CHAPTER 1

Introduction

1.1 Background

The Historic Mine Sites – Inventory and Risk Classification (HMS-IRC) project is a joint project of the Environmental Protection Agency (EPA) and the Department of Communications, Energy and Natural Resources (DCENR) (the Geological Survey of Ireland (GSI) and the Exploration and Mining Division (EMD)). The project, which commenced in February 2006, was managed by the GSI and the work was completed in 2009.

This project identifies waste piles and other features, for example shafts and adits (which are documented in Volume II), associated with closed/abandoned mines in Ireland. It also identifies broader issues of health and safety and the environment linked to closed mine sites. It provides a comprehensive understanding of each mine site/district and scores 27 mine sites/districts (encompassing 82 individual sites) relative to each other. The study assists Ireland to comply with Article 20 of the European Directive 2006/21/EC for the management of waste from the extractive industries. It does not address closed stone, sand and gravel quarries, which also require management under the Directive. It can also be used by Local Authorities to assist in their planning function.

In the past, it was normal practice that mining sites closed with little or no remediation. This practice has left the local environment vulnerable to pollution and site safety is also a common issue. Such historic mine sites may continue to cause ongoing damage to the environment and potential risks to human and animal health in the surrounding areas. There is also the potential that the risks posed by these sites may increase with time as large abandoned tailings impoundments, rock waste piles and underground workings gradually deteriorate. Often no consideration was given to long-term maintenance and aftercare of closed mine sites.

In recent years, detailed investigations have been carried out at a number of the larger abandoned/closed base-metal mine sites, namely Silvermines, Co. Tipperary, Tynagh Mines, Co. Galway, and Avoca Mines, Co. Wicklow. The DCENR with Tipperary North Riding County Council (TNRCC) is currently carrying out large-scale remediation works at Silvermines. A detailed feasibility study for the remediation and long-term management at Avoca managed by the GSI has been completed (Camp, Dresser and McKee (CDM), 2008) and the EPA carried out investigations at Tynagh.

Modern mines operate under proper planning legislation and conditions. Integrated Pollution Prevention Control (IPPC) licensing supports strict environmental standards. Modern mines now implement and fund planned closure, monitored closely by relevant bodies (e.g. EPA, Local Authority).

1.1.1 Definition of historic mine site

Many terms have been used to refer to historic mines including *closed*, *abandoned, derelict* or *orphan.* There is no widely accepted single definition for historic mines. They may be dormant, may or may not have an identifiable owner, and may or may not have been reclaimed. A historic or closed mine site can be defined as one where *minerals are not being worked, the mine site is not in the process of rehabilitation and is not under active management (addressing health and safety, and environmental issues) by a competent person.* A competent person is a person who has the technical knowledge and experience to manage the site.

Some common characteristics of historic mine sites are:

- Ownership of the site is difficult to establish, and can be further complicated by the fact that ownership of minerals can be held separately from the land in which they lie;
- That regular maintenance of the site is not undertaken; and
- Mining ceased without proper rehabilitation.

In this report, the term **historic mine site** will be used to refer to closed mine sites that are not regulated by a current permit(s) under mining, environmental or planning legislation and which encompass infrastructure related to a mine, including, but not limited to, adits, shafts, pits, tailings facilities, waste rock dumps, buildings and mineral processing areas.

1.2 Project objectives and deliverables

1.2.1 Project objectives

The key objective of this study is to establish how many of the sites actually constitute an environmental problem and/or a risk to human and animal health. The specific objectives include:

1. To draw up a list of priority sites for investigation based on existing information;
2. To review existing sampling protocols and to select or develop, as appropriate, a sampling protocol that will be used at each site to ensure reliability and replication at that site for a range of sampling media (e.g. soil, water, sediment, mine wastes, vegetation, etc.);
3. To carry out site investigation and characterisation on the priority sites identified, including an inventory of all extant surface and underground mine workings and associated buildings;
4. To review and document the potential impacts of historic mine sites in Ireland on the environment and human and animal health, and on human safety;
5. To develop a risk classification methodology based on best international practice, i.e. to develop a methodology for risk-ranking historic mine sites that would provide a robust scientific basis for making decisions about actions that need to be taken to minimise or manage risks associated with such sites. To classify the sites investigated according to the system developed; and
6. To present the findings of the work in a two-volume report. Volume I deals with the geochemical and environmental aspects of the sites and Volume II deals with the physical hazards of the site. All information will be compiled and analytical results obtained for each site during this project into a Geographic Information System (GIS) database.

