared, but apparently unmineralised, 0.5 m wide, shale band contained weakly anomalous Pb (112 ppm in BFR 7101), indicating possible movement of metal-enriched fluids along planes of weakness at the margin of two beds of contrasting competence.

2) The Black Burn - Hog Gill - Long Gill catchment.

In Hog Gill at the site of a small fault located 250 m upstream of the Black Burn confluence, numerous slumped black micritic limestone and calcareous siltstone blocks contain irregular patches of sparry calcite and a network of thin calcite veins. Marcasite often fills the cavities and sphalerite occurs irregularly dispersed through the rock, apparently as derived fragments. This is in marked contrast to other micrites in the project area and to those west of Langholm (Gallagher et. al., 1977) in which the sphalerite is clearly of epigenetic origin. Coarse galena crystals are located on the margins of the carbonate veins or as plate-like blooms lining joints. Rock samples from this occurrence (BFR 4846, 4847, 6017, and 6018) and from float dispersed downstream (BFR 4840, 4845, 6019, 6021 and 6022) are enriched in Pb (max. 1149 ppm), Zn (1714 ppm), and Ba (1.27 %), but the total ore mineral content is too low to be of dirtect economic interest (Table 2B).

The most promising discovery of disseminated mineralisation in the study area was made in Black Burn in a 20 - 30 cm thick, carbonate-silica cemented, organic-rich mature sandstone unit located in the north bank of the stream opposite Rowantree Sike. Samples BFR 6023 and 6158 collected 4m apart on the same outcrop indicate a Zn content of between 0.5 and 1 %, the highest Zn grade reported in the project area, but are only weakly enriched in Pb (< 0.01 %) (Table 2B). The mineralised horizon occurs in an alternating sequence of shales, cementstones and siltstones shown on the 1:50000 scale geological map as part of the Harden Beds Formation (Middle Border Group). It is exposed on the eastern limb of a tight anticlinal structure trending roughly north-north-west, the crest of which is cut by a small fault displacing the beds down to the south-east so that the mineralisation is not seen on the western limb of the anticline. Petrological thin section examination (Fortey and Bland, 1995) revealed that fine-grained sphalerite accompanied by massive patches of pyrite are dispersed throughout the diagenetic sparry carbonate cement which forms about 15 % of the rock. A series of 6 channel samples representing each lithological unit, taken vertically through the outcrop (BFR 6152 to 6158), show weak enrichment in Pb and Zn, but no visible sulphides. Attempts to trace the Harden Beds downstream in Black Burn and on the hill side to the south of the stream were unsuccessful due to lack of outcrop. Also no float material resembling the mineralised sandstone unit was discovered, suggesting that the mineralisation is locally developed with no great lateral continuity.

3) The Hartsgarth Burn - Thief Sike catchment.

In Thief Sike two occurrences of Pb-Zn vein mineralisation in limestone (BFR 7047 and BFR 7048/6143) about 70 m apart are responsible for downstream dispersion of mineralised boulders (BFR 6138 - 6141) detectable over 300 - 400 m from source. Both mineralised outcrops comprise heavily veined carbonate-cemented fracture breccias about 1 m thick, in which course galena and sphalerite occur within the margins of the veins and abundant very fine-grained pyrite is disseminated throughout the matrix. Another occurrence of mineralised micritic limestone (BFR 6037) located in Hartsgarth Burn 1.5 km to the south-west of Thief Sike, shows evidence of abundant fracture veinlets, but contains only sphalerite as indicated by the low Pb and high lead values in BFR 6037, Table 2B. The mineralisation at both localities is situated very close to the major north-east trending Tarras Fault and is undoubtedly fault controlled.

OVERBURDEN GEOCHEMISTRY

Sampling and analysis

In an attempt to clarify the source of drainage anomalies in the Black Grain - Green Burn catchment and to trace the extent of mineralisation seen in sparse outcrops, 117 bulk till samples (including 5 replicates) were collected from 112 sites using a portable mechanical auger to sample at 50 m intervals along 4 across-strike traverses (Figure 2). Traverses 1 - 3, drilled in 1994 were sited to intersect the Bedda and Kirk Hill faults. Sampling of a fourth traverse was carried out in 1995 to test the continuity southwards of base-metal anomalies identified on traverse 3 near its intersection with the Bedda Fault.

At each site about 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 4). Additionally a sample of till from the maximum attainable depth was collected from traverses 2, 3 and 4, and after drying and dissaggregation, sieved at 150 μm to produce a fine-fraction for chemical analysis (BFT samples in Table 5). The lithology and morphology of clasts recovered during the wet screening operation was recorded to provide an indication of provenance, and transport distance. Samples were analysed by XRF for the same range of elements as the drainage concentrates.

The average penetration depth of the power auger at 117 sample sites was 3.3 m (< 1 to 8.6 m), but exposures of overburden seen in the lower part of Black Grain exceed 10 m and it is therefore doubtful whether the material sampled from some holes represents basal till. Compositionally the till 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 origin. Farther travelled clasts of greywacke and felsic igneous rocks, the latter probably derived from the granitic intrusions of south-west Scotland and the Cheviots, comprise a small, but conspicuous component of the drift.

Most of the till concentrates are characterised by pale, sandy compositions containing a relatively small heavy mineral component (<5 % by volume) in which magnetite, zircon, hematite and rutile are the principal phases in decreasing order of abundance. Concentrate samples collected over the Birrenswark lavas are readily distinguished by their dark brown appearance and their significantly higher proportion of iron ores and ferromagnesian minerals indicating local derivation of sample material.

Geochemical data for till samples

The geochemical data for panned and sieved tills are presented in Tables 3 and 4 respectively and the spatial distribution for Pb, Zn, Cu and Ba in the panned till shown in Figures 8 - 11 and sieved till, Figures 12 - 15. For conciseness in the text, results for the two sample types are differentiated by the subscripts u and t respectively after the symbol of the element concerned, for example Zn in panned till is abbreviated to Zn_u.

Concentrations of base metals and Ba are generally low in both sample media from traverses 1 and 2, with the notable exception of two panned samples (BFU 7349 and 7354) containing coincident Cu, Pb, Zn and Ba anomalies (Figures 8 - 11). Both sites are located on traverse 2, south-east of the surface trace of the Bedda Fault. Mineralogical examination revealed the presence of abundant coarse grains of sphalerite (mainly corroded) and baryte in BFU 7354, whereas BFU 7349 contained smaller amounts of sphalerite and baryte, but very abundant fine-grained oxidised pyrite and a few grains of galena (Bland, 1995). At a site 50 m north-west of BFU 7354 (BFU 7355), 6 grains of galena were identified, although the analysed sample contained only 16 ppm Pb suggesting poor sub-sampling precision.

On traverse 3, a weak Pb_u, Zn_u anomaly at site BF 7363 (Figures 9 and 10) corresponds to the highest Zn_t and Pb_t values (332 ppm and 95 ppm respectively) recorded in the dataset and to the observation, in the panned till sample, of a little galena and sphalerite and to much oxidised and fresh pyrite. Towards the south-east end of traverse 3 close to the inferred position of the Kirk Hill Fault, very strong enrichment of Ba_u (maximum of 76311 ppm in BFU 7385, Figure 11) and, to a lesser degree Ba_t (maximum of 4516 ppm in BFU 7384, Figure 15) correspond to the presence of abundant coarse fragments of white baryte in the panned till. Since there is no evidence of enrichment of Pb or Zn, either in these samples or in adjacent sites, the source of the Ba anomaly is most probably due to local baryte veining. This source is supported by the presence of numerous angular baryte clasts discovered nearby in a small gulley (see Mineral Occurrences and Rock Geochemistry).

Geochemical data from traverse 4, which follows the interfluve between Thackie Sike and Dow Sike, provides the most convincing evidence of a coherent pattern of high Pb_u and Zn_u (and weak Cu_u and Ba_u) values, related to the Bedda Fault (Table 4 and Figures 7 - 11). Maximum coincident Pb_u and Zn_u concentrations are reached about 150 m downslope of the assumed fault intersection (Figures 7, 9 and 10), in sample BFU 7405 which also contains fresh grains of galena, sphalerite and pyrite and occasional grains of baryte (Bland, 1995). A similar mineral assemblage in which the sulphides show little evidence of corrosion or weathering was recorded in the panned concentrates from adjacent sites (BFU 7402, 7404, 7406, and 7407), indicating derivation from a local source. Along the same traverse a major Ba_u anomaly was detected at two consecutive sample sites near the base of the scarp feature marking the Kirk Hill Fault (Figures 7 and 11), most probably indicating a southwards continuation of the major Ba anomaly detected towards the end of traverse 3. The source of this anomaly is clearly due to the presence of coarse angular fragments of baryte in the panned concentrates, suggesting that

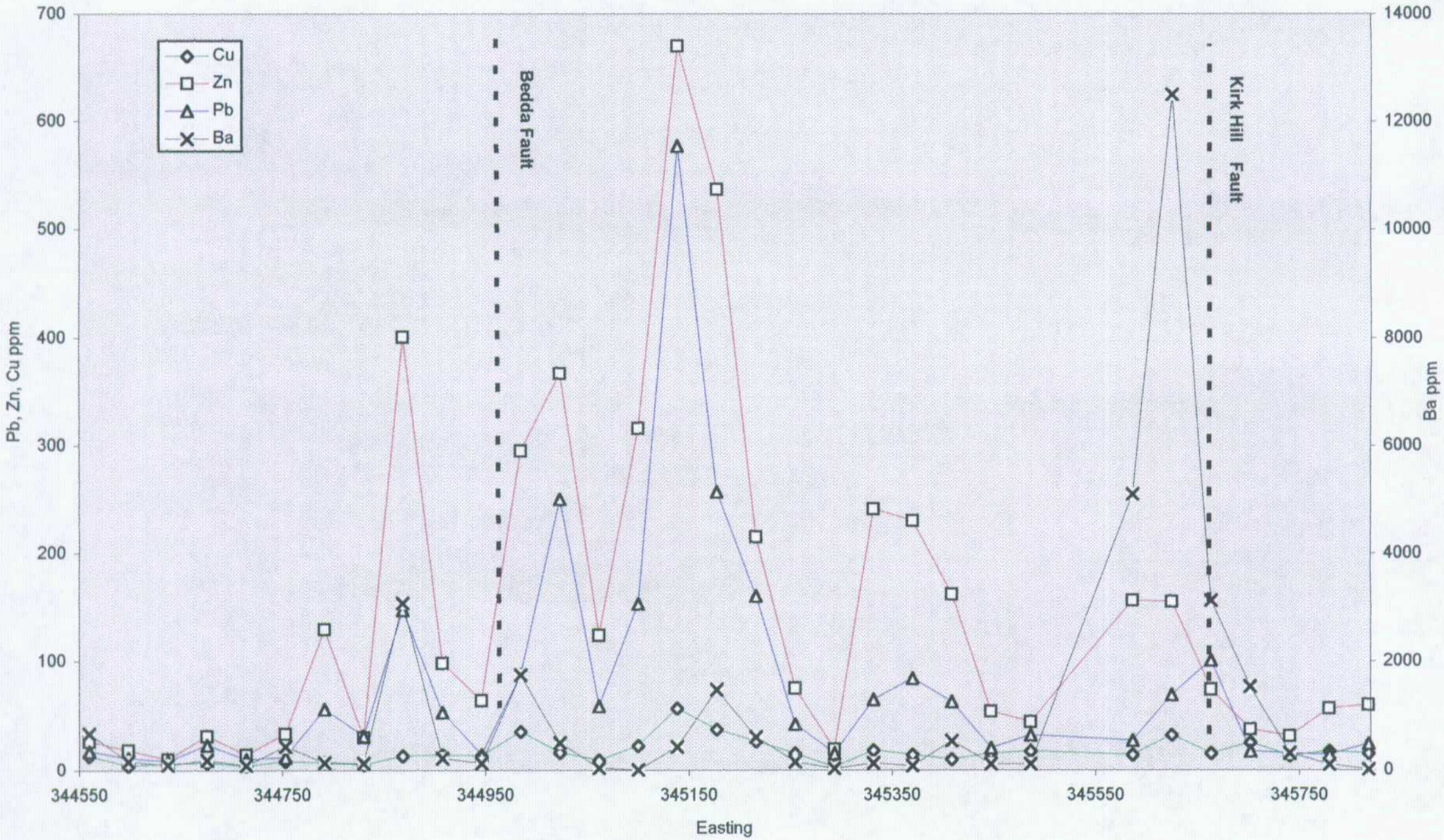

Figure 7 Cu, Pb, Zn, and Ba concentrations in panned tills along Traverse 4, Newcastleton

