The Avoca Mine Site

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**THE AVOCA MINE SITE**

Vincent Gallagher and Pat O'Connor

**INTRODUCTION**

Copper mining is reported to have begun in the Avoca River valley, Co. Wicklow, Ireland, around 1720 (Griffith 1828) and it continued, with interruptions, until 1982. Earlier mining, perhaps dating back to the Bronze Age, may have occurred. In the present century, low grades and low copper prices have ensured that mining at Avoca has always been a marginal proposition. Mining took place in an era when there were few environmental controls in place, and significant environmental degradation has occurred at Avoca. This includes widespread contamination of the mine site and surrounding land surface by spoil and serious pollution of the Avoca river by acid mine drainage (AMD). The river downstream of the mine site is biologically dead. Rich salmon fisheries that existed on the river in the eighteenth century (Bayly 1816) died out 200 years ago.

The Avoca River is the final stretch of the river system that comprises the Avoca–Avonmore catchment, an area of 650km² in the central part of County Wicklow. In 1992, the European Union (EU) provided funding under the Life mechanism to Wicklow County Council to implement its Avoca–Avonmore Catchment Conversion project. The aims of the project were: (1) development of a new, collective and integrated approach to economic development; (2) adoption by industry of new management practices, especially environmental management systems; (3) rehabilitation of existing environmental damage; (4) conservation of existing environmental quality; and (5) infrastructural development in the context of the conversion project. Wicklow County Council in partnership with the Department of Transport, Energy and Communications, chose the Avoca mine site for rehabilitation demonstration projects. These included a detailed characterisation of the site, trials on AMD treatment and revegetation of mine spoil. Avoca has the longest production record of any mine in Ireland and contains a unique range of old and modern mining features. It is a particularly appropriate site for detailed study. The Geological Survey of Ireland (GSI) surveyed the ecology, hydrogeology, geology and mining heritage of the Avoca mine site between 1993 and 1997 and published the results in three reports by Fay (1996), O’Suilleabhin (1996) and Gallagher and O’Connor (1997). The aim of the survey was partly to provide a record of the site and partly to provide sufficient baseline data on the site to inform emerging development plans, including mine heritage initiatives and rehabilitation schemes. The Avoca mine areas are upland areas overlooking the valley of the Avoca River, which flows southward between the two. Mining in the eighteenth and nineteenth centuries was exclusively underground in East Avoca; on the other side of the river, all mining took place underground until a large iron sulphide (pyrite) lode was mined at the North Lode open pit in the 1850s. This open pit was, for a time, reputedly the largest open pit in the world (volume > 200,000m³). In this century, the bulk of ore was also produced underground, but three open pits were also excavated in the 1970s and 1980s.

Prior to 1970, the East Avoca site rose gradually northeastward from the river, reaching a peak of 260m above sea level on Mottee Stone hill in Cronbane townland (Fig. 1). Across the river valley, the land rose more steeply to 205m on Ballymurtagh hill. On both sides of the river, there were extensive piles of waste rock left over after ore dressing at the surface in the eighteenth and nineteenth centuries. The collapse of extensive underground stopes in the nineteenth century and in the early 1960s had caused widespread caving at the surface. Two nineteenth-century open pits remained on Ballymurtagh hill.

Since 1970, modern open-cast mining has transformed part of this landscape. In West Avoca the Pond Lode open pit was excavated and is used as a landfill for domestic refuse. In East Avoca excavation of Cronebane open pit, and subsequently East Avoca open pit (Fig. 1), in the 1970s created two deep, steep-sided pits and generated large volumes of waste rock. The mine site in East Avoca is typically 120–150m wide and has a maximum width of c. 180 m. Partly because of the lack of space on the site and partly because it was intended to use the rock waste for landscaping following pit closure, most of this waste material was piled into a nearby heap, informally called Mount Platt, at the southwestern end of Cronebane pit. This heap is c. 240m above sea level, 30–40m higher than the surrounding land, and has become a new landmark in the district, visible for many kilometres as a steep-sided, flat-topped, red–brown hill almost devoid of vegetation. Other spoil heaps cover extensive areas in East and West Avoca. Most of the ground is covered by a thin layer of relatively fine-grained, red–brown waste rock. Like the spoil heaps, this waste rock substrate supports very little vegetation.

The mine site in both East and West Avoca is bounded on either side chiefly by farmland, forest and heathland. The farmland is mainly used for pasture. A considerable number of dwellings, including a few residential estates, are located on the margins of the site.

The legacy of mining at Avoca is not wholly negative. Many relics of mining, old and modern, remain on the Avoca site. Apart from the more obvious products of modern bulk mining, including open pits and large spoil heaps, there are the remains of nineteenth-century mine buildings, including Cornish engine houses, adits, shafts, cable systems and pits, which were used for settling ochre from mine water. These are important examples of Ireland’s pre-twentieth-century industrial heritage. In recent years, interest in developing the Avoca site as a mine heritage feature has grown. A strong mining tradition remains in the valley sixteen years after the last closure of the mines. It is therefore no longer possible to view the mine site simply as an area of environmental damage in need of physical rehabilitation. Future plans for developing the site are likely to include a significant component of mine heritage, including conservation of the nineteenth-century mine buildings and retention of at least some of the surface features, such as spoil heaps and open pits.

GEOLOGY AND MINERALISATION

The Avoca deposit is hosted by the Avoca Formation, a sequence of 455 million-year-old Ordovician volcanic and sedimentary rocks. The formation comprises a 2–4km wide and a 15km long zone recently subdivided into three members (McArdele 1993) (Fig. 2). Three main ore types have been recognised on a macroscopic scale in the Avoca mine area (Wheatley 1971; Platt 1973; Williams 1984).

(1) In the pyritic zones or banded sulphide ore (Williams 1984) or massive ore (Platt 1973) bands of pyritic ore alternate with bands of sphalerite-rich ore and bands of chlorite and sericite (Platt 1977). Pyrite is the dominant mineral, either banded or as massive lenticles with or without interstitial chalcopyrite, sphalerite and galena in a chloritic matrix. Magnetite, hematite, arsenopyrite, pyrrhotite, bismuthinite and native bismuth are minor constituents; gold is rare. Such ore is typified by the Pond Lode in West Avoca. Other representatives include the North Lode in West Avoca and the Main Lode in East Avoca (Wheatley 1971).

