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Stratabound arsenic and vein antimony mineralisation in Silurian greywackes at Glendinning, south Scotland
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SUMMARY

Stratiform and disseminated pyrite-arsenopyrite concentrations are overprinted by fracture-controlled polymetallic mineralisation including stibnite through at least tens of metres of Silurian sediments at Glendinning, near Langholm. Three shallow boreholes were drilled on an anomaly defined by VLF-EM and IP surveys and by antimony values >20 ppm in thin B-C horizon soils. A parallel conductive zone with an accompanying soil anomaly but lacking an IP response was investigated by a fourth hole. The stratabound sulphides form disseminations and bands parallel to the bedding and are particularly concentrated in intraformational breccia units regarded as debris flows, which, together with the presence of small scale dump folds in the greywackes, testify to the existence of an unstable slope during sedimentation. The thickest such unit has a true thickness of 4 m and together with 8 m of adjoining greywackes grades 0.7% As. Phases of fracture-controlled Fe-As-Sb-Pb-Zn-Cu-(?)Hg mineralisation associated with widespread dolomite and quartz veinlets and narrow breccia veins are superimposed on the stratabound mineralisation. Their spatial association with the stratabound mineralisation, the presence of up to 0.33% Sb in the stratiform arsenopyrite and as much as 5% As in the stratiform pyrite, favour a common source for the arsenic and antimony. This source was probably a synsedimentary metal accumulation in a mid or lower fan environment where euxinic conditions periodically developed.

INTRODUCTION

LOCATION

The old Louisa Mine at Glendinning lies 13 km north-north-west of Langholm (Figure 1) and 26 km south-west of Hawick in southern Scotland. It can be reached from Langholm via the B709 Eskdalemuir road thence by a minor road from Georgefield to the hamlet of Glendinning. A rough track leads eastwards for 1.5 km from Glendinning hamlet to the old mine.

MINING RECORDS

The documentary evidence on this mine is scant and at times at variance with the field evidence. Dewey (1920) stated that the mineralisation was first discovered about 1760 but does not say which vein. A section of the mine is recorded in the margin of a Leadhills mine plan dating from the mid-nineteenth century, but this only shows a single worked structure (op cit p. 55). A total production of nearly 200 tonnes of antimony is recorded from Glendinning Mine, the main periods of production being 1793–1798 and 1888–1891 (op cit).

Field observation suggests that there are three structures which have been worked, as well as several small trials and lines of costean pits. It seems likely that the first discovery of ore minerals took place in Glenshanna Burn as outcrop is scarce elsewhere. The earliest workings lie about 100 m below the main mine dumps [3112 9662] where there is a collapsed adit in the stream bank driven towards the main shaft at a small angle to the stream. About 30 m along this there is possibly a shaft from the surface close to the remains of a dam and wheel pit. On the south side of the stream (Figure 6) there are small dumps and crushing floors on which samples of stibnite abound. A further 50 m downstream from these there is a powder hut of a later phase of working south of which a trench is aligned with the col into Trough Hope (Figure 3). The remains of a shaft with a dump which is now well covered with vegetation occur nearby. It is possible that there were occasions other than those mentioned above on which ores were extracted from the workings. The early phases of operation apparently lacked any mechanisation, or even a track along which a wheeled vehicle might have gained access to the workings.

The main workings, which are probably of mid to late 19th century age, lie on the north side of Glenshanna Burn, and are of a much larger scale than those described above. The vein is described by Wilson (in Dewey, 1920) as trending to the north-east, and dipping at 80° to the SE, or vertical. According to Wilson, quoting unspecified sources, the walls are horizontally slickensided and about 1.3 m apart, within which a zone of small stringers of ore occurred in brecciated country rock. The distribution of ore is said to be very patchy and the volume of gangue minerals small. The mine workings were inaccessible when visited by Wilson more than sixty years ago. He describes the ore as being a highly complex mixture of stibnite, galena, jamesonite and sphalerite, with a little chalcopyrite.
Fig 1 Sketch geological map of the south of Scotland showing the principal known occurrences of antimony and arsenic.
The gangue comprises quartz, calcite and baryte. The major part of the workings, to which it is presumed that Wilson's description applies, comprises three levels, the top one of which is an adit on the flank of Grey Hill (Figure 6). The levels are interconnected by two or possibly three shafts and a number of winzes. Drainage seems to have been a problem on the lower two levels, and it is unlikely that much production took place from them. The last phase of operation took place c.1920 when reinforced concrete footings were built for winding gear and the shafts were cleaned out. However, it seems that most of the capital was spent on elaborate facilities, and production was small before the venture collapsed. Costean pits were sunk on the south side of Glenshanna Burn, and small excavations in the hillside suggest that trial adits were driven in search of a southward extension of the mineralised structure, but there is nothing to suggest that anything was found.

Westwards from the mine site towards Meggat Water (Figure 3) two small adits open into the south bank of the stream. The adjoining dumps are barren of mineralised material. Another small trial occurs in the main valley to the east of Meggadale Farm [3005 9576], which may have been developed in the early part of this century, and was only abandoned because of a drop in the price of antimony ores. There is evidence of a smelting hearth on the banks of Meggat Water adjacent to Glendinning Farm, and another beside Tod Syke, which appears to be related to one of the later phases of working, at which time a proper track was cut to the mine.

**SCOPE OF THE PRESENT INVESTIGATION**

Glendinning Mine is geographically remote from other mining districts in southern Scotland and even prior to this investigation its geological characteristics were regarded as unusual — an isolated vein in Lower Palaeozoic sediments unrelated to major faulting and distant from granitic intrusions. Apart from a few baryte veinlets exposed in Glenshanna Burn there is no outcropping metaliferous mineralisation in the area of Glendinning Mine. The lack of mineralisation controls, evidence of antimony anomalies in drainage samples (Figure 2) and the high value of the metal itself formed the main reasons for this investigation.

As exposure is very poor in the mine area, geochemical soil sampling and geophysical surveys formed the main surface investigations, commencing in 1979. Traverses were oriented NW–SE on the assumption that the mining record of a north-east trending vein was correct. However, coincident soil anomalies and VLF–EM anomalies trending at 015° were obtained in ground where little or no evidence of earlier workings existed. On this new evidence, four shallow boreholes were drilled in 1980. Drill cores were logged on site, then in more detail at the field base. Half-core samples were taken for geochemical analysis and mineralogical study and the remainder stored in Edinburgh.

**REGIONAL GEOLOGY**

In Britain the northern sector of the Caledonides fold belt (the orthotectonic Caledonides) is essentially a high grade metamorphic terrain whereas the southern sector (the paratectonic Caledonides), although containing highly deformed strata, has suffered only very low grade metamorphism. The boundary between the orthotectonic and paratectonic Caledonides probably lies in the vicinity of the Southern Upland Fault and coincides with a continental margin beneath which oceanic crust was consumed at a north-westerly dipping subduction zone during the Lower Palaeozoic (Dewey, 1969; Phillips and others, 1976).

When the present Atlantic Ocean is closed so that the continents are restored to their pre-Mesozoic relationships (e.g. Smith and Briden, 1977) Britain and Ireland are brought into close proximity to Newfoundland and Greenland. The continuity of the Laurentian continental foreland outcrops in east Greenland, north-west Scotland and Newfoundland is then emphasised. In Scotland the Dalradian Supergroup originated in a late Pre cambrian to Cambrian ensialic basin within this foreland (Harris and others, 1978) and has a probable analogue in the Fleur de Lys Supergroup of Newfoundland (Kennedy, 1975). Ophiolite complexes at Ballantrae and in Newfoundland are generally believed to represent oceanic crust obducted onto the continental margin from a series of back-arc basins (Dewey, 1974).

South-east of the Southern Upland Fault a systematic sequence of stratigraphically distinct, steeply dipping greywacke-shale units trends north-east to south-west separated by major strike faults. Within each individual unit the dominant direction of stratigraphic younging is to the north-west but overall progressively younger units crop out sequentially towards the south-east (Walton, 1965; Leggett and others, 1979). This trend is particularly well defined in the north-western half of the Southern Uplands but becomes more confused southeastward. The fault-bounded units are thought to have originated as an accretionary wedge formed above a subduction zone consuming the Lower Palaeozoic Iapetus oceanic plate (McKerrow and others, 1977; Leggett and others, 1979). The wedge built up as successive thin layers of sediment were sheared from the surface of the downgoing plate and underthrust beneath a stack of similar slices. Some rotation of the sedimentary pile may have been caused by the underthrusting but final rotation to the present sub-vertical
Fig. 2 Distribution of antimony (ppm) in heavy mineral concentrates from drainage near Glendinning.
Geology from one-inch Geological Sheet 10 (Scotland)
It is probably the result of tight folding. Several poorly preserved sub-horizontal fold hinges, usually with an associated axial-plane cleavage, were observed within the mine area and are probably of the same general style as the folds well exposed at White Birren quarry 6 km to the south-west (Figure 4). In the quarry section tight folds with sub-horizontal hinge axes, cut by fine quartz and carbonate veins. These may have originated as mass-flow deposits derived from a more distant source than the intraformational breccias. The assemblage of sedimentary features observed suggests deposition in a mid or lower fan environment (e.g. Walker, 1979). Grey and red mudstones are in places interbedded with the greywackes and are frequently mutually interlaminated. The mudstone horizons range up to 1 m in thickness and probably represent a pelagic or hemipelagic deposit.

Good palaeocurrent evidence was obtained at several exposures and, after correction only for bedding inclination, showed a consistent current trend towards the west and south-west. However, at White Birren quarry, 6 km along strike to the south-west there is good evidence for palaeocurrent flow towards the east (Figure 4). This along-strike variation in current direction reinforces the suggestion of deposition in a mid or lower fan environment.

No evidence for contemporary vulcanicity was found in the Glendinning district, but tuffaceous horizons have been reported (Lumsden and others, 1967, p. 14) within the neighbouring Silurian sequence of the Langholm area. The closest of these to Glendinning crops out approximately 11 km to the south-south-east.

In the past unfossiliferous sequences of the type exposed in the Glendinning area have been referred to as the 'Hawick Rocks', an ill-defined assemblage traditionally included in the Llandovery stage of the Silurian (Peach and Horne, 1899; Rust, 1965a). However, work by Craig and Walton (1959) in Galloway, and Warren (1964) near Hawick has suggested that the uppermost parts of the 'Hawick Rocks' sequences in those areas may be Wenlock in age. The stratigraphic position of the Silurian greywackes of the Glendinning area is therefore uncertain, and because of the paucity of outcrop, the steeply inclined nature of the beds, and borehole evidence of rapid lithological variation it has not been possible to devise a local lithostratigraphy.

**GEOLOGY OF THE GLENDINNING AREA**

**STRATIGRAPHY**

The Glendinning area lies within the broad belt of Silurian strata which forms the south-eastern part of the Southern Uplands. The succession consists of medium to fine-grained greywackes well-bedded on the scale of a few centimetres to several metres. Well-developed grading is only occasionally seen but interlamination of the fine greywacke with siltstone is common, together with widespread cross-bedding. A number of intraformational breccia horizons were encountered in the boreholes, some with siltstone and fine sandstone clasts set in a muddy matrix and others with mudstone clasts in a coarser-grained matrix. Of the breccias rich in fine-grained matrix some contained clasts cut by fine quartz and carbonate veins. These may have originated as mass-flow deposits derived from a more distant source than the intraformational breccias. The assemblage of sedimentary features observed suggests deposition in a mid or lower fan environment (e.g. Walker, 1979). Grey and red mudstones are in places interbedded with the greywackes and are frequently mutually interlaminated. The mudstone horizons range up to 1 m in thickness and probably represent a pelagic or hemipelagic deposit.

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**STRUCTURE**

The principal structural elements of the Glendinning area are summarised in Figure 3. Regional bedding strike is north-east to south-west although in places a dextral deflection is apparent, for example in the western part of the Corlaw Burn. Strata are generally steeply inclined with a south-eastward dip. The overall sense of younging is to the north-west (thus most beds are slightly inverted) but south-easterly younging horizons were noted in several places. This alternation of younging direction in adjacent horizons with similar attitudes is likely to be the result of tight folding. Several poorly preserved sub-horizontal fold hinges, usually with an associated axial-plane cleavage, were observed within the mine area and are probably of the same general style as the folds well exposed at White Birren quarry 6 km to the south-west (Figure 4). In the quarry section tight folds with sub-horizontal hinge axes, cut by fine quartz and carbonate veins. These may have originated as mass-flow deposits derived from a more distant source than the intraformational breccias. The assemblage of sedimentary features observed suggests deposition in a mid or lower fan environment (e.g. Walker, 1979). Grey and red mudstones are in places interbedded with the greywackes and are frequently mutually interlaminated. The mudstone horizons range up to 1 m in thickness and probably represent a pelagic or hemipelagic deposit.

Superimposed on the sub-horizontally hinged folds are tight folding zones with hinges plunging steeply to the west-south-west. In style these range from simple S or Z folds with amplitude and wavelength of up to 2 m, to complex fold zones several metres broad (Figure 5). It is possible that these are associated with fracture zones trending north-north-east which form a prominent lineament across the Glendinning area (Figure 3). In situ brecciated and mineralised bedrock has been collected from the surface expression of one such lineament close to BH 3. It is probable that the mined galena-sphalerite-stibnite vein was contained within such a north-north-east trending fracture.

No minor intrusions were observed in the vicinity of the old mine workings but 2.5 km and 4.5 km to the south-west Tertiary dolerite dykes crop out with a trend approximately perpendicular to the regional strike. In the White Birren quarry section a highly altered dolerite dyke is of Lower Devonian type. The Glendinning area is remote from the major Caledonian batholiths of the south of Scotland; the Criffel granite 45 km to the southwest and the postulated Tweeddale granite (Lagios and Hipkin, 1979) 40 km to the north are the closest. There is no geophysical evidence for a major intrusive body beneath the mineralised zone.
Fig. 3 Geology of the area around Glendinning mine, north of Langholm. Fault lineaments inferred from aerial photographs. Antimony distribution in heavy mineral concentrates from tributary alluvium also shown.

Fig. 5 Plan section of tight isoclinal, steeply plunging folds. Located on Fig. 3.
Fig. 4 Tight, gently plunging folds exposed in the southwestern face of White Birren Quarry (located on Fig. 1)
GEOCHEMISTRY

DRAINAGE SAMPLING

From the results of geochemical orientation studies carried out over Lower Carboniferous sediments and lavas to the west of Langholm (Gallagher and others, 1977; Smith, Gallagher and Fortey, 1978), heavy mineral concentrates were identified as the optimum sample type in locating sulphide mineralisation occurring in both veins and disseminations. As a consequence of significantly increased base metal abundances and improved geochemical contrast for Pb, Zn, Cu, Ba, Ni, Fe and Sb relative to minus 150 μm stream sediments, heavy mineral concentrates were used in a high density geochemical reconnaissance survey of the Borders extending from Ecclefechan north-eastwards to Berwick (Smith and others, in preparation).

Samples of heavy minerals 20–30 g in weight, recovered by panning about 3 kg of minus 2.5 mm stream sediment, were subsampled to 12 g (Leake and Aucott, 1973) and analysed by an automatic XRF technique (Leake and others, 1978). Results for antimony and associated anomalous elements in the Glendinning area are presented in Figures 2–5 and in Appendix V, Figures 1–8. Simple statistical analysis of the total sample population indicates in the case of antimony a significant change of slope on the cumulative frequency curve at 20 ppm Sb. Values above this level are regarded as highly anomalous at the regional scale and are mainly confined to Glenshanna Burn, Trough Hope and Corlaw Burn.

Very high antimony (and lead) values in Glenshanna Burn downstream of the mine are considered to reflect severe heavy metal contamination from previous mining activity. Further evidence of contamination is provided by the extensive dispersion of mine dump material downstream of the old workings, the high concentrations of fresh sulphides recovered by panning and the presence of anomalous concentrations of tin in some samples (Appendix V, Figure 7). However, highly anomalous antimony values occurring in the minor north bank tributary, in the main stream above the old mine, and in adjacent catchments are thought to be related to a wider zone of mineralisation extending along strike for 2–3 km north-east and south-west of Glendinning Mine. The distribution of arsenic (Appendix V, Figure 8) is also indicative of a NE–SW trending zone of mineralisation some 5 km in length. Glacial dispersion of ore minerals from the area of outcropping mineralisation in Glenshanna Burn is unlikely to account for the observed distribution of anomalous antimony and arsenic values.

Anomalous values of 11–20 ppm Sb also occur in the catchment of Stennies Water, particularly downstream of its junction with Faw Side Burn (Figure 2). However, dispersion trains are apparently short, and there are no very high antimony or associated ore metal values indicative of a local bedrock source. Further sampling of soils or basal tills would, therefore, be required to establish whether these anomalies are the result of glacial dispersion of heavy minerals over a wide area or of suboutcropping mineralisation obscured by drift on the valley sides or interfluve areas.

Comparison of the distribution of antimony with other elements suggests an association with iron (Appendix V, Figure 1) which is rejected in the Sb against Fe correlation coefficient of 0.45 for all samples (650) derived from Silurian rocks in the regional survey (Smith and others, in preparation). The regional mean value of iron based on log data is 5.5% whereas higher values (6.5–17%) characterise areas of known or inferred antimony mineralisation.

Lead and zinc are both highly enriched in heavy mineral concentrates from the mine area in Glenshanna Burn but decrease downstream to almost background concentrations over a distance of 1 km (Appendix V, Figures 2–3). Elsewhere in the Glendinning area, low levels of lead, zinc, copper and barium are comparable to or lower than the regional means of 20, 100, 23 and 515 ppm respectively, and do not correlate with antimony. In contrast, nickel concentrations (av. 55 ppm) exhibit a small but consistent increase compared with the regional mean (av. 40 ppm) and are notably higher in samples from Trough Hope and Glenshanna Burn (Appendix V, Figure 5).

SOIL SAMPLING

In order to test for possible extensions of the known mineralisation soil samples were collected on a grid pattern around the workings. A sample spacing of 10 m by 100 m was chosen along the same traverses as the geophysical surveys (Figure 7), but this was reduced to 20 m by 100 m on the top of Grey Hill. Samples of B or C horizon soil weighing around 100 g were taken from a depth of 1 m, or as deep as possible in the shallower soils of the higher ground.

The soils of the area are mostly well-oxidised yellow-brown silty clays, in which the content of angular lithic fragments gradually increases with depth. The change from bedrock to residual soil is gradational, and the weathering profile is pockety. The borehole sections show that oxidation penetrates bedrock for some distance, particularly along fracture planes. These soils bear a close resemblance to the residual soils of southwest England. In upper Glenshanna Burn there are considerable accumulations of head deposits, and a short distance above the mine these are overlain by boulder clay, which is well exposed in the stream section where it is about 10 m thick. The boulder clay is ill-drained and covered by up to 1.5 m of peat. Peat development seldom exceeds 0.15 m on the residual soils, presumably due to their free drainage.

The samples were oven dried in their bags and
Table 1 Accuracy limits of XRF analysis

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<tr>
<th></th>
<th>Ba</th>
<th>Sb</th>
<th>Pb</th>
<th>Zn</th>
<th>Cu</th>
<th>Ca</th>
<th>Ni</th>
<th>Fe</th>
<th>Mn</th>
<th>As</th>
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<td>Upper limit (%)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<td>30</td>
<td>1</td>
<td>30</td>
<td>1</td>
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</tr>
<tr>
<td>Lower limit (ppm)</td>
<td>18</td>
<td>7</td>
<td>9</td>
<td>2</td>
<td>4</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
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sieved to pass 200 μm mesh. From each fine fraction a subsample of 12.0 g was obtained by cone and quartering, to which 4 g of elvacite was added. This mixture was ground to around 80 μm mesh and pressed into a pellet for X-ray fluorescence determination of Ce, Ba, Sb, Sn, Pb, Zn, Cu, Ca, Ni, Fe, Mn, Ti and As (see Table 1 for limits of detection).

The data were analysed on the Rutherford Laboratory dual IBM 360/195 computer using the G-EXEC program package, from which graphical displays were generated on a Calcomp drum plotter.

Cerium, tin and titanium showed no significant variation over the area, and were not considered further. The other elements showed near lognormal distributions and hence were log-transformed before further analysis. Log concentration against probability plots were used to determine population breaks or inflection points (Table 2). These were used to chose contour intervals for the isolopleth maps (Figure 6 and Appendix VI).

**ELEMENT DISTRIBUTIONS IN OVERBURDEN**

The normal background level of antimony in soil is <1 ppm (Wedepohl, 1972). Sixty percent of the samples analysed contain >7 ppm, which is the analytical detection limit and all of these samples must be considered to be anomalous. The top population, >55 ppm Sb, is probably related to the presence of mineralised material in the samples, and values of 7–55 ppm to secondary dispersion of antimony in the soil. The maximum concentrations are found in two near-linear zones, the western one of which can be traced north-northeast from the mine workings for 500 m; the second runs parallel, about 130 m to the east, and is of a similar size (Figure 6). Neither appear to be the surface expression of the worked vein from what can be seen of the orientation of the adit. A small antimony anomaly occurs on the south side of Glenshanna Burn close to the old powder hut [8104 9667]. It yields a maximum value of 16 ppm Sb, and measures 150 m by 20 m. Further anomalies occur in the bottom of Trough Hope (Appendix VI, Figure 2), but are closely related to high iron concentrations and may therefore be of secondary type. A single sample containing 28 ppm Sb found at [3066 9619] on the southern spur of Alkin Hill may be of some significance as it coincides with high values of copper, lead and nickel.

Background barium levels are relatively low in the Glendinning area, the mean level for the background population being 165 ppm. There is a higher level population containing in excess of 330 ppm, with a transitional zone down to 210 ppm. Contours at the top and bottom of the transitional population produce a coherent pattern, which coincides with maxima of other elements. In the lower part of the eastern anomaly barium coincides with calcium, and for 200 m on the flank of Grey Hill with copper, zinc, nickel and antimony. In the western anomaly barium occurs with calcium, copper, lead and nickel. Transitional values of barium are found in the vicinity of the

Table 2 Summary statistics, soil samples

<table>
<thead>
<tr>
<th>Element</th>
<th>Maximum</th>
<th>Minimum</th>
<th>Geometric mean</th>
<th>Median</th>
<th>Points of inflection and percentiles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ba</td>
<td>482</td>
<td>101</td>
<td>186</td>
<td>175</td>
<td>205 (79%) 330 (89%)</td>
</tr>
<tr>
<td>Sb</td>
<td>198</td>
<td>0</td>
<td>6.6</td>
<td>8.2</td>
<td>7.2 (43%) 55 (99.3%)</td>
</tr>
<tr>
<td>Pb</td>
<td>213</td>
<td>6</td>
<td>28</td>
<td>27</td>
<td>38 (77%)</td>
</tr>
<tr>
<td>Zn</td>
<td>232</td>
<td>12</td>
<td>52</td>
<td>53</td>
<td>100 (85%) 126 (99%)</td>
</tr>
<tr>
<td>Cu</td>
<td>194</td>
<td>1</td>
<td>13</td>
<td>14</td>
<td>13 (44%) 39 (97.5%)</td>
</tr>
<tr>
<td>Ca</td>
<td>4970</td>
<td>290</td>
<td>708</td>
<td>570</td>
<td>660 (68%) 2300 (89%)</td>
</tr>
<tr>
<td>Ni</td>
<td>92</td>
<td>6</td>
<td>27</td>
<td>27</td>
<td>71 (95%)</td>
</tr>
<tr>
<td>Fe%</td>
<td>11.6</td>
<td>.86</td>
<td>4.89</td>
<td>6.2</td>
<td>6.6 (54%)</td>
</tr>
<tr>
<td>Mn</td>
<td>1860</td>
<td>30</td>
<td>245</td>
<td>270</td>
<td>550 (74%)</td>
</tr>
<tr>
<td>As</td>
<td>2637</td>
<td>0</td>
<td>34</td>
<td>27</td>
<td>24 (46%) 750 (97%)</td>
</tr>
</tbody>
</table>

All values in ppm except Fe(%): 453 samples
Fig 6 Geology and topography of the area around Glendinning Mine showing distribution of antimony in 150μm shallow overburden samples (see Fig. 3 for location and Fig. 7 for sampling traverse lines)
old workings on the south side of Glenshanna Burn, and the boulder clay in the valley floor contains concentrations in excess of 330 ppm downstream of the workings. There is a sharp increase in the barium concentration in the lower part of Trough Hope, where values lie in the range of 200-400 ppm, which may be due to secondary concentration on humic acids or iron and manganese oxides. All the barium concentrations are low when compared with other mineralised areas, and the median concentration is about half that given as the mean for greywackes (Wedepohl, 1972).

