SLIEVE ARDAGH COALFIELD

Background information

Mine District: Slieve Ardagh

Mine Names: Ballynunty, Mardyke, Lickfinn, Gorteen, Earlshill, Ballyphillip, Coalbrook, Foilacamin, Commons, Ballingarry

Elements of interest:
As, Cu, Ni, Pb, Zn, acidity

Project Prefix: SLA-

County: Tipperary

Townland: Various

Grid Reference: E228000, N150000

Introduction

The Slieve Ardagh coalfield underlies the Slieve Ardagh hills in north county Tipperary (right). The hills are underlain by a remnant of the Upper Carboniferous Coal Measures (hatched area, Fig. 1) that are also preserved in the Leinster Coalfield on the Castlecomer plateau, 30 km to the northeast. The main part of the coalfield forms a 13 km-long zone between Ballynunty in the southwest and Commons in the northeast.

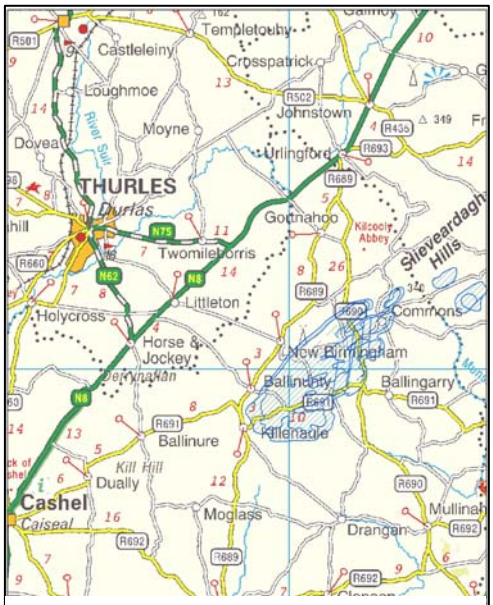

Fig. 1 Slieve Ardagh location

The land comprises rolling hills incised by several streams and tributaries that flow southeastward to join the Kings River, which flows into the Nore at Kilkenny. The land is predominantly grassland, mostly used as cattle pasture. Ballingarry is the most significant settlement in the area but the main Dublin-Cork road, the N8, is within 10km and there has been substantial recent development of single housing on the peripheries of the coalfield.

The coalfield was worked for at least 400 years from the mid-17th century. The earlier mining has left only small traces, however, chiefly small depressions that are the remains of basset shafts and bell pits. The larger-scale mining of the 19th century left behind several mine buildings of significant heritage value as well as numerous adits and shafts. Mining in the last century, especially between the 1950s and 1970s, has had a more obvious impact on the landscape.

Geology and Mineralization

The Slieve Ardagh coalfield is hosted by an outlier (younger rocks surrounded by stratigraphically underlying older rocks) of Upper Carboniferous sandstones, siltstones and shales that sit on the surrounding Lower Carboniferous limestones. The coal seams are within the Westphalian or Coal Measures sequence, the uppermost part of the Upper Carboniferous succession. The rocks are folded into a series of synclines, along a Caledonide northeast-southwest axis in the northeast part of the coalfield and an east-west axis in the south (McArdle 1992; Fig. 2). The hard resistant nature of the sandstones has helped preserve the Upper Carboniferous succession against erosion. Nevertheless, of the nine seams mapped within the coalfield (McArdle 1992), only the two lowest seams, the Glengoole No. 1 and No. 2 seams, are present throughout. The other seams have been eroded for the most part, being preserved only in the cores of synclines, notably at Earlshill (Fig. 2).

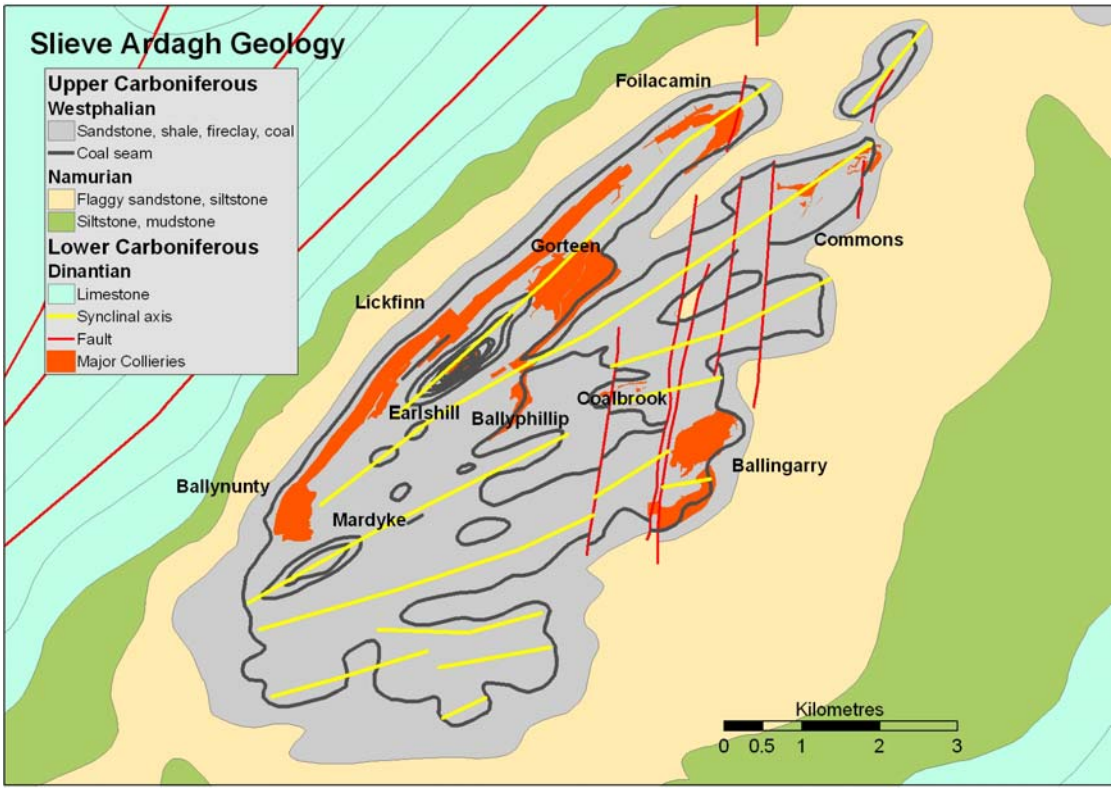

Fig. 2 Slieve Ardagh coalfield: general geology

Slieve Ardagh coal is entirely anthracite. The Lower Glengoole No. 1 seam coal is poor quality with a high sulphur (3.7%) and high ash content (24.7%). In contrast, the coal in the Upper Glengoole No.2 seam was of excellent quality, with low sulphur (0.8%), low ash levels (4.0%) and high calorific value (McArdle 1992). Seam thickness appears to be relatively consistent throughout the coalfield, with the No. 2 seam typically 0.46 m thick. However, thrusting has given rise to local thickening and thinning of the seam as well as crushing of the coal (McArdle 1992). The latter is partly responsible for the high duff (coal fines) content of some of the mined coal. At Ballynunty, the duff content was typically 80 – 100%.

Mining History and Production

Coal was mined in the Slieve Ardagh district since at least the mid 17th century and perhaps even earlier by the Danes in the 11th century. For hundreds of years it brought some prosperity to a region where farming was the only other source of income (www.Ballingarry.net). Until the early 19th century mining was the preserve of individuals, landowners and farmers, who mined outcropping seams to shallow depths. Bassets were shafts sunk directly along the outcrop. Another technique adopted was bell-pitting. The bell pit was a shallow excavation with a narrow cylindrical hole dug from the surface to the seam where it was then widened out into a small chamber as the coal was extracted. Before the roof could become unstable, the pit was abandoned and another sunk nearby. The shape of the pit resembled an upturned bell, hence the name. The sites of numerous bell pits are marked on the old mine maps for Slieve Ardagh, notably at the northeastern end of the coalfield.

In 1826, the Mining Company of Ireland (MCI) established a colliery at Mardyke and so began a more systematic exploitation of the coalfield. Mardyke became the first mining village in Ireland, with miners' houses, a school, offices and police barracks (www.Ballingarry.net). Mardyke closed in 1833 owing to the high (70%) duff content of the coal but the MCI established operations at Foilacamin, Commons and later Earlshill and Ballyphillip. By the end of the century, however, mining had almost ceased apart from the activities of individuals who continued to extract coal from bassets.

The need for indigenous economic resources during the Second World War led to the reopening of Ballynunty by Mianrai Teoranta in 1941. Underground mining extended as far as Lickfinn. However, in 1948 the plant and machinery were moved east to Copper and this new operation was later renamed the Ballingarry colliery. This was purchased by Thomas O'Brien in 1952 and his company, Ballingarry Collieries Ltd., would continue to operate mines in the district for the following 20 years until going into liquidation in 1972 (www.Ballingarry.net). Sites were developed at Gorteen in 1957 and Commons in 1962. In addition, open pit operations were started at Knockanglass (Foilacamin) and Ballyphillip but both were unsuccessful. Kealy Mines reopened the mine at Lickfinn in 1978 but was undermined by lack of capital and sold out to the Canadian Flair Resources in 1982. Despite State investment and a steep rise in the price of anthracite, Flair went into liquidation in 1985, leaving large debts behind (www.Ballingarry.net). Emerald Resources obtained a mining licence in 1989 and was based at Gorteen. It lasted until 1991.

OBrien (1951) has estimated total production, including duff, in the coalfield between 1826 and 1951 to be 3.7 million tons. MCI accounted for 2.4 million tons between 1826 and 1889 and Mianrai Teoranta produced just 100,000 tons between 1941 and 1951. Other individuals and companies between them produced 1.2 million tons. Ballingarry Collieries' output in the period 1952 to 1972 is not known. Production at Gorteen around 1970 was 1,100 tons per week (Powell Duffryn 1970t), although it increased in later years. This might suggest annual production of around 50,000 tons and 0.75 million tons for the 15-year period 1957-1972. Allowing for the other collieries at Ballingarry and Commons, production between 1952 and 1972 may have exceeded 1 million tons. Kealy Mines produced around 10,000 tons from 1979 to 1982. The absence of available data for the 1952-1972 period means that total production figures for the Slieve Ardagh Coalfield are uncertain. However, it seems likely that almost 5 million tonnes, if not more, were produced since 1826.

Site Descriptions and Environmental Settings

The geochemistry of the Slieve Ardagh district is considered as a whole in the geochemistry section (below) rather than on a site-by-site basis. Individual site descriptions in this section review the main features of each site examined. Fig. 3 shows all the shafts, bell pits and adits originally compiled from the various historic sources available. As is clear from this, the Slieve Ardagh district has been intensively explored and exploited. Of the many shafts, bell pits and adits shown on Fig. 2, however, only a small proportion can be seen today. Most have been filled in or covered by subsequent land reclamation. In contrast, the illustration of underground workings probably understates their actual extent because of the unavailability in some cases of suitable colliery plans for compilation purposes. The individual site reports describe the features at each of the numbered locations shown on Fig. 3.

