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THE HAFOD-Y-PORTH COPPER MINE

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Abstract: Mineralization at Hafod-y-Porth is in the form of steeply dipping veins and narrow Breccia zones with a north-easterly strike. These occur near the base of the Ordovician tuffs of the Bedded Pyroclastic Formation, and contain chalcopyrite (the main ore mineral), pyrite, galena and sphalerite in varying amounts, with accessory pyrrhotite and hematite. They were worked by driving a series of five horizontal adits along NE-trending shear zones in rhyolitic tuffs. Two exploratory cross-cuts were also driven in the north-east of the complex, but these appear to have been unsuccessful.

INTRODUCTION

The Hafod-y-Porth Mine lies near the village of Beddgelert, in southern Snowdonia, North Wales (SH54 590482, Fig.1). During June and July 1988, a five-week project was carried out over the mine area as part of an M.Sc. dissertation. This involved the preparation of surface and underground plans, and a geophysical survey. The aim of the project was to investigate the pattern of the mineralization, and the mining methods used for its exploitation.

HISTORY

The mine first appeared in records in 1755, but was almost certainly in operation before this. Despite considerable investment, including the construction of a dressing plant complete with waterwheel and 8-head stamp battery, the mine never appears to have been profitable and changed ownership many times. Official figures (Bick 1982) show only three sales of copper ore from Hafod-y-Porth mine, which are listed in Table 1. Prior to 1867, however, official mine records appear to have ignored production figures from small mines.

Table 1. Recorded Copper Production at Hafod-y-Porth.

Year	Dressed Ore ton	Grade Copper %
1867	20	?
1868	20	6.5
1869	18	6.4

The last mention of Hafod-y-Porth Mine is in 1890, when it changed ownership for the last time. By this date it was almost entirely worked out, and was abandoned shortly afterwards.

GEOLOGY

Regional Structure

The dominant regional feature in Snowdonia is a caldera collapse structure, 20km in diameter, which outlines the limits of the mineralization (Fig 2). A series of felsic magma chambers has been emplaced around the margins of this feature. Within the caldera, the formation of an apical graben zone has resulted in a series of faults with a NE-SW trend (Beavon 1980). One of these, the Beddgelert Fault, was the main focus for a second set of felsic intrusions, as well as for subsequent hydrothermal activity.

Two sets of mineralized veins have been identified in the region (Reedman et al 1985). The dominant set occurs in the centre of the area and is related to the graben formation, having a NE-SW trend. The second set occurs at the northern and southern limits of the graben, with a NW-SE trend parallel to the caldera margin.

During the Caledonian Orogeny, the area suffered compressive deformation and metamorphism of lower greenschist facies. This resulted in the development of a series of folds with NE-trending axes and related axial planar cleavage.

Local Geological Setting

The geology of the area around the Hafod-y-Porth mine consists predominantly of the Ordovician pyroclastic deposits of the Snowdon Volcanic Group (SVG). These are subdivided into the welded and non-welded acid tuffs, and basic tuffite of the Lower Rhyolitic Tuff Formation (LRTF), which contain a few thin lenses of basaltic lava (Fig 3). Small amounts of Bedded Pyroclastic Formation (BPF) tuffs are present, and display a variety of sedimentary features. Regional metamorphism has resulted in extensive silicification of the rocks, with the result that the appearance of the acid tuffs and basic tuffites is almost identical, and they can be impossible to identify in the field. During a recent project by the British Geological Survey, geologists used a hand-held magnetic susceptibility meter (kappameter) to distinguish between these two lithologies (T.B. Colman, pers.com.). The volcanic units have been intruded by a series of small linear and irregularly shaped rhyolite masses, which are aligned with their longest dimension parallel to the Beddgelert Fault.

The tuffs are bounded to the north-west by the sediments of the Nantmor Group. These are shallow-water marine siltstones and sandstones, and contain fossils of brachiopods, gastropods and bryozoa (I.S. Husband, 1989). The contact between the sediments and the volcanics is a NE-trending fault.