Calcium levels are generally low in the greywackes surrounding the mine, and in the boulder clay in the valley bottom. Over the mineralised structures, however, much higher levels are encountered and these anomalies appear to have given rise to calcium-rich soils in the valley bottom downstream from the mine site. The eastern anomaly displays the highest concentrations, which occupy a zone 40 m wide and more than 400 m long on the side of Grey Hill (Appendix VI, Figure 4). There are two smaller anomalies to the east of this, the more intense of which is associated with high zinc and barium concentrations. In the case of calcium, the western anomaly is limited to 100 m in length, much less than for accompanying anomalous elements. Beneath the gap into Trough Hope there is another area of high calcium concentrations associated with copper, zinc, nickel, barium and antimony, though this rapidly dies out southwards.

The background level of copper in this area is around 13 ppm, but 2% of the samples fall into a separate population with concentrations >39 ppm. Most of these anomalous samples lie in the valley bottom in peat-covered boulder clay, though two of them are within the previously described anomalous zones on Grey Hill, and coincide with high lead, zinc, nickel and antimony values in the western anomaly and with calcium, barium and lead in the eastern anomaly. A contour at 20 ppm encloses all the valley bottom, and also both the mineralised structures. The old workings around the powder hut are also marked by copper concentrations of up to 39 ppm. There are isolated higher values in the bottom of Trough Hope, and also on the south side of Alkin Hill and on the west side of Munshiel Hill. The copper distribution is complex, with higher levels over peat-covered boulder clay as well as around the mineralised structures. It is probable that hydromorphic transport is important in governing the abundance of copper in soil.

There are two overlapping populations amongst the iron analyses with a point of inflection at 6.6%. The western anomaly is clearly marked by high iron concentrations, but only two small patches of the eastern anomaly are similarly marked. Parallel to the western anomaly but further west there is a broad anomalous zone coincident with high manganese values. To the east of the eastern anomaly there are two anomalous patches which are coincident with high antimony and copper values. Other anomalous concentrations occur on the south bank of Glenshanna Burn around zones of seepage, in the bottom of Trough Hope, and on the east side of Alkin Hill where a thin linear anomaly coincides with a lineament conspicuous in the aerial photographs.

The lead analyses form two populations with a point of inflection at around 40 ppm, but an examination of the geographic distribution of these samples suggests that there is considerable overlap between the background and anomalous populations. Contours at 50 ppm and 70 ppm enclose the eastern and western anomalies and the valley of Trough Hope (Appendix VI, Figure 5). Both anomalous zones appear to extend across Glenshanna Burn to the south and to die out after about 150 m near the top of the slope. The anomalous zone enclosed in Trough Hope measures 500 m by 100 m. To the west of this there is another small anomalous zone on the flank of Alkin Hill coincident with high copper, nickel and antimony values, suggesting that there might be another small-scale structure in that area.

Background concentrations of manganese appear to extend up to 560 ppm and account for 74% of the samples analysed. A contour drawn at that value delineates the western anomaly and part of the eastern anomaly, but diverges westwards near the base of the slope. Two small patches of manganese concentration to the east of the eastern anomaly lie close to a minor zone of antimony and lead anomalies. To the west of the western anomaly there is a parallel zone of high manganese and iron without any base metal enrichment. There are several narrow anomalous areas running down the south bank of Glenshanna Burn, which are coincident with seepages. High values prevail throughout the lower parts of the Trough Hope valley and over the gap into the valley of Glenshanna Burn valley in damp and ill-drained ground. Conversely on the top of Grey Hill where the drainage is good on the porous soils manganese concentrations are very low.

Nickel concentrations fall into three populations with breaks at 21 ppm and 71 ppm. The highest population marks the eastern, western and 'powder hut' anomalies more sharply than any other element. A contour at 50 ppm follows the 71 ppm contour, but shows that the dispersion is chiefly in a westerly direction, which would be the direction of hydromorphic or ice transport, or both. The 30 ppm contour encloses much of the bottom of the valley of Glenshanna Burn and follows the eastern and western anomalies to the summit of Grey Hill (Appendix VI, Figure 6). Low-order nickel anomalies are also found in the bottom of Trough Hope where these may be related to concentration on humic acids, iron and manganese oxides, and on the southern spur of
Alkin Hill where they are associated with copper, lead and antimony anomalies.

The background concentration for zinc ranges between 0 and 100 ppm with a mean value of 48 ppm. Samples containing >130 ppm Zn form the topmost population, and were collected in peaty hollows. Values between 100 ppm and 130 ppm delineate the western and 'powder hut' anomalies, the boulder clay in between them, and also the bottom of Trough Hope. The eastern anomaly is not marked by any increase in zinc concentration but a small anomaly further to the east is coincident with anomalous copper and barium values.

The distribution of arsenic clearly marks both the eastern and western anomalies. An analysis of the data reveals three populations with boundaries at 25 ppm and 350 ppm. The highest of these coincides with the highest antimony concentrations over the two major anomalies, the enclosed area being attenuated towards the summit of Grey Hill (Appendix VI, Figure 3). The middle population surrounds this, broadening to enclose the entire area of the boulder clay around Glenshanna Burn, and almost reaching the watershed on the south side of the valley, except at the foot of Alkin Hill above the powder hut. Further values in this population are found on the eastern side of Trough Hope, but in this case they do not coincide with high concentrations of other elements. It is probable that the geographical distribution of this element is partially controlled by overburden conditions resulting in relatively low concentrations in the thin porous soils of the hilltops. The highest concentrations are clearly derived from the weathering of arsenical fracture-controlled mineralisation, but taking into account the relatively high background values and the unfavourable conditions for the accumulation or retention of mobile heavy metals in the soil in the background areas it is likely that the underlying greywackes form a diffuse source of arsenic in addition to that derived from the fracture-controlled mineralisation.

After this investigation was completed, soil sampling was extended north-eastwards along strike from the area of Glendinning mine. Anomalous arsenic values were found, utilising the rapid field method of analysis described in Appendix VII, and will be described in a subsequent report.

RESULTS OF GROUND SURVEYS

Anomalies were found with both IP and VLF–EM and are summarised on Figure 7 and Appendix VI, Figure 1. The VLF–EM results are shown as contours of the filtered in-phase component (Fraser, 1969) and the IP anomaly is given as the position of suboutcrop of high chargeability material interpreted subjectively from the pseudosections. Full geophysical profiles of the five lines on which IP measurements were made are given in Appendix IV, with pseudosections of apparent resistivity, chargeability and VLF current-density (calculated by the method of Karous and Hjelt, 1977), and profiles of VLF in-phase and out-of-phase components.

Two distinct linear trends can be recognised on the Fraser-filter contour map. The main anomaly follows the stronger trend, oriented 105°. A broad VLF–EM crossover of about 80% maximum amplitude giving Fraser-filter values of up to 60 is accompanied by a zone of high chargeability (up to 35 ms against background variations of 3 to 8 ms). The width of the source, estimated from pseudosections of chargeability and VLF current-density, is 30 to 50 m and it is probably near-vertical. The absence of steep marginal gradients on the pseudosections suggests that the source is diffuse or fails to reach the surface. In the north, the anomaly becomes confused by cultural noise, while to the south it becomes slightly weaker before running out of the area surveyed. Geophysical logs of BHs 3–4, which were drilled to investigate this anomaly, show a correlation of chargeability, conductivity and SP with fine-grained sulphide regarded as mainly stratabound on petrographic evidence (Figure 8). However, the mise-à-la-masse method failed to show electrical continuity between the mineralisation intersected by these two boreholes.

Several other VLF–EM anomalies share the 015° orientation which is the same as that of the fault lineaments in the district (see Figure 3). The strongest anomalies in fact coincide with the individual fractures or swarms of fractures. Only the main anomaly already described has significantly high chargeability but two noteworthy VLF–EM features with this trend are the double-peaked anomaly 350–400 m west of the main anomaly, and the weaker, relatively narrow feature intersected by BH4. The geo-
Fig. 7 VLF—EM map of the area shown in Fig. 6; IP maxima also shown
physical logs of this borehole show only a narrow zone of high chargeability, conductivity and SP, corresponding to an intersection of fine-grained stratabound sulphide (Figure 8).

The second linear trend visible on the Fraser-filter map runs roughly parallel to the geological strike and to the old workings described by Wilson (in Dewey, 1920). It is much weaker than the first trend; indeed, by subjective contouring it can be reduced to insignificance. Three main anomalous zones may be recognised, lying 150-200 m north of the baseline, approximately along the baseline, and about 150 m to its south. Two of the old workings occur at intersections of these anomalies with anomalies on the 015° trend.

**BOREHOLE GEOPHYSICS**

Boreholes 2, 3 and 4 were logged at 1 m intervals with a lateral IP-SP sonde. The electrode configuration was C₂P₁P₂ with C₂ up the hole and P₁P₂ 0.105 m. Self potentials were measured relative to a stationary electrode at ground level; chargeabilities were measured over the period 150-1020 ms after switch off of a 2 second polarising pulse.

Borehole 2 was logged from 10 m to 110 m (Figure 9). Apparent resistivities ranged from 80 to 4500 ohm metres and chargeabilities range from 4 to 170 ms. Values above 70 ms occur in three zones, 52-61 m, 70-74 m and 91-96 m. These zones also have reduced apparent resistivities down to 80 ohm metres. Anomalous zones of SP at 55 m and 93 m correlate well with IP anomalies.

Borehole 3 was logged from 6 to 190 m. Apparent resistivities ranged from 33 to 14000 ohm metres and chargeabilities from 0 to 193 ms. Numerous zones with chargeabilities above 70 ms were identified (Figure 8) and coincide closely with arsenic and therefore sulphide distribution. The form of the transient decay curve in non-mineralised sections of the borehole is substantially different from that in sulphide-rich sections and indicates a different 'IP' process in operation. SP anomalies up to 100 mV again correlate well with the anomalous zones of IP.

The IP log for BH4 (13-82 m) shows only two thin zones at 26 and 32 m with chargeabilities above 20 ms. These also show small SP anomalies and coincide very closely with the observed distribution of sulphides in the core (Figure 8).

Continuity of mineralisation between boreholes 2 and 3 was partly explored by 'mise-a-la-masse' techniques. A current electrode was placed in a zone of low resistivity at 57 m depth in borehole 2 and the sonde (with the other current electrode and the potential electrodes) was operated in BH 3. No obvious continuity was found between conductive zones in the two boreholes.

The detailed downhole logs, together with descriptions of the methods used, are available in an internal report (Rollin, 1980) from the Head, Applied Geophysics Unit, Institute of Geological Sciences, Nicker Hill, Keyworth, Nottingham NG12 5GG.

**BOREHOLE RESULTS**

**INTRODUCTION**

The shallow drilling carried out near Glendinning mine was designed to investigate the bedrock sources of closely coincident geochemical and geophysical anomalies in ground where exposure is limited to a few small outcrops of unmineralised greywacke. These anomalies are referred to as the eastern and western anomalies in the preceding text and are shown in Figures 6 and 7 together with the sites of the boreholes. Table 3 lists the general characteristics of the boreholes, and a summary of the principal metalliferous intersections obtained is given in Table 4. Details of the lithology of the drill cores and of the mineralisation they display are presented in Appendix I. Geochemical analyses of the cores are given in Appendix II together with summaries of their lithology, mineralisation and the development of features of brecciation, debris flow characteristics and faulting. The petrography and mineralogy of selected core samples are described in Appendix III.

Sections through the four boreholes (Figures 8 and 9) do not differentiate between the main lithologies of the greywacke sequence because of their gradational character and rapid alternation. Approximately 80% of the sequence is composed of grey greywacke ranging from siltstone to sandstone. Mudstone is a minor component, varying

Table 3  Location and general characteristics of boreholes

<table>
<thead>
<tr>
<th>Borehole No.</th>
<th>Nat. Grid Ref. (NY)</th>
<th>Elevation m</th>
<th>Inclination degrees</th>
<th>Azimuth</th>
<th>Depth m</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3139 9652</td>
<td>290.0</td>
<td>50</td>
<td>098</td>
<td>85.27</td>
</tr>
<tr>
<td>2</td>
<td>3147 9693</td>
<td>380.1</td>
<td>50</td>
<td>103</td>
<td>118.80</td>
</tr>
<tr>
<td>3</td>
<td>3143 9669</td>
<td>317.1</td>
<td>60</td>
<td>104</td>
<td>197.82</td>
</tr>
<tr>
<td>4</td>
<td>3135 9671</td>
<td>316.6</td>
<td>50</td>
<td>287</td>
<td>84.87</td>
</tr>
</tbody>
</table>

All located on 1:10 560 Grid Sheet NY 39 NW
Filtered in-phase VLF readings

- Chargeability, milliseconds
- Younging direction
- Bedding
- Fault
- Interaformational breccia
- Breccia vein

**Fig. 8** Geological section through boreholes 3 and 4 at Glendinning (located on Fig. 6) showing distribution of stratabound arsenopyrite—pyrite assemblages, arsenic distribution and IP (chargeability) logs; surface VLF measurements are also given.
Fig. 9 Geological sections through boreholes 1 and 2 showing arsenic distribution in drillcore and the IP log of borehole 2.
Table 4 Principal metalliferous intersections in the boreholes

<table>
<thead>
<tr>
<th>Borehole</th>
<th>Depth (m)</th>
<th>Inclined</th>
<th>True</th>
<th>Generalised lithology</th>
<th>Fe</th>
<th>Cu</th>
<th>Zn</th>
<th>As</th>
<th>Sb</th>
<th>Pb</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>58.99–67.37</td>
<td>8.38</td>
<td>2.2</td>
<td>IFB, siltstone, sandstone</td>
<td>4.28</td>
<td>28</td>
<td>29</td>
<td>2867</td>
<td>55</td>
<td>279</td>
</tr>
<tr>
<td>2 (a)</td>
<td>44.38–61.69</td>
<td>17.31</td>
<td>8.6</td>
<td>Siltstone, breccia vein, sandstone, mudstone</td>
<td>4.79</td>
<td>30</td>
<td>22</td>
<td>4226</td>
<td>70</td>
<td>35</td>
</tr>
<tr>
<td>(b)</td>
<td>90.77–114.73</td>
<td>23.96</td>
<td>c4</td>
<td>Siltstone, IFB, sandstone, breccia vein</td>
<td>4.34</td>
<td>37</td>
<td>23</td>
<td>4728</td>
<td>48</td>
<td>47</td>
</tr>
<tr>
<td>3 (a)*</td>
<td>73.52–107.62</td>
<td>34.10</td>
<td>11.8</td>
<td>IFB, siltstone, sandstone, mudstone</td>
<td>4.51</td>
<td>33</td>
<td>124</td>
<td>6880</td>
<td>145</td>
<td>315</td>
</tr>
<tr>
<td>(b)</td>
<td>124.22–153.05</td>
<td>28.83</td>
<td>7.3</td>
<td>IFB, sandstone, siltstone</td>
<td>4.46</td>
<td>35</td>
<td>19</td>
<td>5008</td>
<td>98</td>
<td>115</td>
</tr>
<tr>
<td>4</td>
<td>24.39–34.10</td>
<td>9.71</td>
<td>c6</td>
<td>Siltstone, sandstone</td>
<td>5.11</td>
<td>30</td>
<td>153</td>
<td>3098</td>
<td>229</td>
<td>505</td>
</tr>
<tr>
<td>General average</td>
<td>(40m)</td>
<td></td>
<td></td>
<td></td>
<td>4.55</td>
<td>32</td>
<td>60</td>
<td>5066</td>
<td>105</td>
<td>187</td>
</tr>
</tbody>
</table>

*On the basis of this intersection, the base metal (Cu:Zn:Pb) ratio of the deposit is 7:26:67.

from grey to green in colour and in places stained maroon. The bedding of these lithologies is commonly disrupted and clasts of one or more types can be incorporated in a matrix of a third (note the high incidence of Feature D in Appendix II logs).

Intraformational breccias (IFBs) and breccia veins are distinctive lithologies characteristically enriched in sulphides and are, therefore, depicted in Figures 8 and 9 along with bedding plane and fault directions inferred from core measurements (see note a, Appendix I). The accompanying histograms of arsenic distribution, based on analyses of half-cores, nevertheless illustrate that arsenopyrite and arsenical pyrite (Appendix III, Table VI–VII) are also widespread in the greywackes, both as stratabound and vein minerals (Appendix II). Other sulphide minerals (see Table 6) occur in very minor amounts and are restricted to ubiquitous quartz and carbonate veinlets. The down-hole variations in chargeability for BHs 2–4 correspond closely to the distribution of arsenic which, as can be seen from Figure 9, is essentially controlled by the observed incidence of stratabound arsenopyrite and pyrite.

Core recovery of 99% or better was achieved throughout the drilling, despite the faulted and brecciated nature of much of the rock. Coring in the important intraformational breccias was complete and bedrock was successfully intersected beneath thick boulder clay in BH 1.

**BOREHOLE 1**
This hole was collared in drift filling the valley of Glenshanna Burn and inclined eastwards to cut the eastern anomaly near its southern end (Appendix VI, Figure 1). Boulder clay persisted to an inclined depth of 26 m and clay-rich bands within it carry higher values of arsenic, antimony and lead than the topmost bedrock (cf. results for CXD 1001–1004 with those for CXD 1005–1007, Appendix II, Table I). Bedding apparently dips at 70°E or steeper and is accompanied by several faults (Figure 9).

Arsenopyrite and pyrite, both stratabound and vein in type, are best developed over some 2 m of IFB and adjoining greywacke at about 50 m below surface. Lead values are somewhat enhanced and traces of stibnite occur in veinlets together with dickite. Gold was detected at the 0.01–0.1 ppm Au level in three of five samples analysed, and traces of mercury are present (Appendix II, Table V).

**BOREHOLE 2**
This hole was sited in weathered bedrock on the south side of Grey Hill some 400 m NNE of BH 1 to intersect the northern part of the eastern anomaly. Bedding is less steeply inclined in the upper and lower sections of the borehole, suggesting folding, while faulting is less common than in BH 1.

Mineralisation of significance commences some 35 m below surface. A 2 m-thick breccia vein containing disseminated pyrite and arsenopyrite (evidenced by high iron values and low calcium values in samples CXD 1131–1132, Appendix II, Table II), is accompanied by sulphide disseminations in adjacent greywackes, yielding an 8.6 m intersection averaging 0.42% As which extends to 48 m below surface. A second thick zone of stratabound sulphide occurs at 70–90 m below surface in greywackes, IFB units and a breccia vein (Table 4 and Figure 9). Because the dip of the bed appears to be almost the same as that of the borehole (50°) the true thickness of this zone is estimated to be only about 4 m. The contents of antimony and base metals in the sulphide zones intersected by BH 2 are unexceptional.

**BOREHOLE 3**
A borehole drilled midway between BHs 1 and 2 to
intersect the IP maximum associated with the eastern anomaly proved to be the most successful of the four. Pyrite and arsenopyrite, mostly strata-bound in character, occur through several tens of metres of rock, although variations in the apparent dip in the upper and lower parts of the section (Figure 8) may signify repetition by folding. A fault at around 40 m inclined depth is a further source of complication. This fault may extend eastwards to surface where a small topographic depression follows the 015° direction of faulting characteristic of the district. A westerly younging direction was inferred from graded bedding observed in the greywackes at 109 m inclined depth.

The highest sulphide concentrations are in two well developed IFBs at around 65 m and 120 m below surface. The upper one is about 4 m thick and together with 8 m of adjoining greywackes grades 0.69% As. Antimony, lead and zinc are somewhat enriched in this zone while calcium is depleted relative to less mineralised rocks higher in the borehole (Appendix II, Table III). The lower IFB is probably 3 m in thickness and when included with 4–5 m of adjacent greywackes yields a grade of 0.5% As (Table 4). Calcium is again depleted but the levels of antimony and base metals are unexceptional. A third zone of lower but nevertheless significant arsenic content is associated with a breccia vein or IFB about 1 m thick 150 m below surface.

The borehole was terminated in greywackes carrying only traces of pyrite and stibnite, but further concentrations of stratabound sulphide may occur at greater depth.

**BOREHOLE 4**
The final borehole was collared 56 m north-east of the main adit portal and drilled westwards to intersect the western geochemical-geophysical anomaly. In the roof of the portal 0.5 m of brecciated greywacke is exposed trending approximately 030°. This structure is probably represented in the zone of faulting intersected at 25–34 m inclined depth where the only mineralisation of note in BH 4 is developed (Figure 8). Pyrite and arsenopyrite are disseminated through the broken greywackes and also occur in veinlets with semseyite, bournonite and sphalerite, thus accounting for the relatively high values of antimony, lead and zinc in this intersection (Table 4). The estimated thickness of 6 m for this faulted zone of mineralisation is based on measurements of bedding in unfaulted, apparently vertical strata elsewhere in the borehole (Appendix I, Table IV). Analyses of four samples from the mineralised zone show that traces of mercury and in one instance a trace of gold are present (Appendix II, Table V).

**PETROGRAPHY**

**NOMENCLATURE**
The predominant lithological type is greywacke. Following Warren's (1963) definition of greywacke as 'a rock comprising poorly sorted angular rock and mineral fragments ranging from sand to conglomerate set in a substantial matrix of finer material', the term has been further augmented and greywacke-sandstone is used to denote those rocks which are of sand grade. The terms greywacke-siltstone and greywacke-mudstone are used to denote those rocks which are below sand grade but which are otherwise comparable with greywackes. These rocks frequently form part of the same sedimentary unit in that the greywacke-siltstone and greywacke-mudstone form the top part of a graded greywacke bed. For brevity, the prefix 'greywacke' has been omitted in the following account.

**SANDSTONES**
These rocks are mainly grey in colour but when weathered they become greenish-grey or brownish (e.g. CXD 1537, Appendix III, Table I). Quartz is the dominant mineral. It is generally angular to sub-angular and ill-sorted and frequently displays undulose strain extinction.

Albite-oligoclase is a minor constituent, forming grains which are always smaller and more rounded than those of quartz. Traces of potassic feldspar are also present, and many of the grains are cloudy due to sericitic alteration. Almost total replacement of feldspar by carbonate is not uncommon.