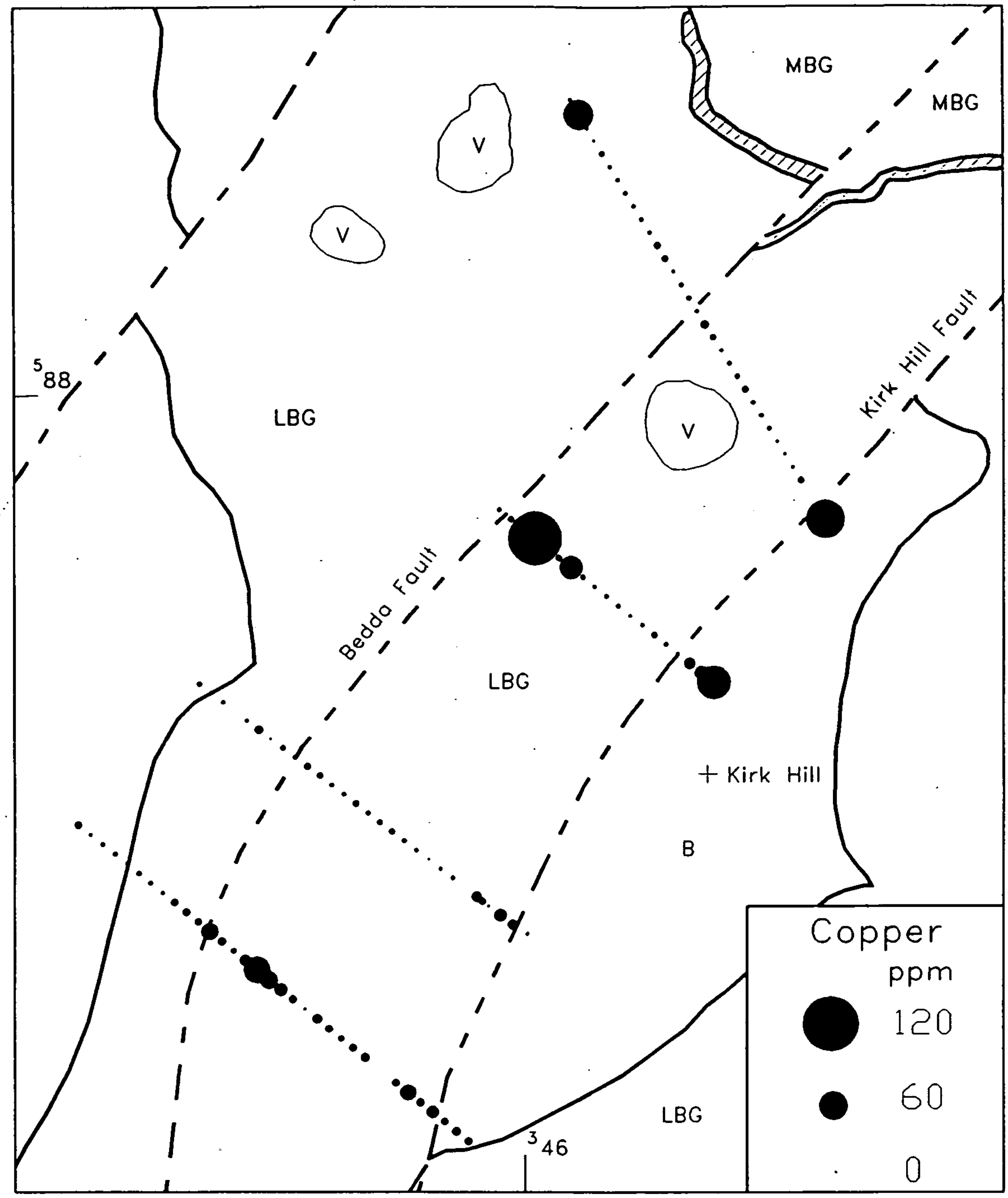

Figure 8 Copper in panned tills

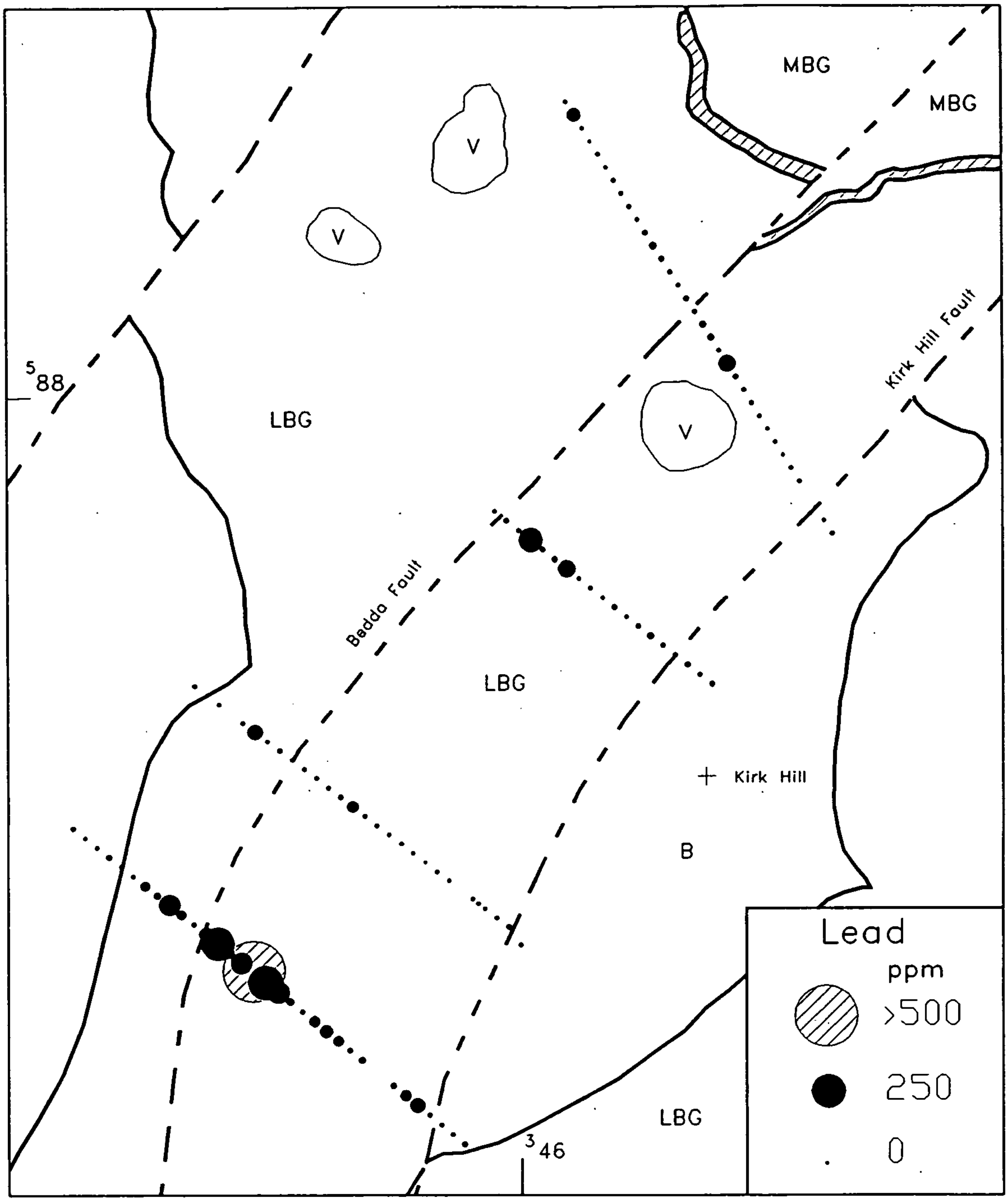

Figure 9 Lead in panned tills

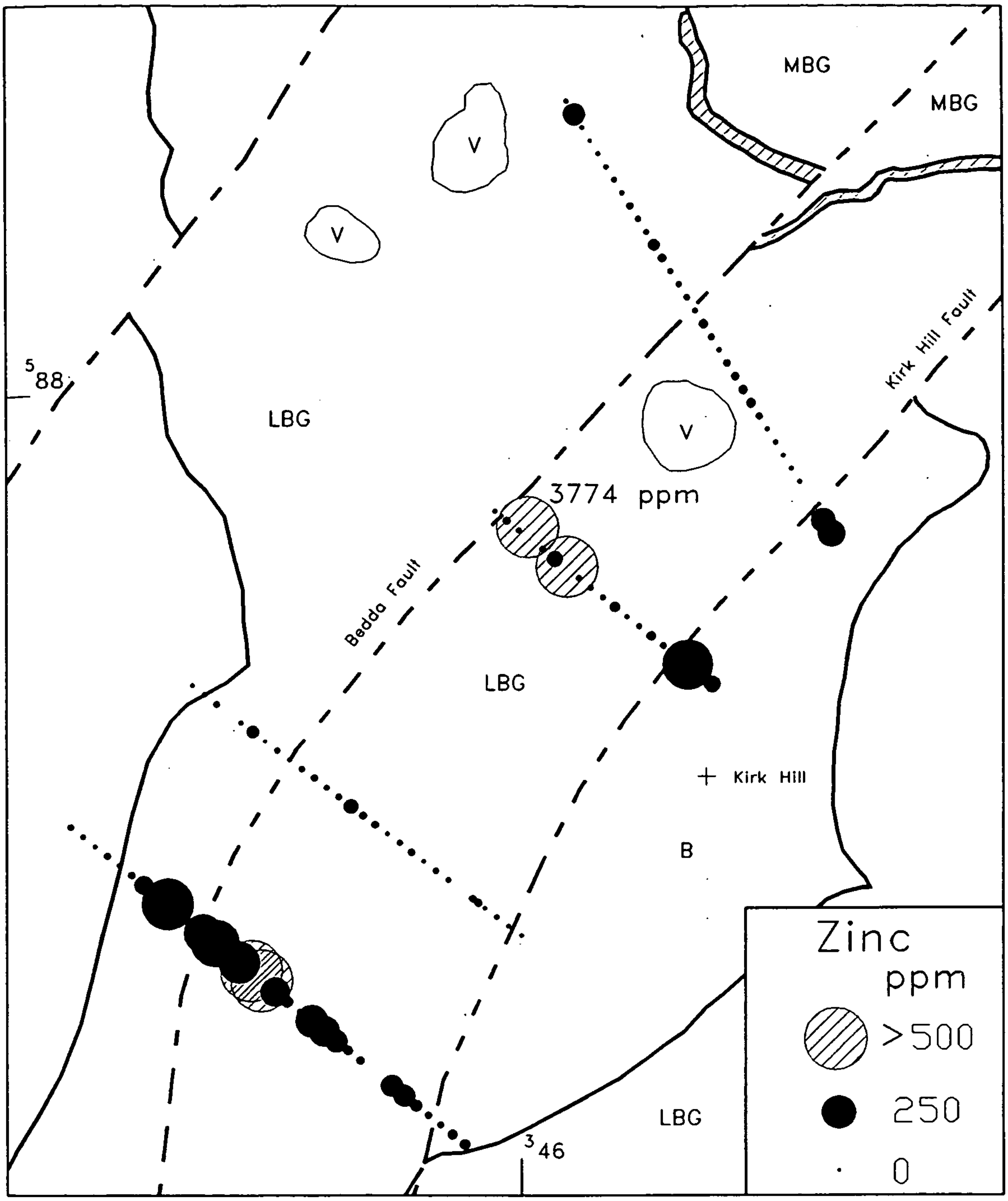

Figure 10 Zinc in panned tills

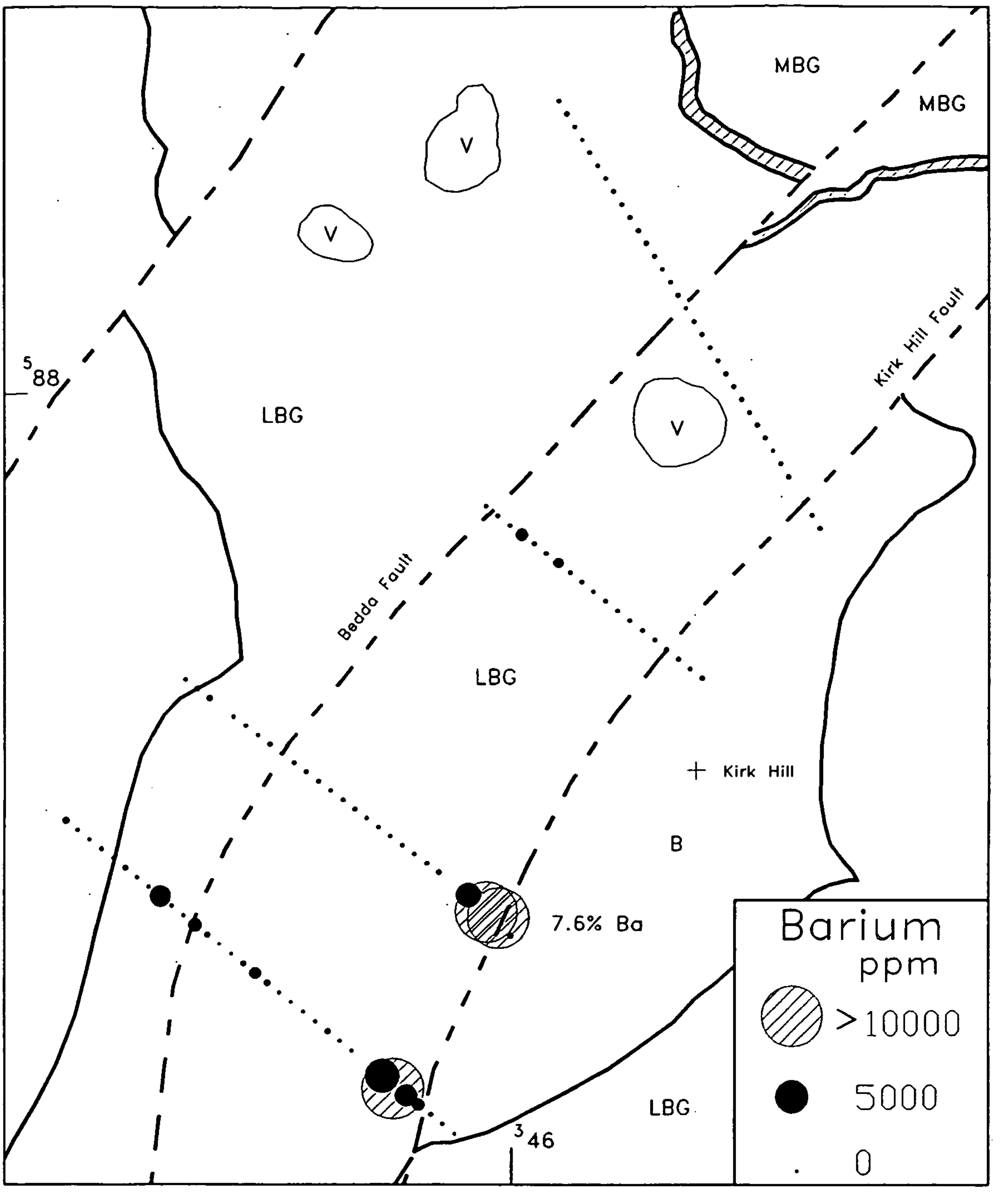

Figure 11 Barium in panned tills

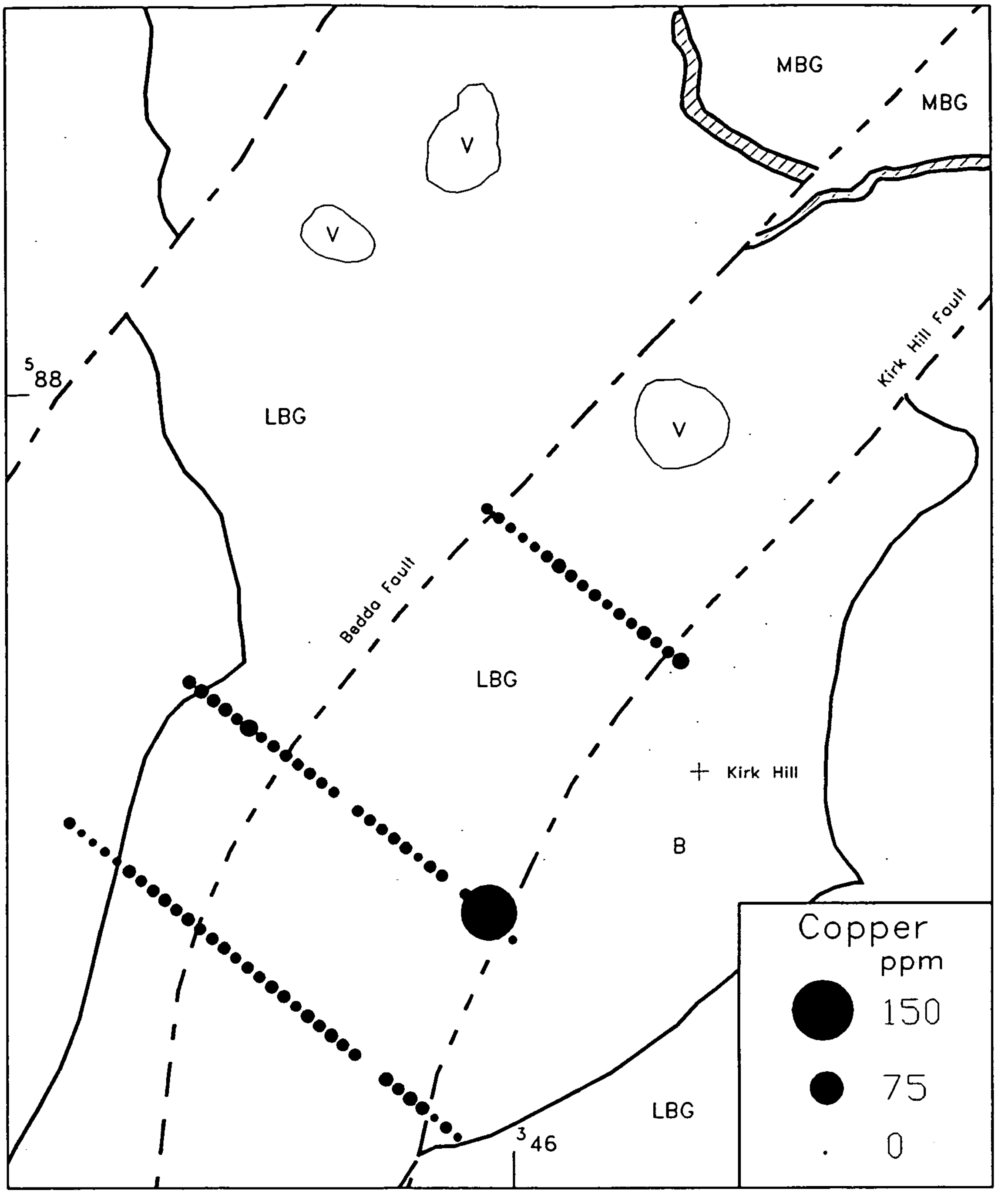

Figure 12 Copper in sieved tills

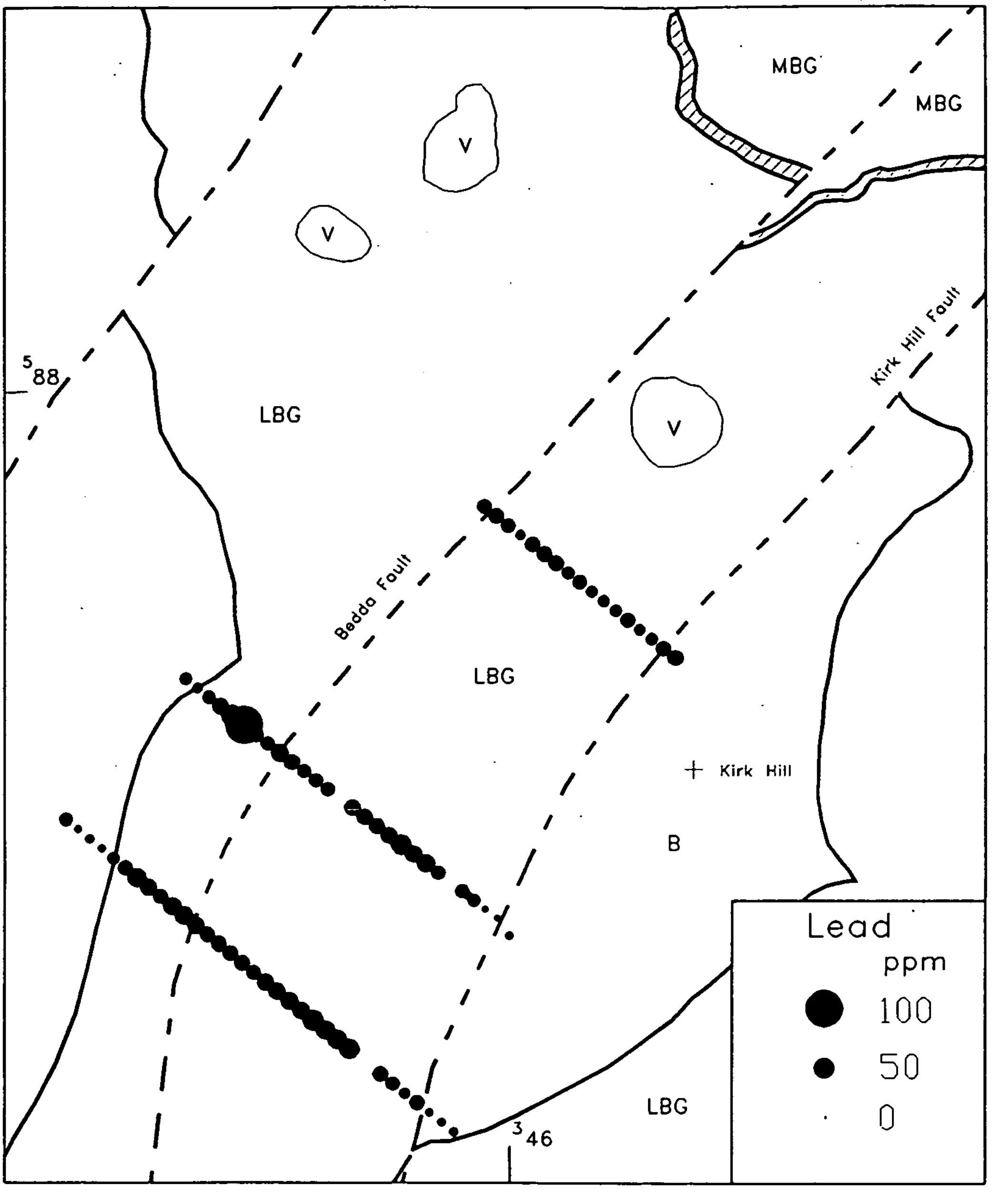

Figure 13 Lead in sieved tills

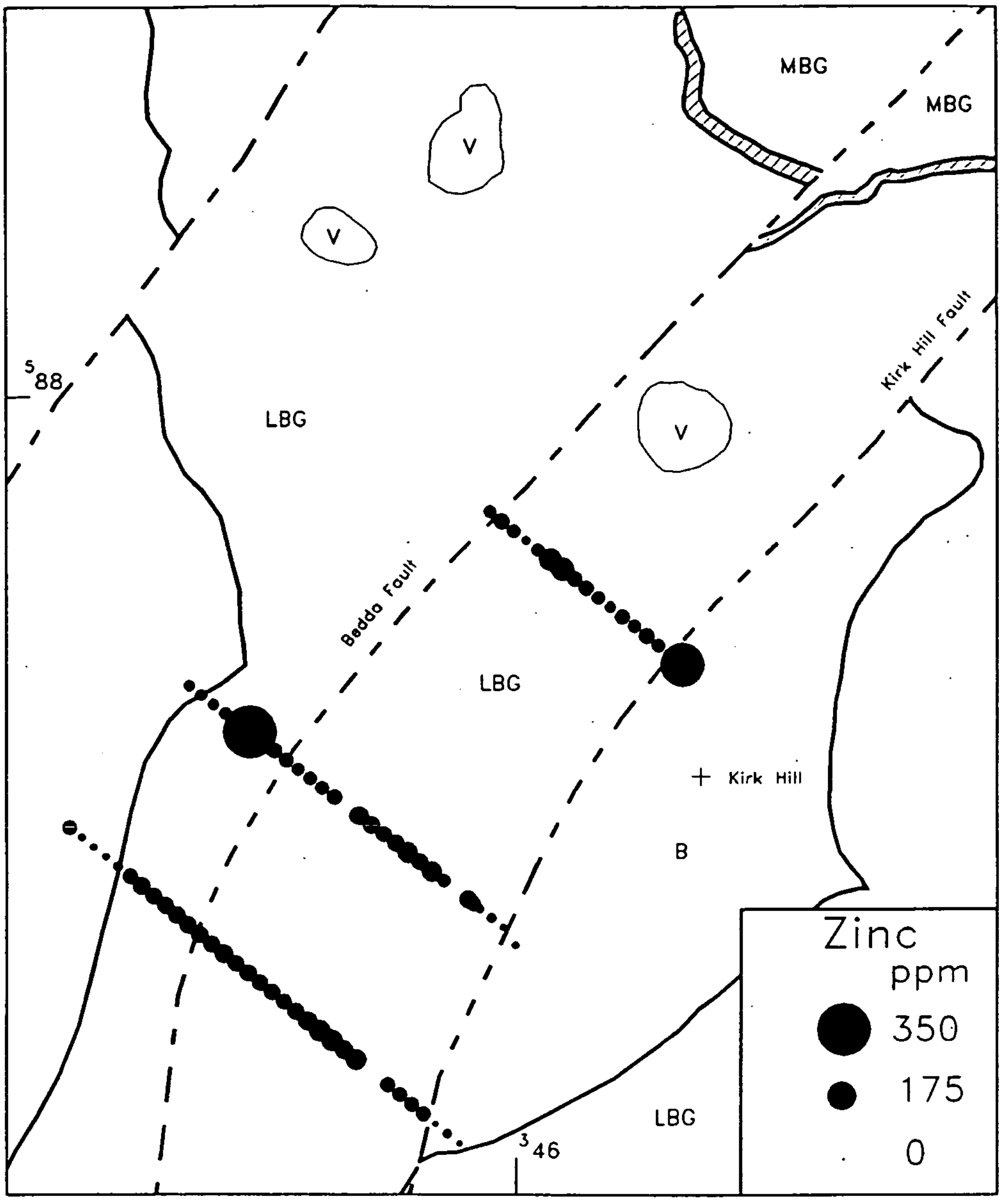

Figure 14 Zinc in sieved tills

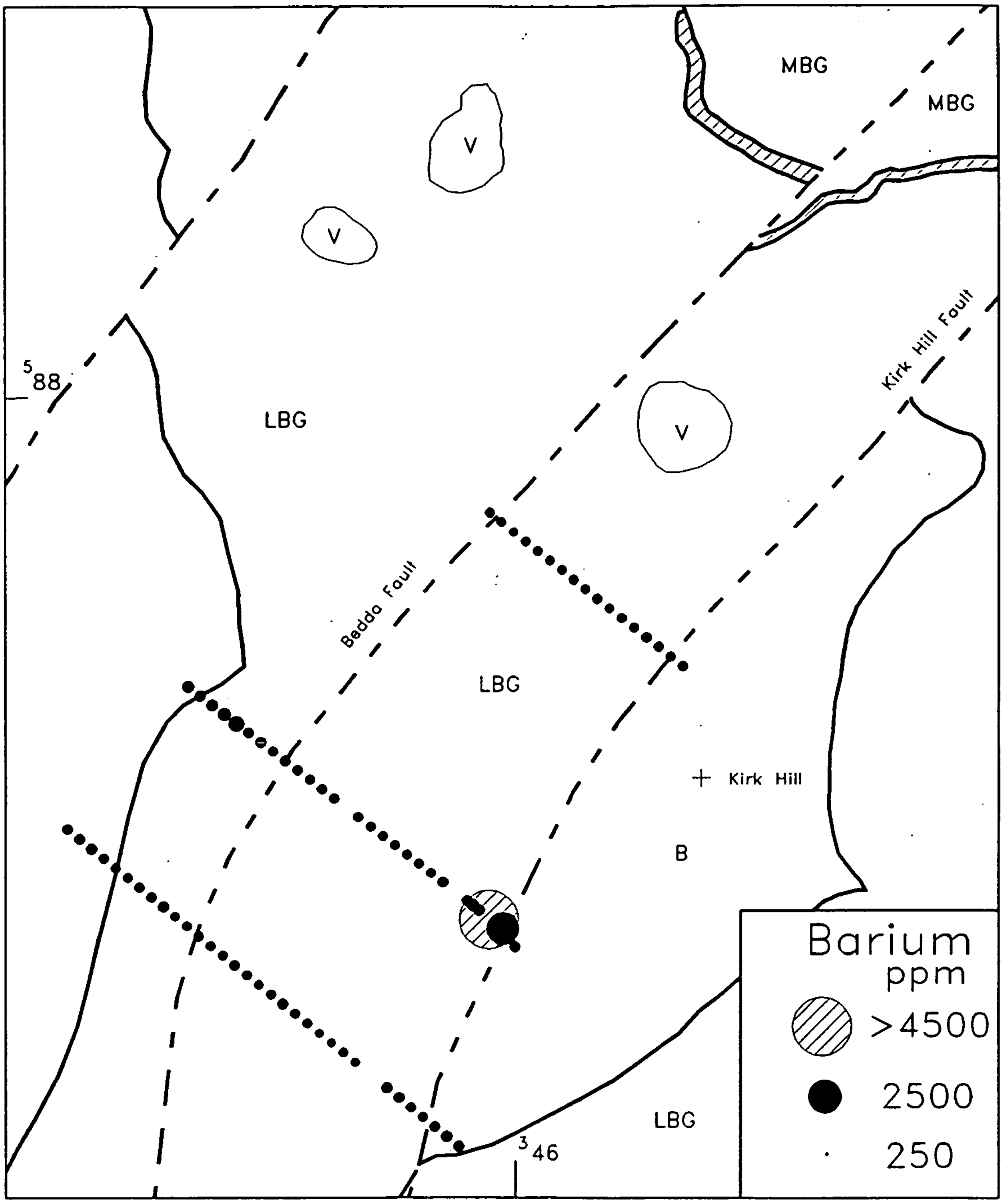

Figure 15 Barium in sieved tills

a narrow zone of fault-controlled baryte veining is developed over at least 600 m strike length between traverses 3 and 4.

The low abundance of metalliferous elements in the fine till fraction generally, and the absence of any appreciable correlation between the two sample media, indicates that little hydromorphic remobilisation has occurred, the principal mechanism being one of clastic dispersion.