(2) In the siliceous zones or vein and disseminated ore (Williams 1984) or stringer ore (Platt 1973) major pyrite, chalcopyrite, sphalerite and lesser galena occur within a siliceous matrix. Arsenopyrite, pyrrhotite, bismuthinite, native bismuth, tetrahedrite, galenobismuthinite and bournonite are minor constituents with cobaltite and lillianite as trace occurrences. The South lode, the south branch of the North lode, the hanging wall in West Avoca and the hanging wall in East Avoca are typical examples (Wheatley 1971).
THE AVOCAL MINE SITE

East Avoca Mine Site

Road, path

Spoil heap

Area of caving and backfilling

Chimney stack

Shafts/engine houses:
A. Billans
B. Baronet’s
C. Farmer’s
D. Air shaft
E. Connary Engine
F. Waggon

Fig. 2 — East Avoca mine site.

(3) In the lead–zinc ore, banded sphalerite, galena and pyrite occur with minor arsenopyrite and chalcopyrite in a chloritic matrix. Tetrahedrite and bournonite are rare. Examples include the lead–zinc lode at West Avoca and the ‘kilmacooite’ zones at Cronebane–Connary (Wheatley 1971).

EAST AVOCAL MINING FEATURES

The East Avoca mine site, as defined today (Fig. 1), covers an area of approximately 341,000 m² (34 ha) but was probably significantly larger in the past. Some peripheral mine features are now obscured by vegetation in colonised or planted areas outside the site. Spoil heaps cover 54% of the mine area (183,689 m²) and open pits cover a further 18% (62,000 m²). The remaining 28% of the site comprises roads, paths and flat-lying parts of the site covered in a thin layer of mine spoil or waste rock. This guide describes briefly the main mine features observed when traversing the site from Whitebridge at the southwestern end to Connary at the northeastern end (Fig. 1).
DEEP ADIT (33m O D)

The Deep adit was driven in the late eighteenth century, probably by the Associated Irish Mining Company (AIMC), in order to drain the Tigroney workings. At that time all existing workings were above the level of the Deep adit (33m O D) and the mine water drained by gravity into the Avoca River as it does today. Timber supports are visible at about 1m from the current entrance of the adit.

This is the main mine discharge point in East Avoca. Most mine water from the Cronebane workings below the level of Cronebane Shallow adit (165m O D) drains to the Deep adit and the mine workings below it. It may discharge immediately along the adit or mix with water flowing from the deeper workings. Eventually, the water levels below the level of the Deep adit will rise and will overflow along the adit. Until the 1980s, water discharged from the Deep adit flowed into the old mill race, following a path along the river bank before discharging into the Avoca River about 600m downstream. Mean monthly discharge from the Deep adit, as measured by Trinity College Dublin (TCD) for the period May 1994-May 1995, was 17.2 l s⁻¹ (range 8.5–37.3 l s⁻¹) (Gray 1995) Corresponding metal discharge rates were 8.1 kg Cu per day, 117 kg Zn per day and 151 kg Fe per day. Similar rates apply for discharges from West Avoca mine workings (Road adit). Approximately 2.5 million litres of AMD is discharged each day into the Avoca River, adding some 100–200 kg Zn, 10–15 kg Cu, 1–2 kg Pb and 1600 kg sulphur per day (mean concentration of SO₄²⁻ in discharge is about 1600 mg l⁻¹).

SAWMILL AND OLD MILL RACE

Low walls in the wooded area beside the Avoca river at Tigroney trace the outline of a nineteenth-century saw mill. The buildings were positioned beside the mill race. The dry bed of the mill race, with thick accumulation of red-brown iron-rich silt, can be traced south from the saw mill over a distance of about 500m to its junction with the Avoca river. Mine water discharged from the Deep adit entered the mill race rather than flowing directly to the river, at least until 1984.

FLAT ROD TUNNELS

Two low tunnels at Tigroney, one exposed in the base of the spoil heap beside the road on the eastern side of the railway line and the other exposed at the base of the west side of the railway embankment, were used for transmitting power from the water wheels to the underground workings (Coy 1996). The westernmost tunnel is close to the line followed by the old mill race. Wynne (1930) states that the amount of water made by the mines was not great because “for many years they were kept unwatered to the 10 fathom level by means of a pump in Williams shaft (Cornish pump) which was driven by flat rods activated by a water wheel at the River level.” Smyth (1853) refers to water wheels being used to pump water from the 40 fathom level at Tigroney. Apparently this was done via Farmers shaft. The flat rod tunnels do not appear to extend beyond Williams shaft and post-date Smyth’s work.

ORE BINS

The two large cylindrical ore bins directly opposite the railway bridge at Tigroney were installed by Saint Patrick’s Copper Mines Ltd (SPCM) between 1958 and 1962. They were used for storing ore brought to the surface by rail from the newly developed 850 adit/level. The ore was loaded onto trucks from a hatch in the base of the bins and brought to the mill in West Avoca by public road.

850 ADIT/LEVEL (45m O D)

This is the only twentieth-century underground mine working in East Avoca. It was driven by SPCM between December 1959 and September 1962 when it had reached a length of 750m. Four small stopes were developed yielding a few hundred thousand tonnes of ore at a grade exceeding 0.8% Cu. Ore was brought to the surface at the adit entrance in 120 ft³–capacity cars hauled by a diesel locomotive running on 36” tracks. It was loaded into the two ore bins prior to trucking to the mill in West Avoca. In situ leaching experiments on copper ore were conducted in the 850 level in the early 1980s by a number of partners under EU funding. Avoca Mines Ltd cleaned up the workings and plant was installed 400m from the entrance. The adit is now bricked up and largely obscured by spoil.