Chlorite occurs probably as a replacement of earlier ferromagnesia mineral fragments and is also assumed to be present in the turbid, undifferentiated matrix, together with small sericite flakes. Large shreds of muscovite showing strained optical characters are of frequent occurrence. Many specimens contain abundant detrital biotite which is invariably altered to hematite. Some of the flakes were isolated and identification as hematite confirmed by X-ray diffraction (CXD 15.31, Appendix III, Table III).

Ferroan dolomite is the most abundant carbonate mineral present. It is a major constituent of the matrix of most of the sandstones although in some instances (e.g. CXD 1537, Appendix III, Table I) it is conspicuous by its absence. As a matrix component it is generally very fine grained and as such its distribution throughout the matrix is only apparent after staining. The mineral is also observed replacing some of the sandstone components such as the feldspars and rock fragments and in some instances replacement has been almost total, thus masking much of the fabric and mineralogy. A second carbonate component again consisting of ferroan dolomite, is associated with epigenetic veins where it occurs as large inter-
Table 5 Modal analyses of greywackes

<table>
<thead>
<tr>
<th>CXD No.</th>
<th>1518</th>
<th>1505</th>
<th>1506</th>
<th>1537</th>
<th>1517</th>
<th>1541</th>
<th>1526</th>
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<tbody>
<tr>
<td>PTS No.</td>
<td>5865</td>
<td>5852</td>
<td>5853</td>
<td>5859</td>
<td>5864</td>
<td>5874</td>
<td>5871</td>
</tr>
<tr>
<td>Quartz</td>
<td>37.20</td>
<td>40.40</td>
<td>51.86</td>
<td>41.86</td>
<td>51.86</td>
<td>35.26</td>
<td>57.73</td>
</tr>
<tr>
<td>Feldspar</td>
<td>0.06</td>
<td>1.06</td>
<td>1.46</td>
<td>1.53</td>
<td>0.13</td>
<td>0.13</td>
<td>0.20</td>
</tr>
<tr>
<td>Sulphide</td>
<td>0.86</td>
<td>1.33</td>
<td>0.26</td>
<td>0.66</td>
<td>0.53</td>
<td>6.20</td>
<td>1.73</td>
</tr>
<tr>
<td>Iron oxide</td>
<td>0.06</td>
<td>0.06</td>
<td>0.73</td>
<td>0.86</td>
<td>0.33</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Tourmaline</td>
<td>0.06</td>
<td>0.13</td>
<td>0.13</td>
<td>0.13</td>
<td>0.06</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Zircon</td>
<td>0.13</td>
<td>0.73</td>
<td>0.26</td>
<td>0.20</td>
<td>0.06</td>
<td>0.33</td>
<td>0.06</td>
</tr>
<tr>
<td>Matrix including dolomite</td>
<td>59.0</td>
<td>51.53</td>
<td>44.73</td>
<td>54.20</td>
<td>46.40</td>
<td>56.80</td>
<td>38.86</td>
</tr>
</tbody>
</table>

Rock fragments:
- Acid igneous
- Basic igneous
- Sedimentary
- Metamorphic


Based on counts of 1500 points on each specimen

locking rhomb-shaped crystals. Wall rock alteration is associated with these carbonate veins and can be quite intense, extending as a front of waning intensity, usually over distances of 0.5 to 1.5 cm.

Carbonate replacement, the most extensive of the chemical changes affecting the wall rock at Glendinning, is a regional phenomenon. Rust (1965b) and Weir (1974) describe intense carbonate replacement in Silurian greywackes from southwest Scotland, and consider that the often patchy carbonate distribution and subsequent replacement may be due to the redistribution of primary material in the sediments. On this basis the matrix dolomite in the sediments at Glendinning may be considered to be of synsedimentary and/or diagenetic origin.

Iron oxide (hematite) occurs throughout the rocks, predominantly as a replacement of biotite and pyrite. It also probably accounts for the red iron staining on most of the rock surfaces and the russet colour of the sub-microscopic matrix. Minor amounts of detrital zircon and tourmaline were noted in most sections.

Small numbers of rock fragments, mainly of sedimentary type, are present in most of the sections examined. However, as already stated, diagenetic carbonate replacement has often been intense so that the composition of many fragments is conjectural. The fragments considered to be of metamorphic origin are usually coarse quartz aggregates which exhibit variegate extinction. Some extremely fine-grained siliceous fragments, tentatively classed as acid igneous in type, could alternatively represent a fine-grained metamorphic rock or even chert fragments. Two fragments of black glass with feldspar phenocrysts representing basic igneous rocks, were also recognised.

Modal compositions of seven sandstones (Table 5) do not correspond to normal greywacke because of carbonate replacement. The matrix contains quartz, chlorite, mica, clay mineral (illite) and hydrated iron oxides as well as dolomite. The nature of the sulphides present is discussed later in the report.

SILTSTONES
These are normally greenish-grey, laminated rocks which are essentially a fine-grained equivalent of the sandstones; the grain size is between that of fine sand and silt. Identification of contained rock fragments is very difficult because of their small particle size.

MUDSTONES
The mudstones in the drill cores are greenish-grey to dark grey or reddish in colour. Cleavage is not well developed but they are frequently laminated with bands measuring 0.5 to 2 mm in width. Some of the mudstones (e.g. CXD 1507, Appendix I, Table I) contain lenses of a more silty character which imparts a distinctive, discontinuous streakiness to the rock. The colour of these pelagic sediments reflects slight differences in mineralogy. Those of greenish aspect are more rich in chlorite while reddish varieties contain abundant hydrated iron oxide. Compositionally the mudstones may be considered as being similar to the matrix of the
sandstones. Bulk XRD analysis (CXD 1565, Appendix III, Table III) indicates a composition of quartz, dolomite, illite and a trace of hydrated iron oxide.

**INTRAFORMATIONAL BRECCIAS**

The breccias are dark grey in colour and consist of large angular fragments of mudstone, siltstone and sandstone. The finer-grained members are frequently strongly sericitised and appear greenish in colour. These fragments frequently contain abundant thinly banded and disseminated pyrite and arsenopyrite (e.g. CXD 1558, Appendix I, Table II). The matrix usually consists of coarsely crystalline quartz with traces of carbonate and abundant disseminated pyrite and arsenopyrite. In one instance (CXD 1566, Appendix I, Table II) have a reddish appearance which can be ascribed to arsenopyrite with a trace of carbonate. These brecciated rocks are invariably dissected by many discontinuous carbonate veins which also contain small amounts of pyrite and arsenopyrite. Some breccias (CXD 1562, Appendix III, Table II) have a reddish appearance which can be attributed to the presence of hematite possibly formed by circulating groundwater. The form and distribution of the sulphide minerals in these rocks is described later in the report.

Where unaffected by tectonic shearing, vein- and fracturing, certain intraformational breccias display the characteristics of debris flows as described by Middleton and Hampton (1973), namely

a. a matrix supported framework,
b. a texture which is internally structureless, and
c. an unsorted and wide range of clast size.

Typical examples are found in BH 3 (75–83 m and 134.7–140.6 m) and BH 4 (15.06–16.19 m).

Some of the clasts of siltstone and fine-grained sandstone in the debris flows contain veins which apparently do not persist into the more mud-rich matrix, suggesting incorporation of clasts from a lithified and veined sequence removed from the area of debris flow deposition. However, many of the clasts in the debris flows seem very similar to material in the bedded greywacke sequence, suggesting a local provenance.

**CLASSIFICATION OF THE TURBIDITE SEQUENCE**

Although there has been no recent sedimentological study of the Silurian rocks of southern Scotland, a broad interpretation of the sequence observed in the borehole cores can be made based on existing models of turbidite fan sedimentation (e.g. Walker and Mutti, 1973). Most of the sediment comprises classical proximal turbidites (typically 1a, c) and classical distal turbidites (typically, 1c, d, e), facies C and D respectively (see Figure 10). Debris flows and slumped horizons (facies F) occur at various positions evidencing downslope mass movement (see below). Local mudstone dominant sections, especially in BH 4 may represent basin—plain or mainly pelagic sedimentation.

The high proportion of facies C and D together with the predominance of fine to very fine sandstone and coarse siltstone suggest a depositional environment ranging from mid fan (depositional lobes) to outer fan for most of the sequence. The presence of crude thickening and coarsening upward sequences (as in Figure 10a) supports this interpretation. Although major slumping and thick debris flows are generally confined to the inner fan environment, minor occurrences are not uncharacteristic of mid-outer fan areas (e.g. Ricci-Luchi, 1975).

The sediment in the boreholes displays a comprehensive range of features indicating downslope movement, from disrupted bedding involving extensional deformation (e.g. boudinage) through slump folds to debris flows. This represents a consistent progression and might further suggest that the debris flows represent truly intraformational deposits (i.e. they are derived from the same formation) as opposed to being derived from older sources. The observed thickness range (<4 m) also suggests that they may be local deposits.

**ORE MINERALOGY**

**INTRODUCTION**

The composition of the worked antimony mineralisation at Glendinning can now only be gauged from dump material and especially from ore fragments remaining on two small sorting floors (Figure 6). The mineral composition of a small number of sorting floor specimens is summarised in Appendix III (Table V). Early records of the lead-antimony sulphide sempseyite (Smith, 1919) and of the antimony oxide valentinite (Dewey, 1920) have been confirmed (MacPherson and Livingstone, 1982) but not those of jamesonite, kermesite and cervantite (Dewey, 1990). Material named jamesonite and cervantite in the Royal Scottish Museum collections are respectively zinkenite and stibiconite (MacPherson and Livingstone, 1982). Traces of valentinite and kermesite may be present in the borehole cores but their identification has not been validated by X-ray studies.

The mineral assemblage recorded in this investigation, based on examination of borehole cores, is listed in Table 6 and in the following sections the main characteristics of the sulphide minerals are described. Figure 11 summarises the paragenetic sequence proposed for the strata-bound and vein mineralisation at Glendinning.
<table>
<thead>
<tr>
<th>Facies Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>a, b</td>
<td>turbiditic/hemipelagic mudstone</td>
</tr>
<tr>
<td>c, d, e</td>
<td>sandstone (fine to very fine) and coarse siltstone</td>
</tr>
<tr>
<td>a, b, e</td>
<td>debris flow</td>
</tr>
<tr>
<td>a, b, c, e</td>
<td>slumping/extensional soft sediment deformation</td>
</tr>
<tr>
<td>a, b, e</td>
<td>graded medium-fine grained sandstone unit</td>
</tr>
<tr>
<td>a, e</td>
<td>facies type</td>
</tr>
<tr>
<td>D, c, d, e</td>
<td>Bouma sequence units</td>
</tr>
<tr>
<td>a, e</td>
<td>thickening/coarsening upwards sequence</td>
</tr>
</tbody>
</table>

**Fig 10** Classified greywacke sequences from the Silurian at Glendinning: (a) BH4, 7.7-17.4 m inclined depth, (b) BH3, 191.3 (stratigraphic base)- 181.0 m inclined depth. Facies type after Walker and Mutti (1973)
**Table 6** Minerals recognised from drill core, boreholes 1–4

<table>
<thead>
<tr>
<th>Silicates</th>
<th>Sulphate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartz</td>
<td>Baryte</td>
</tr>
<tr>
<td>Plagioclase</td>
<td></td>
</tr>
<tr>
<td>Potassic feldspar</td>
<td></td>
</tr>
<tr>
<td>Biotite</td>
<td></td>
</tr>
<tr>
<td>Sericite</td>
<td></td>
</tr>
<tr>
<td>Muscovite</td>
<td></td>
</tr>
<tr>
<td>Chlorite (not differentiated)</td>
<td></td>
</tr>
<tr>
<td>Illite</td>
<td></td>
</tr>
<tr>
<td>Dickite</td>
<td></td>
</tr>
<tr>
<td>Tourmaline</td>
<td></td>
</tr>
<tr>
<td>Zircon</td>
<td></td>
</tr>
<tr>
<td>Oxides</td>
<td></td>
</tr>
<tr>
<td>Hematite</td>
<td>Sulphides</td>
</tr>
<tr>
<td>Goethite</td>
<td>Pyrite*</td>
</tr>
<tr>
<td>?Valentinite</td>
<td>Arsenopyrite*</td>
</tr>
<tr>
<td>?Kermesite</td>
<td>Galena</td>
</tr>
<tr>
<td>Carbonates</td>
<td>Others</td>
</tr>
<tr>
<td>Dolomite</td>
<td>Apatite</td>
</tr>
<tr>
<td>Calcite</td>
<td>Undifferentiated hydrated iron oxides</td>
</tr>
<tr>
<td>Aragonite</td>
<td></td>
</tr>
</tbody>
</table>

*Sulphides found in both stratiform and vein assemblages

**SULPHIDES**

**Pyrite**
Recognised by its colour — pale brass yellow — splendent lustre and crystal habit, the cube [100] and the pyritohedron [210] being dominant. As stratabound mineralisation pyrite can form massive bands of euhedral to subhedral crystal aggregates (0.1–1.5 mm grain size), but it is more commonly disseminated throughout the rocks in grains up to 0.5 mm across. Pyrite was also noted as disseminated globular crystals (up to 0.5 mm diameter), and more rarely as euhedral crystals in later epigenetic quartz and carbonate veins.

Following the method of Ramdohr (1969, p. 781) several thin sections were etched in a solution of \( \text{H}_2\text{SO}_4 + \text{KMnO}_4 \) which enabled structural and textural features to be observed. The interlocking pyrite grains of the stratabound bands as well as the euhedral to sub-euhedral disseminated variety generally display well-developed, oscillatory zoning. However, in some instances this textural feature is absent; Ramdohr (op. cit.) has suggested that the results obtained by this etching method may not be uniform and there is also the possibility that lack of zoning may be due to slight differences in composition or recrystallisation. The globular pyrite grains are unzoned but etching appears to highlight their concentric mode of growth.

Electron microprobe analyses of trace elements in the pyrite from Glendinning (Appendix III, Tables VI–VII) revealed cobalt values of up to 2140 ppm, nickel up to 4990 ppm, and As values which match the highest to be recorded in pyrite (5% As) by Vaughan and Craig (1978, p. 362). Copper values reach 780 ppm. Silver and selenium were below detection limits but antimony reached 1470 ppm. However, apart from arsenic, trace element values were variable with highest Co and Ni values occurring in the same grains. High arsenic values were also recorded in euhedral pyrite disseminated and in veins, and also in globular pyrite.

**Arsenopyrite**
Characterised by its silver-white colour, metallic lustre and prismatic habit: (0.2–5.0 mm grain size). In reflected light a polished surface of the mineral displays blue-green-brown anisotropy. Electron microprobe analyses of the arsenopyrite (Appendix III, Table VIII–IX) indicate Co and Ni values comparable with those obtained from pyrite. The antimony level is appreciable (up to 5000 ppm) and copper reached 540 ppm.

**Sphalerite**
Typified by its translucent brown to yellow colour, resinous lustre, highly perfect cleavage and cubic habit.

**Galena**
Recognised by its lead-grey colour, metallic lustre, perfect cleavage and cubic habit.
**Bournonite** (2PbS. Cu₂S. Sb₂S₃)
Characterised by its steel-grey colour, brilliant metallic lustre, brittle nature (H=2.5) and distinctive prismatic habit. Individual crystals are often traversed by minute cracks. Under reflected light, a polished surface of the mineral displays a characteristic greenish tint. MacPherson and Livingstone (1982) note the presence of 0.2% Sn in bournonite occurring in sorting floor material.

**Semseyite** (9PbS₄Sb₂S₄)
This mineral was identified only in one sample (CXD 1533, Appendix III, Table IV) after crushing and X-ray diffraction of tiny dark grey to black prismatic crystals. It is most probably a constituent of a veinlet in the sample.

**Stibnite**
Typically observed as steel-grey films or ‘blooms’ on fracture surfaces, many of which are associated with carbonate veinlets. Very rarely seen as confused aggregates of acicular dark grey crystals (CXD 1543, Appendix III, Table III). The mineral has a metallic lustre and is subject to a black tarnish. Under reflected light stibnite exhibits very strong blue anisotropy.

**Chalcopyrite**
Recognised by its brass-yellow colour which is often tarnished or iridescent, chalcopyrite occurs only rarely in the cores and only as a vein constituent.

**Tetrahedrite** (Cu₃SbS₃)
Characterised by its appearance in veins as a flint-grey mineral with a typical tetrahedral habit. Identification was confirmed by X-ray powder photography (Ph 6460: CXD 1576).

**Tennantite** (Cu₃AsS₃)
This mineral is isomorphous with tetrahedrite but was distinguished by X-ray powder photography (Ph 6477: CXD 1592).

**Cinnabar**
Recognised by its striking cochineal-red colour, adamantine lustre and low hardness (about 2). The mineral was noted as a minor accessory in panned stream sediment concentrates and its previous transport history had removed any distinct crystal morphology.

### MINERALISATION

#### STRATABOUND MINERALISATION
The stratiform pyrite-arsenopyrite mineral assemblage displays textural features supporting a synsedimentary origin. Perhaps the most obvious feature is the frequent concentration, particularly in the fine-grained lithologies, of pyrite and arsenopyrite in individual bands that lie parallel to the original bedding. Further textural evidence for synsedimentary mineralisation is provided by the intraformational breccias which are considered to have formed by penecontemporaneous fragmentation and redeposition of sulphide sediment and sulphide mud as a result of sediment instability and turbidity flow.

The sulphide-rich bands range up to 8 mm in thickness (e.g. BH2, 46.2 m CXD 1536) and the pyrite from these bands displays strong zoning. Wheatley (1977), with reference to sulphides from Avoca Mine in Ireland, suggests that primary, zoned crystalline pyrite implies growth below the sediment-water interface in a low pH environment supersaturated with iron. It seems very probable that the primary zoned pyrite at Glendinning was formed in a euxinic environment and that the arsenopyrite which is intimately associated with the pyrite is also of synsedimentary origin.

It is generally acknowledged that the Co:Ni ratio in pyrite provides an indicator of the origin of the pyrite (Willan and Hall, 1980). Electron microprobe analyses of the Glendinning pyrite show variable levels of Co (up to 2000 ppm) and Ni (up to 5000 ppm) and low Co:Ni ratios (<6). Willan and Hall (1980) plotted average Co:Ni values of pyrite from some stratiform deposits of exhalative-synsedimentary origin and other types of mineralisation (e.g. pyrite from veins, sedimentary and diagenetic pyrite) and plots of the Co:Ni ratios from Glendinning fall within their field of stratiform deposits of exhalative-synsedimentary origin.

The Sb values in the arsenopyrite and, to a lesser extent, the pyrite, indicate that this element was a significant component of the metals present in the mineralising fluids. It thus seems probable that the antimony present in the later fracture-hosted veinlets as stibnite and other sulphides is of local derivation having been remobilised from the stratabound material. However, the possibility that stibnite or other antimony minerals occur as stratiform constituents cannot be ruled out.

The highest metal values may in part at least be due to derivation of cobalt and nickel from basic rocks of the Iapetus oceanic plate. The lower nickel values are imprecise because they occur near or below the analytical limit of detection. The cobalt values remain relatively high and plot close to those of certain exhalative copper and copper-zinc deposits on Willan and Hall's (1980) Co-Ni diagram. However, the arsenic content of the Glendinning sulphide assemblage is much higher than in the deposits considered by Willan and Hall (1980) so that it is not possible to derive a clear indication of genesis from these data.

#### VEIN MINERALISATION
The second phase of sulphide mineralisation was probably effected by CO₂ and SiO₂-bearing aqueous solutions which invaded fractures in the
rocks. The resultant veinlets post-date Caledonian deformation features such as folds and cleavages, but their upper age limit is uncertain. The network of veins is complex and at least three episodes of vein ing took place (Figure 11): (a) dolomite with a trace of quartz and minor amounts of pyrite, arsenopyrite, galena, bournonite, sphalerite, ssemseyite, chalcocpyrite, tetrahedrite and tennantite; (b) later quartz, with traces of dolomite and minor amounts of pyrite and arsenopyrite, and (c) late-stage fracture-hosted dolomite veins containing stibnite usually in the form of "blooms" or films, which post-date veins (a) and (b).

The identification of cinnabar in panned concentrates from the area suggests a possible but as yet unobserved association of this mineral with the stibnite. Antimony—mercury mineralisation is well documented, for example Maucher and Hill (1968) describe the antimony ore of Schlaining, Austria which occurs in metamorphosed sedimentary (and volcanic) rocks in which phyllites, limestones, dolomites and quartzites predominate. Arsenopyrite and pyrite are constantly associated with the stibnite ore with local concentrations of cinnabar. Muff (1978) considers this association to be strikingly similar to that in the Murchison Range of the north-eastern Transvaal, South Africa. Despite the metamorphic grade of the above examples, the lithologies at Glendinning are not dissimilar, so an antimony—mercury mineral association is perhaps not entirely out of the question.

The mineralisation observed in the drill core is in some respects similar to that collected from the sorting floors related to the worked vein. The stratiform pyrite-arsenopyrite assemblage is however absent from the sorting floor specimens, in which veins containing stibnite, sphalerite and galena, together with traces of pyrite and arsenopyrite, occur in a quartz-dolomite gangue. The fact that in the drill core stibnite was only seen embedded in carbonate in tiny veinlets which postdate the earlier sphalerite-galena-arsenopyrite sulphide mineralised veins suggests either that stibnite formation occurred during two separate events or that in the worked vein the enrichment was more intense and as such masks the order of formation.

CONCLUSIONS

The metal values of the principal mineralised intersections obtained at Glendinning (Table 4) all lie well below present economic grades. Arsenopyrite is the main constituent of economic interest, but only locally does it exceed a few percent of the rocks. The best intersection of arsenopyrite mineralisation is in BH3 where an average grade of 0.69% As is present over 34 m of drillcore, representing a true width of about 12 m. Within this intersection the highest grade is 1.45% As over about 1 m of IFB. The antimony content of this narrow section is only 125 ppm Sb, most of which is probably held in the arsenopyrite lattice. Antimony is highest (0.1%) in the BH4 intersection which is probably related to the worked structure and is accompanied by 1.3% As, 0.3% Pb, 0.08% Zn and 0.1 ppm Au over approximately 0.5 m of greywacke.

The main significance of the results of the limited amount of shallow drilling carried out at Glendinning lies in the recognition of a new type of mineralisation in Britain, namely stratiform arsenopyrite—pyrite mineralisation in a Silurian greywacke sequence. The stratiform sulphides are developed through at least a few tens of metres of succession and over at least a few hundreds of metres of strike length. They were followed by a subordinate phase of NNE—trending vein mineralisation containing antimony and base metal sulphides.

The mineralisation at Glendinning shares many features in common with that reported from the Clontibret area, County Monaghan, some 250 km south-westwards along the regional Silurian strike in Ireland (Cole, 1922; Anglo United Development Corporation Limited, 1980). Stibnite was worked on a very small scale at Clontibret from a narrow quartz vein in Silurian sediments following its discovery in 1774 and the mines were reopened in 1917. Modern exploration has demonstrated that arsenopyrite mineralisation extends for at least 1.5 km along the regional ENE—WSW strike, as well as occurring in narrow NNE—trending veins. The main interest is in gold which occurs both in the veins and in the strike-related mineralisation. In view of the considerable mineralised strike-length found at Clontibret and the distinctive gold association, further study of the Glendinning mineralisation and of its possible strike extension is merited. Although antimony minerals of stratabound type were not observed in the present investigation, the elevated antimony content of the stratiform arsenopyrite and the spatial association of the vein and stratabound mineralisation suggest a common source for the arsenic and antimony. How these metals were concentrated in a turbidite sequence, however, is uncertain. Reimann and Stumpfl (1981) ascribe the formation of stratabound stibnite mineralisation in Lower Palaeozoic rocks of Austria to exhalative activity associated with submarine volcanicity, but in the Glendinning area volcanic rocks are unknown.