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.

The specific targets for investigation were the Bedda and Kirk Hill Faults (Figure 2). Both of these major structures dislocate the strata of the Carboniferous Lower Border Group, but they are poorly exposed in the interfluve areas and thus their control on mineralisation was not well understood.

Geophysical measurements were made along the same traverses used for deep overburden sampling, oriented roughly perpendicular to the local strike direction.

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. 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.

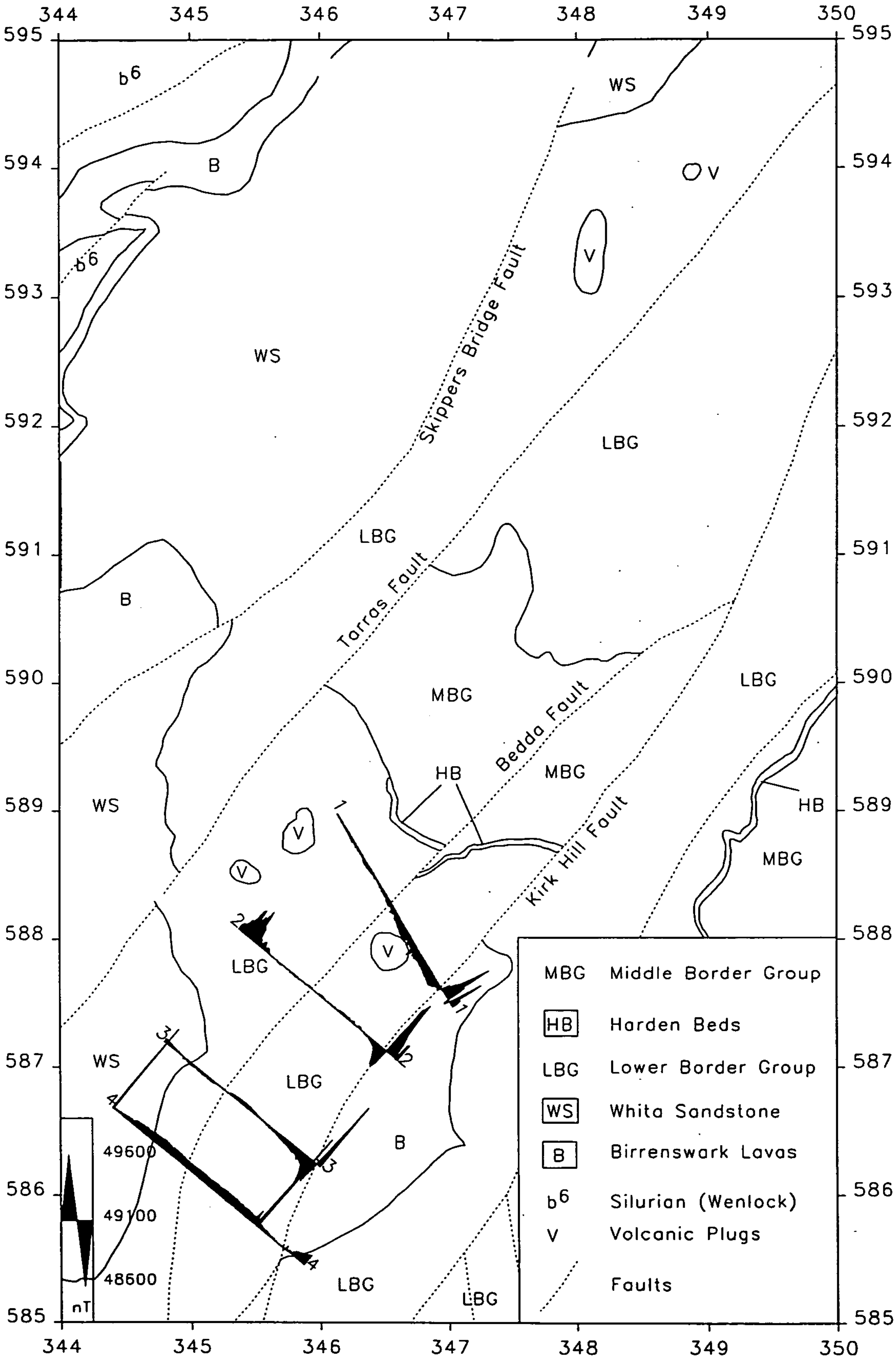

Figure 16 Total field magnetic field profiles, Kirk Hill. All data corrected for diurnal change.

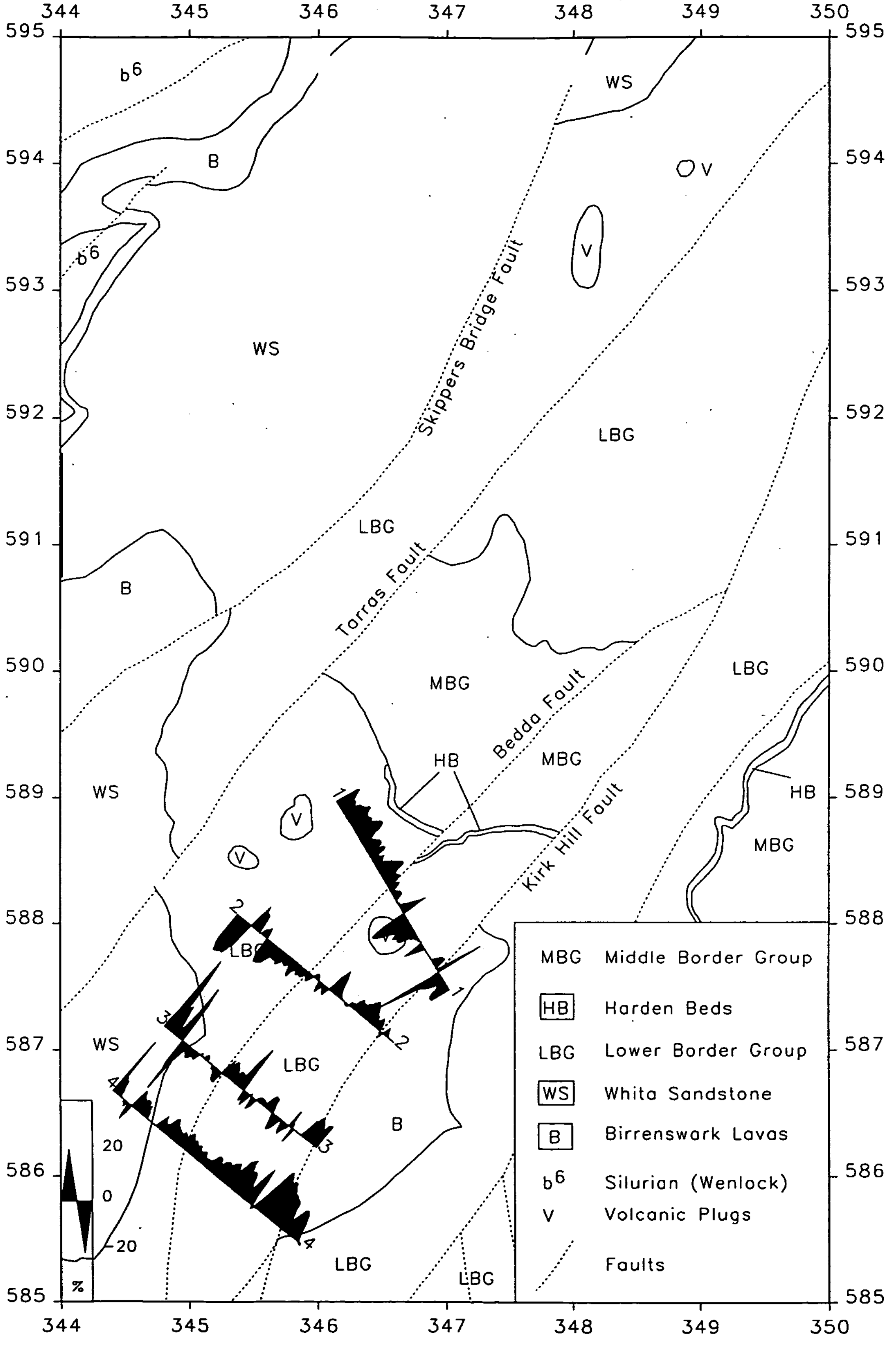

Figure 17 VLF electromagnetic (magnetic field) profiles, Kirk Hill. VLF frequency 16.0 kHz, in-phase component.