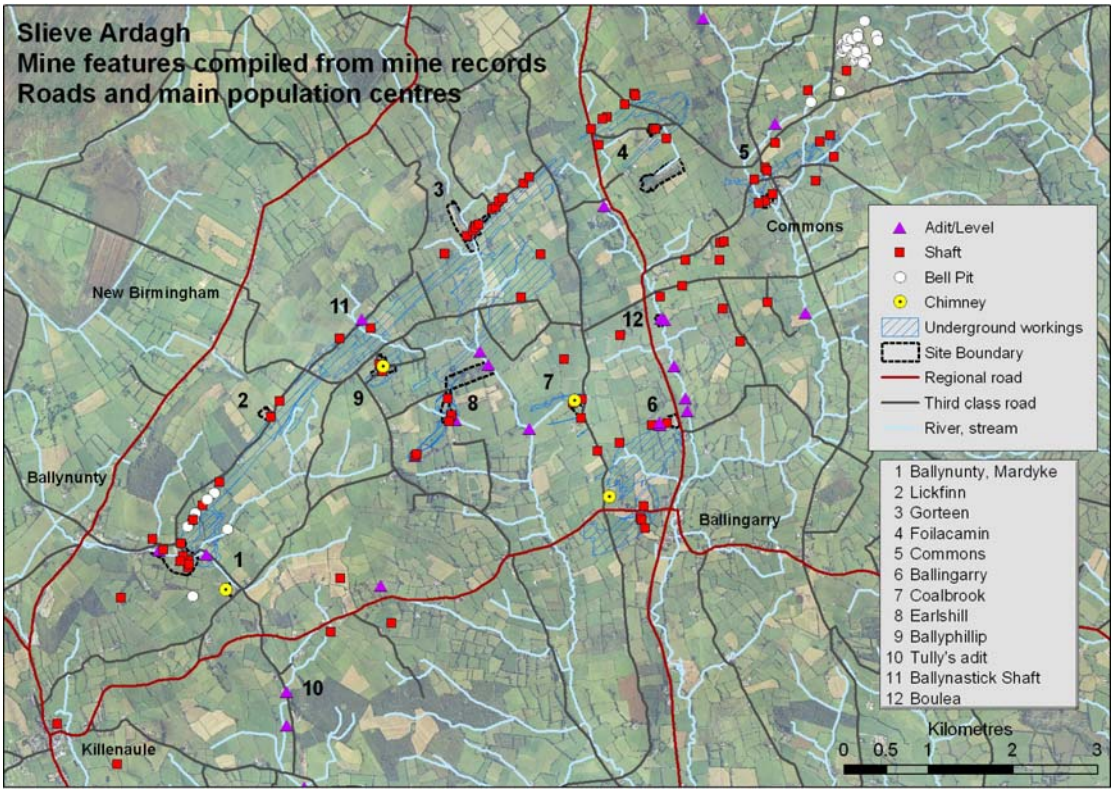

Fig. 3 Slieve Ardagh: overview of original mine features

1. Ballynunty and Mardyke

Mine Names: Ballynunty
Mardyke

Alternative names: Ballynonty

Townland:
Ballynunty; Tullequane
Mardyke

Grid Reference:
E223694, N148455
E224350, N148078

The Ballynunty site (c. 13 ha) lies immediately south of the R691, 1 km east of Ballynunty village (Fig. 4). The Mardyke site (2 ha), with its extant chimney and engine house (photo, above), is a further 600m southeast. Mardyke became the first major centre of coal mining in Slieve Ardagh when the Mining Company of Ireland opened a colliery there in 1826. It closed in 1833 and little or no trace remains of the mine workings. Ballynunty was last operated in the 1940s by Mianrai Teoranta. Three inclines were used at Ballynunty to provide access to underground workings that extended 2km northeast to Lickfinn. The entire operation, including machinery and buildings, was removed in 1948 to Copper, west of Ballingarry village, where a new colliery was established.

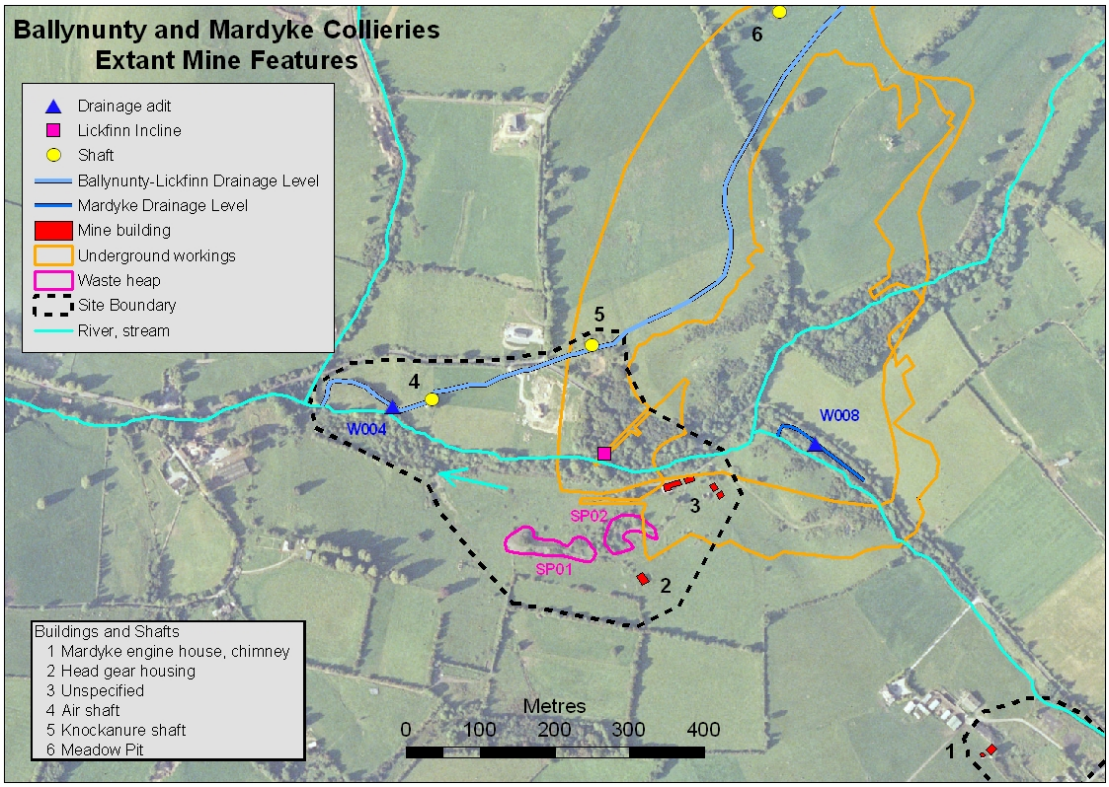

Fig 4 Ballynunty and Mardyke: mine features

Very few traces of mining remain on the Ballynunty site. It is cut by the Ballynunty River that flows west toward Ballynunty village. The mine workings were mainly on the south bank of the river and this part of the site has been largely reclaimed for pasture farming. Two partly vegetated waste heaps are the most obvious signs of mining. Several concrete structures, now serving as a store area for silage and other feed, are probably remnants of Mianrai Teoranta's time on the site. On the north bank of the river, two new houses have recently been built. Within the wooded area along the river bank, an in-filled decline portal (photo, right) can be seen. The remains of several coal wagons are strewn about the river bed. The main drainage adit for the northwestern side of the Slieve Ardagh coalfield, called the Ballynunty-Lickfinn adit (photo, below), discharges into the river at the western edge of the site. An open brick-lined air shaft to this adit is in the centre of a copse of trees, protected by a low barbed-wire fence, but access to it is easy. The Mardyke drainage adit discharges into the same river upstream of the Ballynunty site – the adit itself is invisible in overgrowth. Both adits discharge considerable volumes of water all year round. A rough estimate of flow in the Ballynunty-Lickfinn adit in March 2007 gave 160 l/s. North of the site, the Meadow Pit shaft (Fig. 4) is capped although the cap appears to be unstable. However, the fencing around the shaft is secure. The Knockanure shaft is infilled and has a small waste heap beside it.

The Mardyke site is on a farm close to the farmhouse and outbuildings. The ivy-covered engine house and chimney stack are still standing (photo, previous page). However, the chimney is a hazard: its wall bulges in the centre and is cracked, it lacks a lightening conductor and blocks have already fallen from the top. The engine house is also deteriorating: it is leaning, has cracked walls and missing lintels and lacks a lightening conductor.

2. Lickfinn

Mine Name: Lickfinn

Townland: Lickfinn

Grid Reference: E224756, N150152

The Lickfinn site (Fig. 5) occupies 1.6 ha by the side of the road, 2km northeast of Ballynunty and 5km southwest of Gorteen. It is immediately adjacent to a number of houses that lie along the same road. The surrounding land is mainly cattle pasture. The site dates from the period 1978 to 1983 when first Kealy Mines and then Flair Resources, trading as Tipperary Anthracite, held the mining lease. The site is small as the processing operation was carried on at Gorteen. Both operations were under-resourced and equipment, especially for dealing with serious flooding problems,

inadequate. Despite relatively high prices for anthracite and investment by the Industrial Development Authority, Tipperary Anthracite went into receivership in December 1983. Access to the underground workings was via the main decline adit; a second return drift allowed for circulation of air through the workings. Both these adits were capped in recent years (photo, right) by the Office of Public Works in response to the concerns of local residents.

The site also contains the remains of several mine buildings, a large waste heap and a small lagoon used as a drainage sump, possibly for the washroom facilities. Buildings include the concrete structure of the lamp room and the steel-framed corrugated iron-enclosed workshops (photo, previous page). The remains of the winch system and loading platform (photo, left) are in front of the large waste heap. In recent years the site owner has operated a decorative and garden stone business from the site, storing bagged stone on pallets.

Fig. 5 Lickfinn: mine features

The site is privately owned. Access is easily gained over a metal farm gate or low walls. The adits have been covered by locked manholes set in a concrete cap and there is thus no ready access to underground workings. However, there are several potential mine-related hazards on the site. The northwest face of the waste heap is steep (45°) and represents a fall or collapse hazard. The workshop building is in a state of disrepair, with part of the roof missing. The stability of the winch gear is

uncertain. The lagoon, of unknown depth, is easily reached over a low chain-link fence barbed-wire fence.

3. Gorteen

Mine Name: Gorteen

Alternative Name: Gurteen

Townland: Gorteen Upper; Mellisson

Grid Reference: E227118, N152359

Gorteen (Fig. 6) was the site of the most recent operations in the Slieve Ardagh coalfield. It was the site of underground mining by Ballingarry Collieries Ltd. between 1957 and 1972. Subsequently, the site was used for processing and storing coal mined at Lickfinn by Kealy Mines and Flair Resources. Emerald Resources was also based at Gorteen during its short-lived history at the end of the 1980s.

The site is dominated by the tall concrete gantry from which mining operations were run (photo, above) and by its very large waste heap. The waste heap has an estimated volume of 160,000 m^3 (British Mining Consultants 1982). Other features on the site include large concrete settling tanks, the remains of the mine offices, winch gear and a large metal chute (photo, right). Only the footprint of the processing plant remains. The extensive poured concrete hardstand beside it is strewn with the remains of truck axles and wheels, engine blocks and vehicle batteries. The main decline is partly blocked: a mound of mine waste covers most of the presumed opening and the rest is overgrown with vegetation. The interior of the decline can be seen through the vegetation and it appears that tyres have been dumped into the opening. The return airway entrance, near the office building, is underneath an open but overgrown concrete housing.

There are no drainage adits on site and no obvious mine water discharges. Leachate does run-off the waste heap into the stream that flows along its eastern boundary. This stream is culverted beneath the hardstand area. Where it reappears again in the vicinity of the small reservoir tank below the pre-settling tanks there is strong red discolouration of water. The source of this discolouration is unclear but the possibility of a discharge from the underground workings cannot be excluded.