1.2.2 Project deliverables

The key project deliverables for Volume I are:

1. An inventory of historic mine sites in Ireland;
2. Protocols for conducting site investigations and characterisation for historic mine sites;
3. A semi-quantitative risk assessment methodology developed and applied to each site and utilising site-specific analytical and observational information;
4. Site-specific investigation, characterisation and assessment reports for all the mine sites included in the inventory;

5. Identify site-specific issues which may require further action at each site to minimise the actual and/or potential risk posed by each site to human and animal health and the wider environment; and
6. Publication of a final report and the compilation of all relevant information on each site into a GIS format for future use.

1.2.3 Project management

The project team established to undertake the work includes staff from the EPA, the GSI and consultants employed full-time on the project, with the GSI as manager of the project. International experts were employed by the project to provide expertise in the areas of risk assessment and risk ranking and geostability. A steering committee comprising representatives from the GSI, the EPA and the EMD reviewed the performance of the project in meeting its objectives. A consultative committee comprising representatives from the Department of Environment, Heritage and Local Government (DEHLG), the Department of Agriculture, Fisheries and Food, the HSE, the Health and Safety Authority (HSA), Teagasc, the Central Fisheries Board, the Shannon River Basin District and the County and City Managers Association, in conjunction with the steering committee, provided advice and assistance in their relevant areas of expertise.

1.3 Review of potential impacts of historic mine sites

The working of minerals at metal or coal or industrial mineral mines over the centuries in Ireland has caused varying degrees of environmental damage locally, often in remote and sometimes scenic rural areas. Mining, unlike renewable natural resource land uses (e.g. fishing, farming, forestry), is a transient occupier of land while the minerals of economic interest are being extracted.

It is important to note that mining sites by their nature are anomalous accumulations of the constituents of the orebody, e.g. heavy metals, sulphides, etc. However, the disturbance caused by mining and the generation of various waste streams may result in an increased dispersion of these constituents into the wider environment, causing, in some cases, environmental pollution.

The impacts of mining on the environment may be long term and, in some cases, represent a risk to human health, animal health and the environment unless remediation and long-term management are undertaken. The impact of historic mine sites on the environment can be significant and may include:

- Potential loss of alternative land uses, e.g. agriculture, forestry, conservation, amenity, etc.;
- Pollution of surface and groundwaters through, for example, acid mine drainage (AMD) and/or metal leaching or sedimentation in watercourses;
- Dust generation and heavy-metal deposition, resulting in contamination of soils;
- Rock waste storage and disposal;
- Site safety, for example subsidence, slope instability, open shafts and adits;
- Chemical residues from ore processing; and
- Degradation of the visual environment.

The potential risk posed by the resulting contamination will be site specific and will be determined by linkages or connectivity between the sources of contamination and potential receptors – human, livestock and terrestrial and aquatic ecosystems.

1.3.1 Surface and groundwater contamination

Surface and groundwater contamination may occur through AMD, metal leaching and precipitation and sedimentation.

Acid mine drainage and acid rock drainage (ARD) occur when minerals, e.g. pyrite (FeS_2), containing sulphide and iron are exposed to the weathering effects of air and water. This reaction (oxidation) is catalysed and accelerated by sulphophilic bacteria and results in the formation of sulphuric acid and the release of iron hydroxide. The acid leaches metals from exposed underground workings (this is normally referred to as AMD) or from waste rock piles or tailings on the surface (normally referred to as ARD). This process will continue for as long as the sulphide minerals remain exposed to air and water and until the sulphides are completely oxidised. The environmental impact of AMD/ARD will depend on the sulphide minerals, the host geology, the sensitivity of the receiving environment and the degree of neutralisation, dilution and/or natural attenuation. These acidic waters make their way into surface and groundwaters.

Enhanced metal leaching is associated with acidic drainage due to high metal solubility and sulphide weathering rates under acidic conditions. For many rock types and environmental settings, metal leaching will only be significant where the pH drops below 5.5. However, a neutral pH does not necessarily eliminate metal leaching. While the solubility of aluminium (Al), iron (Fe), and copper (Cu) is greatly reduced in neutral pH drainage, elements such as antimony (Sb), arsenic (As), cadmium (Cd), molybdenum (Mo), selenium (Se) and zinc (Zn) remain relatively soluble and therefore can be found in significant concentrations in drainage water (Price and Errington, 1998). These metal-bearing waters may precipitate their metal load onto a river bed. This can also result in a ferricrete developing on the river bed which destroys the nature of the river bed and impacts on the habitat for aquatic macroinvertebrates.

Erosion occurs when bare rock, soils or processing wastes from mining activities are eroded by wind or water. Subsequently, the eroded material may be deposited in either watercourses or on land, causing contamination. During the mining operations, materials may have been deliberately discharged into watercourses. Livestock accessing rivers may come into contact with such contaminated sediments and this may be a cause for concern depending on the composition of the mine-generated sediment.

