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Introduction

This monograph presents the results of archaeological investigation at a Bronze Age copper mine in south-west Ireland. The Cork and Kerry region was an important source of copper during the Chalcolithic and Bronze Age, with well-known mining centres at Ross Island and Mount Gabriel. There are other prehistoric mines in the region, including the focus of this study, namely Derrycarhoon in county Cork. This mine produced copper during the Middle to Late Bronze Age transition (*c.*1300–1000 BC), a period of significant metal use in Ireland and elsewhere in Europe.

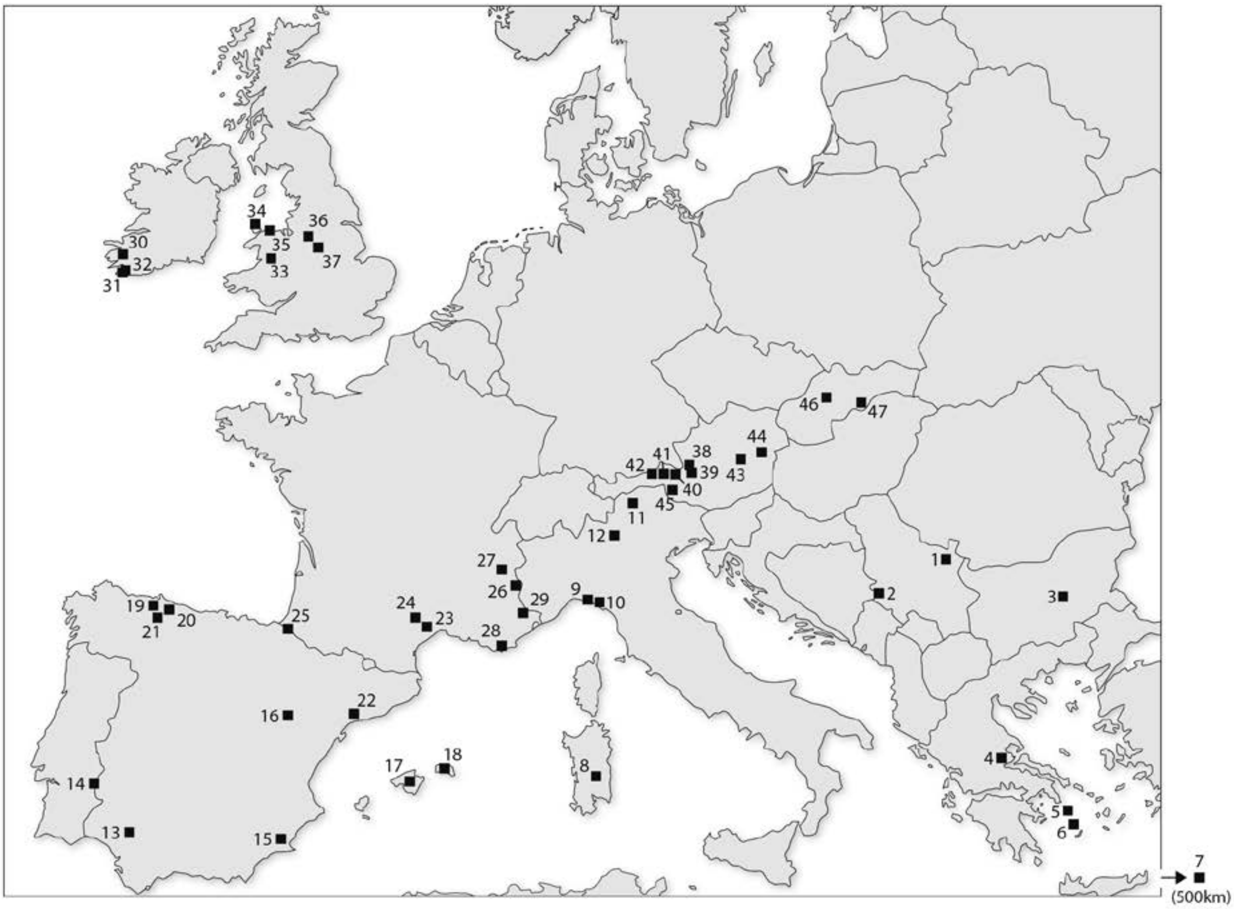
1.1 Prehistoric Copper Mining in Europe

The vast quantity of copper and bronze objects recorded from late prehistoric Europe attests to the importance of metal for different culture groups across the continent. That dependency began slowly with an early use of copper and gold during the Copper Age ('Chalcolithic'), which occurred in different regions between the sixth and third millennia BC. As demand grew across Europe, technical advances led to the widespread adoption of a new metal alloy by 2000 BC, or shortly afterwards. The Bronze Age that followed was marked by a growing dependency on tin-bronze for the production of tools, weapons and other types of metalwork. The mining of copper and tin in certain regions drove the wider supply of bronze along new trade networks that included other commodities. That allowed non-metalliferous regions, such as Denmark, and those where ore deposits could not be easily mined, such as Sweden, to develop sophisticated metalworking without being involved in primary production. That trade, driven by a phenomenal demand for bronze, had important social and economic implications for groups directly involved in copper mining during the second millennium BC.

Across Europe the first discoveries of ancient copper mines occurred when 'old men's workings' with primitive tools were discovered during the industrial mining of recent centuries. That primitive technology, and the absence of historical records, suggested those mines were of considerable antiquity, dating to the Roman period or earlier. The earliest records are in mining literature of the eighteenth and nineteenth centuries, written mostly by engineers interested in the early history of their profession. Such reports led antiquarians to speculate on the significance of ancient mine discoveries as potential sources of metal in the Bronze Age. The first investigations were undertaken in Austria in the late nineteenth century. Over the next century early mine discoveries in other parts of Europe led to research projects where historical research combined with scientific fieldwork involving geoarchaeological survey and excavation.