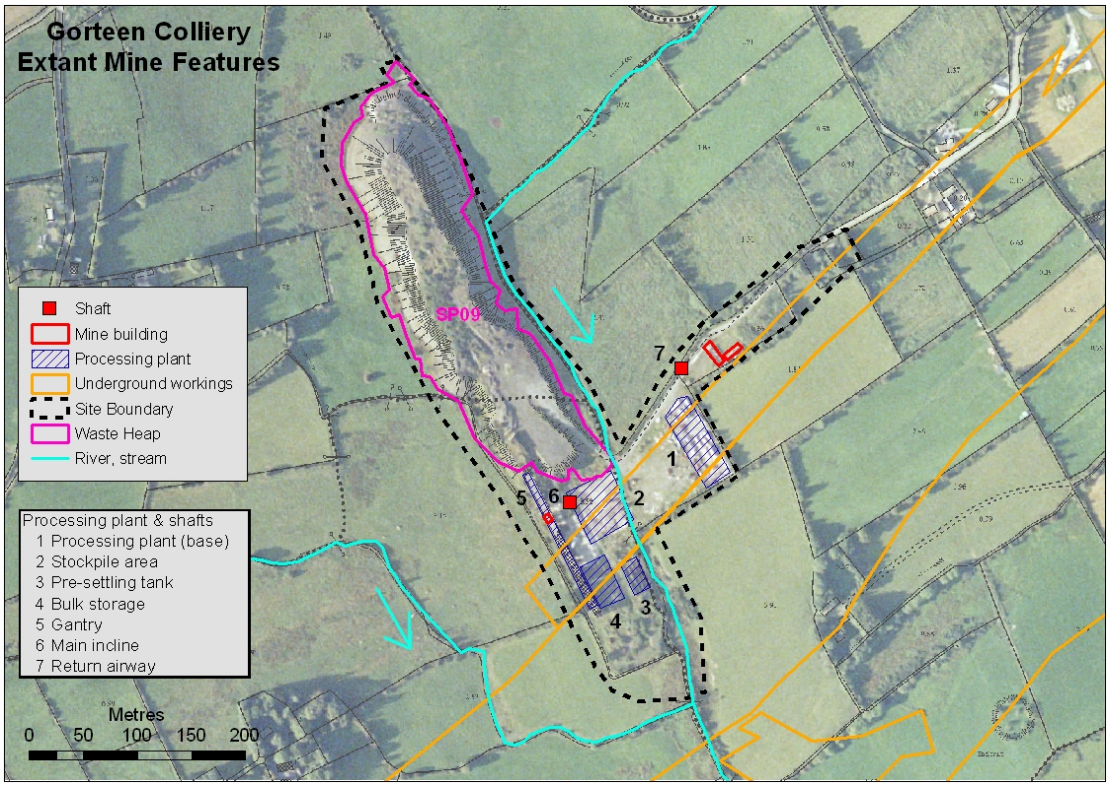

Fig. 6 Gorteen : mine features

The waste heap is the largest within the Slieve Ardagh coalfield. It has a significant coal content and has undergone localized spontaneous combustion in the past, as evidenced by large zones of red-white burnt waste (photo, right). The heap is flat-topped and pock-marked by small pits, apparently dug to contain burning. Thin grass covers the top surface but the sides are largely devoid of vegetation. Though the heap is generally well contoured and apparently stable, its sides, the western ones in particular, are very steep, with slopes of up to 40°.

Most mine features remaining on the Gorteen site represent a hazard to some degree. The gantry is derelict and its upper levels are still accessible. The settling tanks have an unknown depth of water in them. The water is contaminated by coal dust and by dumped material, including electrical goods. The waste heap carries a risk of spontaneous combustion and its sides are unvegetated and potentially unstable. The old mine offices are roofless and the walls are unsupported and in danger of collapse.

4. Foilacamin

Mine Name: Foilacamin

Alternative Name: Knockanglass

Townland: Knockanglass

Grid Reference: E229443, N152973

Foilacamin lies at the northeastern end of the northern side of the Slieve Ardagh coalfield. There are two separate sites at Foilacamin, the old colliery site to the north and the opencast site in the south (Fig. 7). The grid reference given is for the opencast site. The underground mine is the last in an interconnected series of workings along the coal seams that includes Ballynunty, Lickfinn and Gorteen. Foilacamin is connected to the Gorteen workings by the Foilacamin level which drains southwest from Foilacamin. Ballynunty and Lickfinn are drained by the Ballynunty-Lickfinn drainage level. The Foilacamin level and the Ballynunty-Lickfinn level "meet" at Ballynastick shaft, midway between Lickfinn and Gorteen.

The old colliery site (1 ha) is now part of a private house and garden property. The old mine office building is now a private house and the main Foilacamin shaft (right) is located in the garden. The ventilation shaft, located close-by, is now filled in. The old chimney was removed before 1980 when the current owners bought the property. A thickly vegetated (gorse, etc.) waste heap covers the southern part of the site. The main shaft has an arched stone surround and a winch was set across the opening on top, resting on sleepers. The top has now been capped and the front blocked up (right). A wooden lattice covers the only open part beneath the arch. Water was pumped out of this shaft by Ballingarry Collieries Ltd. in the 1960s and 70s, and later by Kealy Mines Ltd. in the 1980s, with the aim of lowering the volume of water in the workings at Gorteen.

The Foilacamin opencast site (8.7 ha), also known as Knockanglass, was opened in the late 1960s by Ballingarry Collieries Ltd. but was unsuccessful and closed within a year (www.ballingarry.net). The excavations here are nevertheless very extensive. The open pit is flooded and drains via an overflow channel to the southwest. It is fed by a drainage channel from the northeast that carries surface water from the surrounding farmland (photo right, viewpoint toward southwest). The northern wall of the pit (hanging wall) is almost vertical but the ground to the south is benched and contains significant volumes of waste. Much of the site has undergone natural revegetation by gorse and other native species. The waste heaps are in use as cattle pasture although grass cover is poor.

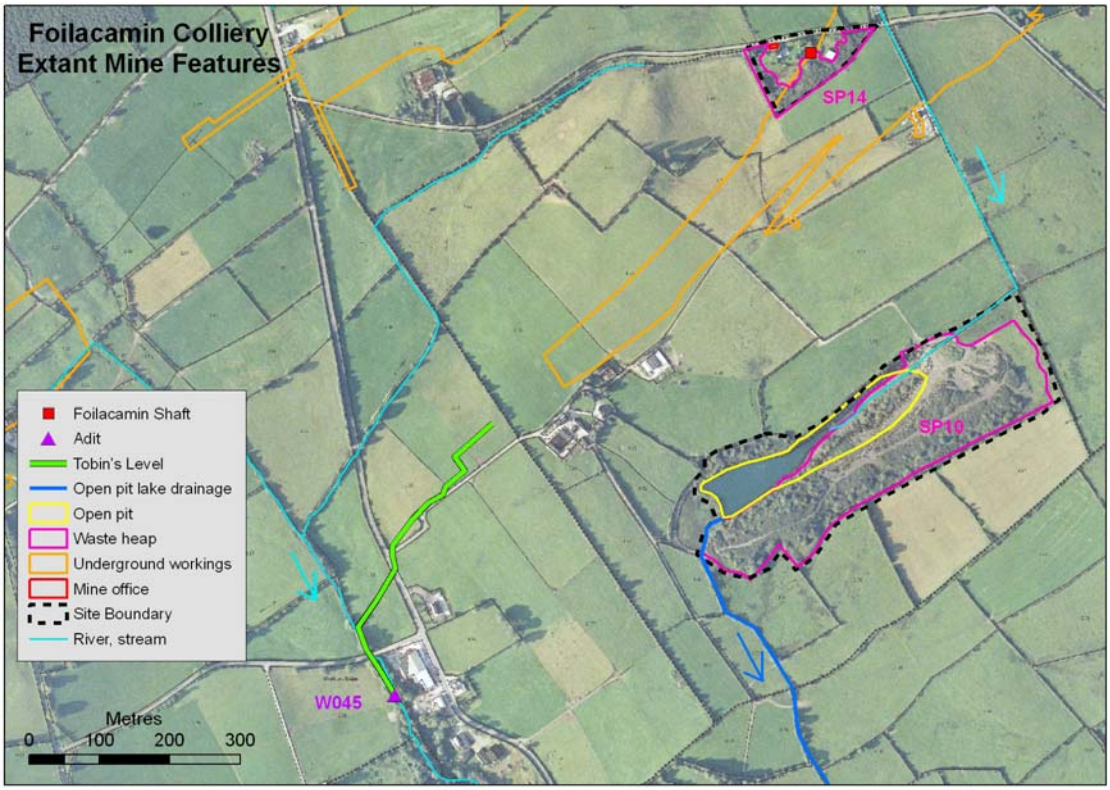

Fig. 6 Foilacamin: mine features

This is one of the only sites in Slieve Ardagh where the surface water chemistry is significantly affected by mining. Initial reconnaissance at the northeastern end of the lake indicated a pH of 6.0 in the drainage stream entering the lake and low pH (4.3) in the lake water itself. Formal sampling and analysis of lake water in December 2006 and July 2007 gave pH readings of 5.6 and 6.0, respectively, with concentrations of Cu (<1 – 45 µg/l), Ni (36-71 µg/l) and Zn (74-77 µg/l) that exceed the typical background (upstream) concentrations for the district (see Geochemistry section, below) as well as the Draft EC Surface Water standards (EC 2007). The composition of the water discharging via the overflow channel to the southwest was very similar. Analysis of water that had collected in a small hollow in the waste heap above the lake gave very low pH in both summer (2.9) and winter (3.7). Metal concentrations were very high for coal waste (245-283 µg/l Cu, 645-785 µg/l Ni, 577-789 µg/l Zn, 478-895 mg/l SO_4). The conclusion drawn from these analyses is that sulphides within the waste heap are leached on contact with rain water. This leachate then enters the lake, either as surface run-off or seepage through the heap, and raises the concentration of certain metals while lowering the pH. The waste heaps at Foilacamin must thus be considered to have some potential to have an adverse impact on surface or groundwater in the vicinity.

Southwest of the open pit Tobin's adit (photo, above) into the local stream. Tobin's adit appears to have been a 19th century adit that drained the old underground

workings immediately north of the open pit. The Cu concentration (44 µg/l) recorded at the adit in summer 2007 was slightly above that for background (upstream) surface water in the district (see Geochemistry section, below).

In summary, the Foilacamin colliery site has been made safe through capping and blocking up of the main shaft housing. The opencast site, however, presents some significant hazards. The open pit itself is the most significant potential hazard to humans and livestock. There is only low barbed wire fencing at the top of the steep north wall although thick gorse provides additional protection around the edge. The depth of the lake is unknown. In addition, the action of rainwater of the solid waste is generating acid rock drainage (ARD). Periods of high rainfall can be expected to add significant quantities of such ARD to the open pit lake. Analyses suggest that the lake water has slightly reduced pH and raised concentrations of Cu, Ni, Zn and SO_4 compared to background concentrations for the district.

5. Commons

Mine Name: Commons

Alternative Names:

Townland: Blackcommon

Grid Reference: E230683, N152681

This was the site of extensive mining by the Mining Company of Ireland in the mid 19th century and also saw numerous private bell-pit excavations. However, relatively few traces now remain (Fig. 8). The surface site of the colliery (2.4 ha) is in a cluster of buildings in the centre of the village (photo, above). They are now in use as farm buildings but there original purpose is unknown. The Engine shaft, located within a mound surrounded by brambles and trees and barbed wire, is open. The width of the opening is 5.2m and the measurable depth 7.7m. A considerable amount of water is flowing into the shaft from a seam located 6 – 7m below the rim. Commons Pit, which appears to have been a shaft to underground workings, is now covered by a silage yard and cow shed (photo, above left). A small waste heap of shale remains beside the site of a third shaft but the shaft itself is not visible.

Almost 1km to the north, on higher ground, Gloune adit discharges a large volume of mine water (> 28 l/s in March 2007) (photo, right) from the shallow workings to the northeast.