1.3.2 Dust generation and deposition

Wind erosion can occur when finer particles from mine waste dumps and tailings become airborne under dry weather conditions. They are subsequently deposited onto other parts of the mine site or onto adjoining lands. This process can have environmental impacts on soil through the deposition of elevated metal material.

1.3.3 Waste rock piles

Many waste piles have elevated metal levels (e.g. As, Pb), and in some cases the level of metals may be toxic. Such waste piles are a concern in situations where there is the possibility of direct contact by humans or animals.

1.3.4 Chemical residues

During mining operations, target minerals are separated from waste minerals using mineral processing techniques that involve the use of chemical reagents. Over the operational life of the mine there may have been accidental spillages of some of these reagents. Usually these would have been cleaned up at the time. The reagents commonly adhere to either the recovered minerals, which are transported offsite, or to the waste minerals, which are deposited in the tailings impoundment. Most of these reagents degrade naturally to harmless compounds.

1.3.5 Site safety

Many mine sites have features such as open pits, high cliff walls, waterbodies, shafts, adits, derelict buildings or steep slopes that may cause a safety hazard. Ground instability is another issue that may occur. Unrestricted public access to such sites is a safety issue. These physical hazards are documented in Volume II.

1.4 Legislation relating to historic mine sites

Legislation relating to mining relates to permission to mine (emanating from DCENR) and to how mining is carried out (largely from the DEHLG) and includes the:

- Minerals Development Acts, 1940 to 1999;
- Environmental Protection Agency Acts, 1992 and 2003;
- Waste Management Acts, 1996 to 2003;
- Water Pollution Acts, 1977 to 1990; and the
- Energy (Miscellaneous Provisions) Act 2006 Part 9 – Rehabilitation of Mines.

Directives from the EU are also relevant and the principal ones related to mining are:

- Directive 76/464/EEC on pollution caused by certain dangerous substances discharged into the aquatic environment of the Community (Dangerous Substances Directive);
- Directive 2000/60/EC establishing a framework for the Community action in the field of water policy (Water Framework Directive);
- Directive 2006/21/EC on the management of waste from the extractive industries (Mining Waste Directive);
- Directive 2006/118/EC on the protection of groundwater against pollution and deterioration (Groundwater Daughter Directive).

1.4.1 Legislation overview

The Minerals Development Acts, 1940 to 1999, under the aegis of the Minister for Communications, Energy and Natural Resources, govern exploration for and development of all minerals other than ordinary clay, stone, sand and gravel. Minerals can be held either by the State or be privately owned. Of the mineral ownership that has been determined, 60% is in State ownership. All gold (Au) and silver (Ag) are State owned.

Current mining, planning and environmental legislation ensures that mine operators make provision for the funding and proper closure and remediation of sites. This is enforced by the Local Authority, the EPA and the DCENR. These arrangements were not in place for historic mine sites.

The legal obligation to deal with environmental and health and safety issues at historic mine sites rests in the first instance with the owner. It is the responsibility of the Local Authority to enforce compliance with environmental legislation within its functional area. Account must also be taken of other legislation that can be invoked, such as the Derelict Sites Act, 1990, which gives bodies such as Local Authorities powers and responsibilities in relation to historic mine sites.

Under current minerals legislation (Section 32 of the Minerals Development Act, 1940) the Minister for the Department of Communications, Energy and Natural Resources has limited powers to enter lands and erect fencing around, for example, shafts and openings where State minerals have been worked. The Minister has no such powers in relation to sites where private minerals have been worked. Provisions were included in the Energy (Miscellaneous Provisions) Act 2006 to give the Minister powers to prepare and implement a mine rehabilitation plan in respect of the site of a historic mine where such a plan is deemed necessary for the purposes of human or animal health or safety, for the protection of the environment, or is otherwise in the public interest. Provision is made also in the Act for the Minister to appoint a Local Authority as agent to prepare and implement such a plan.

Ireland is obliged under Article 20 of Directive 2006/21/EC on the management of waste from the extractive industries to prepare an inventory of closed/abandoned mine waste facilities that cause serious negative environmental impacts or have the potential of becoming in the medium or short term a serious threat to human health or the environment and to periodically update it. The inventory is to be made available to the public and be completed by 1 May 2012. As the historic mine sites inventory and scoring system deals with those minerals covered by the Minerals Development Acts, 1940 to 1999 (Scheduled Minerals), it only partially fulfils this obligation. However, an inventory for closed stone, sand and gravel quarries is also required under the Directive. There is no obligation under this Directive to take any action at listed sites.

1.4.1.1 Water Framework Directive

The Water Framework Directive (2000/60/EEC) came into force on 22 December 2000 and establishes a strategic framework for managing the water environment of the European Community. The Directive establishes a common approach to protecting and setting environmental objectives for all waters, including groundwaters, rivers, lakes, canals, reservoirs, estuaries and coastal waters. The Directive aims at maintaining and improving water quality within the European Community by setting objectives for all waterbodies requiring at least 'good status', 'no deterioration' and 'restoration' where necessary.