WILLIAMS SHAFT

Like most engine shafts in East Avoca, Williams shaft consists of an upper vertical section and a lower inclined section. It is located directly beside the south or bob wall of the engine house and is now covered by a concrete cap. It extends from the surface at 78m O D vertically to a depth of ~39m O D. Thereafter, it inclines south-eastwards following the stratigraphic dip to a depth of ~129m O D. Williams shaft was used for pumping water from the six levels linked to it and was constructed in the mid-nineteenth century.

The engine for this house was built in the Perran foundry in Cornwall around 1860 (Brown 1996) for Williams and Co, who had acquired the lease for the Tigroney–Cronebane mines in 1832. The engine, with a 60” cylinder, was subsequently
old back to Cornwall in 1881 (Brown 1996) following closure of the mines. The walls of the house are largely intact and the engine supports, large cut-granite slabs, remain in place within.

OCHRE PITS

There are two groups of stone-walled pits or tanks linked by drainage channels to each other and to the Wood adit. The upper group consists of three pits below Baronet’s shaft engine house, into which the discharge from Wood adit drained via a narrow channel. These pits are largely intact. The first pit lies 2–2.5m above the level of the second pit. Water was decanted from the first pit via a 2m-wide opening in the stone wall into the second pit. The second pit shares a 2m-thick wall with the third pit. The wall is cut by a 0.5m-wide channel. The third pit is at a slightly lower level than the second pit. From there, the water passed into a narrow drainage channel that took it to the lower two pits located over 200m away. These pits are poorly preserved.

Of the upper group of pits, the first and third pits are fairly regular in shape, with dimensions of approximately 15m x 5m and 18m x 6m, respectively, and areas of 82m² and 114m², respectively. The second pit—the largest of the three—has an irregular shape with area 205m². The walls of the pits, now exposed, are up to 1m high. Only parts of the lower two pits are intact. One is about 30m long and the other is about 25m long. Each is at least 5m wide.

Mianrai Teoranta presumably used these pits for settling out the ochre they produced in the 1940s. Other references to ochre production are scarce, however. The pits were certainly built in the nineteenth century since they are shown on the 1908 Ordnance Survey (O.S.) maps along with the discharge channel. Kinahan (1889) refers to the working of “ochre beds” in 1882 from the back of a large sulphur (pyrites) lode and Hull et al (1888) refer to the raising of sulphur and ochre and the precipitation of copper in Tigroney in 1887. Neither of these references suggest that settling pits were employed. It may be that the pits were constructed around the time that Wood adit was driven in the first half of the nineteenth century, in order to take advantage of the discharge from Wood Adit.

BARONET’S SHAFT ENGINE HOUSE

This house accommodated a rotative engine (Brown 1996) linked to a shaft via a series of rods and cables (Coy 1996). No reference to its operation has been found in the nineteenth-century literature. Smyth’s (1853) account of machinery in use in Tigroney makes reference to one engine only, drawing at the Boundary shaft further east. Otherwise, water wheels were employed. Baronet’s shaft is not shown on Smyth’s map and appears to post-date his visit since, like Williams shaft, it extends to the deeper levels in Tigroney that were only developed in the late 1850s and 1860s. Baronet’s shaft is a deep, inclined shaft extending down to −105m O.D. where it cuts the eastern end of the 77 fathom level.

Today, parts of three walls remain standing and the chimney stack is intact. The bob wall has collapsed. Coy (1996) describes this as more typical of Cornish engine houses than Williams engine house.

FARMER’S SHAFT

This is a narrow shaft located 80m south of the engine house beside the Castlehoward estate boundary in Tigroney. It is fenced off and its opening is straddled by a series of iron bars installed to serve as a frame for concrete or masonry. It extends 156m below the surface level of 117m O.D. to −39m O.D. The purpose of this shaft is not known. Smyth’s map and section (1853) suggests that a whim engine, driven by cables linked to a water wheel on the Avoca river, operated there. Unlike Williams shaft and other engine shafts in East Avoca, Farmer’s shaft does not have an inclined section that extended to the deepest levels.

REVEGETATION ON SPOIL

A number of instances of natural revegetation of spoil can be seen northeast of the copse of trees beside Farmer’s shaft. In one case, a small pine sapling is growing on spoil where ash from a campfire provides some fertile substrate (Plate 3). Close by, grass is growing on spoil ameliorated by rabbit droppings. On the spoil heap SP10, grass is growing on spoil where builder’s rubble, including concrete, has been dumped (Plate 2).

COBBINGS RECLAMATION, CAVED AREAS AND BACKFILLING

Just west of East Avoca open pit, two concrete pillars are probably the remains of the base of a screening plant installed here in 1971 for Avoca Mines Ltd (AML). The plant was used during reclamation of nineteenth-century cobbings and broken ore, separating it into size fractions suitable for the mill. Material of −6” + 1” was delivered to the mill and + 6” material was stockpiled for later use (AML weekly mine reports). At this time, Baronet’s shaft was exposed 60m to the west and there was some old spoil around it. Subsequently, the shaft and older spoil were covered by a spoil heap. This spoil heap (SP8) is unique in Avoca because it is evenly graded and relatively fine. It seems most likely that it is composed of the fine...
material discarded after screening McArdle (1976) refers to fine screenings being backfilled into caved areas. Most of the ground in this area, including that underlying SP8, is caved as a consequence of the collapse of old stopes and there are extensive areas that were backfilled by spoil in the 1970s. Reclamation of the Tigroney dumps ceased at the end of 1971 when attention was switched to dumps in Ballymurtagh in West Avoca.

EAST AVOCA OPEN PIT

This pit lies immediately southwest of Mount Platt. Part of the latter had to be removed to facilitate extraction of mineralised bedrock below it. The pit has a surface area of 20,437m²; it is about 270m long and 80m wide at its centre. It has a maximum depth of 40m and an estimated volume of 375,720m³. The pit was operated between 1978 and 1982. Some 884,000 tonnes of ore grading 0.53% Cu were mined. Its main features are:

1. Several nineteenth-century adits are exposed in the pit.
2. A discharge of acid mine water flows from one level onto the pit floor.
3. Rock exposures include mineralised bedrock from the final blast carried out by Avoca Mines Ltd, an exposure of chalcopyrite-mineralised quartz/chlorite schist breccia at its northeastern end (hanging wall) and two north-west-trending weathered lamprophyre (mircrodiorite) dikes. The hanging wall near the mine entrance has Tigroney Member rocks containing pyrite veinlets in contact with chloritic tuffs of the m nun sequence.
4. Bats (pipistrelle and Lesler’s) were detected roosting in Cronebane Deep adit at the southwestern end of the pit (Fay 1996). A pair of peregrine falcons have nested in the steep northeastern face of the pit for a number of years.
5. Vegetation is essentially absent within the pit, but is quite abundant on some spoil heaps and former soil cover dumped around its rim.