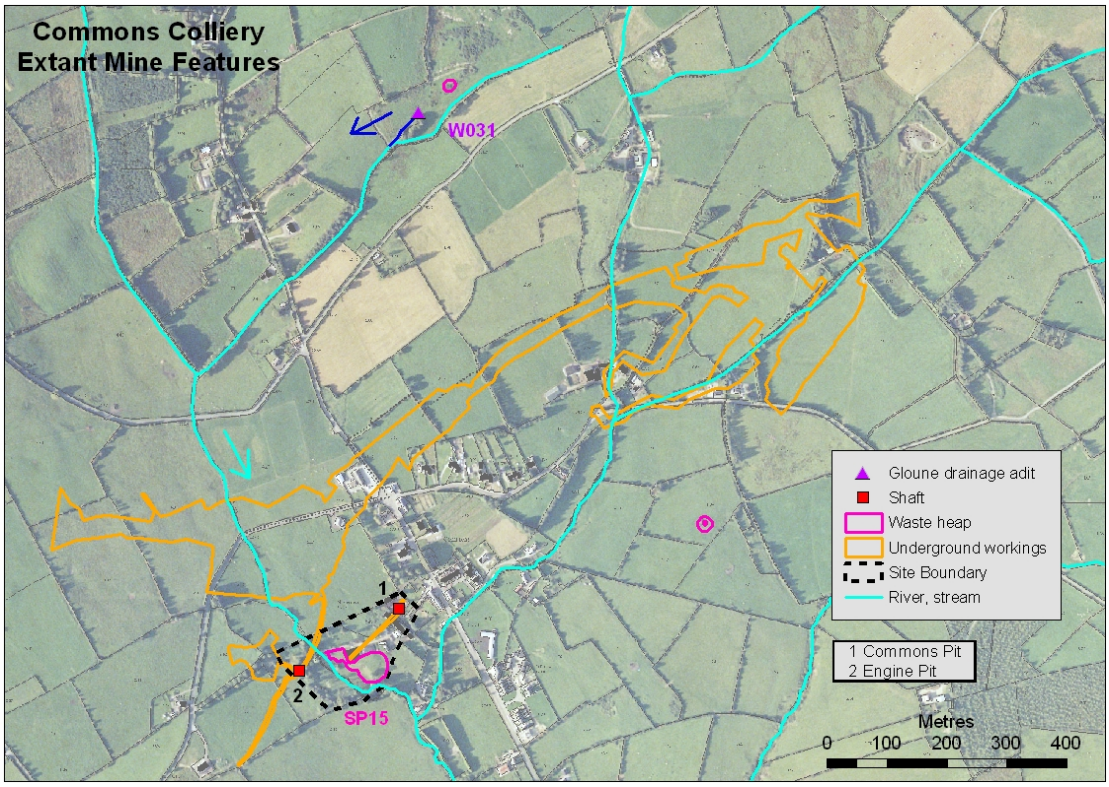

Fig. 8 Commons: mine features

6. Ballingarry

Mine Name: Ballingarry

Alternative Names: Copper, Clashduff

Townland: **Grid Reference:**

Ballingarry Lower; Clashduff E229585, N150065

This site is located in the Copper basin and was worked in the 19th century and possibly earlier. It was the site initially developed by Mianrai Teoranta in 1948 after it abandoned Ballynunty. It was taken over in 1952 by what was to become Ballingarry Collieries Ltd. and worked until 1957. Despite the very extensive operations here little remains on site. The surrounding land is almost entirely under pasture.

The underground workings are in two parts, to the north and south of the road that runs east to Ballingarry village (Fig. 9). Modern mining appears to have been mainly on the northern side. The colliery yard site is now in the service of a car dismantling business (above). Washery walls remain above the yard to the west but there is now no trace of the two parallel declines that ran westward into the underground workings. A small waste heap immediately east of the yard is all that remains of what was reputedly the largest waste heap in Slieve Ardagh: around 515,000 tons were sold to New Rossmore colliery in the Leinster Coalfield.

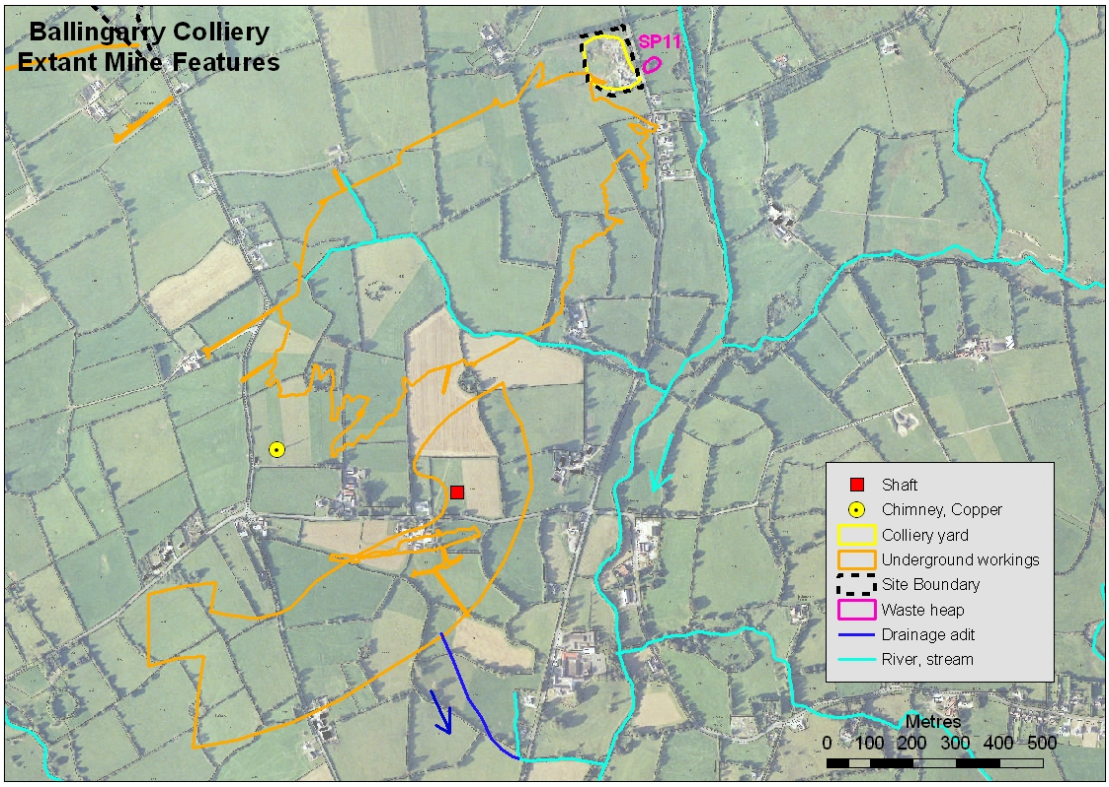

Fig. 9 Ballingarry: mine features

On the western edge of the site stands Copper Chimney (right), one of the finest 19th century (1863) mine buildings remaining in Slieve Ardagh. It is a 30m-high, quadrangular stack with an arched opening at the base. The chimney was apparently intended for ventilation of the level below: a fire built in the base of the chimney would create an updraft to draw air from the underground workings. However, the chimney was never connected to the underground workings (www.ballingarry.net). Loose stonework is apparent above the flange at the top and cracks are visible in the walls. The chimney has no lightening conductor.

7. Coalbrook

Mine Name: Coalbrook

Alternative Name: Lisnamrock

Townland:
Knockalunga; Lisnamrock

Grid Reference:
E228444, N150215

This site is 1km south of Coalbrook village, immediately west of the road. It is also known as Lisnamrock. The site contains two overgrown and plugged shafts and the remains of several mine buildings. The buildings include a substantially intact engine house (photo, above) and an 18m-high quadrangular chimney (photo, left). The small, occupied cottage at the roadside is apparently rebuilt or renovated from the original mine offices. The information about underground workings comes largely from an 1894 plan which shows a drainage adit running south from the workings to meet the local stream (Fig. 10). The status of this adit is unknown.

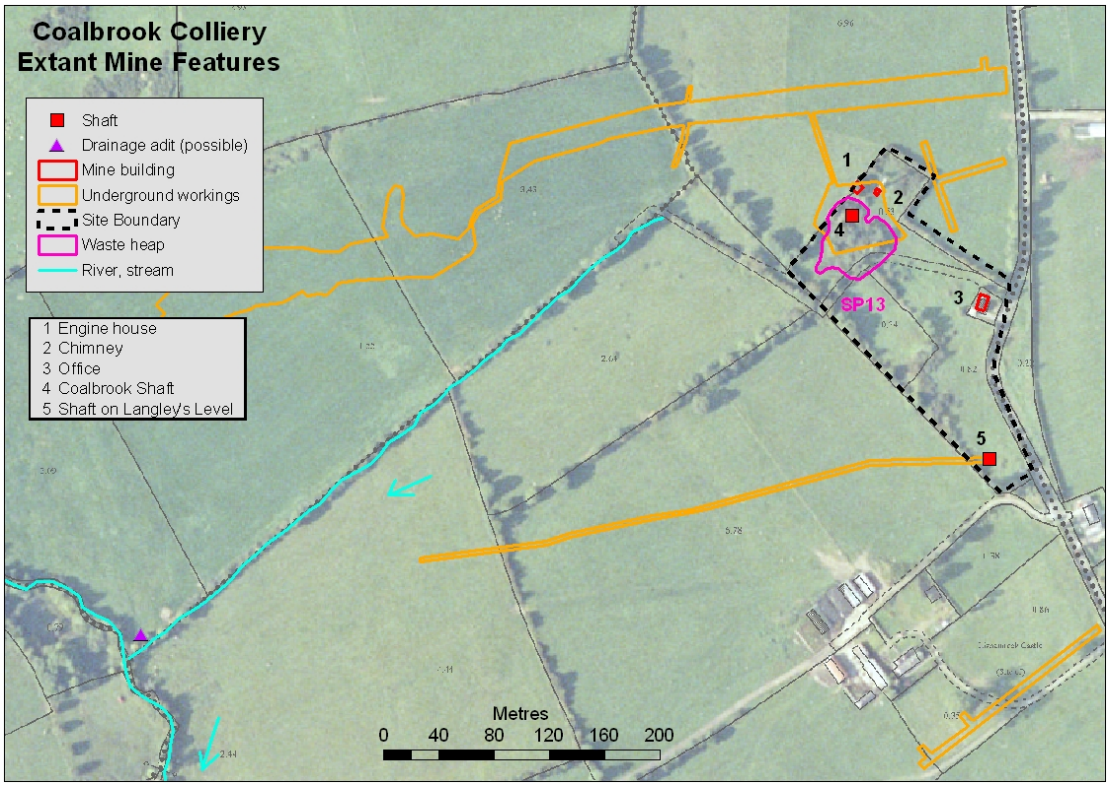

Fig. 10 Coalbrook colliery: extant mine features

The engine house was built from large flat well-hewn stones with massive cubic corner stones and is generally sound. However, cracks are visible in the walls, lintels are missing and there are numerous loose or missing blocks, particularly along the

top. There is no lightening conductor. The chimney is similar in shape to that at Copper but lacks the arched opening at the base. Loose bricks are visible on the walls and it also lacks a lightening conductor. Nevertheless, it appears stable.

Both shafts marked on Fig. 10 are overgrown. Coalbrook shaft is within the waste heap mound and apparently plugged. A 1m-deep hollow overgrown with nettles marks the shaft on Langley's level.

8. Earlshill

Mine Name: Earlshill

Alternative Name:

Townland:
Earlshill

Grid Reference:
E226138, N150707

Earlshill was leased in 1844 by the Mining Company of Ireland from the landowner, Mr. Going, who had previously worked it and the neighbouring Ballyphillip (www.ballingarry.net). Earlshill is sited on a syncline in which the upper coal seams, missing in the rest of the district, were preserved. The mine extended down at least 380 feet (116m). It had closed by the 1880s. Though small, Earlshill has the best remaining group of 19th century mine buildings in Slieve Ardagh or indeed any of the Irish coalfields.