Local Mineralization

Copper mineralization is found in many locations within the

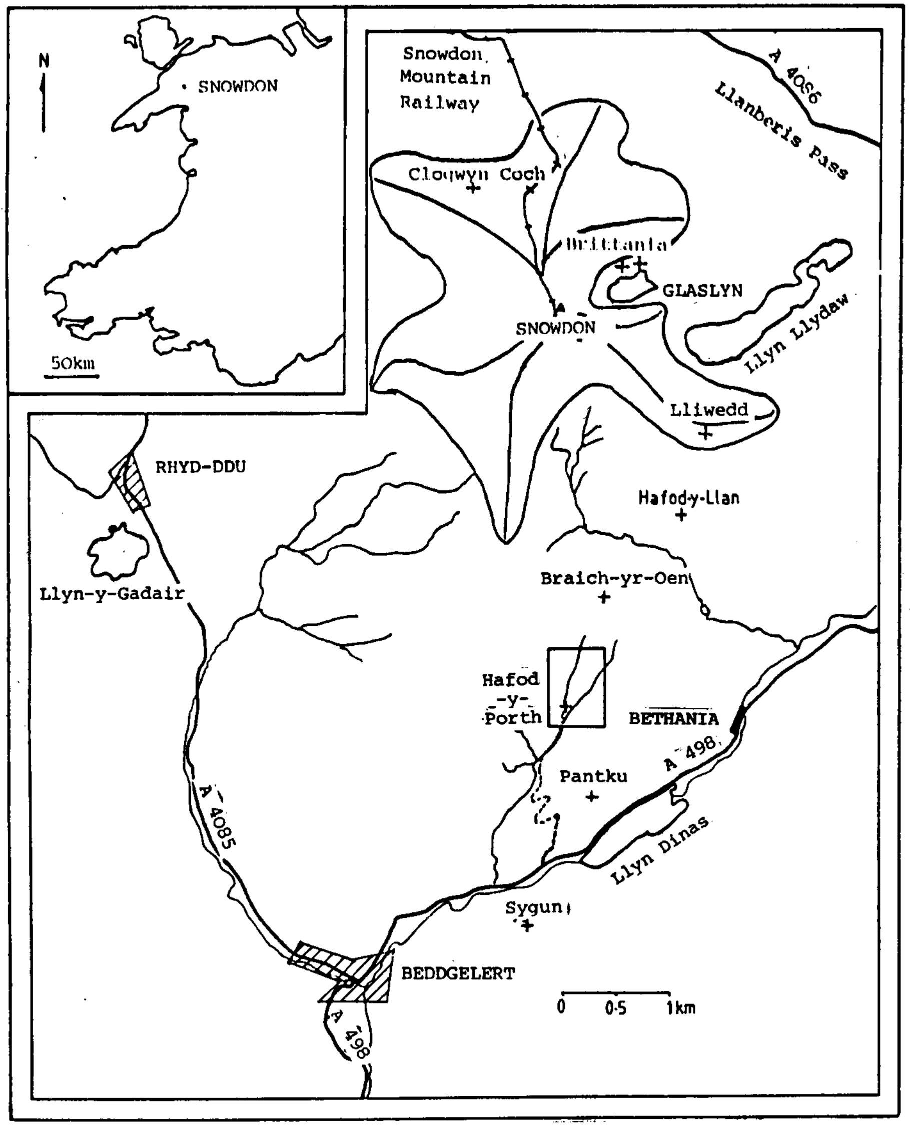


Fig 1. Location of Hafod-y-Porth Mine, Snowdonia, showing other workings in the district (+).

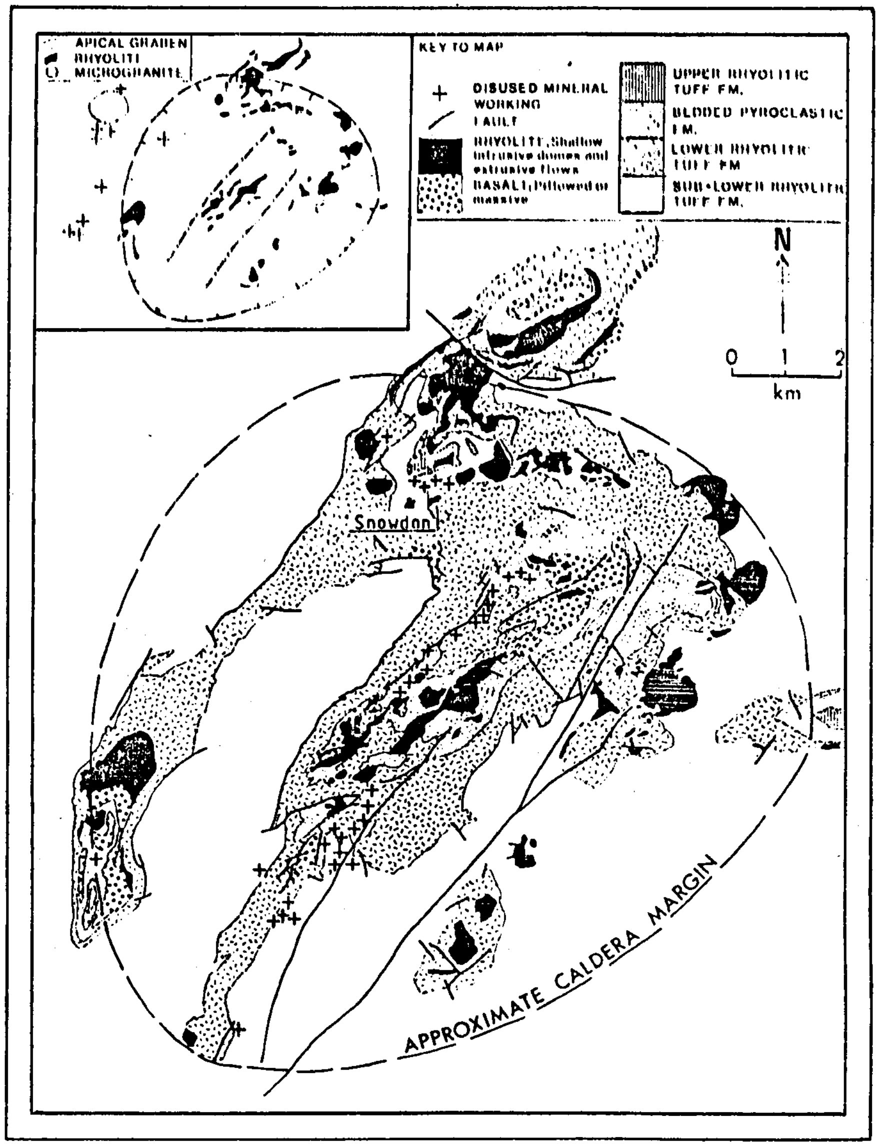


Fig 2. Geology of the Snowdonia District, showing the margins of the Lower Rhyolitic Tuff Formation caldera (Ordovician), and abandoned mineral workings (Reedman et al, 1955).

caldera, and is concentrated along the line of the Beddgelert Fault (Fig 2). Several old mineral workings can be found along this line Hafod-y-Porth, Braichyroen, Hafod-y-Llan and Lliwedd (Fig 1). The ores are mainly found in NE-trending veins parallel to the fault, and consist predominantly of sulphides of copper, iron, lead and zinc, with quartz gangue. Chalcopyrite was the main ore mineral, although this was of low grade, as much of the chalcopyrite contains inclusions of sphalerite (chalcopyrite disease). Some dressed lead ore was also produced, and minor occurrences of gold and silver have been reported from the area (Bick 1982). The mineralization is mainly confined to the base of the BPF, although a few deposits are recorded both in and below the LRTF (Reedman et al 1985).

