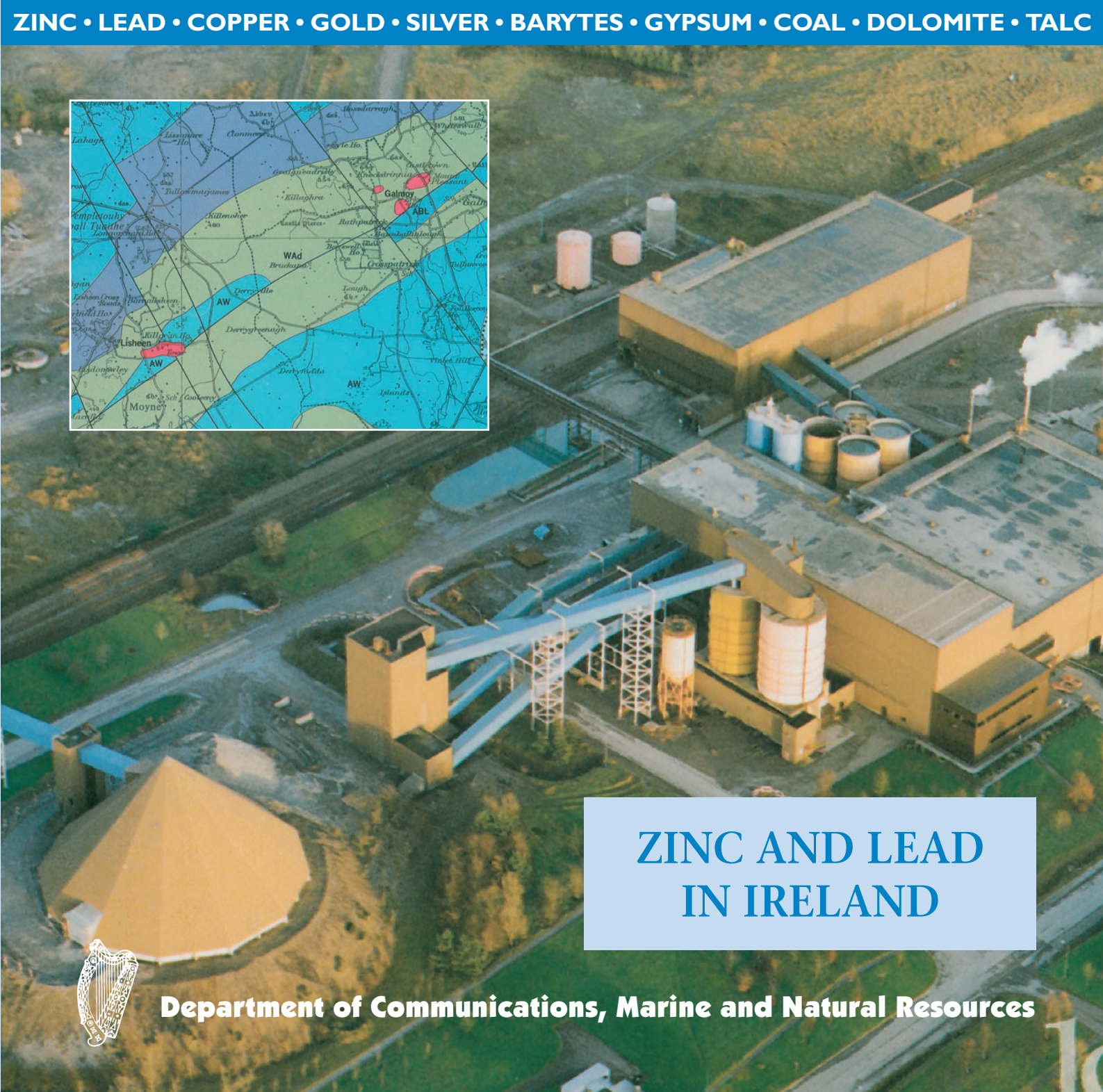
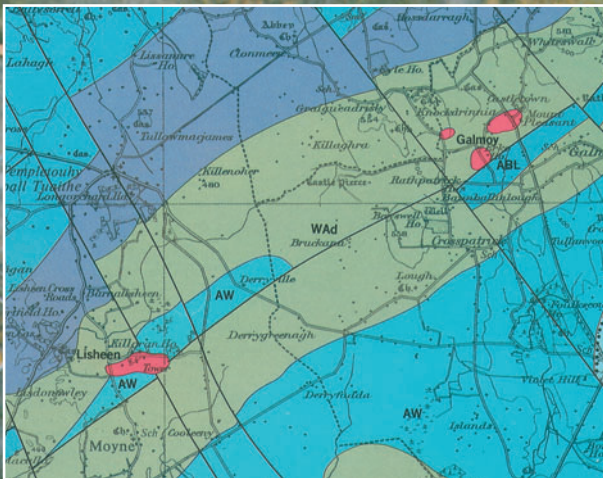