ACKNOWLEDGEMENTS

This investigation was made possible by the close cooperation of Lt Col R. P. Johnson-Ferguson of Westerkirk Mains, Bentpath, Langholm. Numerous colleagues in the Institute assisted at various stages in the investigation.
Fig. 11 Mineral paragenesis in the Silurian greywacke sequence and associated mineralisation at Glendinning
REFERENCES


APPENDIX I

BOREHOLE LOGS

Note (a). The bedding angle (degrees) is the angle between the observed lithological banding or bedding in the cores and the long axis of the borehole core. In constructing the borehole sections (Figures 8 and 9) it was assumed that the true dip of the beds was sub-vertical. However, this is not necessarily the case, owing to evidence at outcrop of tight folding. Faulting is fairly common and may also invalidate the assumption of subvertical bedding.

Note (b). Sample number is a guide to the geochemical analyses in Appendix II. Where more than one lithological unit is included in a single geochemical sample all but the lowest unit in the borehole is denoted by the same sample number in parentheses.
<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Intersection</th>
<th>Bedsing</th>
<th>Lithology</th>
<th>Mineralisation</th>
<th>Sample Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>13.70</td>
<td>13.70</td>
<td>Superficial deposits</td>
<td></td>
<td>1001</td>
</tr>
<tr>
<td>16.30</td>
<td>0.50</td>
<td></td>
<td>Brown clay with pebbles</td>
<td></td>
<td>1000</td>
</tr>
<tr>
<td>30.22</td>
<td>4.39</td>
<td></td>
<td>Silty sandstone, calcareous with clay-filled fractures at 30.22 m, 30.46 m and 30.53 m</td>
<td>Numerous quartz veins</td>
<td>1006</td>
</tr>
<tr>
<td>30.53</td>
<td>0.65</td>
<td></td>
<td>Silty sandstone, calcareous with clay-filled fractures at 30.22 m, 30.46 m and 30.53 m</td>
<td>Thin orange-brown carbonates veinlets cut white quartz veins</td>
<td>1005</td>
</tr>
<tr>
<td>31.15</td>
<td>0.65</td>
<td></td>
<td>Silty sandstone, clayey, minor silicification towards base; sandstone (C65 157) occurs between clay-filled fractures at 31.60 m and 31.30 m</td>
<td>Some calcite veinletting</td>
<td>1008</td>
</tr>
<tr>
<td>31.60</td>
<td>2.36</td>
<td></td>
<td>Silty sandstone with small quartz fragments, i.e. 0.05-0.10 m as minor calcite</td>
<td>Thin calcite veinletting at 39° to some parts averaging 0.1 m in thickness, less frequent near base</td>
<td>1007</td>
</tr>
<tr>
<td>34.09</td>
<td>0.46</td>
<td></td>
<td>Silicones, brecciated and laminar, continuous to a clay gouge at top and base indicating faults</td>
<td>Numerous quartz veins</td>
<td>1006</td>
</tr>
<tr>
<td>37.17</td>
<td>0.96</td>
<td></td>
<td>Breccias, possibly a faulted interformational breccia composed of brown, highly limonitic sediment recognizable in places as silty sandstone (C65 153); sandstone at 37.00-37.12 m</td>
<td>Some dark capillary-like veins in basal mudstones; visible on fractures in sandstone</td>
<td>1009</td>
</tr>
<tr>
<td>40.12</td>
<td>1.05</td>
<td></td>
<td>Breccias, possibly a faulted interformational breccia composed of brown, highly limonitic sediment recognizable in places as silty sandstone (C65 153); sandstone at 37.00-37.12 m</td>
<td>Minor white veinletting</td>
<td>1010</td>
</tr>
<tr>
<td>41.19</td>
<td>2.01</td>
<td></td>
<td>Silty sandstone, breccia, variably limonite-stained, massive streaks of white clay</td>
<td>Calcite veinlets and seams of dark (1) sulphide on white planes</td>
<td>1011</td>
</tr>
<tr>
<td>43.19</td>
<td>2.61</td>
<td></td>
<td>Silty sandstone, containing in places a sandstone and with an irregular calcite parting or clast at 43.16-43.79 m as limeite staining prominent at margin of fractures at 43.00-43.16 m, 43.36-43.36 m and 43.36-43.45 m</td>
<td>Some specular haematite veins with pink-stained patches of dark sulphide patches in fracture at 41.20 m</td>
<td>1012</td>
</tr>
<tr>
<td>45.00</td>
<td>1.23</td>
<td></td>
<td>(?) Redstone, extensively limonite-stained</td>
<td>Some irregular, limonite-stained veinlets</td>
<td>1012</td>
</tr>
<tr>
<td>46.05</td>
<td>2.06</td>
<td></td>
<td>Broken mud and clay depositing fault</td>
<td>Numerous quartz veinlets</td>
<td>1013</td>
</tr>
<tr>
<td>46.50</td>
<td>0.12</td>
<td></td>
<td>Silty sandstone, limonite-stained adjacent to veinletting</td>
<td>Quartz veinlets in mudstone</td>
<td>1012</td>
</tr>
<tr>
<td>46.55</td>
<td>0.35</td>
<td></td>
<td>Breccia, clay and clay gouge containing fault; limonite-stained mudstone at top and base</td>
<td>Few fragments of iron sulphide; occasional quartz veinlets with white calcite blazes</td>
<td>1012</td>
</tr>
<tr>
<td>47.00</td>
<td>1.00</td>
<td></td>
<td>Gilcrete, sandy, somewhat brecciated</td>
<td>Patches of fine-grained iron sulphide; occasional quartz veinlets with white calcite blazes</td>
<td>1012</td>
</tr>
<tr>
<td>47.10</td>
<td>0.49</td>
<td></td>
<td>Interformational breccia of banded silicite clasts in mudstone</td>
<td>Fine-grained pyrite common (6.39) throughout</td>
<td>1012</td>
</tr>
<tr>
<td>48.22</td>
<td>1.07</td>
<td></td>
<td>(?) Redstone, soft, brown, broken with stringers of clay gouge containing a fault</td>
<td>Veinletting of quartz up to 1 mm thick (C65 157)</td>
<td>1013</td>
</tr>
<tr>
<td>49.02</td>
<td>0.30</td>
<td></td>
<td>(?) Redstone, brown, brecciated</td>
<td>Irregular quartz veinlets and thin veinlets of dark (?1) iron oxide</td>
<td>1014</td>
</tr>
<tr>
<td>49.75</td>
<td>1.73</td>
<td></td>
<td>15 Redstone, broken and fine-grained silicite</td>
<td>Calcite on fractures (C65 153)</td>
<td>1015</td>
</tr>
<tr>
<td>50.05</td>
<td>1.30</td>
<td></td>
<td>Silicite</td>
<td>1016</td>
<td></td>
</tr>
<tr>
<td>53.72</td>
<td>1.67</td>
<td></td>
<td>Fault breccia and at 53.16-53.72 m a brown-stained sandstone</td>
<td>Breccia interstitially and heavily varied with quartz</td>
<td>1017</td>
</tr>
<tr>
<td>55.02</td>
<td>1.30</td>
<td></td>
<td>12 Redstone, compact, grey</td>
<td>1018</td>
<td></td>
</tr>
<tr>
<td>55.53</td>
<td>0.51</td>
<td></td>
<td>Silite, heavily stained by limonite</td>
<td>Minor quartz and calcite veinlets</td>
<td>1019</td>
</tr>
<tr>
<td>56.00</td>
<td>0.25</td>
<td></td>
<td>Silite, grey</td>
<td>Calcite veinlets</td>
<td>1019</td>
</tr>
<tr>
<td>58.12</td>
<td>0.26</td>
<td></td>
<td>Sandstones, fine-grained</td>
<td>A few veinlets</td>
<td>1019</td>
</tr>
<tr>
<td>57.08</td>
<td>0.30</td>
<td></td>
<td>Redstone, limonite at top</td>
<td>Some calcite veinlets</td>
<td>1019</td>
</tr>
<tr>
<td>57.71</td>
<td>0.63</td>
<td></td>
<td>Silty sandstone, grey, hard, limonite-stained along fractures and veins</td>
<td>Quartz veinlets</td>
<td>1020</td>
</tr>
<tr>
<td>58.19</td>
<td>0.18</td>
<td></td>
<td>Redstone parting, dark grey, grading downwards</td>
<td>Pyrite in quartz veins and in dark veinlets; layers of specularite</td>
<td>1020</td>
</tr>
<tr>
<td>58.99</td>
<td>0.80</td>
<td></td>
<td>Red sandstone with irregular mudstone clasts grading into fine-grained sandstone at 58.35 m</td>
<td>Pyrite in sandstone clasts; some calcite veinlets</td>
<td>1020</td>
</tr>
</tbody>
</table>
### Inclined depth, m

<table>
<thead>
<tr>
<th>Depth Angle</th>
<th>Limestone</th>
<th>Mineralisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>40.50</td>
<td>Silstone, grey with lime stains along fractures and calcite veins; breccia zone at 40.00-40.50 m; which one clast contains thin vein of sulphides</td>
<td>Loose pieces of fine-grained pyrite, ore cut by calcite veins containing pyrite; pyrite and arsenopyrite in veinlet in breccia clasts; calcite in quartz veins at 39.00 m and 40.50 m</td>
</tr>
<tr>
<td>42.44</td>
<td>Silstone, sandy, highly valued, possibly an interformational breccia in places; sandstone</td>
<td>Nanometre arsenopyrite; nanometric dolomite–quartz veins containing pyrite and arsenopyrite; calcite on fractures (40.00 m)</td>
</tr>
<tr>
<td>48.77</td>
<td>Intrabreccia breccia varying from a totally brecciated rock to a highly valued, silty sandstone; cement composed of quartz and clay, shale matrix (48.00 m)</td>
<td>Pyrite and arsenopyrite disseminated throughout fine-grained pyrite from locally petroelastic to 30 m and below; muscovite altered; fractures; nanometric quartz veins</td>
</tr>
<tr>
<td>57.37</td>
<td>Sandstone, fine-grained with clasts of siltstone which are highly limonite-stained in places</td>
<td>Arsenopyrite and pyrite, apparently stratified at 60.00 m; pyrite also disseminated; nanometric quartz veins</td>
</tr>
<tr>
<td>69.52</td>
<td>Silstone, strongly limonite-stained with contained siltstone partings</td>
<td>Quartz veinlets no sulphides observed</td>
</tr>
<tr>
<td>74.27</td>
<td>Sandstone, fine-grained, grey, very sandy at 75.00-75.50 m; thin limonite staining is common and well-developed shear planes run 10° to the core axis leaving a fault</td>
<td>Veinlets of quartz and dark calcite, soft clay xenotile (lichens) at 74.00-74.50 m</td>
</tr>
<tr>
<td>78.90</td>
<td>Sandstone, fine-grained, highly brecciated, limonitized in part</td>
<td>Veinlets of quartz</td>
</tr>
<tr>
<td>78.97</td>
<td>Laminted siltstone, pale mudstone then sandstone, limonite-stained along veins; disseminated chlorite-limonite</td>
<td>Veinlets of quartz; traces of disseminated pyrite (78.00 m)</td>
</tr>
<tr>
<td>77.92</td>
<td>Sandstone, grey, greywacke, minor limonite staining (77.90 m); mudstone clasts near base</td>
<td>Quartz veins up to 10 mm in thickness running mainly at 60° to the core axis</td>
</tr>
<tr>
<td>78.12</td>
<td>Sandstone, initially limonite-stained; sheared, and veined at 78.00-78.50 m with shear planes in 10° to the core axis; somewhat broken siltstone near base</td>
<td>Quartz veinlets in sheared sandstone; calcite veins in limonite-stained sandstone</td>
</tr>
<tr>
<td>81.96</td>
<td>Mudstone, dark grey with bands of white mudstone, dark sandstone clasts; also sandstone with mudstone clasts</td>
<td>Pyrite in mudstone, quartz veinlets in sandstone clasts, calcite veins in mudstone clasts (78.00 m)</td>
</tr>
<tr>
<td>82.64</td>
<td>Silstone, fine-grained, highly limonite-stained at 81.95-82.50 m</td>
<td>Numerous quartz veinlets up to 1 mm in thickness in at least two generations</td>
</tr>
<tr>
<td>83.22</td>
<td>Mudstone, very fine-grained, pale grey with interbedded grey mudstone</td>
<td>A few veinlets</td>
</tr>
<tr>
<td>85.57</td>
<td>Silstone, grey, laminated with bands of pale grey mudstone (85.00 m); thin bed of green mudstone at 85.20-85.52 m</td>
<td>Some quartz veinlets up to 2 mm in thickness; fine-grained pyrite occurs at margins of green mudstone</td>
</tr>
</tbody>
</table>

**END OF RECORD AT 85.57 m**
### Table II

<table>
<thead>
<tr>
<th>Inclined depth, m</th>
<th>Intersection m</th>
<th>Bedding angle</th>
<th>Lithology</th>
<th>Mineralisation</th>
<th>Sample No. CED</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td></td>
<td></td>
<td>Siltstone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.62</td>
<td>7.62</td>
<td>(120)</td>
<td>Weathered sandstones, siltstones, very minor mudstones</td>
<td>Traces or disseminated pyrite in the sandstones; calcite veinsites; (?) siderite blown on one fracture</td>
<td></td>
</tr>
<tr>
<td>3.36</td>
<td>4.90</td>
<td>15</td>
<td>Siltstones with intercalations of fine-grained sandstones; micaceous band of green mudstones at 13.5-15.3 m, forrenbach fractures at 05.3, 05.9 and 11.2 m</td>
<td>Some irregular calcite veinsites</td>
<td></td>
</tr>
<tr>
<td>2.55</td>
<td>1.90</td>
<td>15</td>
<td>Siltstone, compact, matrix grey, poorly bedded; large siltstone clasts at 13.5-13.8 m; forrenbach fracture surfaces</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.72</td>
<td>3.99</td>
<td>0</td>
<td>Mudstones, shaly with a siltstone band at 14.60-14.80 m</td>
<td>Quarts veinlets common at 36.3 m</td>
<td></td>
</tr>
<tr>
<td>20.17</td>
<td></td>
<td>15</td>
<td>Siltstones, pale coloured with well-developed spongy laminae along bedding; fine-grained sandstones at 19.31-19.48 m; contains micaceous hematite grains</td>
<td>Amethystine calcite veinlets and pyrite grains</td>
<td></td>
</tr>
<tr>
<td>3.67</td>
<td></td>
<td></td>
<td>Sandstones, fine-grained, micaceous with siltstone laminae; pale siltstone and mudstone at 27.65-27.81 m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25.10</td>
<td>1.90</td>
<td>0</td>
<td>Mudstones, grey, weakly laminated having its contact with siltstone unit above preserved for 0.6 m along the core; sheared in planes of core axes</td>
<td>Calcite veinsites, especially at 26.4 m</td>
<td></td>
</tr>
<tr>
<td>17.62</td>
<td>2.72</td>
<td>0</td>
<td>Siltstones with endellite clasts; forrenbach fracture surfaces</td>
<td>Traces of fine-grained pyrite</td>
<td></td>
</tr>
<tr>
<td>28.02</td>
<td>1.30</td>
<td>10</td>
<td>Siltstones, alternating light and dark coloured; non-calcareous; core broken to 30.1 m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.95</td>
<td>2.90</td>
<td>0</td>
<td>Siltstones as above with numerous elongated clasts (up to 10 x 12 mm) of dark muddy siltstones orientated parallel to the core axis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.15</td>
<td>2.90</td>
<td>0</td>
<td>Siltstones as above with elongated mudstone clasts at 30.7-31.0 m</td>
<td>Quarts veinlets</td>
<td></td>
</tr>
<tr>
<td>7.00</td>
<td>1.68</td>
<td>0</td>
<td>Siltstones, alternating light and dark coloured; non-calcareous; sheared and broken on either side of a whole green mudstone at 34.0-34.57 m</td>
<td>Calcite veinlets</td>
<td></td>
</tr>
<tr>
<td>5.34</td>
<td>3.26</td>
<td>0</td>
<td>Fault zone in siltstone and soft mudstones; calcareous</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16.40</td>
<td>1.52</td>
<td>35</td>
<td>Sandstones, non-calcareous with angular clast of pale siltstone at 34.65-35.45 m</td>
<td>Quarts veinlets in siltstone clast</td>
<td></td>
</tr>
<tr>
<td>16.70</td>
<td>1.90</td>
<td>0</td>
<td>Sandstones with intercalating siltstones and mudstones; mudstone clasts in other lithologies; sandstone clasts in mudstone; sheared and voided siltstones at 35.3-35.6 m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12.00</td>
<td>3.90</td>
<td>0</td>
<td>Siltstones, locally varying to fine-grained sandstone with mudstone clasts; some mudstone bands</td>
<td>Pyrite disseminated in siltstone at 42.5 m and (?) sphalerite in quartz veinlets at 10.2 m (CED 132): calcite vein on shear planes at 39.4-39.9 m</td>
<td></td>
</tr>
<tr>
<td>12.77</td>
<td>0.17</td>
<td>0</td>
<td>Fault in sandstone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12.88</td>
<td>1.78</td>
<td>20-40</td>
<td>Siltstones, pale, massive; core broken at 42.0 m; sandstone, locally very weak and breaking in an endellite near base [CED 152-64 (1984)]</td>
<td>Minor struvite pyrite and arsenopyrite at 20.3 and 42.3 m; pyrite, arsenopyrite and traces of sphalerite in quartz veinlets</td>
<td>(1) 1128</td>
</tr>
<tr>
<td>12.88</td>
<td>2.06</td>
<td>25-35</td>
<td>Sandstones, massive, non-calcareous followed by mudstone with clastic calcite at 12.45-12.59 m; then by siltstone and finally mudstone at 12.17-12.40 m</td>
<td>Dissolved pyrite and arsenopyrite locally from breccia; sandstones; struvite pyrite and arsenopyrite in siltstone; pyrite in veinlets; arsenopyrite grains and violet bloom on fractures</td>
<td>(2) 1129</td>
</tr>
<tr>
<td>12.87</td>
<td>1.63</td>
<td>35</td>
<td>Breccia vein composed largely of siltstone bandaged by quartz veins that incorporate clasts or mineralised siltstones; in places an intraformational breccia of siltstone clasts set in a matrix of quartz vein gage at 17.40-17.41 m</td>
<td>Dissolved pyrite and lesser arsenopyrite core at pyrite, common in some silitstone clasts; redbourn (?) arsenopyrite at 15.94-18.07 m; (?) sphalerite in cavity at 16.13 m; some late calcite veinlets</td>
<td>(1) 1130</td>
</tr>
<tr>
<td>12.87</td>
<td>0.90</td>
<td>0</td>
<td>Breccia vein as above, the siltstone clasts forming 20% and sometimes highly pyrite matrix in quartz</td>
<td></td>
<td>(2) 1137</td>
</tr>
<tr>
<td>51.46</td>
<td>2.63</td>
<td>0</td>
<td>Siltstone vein as above, struvite hematite abundant in siltstone clasts, highly visual sandstone clasts also present [CED 1950]; total thickness of breccia vein is 0.90 m</td>
<td></td>
<td>(3) 1137</td>
</tr>
<tr>
<td>53.97</td>
<td>1.57</td>
<td>0</td>
<td>Siltstones, broken and veined but not a true breccia; mudstone at 22.16-23.50 m</td>
<td>Pyrite and arsenopyrite in veins, irregularly disseminated and in quartz veinlets; redbourn (?) arsenopyrite on fractures</td>
<td>(4) 1133</td>
</tr>
<tr>
<td>51.60</td>
<td>1.53</td>
<td>0</td>
<td>Siltstones, unaltered, highly veined</td>
<td>Pyrite and arsenopyrite minor in quartz-calcite veinlets</td>
<td>(5) 1134</td>
</tr>
<tr>
<td>50.62</td>
<td>1.52</td>
<td>0</td>
<td>Siltstones, muddy and intermingled mudstones; vein gage at 55.46-55.80 m</td>
<td>Zn-arsenopyrite veins containing pyrite and arsenopyrite; brassy-red (?) hematite and/or (?) arsenopyrite in veinlet at 56.70 m (CED 151) and around 54.40 m (CED 59); with rem standing up to 6 cm on margins</td>
<td>(6) 1135</td>
</tr>
</tbody>
</table>

31
Siil7tstone, unevenly, locally muddy medium-coloured brecchiated alteration in place [CDB 155, 158]

Siltstone, massive, with brokenOdinate at 56.11-56.41 m then siltstone to 59.82 m

Siltstone, muddy, open broken, subsequently brecchiated siltstone [CDB 159]

Siltstone, massive,elsey bedded

Siltstone, locally fine-grained siltstone, compact; dark nodules pitting at 61.78-62.12 m as pale sandy siltstone at 61.78-61.80 m

Siltstone, muddy and pale coloured, changing to grey siltstone at 63.75 m then with darker siltstone, irregularly-bedded and clast-like at 64.7-65.95 m; remainder is massive siltstone with occasional mudstone clasts

Siltstone, fine-grained, changing at 68.29 m to mudstone than at 68.59 m to siltstone; graded bedding at 67.96-68.10 m consisted laminae in mudstone, the base of which is obscured with many fine veins of quartz

Siltstone, fine-grained, changing to mudstone at 70.34 m with fine quartz veins

Mudstone and siltstone, poorly bedded

Silts.tone, muddy with scattered siltstone lamellae; sand 60 cm is essentially a red-stained mudstone

Mudstone, siltstone and fine-grained siltstone, poorly bedded with minor red staining; fractured

Pale, with dark red siltstone lamellae; core broken at 66.57-67.22 m indicating a fault

Siltstone, compact with leaser siltstones; fine-grained siltstone 60.50-61.20 m

Mudstone with siltstone lenses and much irregular quartz veining at 52.21 m, followed by fine-grained siltstone

Mudstone, siltstone and fine-grained siltstone

Siltstone, poorly bedded, micaceous matrix, brecciated near base; some coarser laminae

Siltstone, poorly bedded with dark grey siltstone laminae

Siltstone, band, consistent with comprises bedding; red staining commencing at 90.25 m consists of patches, atmetamorphosed veins and development at the margins of quartz veins

Siltstone, grey, hard and generally red-stained; fractured at 90.71-90.87 m

Brecchia vein of siltstone fragments in a purplish siltstone matrix with much grey and white quartz; thin seams of rock grey

Siltstone, dark and fine-grained alternating with pale and coarser siltstone; quartz veins locally concentrated in a small shear zone at 94.7-8 m

Siltstone and fine sandstone, brecciated in places with development of quartz and a soft, pale green (2) clay mineral; siltstone at base