The site (Fig. 11) includes three large "banks" or heaps of waste and several well-preserved mine buildings. Two of the waste heaps are flattened and overgrown by gorse, trees and rough grass. The third, on the site of the engine house and chimney, has been reclaimed to pasture. The engine house is now gone but the round chimney remains (photo, above right): cracks are showing on the walls and numerous blocks have fallen from the top where birds appear to be nesting. A hollow beside the chimney is presumably what remains of the engine shaft.

Along the entrance road to the west the old mine manager's house (photo, left) and offices are abandoned but still standing and in reasonable condition. To the rear of the house, in what is now a farm yard, a round building with pitched conical roof is a powder house or magazine (photo, top). The roof is intact and the building dry. The door lintel is broken and requires repair.

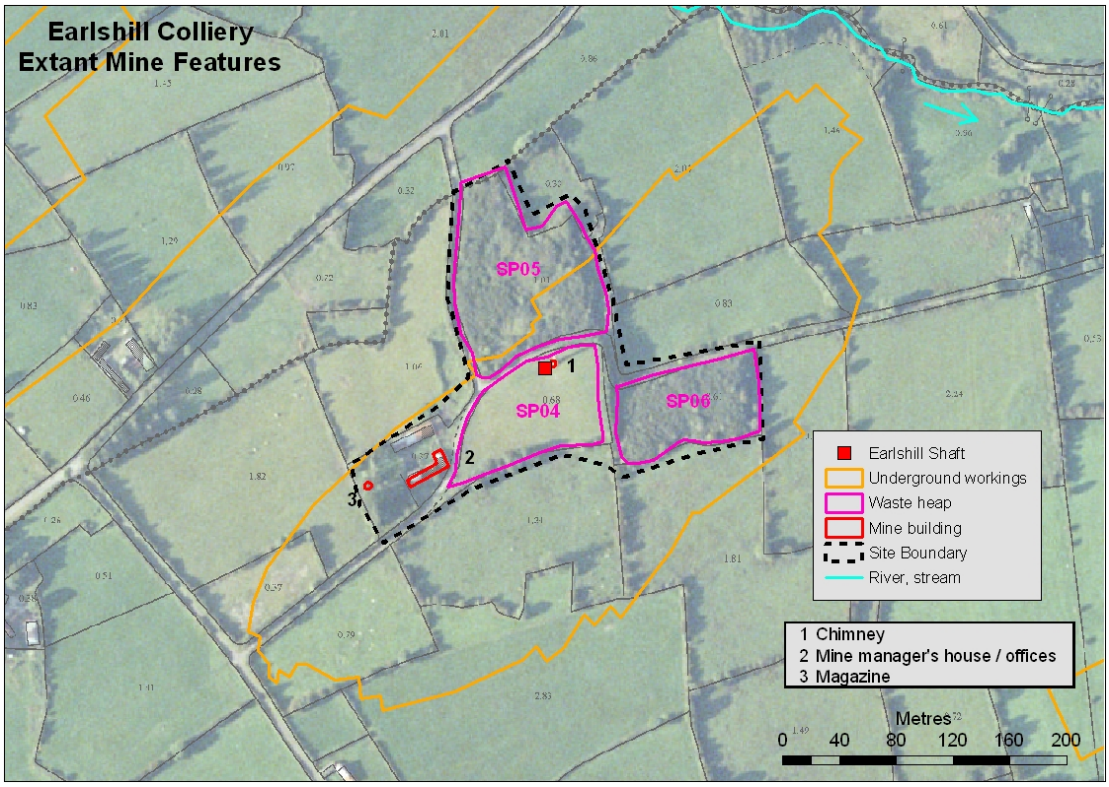

Fig. 11 Earlshill: extant mine features

9. Ballyphillip

Mine Name: Ballyphillip

Alternative Name:

Townland: Ballyphillip

Grid Reference: E227086, N150490

Ballyphillip is less than 1km southeast of the Earlshill site. It was formerly worked by the landowner, Going, in the early 19th century before being leased, along with Earlshill, by the Mining Company of Ireland. The site is part of an active farm and the remaining mine features are surrounded by grassland used mainly as cattle pasture.

Although the underground workings were extensive, stretching for another 0.5km southwest of the current site (Fig. 12), there are few remains left on the surface. No mine buildings are preserved. A large hollow marks the position of the "12ft" shaft. The "A" shaft is hidden in thick overgrowth on a waste heap but a small discharge downslope of it suggests it is still open to some extent. The pH and EC of the discharge (6.9 and 0.22 mS/cm, respectively) differ from those of the stream it flows into (7.7 and 0.17mS/cm upstream; 7.4 and 0.18mS/cm downstream).

The main feature on the Ballyphillip site is the opencast excavation made during the 1960s by Ballingarry Collieries Ltd. (top). This was apparently short-lived as development was stopped because of the high dip of the seam. The opencast area is completely fenced off by intact barbed-wire fencing. It includes an open pit lake, approximately 20 – 25m deep according to local farmers, waste heaps and steep cliffs. The waste heaps form a raised bank around the pit on the southern side so that the site appears as a topographic high against the fields to the south. The site has undergone extensive natural revegetation. Although some fly-tipping of cars has taken place on the northern side, the site is now akin to a nature reserve. It is somewhat remote, difficult to enter and, in consequence, appears to be largely left alone. A stream runs along the eastern boundary of the site and a small flow of water discharges from the lake into it. In addition, the Earlshill drainage adit discharges via a channel, now under the field to the north, into the same stream at the northeastern side of the site.

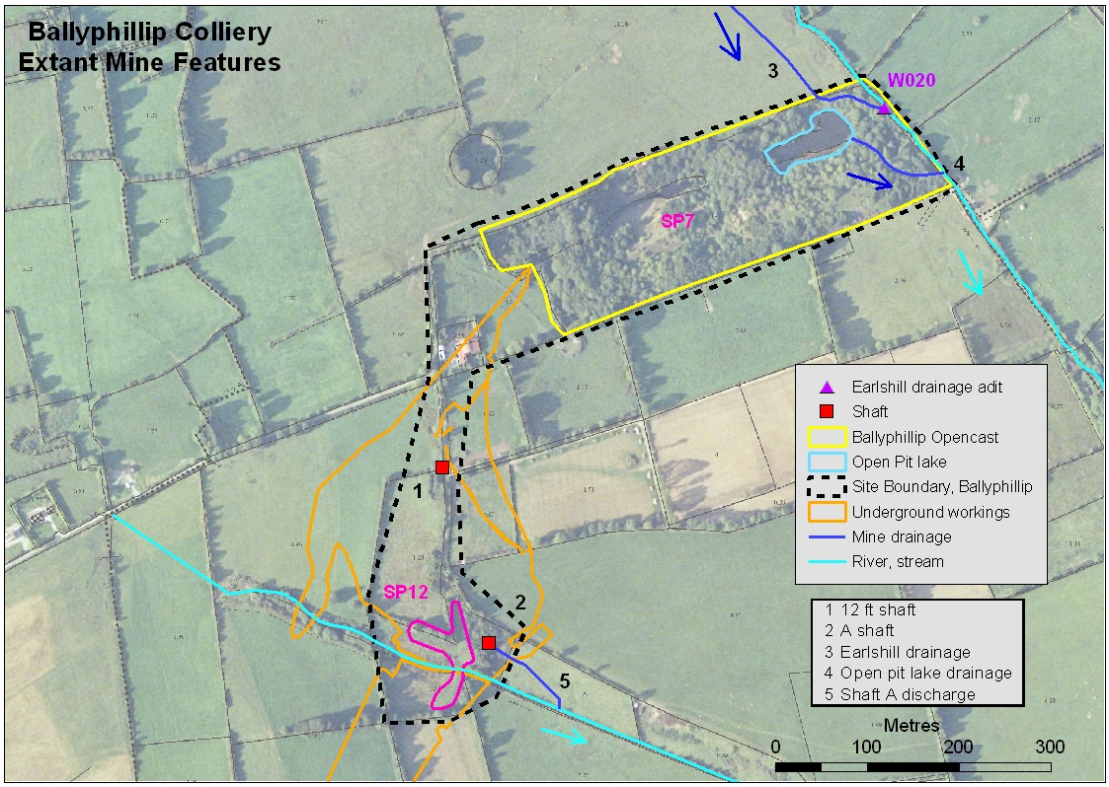

Fig. 12 Ballyphillip: extant mine features

The main potential hazards on the Ballyphillip opencast area are fall hazards to humans and livestock, particularly at the low fence on the northern boundary where there is a steep pit face. The chemistry of the discharges is described in the Geochemistry section (below) but none appears to have any significant impact on the surface water of the area.

10. Tully's Adit

Name: Tully's Adit

Alternative Name:

Townland: Coolquill

Grid Reference: E225005, N146862

Tully's adit is a collapsed adit to the south of the Ballynunty area (Fig. 13) that issues a significant year-round discharge of mine water. The adit drains an area of known workings to the northeast for which no plans are available. The adit discharge was included in the geochemical programme (see Geochemistry section, below).

11. Ballynastick Shaft

Name: Ballynastick shaft

Alternative Name:

Townland: Coolquill

Grid Reference: 225005, 146862

Ballynastick shaft is mid way between Lickfinn and Gorteen. It is over 170m deep and extends through the underground workings that stretch from Ballynunty in the southwest to Foilacamin in the northeast. The three-compartment shaft is securely covered with three cement slabs. A large waste heap that stood beside the shaft has been flattened by the land owner to form a raised platform on which a cattle shed has been built.

12. Boulea Opencast

Name: Boulea opencast

Alternative Name:

Townland: Clashduff

Grid Reference: E229425, N151259

Boulea (1 ha) is 1.2 km north of the Ballingarry site (Fig. 13). It is the site a small open cast that has recently been filled in. The ground had been graded but not seeded by June 2007. A small linear trench is marked on the OSI 6-inch map so presumably this site was worked in the 19th century. More recent work was carried out by Boulea Resources. The site is immediately beside a small river. On the

opposite bank a collapsed and largely filled-in adit (Commons drainage adit) issues a steady flow of mine water. Water also flows from the area of the opencast – an old adit is marked as being present here and the water observed may be drainage from it. Alternatively, the 6-inch map shows a stream flowing through here. No stream is visible today but it may well have been filled in and the observed discharge may be flow along the old stream channel.

Geochemistry

Surface water, stream sediments and solid waste heaps at Slieve Ardagh were analysed to identify possible environmental impacts related to mining. In addition, leachate tests were carried out on composite samples of solid waste.

1. Surface water and groundwater

Surface water and groundwater (well) samples were collected in both winter (December 2006, March 2007) and summer (July 2007). The surface water samples came from streams both upstream and downstream of mine sites, adit and shaft discharges, surface run-off from waste and from open pit lakes. In general, concentrations of potential contaminants were low, with little variation among the parameters analysed. Exceptions were samples of run-off and ponding on exposed coal/shale waste that had relatively low pH and high EC as well as significantly elevated concentrations of Al, Fe, Cu, Ni, Zn and SO_4. Table 1 summarizes the data for some of these parameters for all analyses carried during the project, both in winter and summer. The median values for specific water sources are given in Table 2 where they can be compared to reference values used for the HMS-IRC project. Reference values for Cu, Ni and Zn are exceeded by waters on or running-off solid waste; Cu concentrations in adit discharges typically exceed reference values also.