EXPLORATION AND MINING DIVISION IRELAND

ZINC • LEAD • COPPER • GOLD • SILVER • BARYTES • GYPSUM • COAL • DOLOMITE • TALC



ZINC AND LEAD
IN IRELAND



Department of Communications, Marine and Natural Resources

Historical

PRE – 1960

The earliest evidence of mining is provided by Bronze Age (1,300 BC) copper mines at Mount Gabriel in Co. Cork, southwest Ireland. The first written record is a reference by Ptolemy to copper mining at Avoca, Co. Wicklow, in 150 AD, while there are written accounts of ancient mining at Silvermines, Co. Tipperary (silver and lead), Abbeytown, Co. Sligo (silver and lead) and Allihies, Co. Cork (copper). During the 19th century there was considerable mining activity throughout Ireland, with almost every coastal county yielding at least one mine. This however had ceased by the turn of the century, and up to the 1950s the only mining of any note was for coal, leading to the incorrect assumption that Ireland was devoid of significant mineral resources.

1960 – PRESENT

In a manner reminiscent of the situation over the past few years for a number of countries, it was **legislative changes** that attracted the exploration and mining industry to Ireland. Although a comprehensive Minerals Development Act was introduced in 1940, it was not until the complementary Finance Act of 1956 was in place that Ireland's modern phase of exploration and development began. The Finance Act provided tax incentives for mining and had the effect of attracting a number of Canadian exploration companies to Ireland, a firm relationship that has continued to the present

Although an historically known minor zinc-lead deposit in a Lower Carboniferous calcareous sequence was worked at Abbeytown between 1950 and 1961, the first significant zinc-lead discovery of modern times was made in 1961 when Northgate Exploration, through its subsidiary Irish Base Metals Ltd., discovered the **Tynagh** lead-zinc-silver-copper deposit in County Galway. The mineralization at Tynagh consisted of massive stratiform sulphides hosted in Lower Carboniferous mudbank ("Reef") limestones, a geological setting which had not previously produced any significant mineralization. Then, in 1963, the **Silvermines** zinc-lead orebody was discovered. This orebody is in a similar geological setting to that at Tynagh. Subeconomic deposits were also found at Keel (1962), Courtbrown (1962) and Ballinalack (1969), while significant mineralization was discovered at other localities e.g. Carrickkittle (1966) and Moyvoughly (1968).

Then, in 1970, Tara Exploration and Development Company Ltd. discovered the **Navan** deposit. Initial reserves for this world-class deposit were almost 70 million tonnes grading 10% Zn and 2.5% Pb. The Navan deposit, however, is hosted in Lower Carboniferous carbonates and calcareous clastics at a stratigraphic level considerably below that which hosts the deposits discovered earlier, and represented the first discovery of substantial stratabound mineralization at this level.

There immediately followed the most intensive period of base-metal exploration in Ireland. Unfortunately, during the next fifteen years the efforts of the exploration industry resulted in what can only be described as technical

successes. While a number of minor lead-zinc deposits were found, (e.g. Tatestown-Scallanstown, Oldcastle, Newtown Cashel, Garrycam (near Keel) and Harberton Bridge), no economic deposits were discovered.