Sediments, fine-grained, hard and competent with fine sandstone clays and lamellae; large patches of pale green siltstone [CDB 1547]
<table>
<thead>
<tr>
<th>Inclined</th>
<th>Intersection</th>
<th>Bedding angle</th>
<th>Lithology</th>
</tr>
</thead>
<tbody>
<tr>
<td>98.71</td>
<td>0.12</td>
<td></td>
<td>Intrabreccia breccia consisting of light grey</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>siltstone clasts in a dark grey siltstone matrix</td>
</tr>
<tr>
<td>98.79</td>
<td>0.26</td>
<td></td>
<td>Siltstone; veins of dark quartz containing pyrite</td>
</tr>
<tr>
<td>99.09</td>
<td>0.10</td>
<td></td>
<td>are not by incoherent veils of white quartz</td>
</tr>
<tr>
<td>100.35</td>
<td>1.28</td>
<td></td>
<td>Intrabreccia breccia, as at 98.21-98.71 a</td>
</tr>
<tr>
<td>102.16</td>
<td>1.81</td>
<td></td>
<td>Siltstone; matrix weakly reduced</td>
</tr>
<tr>
<td>106.32</td>
<td>2.16</td>
<td></td>
<td>Siltstone as above with red staining decreasing</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>towards base; sulphides decrease concentrically with</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>degree of staining</td>
</tr>
<tr>
<td>106.67</td>
<td>2.35</td>
<td></td>
<td>Intrabreccia breccia, mainly of siltstone fragments,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>some of sediments; light grey sediments parting at</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>106.63 m</td>
</tr>
<tr>
<td>107.75</td>
<td>1.04</td>
<td>0°</td>
<td>Siltstone, sandy, alternating from light grey to dark</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>grey in colour</td>
</tr>
<tr>
<td>109.47</td>
<td>1.72</td>
<td>0°</td>
<td>Intrabreccia breccia of sandstone, siltstone,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>sediments and quartz; re-stained patches and veils</td>
</tr>
<tr>
<td>111.06</td>
<td>1.62</td>
<td>0°</td>
<td>Sandstone, grey and structureless with some siltstone</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>lenticles; some fractures are developed parallel to the</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>lenticles which probably mark the bedding</td>
</tr>
<tr>
<td>113.15</td>
<td>2.06</td>
<td>0°</td>
<td>Probably an intrabreccia breccia consisting of</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>sandstone, siltstone and quartz with abundant</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>regular and irregular quartz veins; elsewhere the</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>three lithologies are intercalated with matrixy</td>
</tr>
<tr>
<td>114.73</td>
<td>1.56</td>
<td></td>
<td>Intrabreccia breccia at 113.73-115.25 m, grey-green</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>to light red fault gape at 113.25-115.20 m with some</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>brecciation of adjacent rocks; bounding in siltstone,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>with intercalating siltstone lenticles to 114.07 m</td>
</tr>
<tr>
<td>116.30</td>
<td>1.57</td>
<td></td>
<td>Siltstone, lesser sandstone and sediments; sandstone</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>clasts in siltstone; core badly broken 114.73-115.25 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>indicating a fault</td>
</tr>
<tr>
<td>118.80</td>
<td>1.50</td>
<td></td>
<td>Sandstone; siltstone and sediments, commonly brecciated;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>some large patches of quartz</td>
</tr>
</tbody>
</table>

**Table II**

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Minerals</th>
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<tbody>
<tr>
<td>(1160)</td>
<td>Pyrite and arsenopyrite common; veinlets of pyrite with quartz</td>
</tr>
<tr>
<td>(1160)</td>
<td>Disseminated pyrite; stibnite blooms on fractures as at 98.21-98.71 a</td>
</tr>
<tr>
<td>(1160)</td>
<td>Disseminated arsenopyrite and pyrite [OXD 1599]</td>
</tr>
<tr>
<td>(1161)</td>
<td>Pyrite in patches and in veinlets with a trace of (7) stibnite</td>
</tr>
<tr>
<td>(1162)</td>
<td>Pyrite in patches and in veinlets with arsenopyrite and (7) stibnite</td>
</tr>
<tr>
<td>(1163)</td>
<td>Pyrite and arsenopyrite as disseminations, in patches and in veinlets</td>
</tr>
<tr>
<td>(1164)</td>
<td>Pyrite and stibnite on fractures</td>
</tr>
<tr>
<td>(1165)</td>
<td>Pyrite and arsenopyrite disseminated in areas of red splashing; (7) stibnite on fractures</td>
</tr>
<tr>
<td>(1166)</td>
<td>Pyrite and arsenopyrite disseminated and on fractures; stibnite on fractures; quartz vein</td>
</tr>
<tr>
<td>(1167)</td>
<td>Pyrite and arsenopyrite as disseminations in sandstones, as elongate stibnite patches in sandstones</td>
</tr>
<tr>
<td>(1168)</td>
<td>Pyrite, arsenopyrite and (7) stibnite in breccia; traces of pyrite in gapes; finely</td>
</tr>
<tr>
<td>(1169)</td>
<td>disseminated pyrite in sandstones; pyrite in veins and (7) stibnite in quartz veins at 113.64 m</td>
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<tr>
<td>(1170)</td>
<td>Pyrite and minor arsenopyrite in section of breccia cores; veinlets and small patches of pyrite in siltstone</td>
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**Sample No.**

33
<table>
<thead>
<tr>
<th>Depth, m</th>
<th>Interval</th>
<th>Bedding angle</th>
<th>Lithology</th>
<th>Mineralization</th>
<th>Sample No.</th>
<th>CDD</th>
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<td>5L-2</td>
<td>Basefracture deposits</td>
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<td>7.62</td>
<td>3.18</td>
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<td>Siltstone</td>
<td>Calcite veinlets</td>
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</tr>
<tr>
<td>3.30</td>
<td>1.60</td>
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<td>Mudstone, olive-green and silicite</td>
<td>Enargite, pyrite veinlets</td>
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<tr>
<td>9.80</td>
<td>0.50</td>
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<td>Core base</td>
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<td>13.96</td>
<td>4.16</td>
<td>20</td>
<td>Siltstone, mudstone partings and clasts, locally brecciated</td>
<td>Quarts veins, pyrite stringers and at 19.5 m pyrite lenses</td>
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<tr>
<td>16.86</td>
<td>2.90</td>
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<td>Siltstone, broken in plane</td>
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<tr>
<td>20.72</td>
<td>3.86</td>
<td>15</td>
<td>Mudstone and siltstone, laminated, units of silty sandstone; clastic zone at 19.5 m</td>
<td>Green slicken on fractures [L66.154]; quartz veins</td>
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<tr>
<td>21.57</td>
<td>0.85</td>
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<td>Mudstone, soft, clear zones in places</td>
<td>Minor quartz veins</td>
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<tr>
<td>23.60</td>
<td>1.43</td>
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<td>Sandstone, compact with disseminated disseminations hematite and sandstone band at 19.5-24.5 m</td>
<td>(1) grey sulphide on fractures with pyrite and (?) chalcopyrite</td>
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<td>27.79</td>
<td>1.39</td>
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<td>Mudstone, lesser siltstones and sandstones, fractured near base</td>
<td>Minor disseminated sulphide</td>
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<td>28.41</td>
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<td>16</td>
<td>Siltstone and interbedded mudstones; bedding in places offsetting and exhibiting fold structures; clastic zone at 19.5 m</td>
<td>Quartz veinlets</td>
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<tr>
<td>28.54</td>
<td>1.43</td>
<td></td>
<td>Siltstone with minor mudstone clasts and laminae</td>
<td>Calcite veinlets; disseminated sulphide</td>
<td>1058</td>
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<tr>
<td>30.16</td>
<td>2.12</td>
<td></td>
<td>Mudstone compressive deformations into siltstone which exhibits cross-bedding laminitic fractures</td>
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<td>1059</td>
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<tr>
<td>31.32</td>
<td>1.16</td>
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<td>Siltstone compressive deformations into sandstone</td>
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<td>1060</td>
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<tr>
<td>32.72</td>
<td>1.60</td>
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<td>Interbedded breccias of sandstone fragments and lesser siltstone and mudstone fragments; Irregular quartz patches common</td>
<td>Pyrite disseminated, in veins and on fractures</td>
<td>1061</td>
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<tr>
<td>33.47</td>
<td>0.75</td>
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<td>Sandstone, strongly quartz-replaced</td>
<td>Minor disseminated pyrite</td>
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<tr>
<td>36.05</td>
<td>2.59</td>
<td></td>
<td>Interbedded breccias of mudstone fragments and lesser siltstone and sandstone fragments; quartz patches common</td>
<td>Pyrite disseminated and on fractures; quartz veinlets common</td>
<td>1063</td>
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<tr>
<td>38.48</td>
<td>2.43</td>
<td></td>
<td>Siltstone with mudstone clasts and laminae over lowermost 60 cm, broken and fractured in place</td>
<td>Quartz disseminated in veins throughout grey sulphide crystal on fracture at 36.2 m [L66.154]</td>
<td>1064</td>
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<tr>
<td>39.57</td>
<td>1.28</td>
<td></td>
<td>Siltstone with mudstone laminae and clasts, also siltstone; core broken</td>
<td>Rhenium pyrite veinlets</td>
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<tr>
<td>41.28</td>
<td>1.34</td>
<td>5</td>
<td>Siltstone, well-bedded mudstone partings; even broken</td>
<td>Masses pyrite veinlets and patches; minor quartz veinlets</td>
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<tr>
<td>43.25</td>
<td>2.18</td>
<td>5-30</td>
<td>Siltstone to 19.5 m then interbedded with lesser mudstone and interbedded siltstone</td>
<td>Pyrite disseminated in sandstones, on fractures in mudstones</td>
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<td>44.79</td>
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<td>35</td>
<td>Siltstone with lesser interbedded mudstone and sandstones</td>
<td>Disseminated pyrite; quartz veinlets with (?) bornite at 19.5 m</td>
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<tr>
<td>46.22</td>
<td>1.43</td>
<td>60</td>
<td>Siltstone and interbedded mudstones</td>
<td>Disseminated pyrite in siltstone; stimuli in quartz veinlets</td>
<td>1069</td>
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<tr>
<td>47.50</td>
<td>1.38</td>
<td>60</td>
<td>Siltstone with mudstone laminae, especially at 46.9-47.3 m where core is broken with pyrite stringers</td>
<td>Disseminated pyrite in siltstones; stimuli in quartz veins</td>
<td>1070</td>
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<tr>
<td>48.20</td>
<td>1.70</td>
<td></td>
<td>Siltstone and sandstone, poorly bedded with quartz veinlets cut by dolomite veinsite [L66.154]</td>
<td>Pyrite, arsenopyrite and (1) grey sulphide disseminated; pyrite and stilbite on fractures</td>
<td>1071</td>
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<tr>
<td>51.19</td>
<td>1.70</td>
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<td>Sandstone, siltstone and laminae of mudstone</td>
<td>Disseminated pyrite, arsenopyrite and pyrite on fractures</td>
<td>1072</td>
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<tr>
<td>53.87</td>
<td>2.57</td>
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<td>Siltstone with dark mudstone clasts; shear plane at 20° to core area</td>
<td>Trace of pyrite and arsenopyrite in siltstone; quartz veinlets</td>
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<tr>
<td>55.54</td>
<td>2.21</td>
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<td>Siltstone, laminated with paler siltstone and darker mudstone</td>
<td>Pyrite disseminated and in veins with aragonite [L66.154]</td>
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<td>57.05</td>
<td>1.17</td>
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<td>Siltstone, silty with mudstone laminae</td>
<td>Traces of disseminated pyrite</td>
<td>1075</td>
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<tr>
<td>59.35</td>
<td>2.50</td>
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<td>Mudstone initially thin silty sandstone; highly brecciated and irregularly vased by quartz which forms patches up to 10 cm in diameter</td>
<td>Sulfides not observed; greenish, shiny in altered breccia [L66.154]</td>
<td>1076</td>
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<tr>
<td>61.19</td>
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<td>Siltstone with mudstone laminae; calcite-filled shear zones aligned with the laminae</td>
<td>Traces of disseminated pyrite and (1) arsenopyrite</td>
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<tr>
<td>64.45</td>
<td>1.95</td>
<td>10</td>
<td>Sandstone, lesser siltstone and mudstone laminae</td>
<td>Traces of disseminated pyrite</td>
<td>1078</td>
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<tr>
<td>66.37</td>
<td>1.82</td>
<td></td>
<td>Siltstone, siltstones and mudstone, strongly interbedded in places</td>
<td>Disseminated pyrite and arsenopyrite; silicates in quartz veins [L66.154] and stimulate on fracture in siltstone [L66.154]</td>
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</tr>
<tr>
<td>68.19</td>
<td>1.72</td>
<td></td>
<td>Siltstone and silty sandstone, minor mudstone</td>
<td>Minor disseminated pyrite and arsenopyrite; angular silicates in quartz veins [L66.154] and stimulate on fracture in siltstone [L66.154]</td>
<td>1080</td>
<td></td>
</tr>
<tr>
<td>Interval depth, m</td>
<td>Intersection, m</td>
<td>Dip angle</td>
<td>Lithology</td>
<td>Mineralisation</td>
<td>Sample no.</td>
<td></td>
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<td>------------</td>
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</tr>
<tr>
<td>70.01</td>
<td>1.82</td>
<td>30</td>
<td>Sandstone with muscovite laminae</td>
<td>Minor disseminated pyrite and arsenopyrite; quartz veins</td>
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<tr>
<td>72.00</td>
<td>2.03</td>
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<td>Mudstone and subordinate siltstone</td>
<td>Minor disseminated pyrite in siltstone; stibnite bloom on fracture in muscovite [GZ 1511]</td>
<td>1059</td>
<td></td>
</tr>
<tr>
<td>73.25</td>
<td>1.48</td>
<td>30</td>
<td>Sandstone with conspicuous pair green muscovite of 72.35-72.65 m</td>
<td>Intersertal pyrite and arsenopyrite in sandstone</td>
<td>1060</td>
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</tr>
<tr>
<td>75.22</td>
<td>1.70</td>
<td></td>
<td>Siltstone, highly veined and broken</td>
<td>Disseminated pyrite and arsenopyrite common</td>
<td>1061</td>
<td></td>
</tr>
<tr>
<td>83.12</td>
<td>7.90</td>
<td></td>
<td>Intrusive breccia consisting of fragments of siltstone, lesser sandstone and minor mudstone; later shearing common</td>
<td>Pyrite and arsenopyrite common as disseminations, in stratoform veins and in veinlets; stibnite bloom on fractures [GZ 1511]</td>
<td>1062</td>
<td></td>
</tr>
<tr>
<td>85.02</td>
<td>1.90</td>
<td></td>
<td>Siltstone, lesser mudstone and sandstone; quartz veins common especially at 85.60-85.80 m</td>
<td>Stratiform arsenopyrite and pyrite</td>
<td>1063</td>
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<td></td>
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<td></td>
<td>Siltstone and muscovite</td>
<td>Arsenopyrite (crystals up to 2 mm in length) and pyrite as disseminations; stibnite in coarse-carbonate veinsites [GZ 1516]</td>
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<td>90.20</td>
<td>3.45</td>
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<td>Siltstone and mudstone; strongly brecciated especially at 90.2-90.6 m</td>
<td>Pyrite in elongated patches and disseminated with arsenopyrite</td>
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<tr>
<td>91.77</td>
<td>2.77</td>
<td></td>
<td>Siltstone containing dark lathic fragments and occasional mudstone partings especially at 91.6-91.77 m, a shear zone in common</td>
<td>Arsenopyrite in phases, brecciated in quartz veinlets [GZ 1513]</td>
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</tr>
<tr>
<td>93.76</td>
<td>1.79</td>
<td></td>
<td>Sandstone, fine-grained, maroon etching present; highly brecciated at 93.75-93.78 m, a shear zone is intersected with new fine-grained sediment</td>
<td>Disseminated pyrite and arsenopyrite common; gypsiferous in veinlets [GZ 1513]</td>
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<td></td>
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<tr>
<td>95.58</td>
<td>1.82</td>
<td></td>
<td>Siltstone and siltstone, brecciated; some thin mudstone partings, particularly at 95.58 m and at 95.34-95.36 m</td>
<td>Disseminated pyrite and arsenopyrite common throughout; (5) bournonite on fractures at 95.9 m in numerous quartz veinlets and some carbonatite veinlets</td>
<td>1068</td>
<td></td>
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<tr>
<td>97.62</td>
<td>2.04</td>
<td>10</td>
<td>Siltstone, broken but less brecciated than in unit above, a few mudstone partings</td>
<td>Minor pyrite and arsenopyrite as disseminations</td>
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<td></td>
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<tr>
<td>101.57</td>
<td>3.95</td>
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<td>Mudstone, silty and highly fractured, grading at 99.8 m into a competent quartz-rich siltstone</td>
<td>Pyrite, stibnite and (?) bournonite on fractures; quartz veinlets rare</td>
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<td>103.10</td>
<td>2.53</td>
<td>30</td>
<td>Mudstone, silty</td>
<td>Pyrite, stibnite and (?) diopside on fractures; quartz veinlets common; apparent at 103.2 m</td>
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<td>104.49</td>
<td>1.39</td>
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<td>Mudstone to 103.50 then fractured siltstone</td>
<td>Stratabound pyrite and arsenopyrite; pyrite, stibnite and bournonite on fractures and in veinlets [GZ 1512]</td>
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<tr>
<td>107.62</td>
<td>3.13</td>
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<td>Sandstone, silty, grey and compact with minor mudstone brecciated at 107.60-107.62 m</td>
<td>Stratiform arsenopyrite and pyrite, especially in mudstone; stibnite and diopside [GZ 1516] in shearing quartz veinlets</td>
<td>1073</td>
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<tr>
<td>109.73</td>
<td>2.16</td>
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<td>Siltstone, well bedded, with some thin mudstone partings and gradational, sandstone layers; locally brecciated; yellowish-coloured, fine-grained (1) diopside crystals fracture surfaces at 109.6-109.72 m</td>
<td>Slightly disseminated pyrite and arsenopyrite; pyrite images, carbonates veinsite; stibnite on fractures [GZ 1517]</td>
<td>1074</td>
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</tr>
<tr>
<td>111.69</td>
<td>1.97</td>
<td></td>
<td>Mudstone, pass charged and intersected with dark siltstones</td>
<td>Pyrite in pozzolana and in quartz veinlets; stibnite on fractures</td>
<td>1075</td>
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<td>115.00</td>
<td>3.31</td>
<td></td>
<td>Siltstones with some mudstone partings</td>
<td>Disseminated pyrite; stibnite and (?) bournonite in quartz veinlets</td>
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<td></td>
</tr>
<tr>
<td>117.20</td>
<td>2.20</td>
<td>20</td>
<td>Mudstone, finely laminated in places; locally charged especially at 117.2-117.35 m</td>
<td>Pyrite disseminated and in veinlets; small to trace amounts of stibnite on fractures</td>
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<td>120.70</td>
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<td>15</td>
<td>Siltstones, fine-grained, grey and massive, interbedded with lesser mudstone brecciated with quartz veinlets at 120.7-120.72 m</td>
<td>Pyrite weakly disseminated and in veinlets</td>
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<tr>
<td>121.99</td>
<td>1.59</td>
<td>20</td>
<td>Sandstone with interbedded siltstone and muscovite; the siltstone appears to be in the form of clasts</td>
<td>Pyrite weakly disseminated in sandstones; also in veinlets</td>
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<tr>
<td>124.22</td>
<td>3.23</td>
<td>15</td>
<td>Siltstones and mudstone varying abruptly from one to another; lithological bands finely developed</td>
<td>Pyrite disseminated and in quartz veinlets; later are charged with quartz (10-20) to core axis</td>
<td>1080</td>
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<tr>
<td>126.23</td>
<td>2.80</td>
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<td>Sandstone with minor mudstone; probably a clast, at 126.20-126.25 m</td>
<td>Minor disseminated pyrites; quartz veinlets uncommon</td>
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<tr>
<td>128.22</td>
<td>3.00</td>
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<td>Siltstones, silty and minor mudstone; irregularly brecciated in sandstone is displayed by veins and layers</td>
<td>Disseminated pyrite throughout; irregular quartz veins; patches and algal pyrite of bournonite in carbonate veinsites [GZ 1518]</td>
<td>1082</td>
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<tr>
<td>131.62</td>
<td>2.40</td>
<td></td>
<td>Sandstone and minor mudstone; probably a clast, disseminated in veinlets; patches of opaline quartz at 10-20 m</td>
<td>Pyrite and arsenopyrite as veins; disseminated and in veinlets; patch of fine-grained pyrite 12 m across in clast at 131.65 m</td>
<td>1083</td>
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<tr>
<td>132.17</td>
<td>1.95</td>
<td></td>
<td>Siltstone with irregular clasts of muscovite; strongly veined, especially at 132.10-132.17 m</td>
<td>Pyrite disseminated with (?) grey sulphide on fractures and at veinlet margins</td>
<td>1084</td>
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<tr>
<td>Declined depth, m</td>
<td>Intersection</td>
<td>Lithology</td>
<td>Mineralization</td>
<td>Sample No.</td>
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<tr>
<td>136.77</td>
<td>1.56</td>
<td>Siltstone, finely banded</td>
<td>Stratiform pyrite; disseminated pyrite and arsenopyrite; sulphides also in and marginal to quartz veins; the latter are sometimes cut by sulphide veins</td>
<td>1069</td>
<td></td>
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<tr>
<td>140.62</td>
<td>5.91</td>
<td>Interstratified breccia composed of a grey, compact assemblage of sandstone and mudstone; relief set in a dark, sulphide-rich matrix containing dissemin [449106] disseminated pyrite and, in places, arsenopyrite in matrix (GDD 1517, 1521); patches of pyrite up to 2 cm across; pyrite occasionally present in clasts; pyrite and dissemin in quartz-carbonate veins with sulfides and mica on fracture at 143.6 m</td>
<td>1060</td>
<td></td>
<td></td>
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<tr>
<td>142.04</td>
<td>2.02 10</td>
<td>Siltstone, very finely flow-banded</td>
<td>Minor stratiform pyrite; slight tectonites with (1) brecciation in vei nals at 141.60-141.95 m</td>
<td>1096</td>
<td></td>
<td></td>
</tr>
<tr>
<td>144.97</td>
<td>1.43</td>
<td>Siltstone, flow-banded, and sandstone; very brecciated</td>
<td>Pyrite along bedding and in veins</td>
<td>1095</td>
<td></td>
<td></td>
</tr>
<tr>
<td>145.53</td>
<td>1.25 10</td>
<td>Siltstone and mudstone, finely-banded</td>
<td>Strewn, disseminated veins; pyrite and arsenopyrite, especially at 142.3 m; brecciation on fractures [GDD 1522, 1542]</td>
<td>1060</td>
<td></td>
<td></td>
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<tr>
<td>146.47</td>
<td>1.15 20</td>
<td>Sandstone, weakly banded with abundant siliciclastics containing quartz, feldspar grains and variably coarse-grained at 146.60-146.73 m</td>
<td>Pyrite and arsenopyrite as disseminations, on bedding planes and in spaces quartz veins</td>
<td>107</td>
<td></td>
<td></td>
</tr>
<tr>
<td>146.87</td>
<td>1.10 20</td>
<td>Siltstone, finely-banded, mucky in places</td>
<td>Pyrite, arsenopyrite and (? grey sulphide disseminated and in fine stratiform leaves up to 1 mm thick; also minor ash, mica, biotite and at 146.60 m, diabase</td>
<td>1095</td>
<td></td>
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<tr>
<td>148.35</td>
<td>0.17</td>
<td>Interstratified breccia composed of clasts of sandstone up to 25 cm across and of darker siltstone; the clasts are angular to sub-angular and are set in a dark, sulphide-rich matrix; the breccia shown is approximately 90%</td>
<td>Matrix of breccia consists essentially of arsenopyrite and quartz; sulphide; pyrite occurs in clasts; [GDD 1556]</td>
<td>1099</td>
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<tr>
<td></td>
<td></td>
<td>Siltstone, finely-banded being in parallel with contact against interstratified breccia shown; Siltstone, mucky in places, relatively coarse-grained and sulphide-rich in others; Siltstone, dark grey, compact, poorly-banded</td>
<td>Pyrite and arsenopyrite as disseminations and on fractures</td>
<td>1000</td>
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<tr>
<td>150.45</td>
<td>1.50</td>
<td>Siltstone, weakly banded, incorporating clasts of sandstone and mudstone; probably an interstratified breccia at 150.36-150.45 m; somewhat sheared</td>
<td>Pyrite and arsenopyrite as disseminations and on fractures</td>
<td>1000</td>
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<tr>
<td>151.77</td>
<td>1.40</td>
<td>Siltstone, dark grey, compact, poorly-banded</td>
<td>Pyrite, arsenopyrite and (? grey sulphide disseminated and on fractures</td>
<td>1100</td>
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<tr>
<td>153.08</td>
<td>1.08</td>
<td>Siltstone, weakly banded, incorporating clasts of sandstone and mudstone; probably an interstratified breccia at 153.06-153.09 m; somewhat sheared</td>
<td>Pyrite, arsenopyrite and (? grey sulphide disseminated and on fractures</td>
<td>1100</td>
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<tr>
<td>154.07</td>
<td>1.00</td>
<td>Siltstone, weakly banded, some mucky places</td>
<td>Pyrite locally enclaves 10% of mica with arsenopyrite sometimes at 154.06-154.90</td>
<td>1104</td>
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<tr>
<td>157.42</td>
<td>1.55 20</td>
<td>Siltstone, very finely banded with darker sulphidic bands</td>
<td>Pyrite very fine-grained in darker bands; same assemblage in quartz veins at 157.48-157.61 m</td>
<td>1105</td>
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<tr>
<td>159.95</td>
<td>1.91 20</td>
<td>Siltstone and mudstone, finely banded</td>
<td>Disseminated pyrite; quartz veins with pyrite and breccia at 159.64-159.73 m (GDD 1523)</td>
<td>1106</td>
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<td></td>
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<tr>
<td>160.95</td>
<td>1.46 10</td>
<td>Siltstone, finely banded</td>
<td>Disseminated pyrite; quartz-carbonate veins</td>
<td>1107</td>
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<td></td>
</tr>
<tr>
<td>162.27</td>
<td>1.32 10</td>
<td>Siltstone, finely banded</td>
<td>Disseminated pyrite; thick quartz veins at 162.17-162.27 m</td>
<td>1108</td>
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</tr>
<tr>
<td>164.20</td>
<td>1.29</td>
<td>Siltstone, compact, finely banded in places</td>
<td>Disseminated pyrite; quartz veins up to 3 mm thick</td>
<td>1109</td>
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<tr>
<td>166.01</td>
<td>1.61</td>
<td>Siltstone, thinly banded with pyrrhotite</td>
<td>Disseminated pyrite, especially at 166.04-166.55 m (GDD 1556, 1559)</td>
<td>1110</td>
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<tr>
<td>167.10</td>
<td>1.29</td>
<td>Siltstone, fine banded</td>
<td>Stratabound pyrite in dark bands of siltstone; weakly sheared on fractures [GDD 1577]</td>
<td>1111</td>
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<tr>
<td>168.73</td>
<td>1.61 10</td>
<td>Siltstone, finely banded; some brown at 168.22-168.73 m</td>
<td>Streitform pyrite and arsenopyrite; bright, globular pyrite in stringers; aggregations of breccia up to 10 cm in width [GDD 1597, 1521, 1579]</td>
<td>1112</td>
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<tr>
<td>170.04</td>
<td>1.31</td>
<td>Siltstone, finely banded strongly veined at 170.00-170.11 m and at 168.45-168.55 m</td>
<td>Streitform pyrite and arsenopyrite; thinner veins more with intermixed carbonate and central quartz; disseminated in matrix [GDD 1581]</td>
<td>1113</td>
<td></td>
<td></td>
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<tr>
<td>171.59</td>
<td>1.05</td>
<td>Siltstone, finely banded pale siltstone at 171.57-171.71 m containing stratiform pyrite is in contact with a darker mudstone in which pyrite pellets measure up to 1 cm across</td>
<td>Pyrite and arsenopyrite disseminated and in veins; quartz vein 7 mm thick at 170.93 m</td>
<td>1114</td>
<td></td>
<td></td>
</tr>
<tr>
<td>173.11</td>
<td>1.52 15</td>
<td>Siltstone, finely banded, green-tinted; brecciated dark siltstone at 173.27-173.36 m with abundant pyrite</td>
<td>Stratifrom and vein pyrite and arsenopyrite; sulphides locally concentrated in siltstone at vein margin</td>
<td>1115</td>
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<td></td>
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<tr>
<td>Section</td>
<td>Intersection</td>
<td>Depth, m</td>
<td>Dip angle</td>
<td>Lithology</td>
<td>Mineralisation</td>
<td>Sample No.</td>
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<tr>
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<tr>
<td>176.96</td>
<td>1.95</td>
<td></td>
<td></td>
<td>Siltstone, cross-laminated with well defined alternating dark and light laminae</td>
<td>Stratum dark grey (? sulphides at 173.76 m; stratum pyrite and arsenopyrite especially at 170.79-171.96 m</td>
<td>1116</td>
</tr>
<tr>
<td>174.35</td>
<td>1.39</td>
<td></td>
<td></td>
<td>Siltstone, cross-laminated, varying locally to sandstone</td>
<td>Disseminated pyrite and minor arsenopyrite; pyrite in quartz veins</td>
<td>1117</td>
</tr>
<tr>
<td>178.58</td>
<td>2.23</td>
<td></td>
<td></td>
<td>Breccia vein of sediments and siltstone rock fragments set in a quartz-chlorite matrix; the matrix is usually hard, grey and fine-grained but at 176.35 m the quartz is relatively coarse and grey-coloured; the absence of fractures suggests the assemblage is an interbedded/mixed mineral assemblage</td>
<td>Patches of massive pyrite up to 2 cm across in matrix pyrite and arsenopyrite disseminated through some rock fragments [GSD 1526, 1527, 1528, 1529]</td>
<td>1118</td>
</tr>
<tr>
<td>180.24</td>
<td>1.96</td>
<td></td>
<td></td>
<td>Siltstone, grey, passing into fine-grained siltstone at 176.12 m; breccia at 179.45 m than fine-grained sandstone with mineralised pitchstone of siltsstone; remnants in siltsone at 179.96 m</td>
<td>Stratum and disseminated pyrite and arsenopyrite in upper siltstone [GSD 1566]; persisting weakly into the sediments; new pyrite in lower units; some pyrite in veinlets</td>
<td>1119</td>
</tr>
<tr>
<td>182.02</td>
<td>2.62</td>
<td>1.95</td>
<td></td>
<td>Siltstone, medium grey, poorly sorted, grading in places into fine-grained sandstone and into siltstone</td>
<td>(? stelinite in calcite veinsite; quartz veins common at 187.2-228.2 m)</td>
<td>1120</td>
</tr>
<tr>
<td>186.22</td>
<td>1.00</td>
<td></td>
<td></td>
<td>Siltstone, sandy, poorly heated with abrupt variations to sediments and fine-grained siltstone</td>
<td>(?) stelinite on fractures; veins common with only a trace of pyrite</td>
<td>1121</td>
</tr>
<tr>
<td>188.11</td>
<td>1.40</td>
<td></td>
<td></td>
<td>Initially a fine-grained sandstone, then siltsstone laminated with dark mudstone and terminating in fine-grained sandstones, observed at 190.3 m</td>
<td>Trace of disseminated pyrite in the sandstones</td>
<td>1122</td>
</tr>
<tr>
<td>191.13</td>
<td>3.00</td>
<td></td>
<td></td>
<td>Sandstone, compact, massive, dark grey, rarely veined or fractured</td>
<td>Persistent trace of pyriteubby calcite veinlet into a quartz veinlet at 190.07 m</td>
<td>1125</td>
</tr>
<tr>
<td>193.93</td>
<td>2.60</td>
<td>15</td>
<td></td>
<td>Sandstone, fine-grained, massive and uniform with abundant flakes of red micaceous hornblende [GSD 1531]</td>
<td>Trace of pyrite in banded veinlets at 191.25 m and 191.75 m with (? stelinite)</td>
<td>1123</td>
</tr>
<tr>
<td>194.86</td>
<td>0.13</td>
<td>10</td>
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<td>Siltstone, sandy with fine-grained sandstone at 194.3-194.5 m</td>
<td>Minor disseminated pyrite; few veinlets; stelinite bloom [GSD 1546]</td>
<td>1124</td>
</tr>
<tr>
<td>197.82</td>
<td>1.73</td>
<td></td>
<td></td>
<td>Mudstone, lesser siltstone, grading into siltstone towards the base</td>
<td>(?) stelinite bloom on fracture</td>
<td>1127</td>
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</table>