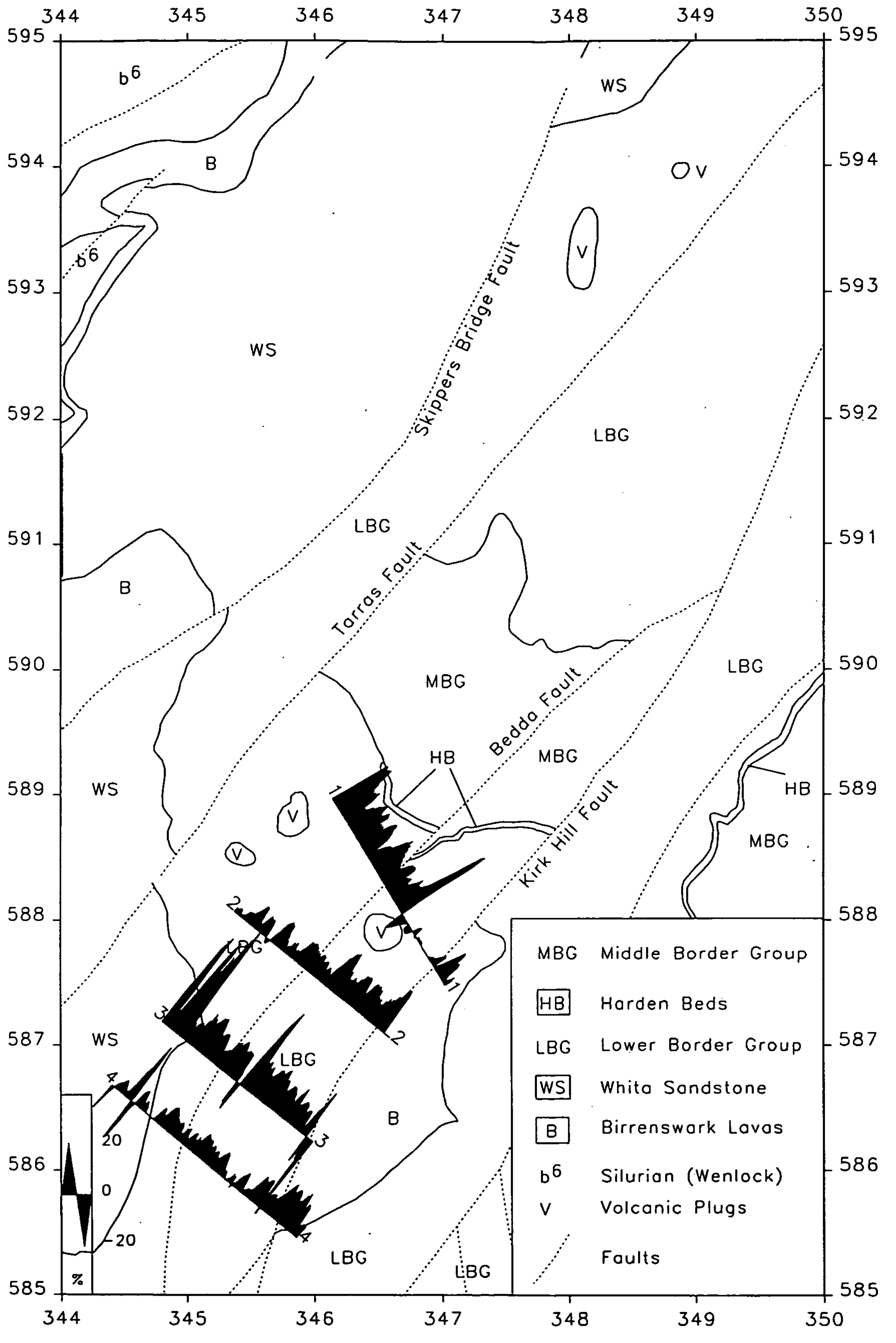

Figure 18 VLF electromagnetic (magnetic field) profiles, Kirk Hill. VLF frequency 24.0 kHz, in-phase component.

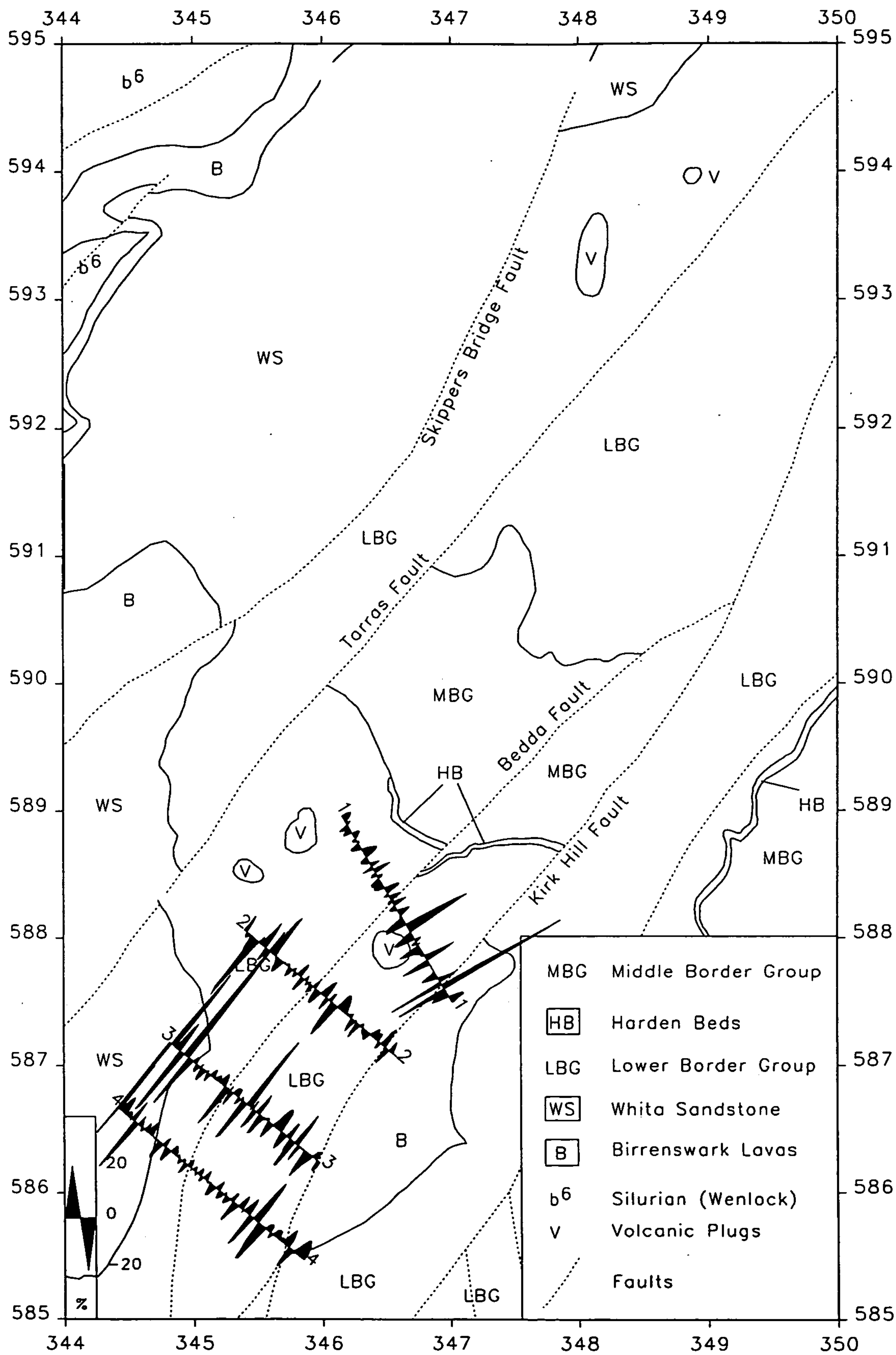

Figure 19 Fraser Filtered VLF electromagnetic (magnetic field) profiles, Kirk Hill. VLF frequency 16.0 kHz. Filtered from in-phase component.

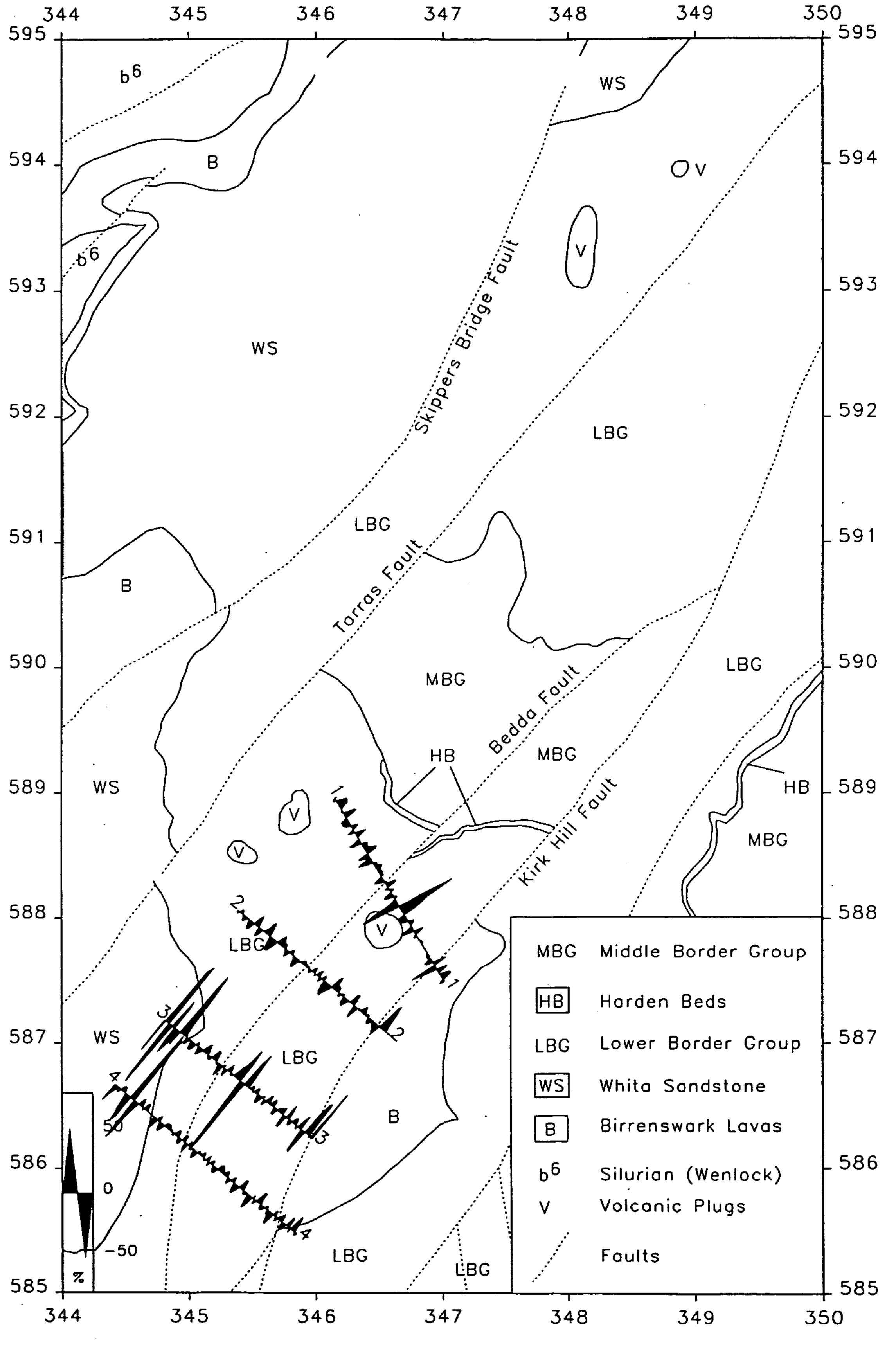

Figure 20 Fraser Filtered VLF electromagnetic (magnetic field) profiles, Kirk Hill. VLF frequency 24.0 kHz. Filtered from in-phase component.

The total field magnetic data are shown in Figure 16. Traverses 1-3 provide clear evidence of a magnetic marker which follows the trace of the Kirk Hill Fault where Lower Border Group lithologies are brought into contact with the exposed Birrenswark Lavas. The shape and form of this magnetic signature is suggestive of a normally magnetised dyke intruded along the faulted contact. Data spikes observed along traverse 4 owe their origin to man-made structures.

A partially defined anomaly mapped along traverse 2 is most probably associated with the presence of a volcanic plug identified in the vicinity.

There are no magnetic features coincident with the Bedda Fault.

VLF data

The VLF in-phase data are shown in Figures 17 and 18. Figures 19 and 20 show the Fraser Filter operator applied to the in-phase VLF data. No coherent structure can be recognised from the VLF responses, which clearly fail to delineate the traces of the Bedda and Kirk Hill faults. An absence of suitable bulk electrical conductivity contrasts seems to be the most likely explanation for this. Variations in the VLF responses, generally low amplitude, probably reflect minor and localised near surface conductivity variations within the Lower Border Group lithologies.

DISCUSSION AND ASSESSMENT

Follow-up investigations guided by the presence of a coherent, broad north-east trending zone of geochemical drainage anomalies, have identified several new in-situ occurrences of base-metal and baryte mineralisation in Lower Border Group sedimentary rocks. It is evident from the distribution of these mainly fracture-bound occurrences, which all lie along an approximately 9 km long, strike-parallel zone at the northern margin of the Northumberland Trough, that they are most likely to reflect fluid movement through or along tensional fractures. The most prospective ground appears to be in the area bounded by the Kirk Hill and Tarras faults, where the exposed rocks are higher in the Lower Border Group succession than the most strongly mineralised rocks to the west of Langholm, which directly overlie the Birrenswark lavas.

Not all of the geochemical anomalies, in particular some of those in the Black Grain - Green Burn catchment, could be traced to outcropping mineralisation and further sources undoubtedly exist beneath the drift. Deep overburden sampling in this catchment confirmed the significance of the major north-east trending faults by identifying substantial base-metal enrichments in a well defined zone close to the surface trace of the Bedda Fault. As the most promising till anomalies occur along the southernmost traverse (traverse 4), and because of the presence of major drainage anomalies in Stanygill Burn, it is possible that further undiscovered mineralised sources exist beneath deep drift in the interfluve area to the south.

Ba shows only a weak association with base-metals, major anomalies being most prominently developed over the Lower Border Group adjacent to the faulted lava-sediment contact along the west side of Kirk Hill. The Kirk Hill Fault also exerts influence on base-metal mineralisation since less than 100 m south of its intersection with traverse 4, an outcrop of vertically dipping limestone, lying in the plane of the fault, contains extensive carbonate-sphalerite-galena veining. Further evidence for the direct control of major faults on the distribution of mineralisation is provided by the discovery of similar occurrences of epigenetic lead-zinc mineralisation in Thief Sike and Hartsgarth Burn close to the Tarras Fault. In all of these cases and in numerous other outcrops and float boulders found in stream sections between the Tarras and Kirk Hill faults, thin carbonate-sulphide veins in ochreous-weathering limestones and cementstones provide the principal source of metals.

The only notable exception to this pattern of weak fracture-controlled mineralisation is the presence of disseminated fine-grained sphalerite-pyrite in an outcrop of the Harden Beds in Black Burn, containing >0.5% Zn. Although apparently confined to a relatively thin (30 - 40 cm) heavily fractured sandstone horizon and not associated with Pb or Cu, this style of mineralisation, in which the sulphides occur within the diagenetic (carbonate) cement, has not been encountered elsewhere in the district. The stratigraphic position of the mineralised bed, at the top of the Lower Border Group succession may be significant in that it coincides with a change from deltaic/lagoonal to deeper water conditions indicated by the presence of an abundant marine fauna in the Harden Beds. Due to poor exposure, attempts to trace the stratabound mineralisation in the immediate vicinity were unsuccessful and an examination of the Harden Beds in the Liddel Valley just north of Newcastleton indicated that the mineralised sandstone unit may only be locally developed.