It was not until 1986, when a further very significant discovery was made, that a revival was sparked in Ireland's base metal industry, a revival which continues to this day. This was the discovery of the **Galmoy** deposit (6.2Mt, 11.31% Zn, 1.12% Pb) by a junior Irish Company, Conroy Petroleum and Natural Resources (now Arcon International Resources). Conroy's success resulted in the return to Ireland of a number of multinational companies, and Galmoy was followed in 1990 by the discovery of the **Lisheen** deposit (18.9Mt, 12.75% Zn, 2.2% Pb). Lisheen was discovered by a Chevron/Ivernia West joint venture with the latter company, another junior Irish exploration company, as operator at the time of discovery.

Ireland now has three underground zinc-lead mines in production, Navan, Lisheen and Galmoy. Ireland is the largest producer of zinc in Europe, and among the top ten producers in the world. While the search for base metals has not returned to the levels attained in the 1970s, in the immediate aftermath of the Navan discovery, nevertheless exploration and discovery have continued at a level that recognises Ireland as constituting prime exploration territory, especially for zinc. Indeed, exploration at Navan in 1999 outlined a further significant tonnage of ore in the South West Extension (SWEX), which is now in development. Also, a more recent discovery adjacent to the CW Zone at Galmoy (the R Zone) will add significantly to the mine life. In addition, the discovery in 2000 of significant zinc-lead mineralization at Pallas Green in Co. Limerick has opened up a new region of potential.

DEPOSIT	YEAR OF DISCOVERY	TONNAGE (Mt)	GRADE (Zn+Pb)
* Economic			
* Tynagh	1961	9.2	11.2%
Courtbrown	1962	1.0	5.5%
Keel	1962	1.8	8.76%
* Silvermines	1963	17.7	8.9%
Ballinalack	1969	7.8	7.4%
* Navan	1970	69.9	12.7%
Tatestown/ Scallanstown	1975	3.6	6.9%
Harberton Bridge	1975	3.7	9.9%
Garrycam	1976	1.4	2.9%
Oldcastle	1977	1.4	5.2%
*Galmoy	1986	6.2	12.43%
*Lisheen	1990	18.9	14.95%
*Navan SWEX	1999	13.5	9.8%
*Galmoy (R Zone)	2002	2.3	25.8%

Significant zinc-lead deposits (resource > 1 Mt) discovered in Ireland since 1960.

WORLD CLASS ZINC-LEAD TERRITORY

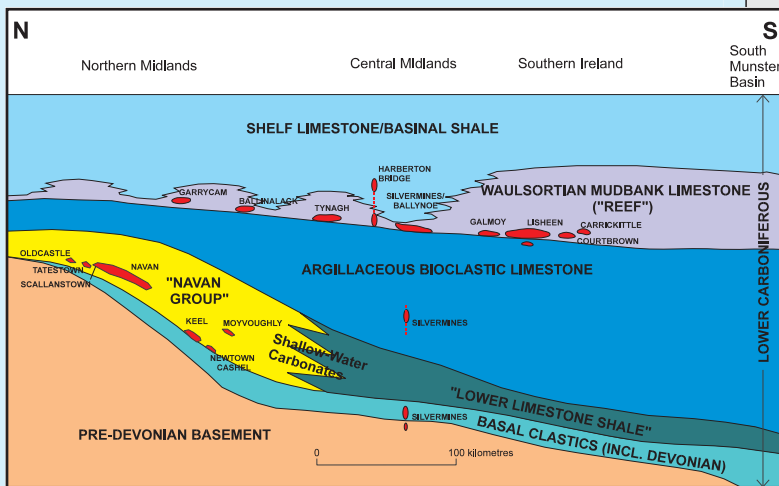
14 Mt of Zinc Metal Found To Date – Largest Deposit 70 Mt

GLOBAL SIGNIFICANCE

Since 1960 Ireland has had a string of significant zinc-lead discoveries, placing it firmly on the world stage as a country with proved prime zinc-lead territory. The known deposits contain some 14 Mt of zinc metal, approximately 1.5% of world zinc found to date. Ranked 1st in the world in terms of zinc discovered per sq. km, and 2nd in the world for lead discovered per sq. km, Ireland's zinc-lead deposits in current production comprise Europe's largest at Navan (70 Mt) the 18.9 Mt Lisheen deposit and Galmoy (6.2 Mt).