The River Basin District (RBD) will be the main unit for managing the water environment and a single River Basin Management Plan (RBMP) must be produced for each RBD. Identification and analysis of the pressures and impacts on the water environment is required in the preparation of an RBMP, which will determine what measures need to be taken in order to achieve 'good status'. For surface waters, 'good status' includes good chemical and ecological status and, for groundwater, includes good chemical and good quantitative status.

The waters in each area where mine sites are located will ultimately be managed by the relevant competent authority under an RBMP, with the objective of achieving good water status. However, waters in mining areas have generally been influenced by both the natural geological conditions of the area and past mining activities. The Water Framework Directive provides for this by stating *In cases where a body of water is so affected by human activity or its natural condition is such that it may be unfeasible or unreasonably expensive to achieve good status, less stringent environmental objectives may be set on the basis of appropriate, evident and transparent criteria, and all practicable steps should be taken to prevent any further deterioration of the status of waters.*

1.4.1.2 Dangerous Substances Directive

Under the Dangerous Substances Directive (76/464/EEC), Member States are required to take appropriate steps to eliminate pollution of waters by List I substances listed in the Annex and to reduce pollution of waters by List II substances also listed in the Annex. List I includes Cd and its compounds. List II includes metalloids and metals, such as Pb, Zn, As and Cu. The Dangerous Substances Directive will remain in force until 22 December 2013, when it will be repealed by the Water Framework Directive.

The Water Quality (Dangerous Substances) Regulations, 2001 (SI No. 12 of 2001), were enacted on 1 July 2001. The Regulations transpose certain requirements of the

Dangerous Substances Directive into national legislation. They prescribe water quality standards in relation to specified List II substances, including Pb, Zn and As, in surface water, e.g. rivers, streams, etc. The Regulations require that the annual mean concentration of certain substances is not exceeded and the standard specified for fresh waters depends upon hardness of water measured in mg/l $CaCO_3$. Where the existing condition of a waterbody does not meet a specified standard in relation to a substance there should be no disimprovement and compliance with the specified standard should occur no later than 31 December 2010 or by 31 December 2015 for specific cases.

However, in common with the Water Framework Directive, exemptions are provided for in the Regulations. Article (9) (2) states that *a specified standard shall not apply in relation to a water body where the Agency [Environmental Protection Agency] is satisfied that the water body is so permanently affected by naturally occurring conditions or by past human activity that compliance with that standard is not feasible or would be disproportionately expensive*.

1.4.1.3 Groundwater Directive

The purpose of the Groundwater Directive (80/68/EEC) is to prevent the pollution of groundwater by substances belonging to the families and groups of substances in List I or List II in the Annex to the Directive and, where possible, to check or eliminate the consequences of pollution that has already occurred. List I substances include Cd and Hg, while Pb, Zn and As are included as List II substances. The Directive requires that Member States prevent the introduction of List I substances into groundwaters and to limit the introduction of List II substances.

However, in common with the Water Framework Directive, exemptions are provided for in the Directive. Article 4 (2) states *that should prior investigation reveal that the groundwater into which the discharge of substances in List I is envisaged is permanently unsuitable for other uses, especially domestic or agricultural, the Member States may authorise the discharge of these substances provided their presence does not impede exploitation of ground resources. These authorisations may be granted only if all technical precautions have been taken to ensure that these substances cannot reach other aquatic systems or harm other ecosystems*.

It is likely that groundwaters in many of the mining areas have been influenced by both the natural geological conditions of the area and past mining activities.

Information on the status of groundwater in these areas is limited in this study. Groundwater samples have been taken where this has been feasible.