Lower Border Group rocks in the area of the investigation are characterised by relatively thin carbonate units, generally <2 m in thickness, collectively accounting for less than 10% by volume of the total succession. If surface outcrop is representative of the deeper succession then the possibility of a large replacement, Irish-style, deposit forming in this dominantly arenaceous sequence is unlikely. However, the geochemical anomalies and mineralised rocks may be the distal expression of deeper-seated, posiibly breccia infill or stratabound mineralisation, concealed by a barren sedimentary cover sequence. This possibility should not be disregarded since several of the major sediment-hosted deposits of central and southern Ireland have comparable surface geochemical expression and associated minor, fracture-controlled Pb-Zn shows (Hitzman, et al., 1992). Scout drilling would be required to test this possibiblity.

CONCLUSIONS AND RECOMMENDATIONS

1) The results of the panned concentrate drainage surveys define an area between the Tarras and Kirk Hill faults containing large base-metal and barium anomalies. This work and subsequent follow-up investigations indicate that the principal Zn and Pb anomalies, are attributable to sphalerite-galena-pyrite-carbonate mineralisation in veinlets and narrow breccia zones hosted by thin limestones and cementstones and situated adjacent to major north-easterly trending basin-margin faults. Copper anomalies, which are restricted to the southern part of the area, are caused by the presence of cupriferous pyrite and copper minerals in the panned concentrates. Although no outcropping Cu-mineralisation was discovered, the proximity of the drainage anomalies to the faulted margin of the Birrenswark lavas invites comparison with the geological setting and genesis of Cu-mineralisation in the area west of Langholm. Barium is only weakly enriched in those samples containing the highest base-metal values, but shows very marked concentration in streams crossing the faulted lava-sediment contacts.

2) A deep overburden survey in the Black Grain - Green Burn catchment identified a prominent zone of coincident Zn - Pb and minor Cu and Ba anomalies in panned till samples collected over the inferred surface trace of the Bedda Fault and extending across strike for at least 300 m. A southward extension of this anomalous zone may exist in the unexplored ground to the south of traverse 4. Other, scattered anomalies, chiefly of Pb_{tt} on traverse 2, indicate a possible source of the drainage-Pb anomaly in the poorly exposed ground near the head of Green Burn. Major Ba_{tt} anomalies were traced

to an area where numerous baryte clasts suggest the presence of vein-style baryte mineralisation associated with the Kirk Hill Fault.

3) Magnetic surveys conducted in the area of the overburden sampling clearly identify the Kirk Hill Fault as a major structure extending over the minimum 2.5 km of explored strike between traverses 1 and 4. Magnetic and VLF measurements failed to detect the Bedda Fault, probably because of poor electrical conductivity contrasts between different sedimentary units within the Lower Border Group succession.

4) Evidence of disseminated syndiagenetic sphalerite-pyrite mineralisation was discovered in a carbonate-cemented sandstone unit in the Harden Beds near the top of the Lower Border Group succession in Black Burn. No galena or other ore minerals were seen and the outcrop could not be traced outside of the stream section due to the thickness and extent of the drift. However, this represents the first discovery in the area of an economically more important style of mineralisation, and deep overburden work and diamond drilling is therefore merited to test the possible continuity and thickening of the mineralised sandstone unit along strike.

5) Considering the relatively small area of this investigation, and the thick and continuous glacial deposits obscure all, but a small proportion of the bedrock, a surprisingly large number of new mineral occurrences have been discovered. Although the overall distribution and magnitude of geochemical anomalies, and the low grade of the observed mineralisation are consistent with the presence of numerous small epigenetic occurrences scattered along the 9 km strike of the project area, the possibility that these reflect the distal expression of more substantial stratabound or breccia infill mineralisation cannot be discounted. To establish possible extensions of mineralisation down dip in the most favourable, but poorly exposed ground south-east of the Bedda Fault, further deep overburden sampling and/or diamond drilling are recommended on targets defined by structural analysis and geophysical survey.

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Table 2A Newcastleton Surface Rock Descriptions

SAMPLE REF. NO.	EASTING	NORTHING	LOCALITY	COMMENTS
BFR2939	350150	594890	TOFTSHOLM SIKE 600M UPSTM. OF FM.~20M ABOVE WALL	DARK LMSTN. BLDRS. THIN CA VNLTS & JNTS WITH BLACK XSTALS ?ZNS.
BFR2941	349990	594990	TOFTSHOLM SIKE, E.OF RAEGILL BOGS, 700M UPSTM. OF FM.	DARK LMSTN. BLDR. CA-JOINT COATING+THIN SMEAR OF FES.
BFR4840	346290	589220	HOG GILL~80M UPSTM. OF CONFLU. WITH BLACKBURN	FLOAT BLDR. CALC. VNLTS+ORGANICS, PBS-ZNS-FES ON JOINT(SEE ALSO BFP4839,4841).
BFR4845	346290	589320	HOG GILL~250M UPSTM. OF CONFL. WITH BLACK BURN	MICRITE BLDR. MANY CA-BA VNLTS. CRSE PB + FES IN CALC. VNLT, ZNS? IN CALC. VUG
BFR4846	346240	589380	HOG GILL~100M DWNSTM. OF CONFL.WITH NE TRIB	SLUMPED MICRITE BLOCK (SMALL FAULT) LGE CA-FILLED VUGS WITH FES/CUS? HALO.
BFR4847	346240	589380	HOG GILL~100M DWNSTM. OF CONFL.WITH NE TRIB.	SLUMPED LMST BLOCK AT FAULT, CALC-FES-ZNS VNLTS. & CAVITY FILLINGS.
BFR4947	345090	590400	LONG GILL 5M UPSTM. FROM UNNAMED W.BANK TRIB.	VEINED LAVA. OR-BRN (LIMONITE/SIDERITE) VNS CROSS CUTTING QTZ/CALC. VEINS
BFR4948	345020	589340	ROUGH GILL APPROX 600M ABOVE LONG GILL CONFL.	CALCAREOUS SLTSTN. LGE. GREEN GRAINS (?LAVA CLSTS), A FEW CALC. CAVITIES.
BFR5234	345280	586310	BLACK GRAIN~250M DWNSTM. POWERLINE	CEMENTST. WITH CA-FES. JOINTS+ SPAR FILLED CAVITIES
BFR5235	345260	586560	BLACK GRAIN~70M DWNSTM. OF POWERLINE	MICRITE+ANASTOM. CA-VNLTS. BA IN LARGER VNS. ABUND. RADIAT. FES+?ZNS
BFR5434	345210	585800	DOW SIKE 300M UPSTM. STANYGILL BURN	V DARK MICRITE,WITH FINE VNS CA.+RADIAT. PATCHES FES. POSS. B'ROCK NEARBY
BFR5435	345210	585800	DOW SIKE 300M UPSTM. STANYGILL BURN	BROWN MICRITE, EXTENSIV. CA-FES VND. SOME BRECCIATION
BFR5436	345370	585160	STANYGILL BURN 300M UPSTM. CONFL. WITH TINNIS BURN	DK. GREY MICRITE, CA- VNG. 2 SMALL PATCHES/NODULES PBS
BFR5437	345270	585810	DOW SIKE 300M UPSTM. STANYGILL BURN	BANDED FISSILE ROCK WITH THIN COALS. ?SYNGENETIC FES // TO BEDDING
BFR5923	349200	593420	THIEF SIKE APPROX 600M DWNSTM. OF VENT AGGLOM.	DARK CARBONATE-VND. LMSTN WITH BLACK ZNS IN VEINS
BFR5924	345300	586290	BLACK GRAIN- 80M UPSTM. OF THACKIE SIKE JN.	FES IN FAULTED CALC. SLTSTN/SSTN. CA-BA VNS.
BFR5928	345500	585820	BLACK GRAIN APPROX 70M UPSTM. JN. WITH GREEN BURN	FAULT ZONE? MICACEOUS SST WITH FES VNS.
BFR6003	345300	586260	BLACK GRAIN 50M UPSTM.THACKIE SIKE JN.	CALCITE IN ANASTOMISING FRACT. TRENDING 332, DIP VERT.
BFR6004	345430	586000	BLACK GRAIN 260M UPSTM. CONFL. WITH GREEN BURN	INTENSELY CARB. VND. MICRITE, ?FAULT TRENDING 126 DEG.
BFR6005	345470	585890	BLACK GRAIN 140M UPSTM. CONFL. WITH GREEN BURN	STREAM CLAST, SHEARED VUGGY SST WITH STRONG LIMONITIC STAINING.
BFR6006	345400	586100	BLACK GRAIN 400M UPSTM. CONFL. WITH GREEN BURN	STREAM CLAST INTENSELY CARB. VEINED ?PINK BARYTES
BFR6008	345000	587260	BLACK GRAIN 90M UPSTM. OF ROAD	TWO STREAM CLAST SAMPLES
BFR6016	346270	589350	HOG GILL, 250M UPSTM. BLACK BURN	SHALE CONTAINING BOTRYOIDAL FE-RICH ?DIAGENETIC CONCRETIONS
BFR6017	346270	589350	HOG GILL, 250M UPSTM. BLACK BURN	MICRITE 10CM FROM FAULT, THIN CARB. VEINS WITH MINOR SPHALERITE?
BFR6018	346270	589350	HOG GILL, 250M UPSTM. BLACK BURN	FAULT GOUGE FROM FAULT(TRENDING 320 DEG.) ADJ. TO BFR6017
BFR6019	346270	589350	HOG GILL, 250M UPSTM. BLACK BURN	STM CLAST, GALENA+ ?SPHAL ON JNT/BED SURFACE
BFR6020	346230	589400	HOG GILL, 200M DWNSTM. E BANK TRIB.	NUMEROUS CAL. VEINS WITH TRACE PYRITE IN MICRITE
BFR6021	346270	589350	HOG GILL 250M UPSTM. BLACK BURN	STREAM CLAST. CAL. VEIN WITH 1 GRAIN SPHALERITE
BFR6022	346250	589380	HOG GILL 300M UPSTM. BLACK BURN	STREAM CLAST WITH CAL. VEINS AND PATCHES

Table 2A continued

SAMPLE REF NO.	EASTING	NORTHING	LOCALITY	COMMENTS
BFR6023	346660	589130	BLACK BURN OPPOSITE JN. OF ROWANTREE SIKE	SYNGENETIC PYRITE / MARCASITE REPLACING ORGANIC FRAGMENTS (HARDEN BEDS).
BFR6037	349210	592480	HARTSGARTH BURN 200M UPSTM. TRACK TO FARM	IN SITU. CAL. IN FRACTURES WITH IRREGULAR PYRITE BLEBS.
BFR6038	348750	592340	HARTSGARTH BURN AT JN. WITH 2ND TRIB UPSTM. OF FM.	CALCITE VEIN, 3-10CM THICK, >5M LONG IN O'CROP, NO VISIBLE SULPHIDES
BFR6048	345600	589120	BLACK BURN 100M DWNSTM. CONFL. WITH ROUGH GILL	SULPHIDE? IN CAL. VEINS. 2 SAMPLES- HYDROCARBON & TRACE ELEMENT
BFR6051	345370	586150	BLACK GRAIN 420M UPSTM. CONFL. WITH GREEN BURN	STREAM CLAST, LIGHT BROWN OXIDATN. SURFACE, 1CM WIDE CAL. VNS., ?SULPHIDES
BFR6055	346100	589600	HOG GILL 500M UPSTM. BLACK BURN	SELECTION OF CEMENTSTONE CLASTS FROM 400M OF STREAM SECTION
BFR6056	345900	589730	HOG GILL 420M UPSTM. OF JN. WITH E TRIB.	HIGHLY LIMONITIC SOFT COARSE GRAINED SST
BFR6066	344740	588780	GOAT LINN 180M DWNSTM. CONFL. DRAINING YADE FLOW	2 SAMPLES, 1 HYDROCARBON, 1 TRACE ELEMENT WITH ? PYRITE
BFR6103	345360	586150	BLACK GRAIN 300M UPSTM. CONFL. GREEN BURN	BLACK SHALE INTERBEDDED WITH MICRITE
BFR6104	345420	586030	BLACK GRAIN 250M UPSTM. CONFL. WITH GREEN BURN	FLOAT SAMPLE CAL. VEINS AND RADIAL SPHEROIDS OF PYRITE
BFR6105	345420	585960	BLACK GRAIN 200M UPSTM. CONFL. WITH GREEN BURN	ABUNDANT VEINS IN O'CROP, IRREGULAR BLEBS OF SULPHIDE
BFR6111	345020	587210	BLACK GRAIN 90M UPSTM. C ROAD	STREAM CLAST, GREY MICRITE WITH NETWORK OF VEINLETS
BFR6138	349320	593240	THIEF SIKE 600M DWNSTM. CONFL. WITH BLACK SIKE	FOSSILIFEROUS MICRITE STREAM CLAST MM SCALE VEINING
BFR6139	349250	593370	THIEF SIKE 500M DWNSTM. CONFL. WITH BLACK SIKE	STREAM CLAST:THIN COATING GALENA ON SURFACE.
BFR6140	349200	593450	THIEF SIKE 450M DWNSTM. CONFL. WITH BLACK SIKE	ALGAL LIMESTONE STREAM BOULDER. SLICKENSIDED, CRSE. SPHALERITE
BFR6141	349190	593470	THIEF SIKE, 740 M DWNSTM. OF JN. WITH BLACK SIKE.	STREAM CLAST
BFR6142	349130	593542	THIEF SIKE 400M BELOW CONFL. WITH BLACK SIKE	STREAM CLAST
BFR6143	349130	593542	THIEF SIKE 600M BELOW JN. WITH BLACK SIKE	INTENSELY VEINED CEMENTSTONE O'CROP, INTERBEDDED SHALES
BFR6152	346660	589130	BLACK BURN, 160M DWNSTM. HOG GILL JUNC, N BANK	HARDEN BEDS CHANNEL SAMPLE, TOP 0-40CM
BFR6153	346660	589130	BLACK BURN, 160M DWNSTM. HOG GILL JUNC, N BANK	HARDEN BEDS, 40-80 CM FROM TOP OF O'CROP
BFR6154	346660	589130	BLACKBURN, 160M DWNSTM. HOG GILL JN., N BANK	HARDEN BEDS, 80-110 CM FROM TOP OF O'CROP
BFR6155	346660	589130	BLACKBURN, 160M DWNSTM. HOG GILL JN., N BANK	HARDEN BEDS, 110-150 CM FROM TOP OF O'CROP
BFR6156	346660	589130	BLACKBURN, 160M DWNSTM. HOG GILL JN., N BANK	HARDEN BEDS, 150-190 CM FROM TOP OF O'CROP
BFR6157	346660	589130	BLACKBURN, 160M DWNSTM. HOG GILL JN., N BANK	HARDEN BEDS, 190-230 CM FROM TOP OF O'CROP
BFR6158	346660	589130	BLACKBURN, 160M DWNSTM. HOG GILL JN., N BANK	HARDEN BEDS, HARD, ORG.-RICH, FRACTURED SST 230-240 CM FROM TOP OF O'CROP
BFR6159	346660	589130	BLACKBURN, 160M DWNSTM. HOG GILL JN., N BANK	HARDEN BEDS, DARK CARBONACEOUS, 240-280 CM FROM TOP OF O'CROP
BFR6162	349224	588770	SMALL GULLEY, 700M NE WHITHAUGH	0.1 M OCHREOUS ?CARB. HORIZ. WITH ORANGE CLAY IN ?HARDEN BEDS
BFR6163	349224	588770	SMALL GULLEY, 700 M NE WHITHAUGH	O.5 M THICK SANDY MICRITE ABOVE OCHREOUS HORIZON OF BFR 6162