Table 1 Summary statistics for all water samples, Slieve Ardagh

	pH	EC	Al (tot)	Cd (tot)	Cu (tot)	Ni (tot)	Zn (tot)	SO_4
		mS/cm	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
n	61	61	61	61	61	61	61	61
Minimum	2.87	0.07	49	<1	<1	2	26	6,000
Maximum	8.53	1.59	50980	31	283	785	789	895,000
Median	7.31	0.35	453	<1	26	9	56	23,000
Mean	7.17	0.39	2577	1.9	32.6	38.6	87.5	64,000

Table 2 Median values for water based on source, Slieve Ardagh

Medians	pH	EC	Al (tot)	Cd (tot)	Cu (tot)	Ni (tot)	Zn (tot)	SO_4
		mS/cm	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
Upstream (n=12)	7.62	0.22	535	<1	8	5	37	9000
Downstream (18)	7.34	0.34	520	<1	20	12	50	24000
Adit/Shaft discharge (17)	7.02	0.38	291	<1	34	8	50	27000
Waste run-off (3)	3.70	0.79	35880	29	245	645	577	478000
Open Pit Lake (5)	6.86	0.32	676	<1	<1	36	74	124000
Well (6)	8.20	0.55	80	1.3	37	10	65	23500
Reference value	6.5-9.5	< 2.5	200	0.25	5 - 30	20	8 - 100	250,000

***Reference value: Table 3.1.3, Chapter 3, main report. Values for Cu, Zn vary according to hardness of water**

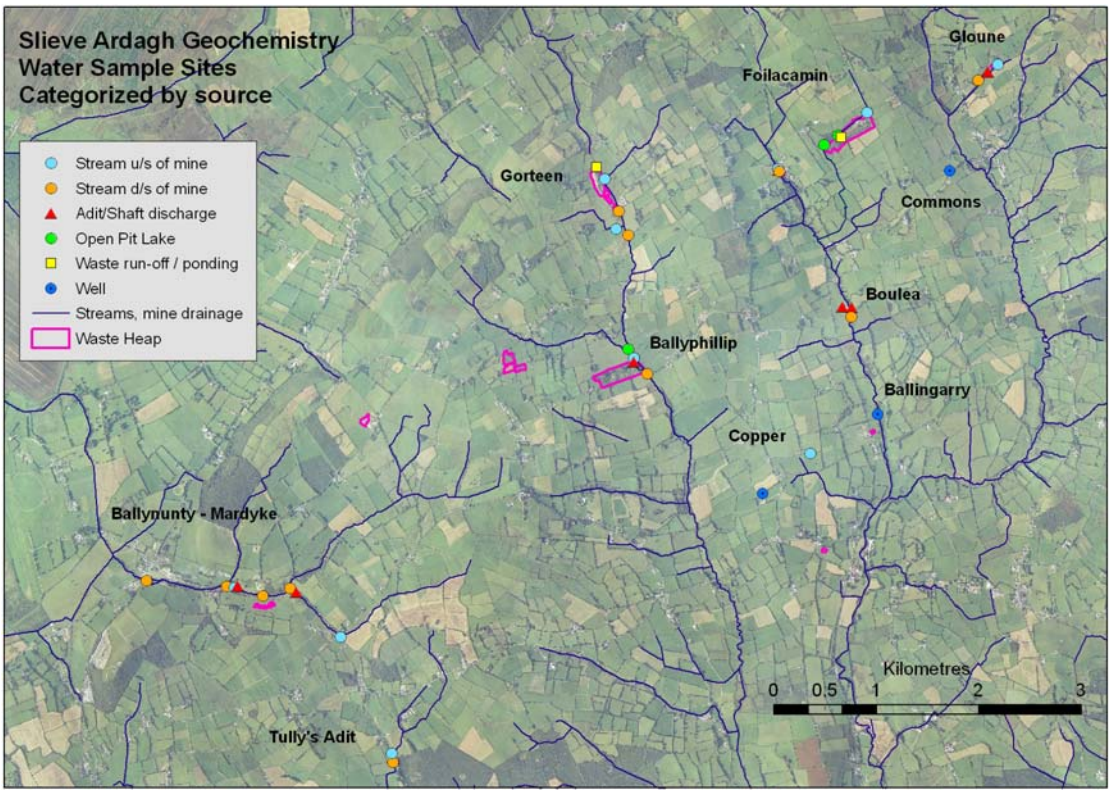

Fig. 13 Slieve Ardagh: water sampling sites

The highest EC and element concentrations and lowest pH were measured in run-off and ponded water on the waste heaps at Gorteen and Foilacamin. Other waste heaps were not similarly sampled as run-off and/or ponding were not observed during field work. The most extreme values (maxima in Table 1) were measured at Foilacamin where samples of open pit lake water also had somewhat reduced pH and elevated SO_4.

Fig. 14 shows a partial plot of Zn (tot) v SO_4 where values of Zn > 300 µg/l and SO_4 > 300,000 µg/l, i.e. samples from Foilacamin run-off only, are excluded. Most water samples have Zn < 150 µg/l and SO_4 < 70,000 µg/l and cannot readily be separated on the basis of these chemical parameters. The exceptions, apart from the run-off samples, are four downstream samples and four open pit lake samples. The downstream samples are all from two sites in Gorteen, taken in both winter and summer, and the open pit lake samples are all from Foilacamin, again taken in both winter and summer. In both cases, this suggests that the waste at Gorteen and

Foilacamin is influencing the composition of the surface water at the sites. The corollary is that elsewhere in the Slieve Ardagh district surface water does not appear to show any significant impact from mining. Of particular interest are the relatively low concentrations of metals and SO_4 observed in adit discharges (Fig. 14 and Table 2). By analogy with the run-off samples, where direct contact between the water and coal waste can be observed, it appears that water draining the underground mine workings via adits may not be equilibrating chemically with coal and the sulphide minerals it contains.

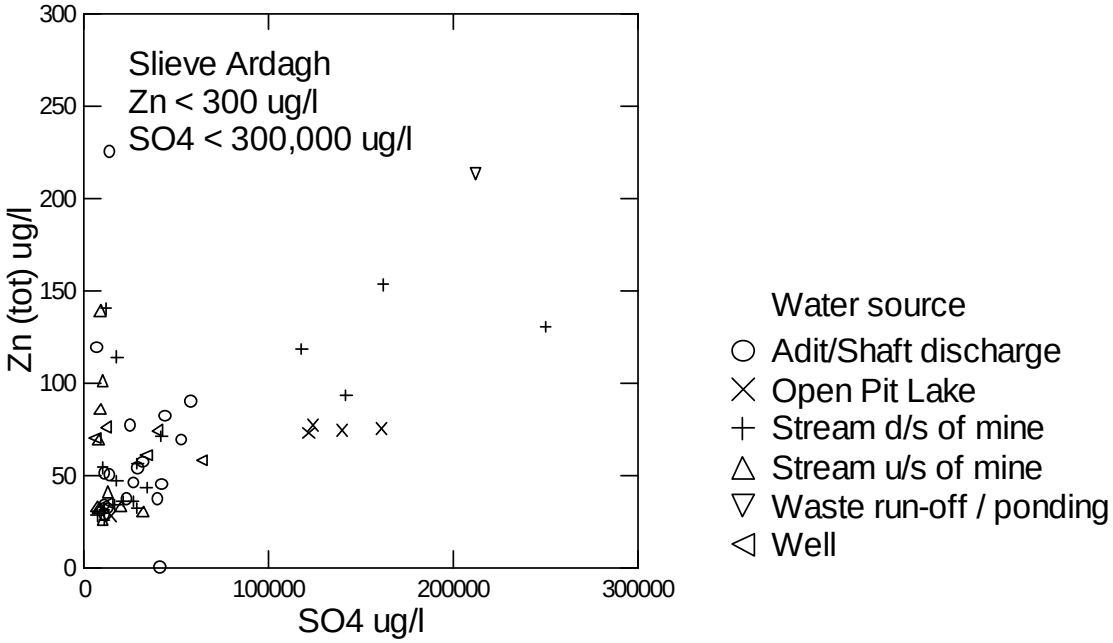

Fig. 14 Zn v SO_4 by water source, Slieve Ardagh

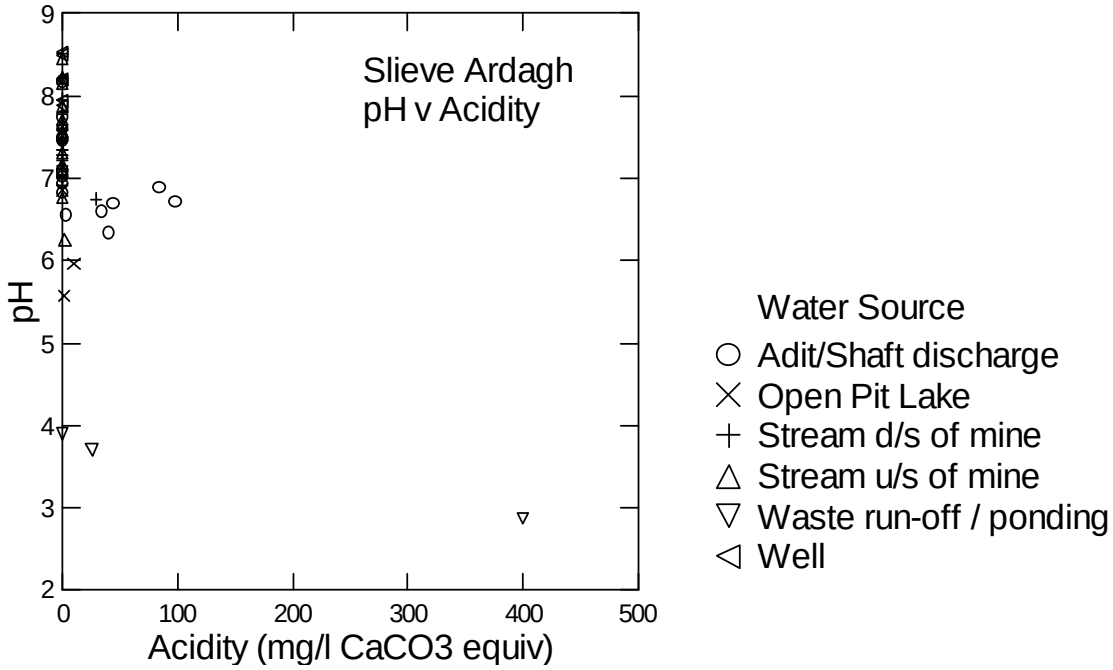

Fig. 15 pH v Acidity, Slieve Ardagh

Apart from metal contamination, the most important chemical issue related to mine water discharges from coal mines worldwide is acid mine drainage (AMD) or acid rock drainage (ARD), generated as a consequence of reaction between mine water and sulphides, mainly pyrite, in the coal and its host rock. Although some run-off samples at Slieve Ardagh had low pH, only one, taken in summer at Foilacamin, had acidity in excess of 100 mg/l $CaCO_3$ equivalent (Fig. 15). Most water samples taken at Slieve Ardagh had pH > 7 and alkalinity was measured instead but for those with pH < 7 the measured acidity is generally low. This reflects the general absence of significant concentrations of ions, e.g. metals, in the water. In consequence, although low-pH, high-acidity samples can be generated under specific circumstances and in specific locations, acidity is generally not a significant factor at Slieve Ardagh and the risk of AMD therefore appears to be low.

2. Stream Sediments

Stream sediments were collected in the vicinity of four collieries, in three streams both upstream and downstream of the sites (Fig. 16). In addition, the sediment in the Ballynunty-Lickfinn adit discharge stream was sampled for comparison. Table 3 summarizes the results.

Although four "upstream" sites were sampled, two of these, at Foilacamin and Ballyphillip, while upstream of the opencast pits are subject to impact from mine waste. At Foilacamin, the sampled stream incises a field above the opencast that is at least partly composed of mine waste that has been covered and grassed. At Ballyphillip, some minor adits are suspected of discharging into the stream above the "upstream" sampling point. In both cases the site was sampled in the absence of a more suitable location further upstream.