Prehistoric copper mines are now recorded in many parts of Europe (Figure 1.1; reviewed by O'Brien 2015). The earliest known examples are in the Balkans, including Rudna Glava in eastern Serbia worked in the sixth and fifth millennia BC, and Aibunar in the Sredna Gora mountains of Bulgaria. In northern Italy, early copper mines are recorded in the Ligurian Alps, at Libiola dated to the later fourth millennium BC, and at Monte Loreto worked *c.*3500–2500 BC. The earliest copper mines in France are in the district of Cabrières-Peret of the Languedoc, where copper workings and production sites spanning the third millennium BC have been identified. In Spain, the earliest mines are in the Cantabrian mountain range, at El Aramo and El Milagro in Asturias, and La Profunda in León, which date from the mid-third millennium BC into the early centuries of the Bronze Age.

Copper mining intensified in many parts of Bronze Age Europe during the second millennium BC. Major producers included the mines of the Troodos Mountains of central and western Cyprus, from where the word 'copper' derives. Other large mines are found in the eastern Alps, with Bronze Age copper production on an enormous scale in several parts of Austria. The most important sources were in the Salzach valley, including both the Mitterberg mountain area west of Bischofshofen (O'Brien 2015, fig. 7.6), the St Veit area to the south and the Glemmtal area to the west. Farther west, Bronze Age mining was undertaken in the Kelchalm and Schwaz-Brixlegg areas of north Tyrol, the Matrei area of east Tyrol, and in parts of eastern Austria, such as Eisenerz in Obersteiermark. The Austrian mines were worked at various times *c.*1800–700 BC, with near-industrial levels of production *c.*1500–1000 BC, supplying copper across Europe as far as Britain and Ireland. That mining extended into the southern Alps in northern Italy, with Chalcolithic and Late Bronze Age copper smelting recorded in the Trentino district of south Tyrol. In southern France, some copper mines in the Languedoc, and at St Véran in the Alps, were worked into the early centuries of the Bronze Age. Other early copper mines have been identified along the southwestern end of the Massif Central in southern France. These include mines at Bouco-Payrol in Aveyron, and possibly in the district of Seronais between St Girons and Foix in the south. Bronze Age mines have been identified in many parts of Spain, including the aforementioned examples in Cantabria, and a notable concentration in Huelva and surrounding provinces of the south-west region. Examples there include the mines at Chinflon and Cuchillares in Huelva (Figure 1.2), Potosí and Aznalcóllar in Sevilla, La Loba in Cordoba and Berrocal in Badajoz (*ibid.*).