CRONEBANE SHALLOW ADIT AND LEVEL
(165m O D)

This was driven in the late eighteenth century by AIMC and runs to the northeastern end of the Cronebane mine area. It appears to have been the main Cronebane mining adit and level in use at this time although no contemporary references to it have been found. The adit discharges a small amount of mine water today, draining the mine workings located in the area of Cronebane open pit.

Cronebane Shallow adit, along with Madam Butler’s adit, drains the upper parts of the underground mine workings in the Cronebane area. The AICM (1789–1811) appear to have precipitated copper from the water discharged from this adit. In the latter part of the nineteenth century, the discharge was directed to the ochre pits near Baronet’s engine house and the now dry water course can be traced in places. The AML began a Cu cementation project here in 1971. At this time the discharge from the adit was about 1–19 l s⁻¹ (AML weekly reports). They constructed a 9000l reservoir and collected water from the adit, piping it to an area overlying extensively caved stopes (the area around SP8 today). After reclamation of the Tigroney waste dumps, fine screenings were backfilled into the area of caving. The water percolated downwards through this material and through mineralised rock in the 850 stopes (estimated 0.35% Cu). It then collected in the 850 level where it was passed through cementation launders to allow copper precipitation. Waste water was allowed to run to the Deep adit. A target of 9,000kg per month recovered copper was set for this plant but only 10% of this was achieved. The plant was allowed to run for much of the remaining period until the mine closed, the launders were cleaned out occasionally and the product was added to the mill concentrate.

Today, water discharged from the Shallow Adit collects in a pond before flowing through a pipe below the nearby road, after which it runs into the ground and percolates to the mine workings below. The adit has silted up rapidly since 1995.

MOUNT PLATT AND OTHER SPOIL HEAPS

The East Avoca heaps were produced in several ways by past mining activities:

1. Miners of the eighteenth and nineteenth centuries left waste rock underground as backfilling for stopes (mined areas) but the ore was dressed or ‘cobbed’ on the surface and the discarded low-grade ore was called ‘cobblings’. Large piles of cobblings were created in this way. In East Avoca, the spoil heaps in the Connary area include nineteenth-century waste piles. Avoca Mines Ltd recovered ore from cobblings in Tigroney West in the 1970s.
2. Excavation of Cronebane open pit in the 1970s produced large volumes of spoil. Much of this was built up to form Mount Platt (SP20), partly because of lack of space, but also as part of a policy by Avoca Mines Ltd to achieve re-landscaping and rehabilitation of the site. Excavation of East Avoca open pit produced relatively small amounts of surface waste, notably around the edge of the pit and immediately southwest of it (SP10). Most of the material excavated in the pit was removed directly to the mill.

The total volume of spoil calculated for East Avoca is 1,035,809m³ (Gallagher and O’Connor...
Mount Platt accounts for 715,052m³ or 69% of the total. Five other spoil heaps account for a further 279,599m³ or 27% of the total volume of spoil. Each of the 26 remaining heaps and sub-heaps typically covers less than 1000m² of the surface and contains several hundred cubic metres of spoil.

**CRONEBANE OPEN PIT**

Waste rock and mune spoil, which were left behind after surface stripping and extraction of ore, were piled up at the southwestern end of the pit to form Mount Platt. The pit itself occupies an area of 62,084m², has a maximum depth of about 40m and an estimated volume of approximately 700,000m³. It is 600m long and is 120m wide at its central point. The area referred to above is the area of the original pit. Approximately 40% of the original pit area is backfilled by spoil that forms a plateau, approximately 30m high and 200m long, which merges into the northeastern side of Mount Platt. At its northeastern end, there is a pond perched on a raised, dammed area. This was created by Connary Minerals in the late 1980s to act as a reservoir for their pilot gold recovery plant built in the backfilled area of the pit. The pit was excavated between 1971 and 1975, and minor extraction was carried out in 1978. About 540,000 tonnes of ore grading 1.23% Cu were produced. The top 30m comprised a soft clayey ore with high concentration of Cu produced by supergene alteration of mineralised bedrock. This was easily mined using mechanical scrapers and bulldozers. The lower part of the pit was mined from typical bedrock using conventional drill/blasting techniques.

The pit floor contains numerous boulders where collapse occurred previously. Small falls of rock are a regular occurrence. Major collapses can occur typically after intensive rainfall.

**CONNARY ENGINE SHAFT**

This was the most important shaft for dewatering the underground workings at Connary. It is located a short distance from Barry's shaft and is covered by a concrete cap with a vent pipe. Water was pumped from the shaft and drained via a series of sluices to Connary Crossroads and then down-hill to the north. The nearby furnace house and concrete water tank are the only remains of the engine house complex that was located here. The shaft extends vertically from 278m to 159m O.D. and then inclines southeast along the dip of the ore zone to a depth of 105m O.D. According to Smyth (1853), a steam engine with a 30" cylinder was in use here in the mid-nineteenth century.

The mainly intact outer stone walls of the furnace house are all that remain of the engine house on Connary engine shaft. This has a modern corrugated iron roof now and is used as a barn. The engine house was built here prior to 1841. Smyth (1853) refers to a 30" cylinder engine in operation in Connary, and Wynne (1930), indicates that it was operating on Connary engine shaft. Roberts' map (1840) shows the engine on Connary engine shaft driving a whin on nearby Connary whin shaft.