1.5 Overview of the geology and mining history of Ireland

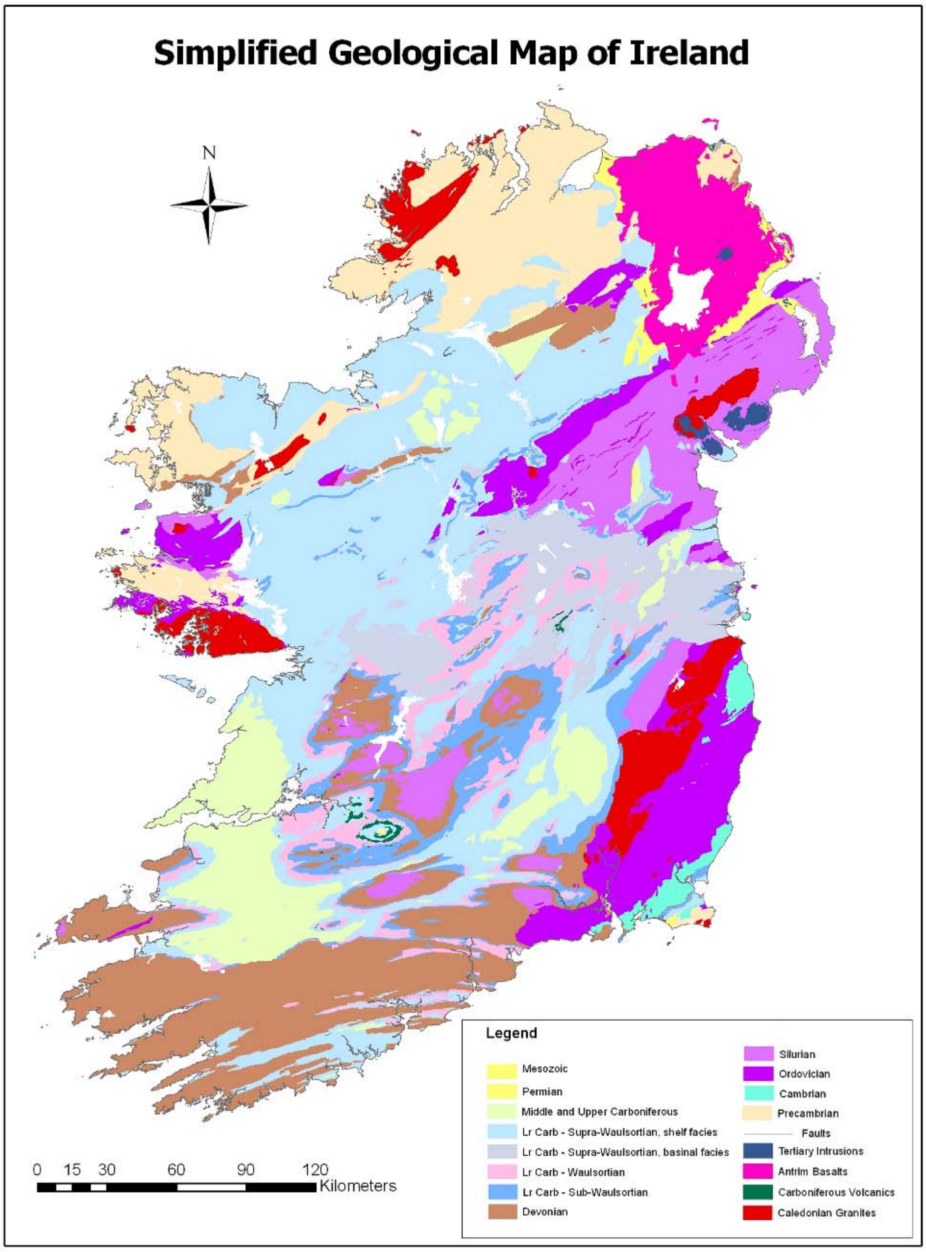
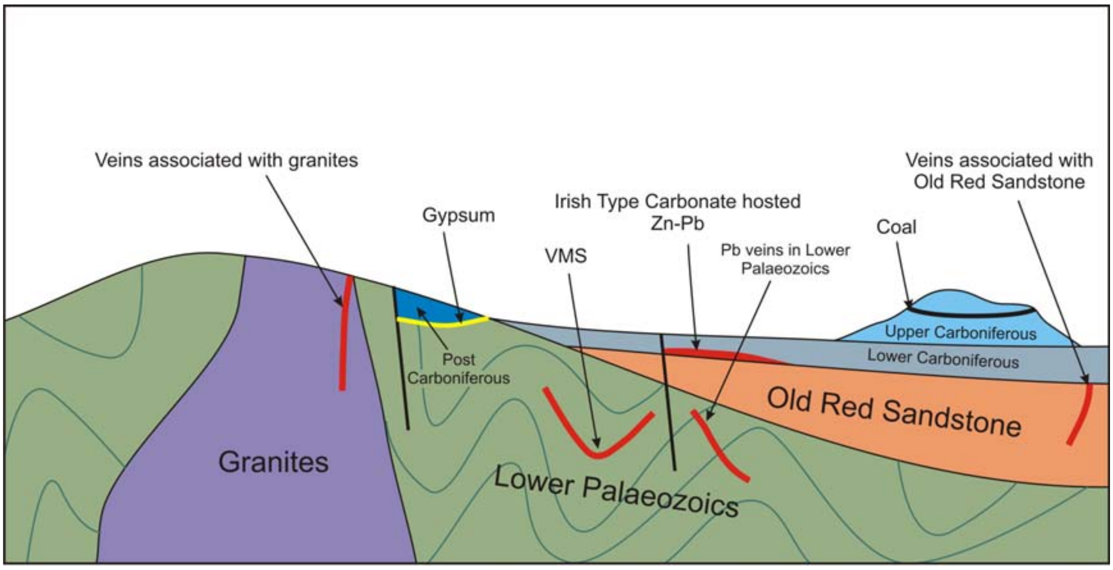


Figure 1.1 Geology map of Ireland.