END OF RESUMES AT 197.82 m
<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Lithology</th>
<th>Mineralization</th>
<th>Sediment depth, m</th>
<th>Inclined depth, m</th>
<th>Intersection angle</th>
<th>Bedding angle</th>
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</thead>
<tbody>
<tr>
<td>CXD 1024</td>
<td>Superficial deposit</td>
<td>Quarts and calcite veinlets</td>
<td>2.13</td>
<td>5.06</td>
<td>2.40</td>
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</tr>
<tr>
<td>CXD 1025</td>
<td>Banded, limonite-stained and soft green mudstone</td>
<td>Calcite veinlets in mudstone</td>
<td>2.35</td>
<td>5.28</td>
<td>1.40</td>
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<tr>
<td>CXD 1026</td>
<td>Silite with broken mudstone partings</td>
<td>Orange-stained calcite veinlets</td>
<td>1.90</td>
<td>5.52</td>
<td>0.95</td>
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</tr>
<tr>
<td>CXD 1027</td>
<td>Mudstone with silicate clast at 7.46 m; maroon coloured</td>
<td>Calcite veinlets in mudstone</td>
<td>1.90</td>
<td>6.00</td>
<td>0.95</td>
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<tr>
<td>CXD 1028</td>
<td>Mudstone with disseminated micronite hematite; mudstone with maroon coloured bands, notably at 8.28-8.42 m</td>
<td>More than calcite veinlets</td>
<td>1.90</td>
<td>9.52</td>
<td>1.16</td>
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<tr>
<td>CXD 1029</td>
<td>Silite with numerous mudstone partings, contacts usually abrupt but sometimes gradational</td>
<td>More than calcite veinlets</td>
<td>1.90</td>
<td>12.00</td>
<td>1.33</td>
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<tr>
<td>CXD 1030</td>
<td>Mudstone with a silicate band at 13.15-13.26 m</td>
<td>A few regular calcite veinlets up to 8 cm thick</td>
<td>8.00</td>
<td>13.16</td>
<td>0.60</td>
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<tr>
<td>CXD 1031</td>
<td>Banded, grey, dark to light grey in colour, calcite; some thin mudstone partings</td>
<td>Calcite yielding common except in areas of silstone</td>
<td>8.00</td>
<td>14.00</td>
<td>1.13</td>
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<tr>
<td>CXD 1032</td>
<td>Silite with 17.27 m, mudstone; cut by thin</td>
<td>Numerous, irregular, orange-stained calcite veinlets</td>
<td>8.00</td>
<td>14.43</td>
<td>0.43</td>
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<tr>
<td>CXD 1033</td>
<td>Silite, grey and compact grading into olive-green</td>
<td>Numerous irregular calcite veinlets and some quartz veinlets</td>
<td>8.00</td>
<td>20.66</td>
<td>3.01</td>
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<tr>
<td>CXD 1034</td>
<td>Silite, grey, hard and competent except at 21.58-21.68 m where it is broken and discoloured</td>
<td>Pyrite impregnated broken section, occurring into hard silite with intergrown pyrrhotite</td>
<td>8.00</td>
<td>25.04</td>
<td>1.13</td>
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<tr>
<td>CXD 1035</td>
<td>Silite, grey, very fractured, limonites at base; sandstone from 21.70 m, shows at 21.70 m with numerous quartz and calcite veinlets</td>
<td>Pyrite and arsenopyrite disseminated through lower</td>
<td>8.00</td>
<td>27.17</td>
<td>1.09</td>
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<tr>
<td>CXD 1036</td>
<td>Siltstone, fine-grained, initially broken and crumbled</td>
<td>pyrite and arsenopyrite disseminated through broken rock and with arsenopyrite and sphalerite (CED 155c 155f)</td>
<td>8.00</td>
<td>28.49</td>
<td>1.12</td>
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<tr>
<td>CXD 1037</td>
<td>Sandstone with thin developments of quartz resulting in a hard, competent rock densely brecciated</td>
<td>This quartz vein with minor pyrite and arsenopyrite</td>
<td>8.00</td>
<td>29.41</td>
<td>1.12</td>
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<tr>
<td>CXD 1038</td>
<td>Sandstone, massive strongly brecciated (CED 155s 155l)</td>
<td>Arsenopyrite and pyrite as disseminations and in veinlets with bournonite at 29.5 m</td>
<td>8.00</td>
<td>30.82</td>
<td>1.41</td>
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<tr>
<td>CXD 1039</td>
<td>Silite with calcite veins; calcite veinlet at 31.61 m with (?) grey calculite</td>
<td>Quartz veinlets; calcite veinlet at 31.61 m with (?) grey calculite</td>
<td>8.00</td>
<td>32.62</td>
<td>1.00</td>
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<tr>
<td>CXD 1040</td>
<td>Silite with silicate septates, somewhat brecciated at 24.60-24.62 m (CED 155d)</td>
<td>Pyrite and arsenopyrite disseminated through broken rock and with arsenopyrite and sphalerite (CED 155c 155f)</td>
<td>8.00</td>
<td>46.77</td>
<td>1.17</td>
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<tr>
<td>CXD 1041</td>
<td>Silite, grading in places into fine-grained sandstone containing fibrous fragments and micronite hematite; mudstone partings brecciated and reprinted at 23.34-23.70 m</td>
<td>Regular calcite veinlets up to 1 cm thick but no visible sulphide</td>
<td>8.00</td>
<td>46.77</td>
<td>2.17</td>
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<tr>
<td>CXD 1042</td>
<td>Mudstone, silt and calcareous</td>
<td>Numerous quartz veinlets</td>
<td>8.00</td>
<td>46.77</td>
<td>1.17</td>
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<tr>
<td>CXD 1043</td>
<td>Sandstone, massive</td>
<td>Regular calcite veinlets</td>
<td>8.00</td>
<td>46.77</td>
<td>1.33</td>
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<tr>
<td>CXD 1044</td>
<td>Silty mudstone, initially laminated, pale to dark grey when compact; maroon laminations parallel to bedding in band 10 cm signalling variation of sandstone in bent unit</td>
<td>Regular calcite veinlets common</td>
<td>8.00</td>
<td>46.77</td>
<td>2.49</td>
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<tr>
<td>CXD 1045</td>
<td>Sandstone, grey, hard and massive</td>
<td>Calcite and quartz veinlets fairly common</td>
<td>8.00</td>
<td>46.77</td>
<td>2.13</td>
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<tr>
<td>CXD 1046</td>
<td>Mudstone with extensive maroon staining</td>
<td>Calcite veins especially at 51.85-51.86 m, red stained</td>
<td>8.00</td>
<td>46.77</td>
<td>2.13</td>
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<tr>
<td>CXD 1047</td>
<td>Sandstone grading in places into silty sandstone; mudstone clasts apparently broken in situ at 49.43-49.98 m</td>
<td>Red stained calcite veinlets up to 1 cm thick</td>
<td>8.00</td>
<td>46.77</td>
<td>2.13</td>
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<tr>
<td>CXD 1048</td>
<td>Mudstone, hard, compact, massive with some micronite hematite; mudstone partings contain deformed calcite veinlets at 51.10 m; some soft sediment information</td>
<td>Calcite veinlets up to 1 cm thick</td>
<td>8.00</td>
<td>46.77</td>
<td>2.13</td>
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<tr>
<td>CXD 1049</td>
<td>Silite grading into sandstone in places; interstitial clasts of dark mudstone are present; minor maroon staining along bedding planes</td>
<td>Calcite veinlets commonly</td>
<td>8.00</td>
<td>46.77</td>
<td>2.13</td>
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<td>Inclined Depth, m</td>
<td>Intersection m</td>
<td>Bedding Angle</td>
<td>Lithology</td>
<td>Mineralization</td>
<td>Sample No.</td>
<td>Geo</td>
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<tr>
<td>65.67</td>
<td>2.94</td>
<td>L0</td>
<td>Mudstone and siltstone exhibiting soft sediment deformation; a thin light green mudstone parting with some maroon staining; possible concretionary structure at 66.29 m</td>
<td>Stibnite &quot;blonde&quot; on fractures with calcite</td>
<td>39</td>
<td></td>
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<tr>
<td>68.72</td>
<td>3.95</td>
<td></td>
<td>Mudstone and siltstone, less deformed than in preceding unit</td>
<td>Stibnite &quot;blonde&quot; on fractures with calcite</td>
<td>39</td>
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<td>Siltstone grading in places into sandstone; somewhat calcareous; micaceous hematite throughout; a few mudstone partings</td>
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<td>Mudstone, olive-green with bands of light green mudstone with which maroon staining is associated; a small sandstone clast at 71.9 m</td>
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<td>Sandstone, silty, calcareous with disseminated micaceous hematite; grades into siltstone in places with a few mudstone partings</td>
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<td>Mudstone and siltstone, preassociated in places; pale coloured siltstone in calcarceous</td>
<td>Extensive calcite veinlets, irregular, especially at 80.63-80.85 m in right-engine to core axis</td>
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End of Appendix 2
APPENDIX II

GEOCHEMICAL ANALYSES OF DRILLCORE

Note (a). For more detailed lithological descriptions the sample number and sample depth should be cross-referenced to the corresponding borehole table in Appendix I; IFB denotes infraformational breccia.

Note (b). In the column headed 'Feature', B signifies the development of brecciation, D the presence of characteristics suggestive of debris flow development and F the occurrence of faulting.

Note (c). The incidence of vein and stratabound mineralisation was estimated visually during logging and classified as significant, trace or absent. For an explanation of the abbreviations refer to the list given in Appendix III.
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<td>0.98 Bluestone, sandstone, andesite</td>
<td>Py</td>
<td>5.06 0.43 4.98 15</td>
<td>30</td>
<td>216 139 213</td>
<td>39 134 50</td>
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42
### APPENDIX II TABLE IV - BOREHOLE 4

<table>
<thead>
<tr>
<th>Sample Depth</th>
<th>Inter-</th>
<th>Generalised Lithology</th>
<th>Mineralisation</th>
<th>Stratabound</th>
<th>Vein</th>
<th>ppm</th>
<th>Bl No</th>
<th>Ag</th>
<th>V</th>
<th>Au</th>
<th>Hg</th>
<th>Bl U</th>
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<tr>
<td>LWP (m)</td>
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<tr>
<td>1041 16.44</td>
<td>16.44</td>
<td>2.99 Silicate, siltstone</td>
<td>P</td>
<td>3.45</td>
<td>0.53</td>
<td>8.04</td>
<td>55</td>
<td>110</td>
<td>74</td>
<td>76</td>
<td>165</td>
<td>110</td>
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<tr>
<td>1042 18.63</td>
<td>18.63</td>
<td>2.39 Siltstone</td>
<td>D</td>
<td>3.59</td>
<td>0.51</td>
<td>5.92</td>
<td>53</td>
<td>103</td>
<td>24</td>
<td>101</td>
<td>172</td>
<td>66</td>
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<tr>
<td>1043 21.22</td>
<td>21.22</td>
<td>2.17 Medesite, siltstone</td>
<td>D</td>
<td>2.57</td>
<td>0.57</td>
<td>8.04</td>
<td>47</td>
<td>102</td>
<td>32</td>
<td>66</td>
<td>159</td>
<td>105</td>
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<td>1044 23.39</td>
<td>23.39</td>
<td>1.33 Siltstone</td>
<td>F</td>
<td>2.95</td>
<td>0.49</td>
<td>2.36</td>
<td>34</td>
<td>55</td>
<td>43</td>
<td>77</td>
<td>142</td>
<td>77</td>
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<tr>
<td>1026 25.32</td>
<td>25.32</td>
<td>1.65 Siltstone, sandstone</td>
<td>F</td>
<td>3.12</td>
<td>0.47</td>
<td>2.69</td>
<td>10</td>
<td>125</td>
<td>24</td>
<td>83</td>
<td>216</td>
<td>85</td>
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<td>1027 27.17</td>
<td>27.17</td>
<td>1.75 Medesite, siltstone</td>
<td>F</td>
<td>3.72</td>
<td>0.43</td>
<td>5.38</td>
<td>10</td>
<td>186</td>
<td>89</td>
<td>280</td>
<td>101</td>
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<td>1028 28.49</td>
<td>28.49</td>
<td>1.12 Sandstone</td>
<td>B</td>
<td>7.03</td>
<td>0.26</td>
<td>5.90</td>
<td>28</td>
<td>48</td>
<td>387</td>
<td>80</td>
<td>207</td>
<td>156</td>
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<td>1029 30.82</td>
<td>30.82</td>
<td>1.41 Siltstone</td>
<td>B</td>
<td>3.54</td>
<td>0.43</td>
<td>5.09</td>
<td>29</td>
<td>48</td>
<td>387</td>
<td>80</td>
<td>207</td>
<td>156</td>
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<tr>
<td>1030 33.19</td>
<td>33.19</td>
<td>1.48 Siltstone</td>
<td>B</td>
<td>3.46</td>
<td>0.50</td>
<td>5.16</td>
<td>14</td>
<td>52</td>
<td>246</td>
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<td>1031 34.60</td>
<td>34.60</td>
<td>2.87 Siltstone</td>
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<td>4.15</td>
<td>0.48</td>
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<td>20</td>
<td>88</td>
<td>10</td>
<td>110</td>
<td>190</td>
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### APPENDIX II TABLE V

**Analyses for additional elements in selected core samples**

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>From (m)</th>
<th>To (m)</th>
<th>Inter-</th>
<th>Generalised Lithology</th>
<th>Feature</th>
<th>Stratabound</th>
<th>Vein</th>
<th>Bl No</th>
<th>Ag</th>
<th>V</th>
<th>Au</th>
<th>Hg</th>
<th>Bl U</th>
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</thead>
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<tr>
<td>Norebole 1 (see also Table IV)</td>
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<tr>
<td>1021 55.59</td>
<td>60.50</td>
<td>1.01</td>
<td>Silicate</td>
<td>P</td>
<td>Pr, Ap</td>
<td>112</td>
<td>2 2</td>
<td>1 5</td>
<td>0.052</td>
<td>0.12</td>
<td>2 5</td>
<td></td>
<td></td>
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<tr>
<td>1022 62.50</td>
<td>62.44</td>
<td>1.46</td>
<td>Silicate, (?)/Pr</td>
<td>(?)/Pr</td>
<td>Ap</td>
<td>73</td>
<td>6 0</td>
<td>0 5</td>
<td>0.11</td>
<td>0.06</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1023 63.16</td>
<td>63.16</td>
<td>1.00</td>
<td>IPB</td>
<td>D</td>
<td>Pr, Ap</td>
<td>76</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.010</td>
<td>0.13</td>
<td>3</td>
<td></td>
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<tr>
<td>1024 63.16</td>
<td>63.16</td>
<td>1.00</td>
<td>IPB</td>
<td>D</td>
<td>Pr, Ap</td>
<td>65</td>
<td>1</td>
<td>2</td>
<td>6 &lt;0.01</td>
<td>0.22</td>
<td>0.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1025 65.46</td>
<td>65.77</td>
<td>1.23</td>
<td>IPB</td>
<td>D</td>
<td>Pr, Ap</td>
<td>66</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>0.16</td>
<td>3</td>
<td></td>
</tr>
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</table>

| Norebole 2 (see also Table IV) |          |       |       |                       |         |             |      |       |     |    |    |    |     |
| 1026 67.58 | 67.17    | 1.05  | Silicate, sandstone | P               | Pr, Ap | 54 | 0 | 0 | 3 | <0.01 | 0.16 | 7  |
| 1027 28.21 | 28.29    | 1.12  | Sandstone | B               | Pr, Ap | 73 | 2 | 1 | 3 | 0.100 | 0.65 | 6 2  |
| 1028 29.29 | 29.41    | 1.41  | Sandstone | B               | Pr, Ap | 64 | 2 | 0 | 2 | <0.01 | 0.14 | 1 0  |
| 1029 25.81 | 26.02    | 1.41  | Sandstone | B               | Pr, Ap | 59 | 1 | 2 | 0 | 0 | 0.01 | 0.16 | 2 4  |

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### APPENDIX III

**PETROGRAPHY AND MINERALOGY OF SELECTED CORE SAMPLES AND MINE DUMP SAMPLES, AND ELECTRON MICROPROBE ANALYSES OF SULPHIDES**

**Introduction**
Specimens were examined in polished thin section and investigated by X-ray diffraction, X-ray fluorescence analysis, electron microprobe analysis and carbonate staining using Alizarin-red solution. The diffraction technique employed was powder photography and the results given in the tables bear the powder film numbers. Analyses by XRF were effected by scans of polished thin sections, panning concentrates and powder camera diffraction mounts using a Siemens's VRS manual spectrometer. The results are expressed in Tables I–IV, corresponding to samples from BHs 1–4 respectively, and in Table V which deals with dump specimens from the sorting floors associated with the old mine workings.