Prehistoric Copper Mines in Europe

1. **Rudna Glava**, Serbia; 2. **Jarmovac**, Serbia; 3. **Ai Bunar**, Bulgaria; 4. **Othrys Mountains**, Greece*; 5. **Kythnos***; 6. **Seriphos***; 7. **Troodos Mountains**, Cyprus; 8. **Funtana Raminosa**, Sardinia*; 9. **Libiola**, eastern Liguria; 10. **Monte Loreto**, eastern Liguria; 11. **Trentino***; 12. **Campolungo**, Lombardy; 13. **Chinflon**, Huelva; 14. **Mocissos**, Portugal; 15. **Sierra de Orihuela**, south-east Spain; 16. **Loma de la Tejeria**, Teruel*; 17. **Mallorca***; 18. **Mitja Lluna**, Minorca; 19. ***El Aramo***, Asturias; 20. **El Milagro**, Asturias; 21. **La Profunda**, León; 22. **Montsant**, Tarragona; 23. **Cabrières**, Languedoc; 24. **Bouco-Payrol**, Aveyron; 25. **Causiat**, western Pyrenees; 26. **Saint-Véran**, French Alps; 27. **Les Rousses**, Grandes Rousses Massif; 28. **Maraval**, Toulon; 29. **Clue de Roua**, Alpes-Maritimes; 30. **Ross Island**, Co. Kerry; 31. **Mount Gabriel**, Co. Cork; 32. **Derrycarhoon**, Co. Cork; 33. **Cwmystwyth**, mid Wales; 34. **Parys Mountain**, Anglesey; 35. **Great Orme**, north Wales; 36. **Alderley Edge**, Manchester; 37. **Ecton**, Staffordshire; 38. **Mitterberg**, Salzburg; 39. **St. Veit**, Salzburg; 40. **Saalfelden-Becken**, Salzburg; 41. **Kitzbühel-Kelchalm**, North Tyrol; 42. **Schwaz-Brixlegg**, North Tyrol; 43. **Eisenerz**, Upper Styria*; 44. **Prein**, Lower Austria*; 45. **Virgental**, East Tyrol; 46. **Spania Dolina-Piesky**, Lower Tatras Mountains; 47. **Spanie Pole**, Rimavská Sobota, Slovakia.

* *indicates areas with evidence of smelting where early copper mines are likely to exist.*

Figure 1.1 Prehistoric copper mines in Europe (O'Brien 2015; smaller mines in the same regions not shown).

Britain was both a major producer and consumer of copper in the Bronze Age. The earliest copper used *c.*2500–2100 BC was arsenical metal sourced through Beaker culture exchanges with Ireland and the European mainland. The mining of local copper deposits began *c.*2200–2000 BC, at a time when bronze metallurgy was developed using tin sources discovered in Cornwall and Devon. Research in recent decades confirms there was intense copper mining activity in Wales and north-west England in the Early to Middle Bronze Age, *c.*2100–1400 BC (Figure 1.3). Copper mines in the mountains of central Wales include Cwmystwyth where mining commenced around 2100 BC at an altitude of 420m, and continued for the next 400 years or so with open trench extraction of oxidised mineralisation to a depth of *c.*12m (Timberlake 2003). Other examples have been investigated at Nantyreira, Nantyrickets, Llancynfelin, Nantyrarian, Tyn y Fron, Ogof Wyddon and Erglodd (Timberlake 2009). Copper mines of similar age are recorded at Ecton in the Peak District of Staffordshire (Timberlake 2009), and at Alderley Edge near Manchester (Figure 1.4), where surface pits extracted secondary copper minerals from soft Triassic sandstones using fire-setting and stone hammers (Timberlake and Prag 2005).