Table 2A continued

SAMPLE REF NO.	EASTING	NORTHING	LOCALITY	COMMENTS
BFR6164	349280	588780	WEST FLWNG. STM. APPROX. 800M NE OF WHITHAUGH	DARK VND. MICRITE STM BOULDER WITH LIMONITIC JNTS AND SPARRY CAL.
BFR6167	345820	586550	E BANK GREEN BURN 100M DWNSTM. OF S EDGE SHEEPF'LD	SANDY MICRITE WITH CRS BLADED BARYTE ON TWO ORTHOG. VERT. JNTS
BFR6168	345820	586550	E BANK GREEN BURN 100M DWNSTM. OF S EDGE SHEEPF'LD	SANDY MICRITE WITH COARSE BARYTE AS IN BFR 6167
BFR6169	345742	586260	GREEN BURN APPROX 80M DWNSTM. OF FENCE	OCHREOUS WTHD. LMSTN. 4M WIDE, VERT. DIP, STRIKE N-S ABUN. CAL VNG.
BFR6170	345742	586260	GREEN BURN APPROX. 80M DWNSTM. OF FENCE	MICROCRYSTLLN. LMSTN. OCHR. WEATHERED, SEVERAL PHASES OF CAL. VNG.
BFR7037	346610	589110	BLACK BURN 50M UPSTM. CONFL. WITH ROWANTREE SIKE	V. HARD DENSE DOLOMIT. LMSTN, THIN CALCITE/SIDERITE/ ?SPHALERITE VNS
BFR7038	345880	589030	LONG GILL 75M UPSTM. GOAT LINN (W'FALL)	STREAM FLOAT
BFR7039	349260	593320	80M S OF S END OF ENCLOSURE, W SIDE OF THIEF SIKE	CALCITE VNLTS WITH ZNS AND PBS XSTALS AND ZNS COATINGS, FLOAT SAMP.
BFR7043	346580	589125	BLACK BURN 10M DWNSTM. OF S BNK TRIB. AT W'FALL	STREAM FLOAT
BFR7044	346415	589110	BLACK BURN 100M DWNSTM. OF JN. WITH S BANK TRIB.	BEDROCK LIMESTONE IN A 20CM THICK BED
BFR7047	349200	593460	THIEF SIKE 100M N OF N SIDE OF ENCLOSURE (SEE BFR 7047)	HEAVILY VND. CEMENSTN. WITH COARSE GALENA XSTALS.
BFR7048	349130	593542	THIEF SIKE 150M N OF END OF OVAL ENCLOSURE	INTENSELY VEINED CEMENTSTONE BRECCIA WITH CSE ZNS
BFR7053	346780	589110	BLACK BURN 125M DWNSTM. CONFL. ROWANTREE SIKE	PALE PINK AND WHITE SUGARY CALCITE IN VUGS AND VEINLETS
BFR7070	345520	585760	CONFL. OF BLACK GRAIN AND GREEN BURN	PYRITE AND SPHALERITE IN AND ON MARGINS OF CALCITE VEIN
BFR7072	345500	585720	STANYGILL BURN AT CONFL. WITH DOW SIKE	DK BRWN/BLCK ORG.? RICH XSTALLINE MINERAL IN CALCITE VEIN. STRM FLOAT
BFR7073	345500	585730	DOW SIKE 15M UPSTM. CONFL. WITH STANYGILL BURN	SPHALERITE IN CALC VEIN. O'CRP 1M X 1.5M. STRIKE 010 DEG DIP 85 DEG W
BFR7074	345340	585800	DOW SIKE 175M UPSTM. CONFL. WITH STANYGILL BURN	FLOAT BLDR. THIN CALC VN + SPHAL. VND LMST O'CRP 15M DWNSTM/30M UPST
BFR7075	345480	585840	THAKIE SIKE 75M UPSTM. CONFL. WITH GREEN BURN	O'CROP WITH CALC/PYRITE/MARCASITE VNS. POSS SILVERY GREY GALENA (DISSEM)
BFR7076	346665	589130	N BANK OF BLACK BURN 10M E OF MOULY SIKE	THIN (5CM) BAND OF V. BROKEN OCHREOUS MUDDY SILTSTONE IN HARDEN BEDS.
BFR7077	346575	589120	BLACKBURN APPROX 65M UPSTM. OF MOULY SIKE	SMALL ROUNDED AGG. PATCHES OF ?CU-FES DISSEM. IN CMNTST. FLOAT BLDR
BFR7078	346660	589135	BLACKBURN 40M DWNSTM. MAIN HARDEN BEDS O'CROP.	FLOAT BLDR, HARD CSE SSTN, DOLOMIT. WTHNG. (CF. MAIN ZNS IN HARDEN BEDS)
BFR 7101	345743	586260	E BANK GREENBURN 80M DWNSTM. 4 WALL INTERSECT.	45 CM THICK BED BETWEEN NEAR VERT. BEDDED DOLOMTSD. LST WITH PBS & ZNS
BFR 7102	346135	586330	KIRK HILL, SMALL QUARRY ON W SIDE OF THE SUMMIT.	DENSE, NON-VESIC. ALTERED PYRXS, FAINTLY PINK FELDSPARS
BFR 7103	347110	591555	RIGGING SIKE, 500M UPSTM. RALTON BURN. NE OF CAIRN	DIRECTLY OVERLYING A THIN ORANGE SST UNIT
BFR 7104	345495	585740	DOW SIKE. 15M ABOVE ITS CONFL. WITH STANYGILL BRN.	ALTERED SST AND EXTENSIVELY VND WITH CALCITE
BFR 7105	345495	585740	DOW SIKE. 15M ABOVE CONFL. WITH STANYGILL BURN	SST BRECCIA - FRAGMENTS OF SST AND SHALE. FINE, CALCITE VNG.
BFR 7106	345510	585665	STANYGILL BURN 25M DWNSTM. DOW SIKE JN.	CMNTSTN. WITH QTZ AND CALCITE VNING AND SMALL XSTALS OF GALENA

Table 2B Newcastleton Surface Rock Data

SAMPLE REF. NO.	EASTING	NORTHING	ROCK TYPE	STYLE	MINERALS	Cu (ppm)	Pb (ppm)	Zn (ppm)	Ba (ppm)	Ni (ppm)	Sb (ppm)	Sn (ppm)	Fe (ppm)	As (ppm)
BFR2939	350150	594930	LIMESTONE	VEIN/JOINT	CA, ZN	12	32	213	58	7	<1	<1	33430	ND
BFR2941	349970	595040	LIMESTONE	JOINT	FE	5	8	60	158	7	<1	0	26430	ND
BFR4840	346290	589220	SILTSTONE	VEIN	CA, PB, ZN, FE	2	1149	1444	95	8	48	<1	30260	ND
BFR4845	346290	589320	LIMESTONE	VEIN	CA, BA, PB, FE, ?ZN	1	336	1714	127874	24	19	<1	19320	ND
BFR4846	346240	589380	LIMESTONE	CAVITY	CA, FE, CU	3	1105	727	205	5	<1	0	24540	ND
BFR4847	346240	589380	LIMESTONE	VEIN/CAVITY	CA, ZN, FE	1	255	5577	653	24	<1	<1	36320	ND
BFR4947	345090	590400	BASALT	VEIN	CA, LIMONITE	21	10	92	507	118	<1	<1	76770	ND
BFR4948	345020	589340	SILTSTONE	CAVITY	CA	2	1	42	66	9	0	<1	32560	ND
BFR5234	345280	586310	CEMENTSTONE	JOINT/CAVITY	CA, FE	3	30	20	143	20	1	3	38030	ND
BFR5235	345260	586560	LIMESTONE	JOINT/FRACTURE	CA, ?ZN, FE	1	121	2780	382	20	<1	<1	77510	ND
BFR5434	345210	585800	LIMESTONE	VEIN	CA, FE	2	27	23	32	8	<1	<1	43000	ND
BFR5435	345210	585800	LIMESTONE	VEIN	CA, FE	1	48	149	137	17	<1	<1	77200	ND
BFR5436	345370	585160	LIMESTONE	VEIN	CA, PB	4	42	102	80	6	<1	3	41670	ND
BFR5437	345270	585810	SANDSTONE	STRATABOUND	FE	14	109	290	219	55	<1	<1	86670	ND
BFR5923	349200	593420	LIMESTONE	VEIN	CA, ZN	6	29	1319	149	3	0	3	19700	ND
BFR5924	345300	586290	SANDSTONE	VEIN	CA, BA	10	14	214	806	16	4	0	62530	ND
BFR5928	345500	585820	SANDSTONE	VEIN	FE	5	14	29	1429	14	5	2	41020	ND
BFR6003	345300	586250	LIMESTONE	VEIN	FE, CA, BA	19	67	40	12080	76	1	2	91761	ND
BFR6004	345430	586000	LIMESTONE	VEIN	CA, FE-DOLOMITE	9	28	12	67	13	1	0	51895	ND
BFR6005	345470	585890	SANDSTONE	?DISSEMINATED	LIMONITE	7	0	14	271	20	2	0	46230	ND
BFR6006	345400	586100	LIMESTONE	VEIN	FE, CA	14	39	19	3283	36	0	1	70779	ND
BFR6008	345000	587260	SANDSTONE	VEIN	CA	5	1	7	204	8	1	0	20353	ND
BFR6016	346270	589350	SHALE			21	1	13	235	17	0	0	26647	ND
BFR6017	346270	589350	LIMESTONE	VEIN	ZN, CA	9	22	191	163	15	2	0	19024	ND
BFR6018	346270	589350	CLAY GOUGE	FAULT		18	15	53	344	24	2	1	20772	ND
BFR6019	346270	589350	LIMESTONE	JOINT/FRACTURE	PB, ZN	7	320	82	34	7	1	0	25598	ND
BFR6020	346230	589400	LIMESTONE	VEIN	CA, FE	10	24	75	172	11	1	1	26297	ND
BFR6021	346270	589350	LIMESTONE	VEIN	ZN, CA	8	179	142	135	8	1	1	26437	ND
BFR6022	346250	589380	LIMESTONE	VEIN/LENS	FE, CA	7	67	2351	186	15	1	0	22381	ND

Table 2B continued

SAMPLE REF NO.	EASTING	NORTHING	ROCK TYPE	STYLE	MINERALS	Cu (ppm)	Pb (ppm)	Zn (ppm)	Ba (ppm)	Ni (ppm)	Sb (ppm)	Sn (ppm)	Fe (ppm)	As (ppm)
BFR6023	BFR6023	346660	589130	DISSEMINATED	FE, ZN	37	156	>4500	138	41	2	1	25528	ND
BFR6037	BFR6037	349210	592480	JOINT/FRACTURE	FE, CA	10	26	540	2713	9	1	0	25108	ND
BFR6038	BFR6038	348750	592340	VEIN	CA	16	2	8	2031	2	0	0	4406	ND
BFR6048	BFR6048	345600	589120	VEIN	ZN, PB	8	75	339	41	5	1	0	13079	ND
BFR6051	BFR6051	345370	586150	VEIN	PB, ZN, CA	15	>11200	>4500	44	11	0	0	23500	ND
BFR6055	BFR6055	346100	589600	VEIN	ZN, CA	32	17	76	334	17	1	0	29375	ND
BFR6056	BFR6056	345900	589730		LIMONITE	6	5	21	393	11	2	0	25668	ND
BFR6066	BFR6066	344740	588780	VEIN	CA	5	5	7	288	5	2	0	20982	ND
BFR6103	BFR6103	345360	586150			31	66	60	356	60	1	2	31193	ND
BFR6104	BFR6104	345420	586030	VEIN	FE, ZN, CA	12	17	178	331	21	1	0	37208	ND
BFR6105	BFR6105	345420	585960	VEIN	CU, FE, QUARTZ	13	29	25	1519	19	1	1	92181	ND
BFR6111	BFR6111	345020	587210	VEIN	BA	8	12	10	1932	9	2	0	23290	ND
BFR6138	BFR6138	349320	593240	VEIN	ZN, CA	7	13	532	144	10	1	0	21751	ND
BFR6139	BFR6139	349250	593370	VEIN	PB, CA	9	89	114	86	9	1	0	21821	ND
BFR6140	BFR6140	349200	593450	VEIN	ZN, CA	6	40	499	1071	6	2	0	18324	ND
BFR6141	BFR6141	349190	593470	VEIN	CA	6	40	499	1071	6	2	0	18324	ND
BFR6142	BFR6142	349140	593550	VEIN	PB, ZN, CA	11	502	340	104	8	0	0	21332	ND
BFR6143	BFR6143	349140	593550	VEIN	PB, CA	11	336	557	99	11	1	0	24479	ND
BFR6152	BFR6152	346660	589130			6	178	125	121	8	2	0	16646	ND
BFR6153	BFR6153	346660	589130			31	53	157	345	53	3	4	43573	ND
BFR6154	BFR6154	346660	589130			34	110	93	383	56	2	3	55672	ND
BFR6155	BFR6155	346660	589130			14	186	152	234	17	0	1	30214	ND
BFR6156	BFR6156	346660	589130			31	133	398	319	45	2	5	41195	ND
BFR6157	BFR6157	346660	589130			22	43	559	460	44	4	0	40355	ND
BFR6158	BFR6158	346660	589130	DISSEMINATED		27	81	5412	193	22	2	0	11540	ND
BFR6159	BFR6159	346660	589130			24	55	221	274	39	1	0	33082	ND
BFR6162	BFR6162	349224	588770			17	7	15	176	10	3	0	32802	ND
BFR6163	BFR6163	349224	588770			8	12	89	585	10	0	0	14827	ND
BFR6164	BFR6164	349280	588780	VEIN	LIMONITE	9	15	9	32	7	7	0	19164	ND

Table 2B continued

SAMPLE REF NO.	EASTING	NORTHING	ROCK TYPE	STYLE	MINERALS	Cu (ppm)	Pb (ppm)	Zn (ppm)	Ba (ppm)	Ni (ppm)	Sb (ppm)	Sn (ppm)	Fe (ppm)	As (ppm)
BFR6167	345820	586550	LIMESTONE	JOINT/FRACTURE	BA	6	12	8	3304	7	1	0	13708	ND
BFR6168	345820	586550	LIMESTONE	JOINT/FRACTURE	BA	6	11	6	2912	7	1	0	13638	ND
BFR6169	345742	586260	LIMESTONE	VEIN	PB, CA	8	1618	1203	216	8	0	0	25388	ND
BFR6170	345742	586260	LIMESTONE	VEIN	ZN, CA	10	14	5681	257	7	0	0	39236	ND
BFR7037	346610	589110	LIMESTONE	VEIN	CA, SIDERITE, ?ZN	7	79	31	107	11	<1	ND	32084	8
BFR7038	345880	589030	LIMESTONE	VEIN	CA, ?BA	5	35	34	82	8	<1	ND	22508	1
BFR7039	349260	593320	CEMENTSTONE	VEIN	ZN, PB	5	38	314	131	7	3	ND	18314	3
BFR7043	346580	589125	LIMESTONE	FAULT	PB	4	129	133	38	8	<1	ND	24745	5
BFR7044	346415	589110	LIMESTONE	VEIN	BA, FE, CA	6	246	66	164	16	<1	ND	21320	0
BFR7047	349200	593460	CEMENTSTONE	VEIN	PB	5	1341	860	81	6	0	ND	15728	-2
BFR7048	349130	593542	CEMENTSTONE	VEIN	ZN	6	104	1469	331	7	<1	ND	17755	2
BFR7053	346780	589110	LIMESTONE	VEIN/POD	CA	5	12	86	83	7	2	ND	19852	2
BFR7070	345520	585760	LIMESTONE	VEIN	FE, ZN, CA	6	40	438	79	18	<1	ND	34531	1
BFR7072	345500	585720	LIMESTONE	VEIN/POD	CA	3	44	34	904	16	6	ND	14679	0
BFR7073	345500	585730	LIMESTONE	VEIN	CA, ZN	4	20	799	569	9	<1	ND	12652	1
BFR7074	345340	585800	LIMESTONE	VEIN	ZN	6	20	82	271	12	<1	ND	41101	1
BFR7075	345480	585840	LIMESTONE	VEIN/DISSEM.	FE, ?PB	8	83	799	21	23	<1	ND	58017	0
BFR7076	346665	589130	MUDSTONE	VEIN	ZN	29	144	477	464	33	<1	ND	87165	6
BFR7077	346575	589120	CEMENTSTONE	DISSEMINATED	FE	1	51	112	88	4	<1	ND	16077	6
BFR7078	346660	589135	CONGLOM.	DISSEMINATED	ZN	5	18	74	127	11	<1	ND	21809	3
BFR 7101	345743	586260	SHALE			20	112	50	517	12	<5	ND	25185	17
BFR 7102	346135	586330	BASALT			10	17	297	451	63	<5	ND	77625	11
BFR 7103	347110	591555	MICRITE			4	7	4	632	4	<5	ND	13110	<5
BFR 7104	345495	585740	SANDSTONE	VEIN	CA	9	32	138	107	30	<5	ND	37329	7
BFR 7105	345495	585740	SANDSTONE	VEIN	CA	7	22	95	147	16	<5	ND	20631	<5
BFR 7106	345510	585665	CEMENTSTONE	VEIN	CA, BA, PB	6	20	14	2860	7	<5	ND	31878	<5

CA = Calcite; FE = Pyrite; PB = Galena;
ZN = Sphalerite; CU = Chalcopyrite; BA = Baryte

Table 3 Newcastleton Panned Concentrate Data (Reconnaissance Survey, 1976)