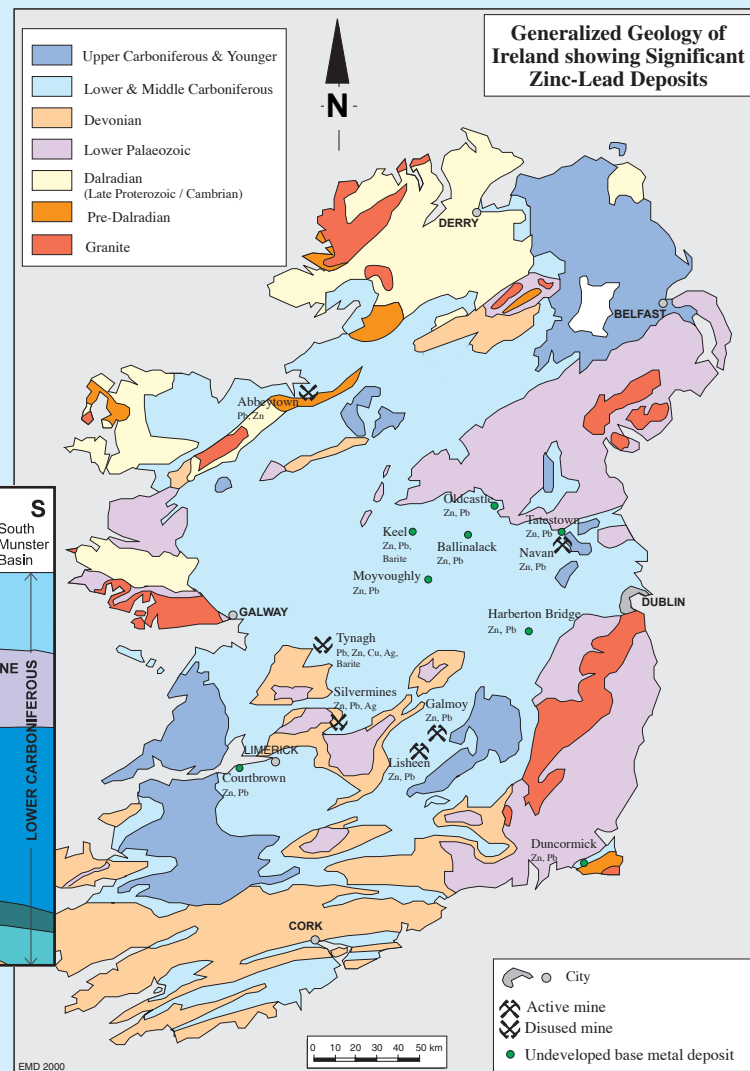
Favourable Geology

Ireland is fortunate in having a widespread carbonate succession that has proved a favourable host. The bulk of these carbonates occur in a world-class orefield, the **Central Ireland Basin** mineral province, where thick Lower Carboniferous carbonate rocks occur in a number of sub-basins. The known deposits display clear evidence of stratigraphic and structural control. Stratigraphic control is evinced by their occurrence in three preferential settings, although not exclusively, and mineralization traces are stratigraphically widespread. Firstly, the shallow-water carbonates of the **Navan Group** (50-400m thick) that hosts the Navan deposit and several subeconomic deposits in the northern part of the province. Secondly, the **Waulsortian**



Diagrammatic section showing the stratigraphic extent of Zn-Pb mineralization in the Lower Carboniferous.