Table 3 Summary statistics for stream sediment analyses, Slieve Ardagh

mg/kg	As	Zn	Cu	Ni	Fe	Mn
All data						
n	10	10	10	10	10	10
Minimum	9	42	0.0	0.0	16555	572
Maximum	178	564	113	724	207570	54623
Median	19	210	46	158	43986	4442
Mean	42	221	47	197	66696	10911
By location						
Upstream median (n=2)	9	54	10	0	18522	866
Upstream (partial) median (n=2)	22	231	84	143	44517	3663
Downstream median (n=5)	23	255	45	200	44557	4962
Adit discharge stream (n=1)	105	564	62	724	165866	54623

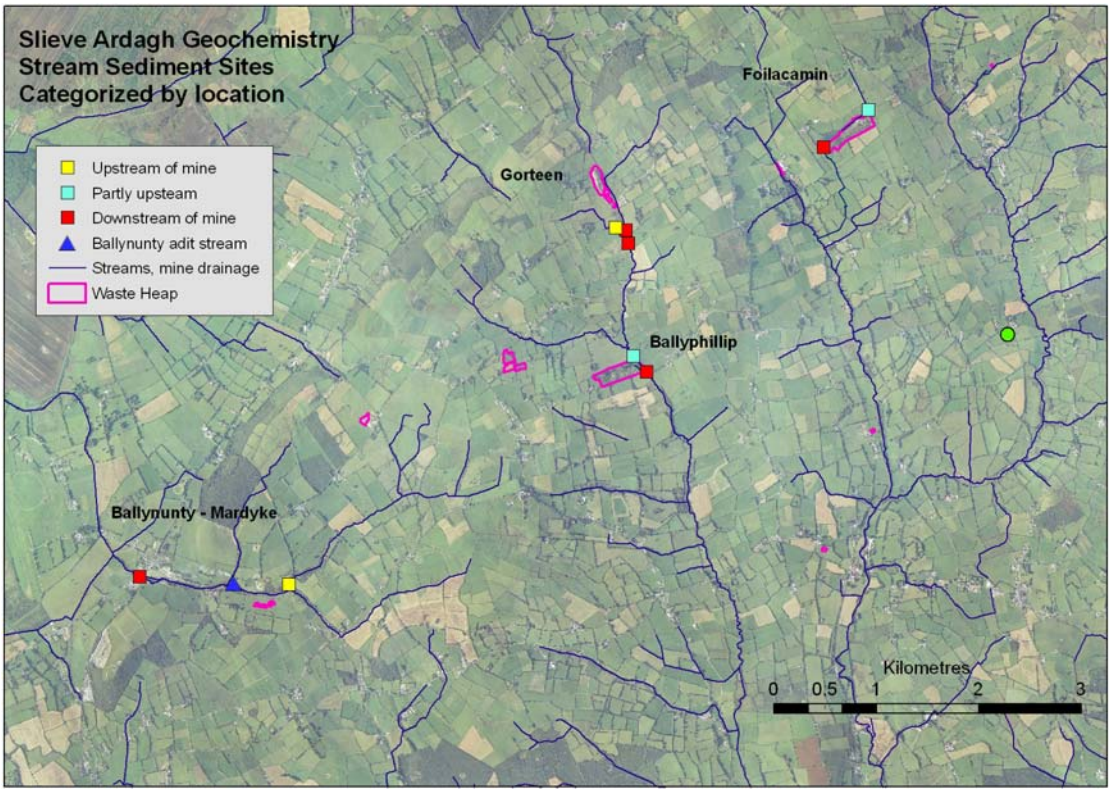

Fig. 16 Stream sediment sampling sites, Slieve Ardagh

The total number of samples collected (10) is low but it is nevertheless possible to discern some patterns in the data. Some elements, e.g. Sb, Cd, Cr, V, were below the detection limit in all or most samples whereas As, Zn, Cu, Ni, and Mn are present in concentrations well above those found in the two truly upstream samples. The concentrations of the elements in downstream samples and the adit discharge stream indicate that the elevated concentrations measured can be directly attributed to coal mining. This is well illustrated by Fig. 17.

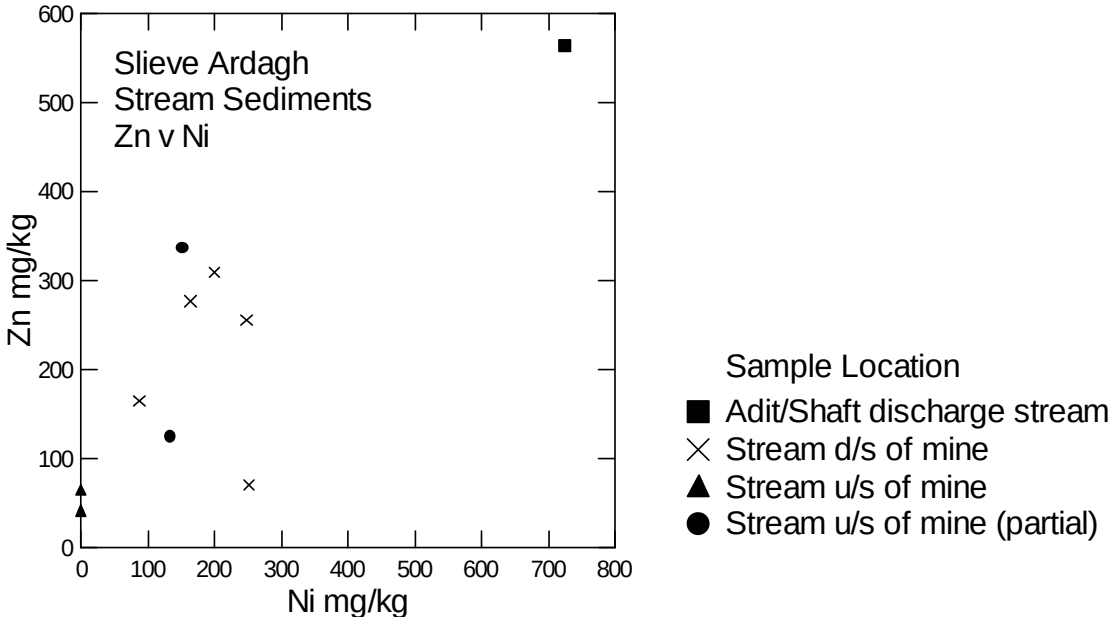

Fig. 17 Zn v Ni, Stream sediments, Slieve Ardagh

The presence of Ni in stream sediments and the failure to detect it in solid waste analyses is of interest. The fine fraction (< 150 µm) collected tends to concentrate metals and this may be sufficient to account for the observed data. Certainly, Ni seems to be present in coal mine waste but at levels too low to be detected and measured using the techniques employed in this study.

3. Solid Waste XRF

Solid waste analyses were carried out *in situ* by portable XRF at Gorteen and Foilacamin. The choice of sites reflected the presence of uncovered waste with significant coal content as well as prior water analyses that suggested the possibility of raised concentrations of particular metals in the waste.

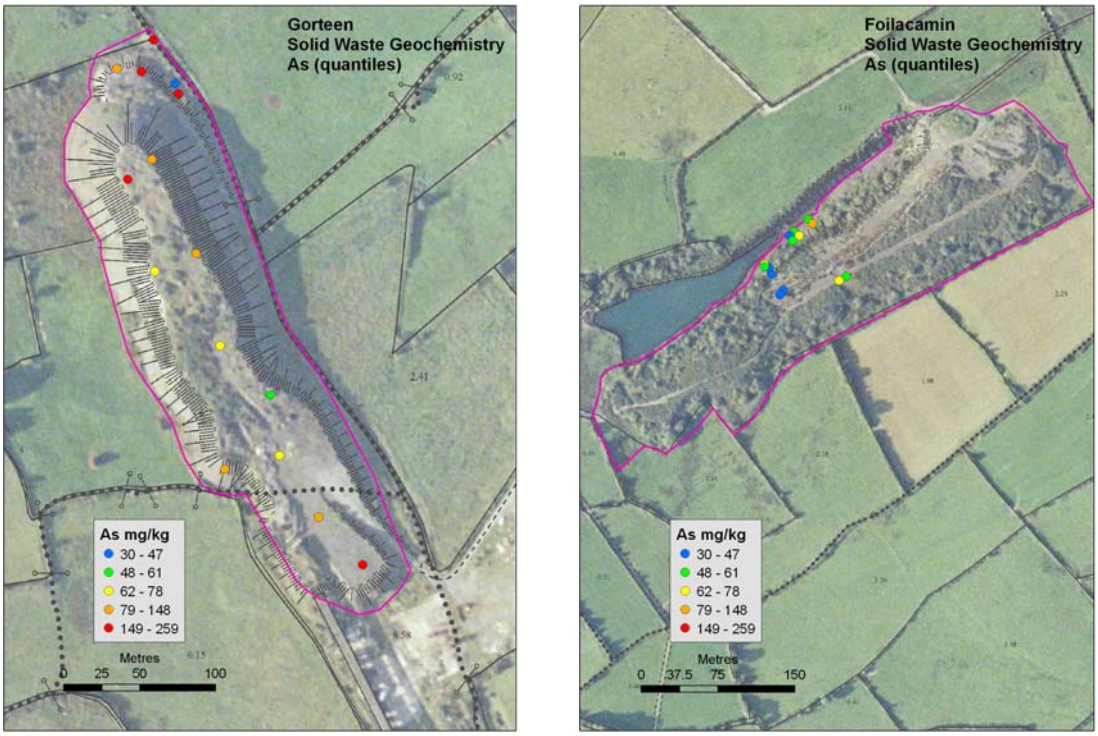

Fig. 18 Solid waste geochemistry: As in spoil, Gorteen and Foilacamin

Analysis of the waste at Foilacamin and Gorteen revealed elevated levels in some samples of Sb, As, Cu, Zn, Pb, Cr and V. Of these, only As and Pb were detected in all samples. Table 4 summarizes the data. Compared to waste analysed on metallic mine sites, the waste at Slieve Ardagh has relatively very modest absolute concentrations of metals. However, compared to regional median data from the National Soils Database (www.epa.ie/nsdb), computed using soils overlying the Upper Carboniferous bedrock in the Slieve Ardagh – Leinster Coalfield area, the waste at Slieve Ardagh is clearly enriched, if moderately so, in As and Pb. The highest values obtained for Cu and Ni are also well in excess of soil values for the region.

There is no clear correlation with water analyses. Ni, which is present in high concentrations in run-off water samples at Foilacamin and Gorteen, was typically below the detection limit. As, detected in all solid waste samples, was not detected in any water analysis despite the reduced-pH conditions that would be expected to

increase its solubility. In the case of Ni, this may reflect high detection limits in the XRF -

Fig. 19 shows the As distribution at Gorteen and Foilacamin. Other elements produce similar maps. The classification is based on all samples analysed to allow direct comparison of the two sites. As concentrations are generally higher at Gorteen than Foilacamin, with particularly high values clustered around the northern flank of the heap. In contrast, although it yielded higher metal concentrations in run-off water than were measured at Gorteen, solid waste at Foilacamin generally has lower As concentrations. The highest concentrations of Zn and Cu are also found at Gorteen (Table 4).