THE MINE COMPLEX

The approach to the mine workings is a track which leads north from Hafod-y-Porth Farm (SH64 609497) past the ruins of cottages or lower mine buildings. From this point the workings stand out as a line of spoil heaps extending north-east up the hillside. The track continues up the valley to the main mine complex, 800m north of the farm (Fig 4). At the lowest point of the workings stand the ruins of a large building identified from an 1873 prospectus illustration (Fig 5, Bick 1982), as the mine managers's residence and office, with stores and a smithy. The track heads north-east, uphill past the remains of the powder house to a levelled area behind a massive retaining wall. This was the site of the original dressing floor and stamp house, which once had a 24-foot waterwheel and 8-head stamp battery. No evidence remains as to the nature of the buildings. The equipment was sold in 1845, after which the ore was dragged over the mountain to be dressed at the Hafod-y-Llan mill (SH65 623521). The miners' barracks are on a small ridge overlooking the dressing area. The spoil heaps are rich in sulphide minerals, suggesting that the miners could only process the highest-grade ore. Samples collected from these tips contain chalcopyrite, pyrite, sphalerite, pyrrhotite and galena in varying amounts. Weathering of these minerals has given rise to a dark blue staining on many of the blocks, particularly those rich in pyrite.

Surface Workings

The complex contains three shaft systems, which are surrounded by low walls. The shafts are funnel-shaped, widening at the top to a diameter of several metres and vary from 10 to 13m in depth . Some of these shafts have small trial drives in the sides, but their primary function was for ventilation.

The hillside is dotted with small trial excavations. These are concentrated around the central section of the complex, where the miners searched for veins displaced by faulting. Some of these trials contain rich veins and aggregates of pyrite, sphalerite and chalcopyrite. Examination of these trials suggests that the main guide to the possible presence of ore was the dark blue staining on the exposed rock, also observed in the spoil heaps.

Underground Workings

The underground workings at Hafod-y-Porth consist of seven adits, one of which is flooded and inaccessible. The main excavations are in the centre of the area and follow north-easterly trending veins. Workings with a north-westerly trend were exploratory cross-cuts, searching for veins displaced by faulting. A schematic section through the centre of the area shows the adits to have a vertical separation of between 25 and 40m (Fig. 6). The adit numbers used are purely for convenience and have no historical basis.

The tunnels vary from 1.5-1.8m in width and 1.8-2.0m in height, and slope gently upwards for drainage. They were driven into the rock by blasting with gunpowder, and the walls bear the scars of numerous hand-drilled shot-holes. This was a laboriously slow process, and the rate of advance would have been only a few metres per week. The ore was removed using mine waggons which ran on iron rails. In the lower workings many of these rails are still in place on their wooden sleepers, and originally extended from the adits to the spoil heaps and dressing floor, but much of this was sold off along with the dressing equipment in 1845. The three adits to the north and west of the area (Nos. 5, 6 and 7) do not contain tracks but are still over 1.5 metres wide. These may have originally contained tracks which were later removed for use in other areas of the mine.

No. 1 Adit

This drive is probably the oldest in the complex, starting close to the dressing floor. The entrance is in a narrow breccia zone, where angular fragments of dark grey tuff are enclosed in thick quartz veins. The adit consists of a straight drive, just over 60m in length (Fig. 7). The first 10m are poorly drained and water has collected to a depth of 30cm, which remains constant even in dry weather. The walls of the adit are composed of a dark tuffaceous rock, witha strongly developed cleavage which dips steeply to the north-west. Thin quartz veins run parallel to this cleavage, and the rocks contain disseminated pyrite and chalcopyrite. Two sets of fractures cut the wall rock. One set is roughly parallel to the cleavage, and often contains quartz veins with pyrite and sphalerite in the centre. The second set has a roughly NW-SE strike and is either unmineralized or contains only quartz. These fractures are often the sites of an intense blue and orange staining, thought to be attributed to copper and iron compounds respectively. The end of the tunnel is strongly sheared parallel to the cleavage.

No. 2 Adit

This adit is in a gully 50m to the north-west of No. 1 Adit. The entrance is flooded to a depth of 1.5m, and was inaccessible at the time of the survey, therefore no plans could be prepared. The workings are presumed to follow a north-easterly vein for approximately 25m, and then divert north-west along a fault to connect with the western shaft. The bottom of this shaft is dry, and it is expected that only the first 10-15m of these workings are flooded.

No. 3 Adit

This is the largest excavation in the complex, with 4 shafts (one of which is flooded), and over 150m of drives (Fig. 8).