Limestone, a mudbank complex up to 1,500m thick which thins into isolated units set in an argillaceous bioclastic envelope to the north, that hosts the Tynagh, Silvermines, Galmoy, Lisheen and Harberton Bridge deposits as well as a number of minor ones. Significant mineralisation has also been found in the underlying sub-Waulsortian strata (Silvermines, Lisheen). Thirdly, the overlying shelf limestone facies of the **Supra-Waulsortian** strata, in which cross-cutting deposits at Harberton Bridge and nearby (Allenwood, Rickardstown) are developed. The structural pattern of widespread normal faulting is also favourable, in that the deposits found to date are all associated with ENE trending faults that often appear to have acted as conduits



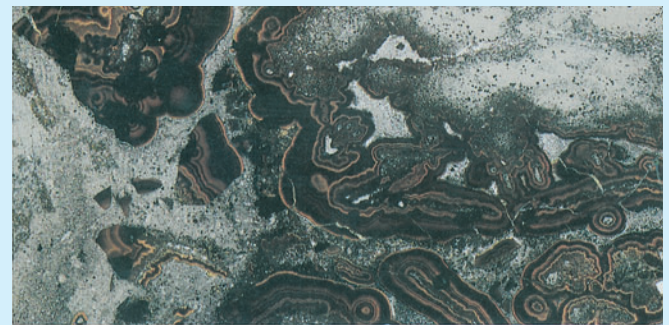
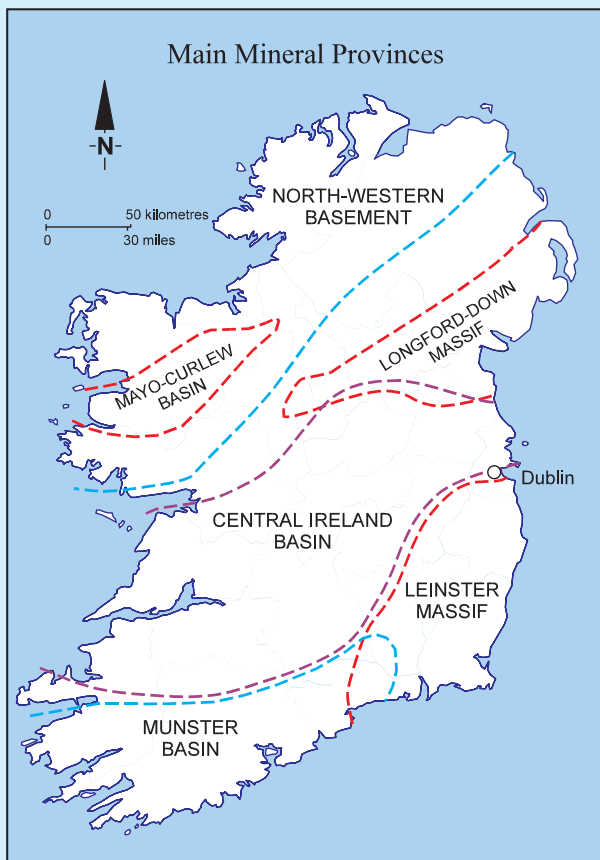
for hydrothermal fluids, and control by known basement lineaments has also been suggested. Other regions also have potentially favourable geological settings, although with limited discovery success to date. Metamorphic rocks in the **North-Western Basement** are known to contain minor stratabound base metal and barite mineralization, with numerous historic workings, while the Abbeytown deposit is located in the Lower Carboniferous cover. Thick Lower Carboniferous clastics in the **Munster Basin** have also been shown to contain structurally influenced zinc-lead mineralization.

Mineralization

Three gross styles of mineralization are recognised. Most significant are the stratabound (and in some cases stratiform) deposits hosted in the Navan Group and Waulsortian Limestone (the so-called 'Irish type'), and the cross-cutting deposits (MVT) typically found in the Waulsortian Limestone and Supra-Waulsortian lithologies. Vein-hosted mineralization is widespread in several provinces, but is not economically important.

The stratabound deposits are preferentially located in the stratigraphically lowest non-argillaceous carbonate strata. At Navan the mineralization occurs as stacked stratabound lenses, while the Waulsortian-hosted deposits have a variety of form, with regular (Lisheen, Garrycam) or irregular tabular

lenses (Galmoy, Upper Silvermines), cross-cutting epigenetic zones (Lower Silvermines) or discrete pods (Tynagh, Ballinalack). Sphalerite and galena are the main sulphides, with a range of textures from finely laminated sphalerite rhythmites to host-rock replacement to cavity infill. Barite is usually associated, the proportion varying between deposits, and silver is typically present, while haematitic ironstones are developed laterally at Tynagh and Ballinalack. Enhanced zones of mineralization are associated with NE or ENE trending faults or mineralized fractures. Pre-mineralization dolomitization seems widespread, with a hydrothermal ore-related phase prominent at Silvermines, Galmoy and Lisheen.