Bronze Age mining began along the north Wales coastline around 2000 BC, with workings at Parys Mountain on

Figure 1.2 Bronze Age trench copper mines at Chinflon, Huelva province, south-west Spain (photograph: William O'Brien).

Anglesey, and on the Great Orme, a limestone headland near Llandudno. The latter is one of the largest copper mines in Bronze Age Europe, worked more or less continuously from *c.*1700–800 BC (Dutton and Fasham 1994; Lewis 1994, 1998), with peak production in the Middle Bronze Age, *c.*1600–1400 BC (Williams and Le Carlier de Veslud 2019). That mining took the form of open-casts and trenches on exposures of oxidised mineralisation in rotted dolomitised limestone (Figure 1.5). These surface workings continued underground to form an elaborate complex of tunnels approximately six kilometres in total length and up to 65m in depth. Stone hammers and bone gouges were used to tunnel the softer limestone, with fire-setting used on harder rock.

In conclusion, the size of Bronze Age copper mines varied considerably across Europe, from small-scale production for mostly local needs, to larger sustained operations with near-industrial output. The latter were part of extensive trade networks, prominent examples being the mines of Cyprus and the Austrian Alps. Still greater were the copper mines of Kargaly in the southern Urals of Russia. Mining commenced there in the later fourth and early third millennia BC, reaching a peak in the second millennium BC with many thousands of individual mine operations. Some estimates suggest that up to two million tonnes of copper ore were extracted at Kargaly during the Bronze Age (O'Brien 2015, 187).

The archaeological record

The archaeology of Bronze Age copper mining is distinctive to the activity itself and its geological environment. Much depends on the time and energy commitment to mining at a given location. That involved varying amounts of rock extraction, creating surface openings that may lead into underground workings. These mines vary in size and form depending on the geological setting, the technology employed and the scale of operation. They include surface pitting and trenching to varying depths, as well as underground mining accessed by tunnels and vertical or inclined shafts. The bedrock openings are generally accompanied at the surface by dumps of broken rock ('spoil') discarded by the miners, the size of which can be an indication of the scale of rock extraction. Other activity areas are not well exposed today, such as mining camps where hut shelters, hearths and cooking areas, equipment and fuel stores were located, as well as places where copper ore was smelted to metal in furnaces. The preservation of that archaeological evidence can vary considerably, depending on the geological environment, soil conditions, mine drainage, and disturbance caused by later mining and other activities. Many early copper mines in temperate Europe flooded soon after they were abandoned, resulting in waterlogged preservation of wood and other organic materials. There can also be excellent preservation of organic materials, particularly bone artifacts, where mining was carried out in calcareous geology.