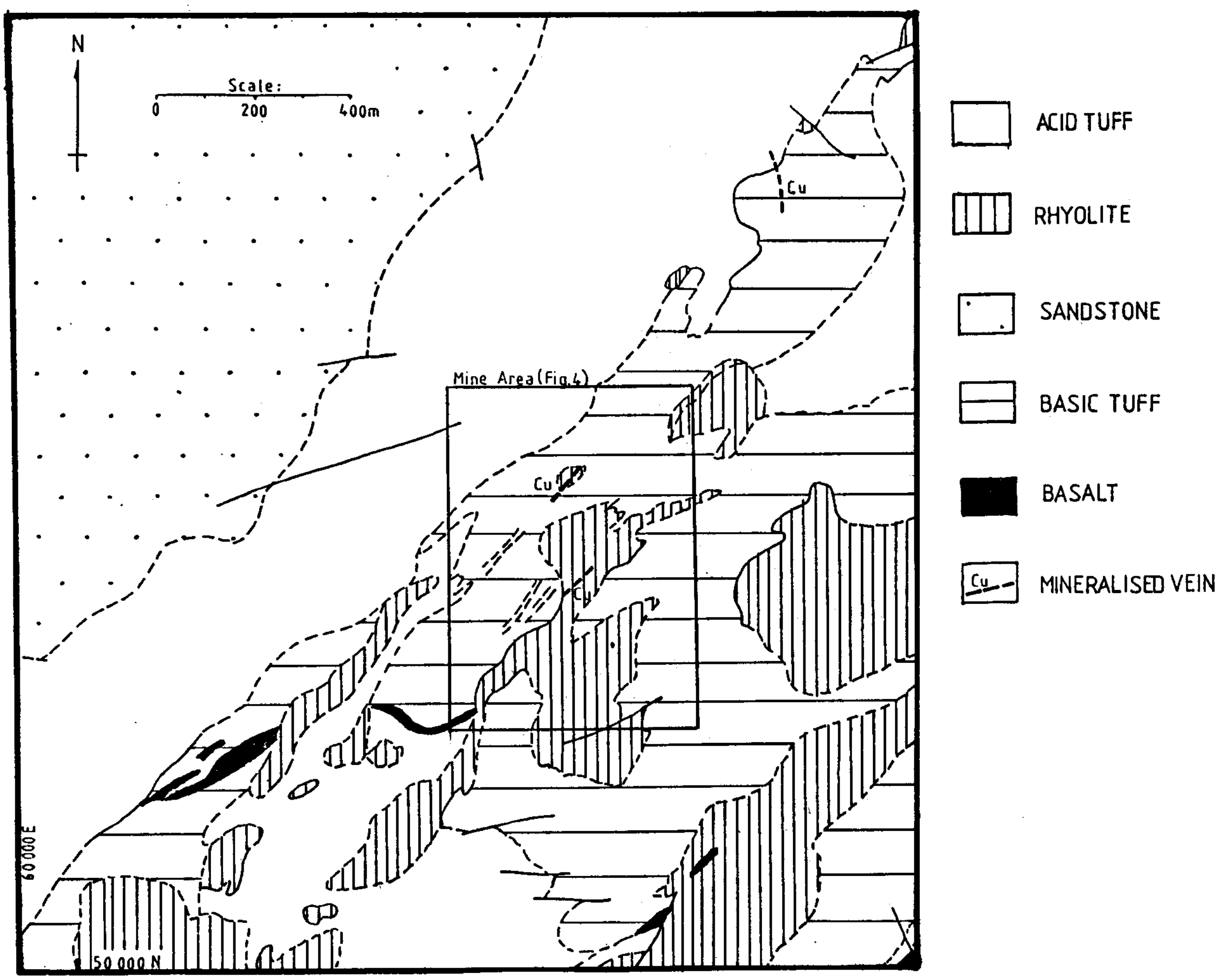


Fig 3. Sketch geological map of the Ordovician volcanic formations around Hafod-y-Porth mine

This entrance is approximately 30m above the No. 1 adit and in fact lies directly over the end of these workings (Figs 4 & 6). No connection exists between the two adits. The rocks at the entrance to No. 3 adit are massive grey tuffs containing some disseminated pyrite, with both the usual cleavage and fractures. In addition, a set of sub-horizontal joints forms shelves in this tunnel. Approximately 15m from the entrance, the workings widen into a large shaft area open to the surface. This shaft is too near the entrance to have been driven for ventilation, and the side walls have been considerably stoped along stained shear zones. The mineralization pattern must have been more complex, as two cross-cuts have also been driven. One possibility is that this area represents the intersection of two veins, resulting in a wide zone of mineralization. The main drive continues north-eastwards as before and passes under the second shaft, which is 12m deep and was driven purely for ventilation purposes. The wall rocks at this point are mainly medium-grained tuffs with dark felsic clasts, however a few thin bands of ignimbrite with white flame-shaped fragments are present. Approximately 50m into the complex, the workings abruptly change direction, apparently following a fault which displaces the vein to the north-west. Patches of bright blue staining can be seen on the walls, and in some areas the rocks are encrusted with skeletal growths of white crystals. The composition of these is uncertain as they did not dissolve in water or react with dilute hydrochloric acid. Several side adits have been driven from the cross-cut, following shearzones in an attempt to find the displaced vein. The largest of these has a strange echo, suggesting that there may be other workings beneath the floor. Opposite the entrance to this cross-cut is a flooded shaft, at least 2m deep, partially hidden behind a pile of debris.

After 35m the main drive curves back around to its original heading. At this point the roof has been stoped to a height of 4m, and a side adit has been driven to the south-west, following another shear zone. This has been filled with waste rock but is at least 3m long. A few metres further on the tunnel passes under the third surface shaft. This is 12.5m deep and was primarily for ventilation, but is also wide enough to allow men and materials to pass between this level and the No. 4 adit above. Two large wooden beams lie at the bottom of this shaft, and may have been part of a hoisting system.

The end of the tunnel is 15m past the third shaft, and here two short side adits have been excavated. Lines of soft red limonitic stalactites follow fractures in the roof, and the walls and floor of the workings are covered in a thick red mud, which is up to 30cm deep on some parts of the floor. It would appear that iron-rich solutions are percolating down through the fracture systems from the spoil heaps and mine workings above this area.

No. 4 Adit

Although this working lies directly above the end of No. 3 Adit, and is linked by a shaft, the main entrance is above ground where the shaft widens at the surface. The rocks around the shaft are stained dark blue, and several trials around both the shaft and the adit are extremely rich in