**CONNOREE MINE COMPANY COUNT HOUSE AND OFFICES**

An abandoned cottage and the ruins of other buildings, less than 100m from Connary Engine shaft, stood on the site of the offices and count house of the Connoree Mining Company until late 1995. All buildings were stone-walled and appeared to date from the last century. Permissions for demolition of these buildings, in the context of an application for building permission, was granted by Wicklow County Council and a modern bungalow now stands on the site. The loss of these historic buildings, rarely preserved in other mine sites, highlights the need for a thorough, up-to-date inventory of abandoned mine sites in Ireland.

**WAGGON SHAFT ENGINE HOUSE**

Waggon shaft is no longer exposed but the site was at the western boundary of the main fenced area just southwest of Connary Crossroads. The engine that operated on this shaft was housed about 100m away where, today, an intact chimney...
stack is the only remaining feature. Brown (1996) suggests that an 18" engine may have operated here. Smyth's section, from his map (1853), shows the disposition of shafts and engine houses at Connary. Around 1840, there was no engine in use on Waggon shaft, according to Roberts' map (1840), so this stack may date from the period 1841-53.

WEST AVOCA MINING FEATURES

Most of the modern mining at Avoca took place in the West Avoca mine. This was mainly underground mining but one open pit was also operated. Excavation of this pit together with the construction and subsequent removal of the mill and extensive workshops have significantly reduced the number of surface mine features on the site. The West Avoca site covers an area of approximately 286,000m². There is a relatively large number of buildings dating from the modern mining period scattered in and around the mine site. Most of these in the areas surrounding the site were mine workers' accommodation and are now private dwellings. Spoil heaps cover 29% of the mine area (81,690m²) and the open pits cover a further 12% (33,181m²). The remaining 59% of the site comprises roads, paths, heathland and forested areas and the sites of the mill and other buildings are now landscaped and revegetated.

Because of the landfill operation, it is not generally possible to walk through the whole site from its entrance on the Avoca–Meetings Road. Instead, the upper parts on Ballymurtagh hill can be accessed via the Red Road (Fig. 3).

ROAD ADIT

Road adit was driven in the nineteenth century to Ballygahan shaft and served as a drain for water being pumped up the shaft from the deep mine workings. In 1864, a 50" cylinder pumping engine was used to raise water 600 feet (180m) from the bottom of the mine and discharge it through this adit. An average of 10,000 gallons (45,500 litres) were raised per hour (Barnes 1864).

The adit is located beside the main Avoca–Rathdrum road opposite the Wicklow County Council yard (Fig 3). Recent collapse of covering spoil has revealed the adit again. It is the main point of discharge for mine water in West Avoca and was used by both SPCM and AML. Mean monthly discharge from the adit, as measured by TCD for the period May 1994–May 1995, was 16.9 l s⁻¹ (range 6.1–35.2 l s⁻¹) (Gray 1995). The combined mean monthly discharge for both the Road adit and the Deep adit in East Avoca was 2.95 million litres per day. The Road adit discharge is currently channelled into a pipe and directed into the Avoca river.

A large number of buildings used, and in many cases purpose built, by SPCM staff remain on and around the West Avoca mine site. The building north of the site entrance was built by SPCM as its main office and was later used by AML for the same purpose. It is now being renovated for use as a miners' museum. Behind this building are the old staff hostels. Avoca Mines Ltd later converted these to apartments, also for staff accommodation. The remaining buildings are outside the site and include a garage, a laboratory used for sample analyses by SPCM, twelve houses used as staff quarters, including Directors' Lodge and Mine Manager's house. Most of these appear to have been built by SPCM and were subsequently used for the same purpose by AML. All are now in private hands. West of the Red Road is the building used as a magazine by SPCM for storing explosives.

Avoca Mines Ltd used many of the buildings constructed by SPCM, including the now dismantled mine buildings such as the mill and the housing stock. Apart from these buildings, the only remains that are specific to AML are the concrete foundations of workshops which are visible east of the entrance road to the West Avoca landfill. These foundations are on land covered by spoil but are surrounded by flourishing native plant species including birch and pine (Fay 1996). The plants grow only at the contact between the concrete and spoil where breakdown of the concrete has led to local neutralisation of the acidic spoil. Between these foundations and the site access road is a large area of ground that has been landscaped and revegetated by Wicklow County Council using imported topsoil. Grass growth is patchy.

SPOIL HEAPS

Spoil heaps in West Avoca (Fig 3), like those in East Avoca, are products of both old and modern mining activities. The most prominent heaps, including SP33, overlook the access road and above the modern mine portal, SP34a, SP34b and SP35 on Ballymurtagh hill and SP39 running along beside the main road below Bell Rock, were all produced in the nineteenth century as a result of surface ore dressing. Some, notably SP35 and SP34a, show stratification that is a feature of cobbings. Some of the older heaps, especially SP33, are extensively colonised by local plant species, notably heather, gorse, pine and birch, which provide a distinctive contrast with revegetation carried out by Wicklow County Council.

MAIN PORTAL AND KNIGHT TUNNEL

(65m O D)

The Knight Tunnel was the main access tunnel to the underground mine in modern times. Shafts
were not used in modern times except for services. The tunnel opening measured 5m × 5m at its portal. Trackless vehicles, including load-haul-dump and drilling vehicles, were driven along it and could enter all parts of the underground workings. The opening of the Knight Tunnel thus signalled the start of the modern mining era in Avoca when large volumes of ore could be transported rapidly from the mining face. In the deeper levels, the ore was carried to an underground crusher and then on to the surface mill by a conveyor. In the upper levels of the mine, trackless vehicles were used to transport ore. SPCM began constructing the decline in 1955 and it reached the 1670 level (in the mine, the 1000 feet level is at 0m O.D., the 1670 level is 670 feet below the 1000 level at −200m O.D.) Avoca Mines Ltd extended it in the early 1970s to the 2000 level (−300m O.D.). The tunnel has a decline of 12 degrees and descends vertically 350m by reversing the direction at six points.