Figure 1.1 is a simplified geological map of Ireland and shows the disposition of rock largely from an age perspective. Ireland has a diverse geology for its area, with rocks ranging in age from Precambrian (approximately 4.6 billion years to 540 million years) to Quaternary (approximately 2.5 million years to present). However, most rocks are from the Palaeozoic era (approximately 540 to 250 million years ago). This overview relates mineral deposits to the principal geological events in Ireland. Figure

1.2 is a schematic north–south geological section through the country, with typical mineral deposits illustrated in their respective geological units.

Figure 1.2 Schematic north–south geological section of mineral deposits in



Ireland.

1.5.1 Precambrian

The oldest rocks in Ireland occur in the north-west (Galway, Mayo and Donegal) and south-east (Rosslare), and originated on separate continents that were brought together during the later Ordovician and Silurian Periods. Most Precambrian rocks occur in the north-west where they are known as the Dalradian. They are composed mainly of metamorphosed marine sedimentary rocks (quartzite) but include volcanic and intrusive rocks, marbles, greywackes, slates, and metamorphosed glacio-marine deposits.

Mineralisation in the Dalradian is relatively minor. It is comprised for the most part of narrow veins of sulphide minerals (galena, chalcopyrite and sphalerite), skarns deposits in Connemara, and rare stratiform sedimentary exhalative (SEDEX) mineralisation in Co. Donegal. Only the veins were worked to any significant extent.

1.5.2 Lower Palaeozoic (Cambrian, Ordovician and Silurian Periods)

The geological evolution of Ireland continued in the Lower Palaeozoic, with the north-west and south-east separated by the Iapetus Ocean and consequently separate geological formations were developed on the different sides of the Ocean.

To the north-west some Dalradian rocks may be of Cambrian age while Ordovician rocks are comprised of slates, greywackes, and mafic and felsic volcanic lithologies in Counties Mayo, Galway and Cavan. Silurian rocks occur in Counties Mayo, Galway, Roscommon, Cavan, Louth and Monaghan and are mainly composed of slates, greywackes and quartzites.

The rocks of the south-east occur primarily in Counties Wicklow, Wexford and Waterford and parts of adjoining counties and are mainly slates, greywackes, quartzites, and mafic and felsic volcanics.

The close of the Iapetus Ocean led to the collision of the two continents and resulted in the Caledonian Orogeny (Grampian Phase), which resulted in mountain building, deformation, metamorphism, and the intrusion of large volumes of granite magma. The Leinster, Galway and Donegal Granites are the principal granitic intrusions and were emplaced at this time.

Mineralisation comprises two main types. One is volcanogenic massive sulphides (VMSs), as at Avoca in Co. Wicklow, where both stratiform and stringer Cu and pyrite mineralisation along with minor Pb and Zn sulphides are associated with felsic volcanic rocks. The other principal style of mineralisation is vein type comprising, for the most part, the sulphides of Cu, Pb and Zn. Some of the veins in Counties Monaghan and Mayo are gold bearing. Veins occur in most rock types but are especially common in greywackes (Co. Monaghan) and in granites (e.g. Glendalough, Co. Wicklow).

1.5.3 Upper Palaeozoic (Devonian, Carboniferous and Permian Periods)

Following the Caledonian Orogeny, there occurred a long period when the rocks forming the Caledonian Mountain Belt were subjected to erosion. The transported sediments were deposited in a fluvial environment forming the Devonian Old Red Sandstones. Devonian rocks crop out as far north as Co. Tyrone but occur mainly across the south in Counties Cork and Kerry. Devonian rocks also occur in the Midlands where they underlie the younger Carboniferous rocks of the Central Plain. They comprise conglomerates, sandstones, siltstones and mudstones.

Mineral deposits in the Devonian are mainly confined to West Cork and consist of vein-type deposits of Cu sulphides (e.g. Allihies) and barite vein deposits (e.g. Lady's Well). Following the Devonian, a marine transgression from the south led to the development of Carboniferous limestones of various types. From a mineralisation point of view, there are two important limestones, the Navan Beds and the Waulsortian. The Waulsortian Mudbank limestone is a thick mound-like body of mud-sized calcium carbonate. These mounds often coalesce to form thick continuous layers. These Waulsortian rocks occur across the Central Plain from Cork in the south as far northward as Co. Westmeath. The currently operating Navan deposit in Co. Meath is hosted in the Navan Beds.