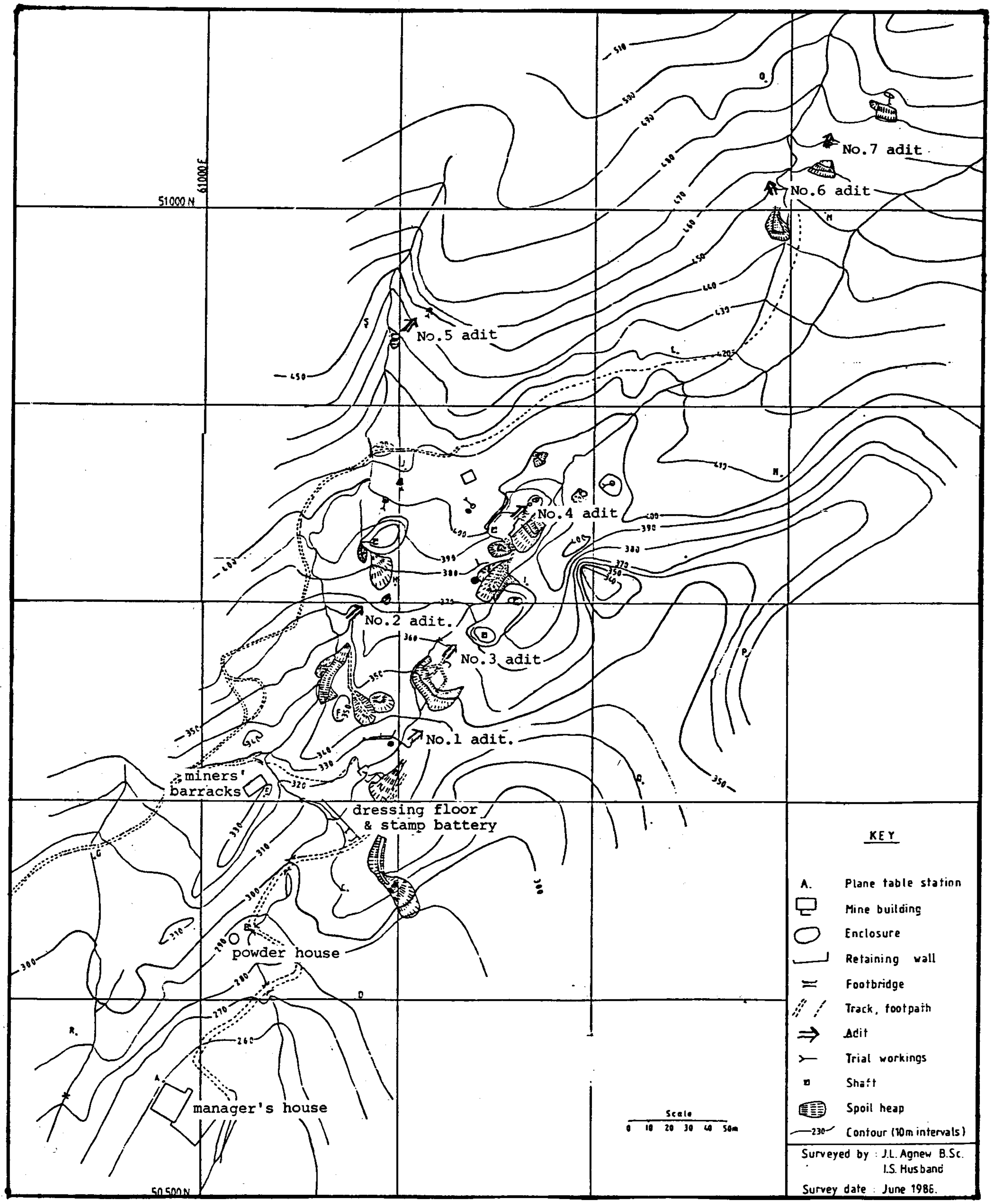
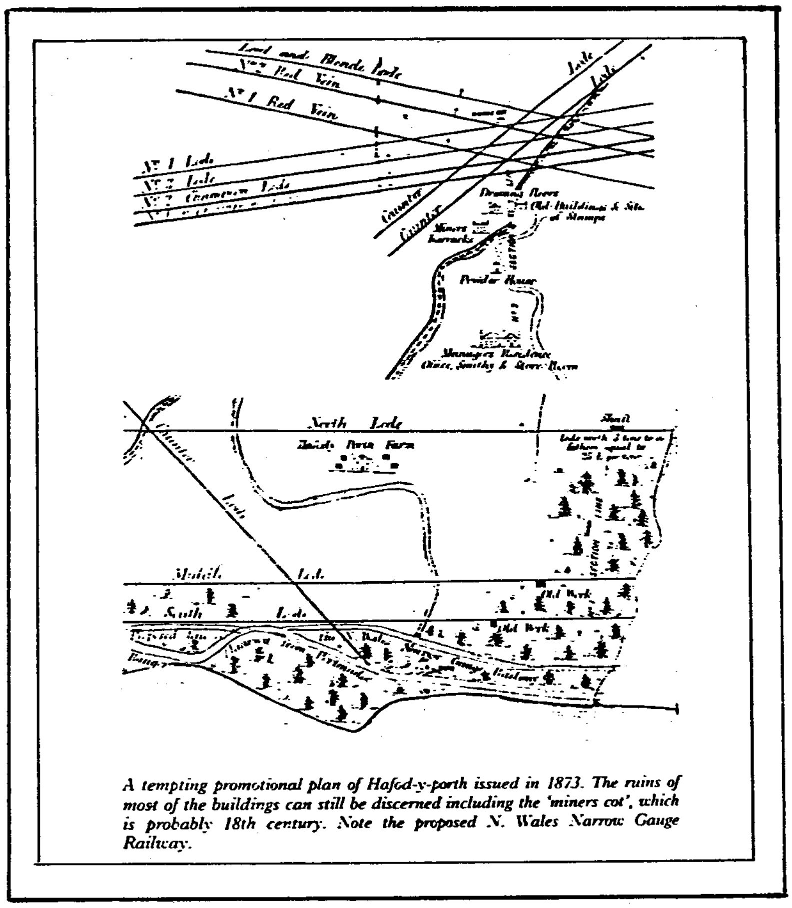


Fig 4. Plan of mine workings, Hafod-y-Porth, Snowdonia.



A tempting promotional plan of Hafod-y-porth issued in 1873. The ruins of most of the buildings can still be discerned including the 'miners cot', which is probably 18th century. Note the proposed N. Wales Narrow Gauge Railway.

Fig 5. Mine Plan, circa 1873, reproduced from Bick (1982).