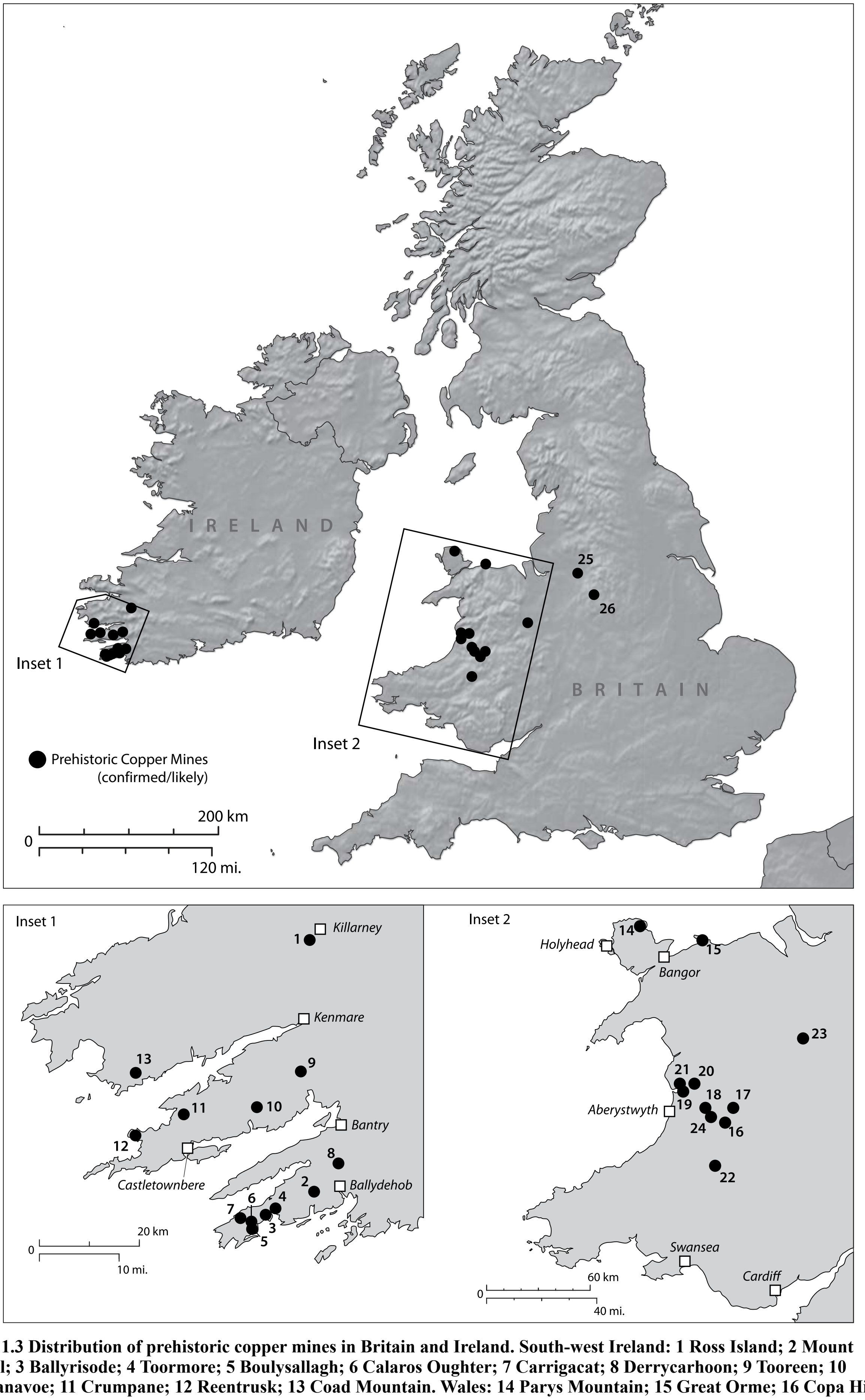


Figure 1.3 Distribution of prehistoric copper mines in Britain and Ireland. South-west Ireland: 1 Ross Island; 2 Mount Gabriel; 3 Ballyrisode; 4 Toormore; 5 Boulysallagh; 6 Calaros Oughter; 7 Carrigacat; 8 Derrycarhoon; 9 Tooreen; 10 Canshanavoe; 11 Crumpane; 12 Reentrusk; 13 Coad Mountain. Wales: 14 Parys Mountain; 15 Great Orme; 16 Copa Hill, Cwmystwyth; 17 Nantyreira; 18 Nantyrarian; 19 Llancynfelin; 20 Ogof Wyddon; 21 Panteidal; 22 Pen Cerrig y Mwyn; 23 Llanymynech Ogof; 24 Tyn y From. England: 25 Alderley Edge; 26 Ecton (after O'Brien 2015).