Carboniferous rocks underlie approximately half of the country. In terms of Irish metal mining, the Lower Carboniferous is by far the most important unit for ore deposits. From the 1950s, when the modern phase of mining commenced, up until today, the Lower Carboniferous continues to provide the greatest amount of metal and the greatest prospects for the future. Six major deposits have been worked since the initial discovery, in 1961, at Tynagh in Co. Galway. The subsequent discoveries were Silvermines, Co. Tipperary (which also had historic production), Gortdrum, also in Co. Tipperary, Navan in Co. Meath (the largest Zn–Pb orebody in Europe and the sixth largest in the world), Galmoy, Co. Kilkenny, and Lisheen, Co. Tipperary. The latter three deposits continue working today and together make Ireland the largest producer of Zn and Pb in Europe. The deposits are commonly known as Irish Type, having features that are intermediate between Mississippi Valley-type and SEDEX-type deposits. They are much sought after on account of their high grades and clean metallurgy. Major barite deposits also occur in this interval with both stratabound (e.g. Silvermines) and vein-type (e.g. Benbulben) deposits occurring.

Following the Lower Carboniferous, deltaic conditions prevailed over much of Ireland, resulting in the deposition of sandstones and coal deposits. There are now three major areas underlain by Middle and Upper Carboniferous rocks – in Leinster (Counties Kilkenny, Laois and Carlow), Slieve Ardagh (Counties Kilkenny and Tipperary) and Connacht (Counties, Leitrim, Roscommon, Sligo and Cavan). There are also smaller deposits in Kanturk (Co. Cork) and at Cratloe (Co. Limerick). The principal deposits of these rocks are thin coal seams, which in Slieve Ardagh and Leinster are anthracite grade and in Connacht are bituminous-grade coals.

Permian rocks occur at Kingscourt in Co. Cavan (and neighbouring parts of Counties Monaghan and Meath). They comprise massive gypsum deposits formed in shallow coastal lagoons subjected to evaporation (sabhkas). At Kingscourt, two main gypsum and anhydrite layers (totalling about 45 m in thickness) are interbedded with red and purple mudstones of uppermost Permian age. In the past, gypsum has been mined from both layers at Kingscourt in several underground operations and is currently extracted from the upper layer in a major opencast pit at Knocknacran in Co. Monaghan.

1.5.4 Post-Palaeozoic

There are very few post-Palaeozoic rocks in onshore Ireland, except for Northern Ireland where there are Jurassic, Cretaceous and Tertiary rocks – the latter which includes the famous Antrim basalts and the Giants Causeway. In the south, there are a few instances where sinkholes in the Carboniferous limestones have preserved younger rocks such as at Killarney where Cretaceous chalk is preserved. No mining activity is known from these rocks although one such sinkhole has been investigated as a potential ball clay source.

1.6 Mining in Ireland

Mining supported the economic welfare of local communities for a decade or more. At some celebrated sites (e.g. Avoca, Silvermines) mining activity spanned hundreds of years and employed thousands of workers and a rich industrial and cultural heritage is now linked to these sites.

1.6.1 Overview

Ireland has a rich mining history dating back to the Bronze Age. Cowman and Morris (2003) provide an overview of mining prior to 1700. Many deposits and deposit types have been worked over the years. The MinLocs database in the GSI has over 5,000 entries, which include both metallic and non-metallic commodities (almost 200 different commodities are recorded). Of these entries, almost 1,500 are for metallic minerals, while some 3,300 are for non-metallic minerals, with the remainder containing both metallic and non-metallic minerals. Of the total 5,000+ locations in the database, just over 450 are described as mines, while some 1,300 are described as quarries. The remainder are either borehole intersections or outcrops (natural or man-made) of one form or another with the occurrence of a mineral or rock.

Within the group of 450 mines, some 350 were worked for metallic commodities while there were approximately equal numbers of non-metallic and coal operations, 49 and 57, respectively. Of the 450+ mines, some 220 had what could be described as significant workings or production.

The former mines can also be classified according to time of working and commodity produced. Using this as a basis the following groupings may be identified:

1. Underground and surface mining operations for coal;
2. Workings for industrial minerals prior to the 1920s;
3. Modern workings for industrial minerals (latter half of the 20th century);
4. Base-metal veins worked for the most part prior to the 20th century – but some workings operated into the 1950s;
5. Modern (industrial) operations mainly from the latter half of the 20th century.

1.6.2 Coal mines

Coal measure rocks, in Ireland, date from the Upper Carboniferous and occur in four areas – the Leinster Coalfield, straddling Counties, Kilkenny, Laois and Carlow; the Slieve Ardagh Coalfield on the border of Counties Kilkenny and Tipperary; the Kanturk Coalfield in north-west Co. Cork; and the Connacht Coalfield, straddling Counties Leitrim, Roscommon, Sligo and Cavan. The type of coal worked varied from anthracite in the southern coalfields to bituminous coal in the Connacht Coalfield. Coal working methods varied over time also, with opencast, bell pits and longwall mining being the principal types. Most coal mining operations in Ireland date from the 18th century and the various coalfields were worked intermittently up until the 1990s.