Galmoy rock matrix breccia (x 3) showing sphalerite and galena. (Courtesy: Irish Association for Economic Geology).

The MVT deposits found at Harberton Bridge and nearby are typified by their cross-cutting nature and breccia association, with intermittent mineralization extending from the Navan Group upwards through the Lower Carboniferous sequence. Deposit form varies from tabular, dome, or pipe style, but is typically as tabular bodies at the base of the Waulsortian Limestone, and in some cases extend upwards for up to 500m into overlying strata. The bodies have a basal rock-matrix core, overlain by cavity-fill breccias and enclosed by crackle breccias. Marcasite, sphalerite and galena are the typical sulphides, formed as clasts or coarsely crystalline forms in the rock-matrix breccias, and as sulphide cement in the other breccia types. Dolomitization is extensive, with pre- and post-ore phases.

Exploration Targets

The last 40 years of exploration have identified a number of key targets, especially in the orefield of the Central Ireland Basin.

- The lowest non-argillaceous carbonates of both the Navan Group in the northern part of the Basin, and the Waulsortian in the central and southern parts.
- Major NE or ENE trending fault structures that displace the Navan Group or Waulsortian Limestones. Locations near or against inliers are targets, as are the points of maximum throw on faults.
- The Munster Basin, where major fault structures are known, and thick Lower Carboniferous fine-grained clastics have yielded high-grade intersections of lead-zinc over short intervals.
- The Dalradian metamorphic rocks of the North-Western Basement, where good zinc-lead intersections have been found, and in the cover rocks of Carboniferous age.

All modern discoveries have been at shallow levels (< 200m), suggesting that deeper deposits remain to be discovered.

Major Deposits

- **Galmoy**

The Galmoy zinc-lead deposit, owned and operated by Arcon Mines Ltd., was discovered in 1986. Two separate sulphide orebodies occur approximately 70m below surface and are hosted in basal Waulsortian (Lower Carboniferous) "Reef" mudbank limestones. The host rock has been extensively dolomitized and brecciated, and the mineralization is regarded as replacement/stratabound. There are three orebodies, the G the CW and the K. The G orebody is a classic "Irish type" deposit and occurs in the hanging wall of a major northeast fault, the G Fault. The CW and K orebodies, located to the northeast and north of the G orebody respectively, may be related to northwest linear structures associated with the G Fault.

Production at Galmoy commenced in early 1997. Milled tonnage in 2003 was 660,000t (the same as in 2002), grading 11.27% Zn and 2.66% Pb. This produced 119,000t of zinc concentrate (51.68% Zn). Total production (1997 to 2003) is 3.8Mt grading 10.72% Zn and 1.41% Pb. Reserves at end of June 2003 were 5Mt grading 14.5% Zn and 4.3% Pb. This includes the R Zone mineralization, discovered in 2002. Arcon International Resources believe that the mine life will be extended to 2012.

- **Lisheen**

The carbonate-hosted zinc-lead deposit at Lisheen was discovered in 1990 as a result of geological modelling and shallow soil geochemistry, including the use of

concentrate (53.9% Zn) and 35,000t of lead concentrate (60.0% Pb). Total production (1999 to 2003) is 5.09Mt grading 11.63% Zn and 2.41% Pb. Reserves at end 2003 were 9.86Mt grading 12.41% Zn and 2.14% Pb, with additional Resources of 0.89Mt grading 12.25% Zn and 1.12% Pb. In September 2003 the operator and 50% owner, Anglo American, purchased the other 50% from junior partner Ivernia West.