Sample Ref. No.	Easting	Northing	Cu (ppm)	Pb (ppm)	Zn (ppm)	Ba (ppm)	Ni (ppm)	Sb (ppm)	Sn (ppm)	Fe (ppm)	Mn (ppm)
BFP2230	345160	590680	4	1	0	108	1	0	3	6900	<100
BFP2231	345080	590500	0	1	0	102	2	2	0	11000	<100
BFP2232	346000	589680	0	108	74	122	9	0	3	36000	<100
BFP2254	345090	590210	8	15	11	78	14	0	0	62800	<100
BFP2255	346290	589210	1	549	1268	388	32	0	0	83100	300
BFP2256	344670	589560	0	19	50	374	40	0	0	101800	200
BFP2257	344410	589980	10	13	31	578	32	0	4	68700	400
BFP2258	345550	589170	3	4	5	486	5	0	1	20100	<100
BFP2259	345620	589160	1	4	10	178	7	0	0	24500	<100
BFP2272	347840	587790	1	4	11	115	8	0	0	23500	<100
BFP2316	344480	593450	15	22	117	3766	42	0	3	170900	800
BFP2317	344100	593130	13	0	18	635	12	2	6	69700	200
BFP2320	344500	592280	0	29	42	327	38	4	9	106600	700
BFP2436	344730	587030	0	13	34	867	15	0	0	28100	200
BFP2437	345020	587250	2	9	42	1062	6	0	0	10700	<100
BFP2477	344160	585540	14	21	29	8312	10	2	1	20200	<100
BFP2478	344160	585400	11	15	16	105	5	3	4	6700	<100
BFP2479	344450	585300	3	16	37	565	5	1	3	10100	<100
BFP2480	344270	585060	3	5	110	169	7	0	2	17200	<100
BFP2484	345820	586520	0	19	317	5182	19	0	1	46400	<100
BFP2485	345470	586100	0	4	33	217	3	1	5	9300	<100
BFP2486	345502	585800	103	119	1485	1337	38	2	0	91500	300
BFP2487	345560	585820	0	98	402	1637	17	0	4	53600	200
BFP2504	345230	586490	7	137	2011	4148	14	6	2	30000	200
BFP2507	345250	586680	48	56	302	8077	13	1	0	26700	200
BFP2508	345290	586920	0	13	39	167	17	0	2	31100	300
BFP2509	345950	587300	0	0	10	143	6	0	0	5700	<100
BFP2510	347510	585160	0	12	104	365	9	2	1	26500	<100
BFP2513	346770	585050	0	25	57	2217	31	0	0	80500	300
BFP2514	346390	585250	0	18	48	2646	31	4	2	55600	200
BFP2515	346900	585060	1	41	116	2947	32	0	5	81800	400
BFP2539	345500	591140	0	4	0	191	4	8	3	5000	<100
BFP2540	345690	590280	0	6	0	227	6	0	1	5500	<100
BFP2541	345590	590780	0	9	0	152	9	0	0	3000	<100
BFP2542	345560	590770	0	6	4	223	6	0	0	5000	<100
BFP2543	345550	591150	0	1	0	240	1	0	3	1600	<100
BFP2544	345560	591620	0	11	0	211	10	0	2	3200	<100
BFP2545	346650	590820	0	11	23	256	9	1	0	8200	<100
BFP2546	346700	589960	0	14	182	195	10	0	2	20400	<100
BFP2547	348770	590370	0	4	104	373	9	2	0	21500	<100
BFP2548	348620	590680	0	31	4629	298	17	1	22	31700	300
BFP2549	348760	590700	0	9	30	233	11	1	0	35400	200
BFP2583	347390	589420	0	10	54	248	16	1	7	45900	<100
BFP2584	346900	589770	0	125	93	205	55	12	45	261700	1700
BFP2585	347240	589230	10	13	13	199	5	0	1	28600	200
BFP2586	347000	589120	27	117	1304	629	47	0	0	139700	300
BFP2587	346210	589420	0	48	24	158	7	0	0	27700	<100

Table 3 (continued) Newcastleton Panned Concentrate Data (Reconnaissance Survey, 1976)

Sample Ref. No.	Easting	Northing	Cu (ppm)	Pb (ppm)	Zn (ppm)	Ba (ppm)	Ni (ppm)	Sb (ppm)	Sn (ppm)	Fe (ppm)	Mn (ppm)
BFP2588	345840	588920	4	17	44	483	21	2	0	18300	200
BFP2589	345090	588800	6	2	18	178	3	0	0	10500	200
BFP2594	344590	588610	0	6	11	287	4	0	1	9300	200
BFP2595	344490	588650	0	2	2	142	3	5	0	8700	<100
BFP2596	348120	590960	0	8	22	166	9	0	1	25200	<100
BFP2597	347680	590560	0	71	39	258	9	0	0	16900	200
BFP2598	347690	591110	0	4	0	179	2	2	3	4600	<100
BFP2599	347680	591650	0	9	12	210	12	2	1	8700	<100
BFP2600	347280	591900		8	2	177	5	6	0	5300	<100
BFP2601	347170	591820	0	8	13	265	5	0	0	5400	<100
BFP2602	346610	591920	0	1	0	197	3	4	2	3500	<100
BFP2603	346790	591600		18	14	467	16	0	0	11600	200
BFP2604	347280	591480	0	2	0	175	2	0	2	5500	<100
BFP2605	347480	591360	0	6	1	208	3	0	0	4200	<100
BFP2606	347350	590770	2	4	4	177	2	1	1	6500	<100
BFP2650	348680	591210	0	18	23	258	12	0	0	14100	<100
BFP2651	348500	591110	0	12	14	178	14	0	4	11900	<100
BFP2652	347780	590200	0	30	95	235	7	0	0	14900	<100
BFP2653	347700	590190	3	23	64	260	10	3	3	39500	200
BFP2654	347950	589800	0	12	32	241	4	2	0	14200	<100
BFP2655	347900	589740	4	11	46	235	9	4	4	28400	<100
BFP2656	348190	589470		21	54	220	8	3	4	14600	<100
BFP2657	348500	589340	1	15	53	242	10	1	3	31000	<100
BFP2899	347410	593920	0	9	124	107	4	0	0	15100	<100
BFP2900	347360	593930	0	25	250	183	33	6	5	70900	400
BFP2901	347300	593770	28	17	14	92	8	0	3	22500	200
BFP2902	347050	593750	0	20	46	208	20	5	0	48300	300
BFP2903	346350	593840	0	8	19	90	6	0	0	18900	200
BFP2904	345940	593270	0	14	21	252	30	6	0	12300	<100
BFP2905	345960	593220	0	15	5	56	8	1	0	9800	<100
BFP2906	346430	593480	28	14	10	3012	6	5	4	8100	<100
BFP2907	346920	593650	3	10	171	746	9	3	0	20100	<100
BFP4010	348470	586450	20	62	273	687	29	3	5	162300	800
BFP4011	348840	586440	9	17	52	205	11	0	2	47400	200
BFP4013	349920	586520	5	1	49	237	3	0	3	18100	<100
BFP4014	349610	586410	3	10	47	357	5	4	4	32800	<100
BFP4018	349770	587880	1	17	28	125	7	0	0	44200	200
BFP4023	347510	592200	2	5	6	110	3	3	0	5600	<100
BFP4024	347400	592370	0	8	3	95	4	1	1	12900	<100
BFP4025	347030	592640	0	3	26	77	15	3	3	11800	<100
BFP4026	346850	592680	7	8	102	37	16	2	3	10700	<100
BFP4027	346820	593200	8	4	11	76	78	0	0	16200	<100
BFP4028	347240	593120	14	13	278	461	15	0	0	48300	<100
BFP4029	347440	593210	0	0	29	58	62	0	0	22300	<100
BFP4030	347500	592930	28	103	55	541	19	2	0	38200	<100
BFP4031	347530	592740	0	1	8	83	3	2	1	7500	<100
BFP4103	348340	594650	0	16	30	210	8	6	1	15200	<100

Table 3 (continued) Newcastleton Panned Concentrate Data (Reconnaissance Survey, 1976)

Sample Ref. No.	Easting	Northing	Cu (ppm)	Pb (ppm)	Zn (ppm)	Ba (ppm)	Ni (ppm)	Sb (ppm)	Sn (ppm)	Fe (ppm)	Mn (ppm)
BFP4104	348790	594110	0	31	197	288	4	9	4	8000	<100
BFP4105	348790	594130	0	7	22	153	5	1	0	9500	<100
BFP4106	349200	593450	0	643	3307	1027	8	1	0	15900	<100
BFP4107	349520	592890	0	14	251	255	6	8	2	18800	200
BFP4108	348900	593040	0	10	180	147	15	5	0	14500	<100
BFP4109	349210	592590	0	13	299	215	6	0	1	15000	<100
BFP4271	349070	592400	10	28	145	341	8	0	0	28400	<100
BFP4272	348270	592420	0	6	34	169	4	3	0	11300	<100
BFP4273	347930	592480	15	7	30	186	3	2	0	15700	<100
BFP4274	349780	592080	6	4	85	133	1	0	2	10200	<100
BFP4302	348690	585410	2	18	19	83	3	4	3	20900	<100
BFP4303	348030	585110	4	9	70	128	7	2	0	30000	<100
BFP4304	348060	585680	7	13	26	116	8	2	1	47500	200
BFP4589	347290	588600	2	5	34	539	4	1	1	6500	<100
BFP4590	346710	588350	2	138	51	160	15	0	4	53200	<100
BFP4591	347400	588020	1	16	30	120	15	2	3	44500	<100
BFP4592	347650	587140	9	21	34	202	18	1	3	45000	200
BFP4593	347680	587890	3	4	21	158	1	6	2	13600	<100
BFP4594	347840	588500	10	22	96	195	11	0	61	24800	<100
BFP4596	347830	588670	3	257	194	208	18	0	1	59200	<100
BFP4771	347160	589090	13	61	189	298	17	0	3	35000	<100
BFP4772	347060	589000	4	3	21	132	9	4	1	12800	<100
BFP4843	346290	589600	0	11	19	178	9	4	6	10700	<100
BFP4844	346210	589060	10	17	277	703	27	1	3	76700	300
BFP4914	345060	590970	0	15	20	143	5	3	5	16300	<100
BFP4915	344820	591150	4	37	40	168	15	2	5	55800	200
BFP4916	344310	590100	0	11	28	207	17	3	1	63300	300
BFP4917	344740	589600	1	34	45	185	39	0	114	113500	500
BFP4918	344970	589400	0	30	63	1292	50	0	23	83200	400
BFP4988	348940	591180	1	19	66	263	8	4	7	14800	<100
BFP4989	349780	591500	1	3	15	75	5	0	0	12300	<100
BFP5002	344290	588360	0	3	12	202	5	1	0	2800	<100
BFP5003	345400	588520	4	12	31	253	8	0	0	12400	<100
BFP5004	345470	588660	0	12	20	225	9	3	0	13700	<100
BFP5006	345990	588900	1	6	34	166	33	0	0	65900	<100
BFP5096	345490	585580	62	45	799	3665	21	0	3	43100	400
BFP5097	345370	585160	133	82	1279	1754	35	0	23	98300	800
BFP5192	345680	586140	0	20	253	906	12	0	0	26300	300
BFP5193	346120	586910	0	32	553	259	11	0	0	20000	200
BFP5194	345920	586920	0	230	65	182	16	0	0	35000	200
BFP5213	348790	590600	0	18	52	231	12	0	0	17400	300
BFP5215	348540	590970	0	14	23	195	7	0	0	7800	<100
BFP5216	348050	591210	0	9	63	306	6	0	0	13800	<100
BFP5217	348340	590430	0	12	29	179	13	3	0	17100	<100
BFP5218	348280	589660	0	16	28	213	6	5	0	10800	<1000
BFP5516	345210	586980	18	25	21	2558	20	0	8	26200	200

Table 3 (continued) Newcastleton Panned Concentrate Data (Follow-up Survey, 1993 and 1994)

Sample Ref. No.	Easting	Northing	Cu (ppm)	Pb (ppm)	Zn (ppm)	Ba (ppm)	Ni (ppm)	Sb (ppm)	Sn (ppm)	Fe (ppm)	Mn (ppm)
BFP7506	345218	587056	4	7	84	3618	6	<1	<1	8211	nd
BFP7507	345300	586928	3	12	25	226	10	1	<1	18492	nd
BFP7508	345200	586821	5	18	103	210	6	<1	2	8625	nd
BFP7509	345028	586823	45	83	1144	1059	40	<1	1	49197	nd
BFP7510	345960	587510	3	7	17	269	13	4	1	7935	nd
BFP7511	345840	587060	6	13	20	244	8	3	4	16077	nd
BFP7513	345950	587060	12	226	666	408	34	<1	14	58029	nd
BFP7514	346200	587130	3	8	29	347	6	<1	2	6969	nd
BFP7515	346180	587180	1	7	24	261	4	2	<1	3036	nd
BFP7522	345196	586503	6	24	468	642	4	<1	<1	9867	nd
BFP7523	345242	586255	10	41	322	20274	19	1	<1	42159	nd
BFP7524	344955	586540	5	11	154	2334	5	1	1	14628	nd
BFP7532	344880	586020	5	17	56	346	8	<1	3	20562	nd
BFP7533	345450	585760	99	28	1036	1352	15	2	12	36432	nd
BFP7534	345550	585680	10	105	196	1439	17	<1	4	54234	nd
BFP7535	345480	586150	1	5	47	178	4	2	2	4209	nd
BFP7536	345880	586360	17	13	39	135837	17	<1	7	24081	nd
BFP7537	345850	586420	6	14	115	208	15	2	7	42504	nd
BFP7550	345110	586360	15	79	298	6000	28	<5	10	74001	nd
BFP7551	345290	586265	227	41	535	2856	31	<5	<5	34972	nd
BFP7552	345010	585880	39	16	335	631	19	<5	<5	23361	nd
BFP7553	345483	585840	93	28	240	1657	13	<5	<5	25460	nd
BFP7554	345635	586060	3	12	119	248	13	<5	<5	12870	nd
BFP7555	346065	586760	9	21	1217	17	28	<5	<5	71902	nd
BFP7556	346870	586560	7	24	50	161	13	5	58	40288	nd
BFP7557	347160	589410	19	55	65	74	30	<5	9	117576	nd
BFP7558	347060	589060	6	19	28	119	13	<5	5	41757	nd
BFP7559	346620	589010	5	10	24	28	13	<5	9	27698	nd
BFP7560	347400	589160	8	14	26	178	10	<5	<5	29516	nd
BFP7561	347370	590400	17	46	227	91	26	6	8	104636	nd
BFP7562	347250	590665	10	31	28	140	13	<5	<5	40148	nd
BFP7563	347415	591040	2	13	18	127	7	<5	7	10492	nd
BFP7564	347385	591395	2	11	12	176	4	<5	<5	7974	nd

Table 4 Newcastleton Panned Till Data

Sample Ref. No.	Traverse No.	Distance (m)	Easting	Northing	Cu (ppm)	Pb (ppm)	Zn (ppm)	Ba (ppm)	Ni (ppm)	As (ppm)	Sn (ppm)	Sb (ppm)	Fe_2O_3t (%)
BFU7301	T1	0	346150	588965	5	7	13	190	3	2	4	1	0.92
BFU7302	T1	50	346176	588922	64	87	155	398	46	19	<1	<1	13.29
BFU7303	T1	100	346202	588879	4	7	11	179	5	4	<1	<1	1.04
BFU7304	T1	150	346227	588836	2	4	6	112	2	4	<1	<1	0.30
BFU7305	T1	200	346253	588794	9	10	10	201	9	<1	3	2	2.47
BFU7306	T1	250	346279	588751	6	10	16	178	6	4	3	3	2.45
BFU7307	T1	300	346305	588708	5	15	20	191	8	4	<1	2	2.88
BFU7308	T1	350	346330	588665	6	13	16	224	6	2	<1	1	1.77
BFU7309	T1	400	346356	588622	5	14	31	207	14	4	4	8	5.08
BFU7310	T1	450	346382	588579	6	10	22	262	9	5	1	<1	3.75
BFU7311	T1	500	346408	588536	6	18	20	286	6	7	5	<1	2.82
BFU7312	T1	550	346433	588494	13	32	70	307	23	14	4	<1	9.46
BFU7313	T1	600	346459	588451	12	21	44	261	16	14	9	4	7.66
BFU7314	T1	650	346485	588408	4	13	19	172	9	1	2	4	3.41
BFU7315	T1	700	346511	588365	8	10	22	203	8	6	4	3	3.72
BFU7316	T1	750	346536	588322	5	8	16	273	9	5	4	1	2.57
BFU7317	T1	750	346536	588322	8	18	26	301	11	3	<1	1	3.62
BFU7318	T1	750	346536	588322	8	18	26	217	11	<1	3	<1	4.23
BFU7319	T1	800	346562	588279	6	14	19	200	8	2	3	1	2.14
BFU7320	T1	850	346588	588236	16	28	52	282	21	11	7	<1	6.84
BFU7321	T1	900	346614	588194	10	31	31	333	12	2	2	<1	2.58
BFU7322	T1	950	346639	588151	4	12	16	222	6	3	5	<1	1.71
BFU7323	T1	1000	346665	588108	6	112	35	236	13	5	8	2	4.26
BFU7324	T1	1050	346691	588065	8	19	43	312	16	10	<1	<1	5.77
BFU7325	T1	1100	346717	588022	11	16	51	283	17	9	1	<1	4.96
BFU7326	T1	1150	346742	587979	6	14	52	283	10	2	<1	<1	3.52
BFU7327	T1	1200	346768	587936	6	13	33	216	10	7	4	<1	3.85
BFU7328	T1	1250	346794	587894	7	10	15	316	16	4	1	<1	4.64
BFU7329	T1	1300	346820	587851	3	12	17	303	6	<1	1	<1	0.97
BFU7330	T1	1350	346845	587808	3	7	10	112	7	<1	1	<1	1.50
BFU7331	T1	1400	346871	587765	4	12	14	236	6	5	<1	<1	1.80
BFU7332	T1	1450	346897	587722	11	14	14	307	10	4	3	7	1.25
BFU7333	T1	1550	346948	587636	8	2	5	267	5	2	<1	2	0.80
BFU7334	T1	1600	346974	587594	82	8	174	263	304	4	4	1	17.92
BFU7335	T1	1650	347000	587551	16	15	199	307	192	4	2	2	14.16
BFU7336	T2	0	346615	587060	72	20	114	323	207	14	6	4	19.37
BFU7337	T2	50	346576	587091	30	12	115	274	123	7	2	<1	13.39
BFU7338	T2	100	346537	587123	23	21	383	364	114	7	3	<1	14.20
BFU7339	T2	150	346498	587154	5	15	28	334	11	4	5	3	3.28
BFU7340	T2	200	346460	587186	7	16	28	270	10	4	<1	<1	3.54
BFU7341	T2	250	346421	587217	11	30	51	251	20	4	8	3	8.05
BFU7342	T2	300	346382	587249	6	16	21	252	11	<1	5	<1	3.41
BFU7343	T2	350	346343	587280	4	9	16	202	8	3	2	<1	1.75
BFU7344	T2	400	346304	587312	8	21	58	239	10	8	<1	<1	5.79
BFU7345	T2	450	346265	587343	7	10	21	213	13	7	5	<1	3.73
BFU7346	T2	500	346226	587375	6	14	22	244	11	5	3	2	3.58
BFU7347	T2	500	346226	587375	6	11	22	199	12	5	2	<1	3.95
BFU7348	T2	550	346188	587406	9	11	25	187	10	9	3	1	4.78