Figure 1.4 Bronze Age and later trench mining along the Engine Vein, Alderley Edge, Manchester, England (photograph: William O'Brien).

Figure 1.5 Bronze Age trench workings at the Great Orme copper mine, north Wales (photograph: William O'Brien).

The recovery of this evidence mostly focuses on mine workings of a 'primitive' character, accompanied by spoil deposits with distinctive mining artifacts. Dating can be controversial, particularly for sites with several phases of mining where diagnostic material culture is absent. Prehistoric copper mines cannot generally be dated on surface features alone. While the technology used may indicate a certain antiquity, that must be critically assessed for different regions. For example, fire-setting was widely used in Bronze Age mining, however this method had an earlier history and continued to be used into early modern times in some parts of Europe. This need not be a difficulty as fire-setting leaves wood fuel residues that allow such mines to be dated by the radiocarbon method. The discovery of distinctive artifacts, such as pottery, can also indicate the age and cultural affinities of a mining group. Such finds are not common in Bronze Age mines, where specialized mining implements typically occur, including wooden and bone tools that can also be radiocarbon dated. Stone tools are the most common finds in early copper mines, including cobble hammers or 'mauls', anvils and grinding stones. While caution is advisable in dating such basic implements, radiocarbon dating confirms they were widely used in prehistoric copper mining in Europe.

The distribution of Bronze Age copper mines today reflects the survival and investigation of field evidence, and also the geological occurrence and accessibility of copper deposits. The latter do not occur evenly across Europe, which is partly why it took three millennia or so for copper metallurgy to spread across the continent. Not all copper deposits could be mined in the prehistoric period, as many occur at great depth in orebodies with low metal content and complex mineralogy and chemistry. Conversely, many locations where copper was extracted in the Bronze Age were not economically viable in historic times, which can contribute to the survival of early mines. Cultural preferences must also be considered, not least the efforts of some source regions to control metal supply by restricting the dissemination of mining and metallurgical knowledge. Other factors include perceived 'ownership' of the mineral resource, the motivation to invest time and energy in mining, and the value attached to the resulting metal. Not all regions with copper deposits responded in the same way to the opportunities presented by the new technology. Some were less receptive due perhaps to their cultural outlook and economic priorities, or an inability to mobilise the considerable resources required to engage in mining and metal production. Those regions with comparative advantages in other resources possibly chose to obtain metal through trade, as was necessary for regions with no natural sources of copper. Some groups exploited metal resources at a low level, embedded within economies where agriculture was a greater priority. For others, copper mining became a key economic activity that shaped the development of their societies over many centuries. Those mining traditions were determined by cultural choice and socio-economic background, as well as being contingent on historical and environmental circumstances.

Copper supply in prehistoric Europe

Broadly, there were three types of copper mining in Chalcolithic and Bronze Age Europe, based on the type of copper mineralisation exploited and the prevailing smelting technology. The extraction of native (pure) copper is not well recorded due to the rarity of its use in prehistoric Europe. The focus here is on copper ore, namely metallic minerals that occur in a concentrated form in an orebody and can be mined with prevailing technology.

The earliest mining involved the extraction of secondary minerals, such as malachite and azurite, from surface zones of oxidation. These minerals are rich in copper and relatively easy to smelt using a primitive hearth or crucible technology. They were first mined in the Chalcolithic, and where locally available continued to be exploited in the Bronze Age, as recorded at Mount Gabriel-type mines in south-west Ireland, the Great Orme and other mines in Wales, and the mine at the centre of this study.