Table 4 Summary statistics for solid waste analyses, Slieve Ardagh

mg/kg	**As**	**Zn**	**Cu**	**Ni**	**Pb**
All analyses					
n	29	29	29	29	29
Minimum	30	0.0	0.0	0.0	51
Maximum	259	209	303	98	221
Median	68	0.0	25	0.0	111
Mean	94	16	35	3.4	118
Foilacamin					
n	14	14	14	14	14
Minimum	30	0.0	0.0	0.0	106
Maximum	87	53	73	98	221
Median	52	0.0	52	0.0	140
Mean	55	7	38	7	144
Gorteen					
n	15	15	15	15	15
Minimum	37	0.0	0.0	0.0	51
Maximum	259	209	303	0.0	166
Median	100	0.0	0.0	0.0	84
Mean	130	24	33	0.0	93
NSDB **(median)**					
Namurian-Westphalian (n=20)	7	71	13	18	23

There are numerous waste heaps in the Slieve Ardagh district, comprising coal waste and slate. Many are grassed over or otherwise overgrown by vegetation. Volume estimations have been made on many of these heaps and they have been included in the HMS Scoring System for risk ranking of sites. Table 5 below lists the solid waste heaps for which volumetric data is available.

Table 5 Solid waste heaps, Slieve Ardagh district

Waste ID	Area (m^2)	Volume (m^3)
SLA-SP01	2897	17382
SLA-SP02	1944	2700
SLA-SP03	4983	21510
SLA-SP04	6292	6292
SLA-SP05	10556	35890
SLA-SP06	5629	5629
SLA-SP07,8	65558	216349
SLA-SP09	36302	280670
SLA-SP10	61566	248797
SLA-SP11	857	1286
SLA-SP12	2940	5580
SLA-SP13	2182	873
SLA-SP14	6626	22528
SLA-SP15	2748	4675
SLA-SP16	29	15.6
SLA-SP17	51	412.58

4. Site Scores

Table 6 Site Scores for mine waste, Slieve Ardagh

Waste	**SP01**	**SP02**	**SP03**	**SP04**	**SP05**	**SP06**
1. Hazard Score	**12**	**11**	**12**	**11**	**13**	**11**
2. Pathway Score						
Groundwater	1.72	1.61	1.61	1.51	1.70	1.50
Surface Water	1.25	1.16	0.14	0.02	0.03	0.02
Air	0.00	0.00	0.00	0.00	0.01	0.00
Direct Contact	0.02	0.02	0.01	0.06	0.57	0.05
Direct Contact (livestock)						
3. Site Score	**3**	**3**	**2**	**2**	**2**	**2**

Waste	**SP07,8**	**SP09**	**SP10**	**SP11**	**SP12**	**SP13**
1. Hazard Score	**22**	**24**	**33**	**11**	**11**	**11**
2. Pathway Score						
Groundwater	2.54	3.74	6.08	0.60	1.43	1.39
Surface Water	0.09	8.91	12.32	0.09	0.02	0.02
Air	0.02	0.02	0.11	0.00	0.00	0.00
Direct Contact	0.15	0.20	0.21	0.00	0.03	0.03
Direct Contact (livestock)						
3. Site Score	**3**	**13**	**19**	**1**	**1**	**1**

Waste	SP14	SP15	SP16	SP17	W004	W008
1. Hazard Score	**12**	**11**	**11**	**11**	**31**	**11**
2. Pathway Score						
Groundwater	1.90	1.29	0.60	0.69	3.25	0.44
Surface Water	0.02	0.02	0.02	0.02	3.13	1.56
Air	0.00	0.00	0.00	0.00	0.00	0.00
Direct Contact	0.01	0.01	0.00	0.00	0.00	0.00
Direct Contact (livestock)						
3. Site Score	2	1	1	1	6	2

Waste	W010	W020	W045	W048	W049	W031
1. Hazard Score	**15**	**11**	**6**	**16**	**28**	**11**
2. Pathway Score						
Groundwater	0.31	0.07	0.16	0.23	0.85	1.08
Surface Water	0.51	0.09	1.87	2.49	4.68	2.79
Air	0.00	0.00	0.00	0.00	0.00	0.00
Direct Contact	0.00	0.00	0.00	0.00	0.00	0.00
Direct Contact (livestock)						
3. Site Score	**1**	**0**	**2**	**3**	**6**	**4**

Waste	Stream seds Ballynunty	Stream seds Foilacamin	Stream seds Gorteen-Ballyphillip	Totals
1. Hazard Score	**37**	**5**	**53**	**451**
2. Pathway Score				
Groundwater				36.32
Surface Water				41.27
Air				0.18
Direct Contact				1.37
Direct Contact (livestock)	14.90	1.02	21.37	37.29
3. Site Score	**15**	**1**	**21**	**118**

Table 6 gives the HMS-IRC site scores for each individual waste source in Slieve Ardagh that has been scored. The total score for the district is 117, placing the district in HMS-IRC Class IV. Of this score of 117, solid waste accounts for almost 50% (57), stream sediments 32% (37) and adit discharges 20% (23) (Fig. 19). Solid waste was analysed only at two sites, Gorteen and Foilacamin, but the median concentrations of the analyses for these two sites were applied to all other waste heaps in order to generate site scores. The high proportion of the total site score contributed by solid waste (total score = 57) reflects (1) the large number of waste heaps recorded in the district, most contributing very lows scores (1 – 2), as well as the contribution of two very large heaps at Gorteen (score = 13) and Foilacamin (19) and (2) the generally low scores of the mine adit discharges. The latter do not generally contain high concentrations of metals so, despite the large volumes of water discharged by some of them, notably at Ballynunty (score = 6) and Gloune (4), they make only limited contributions to the total score.

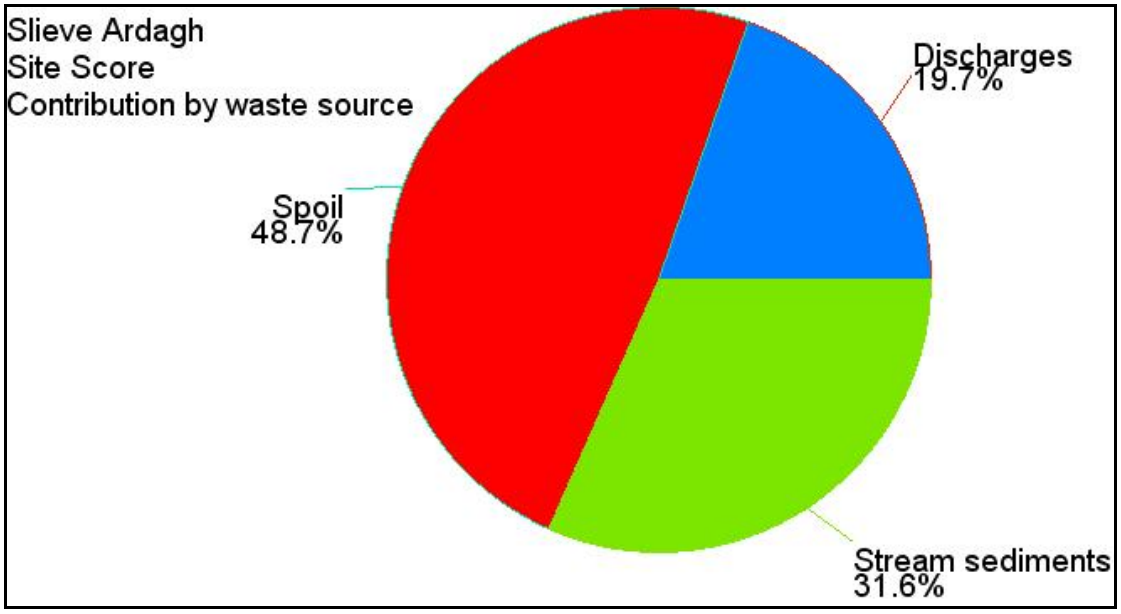

Fig. 19 Slieve Ardagh district, site scores, contribution by waste source

Fig. 20 shows the contribution to the total site score by individual pathways. The proximity of streams to most sites boosts the surface pathway score but this is balanced by the groundwater vulnerability ("extreme" aquifer vulnerability in most cases, according to GSI's classification). The relatively large contribution by stream sediments reflects the extensive drainage network in the area, the fact that three streams are scored and the low absolute scores contributed by solid waste and water discharges.

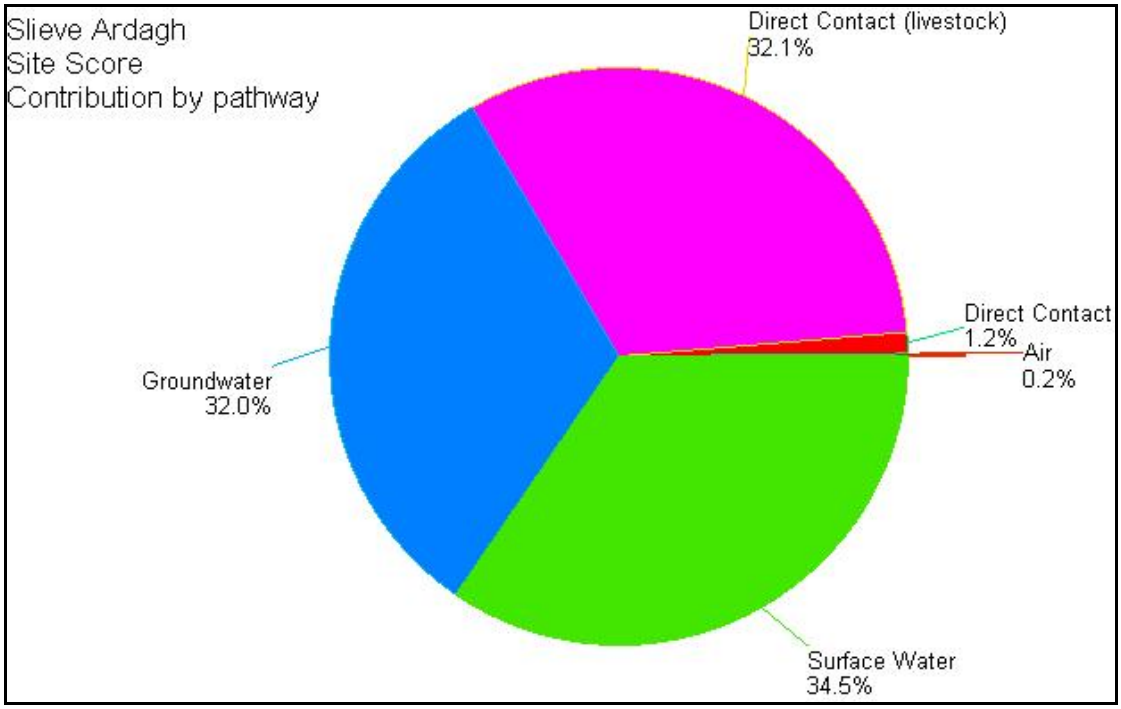

Fig. 20 Slieve Ardagh district, site scores, contribution by pathway

5. Geochemical Overview and conclusions

The Slieve Ardagh district is a very extensive area with numerous abandoned mine operations. The upland area is drained by a network of streams that is exposed to potential impacts from coal mining. Large waste heaps, open pit lakes and active drainage adits are the main potential sources of environmental impacts in the district.

Stream water generally has low concentrations of most parameters measured. Water that is in direct contact with solid mine waste (surface run-off) has relatively high concentrations of elements such as Al, Cu, Ni, Zn and SO_4 as well as low pH and high EC. Surface water samples taken immediately downstream of such run-off, in open pit lakes and streams, can show raised element concentrations and reduced pH. Adit discharges in general have similar compositions to stream water and do not display the high element concentrations or low pH that characterize surface run-off. From this it can be concluded that the water draining the underground mine workings is not attaining chemical equilibrium with sulphide-bearing coal and its host rocks.

Solid waste analyses at two sites have demonstrated that at least some coal waste in Slieve Ardagh has elevated metal concentrations: As, Zn, Cu, Ni and Pb were all measured in concentrations exceeding regional background levels. Stream sediments gave somewhat similar results and demonstrate that coal mining has had a measurable environmental impact at Slieve Ardagh. The total HMS-IRC Site Score for the district is 117, placing it in Class IV.

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