- **Silvermines**

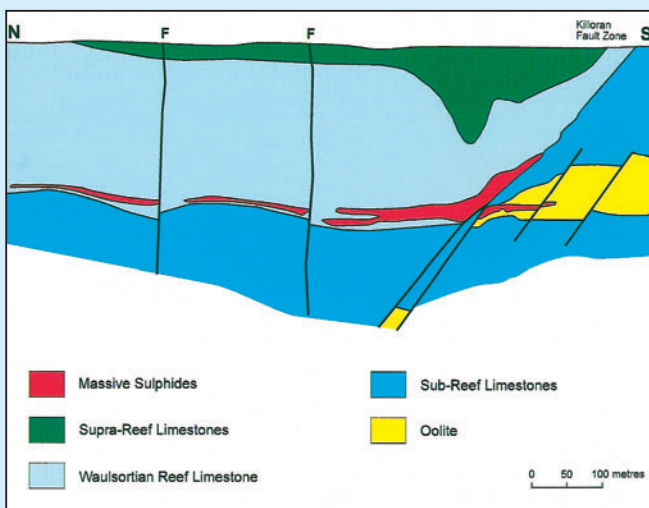
Historically, lead, silver, copper and zinc had been mined near Silvermines from vein deposits in Silurian metasediments and basal Carboniferous clastics that were associated with the E-trending Silvermines Fault Zone. In 1963, following geochemical and geophysical surveying, a largely geologically-directed drilling programme intersected ore-grade lead-zinc mineralization in Lower Carboniferous carbonates in the hanging wall of the northerly-downthrowing Fault. The Silvermines deposits comprise two main styles of mineralization; the upper zones are typically stratiform sedex massive sulphides and occur at the base of the Waulsortian "Reef" Limestone; the lower zones are epigenetic (veins, breccias) and occur within an underlying dolomite and in the basal clastics and Silurian metasediments. The lower zone represents a feeder to the upper zone. The upper zone contained 12.94Mt grading 6.78% Zn and 2.55% Pb, while the lower zone contained 4.74Mt grading 5.49% Zn and 2.44% Pb.

The underground mine began production in 1968, and from then until closure in 1982 the operators, Mogul of Ireland, produced some 10.78Mt of ore grading 7.36% Zn and 2.70% Pb. There remains a deposit of some 6.89Mt grading 4.98% Zn and 2.26% Pb.

- **Tynagh**

This Lower Carboniferous carbonate-hosted, stratiform, lead-zinc-copper-silver-barite orebody was found in 1961 as a result of conventional shallow soil geochemistry and geophysics (EM and IP). There are two zones of primary mineralization, of which the second one was discovered by geologically-directed drilling in 1967-1968, and an overlying near-surface zone of secondary mineralization. The near-surface residual oxide ore was developed by open-pit, as were some of the sulphides, while the remainder of the sulphide orebody was worked underground. The primary sulphide mineralization (galena, sphalerite, chalcopyrite) was hosted mainly as lenticular bodies in Waulsortian micrites in the hanging wall of the E-trending North Tynagh Fault. The higher grades of mineralization are found adjacent to the Fault and towards the base of the Waulsortian. The deposit contained approximately 10Mt grading 8% Pb and 4% Zn, with economic grades of copper and silver. In addition, sand-grade barite was recovered from the tailings.

The mine commenced production in 1965 in the residual orebody, which was worked until 1974, when mining became entirely underground. The orebody was worked out by 1980.



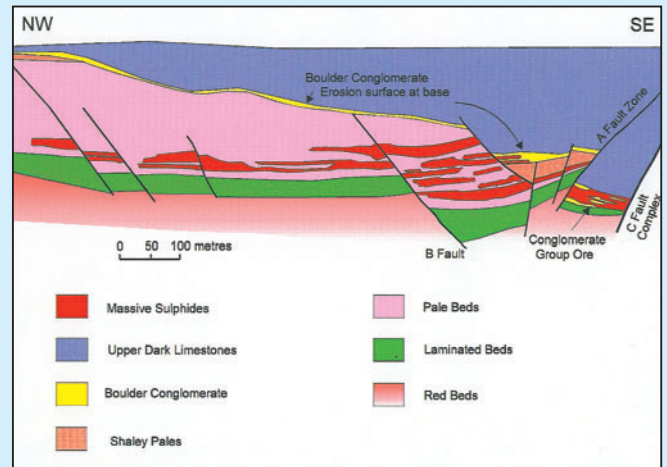
Diagrammatic cross section through the Lisheen deposit (Main Zone) Co. Tipperary.