Table 4 continued

Sample Ref. No.	Traverse No.	Distance (m)	Easting	Northing	Cu (ppm)	Pb (ppm)	Zn (ppm)	Ba (ppm)	Ni (ppm)	As (ppm)	Sn (ppm)	Sb (ppm)	Fe_2O_3t (%)
BFU7349	T2	600	346149	587438	49	121	913	1135	24	9	<1	<1	5.31
BFU7350	T2	650	346110	587469	12	25	104	167	8	6	3	1	2.80
BFU7351	T2	700	346071	587501	11	22	30	219	9	<1	<1	<1	3.64
BFU7352	T2	700	346071	587501	8	14	19	220	8	3	<1	<1	2.95
BFU7353	T2	700	346071	587501	9	17	20	265	7	<1	<1	<1	2.93
BFU7354	T2	750	346032	587532	117	173	3774	1586	63	15	3	<1	11.49
BFU7355	T2	800	345993	587563	4	16	21	149	6	5	2	<1	3.71
BFU7356	T2	850	345954	587595	11	20	37	193	13	8	1	<1	6.23
BFU7357	T2	900	345916	587626	6	13	16	167	6	<1	<1	<1	1.74
BFU7358	T3	0	344950	587055	8	10	12	235	9	1	<1	<1	3.32
BFU7359	T3	50	344989	587025	6	8	19	425	9	1	<1	<1	2.78
BFU7360	T3	100	345028	586994	6	9	29	542	10	6	1	2	2.47
BFU7361	T3	150	345067	586964				Sample lost					
BFU7362	T3	200	345105	586933	5	11	12	212	6	4	<1	<1	1.80
BFU7363	T3	250	345144	586903	16	102	80	172	21	20	<1	<1	8.99
BFU7364	T3	300	345183	586872	1	7	5	163	3	1	2	<1	0.47
BFU7365	T3	350	345222	586842	8	16	26	299	9	10	<1	<1	4.12
BFU7366	T3	400	345261	586811	7	11	13	190	6	6	1	<1	1.48
BFU7367	T3	450	345300	586781	12	16	23	268	10	9	7	1	3.57
BFU7368	T3	500	345339	586751	10	14	30	271	12	9	3	<1	3.98
BFU7369	T3	550	345377	586720	6	16	20	219	12	10	4	1	3.25
BFU7370	T3	600	345416	586690	6	19	28	196	7	4	<1	5	3.21
BFU7371	T3	650	345455	586659	11	70	94	251	11	5	<1	5	4.23
BFU7372	T3	700	345494	586629	7	15	38	208	11	3	<1	<1	3.32
BFU7373	T3	750	345533	586598	9	13	37	194	11	9	3	<1	3.17
BFU7374	T3	800	345572	586568	10	11	11	140	7	2	3	<1	1.77
BFU7375	T3	850	345611	586538	7	12	22	197	9	3	<1	<1	3.56
BFU7376	T3	900	345649	586507	5	9	31	185	6	6	<1	<1	2.18
BFU7377	T3	950	345688	586477	1	4	7	192	4	<1	<1	2	0.25
BFU7378	T3	1000	345727	586446	5	13	23	182	10	<1	2	6	3.18
BFU7379	T3	1050	345766	586416	6	10	18	408	8	4	<1	<1	2.68
BFU7380	T3	1150	345844	586355	20	13	37	228	13	6	<1	<1	4.65
BFU7381	T3	1175	345863	586340	14	12	40	3630	48	5	5	4	8.77
BFU7382	T3	1200	345883	586324	2	7	7	233	5	2	3	2	1.06
BFU7384	T3	1250	345921	586294	25	12	19	55051	61	11	3	<1	3.08
BFU7385	T3	1300	345960	586264	19	21	13	76311	36	12	9	1	9.50
BFU7386	T3	1350	345999	586205	5	13	11	403	7	3	<1	<1	2.22
BFU7390	T4	0	344560	586590	13	17	26	674	12	3	6	<5	3.22
BFU7391	T4	50	344599	586558	4	11	18	167	5	4	<5	<5	4.09
BFU7392	T4	100	344637	586526	6	8	10	96	7	3	<5	<5	2.39
BFU7393	T4	150	344676	586495	7	23	31	185	13	8	<5	<5	7.58
BFU7394	T4	200	344714	586463	4	10	14	90	8	6	<5	<5	3.59
BFU7395	T4	250	344753	586431	8	12	33	433	6	5	<5	<5	5.07
BFU7396	T4	300	344791	586399	7	56	129	136	13	8	<5	<5	10.35
BFU7397	T4	350	344830	586367	5	31	30	134	10	6	6	<5	5.08
BFU7398	T4	400	344869	586336	13	147	401	3069	15	17	6	<5	6.90
BFU7399	T4	450	344907	586304	14	53	98	221	15	14	5	<5	5.51
BFU7400	T4	500	344946	586272	13	14	64	128	6	9	<5	<5	3.05

Table 4 continued

Sample Ref. No.	Traverse No.	Distance (m)	Easting	Northing	Cu (ppm)	Pb (ppm)	Zn (ppm)	Ba (ppm)	Ni (ppm)	As (ppm)	Sn (ppm)	Sb (ppm)	Fe_2O_3t (%)
BFU7401	T4	550	344984	586240	35	88	295	1750	14	9	<5	5	5.56
BFU7402	T4	600	345023	586208	16	250	367	500	17	13	<5	<5	6.33
BFU7403	T4	650	345062	586177	9	59	124	39	17	11	<5	<5	5.53
BFU7404	T4	700	345100	586145	22	153	316	6	24	9	<5	<5	7.75
BFU7405	T4	750	345139	586113	57	577	670	424	22	14	<5	<5	6.96
BFU7406	T4	800	345177	586081	37	257	537	1477	19	16	<5	<5	6.45
BFU7407	T4	850	345216	586049	26	160	215	604	17	10	<5	<5	5.60
BFU7408	T4	900	345254	586018	15	42	75	155	13	13	<5	<5	7.60
BFU7409	T4	950	345293	585986	3	15	19	29	7	2	<5	<5	3.20
BFU7410	T4	1000	345332	585954	18	65	241	128	11	8	6	<5	5.34
BFU7411	T4	1050	345370	585922	14	84	230	82	15	15	<5	<5	6.58
BFU7412	T4	1100	345409	585890	10	63	162	532	11	10	<5	<5	4.72
BFU7413	T4	1150	345447	585859	15	20	54	117	10	6	5	<5	3.50
BFU7414	T4	1200	345486	585827	17	32	44	113	22	19	6	<5	11.49
BFU7415	T4	1330	345586	585744	14	27	156	5101	17	12	<5	<5	4.45
BFU7416	T4	1380	345625	585712	32	69	155	12500	30	18	6	<5	9.41
BFU7417	T4	1430	345663	585680	15	101	74	3125	31	10	<5	<5	8.58
BFU7418	T4	1480	345702	585649	25	17	37	1538	27	9	<5	<5	6.43
BFU7419	T4	1530	345741	585617	13	15	31	311	22	6	<5	<5	5.88
BFU7420	T4	1580	345779	585585	17	14	57	110	43	19	<5	<5	12.28
BFU7421	T4	1630	345818	585553	15	24	60	20	33	19	<5	7	11.37

Table 5 Newcastleton sieved till data

Sample Ref. No.	Easting	Northing	Traverse No.	Distance (m)	Cu (ppm)	Pb (ppm)	Zn (ppm)	Ba (ppm)	Ni (ppm)	As (ppm)	Sb (ppm)	Fe_2O_3t (%)	MnO (%)
BFT7338	346537	587123	T2	100	34	37	272	573	130	5	<1	9.89	0.120
BFT7339	346498	587154	T2	150	22	35	82	533	43	8	<1	6.70	0.054
BFT7340	346460	587186	T2	200	20	28	78	562	43	5	5	5.58	0.032
BFT7341	346421	587217	T2	250	28	25	91	611	61	8	<1	7.60	0.076
BFT7342	346382	587249	T2	300	20	34	74	549	42	6	1	5.03	0.018
BFT7343	346343	587280	T2	350	22	28	84	534	49	10	<1	8.50	0.077
BFT7344	346304	587312	T2	400	17	26	62	522	37	6	1	4.72	0.020
BFT7345	346265	587343	T2	450	22	26	74	608	39	5	<1	6.10	0.061
BFT7347	346226	587375	T2	500	21	34	86	562	44	8	1	6.09	0.089
BFT7348	346188	587406	T2	550	23	29	88	580	45	6	1	5.99	0.123
BFT7349	346149	587438	T2	600	28	37	139	543	43	6	1	5.99	0.077
BFT7350	346110	587469	T2	650	22	37	132	532	42	10	2	5.97	0.079
BFT7351	346071	587501	T2	700	17	35	72	545	35	1	<1	4.67	0.052
BFT7354	346032	587532	T2	750	16	22	46	517	32	2	1	4.13	0.033
BFT7355	345993	587563	T2	800	18	33	75	497	29	5	1	5.23	0.073
BFT7356	345954	587595	T2	850	22	36	90	542	40	6	<1	5.89	0.093
BFT7357	345916	587626	T2	900	21	34	71	559	26	6	<1	4.49	0.066
BFT7358	344950	587055	T3	0	26	27	58	719	50	14	2	5.92	0.073
BFT7359	344989	587025	T3	50	28	23	60	681	54	12	3	6.41	0.116
BFT7360	345028	586994	T3	100	26	31	59	708	40	17	<1	5.90	0.066
BFT7361	345067	586964	T3	150	27	41	68	789	45	24	2	6.16	0.081
BFT7362	345105	586933	T3	200	22	53	125	1044	76	32	<1	11.23	0.501
BFT7363	345144	586903	T3	250	36	95	332	590	66	40	<1	10.19	0.057
BFT7364	345183	586872	T3	300	19	37	93	633	47	1	1	3.86	0.013
BFT7365	345222	586842	T3	350	22	32	91	562	48	12	1	6.20	0.122
BFT7366	345261	586811	T3	400	23	42	85	605	40	18	<1	5.96	0.121
BFT7367	345300	586781	T3	450	22	37	71	563	36	14	1	5.66	0.092
BFT7368	345339	586751	T3	500	21	32	77	555	43	6	<1	5.52	0.084
BFT7369	345377	586720	T3	550	21	32	77	559	42	11	3	5.79	0.081
BFT7370	345416	586690	T3	600	19	33	87	563	43	5	4	5.11	0.080
BFT7372	345494	586629	T3	700	21	38	110	551	43	12	1	5.70	0.050
BFT7373	345533	586598	T3	750	22	38	102	549	42	10	<1	5.89	0.106
BFT7374	345572	586568	T3	800	21	37	89	542	37	5	<1	6.07	0.047
BFT7375	345611	586538	T3	850	23	39	100	537	42	8	4	5.99	0.085
BFT7376	345649	586507	T3	900	24	49	123	554	45	12	<1	6.74	0.075
BFT7377	345688	586477	T3	950	15	40	98	567	38	6	<1	2.84	0.020
BFT7378	345727	586446	T3	1000	23	43	120	558	43	14	<1	5.48	0.094
BFT7379	345766	586416	T3	1050	23	32	74	619	41	14	2	5.38	0.091
BFT7380	345844	586355	T3	1150	22	33	103	642	43	7	5	6.46	0.152
BFT7381	345863	586340	T3	1175	22	19	83	770	43	9	<1	6.65	0.032
BFT7382	345883	586324	T3	1200	26	31	45	712	35	7	4	4.07	0.029
BFT7384	345921	586294	T3	1250	131	13	53	4516	313	21	1	19.47	0.810
BFT7385	345960	586264	T3	1300	29	12	34	2409	60	8	5	9.57	0.176
BFT7386	345999	586205	T3	1350	14	18	34	646	23	7	<1	4.62	0.270
BFT7390	344560	586590	T4	0	22	31	82	597	60	7	<5	4.48	0.047
BFT7391	344599	586558	T4	50	12	15	36	620	33	9	<5	4.38	0.067
BFT7392	344637	586526	T4	100	12	20	31	689	28	14	<5	4.73	0.196
BFT7393	344676	586495	T4	150	16	17	33	576	32	17	<5	5.58	0.083

Table 5 continued

Sample Ref. No.	Easting	Northing	Traverse No.	Distance (m)	Cu (ppm)	Pb (ppm)	Zn (ppm)	Ba (ppm)	Ni (ppm)	As (ppm)	Sb (ppm)	Fe_2O_3t (%)	MnO (%)
BFT7394	344714	586463	T4	200	15	28	51	579	37	20	<5	5.41	0.035
BFT7395	344753	586431	T4	250	25	35	89	553	43	7	<5	5.09	0.081
BFT7396	344791	586399	T4	300	21	46	103	610	44	12	<5	5.33	0.052
BFT7397	344830	586367	T4	350	24	40	94	610	44	7	<5	5.21	0.048
BFT7398	344869	586336	T4	400	26	35	99	671	42	15	<5	5.15	0.068
BFT7399	344907	586304	T4	450	23	44	103	525	45	9	<5	5.40	0.089
BFT7400	344946	586272	T4	500	26	45	103	556	43	4	<5	4.69	0.077
BFT7401	344984	586240	T4	550	22	43	97	577	39	6	<5	5.17	0.084
BFT7402	345023	586208	T4	600	24	37	96	551	43	13	<5	5.07	0.077
BFT7403	345062	586177	T4	650	24	39	108	546	43	11	<5	4.96	0.056
BFT7404	345100	586145	T4	700	21	37	94	589	45	6	<5	5.03	0.077
BFT7405	345139	586113	T4	750	22	37	97	541	39	7	<5	5.07	0.085
BFT7406	345177	586081	T4	800	22	34	94	517	44	11	<5	5.37	0.081
BFT7407	345216	586049	T4	850	25	40	94	532	45	6	<5	5.58	0.073
BFT7408	345254	586018	T4	900	24	41	90	652	43	12	<5	5.38	0.084
BFT7409	345293	585986	T4	950	20	42	99	533	46	9	<5	5.51	0.095
BFT7410	345332	585954	T4	1000	26	41	113	518	41	14	<5	5.57	0.109
BFT7411	345370	585922	T4	1050	24	50	129	451	41	9	<5	5.41	0.098
BFT7412	345409	585890	T4	1100	27	46	127	473	51	7	<5	5.43	0.107
BFT7413	345447	585859	T4	1150	24	46	110	527	38	15	<5	6.03	0.103
BFT7414	345486	585827	T4	1200	22	48	125	496	41	8	<5	5.76	0.227
BFT7415	345586	585744	T4	1330	28	36	85	652	43	11	<5	5.52	0.104
BFT7416	345625	585712	T4	1380	23	31	83	619	44	7	<5	5.55	0.100
BFT7417	345663	585680	T4	1430	28	24	86	567	58	11	<5	6.97	0.095
BFT7418	345702	585649	T4	1480	26	35	86	569	43	12	<5	6.07	0.111
BFT7419	345741	585617	T4	1530	13	16	25	626	28	7	<5	5.31	0.116
BFT7420	345779	585585	T4	1580	22	17	49	687	51	10	<5	7.45	0.168
BFT7421	345818	585553	T4	1630	15	20	25	680	28	15	<5	4.80	0.102