The Knight Tunnel was sealed by a concrete plug after the mine closed in 1982. The access road constructed by Wicklow County Council to...
provide access to the landfill site in Pond Lode open pit largely obscured what remains of the portal but the top of it is still visible

BALLYGAHAN SHAFT

Ballygahan shaft dates from at least the first half of the nineteenth century and was the main shaft in the old Ballygahan mine, used both for pumping water and for hoisting ore (Fig 3). Power was supplied via an overshot water wheel of ‘50 feet diameter and 30 inches breast’ (Smyth 1853) In the 1940s, Mianrai Teoranta rehabilitated the shaft and deepened it to −230m O D, 290m below the surface, driving a new level, the 1670 level (−201m O D), 750m to the southwest (Mining Services 1963) Munrani Teoranta, SPCM and AML used this shaft as the main discharge route for mine water Reservoirs were located at the 1670 and 70fm levels Munrani Teoranta pumped water from the 1670 level to the 70fm level and from there to the river via the Road adit. SPCM installed a pump to pump water directly to the Road adit from the 1670 level Avoca Mines Ltd followed this procedure. Electrical cables and water lines were also brought into the mine via the shaft.

Ballygahan shaft is a small, four-compartment shaft, timbered with 8” x 8” (20cm x 20cm) sets of 4’1” x 3’10” (1.23m x 1.15m), were used for hoisting ore (Mining Services 1963)

POND LODE OPEN PIT

The Pond Lode open pit has been referred to in recent years as Ballymurtagh open pit but this name could equally be applied to the North Lode or Weaver’s Lode open pits. Its original name is preferred here. It was excavated between 1973 and 1979 by Avoca Mines Ltd. on the surface extension of the Pond Lode and a total of 1,077,730 tons of ore, grading 0.6% copper, was produced. In the early 1850s, Smyth (1853) as part of the westward extension of the mine. By 1864, they had reached their final depth of about 300m below the surface and formed ‘an efficient means of communication, drainage and discharge’ (Barnes 1864). The shafts were used for pumping water (Engine shaft) and raising ore (Drawing shaft). According to Barnes (1864), a whim engine was used on the drawing shaft. In the modern era, the Twin shafts have been used only for ventilation purposes and as an escape way.

Each shaft consists of a bare single compartment, 7’ x 7’ (21m x 21m) in size (Mining Services 1963). When originally constructed, the shafts were vertical over the first 221m to a depth of −90m O D and then inclined to −170m O D. They connect with the Margaret adit and with the modern 995, 1121 and 1300 levels. Today, the shafts have concrete caps. The remains of hoisting wheel supports are visible nearby.

Two engine houses are located nearby and were apparently employed on the Twin Shafts. The walls and chimney stack of the northernmost one, located on the Drawing shaft, lie behind the ruins of Mianrai Teoranta’s storage buildings and are largely intact though covered in ivy. The southernmost one, beside the Engine shaft, is immediately beside the farm road and is now in ruins with only the base of parts of three walls discernible. Both of these buildings presumably date from the early 1860s when sinking of the Twin Shafts was completed. As noted by Coy (1996), the intact chimney stack is lower than other stacks at Avoca. The Drawing shaft was worked by a whim engine that raised the ore from underground; the engine employed on the Engine shaft was used for pumping out water.

TRAMWAY ARCH AND ENGINE HOUSE STACK

This tramway was built to haul ore from West Avoca to Arklow harbour. Previously, ore had always been carted to Arklow by local people who agreed a price per ton of ore and supplied their own horse and cart. But there had been recurrent difficulties, with transport periodically in short supply, for example at harvest time when all available carts were needed in the fields (Cowman 1994). Henry Hodgson, proprietor of Ballygahan mine and director of WCMC, which operated Ballymurtagh mine, decided to construct a tramway to haul ore to Arklow at this time, the national rail network consisted of a short line from Dublin to Kingstown (Dún Laoghaire). The tramway was completed in 1846, a fortuitous date since the beginning of the Great Famine sharply reduced the availability of drivers and transport (Barnes 1864). ‘Before 1846, and the famine period, the neighbourhood supplied horses and carts in abundance. Since that date the ores have been carted to Arklow by tramway’. Ore from East Avoca continued to be transported by horse and cart. Between 1857 and 1859, the Avoca-Dublin railway
was joined with Hodgson’s Avoca–Arklow railway.

The only remains of the Tramway Engine house is an ivy-covered stack standing immediately beside the path of the old tramway. The engine was used to haul ore wagons. The engine house is now demolished. The tramway probably began at the Tramway Engine house originally, and followed a straight line southeast before running along that part of what is now the Red Road. Later, as the North mine was being developed, the tramway was extended to the north over an arch to the North Lode open pit. The Tramway Arch is one of the most striking architectural features preserved at Avoca.

**BALLYGHAHAN ENGINE HOUSE**

This house consists of an intact chimney stack and low, ruined walls on the overgrown ground above the northern wall of Pond Lode open pit. No reference has been found to it in the literature and it is not marked on any pre-twentieth-century maps seen during this study. No mine workings are known to lie below it or even close to it. A narrow channel immediately east of the house may be a counter balance pit or flat rods channel. It appears to extend southwards. If it is a flat rods channel, then it must originally have extended to a shaft. A straight line extending 70–80m south along the direction defined by the channel passes within 10m of a shaft marked on the 1908 O S map but absent from Mianrai Teoranta’s 1951 map and from Smyth’s 1853 map. The identity of this shaft is unknown. It does not appear to have been an engine shaft. The Ballymurtagh Old Engine shaft, the only known engine shaft in the vicinity, was further west. If the line of the channel is extended 135m northwards it passes within 6m of Wheatley’s shaft. The closest existing shaft is Wheatley’s shaft (at 100m distance) on Weaver’s lode. This house consists of an intact chimney stack and low, ruined walls on the overgrown ground above the northern wall of Pond Lode open pit. No reference has been found to it in the literature and it is not marked on any pre-twentieth-century maps seen during this study. No mine workings are known to lie below it or even close to it. A narrow channel immediately east of the house may be a counter balance pit or flat rods channel. It appears to extend southwards. If it is a flat rods channel, then it must originally have extended to a shaft. A straight line extending 70–80m south along the direction defined by the channel passes within 10m of a shaft marked on the 1908 O S map but absent from Mianrai Teoranta’s 1951 map and from Smyth’s 1853 map. The identity of this shaft is unknown. It does not appear to have been an engine shaft. The Ballymurtagh Old Engine shaft, the only known engine shaft in the vicinity, was further west. If the line of the channel is extended 135m northwards it passes within 6m of Wheatley’s shaft. The closest existing shaft is Wheatley’s shaft (at 100m distance) on Weaver’s lode, but this lies oblique to the line of the channel. Of these, Wheatley’s shaft is the most likely to have been operated using an engine, given its depth.