historic exploration data. Mineralization occurs as massive stratiform sulphide lenses at the base of dolomitized Waulsortian (Lower Carboniferous) "Reef" micrites in the northern hanging wall of the ENE trending Killoran Fault Zone. Production at the underground mine commenced in September 1999. During 2003 the mine produced 1.52Mt of ore grading 12.30% Zn and 2.08% Pb. This yielded 314,000t of zinc

- **Navan**

Discovered in 1970 and brought into production in 1977, the Navan deposit supports the largest zinc mine in Europe, the eighth largest in the world. The orebody comprises a stacked series of lenses of massive stratiform sulphides hosted in Lower Carboniferous carbonates. The mine is owned by New Boliden and operated by its wholly-owned subsidiary, Tara Mines Limited.

During 2003 the mine produced 2.5Mt of ore grading 7.94% Zn and 1.68% Pb. This produced 335,000t of zinc concentrate (56.2% Zn) and 47,000t of lead concentrate (62.3% Pb). Total production (1977 to 2003) is 57.7Mt grading 8.33% Zn and 2.05% Pb. At the end of 2002, total Ore Reserves (Proven and Probable) were 24.4Mt grading 9.2% Zn and 1.9% Pb. In addition, Mineral Resources (Measured, Indicated and Inferred) totalled 21.2Mt grading 7.3% Zn and 2.2% Pb.



Diagrammatic NW-SE cross-section through the central part of the Navan deposit, Co. Meath.

Data Availability

A substantial amount of information is available from two Divisions, both within the Department of Communications, Marine and Natural Resources.

- **Exploration and Mining Division**

The Exploration and Mining Division (EMD) deals with minerals policy, the administration of the State mining and prospecting system and minerals promotion. The Division comprises both administrative and technical staff, and is a key reference point with a full support service on all regulatory matters, including:

- Legislative provisions
- Reference information on the geographical areas of all prospecting licences
- A quarterly publication on current ground holdings, or directly on an informal basis
- A contact for companies new to Ireland, or those interested in joint venture arrangements
- General reviews on various aspects of exploration and mining in Ireland
- Information on consultants and contractors based in Ireland
- Information on environmentally sensitive areas
- Exploration company reports released since 1 January 2000, in digital format
- Release of airborne geophysical surveys submitted by exploration companies

- **Geological Survey of Ireland**

The Geological Survey of Ireland (GSI) is a Division whose

mandate is the provision of earth science information and advice. Relevant data sources include:

- Paper geological maps at various scales. 1:100,000 maps with selected mineral localities described in associated reports. 1:25,000 and 1:10,560 *ms* maps with outcrop data. Smaller-scale mineral deposit and metallogenic maps of Ireland
- Digital maps. Seamless geological map, based on 1:100,000 paper maps (available end 2003). All outcrops on 1:10,560 *ms* maps will be digitised (available mid 2003), and borehole database (15,000 holes) available shortly
- Mineral Exploration Open File. Assessment reports submitted by exploration companies under the terms of their Prospecting Licences and released upon surrender of the licence or six years after lodgement
- Mine Records. Drawings, plans and documents on historic and recent mines that have now closed
- Mineral Localities Database. Summary information for over 5,500 known mineral localities
- Regional Geochemical Database. Multielement data in both map and digital formats for selected areas
- Publications on selected mineral commodities in Ireland, and mineral locality data compilations
- Drillcore. 180,000m of drill core is available for inspection in a modern core library
- Aeromagnetic data. 49,000 line km at a 1-2 km line spacing of regional aeromagnetic data (1979-1981), covering the central two-thirds of the country. Data is also available from two localised helicopter surveys (magnetic, frequency EM, radiometric).

Further Information

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Cover photographs: Aerial view of Tara Mines Ltd. at Navan, Co. Meath (courtesy: Tara Mines Ltd.); inset, reduced part of 1:100,000 bedrock geological map of the area around Galmoy and Lisheen (published by GSI).