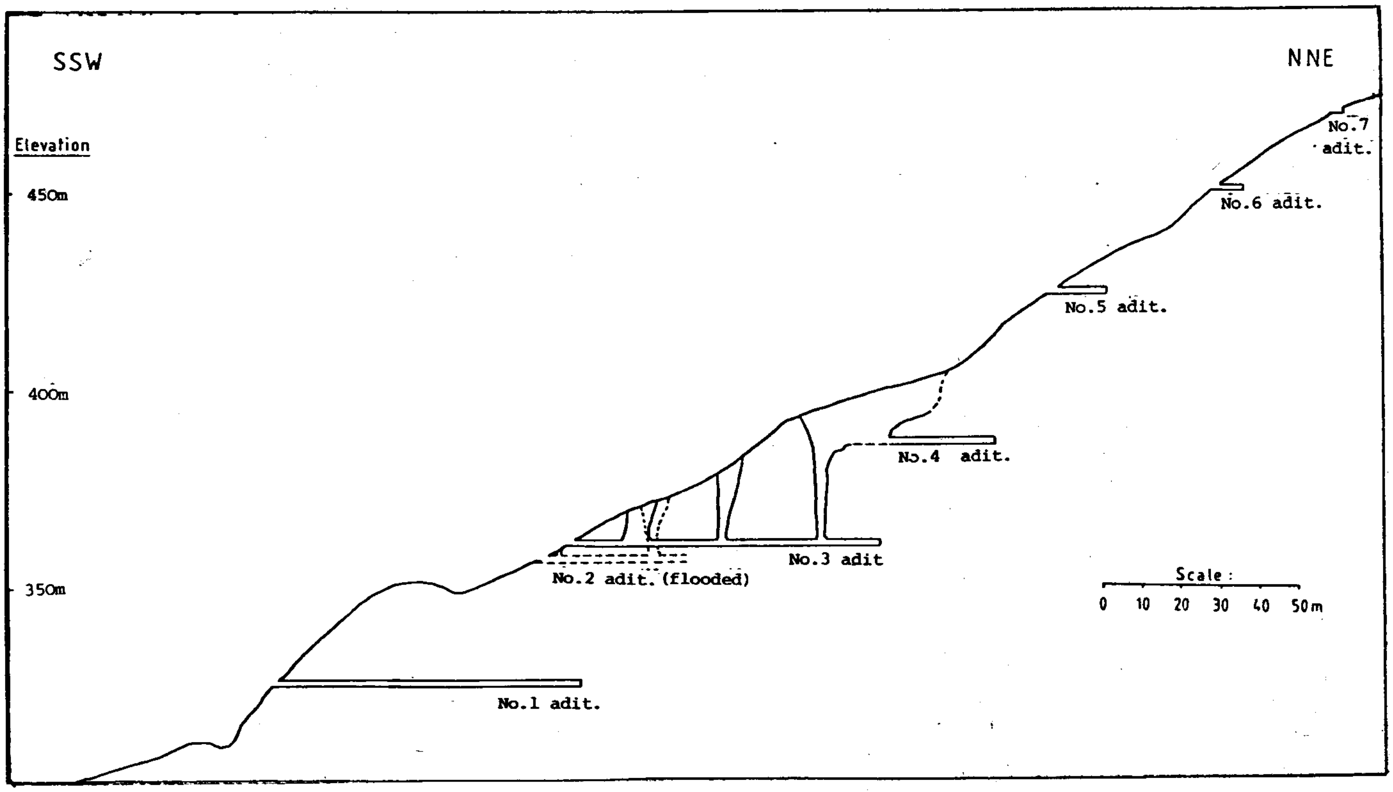


Fig 6. Schematic section through the Hafod-y- Porth Mine Area.

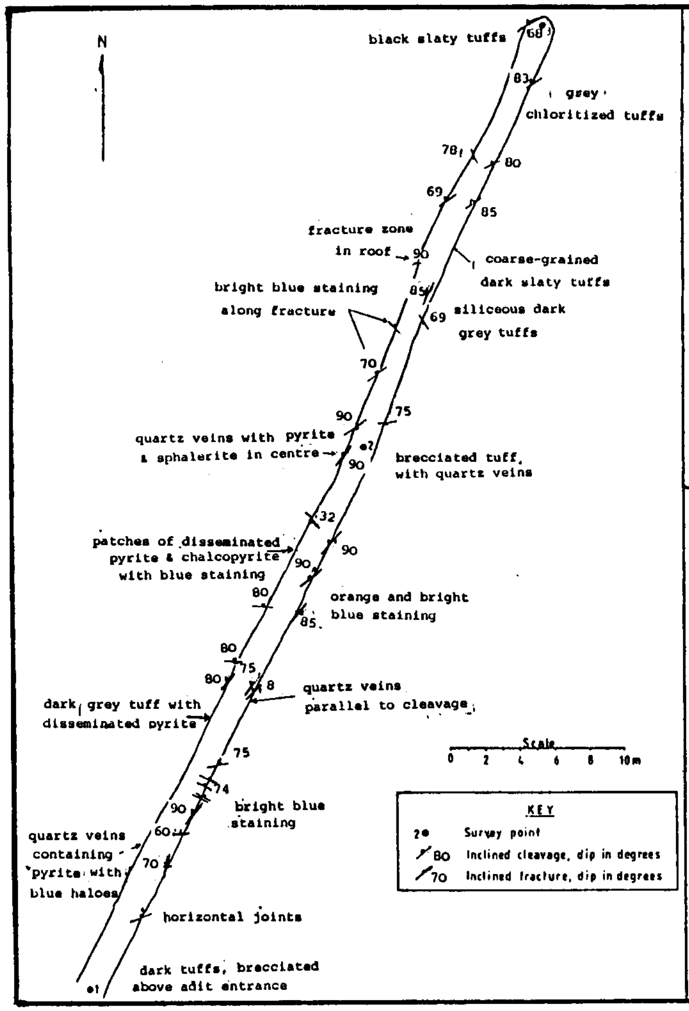


Fig 7. Plan of No.1 Adit.