Microprobe analyses were carried out by B. Beddoe-Stephens with a Cambridge Instruments Microscan 5 on 14 pyrite grains and 14 arsenopyrite grains and the results are given in Tables VI–IX.

**Mineral abbreviations used in Tables I–V**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Mineral Abbreviation</th>
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<tbody>
<tr>
<td>Ap</td>
<td>arsenopyrite</td>
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<tr>
<td>Ar</td>
<td>aragonite</td>
</tr>
<tr>
<td>At</td>
<td>apatite</td>
</tr>
<tr>
<td>Br</td>
<td>baryte</td>
</tr>
<tr>
<td>Bu</td>
<td>boumnonite</td>
</tr>
<tr>
<td>Ca</td>
<td>calcite</td>
</tr>
<tr>
<td>Cy</td>
<td>clay minerals</td>
</tr>
<tr>
<td>Dk</td>
<td>dickite</td>
</tr>
<tr>
<td>Do</td>
<td>dolomite</td>
</tr>
<tr>
<td>Gl</td>
<td>galena</td>
</tr>
<tr>
<td>Gs</td>
<td>unidentified grey sulphide</td>
</tr>
<tr>
<td>Hm</td>
<td>hematite</td>
</tr>
<tr>
<td>Py</td>
<td>pyrite</td>
</tr>
<tr>
<td>Qz</td>
<td>quartz</td>
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<tr>
<td>RF</td>
<td>rock fragments</td>
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<td>Sm</td>
<td>semseyite</td>
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<td>Sp</td>
<td>sphalerite</td>
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<td>St</td>
<td>stibnite</td>
</tr>
<tr>
<td>Tm</td>
<td>tourmaline</td>
</tr>
<tr>
<td>Tn</td>
<td>tennantite</td>
</tr>
<tr>
<td>Tt</td>
<td>tetrahedrite</td>
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<tr>
<td>Zc</td>
<td>zircon</td>
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</table>

44
<table>
<thead>
<tr>
<th>Sample Number (CXD)</th>
<th>Depth (ft)</th>
<th>301 No.</th>
<th>Name</th>
<th>Mineral Constituents Major</th>
<th>Minor</th>
<th>Comments</th>
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</thead>
<tbody>
<tr>
<td>1531</td>
<td>31.75-31.79</td>
<td>5859</td>
<td>Sandstone</td>
<td>Qt Bt RF Zn Co</td>
<td></td>
<td>Matrix consists of chlorite, clay minerals, muscovite, sericite and hematite; original biotite altered to hematite; veinlets contain dolomite</td>
</tr>
<tr>
<td>1538</td>
<td>36.30-36.46</td>
<td>5860</td>
<td>Sandstone</td>
<td>Qt Bt RF Zn Co</td>
<td></td>
<td>Turbid matrix consists of clay minerals, muscovite, sericite, hematite, trace chlorite; veinlets contain hematite; siltstone on fracture surfaces</td>
</tr>
<tr>
<td>1577</td>
<td>47.52-47.62</td>
<td>6359</td>
<td>Siltstone</td>
<td>Qt Bt RF Zn Co</td>
<td></td>
<td>Intensely altered; replacement by carbonate and hematite; disseminated pyrite largely replaced by hematite</td>
</tr>
<tr>
<td>1539</td>
<td>50.00-50.08</td>
<td>6357</td>
<td>Siltstone</td>
<td>Qt Bt RF Zn Co</td>
<td></td>
<td>Dickite abundant along fracture surfaces; trace of disseminated pyrite</td>
</tr>
<tr>
<td>1575</td>
<td>54.86-54.94</td>
<td>6357</td>
<td>Sandstone</td>
<td>Qt Bt RF Zn Co</td>
<td></td>
<td>Matrix strongly altered with traces of hematite, biotite, muscovite and carbonate; minor disseminated pyrite; calcite in veinlets</td>
</tr>
<tr>
<td>1500</td>
<td>61.51-62.00</td>
<td></td>
<td>Sandstone</td>
<td>Qt Bt RF Zn Co</td>
<td></td>
<td>Veinlets contain pyrite, arsenopyrite, quartz and dolomite; trace of stibnite on fracture surfaces</td>
</tr>
<tr>
<td>1501</td>
<td>69.64-69.64</td>
<td></td>
<td>Breccia</td>
<td>Qt Bt RF Zn Co</td>
<td></td>
<td>Biotite from possible fault zone; strong alteration to dickite; trace disseminated pyrite and arsenopyrite; stibnite on fracture surfaces</td>
</tr>
<tr>
<td>1502</td>
<td>69.63-69.10</td>
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<td>Breccia</td>
<td>Qt Bt RF Zn Co</td>
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<td>As for CXD 1501 except no apparent sulphide mineralisation</td>
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<td>1503</td>
<td>69.16-69.11</td>
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<td>Qt Bt RF Zn Co</td>
<td></td>
<td>As for CXD 1501 but no stibnite apparent</td>
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<td>1504</td>
<td>59.19-59.22</td>
<td></td>
<td>Breccia</td>
<td>Qt Bt RF Zn Co</td>
<td></td>
<td>Alteration less intense than CXD 1501-1503; disseminated pyrite and arsenopyrite</td>
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<tr>
<td>1505</td>
<td>75.48-75.49</td>
<td></td>
<td>Breccia</td>
<td>Qt Bt RF Zn Co</td>
<td></td>
<td>Feldspar clasts strongly sericitised; matrix consists of clay minerals, sericite, muscovite shreds, chlorite and anhydrite iron oxide; traces of disseminated pyrite</td>
</tr>
<tr>
<td>1506</td>
<td>74.34-75.97</td>
<td>5803</td>
<td>Sandstone</td>
<td>Qt Bt RF Zn Co</td>
<td></td>
<td>Feldspar clasts strongly sericitised; matrix consists of clay minerals, sericite, muscovite shreds, dolomite, traces of chlorite and anhydrite iron oxide; trace of disseminated pyrite</td>
</tr>
<tr>
<td>1507</td>
<td>79.16-79.22</td>
<td>5861</td>
<td>Mudstone</td>
<td>Qt Bt RF Zn Co</td>
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<td>Trace of disseminated globular pyrite</td>
</tr>
<tr>
<td>1508</td>
<td>83.56-83.75</td>
<td>6358</td>
<td>Siltstone</td>
<td>Qt Bt RF Zn Co</td>
<td></td>
<td>Turbid matrix largely comprised of dolomite; veins contain pyrite and tetrahedrite (confirmed by XRD: Fe 66.96%); finely disseminated pyrite also present; trace of stibnite on fracture surfaces</td>
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TABLE II
Petrography of core specimens, 1997

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<tr>
<th>Sample Number (GBX)</th>
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<th>Name</th>
<th>Mineral Constituents</th>
<th>Comments</th>
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<td>1545</td>
<td>42.20-42.27</td>
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<td>Py Ap St</td>
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<td>1560</td>
<td>42.25-42.30</td>
<td>6025</td>
<td>Mudstone</td>
<td>Py Ap Mn Mn</td>
<td>Strongly serpentinitized; stratiform pyrite and arsenopyrite concentrated in narrow bands parallel to original bedding; albitization and carbonate due to late-stage veins of dolomite and hematite (confirmed by XRD, Ph 6416, 6417)</td>
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<td>44.30-44.32</td>
<td>Sandstone</td>
<td>Qs</td>
<td>Py Ap St</td>
<td>Contains &quot;flames&quot; of mudstone; minute traversing vein contains pyrite and arsenopyrite; trace of stibnite on fracture surfaces</td>
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<td>46.17-46.25</td>
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<td>Py Ap St</td>
<td></td>
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<td>46.20-46.25</td>
<td>Mudstone</td>
<td>Py Ap St</td>
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<td>1536</td>
<td>46.46-46.77</td>
<td>Breccia</td>
<td>Qs Py</td>
<td></td>
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<tr>
<td>1585</td>
<td>46.91-46.97</td>
<td>Sandstone</td>
<td>Qs</td>
<td>Py Ap St</td>
<td>Contains eflames of mudstone; single traversing vein contains pyrite and arsenopyrite; trace of stibnite on fracture surfaces</td>
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<td>1586</td>
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<td>Siltstone</td>
<td>Qs</td>
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<td>1587</td>
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<td>Neopelite</td>
<td>Qs HP</td>
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<td>Py Ap St</td>
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<td>Py St Mn</td>
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<td>Py St Mn</td>
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<tr>
<td>1592</td>
<td>57.41-57.87</td>
<td>Siltstone</td>
<td>Qs Ap Py</td>
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</table>

Dark grey sulphide in quartz veins (confirmed as tetrahedrite and bornite by XRD analysis (Ph 6477))

Non-laminated; traversed by at least two generations of veins (i) contains traces of pyrite and arsenopyrite; (ii) interwoven type (i) and contains minute crystals of pyrite; stibnite on fracture surfaces

Strongly sericitised; stratiform pyrite and arsenopyrite concentrated in narrow bands parallel to original bedding; albitisation and carbonate due to late-stage veins of dolomite and hematite (confirmed by XRD, Ph 6416, 6417)

Contains "flames" of mudstone; minute traversing vein contains pyrite and arsenopyrite; trace of stibnite on fracture surfaces

Pyrite and arsenopyrite in bands parallel to original bedding; trace of stibnite on fracture surfaces

Strongly sericitised; stratiform pyrite and arsenopyrite exhibit slight hematitic alteration

Pyrite and arsenopyrite in bands parallel to original bedding; trace of stibnite on fracture surfaces

Hematite alteration associated with minute quartz-carbonate veins (possibly replacing pyrite); matrix of quartz and trace carbonates; veins contain quartz and dolomite; traces of pyrite altered to hematite; stibnite on fracture surfaces

Coarse quartz veins; fragments are set in a quartz matrix; fragments contain abundant aggregates of prismatic crystals of hematite probably replacing arsenopyrite (XRF scan indicated major Fe)

Red veins identified as hematite plus a mica mineral by XRD analysis (Ph 6425)

Red mineral identified by XRD analysis as hematite plus mica mineral (Ph 6412)

Reddish hematitic alteration obscures much of the mineralogy; pyrite sparsely disseminated; trace of stibnite on fracture surfaces

Abundant disseminated arsenopyrite with subordinate globular pyrite; complex vein network; infilling minerals are quartz, dolomite, dickite and traces of pyrite and arsenopyrite
<table>
<thead>
<tr>
<th>Sample Number (CXD)</th>
<th>Depth (m)</th>
<th>PI'S No</th>
<th>Name</th>
<th>Mineral Constituents</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1550</td>
<td>59.05-59.17</td>
<td></td>
<td>Breccia</td>
<td>Qs RF Bo Py Ap</td>
<td>Sandstone or siltstone fragments set in a quartz-dolomite matrix; finely disseminated pyrite and arsenopyrite</td>
</tr>
<tr>
<td>1564</td>
<td>60.11-60.20</td>
<td>6028</td>
<td>Sandstone</td>
<td>Qs Bo Py Ap</td>
<td>Strong sericitization; disseminated pyrite with subordinate arsenopyrite; veinlets contain dolomite with trace pyrite</td>
</tr>
<tr>
<td>1573</td>
<td>68.13-60.23</td>
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<td></td>
<td></td>
<td>Grey sulphides in veinlets identified as galena plus tetrabedrite (Th 65%)</td>
</tr>
<tr>
<td>1583</td>
<td>74.94-74.99</td>
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<td></td>
<td></td>
<td>Grey sulphides in veinlets identified as chalcopyrite (Pt 62%)</td>
</tr>
<tr>
<td>1558</td>
<td>98.57-112.62</td>
<td>6022</td>
<td>Breccia</td>
<td>RF Qs Bo Py Ap</td>
<td>Rock fragments consist of mudstone, siltstone and sandstone and all contain disseminated pyrite and arsenopyrite; quartz-dolomite matrix contains disseminated pyrite and arsenopyrite; fine, minor veinlets contain traces of pyrite and arsenopyrite</td>
</tr>
<tr>
<td>1559</td>
<td>100.23-100.30</td>
<td>6023, 6023A</td>
<td>Siltstone</td>
<td>Qs Bo Py He (Ap)</td>
<td>Fabric masked by intense carbonate alteration; where alteration is most intense, arsenopyrite is almost completely replaced by hematite and dolomite; pyrite appears to have suffered little or no alteration</td>
</tr>
<tr>
<td>1567</td>
<td>112.01-112.97</td>
<td>6053</td>
<td>Mudstone</td>
<td>Bo Py Ap</td>
<td>Nature of original rock difficult to evaluate as carbonate is alteration intense; banded pyrite and arsenopyrite probably stratiform</td>
</tr>
<tr>
<td>Sample Number (C.D.)</td>
<td>Depth (m)</td>
<td>FMS No</td>
<td>Name</td>
<td>Mineral Quantities</td>
<td>Comments</td>
</tr>
<tr>
<td>---------------------</td>
<td>-----------</td>
<td>--------</td>
<td>----------</td>
<td>----------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>1542</td>
<td>0.00</td>
<td></td>
<td></td>
<td></td>
<td>Small green flakes from vein identified by XRD analysis as a dioctahedral mica mineral (Rn 6322)</td>
</tr>
<tr>
<td>1544</td>
<td>36.28-36.30</td>
<td>6033</td>
<td>Sandstone</td>
<td>Qt</td>
<td>Grey sulphides in veinlets identified by XRD analysis as bournonite (Rn 6451)</td>
</tr>
<tr>
<td>1550</td>
<td>45.69-45.77</td>
<td>6035</td>
<td></td>
<td>SB De Py Do</td>
<td>Such grey sulphides in vein identified by XRD analysis as bournonite (Rn 6450)</td>
</tr>
<tr>
<td>1559</td>
<td>65.05-65.13</td>
<td>6035</td>
<td>Sandstone</td>
<td>Qt</td>
<td>Quarts and undifferentiated rock fragments set in a matrix of clay minerals, sericite, dolomite and a trace of chlorite; two generations of veining (i) dolomite with traces of pyrite and (ii) quartz; the quartz veins cross-cut and postdate the dolomite veins</td>
</tr>
<tr>
<td>1560</td>
<td>75.5</td>
<td></td>
<td></td>
<td></td>
<td>Clear tabular aragonite from a late stage fracture identified by XRD analysis as aragonite (Rn 6313)</td>
</tr>
<tr>
<td>1570</td>
<td>57.85-57.95</td>
<td>6033</td>
<td>Breccia</td>
<td>E P Qs Do</td>
<td>Fragments of sandstone and sandstone strongly altered to sericite and chlorite; matrix consists of quartz and dolomite; a fine network of quartz-carbonate veins have provided localised sites for strong carbonate alteration; traces of globular pyrite in matrix; greenish mineral associated with altered rock fragments identified by XRD analysis as a dioctahedral mica mineral (Rn 6457)</td>
</tr>
<tr>
<td>1509</td>
<td>65.78-65.85</td>
<td>6034</td>
<td>Mudstone</td>
<td>Qt, Do</td>
<td>Specimen very friable; abundant disseminated pyrite and arsenopyrite; veins of stibnite on fracture surfaces</td>
</tr>
<tr>
<td>1593</td>
<td>65.93-66.05</td>
<td>6362</td>
<td>Mudstone</td>
<td>Qt, Do</td>
<td>Discrete patches of disseminated pyrite; quartz-dolomite veins containing traces of pyrite</td>
</tr>
<tr>
<td>1513</td>
<td>66.78-66.83</td>
<td>6034</td>
<td>Sandstone</td>
<td>Qt</td>
<td>Fine acicular stibnite on fracture surfaces confirmed by XRD analysis (Rn 6322)</td>
</tr>
<tr>
<td>1510</td>
<td>67.92-68.02</td>
<td></td>
<td>Mudstone</td>
<td>Qt</td>
<td>Stibnite blooms on fracture surfaces confirmed by XRD analysis (Rn 6320)</td>
</tr>
<tr>
<td>1511</td>
<td>70.36-70.42</td>
<td></td>
<td>Mudstone</td>
<td>Qt, Do</td>
<td>Blooms of stibnite on fracture surfaces; trace of disseminated pyrite</td>
</tr>
<tr>
<td>1514</td>
<td>79.38-79.62</td>
<td>6360</td>
<td>Breccia</td>
<td>Ap Py</td>
<td>Siltstone or sandstone fragments set in a quartz-carbonate matrix; although the rock is strongly sheared stratiform arsenopyrite with subordinate pyrite are still recognisable</td>
</tr>
<tr>
<td>1517</td>
<td>88.81-89.90</td>
<td>56562, 56564</td>
<td>Siltstone</td>
<td>Qt, Do</td>
<td>Occasional arsenopyrite present in matrix; arsenopyrite and pyrite in bands, trace of stibnite on fracture surfaces; two generations of veining (i) dolomite with traces of pyrite and (ii) quartz with traces of dolomite and arsenopyrite; the quartz veins cross-cut the dolomite veins</td>
</tr>
<tr>
<td>Sample Number</td>
<td>Depth (m)</td>
<td>Tax No.</td>
<td>Name</td>
<td>Mineral Constituents</td>
<td>Comments</td>
</tr>
<tr>
<td>---------------</td>
<td>----------</td>
<td>--------</td>
<td>--------</td>
<td>----------------------</td>
<td>----------</td>
</tr>
<tr>
<td>1513</td>
<td>83.35-83.41</td>
<td>1513</td>
<td>Mudstone</td>
<td>Ap</td>
<td>Despite shearing, bands of arsenopyrite with traces of pyrite are roughly parallel to the original bedding.</td>
</tr>
<tr>
<td>1514</td>
<td>86.93-87.02</td>
<td>1514</td>
<td>Sandstone</td>
<td>Qz, Py, Ap, RF, Do, St</td>
<td>Despite obliteration of most primary features by shearing, bands of arsenopyrite and pyrite lying roughly parallel to the original bedding can still be seen; two generations of veinings, (i) dolomite veins and (ii) later veins containing quartz, dolomite and dickite; veins are devoid of sulphide minerals.</td>
</tr>
<tr>
<td>1502</td>
<td>90.92-91.17</td>
<td>1502</td>
<td></td>
<td>Mn, Ap, Sp</td>
<td>Grey sulphides identified by XRD analysis as boouronite, arsenopyrite and a trace of sphalerite (Ph 6457).</td>
</tr>
<tr>
<td>1503</td>
<td>83.35-83.41</td>
<td>1503</td>
<td>Breccia</td>
<td>RF, Qz, Py, Ap, Do, Sp</td>
<td>Fragments of sandstone or siltstone containing traces of disseminated pyrite and arsenopyrite; matrix consists of coarse crystalline quartz with a trace of dolomite; veins contain coarse plagioclase dolomite with a trace of pyrite and cross-cutting quartz veins containing pyrite and arsenopyrite; confirmed by XRD analysis (Ph 6459).</td>
</tr>
<tr>
<td>1515</td>
<td>103.83-103.91</td>
<td>1515</td>
<td>Mudstone</td>
<td>Ap, Py, Mn, St</td>
<td>Arsenopyrite and pyrite in bands parallel to original bedding.</td>
</tr>
<tr>
<td>1516</td>
<td>106.91-106.94</td>
<td>1516</td>
<td>Mudstone</td>
<td>Ap, Py, Qz, Do, Mn, St</td>
<td>Arsenopyrite is disseminated in varying amounts through the rock; differential distribution of disseminated arsenopyrite; however, together with minor pyrite it is also concentrated in a band of dolomite veins parallel to the original bedding; matrix contains quartz, dolomite and dickite (confirmed by XRD analysis: Ph 6318); stibnite found on fracture surfaces.</td>
</tr>
<tr>
<td>1517</td>
<td>109.23-109.31</td>
<td>1517</td>
<td>Sandstone</td>
<td>Qz, Py, Ap, St, RF, F1, Mn, Do</td>
<td>Sparse distribution of disseminated pyrite and arsenopyrite; stibnite on fracture surfaces; two generations of veinings, (i) dolomite veins (ii) late veins of quartz with traces of dolomite and pyrite.</td>
</tr>
<tr>
<td>1518</td>
<td>126.69-128.61</td>
<td>1518</td>
<td>Sandstone</td>
<td>Qz, Py, Mn, RF, F1, Mn, Do</td>
<td>Finely disseminated pyrite; narrow dolomitic vein contains tiny crystals of boouronite.</td>
</tr>
<tr>
<td>1519</td>
<td>134.73-134.79</td>
<td>1519</td>
<td>Breccia</td>
<td>Qz, Do, RF, Mn, Py</td>
<td>Fragments of mudstone, sandstone and quartz set in a matrix containing quartz, carbonate, dickite and abundant disseminated pyrite; narrow quartz-carbonate veins contain minor amounts of pyrite.</td>
</tr>
<tr>
<td>1520</td>
<td>137.90-137.94</td>
<td>1520</td>
<td>Breccia</td>
<td>Qz, Do, RF, Mn, Py</td>
<td>Similar to specimen CDD 1519; dickite identified by XRD analysis (Ph 6318).</td>
</tr>
<tr>
<td>1521</td>
<td>153.63-153.74</td>
<td>1521</td>
<td>Breccia</td>
<td>Qz, Do, RF, Mn, Py</td>
<td>Similar to CDD 1519 except that a trace of arsenopyrite is present while dickite is uncommon.</td>
</tr>
<tr>
<td>1573</td>
<td>143.69-143.67</td>
<td>1573</td>
<td>Sandstone</td>
<td>RF, Do, Mn, Do, Py</td>
<td>Associated with a thin brecciated zone; a dolomite rich vein contains boouronite and baryte, confirmed by XRD analysis (Ph 6306); trace of disseminated pyrite.</td>
</tr>
<tr>
<td>Sample Number (CDD)</td>
<td>Depth (m)</td>
<td>PMB No</td>
<td>Name</td>
<td>Mineral Constituents Major</td>
<td>Minor</td>
</tr>
<tr>
<td>---------------------</td>
<td>-----------</td>
<td>---------</td>
<td>--------</td>
<td>---------------------------</td>
<td>-------</td>
</tr>
<tr>
<td>1522</td>
<td>105.05-105.11</td>
<td>5865</td>
<td>Mudstone</td>
<td>Py Ap Br Do</td>
<td></td>
</tr>
<tr>
<td>1505</td>
<td>105.17-105.26</td>
<td>6029</td>
<td>Mudstone</td>
<td>Py Ap Do</td>
<td></td>
</tr>
<tr>
<td>1506</td>
<td>106.07-106.24</td>
<td>6030</td>
<td>Breccia</td>
<td>RF Qa Ap</td>
<td>Py</td>
</tr>
<tr>
<td>1523</td>
<td>107.63-107.69</td>
<td>5869</td>
<td>Mudstone</td>
<td>Py Ap Le Do Op Br Go</td>
<td></td>
</tr>
<tr>
<td>1522</td>
<td>105.40-105.55</td>
<td>6021</td>
<td>Mudstone</td>
<td>Py Qa Go Cl</td>
<td></td>
</tr>
<tr>
<td>1524</td>
<td>105.75-106.00</td>
<td>5011</td>
<td>Siltstone</td>
<td>Qs Py Ho Ul Ht</td>
<td></td>
</tr>
<tr>
<td>1571</td>
<td>106.42-106.61</td>
<td>5096</td>
<td>Siltstone</td>
<td>Qs Py Hm St</td>
<td></td>
</tr>
<tr>
<td>1525</td>
<td>106.01</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1553</td>
<td>106.14-106.18</td>
<td></td>
<td>Mudstone</td>
<td>Py Ap</td>
<td></td>
</tr>
<tr>
<td>1572</td>
<td>106.62-106.73</td>
<td>6035</td>
<td>Siltstone</td>
<td>Qa Py Ap</td>
<td></td>
</tr>
<tr>
<td>1501</td>
<td>154.60-159.66</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>1506</td>
<td>175.27-175.30</td>
<td>5071</td>
<td>Sandstone</td>
<td>Fl Th Sc RF Py Hm</td>
<td></td>
</tr>
</tbody>
</table>