**NORTH LODE OPEN PIT**

North Lode open pit was mined by the Wicklow Copper Mining Company in the 1850s. When finished it had a length of about 300m, a maximum width of 30m and an average depth of 30m. The area of 7,774m² implies a volume of 233,220m³ if the walls of the pit are taken to be vertical. It was, for a time, the largest open pit in the world (P McArdle, pers comm). A contemporary account (Anon 1865) catches well the wonder of the North Lode and its workings: ‘I have never seen anything equal to [the Great North Lode]. On the surface of the hill appears a large bed of gossan, comprised of brown he-

matore ore, which reaches the enormous width of 100 feet. This gossan has been worked as a quarry at the surface to this enormous width. It is a most striking sight to stand upon the edge of this great excavation and mark its enormous size which certainly shakes all of our preconceived notions about lodes and mineral veins.’ Gossan, a valuable ore containing 52% iron, formed a supergene cap to massive pyrite ore, which was the main export from Avoca in the 1850s. The pyrite was mined mainly from underground workings that remain mostly intact below the open pit.

In the modern underground mine, waste rock was backfilled underground. North Lode open pit was employed by AML as an emergency tailings pond. It is now filled by tailings and covered with a surface layer of spoil (SP34). Only the uppermost sections of the pit walls at the southwestern end of the pit remain as evidence of the pit’s existence. The surface is currently the site of the Life project revegetation trials conducted by Wicklow County Council. There is also some extensive natural colonisation of spoil by heather and gorse, especially at the southwestern end in the area sheltered by the exposed pit walls.

**NORTH LODE SHAFTS**

**New Western shaft**

Building started on this vertical shaft around 1860 (Barnes 1861) and extended to 141m O D, 49m below the surface, where it connected with the western end of the North Lode. It was sunk at the western end of the North Lode, providing a link to the levels being driven westwards along the lode. This shaft was open along its length in 1951 (Mianrai Teoranta). It is now capped and surrounded by a fence in an area overgrown by gorse and heather.

**Inclined shaft**

This short shaft is located beside the New Western shaft within the same fenced area and was sunk around the same time. The North Lode mine was developed in both an easterly and westerly direction simultaneously and the Inclined shaft and the New Western shaft were probably the last ones to be sunk. The Inclined shaft is very short and does not connect to any North Lode levels (Mianrai Teoranta 1951). A note on Mianrai Teoranta’s 1951 map/section suggests that it was used for working ochre deposits.

**Air shaft**

This is a short vertical shaft. It is not shown on the Mianrai Teoranta map and its depth is unknown. It is surrounded by a fence. Some steel...
bars are set across the top, but the shaft is effectively open.

**Whelan’s shaft**

This is the only remaining shaft on Weaver’s lode (Fig. 3). This lode was regarded as a reserve by WCMC and was not opened beyond the 300ft level (54m below surface). Whelan’s shaft was sunk vertically to 138m O.D., 45m below the surface, and then inclined to 114m O.D. It was linked to the Spa adit. In 1951, the shaft was apparently open along its length (Mianrai Teoranta 1951). Today it is capped and fenced off.

**Wheatley’s shaft**

This was also known as the Eastern Whim shaft. In 1951 it was open along its length (Mianrai Teoranta 1951). It extends vertically 48m below the surface to the 45ft level (120m O.D.) and then inclines to the 80ft level (63m O.D.), intersecting the 60ft level (95m O.D.). Little information is available about its development. It is now capped and fenced off.

**REVEGETATION TRIALS**

Revegetation trials were conducted on acid-generating mine spoil at West Avoca in 1995 as part of the Life project. The following description is based on that of Gallagher et al. (1998). Composted sewage sludge was tested as an ameliorant and two different approaches were examined: (1) the use of non-phytotoxic, metalliferous mine spoil amended with composted secondary sewage sludge as a soil substitute; (2) the use of various capillary barrier layers (pebbles, low permeability liner, etc.) covered with a revegetated top-soil, also amended with composted sludge. Mine spoil was classified on-site into ‘phytotoxic’ (characterised by little or no natural colonisation by vegetation, low pH, high acid-generating potential (AGP) and high heavy metal concentrations) and ‘non-phytotoxic’ (characterised by successful natural colonisation by vegetation, higher pH, lower AGP and lower concentrations of most heavy metals). Two sites were used, one on the North Lode open pit (North Lode site) and the other close to the Tramway Engine house (Ballymurtagh Crest site) (Fig. 4; Plate 4). Sewage sludge for the pilot project came from seven secondary treatment plants in Co. Wicklow. Sludge was delivered to the site as pressed sludge with 15% dry solids content. Composting the sludge on site was carried out both to improve digestion and for ease of application. Sludge was mixed with wood chip in the ratio of 1:2.

Spoil on the North Lode site includes both phytotoxic and non-phytotoxic varieties, the latter being colonised in places by native species such as pine and birch. The non-phytotoxic spoil was excavated, transported and placed over phytotoxic spoil in large plots (90–270m²) 0.8m in depth. Ground limestone was incorporated into the surface 20cm of spoil at various rates (0–80 tons ha⁻¹). Composted sewage sludge was also incorporated in the surface 20cm at application rates varying from 138 tons ha⁻¹ to 248 tons ha⁻¹ (dry weight). A control plot using non-metalliferous sandy subsoil from outside the mine site was also established.

The spoil on Ballymurtagh Crest had much higher metal contents and was considered phytotoxic. This spoil was graded to give several plots, each with a level, compact surface. Various barriers were placed on top of the spoil and were in turn covered by 0.3m of imported topsoil.