1.6.3 Vein operations

Up until the start of the 20th century, most mining operations in Ireland worked metalliferous veins. Most of these were for Cu or Pb while a smaller number were worked for either Fe or Zn. Silver was commonly recovered from the Pb veins.

The veins occurred in a number of settings:

1. Pb (and Ag) veins associated with granites, e.g. Glendasan, Co. Wicklow;
2. Cu veins within volcanic rocks with a VMS affinity, e.g. Bunmahon, Co. Waterford;
3. Cu veins within sandstone lithologies, e.g. Allihies, Co. Cork; and
4. Pb (and Ag) veins in limestone lithologies, e.g. East Co. Clare.

1.6.4 Modern mining

Modern mining operations in Ireland commenced in the 1960s with the development of the Tynagh mine. This heralded a new era for mining in Ireland as it focused attention on the prospectivity of the Irish Midlands for carbonate-hosted Zn–Pb deposits. This attention was rewarded with the discovery and eventual development of a further five deposits and the finding of ten other sub-economic deposits. The historic mine at Avoca was intermittently active from about 1720 until 1982. The early workings of this deposit were largely by primitive means (until the latter part of the 19^{th} century). However, in the late 1950s modern mechanised mining methods were applied to this VMS deposit. There were, or are, also a number of modern mining operations for industrial minerals, in particular for barite and gypsum. Figure 1.3 shows the mining sites and districts in Ireland that were investigated for the HMS-IRC project. Not all of these sites contain mine waste and therefore only the relevant ones have been scored and classified.

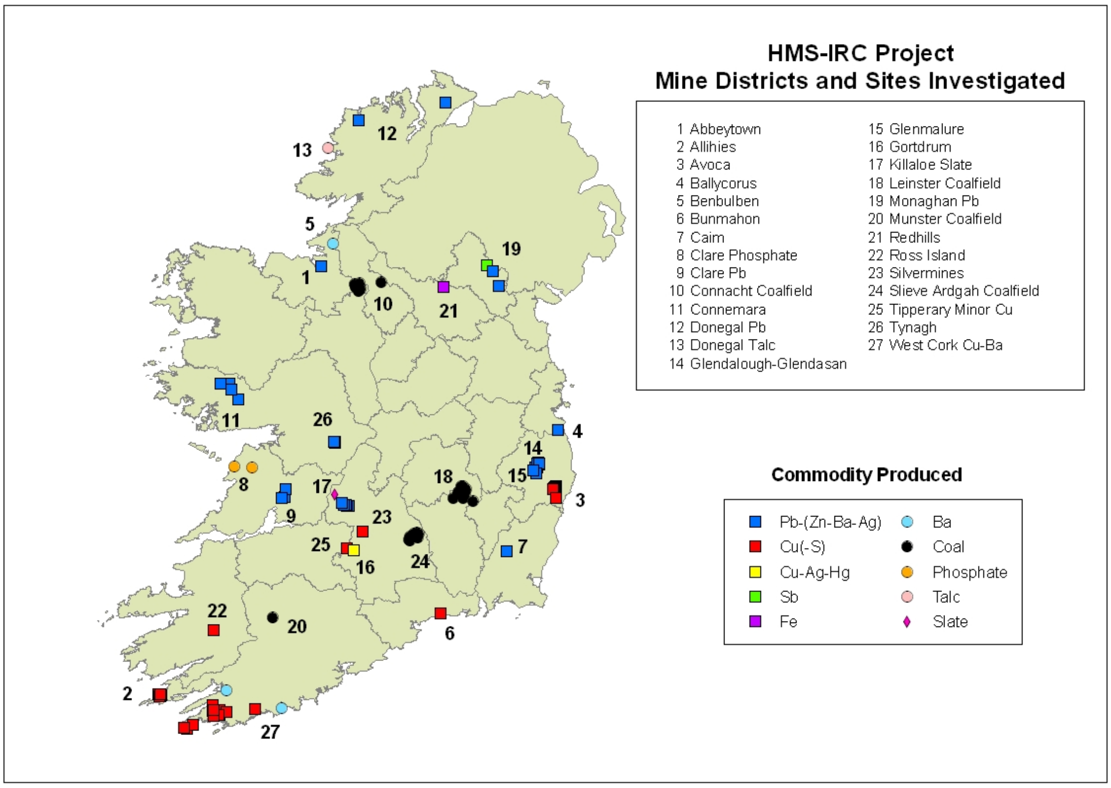


Figure 1.3 Mines and mining districts in Ireland investigated for the HMS-IRC project.