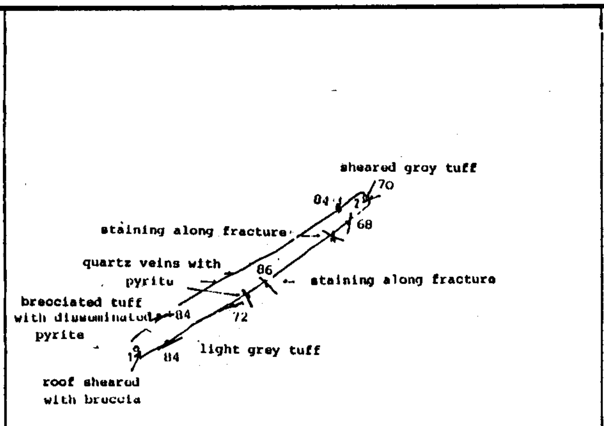


Fig 9. Plan of No.5 Adit.

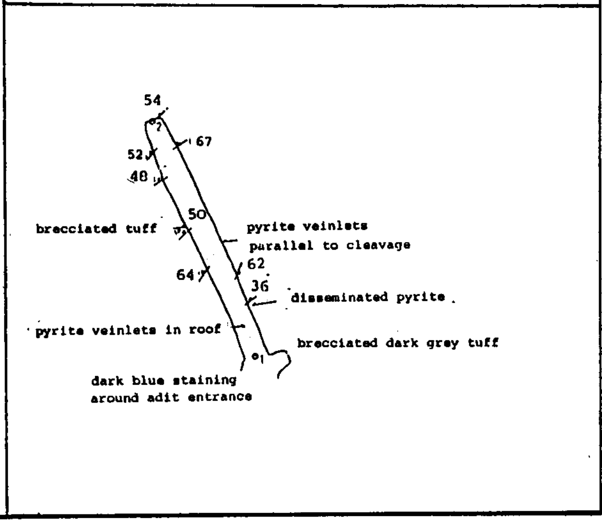


Fig 11. Plan of No.7 Adit.