On the North Lode site, each plot was planted with trees at 1m spacing: silver birch (Betula pendula), lodgepole pine (Pinus contorta) and Scots pine (Pinus sylvestris). After the first growing season, birch showed higher survival and growth rates than both pine species. All three species showed higher survival and growth rates where the spoil was not surface-compacted by tracked machines, but metal concentrations in soil percolate and surface runoff were also higher in uncompacted spoil, probably because of increased porosity and oxidation.

On the Ballymurtagh Crest site, the imported topsoil was placed as a 0.3m layer over different types of capillary barriers separating it from phytotoxic spoil underneath. The function of the barriers was to stop contact between plant roots and acidity and metals in the underlying spoil. These barriers were 2mm high-density polyethylene (HDPE), 0.3m bentonite clay mixed with sand (1:10 ratio), and 0.1m of 10mm gravel. A potential attenuation barrier of 0.15m composted sludge, held in place by conifer brash, was placed...
THE AVOCA MINE SITE

Above—Cronebane Open Pit with Mount Platt in the distance and natural tree revegetation in the foreground (photograph by M. Parkes).

Left—Building rubble provides a foothold for plants on a steep slope (photograph by V. Gallagher).

Below left—Natural revegetation on spoil ameliorated by ash from a camp fire, East Avoca (photograph by M. Parkes).

Below—Ballymurtagh Crest trial plots 6, 7 and 8 under grass in May 1997 (photograph by V. Gallagher).
under 0.3m topsoil in another plot. As well, a plot without a layer separating 0.3m topsoil from spoil underneath formed a control. All plots had composted sludge applied at a rate of 248 tons (dry weight) ha$^{-1}$, and were sown to grass (Phleum pratense) in early October 1995. At sowing, 100kg ha$^{-1}$ K and 50kg ha$^{-1}$ P were applied as 0.10.20 fertiliser. No lime was applied, the topsoil was originally from agricultural land Grass biomass was higher in topsoil on HDPE than in topsoil on bentonite, but drought stress was evident in parts of these plots. Highest biomass was recorded from the composted sludge barrier plot. The long-term self-sustainability of the grass cover requires development of a soil decomposer community, and cannot be assessed until at least three years after establishment.

In the absence of an infiltration barrier (e.g. HDPE liner), successful vegetation cover on non-phytotoxic spoil will benefit the landscape and have a possible productivity benefit (birch timber). However, there will still be a level of contamination in soil percolate from this revegetated non-phytotoxic spoil, although this will not increase overall site contamination. If a surface barrier covered by a revegetated non-phytotoxic spoil layer is used to prevent rainwater infiltration, this soil percolate will emerge as surface drainage and will therefore require treatment before discharge. The use of non-phytotoxic metalliferous spoil as a soil substitute can therefore only be recommended where an infiltration barrier is not used, and where vegetation cover is demonstrated to be self-sustaining. Since the cost of the HDPE barrier alone, including placement, is c. £IP 50,000 per hectare (c. FRF 445,000), and not including drainage, other layers, grading or backfilling, the use of an infiltration barrier is likely to be prohibitively expensive given that the total area of the mine site is 0.63km$^2$ or 63ha.

CONCLUSIONS

The Avoca Valley has supported mining activity for nearly 300 years. Throughout their history the Avoca mines have provided local employment and created wealth for their owners. Historical records and archival material are plentiful and they provide insights into the mining history of the site, the changing technologies used to extract ore and the social conditions of the mining communities. These records, together with the many remaining physical mine features (engine houses, mine buildings/machinery, adits/shafts, spoil heaps, open pits), represent a mining or industrial heritage that is significant by Irish and European standards.

Prolonged mining activity in East and West Avoca has also caused significant environmental impacts, including open pits, spoil heaps, soil contamination and surface-water pollution. Today the mine lands are largely derelict and, for the most part, poorly vegetated. Reclamation of mined ground by natural species of pine, birch, heather and gorse is taking place so slowly that it will be many decades before an acceptable ground cover is established on the site. Waters discharging from the underground mine workings are acidic and contain high metal concentrations. The Avoca River is biologically dead below the mine site. For more than 200 years, the river has been unable to support significant fish life.

Mining at Avoca was conducted throughout its entire history, even in the 1970s, on a level that would not be permissible by today’s rigorous environmental standards. The Avoca River has been used since the eighteenth century as a sink for AMD produced during mining of the volcanic rocks. Even in the 1970s, when public awareness about environmental pollution at the mines was increasing, the mine was such a marginal financial endeavour that no significant resources were allocated to pollution control or remediaiton. The water treatment trials carried out as part of the LIFE project (Gallagher et al. 1998) have shown that active treatment of AMD with magnesium hydroxide can neutralise and precipitate toxic heavy metals from Avoca mine water. However, there remain large reserves of pyritiferous rock in underground workings at Avoca where they interact with water in the presence of air, thereby ensuring that AMD will continue to be generated as long as groundwater continues to flow into the mine workings, with significant cost implications for any active treatment system. Alternative, passive systems, for example using artificial wetland, should be assessed in Avoca.

Although spoil heaps can be considered to have some mine heritage value, some revegetation of spoil will be needed in the future both for aesthetic reasons and to help stabilise the heaps. The revegetation trials have shown that one waste product, sewage sludge, can be used to aid revegetation of Avoca mine spoil, thereby ameliorating the environmental effects of another waste product. Partial success has been achieved in developing ground cover using a variety of plants including native species such as birch and pine. Natural colonisation of non-phytotoxic spoil by heather and gorse indicates that it should be possible to achieve a sustainable long-term ground cover on suitably ameliorated phytotoxic spoil.

The failure of the last mine operator, Avoca Mines Ltd, to undertake remediation of the mine site has preserved relics of modern mining that might otherwise have been lost: open pits with excellent outcrops, accessible adits and shafts, mine buildings and even spoil heaps, which are impor-
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tant features for those interested in mining and industrial heritage. Natural revegetation of the mine site, however slowly it is proceeding, is creating unusual and attractive habitats. The importance of Avoca as a mine heritage site is enhanced by the knowledge that planning authorities now require rehabilitation of mine sites after closure. Well-preserved mining features are likely to be even rarer in the future.

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