Pyrite and arsenopyrite occur in bands parallel to the original bedding whereas bournonite (Pn 6/32) is confined to fracture surfaces; the veinlets present are composed of dolomite, with traces of pyrite and arsenopyrite. Pyrite and arsenopyrite occur in two distinctive bands about 1 m wide which lie parallel to the original bedding, and also in minor amounts in dolomite-rich veinlets. Fragments consist of recrystallised mudstone or siltstone which contain globular pyrite and bands of pyrite roughly parallel to the original bedding; matrix contains quartz and arsenopyrite. Veinlets are comprised of dolomite with traces of pyrite. Finely disseminated pyrite and arsenopyrite occur in bands parallel to the original bedding; arsenopyrite is the dominant sulphide; globular pyrite has formed around the arsenopyrite crystal boundaries. Minor sulphide is dolomite veins is bournonite (Pn 6/32). Finely disseminated pyrite altering to hematite; two generations of veinings, (i) dolomite-quartz veins with abundant to minor crystals of pyrite and (ii) later quartz veins devoid of sulphide minerals.
TABLE III (continued)

<table>
<thead>
<tr>
<th>Sample Number (OXD)</th>
<th>Depth (m)</th>
<th>FM No</th>
<th>Name</th>
<th>Mineral Constituents</th>
<th>Major</th>
<th>Minor</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1527</td>
<td>176.92-176.92</td>
<td>5856</td>
<td>Breccia</td>
<td>RF Qz Py</td>
<td>DO Sr</td>
<td></td>
<td>Rock fragments are predominantly mudstone, strongly sericitised and carrying abundant disseminated pyrite; the quartz-dolomite matrix contains areas of massive pyrite seemingly confined to certain zones; traces of dolomite in matrix; complex network of quartz and dolomite veins</td>
</tr>
<tr>
<td>1528</td>
<td>177.08-177.15</td>
<td>5857</td>
<td>Breccia</td>
<td>RF Qz</td>
<td>Ap Py Do</td>
<td></td>
<td>Similar to specimen OXD 1527 except that traces of disseminated arsenopyrite occur in some of the rock fragments whereas the zones of massive pyrite are absent</td>
</tr>
<tr>
<td>1530</td>
<td>177.70-177.75</td>
<td>6032</td>
<td>Breccia</td>
<td>RF Qz</td>
<td>Ap Py Do</td>
<td>Trace of disseminated pyrite and arsenopyrite in a quartz-dolomite matrix</td>
<td></td>
</tr>
<tr>
<td>1531</td>
<td>177.76-177.81</td>
<td>6032</td>
<td>Breccia</td>
<td>RF Qz Pr</td>
<td>DO Do</td>
<td></td>
<td>Similar to specimen OXD 1527</td>
</tr>
<tr>
<td>1568</td>
<td>178.64-178.69</td>
<td>6032</td>
<td>Siltstone</td>
<td>Qa</td>
<td>Py Ap Do</td>
<td>Incorporates irregular, film-shaped masses of mudstone which contain isolated crystals of arsenopyrite and pyrite; arsenopyrite and pyrite are disseminated throughout the siltstone; intervals contain dolomite with a trace of pyrite</td>
<td></td>
</tr>
<tr>
<td>1532</td>
<td>193.12-193.20</td>
<td>5857</td>
<td>Sandstone</td>
<td>Qa</td>
<td>RF Hg</td>
<td>Abundant, bronze-coloured flaky mineral identified as hematite which appears to be replacing biotite</td>
<td></td>
</tr>
<tr>
<td>1532</td>
<td>194.88-194.98</td>
<td>5857</td>
<td>Mudstone</td>
<td>Py St</td>
<td></td>
<td>Finely laminated; sparse dissemination of pyrite; stibnite bloom on fracture surfaces</td>
<td></td>
</tr>
<tr>
<td>Sample Number (GEO)</td>
<td>Depth (m)</td>
<td>PTD NO</td>
<td>Name</td>
<td>Mineral Constituents</td>
<td>Comments</td>
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<tr>
<td>1530</td>
<td>26.92-26.96</td>
<td>5873</td>
<td>Sandstone</td>
<td>Qs</td>
<td>Py Ap St RF</td>
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</tr>
<tr>
<td>1533</td>
<td>27.50-27.55</td>
<td>5873</td>
<td>Breccia</td>
<td>Qs RF</td>
<td>Py Ap St RF; matrix: from the crushed sample the following were identified by XRD analysis: sphalerite (Pn 6306, 5313); arsenopyrite (Pn 6306, 6309, 5311); arseneopryte (Pn 6306, 6309, 5311); sphalerite (Pn 5313) and quartz (Pn 6307)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1571</td>
<td>27.62-27.67</td>
<td>6356</td>
<td>Sandstone</td>
<td>Qs</td>
<td>Py Ap St Gl Bi</td>
<td></td>
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</tr>
<tr>
<td>1571</td>
<td>29.41-29.50</td>
<td>5874</td>
<td>Sandstone</td>
<td>Qs</td>
<td>Py Ap St RF; pyrite, arsenopyrite and trace of bournonite in quartz carbonate veins</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1574</td>
<td>29.53-29.56</td>
<td>5874</td>
<td>Sandstone</td>
<td>Qs</td>
<td>Py Ap St RF; pyrite, arsenopyrite and trace of bournonite in quartz carbonate veins</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1535</td>
<td>33.17-33.22</td>
<td>5875</td>
<td>Sandstone</td>
<td>Qs</td>
<td>Py Ap St RF; pyrite, arsenopyrite and trace of bournonite in quartz carbonate veins</td>
<td></td>
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</table>

**TABLE IV**

**Petrography of core specimens, BIU**
TABLE V

Petrographic data for specimens from the sorting floors of Glendinning Mine

<table>
<thead>
<tr>
<th>Sample Number DBR</th>
<th>PT3 Number</th>
<th>Mineral Constituents</th>
<th>% Quartz-Carbonate Gangue</th>
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<tr>
<td>501</td>
<td>4886</td>
<td>St Sp</td>
<td>30</td>
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<tr>
<td>502</td>
<td>4887</td>
<td>Sp Gl</td>
<td>St Py</td>
</tr>
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<td>503</td>
<td>4888</td>
<td>Sp Gl</td>
<td>Py</td>
</tr>
<tr>
<td>504</td>
<td>4889</td>
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<td>St Sp Gl</td>
<td>Py</td>
</tr>
<tr>
<td>507</td>
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<td>Sp Gl</td>
<td>Py Ap St</td>
</tr>
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<td>4893</td>
<td>Gl</td>
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</tr>
<tr>
<td>509</td>
<td>4894</td>
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<td>Gl St Sp</td>
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### TABLE VI

<table>
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<tbody>
<tr>
<td>Fe</td>
<td>41.73</td>
<td>41.20</td>
<td>41.93</td>
<td>41.70</td>
<td>41.07</td>
<td>45.24</td>
<td>45.98</td>
<td>55.07</td>
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<tr>
<td>S</td>
<td>5.97</td>
<td>5.55</td>
<td>5.35</td>
<td>5.28</td>
<td>5.17</td>
<td>5.04</td>
<td>5.32</td>
<td>5.19</td>
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<td>As</td>
<td>2.83</td>
<td>1.25</td>
<td>5.31</td>
<td>1.87</td>
<td>1.98</td>
<td>1.75</td>
<td>1.95</td>
<td>3.25</td>
</tr>
<tr>
<td>Total</td>
<td>99.97</td>
<td>91.10</td>
<td>99.59</td>
<td>98.83</td>
<td>99.37</td>
<td>99.75</td>
<td>100.55</td>
<td>100.11</td>
</tr>
</tbody>
</table>

Atomic formulae (3.000)

| Fe | 0.957 | 0.975 | 1.000 | 0.998 | 1.001 | 0.977 | 0.987 | 0.987 | 0.998 |
| S  | 1.995 | 2.001 | 1.912 | 1.921 | 1.964 | 1.937 | 1.993 | 1.960 | 1.963 |
| As | 0.060 | 0.046 | 0.060 | 0.061 | 0.032 | 0.057 | 0.020 | 0.065 | 0.060 |

| ppm | 126 |
| Ni | 0.900 | 1.000 | 0.900 | 0.900 |
| Co | 1.900 | 1.800 | 1.800 | 1.800 |
| Mn | 1.900 | 1.800 | 1.800 | 1.800 |
| Ag | 1.900 | 1.800 | 1.800 | 1.800 |
| As | 1.900 | 1.800 | 1.800 | 1.800 |
| Cu | 1.900 | 1.800 | 1.800 | 1.800 |
| PPM No | 6000 | 6000 | 6000 | 6000 |
| CoNo | 1563 | 1563 | 1563 | 1563 |
| EH No | 2 | 2 | 2 | 2 |

Notes: Values in brackets are below 95% confidence detection limit. (Lower limit of detection: 50-100 sec. counts). * Low totals probably due to poor specimen surfaces related to abundant microscopic inclinations in grains.

### TABLE VII

<table>
<thead>
<tr>
<th>1</th>
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<td>45.93</td>
</tr>
<tr>
<td>S</td>
<td>50.76</td>
<td>52.99</td>
<td>51.11</td>
</tr>
<tr>
<td>As</td>
<td>5.18</td>
<td>0.62</td>
<td>1.63</td>
</tr>
<tr>
<td>Total</td>
<td>101.32</td>
<td>98.91</td>
<td>98.97</td>
</tr>
</tbody>
</table>

Atomic formulae (3.000)

| Fe | 0.989 | 0.984 | 1.011 | 0.976 |
| S  | 1.927 | 2.006 | 1.959 | 1.969 |
| As | 0.084 | 0.010 | 0.030 | 0.054 |

| ppm | 480 |
| Ni | (0) | (0) | (0) | (0) |
| Co | 1900 | 1900 | 1900 | 1900 |
| Mn | 600 | 600 | 600 | 600 |
| Ag | 700 | 700 | 700 | 700 |
| As | 1000 | 1000 | 1000 | 1000 |
| Cu | 760 | 760 | 760 | 760 |
| PPM No | 5854 | 5854 | 5854 | 5854 |
| CoNo | 1512 | 1512 | 1512 | 1512 |
| EH No | 2 | 2 | 2 | 2 |

Notes: Values in brackets are below 95% confidence detection limit. (Lower limit of detection: 50-100 sec. counts). * Low totals probably due to poor specimen surfaces related to abundant microscopic inclinations in grains.
### Table VIII

#### Electron microprobe analyses of stratified amorphoolite

<table>
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<th>Wt %</th>
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<th>5</th>
<th>6</th>
<th>7</th>
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<td>34.09</td>
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<td>As</td>
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<td>12.95</td>
<td>12.32</td>
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<td>12.32</td>
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<td>100.22</td>
<td>99.47</td>
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**Atomic formulae (1.000)**

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<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<tr>
<td>Fe</td>
<td>1.007</td>
<td>0.993</td>
<td>0.994</td>
<td>0.991</td>
<td>0.999</td>
<td>1.006</td>
<td>0.988</td>
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<tr>
<td>S</td>
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<td>1.074</td>
<td>1.053</td>
<td>1.067</td>
<td>1.072</td>
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<tr>
<td>As</td>
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<td>0.933</td>
<td>0.963</td>
<td>0.962</td>
<td>0.929</td>
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**ppm**

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<th>1820</th>
<th>(90)</th>
<th>(6)</th>
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<th>240</th>
<th>190</th>
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<td>Co</td>
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<td>690</td>
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<td>760</td>
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<td>1380</td>
<td>3250</td>
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<tr>
<td>As</td>
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<td>(6)</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>(6)</td>
</tr>
<tr>
<td>Se</td>
<td>480</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>500</td>
<td>–</td>
</tr>
<tr>
<td>Cu</td>
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<td>430</td>
<td>420</td>
<td>(110)</td>
<td>–</td>
<td>260</td>
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**PET No**

| 6029 | 6029 | 6030 | 6030 | 6030 | 6035 | 6025 |

**CSED No**

| 1565 | 1565 | 1566 | 1566 | 1566 | 1572 | 1572 |

**HR No**

| 3    | 3    | 3    | 3    | 3    | 3    | 3    |

**Depth (a)**

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### Table IX

#### Electron microprobe analyses of vein asperrymulite

<table>
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<th>Wt %</th>
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<th>7</th>
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<td>34.72</td>
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<tr>
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<td>98.33</td>
<td>97.36</td>
<td>97.11</td>
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<td>99.20</td>
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**Atomic formulae (3.000)**

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<th>Wt %</th>
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<tr>
<td>S</td>
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<td>0.914</td>
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**ppm**

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<th>(60)</th>
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<th>(60)</th>
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<tr>
<td>Co</td>
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<td>660</td>
<td>660</td>
<td>660</td>
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<tr>
<td>Sb</td>
<td>220</td>
<td>140</td>
<td>150</td>
<td>150</td>
<td>150</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>As</td>
<td>(6)</td>
<td>(6)</td>
<td>(6)</td>
<td>(6)</td>
<td>(6)</td>
<td>(6)</td>
<td>(6)</td>
</tr>
<tr>
<td>Se</td>
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<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
</tr>
<tr>
<td>Cu</td>
<td>480</td>
<td>360</td>
<td>430</td>
<td>480</td>
<td>320</td>
<td>540</td>
<td>310</td>
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</table>

**PET No**

| 6027 | 6027 | 5854 | 5854 | 5854 | 5854A | 5854A |

**CSED No**

| 1563 | 1563 | 1512 | 1512 | 1512 | 1512 | 1512 |

**HR No**

| 3    | 3    | 3    | 3    | 3    | 3    | 3    |

**Depth (a)**

<table>
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<th>57.12</th>
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<td>–60.90</td>
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</table>

* Lower limit of detection: 80–100 sec. counts
APPENDIX IV

GEOPHYSICAL PROFILES

In the geophysical survey of the Glendinning mine area, IP measurements were made along five NW–SE profiles. The detailed results are presented here as Figures 1–5. Apparent resistivity and chargeability results are given in the form of pseudosections and VLF–EM results are plotted as profiles of the percentage in-phase and out-of-phase component. The apparent VLF current-density was calculated by the method of Karous and Hjelt (1977) and is presented as pseudosections. The corresponding topographic profiles and the available geological information are also shown in Figures 1–5. The location of each traverse is shown on Appendix VI, Figure 1.
APPENDIX E, Fig 1 GEOPHYSICAL PROFILES FOR LINE 300N

APPARENT RESISTIVITY IN OHM METRES

CHARGEABILITY IN MILLISECONDS

VLF - EM

APPARENT CURRENT DENSITY
APPENDIX IV, Fig 2 GEOPHYSICAL PROFILES FOR LINE 100N
APPENDIX IV Fig 3 GEOPHYSICAL PROFILES FOR LINE 1005
APPENDIX E, Fig 4  GEOPHYSICAL PROFILES FOR LINE 300S

APPARENT CURRENT DENSITY

APPARENT RESISTIVITY IN OHM METRES
APPENDIX IV, Fig 5 Geophysical Profiles for Line 500s
APPENDIX V

DISTRIBUTION OF METALS IN HEAVY MINERAL CONCENTRATES FROM DRAINAGE NEAR GLENIDINNING

Geochemical maps showing the distribution of iron, zinc, lead, copper, nickel, barium, tin and arsenic in panned concentrates are presented in Figures 1 - 8.
Appendix V, Fig. 1 Distribution of iron (%) in heavy mineral concentrates from drainage near Glendinning
Appendix V, Fig. 2 Distribution of zinc (ppm) in heavy mineral concentrates from drainage near Glendinning
Appendix V, Fig. 3  Distribution of lead (ppm) in heavy mineral concentrates from drainage near Glendinning
Appendix V, Fig. 4 Distribution of copper (ppm) in heavy mineral concentrates from drainage near Glendinning
Appendix V, Fig. 5 Distribution of nickel (ppm) in heavy mineral concentrates from drainage near Glendinning
Appendix V, Fig. 6. Distribution of barium (ppm) in heavy mineral concentrates from drainage near Glendinning
Appendix V, Fig. 7  Distribution of tin (ppm) in heavy mineral concentrates from drainage near Glendinning
Appendix V, Fig. 8 Distribution of arsenic in heavy mineral concentrates from the Glendinning area
APPENDIX VI

GEOPHYSICAL MAP AND MAPS OF METAL DISTRIBUTION IN OVERBURDEN IN THE GLENDINNING MINE – TROUGH HOPE AREA
Appendix VI, Fig. 1 VLF-EM map of the area around Glendinning mine; IP maxima are also shown
Appendix VI, Fig. 2 Distribution of antimony in shallow overburden
Appendix VI, Fig. 3 Distribution of arsenic in shallow overburden
Appendix VI, Fig. 4 Distribution of calcium in shallow overburden
Appendix VI, Fig. 5 Distribution of lead in shallow overburden
Appendix VI, Fig. 6 Distribution of nickel in shallow overburden
Appendix VI, Fig. 7 Element maxima trends in shallow overburden
APPENDIX VII
RAPID FIELD ESTIMATION OF ARSENIC

Introduction
The method is based on the well-known Gutzeit technique whereby arsenic released by an appropriate dissolution procedure is converted to arsine which then forms a coloured complex with \( \text{HgCl}_2 \).

A portion of prepared sample is mixed with solid \( \text{KHSO}_4 \), \( \text{SnCl}_2 \) and \( \text{KI} \). On the addition of water \( \text{H}_2\text{SO}_4 \) is produced releasing some arsenic which is then reduced to \( \text{As}^{(III)} \). When \( \text{Zn} \) dust is added nascent hydrogen is formed which reacts with \( \text{As}^{(III)} \) to form arsine; the nascent hydrogen also serves to carry arsine from the reaction vessel, through a column of paper soaked in lead acetate to remove \( \text{H}_2\text{S} \), and onto a piece of filter paper impregnated with \( \text{HgCl}_2 \). The coloured spot produced is compared visually with a set of standard spots and the arsenic content of the sample is calculated. The development and previous applications of the method have been described by Peachey and others (1982).

Although total arsenic is not determined the method identifies anomalous samples and assists in on-site decision making and the need for alkalies and strong acids is avoided. Moreover the method is rapid and can be operated by unskilled staff. Care should be taken when interpreting results since arsenic held in secondary phases is released more readily than arsenic held in primary phases.

Fourteen samples from a traverse were analysed using the field method (analyst: B. P. Vickers) and by X-ray fluorescence spectrometry (analyst: D. J. Bland). The results obtained by both methods are compared in Figure 1. The conclusions reached from earlier work are confirmed, i.e. there is a close coincidence between the distribution patterns shown in Figure 1 and although the field method detected only a fraction of the total arsenic the anomalous samples are clearly identified.

Method
The \( \text{HgCl}_2 \) papers, lead acetate papers and the standards were prepared in the main laboratory.

Apparatus: Balance or standardised scoops; Gutzeit apparatus (see Figure 2).

Chemicals: (AR Grade chemicals were used throughout)
- Potassium bisulphate (\( \text{KHSO}_4 \))
- Stannous chloride (\( \text{SnCl}_2 \cdot 2\text{H}_2\text{O} \))
- Potassium iodide (\( \text{KI} \))
- Zinc powder
- Mercurochrome papers.

These are available commercially but can be prepared by soaking filter papers in mercuric chloride solution (about 25 g \( \text{HgCl}_2 \) in 100 ml ethanol).

The papers are air-dried, cut to size and stored in a box.

Lead acetate papers are prepared by soaking strips of filter paper (10 X 2 cm) in a saturated, aqueous solution of lead acetate. The papers are then air-dried.

Procedure:
1. Transfer 0.2 g sample and about 3.6 g \( \text{KHSO}_4 \) into the reaction bottle.
2. Add 10 ml of water.
3. Add 0.1 g \( \text{SnCl}_2 \cdot 2\text{H}_2\text{O} \).
4. Add 0.05 g \( \text{KI} \).
5. Add 1.0 g \( \text{Zn} \) powder and immediately insert the bung holding the glass tube and cup containing the \( \text{HgCl}_2 \) paper.
6. Swirl and leave for 20 minutes or until the reaction subsides. Residues from the reaction vessels should be flushed away with large volumes of water.
7. Compare the colour of the spot on the \( \text{HgCl}_2 \) paper with a set of standards.
8. Calculate the arsenic content from:
\[ \text{As}(\text{ppm}) = 5 \times \mu \text{g As corresponding to matched standard.} \]
Appendix VII

Figure 1: Arsenic results obtained by the field method and by X.R.F.
Appendix vii

Figure 2: "Gutzeit" apparatus (Scale—approximately half size)