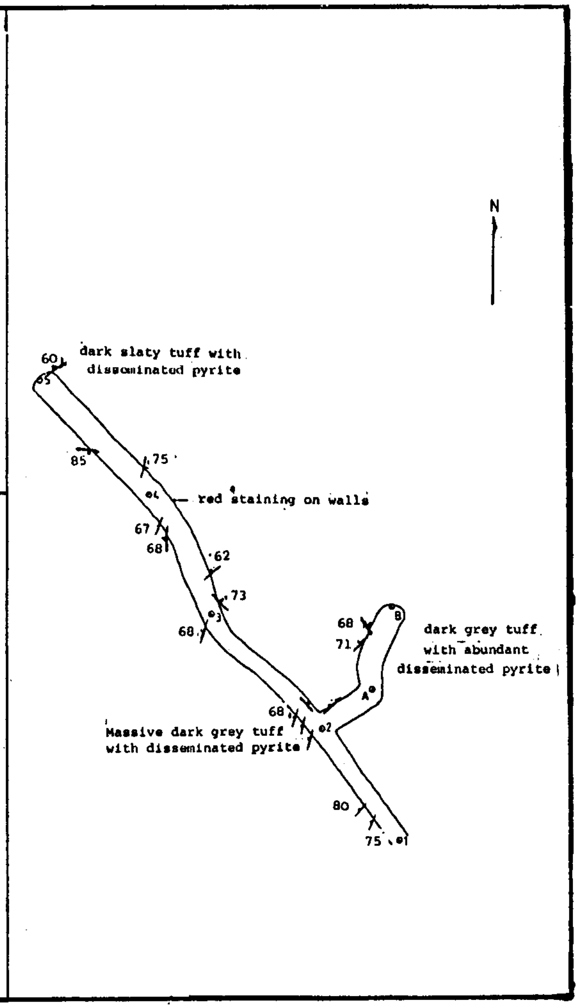


Fig 10. Plan of No.6 Adit

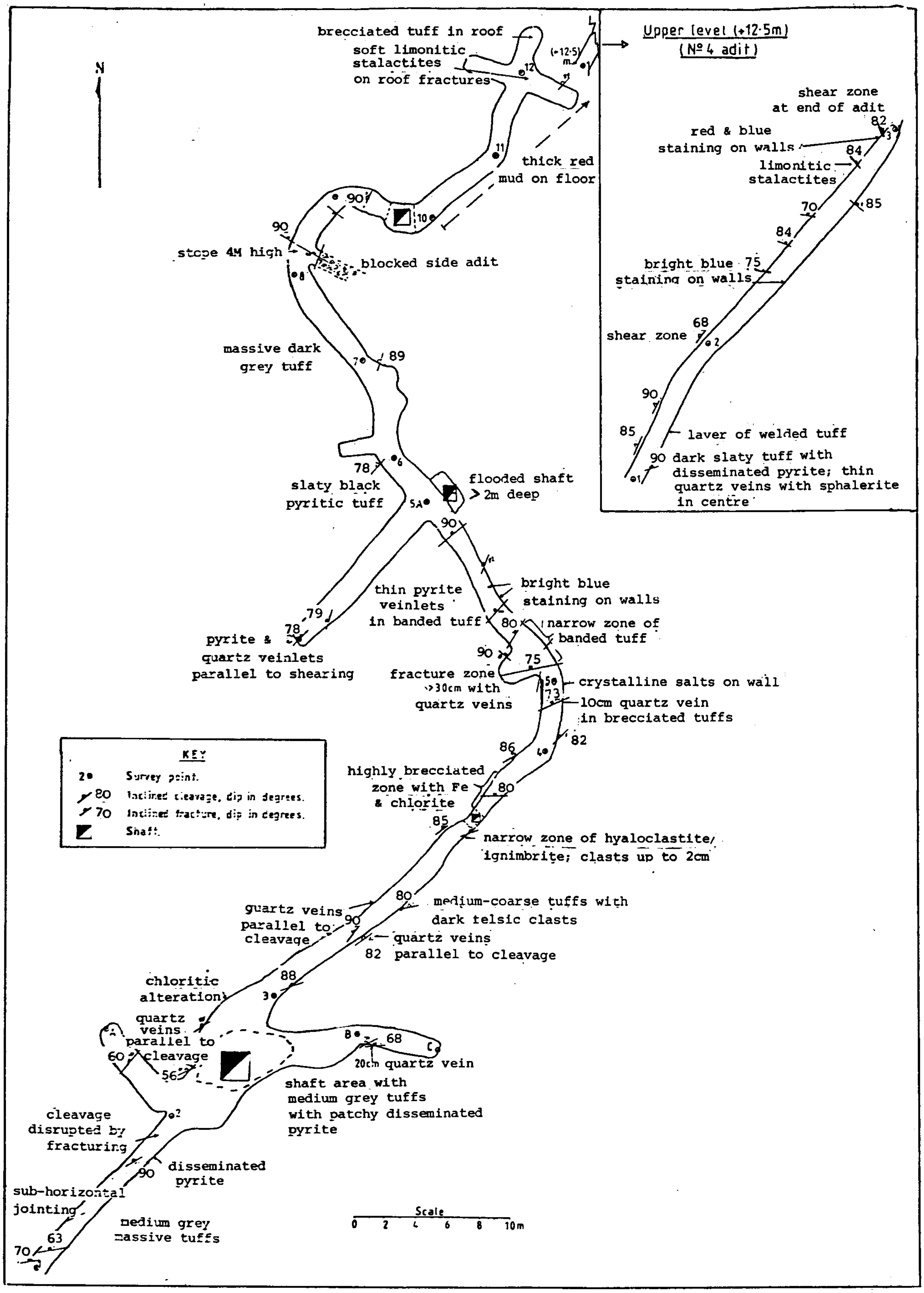


Fig 8. Plan of No.3 Adit, and (inset) No.4 adit.

pyrite. The adit is slightly over 25m in length (Fig. 8 inset), and the geology is identical to that of No. 3 adit. Thin quartz veins containing pyrite and sphalerite occur close to the entrance, and patches of red and bright blue staining can be seen beside fracture zones. Soft limonitic stalactites follow fractures in the roof of the adit, which terminates in a shear zone.

No. 5 Adit

This adit lies in a side valley on the north-west of the main complex. The drive is just over 15m in length, and like the others follows a north-west trending shear zone (Fig 9). Brecciated tuff above the entrance contains aggregates of pyrite and sphalerite, and disseminated pyrite can be seen in the walls of the tunnel. The possibility exists that this vein is the faulted continuation of that followed in No. 2 adit, as an extension of the main fault in No. 3 adit passed just south of the entrance to No. 5. A geophysical survey also suggests that the veins have been displaced by NW-SE trending sinistral faults.

No. 6 Adit

The entrance to this 35m cross-cut is flooded, with water 1m deep remaining even in dry weather, due to a stream flowing past the opening. The adit slopes upward, such that the water level at the far end is only 30cm deep 10m from the entrance, a short side drive has been cut following the cleavage (Fig 10), and the walls of this branch are rich in disseminated pyrite. Although this cross-cut appears to have been unsuccessful in finding a vein, both this and No. 7 Adit correspond with a major NE-trending VLF anomaly.

No. 7 Adit

Situated in the far north-east of the complex, the trend of this 15m adit suggests that it was driven as a crosscut in an attempt to locate the mineralized vein (Fig 11). The rocks at the entrance to the adit and the adjacent trial are marked by a dark blue staining and the walls contain pyrite, both disseminated and in veinlets parallel to the cleavage. There are no side adits, and as with No. 6 adit, no indication that the search was successful.

INTERPRETATION

The mining methods were simple, and the work was carried out with no real geological insight. The miners followed shear zones until these were displaced by faulting, and then worked along the fault in the hope of finding the vein. How they decided on the direction of the faulting is unknown, and may have been random. The only exploration method available was simple prospecting, by searching for stained rock and then excavating until this either developed into a vein or proved barren, with the latter being more common.

One point of interest is the pattern of the mineralization. The mining plan indicates that the chalcopyrite ore seems to have occurred in narrow veins at particular horizons, with a vertical spacing of 25 to 40 metres. If this is the case there must be considerable structural control on the mineralization, which may occur at the intersection of cleavage related shear zones and sub-horizontal joint planes.

CONCLUSIONS

i) The mineralization at Hafod-y-Porth is subduction related and is associated with a hydrothermal system driven through volcanic rocks erupted from a high-level felsic magma chamber. The veins are controlled by caldera collapse structures and subsequent apical graben formation.

ii) The mine must have been operated on an extremely inefficient basis compared with other mines in the area. During 130 years of production only 58 tons of dressed copper ore were recorded. Although the actual amount is likely to be several times this amount, this still could not justify such a long period of operation however intermittent the production. A deposit of this size should have been exhausted within a fraction of this time.

iii) Although most of the veins in the central mining area have been worked out, geophysical evidence implies that several major mineralized zones around the margins of the complex have yet to be exploited. The geophysical survey revealed the presence of several steeply dipping conductors which have a north-easterly trend. These are at a depth of approximately 15m and in places are strongly magnetic. This appears to represent a vein system containing zones or pods of magnetic minerals. The nature of this mineralization is uncertain and may differ considerably from the assemblages previously mined. In the early 1970's Noranda-Kerr expressed an interest in drilling around the major (7000 gamma) magnetic anomaly, but this project was subsequently abandoned (T. Colman pers. com.).

ACKNOWLEDGEMENTS

I wish to thank Mr. T. Colman, of the British Geological Survey, Keyworth, both for his help with the project and for permission to use the regional structural map (Fig 2). Mr. David Bick kindly allowed the reproduction of the 1873 prospectus illustration (Fig 5). The report is based on a dissertation prepared for a M.Sc. degree course at the University of Leicester.

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