The second type of mining involved the use of fahlore ('grey copper ore'), namely complex sulfosalts of the tennantite–tetrahedrite series. These were rich in copper, with high levels of arsenic and/or antimony that added significantly to the quality of the smelted metal. Like the oxidised ores, fahlore can be smelted using a low temperature, non-slagging technology. Fahlore mining probably commenced in central Europe in the fourth millennium BC, and is particularly associated with the spread of Beaker culture metallurgy in western Europe in the third millennium BC. Examples include El Aramo in northern Spain, Cabrieres in southern France and Ross Island in Ireland. The use of fahlore declined significantly with the adoption of tin bronze around 2000 BC, but developed further in Austria during the Late Bronze Age, at mines such as Brixlegg and Mauk in North Tyrol.

A third type of prehistoric mining in Europe centred on the extraction of sulphide ores, particularly copper-iron sulphides such as bornite and chalcopyrite. Their first exploitation is not well dated, probably beginning in the Alpine zone during the Early Bronze Age. While sulphide ores can be reduced with primitive processes, the efficient recovery of metal requires an advanced furnace technology, which may have been first developed in Austria in the Early to Middle Bronze Age. On current knowledge, that technology was not present in Britain or Ireland during the prehistoric period.

While Bronze Age mines produced smelted copper, recycling was also an important source of metal in that period. For many metalworking traditions the supply of bronze included primary metal coming directly or indirectly from a mine source, as well as secondary metal recycled from scrap over time. With recycling, the circulation of bronze could include mixtures of both types from the same or different mines, with obvious implications for understanding the final metal composition and its geological origin.

1.2 Metal in Bronze Age Ireland

Copper metallurgy was introduced to Ireland in the mid-third millennium BC as part of the Beaker culture network of contacts across north-west Europe. The new technology was rapidly adopted, with copper objects in circulation across the island during a short-lived Chalcolithic ('Copper Age'), *c*.2400–2100 BC. This was driven by the discovery of a major source of arsenicated copper at Ross Island, Killarney, Co. Kerry. The earliest use of tin-bronze occurred around 2100 BC, with widespread adoption of this metal across Ireland represented by large-scale production of Killaha series axeheads over the next two centuries (Harbison 1969). As the Early Bronze Age progressed the scale of production gradually increased, linked to new mine sources, recycling and a spreading knowledge of metalworking across Ireland. This is reflected in the large number of developed bronze axeheads, including many decorated examples, from the period *c*.2000–1600 BC (Harbison 1969a). That, together with early expertise in sheet gold (discs and lunulae) indicates a standard of metalworking on a par with many other regions of Europe.

The successful introduction of copper alloying to Ireland is all the more remarkable when the paucity of tin sources is considered. The first bronzes were made with copper from Ross Island mine mixed with metallic tin, but there are no sources of the latter in the south-west region. Of greater significance was the supply of tin from south-west England, with archaeological evidence the alluvial tin deposits of Cornwall and Devon were exploited in the Early Bronze Age. The discovery of Irish lunulae in Cornwall (Taylor 1980), as well as Irish-type bronze axeheads in stream tin workings in that region (Shell 1979; Penhallurick 1986), indicates trade in metals across the Irish Sea from around 2000 BC. This is supported by lead isotope analysis that points to south-west England as a potential source of early gold in Ireland (Standish *et al*. 2015). The supply of tin was likely to have been a constraint on primary bronze production in Ireland throughout the Bronze Age. It is difficult to know how connections with Cornwall were affected by the closure of Ross Island mine *c*.1900–1800 BC, when attention may have turned to alternative sources in Ireland, such as the small alluvial deposits in Wicklow and the Mourne Mountains (Warner *et al*. 2010).

Wherever the tin came from, there was certainly a growing dependency on bronze to make weapons and work implements in Ireland from *c*.1600 BC (Ramsey 1995). Approximately 2500 bronze artifacts are recorded in Ireland for the period *c*.1600–1300 BC. These include the output of flanged axeheads and palstaves, dirks, rapiers and looped spearheads during the Killymaddy phase of the Middle Bronze Age (*c*.1550–1350 BC). Metal production intensified during the Bishopsland phase (*c*.1350–1100 BC), when influences from Continental Europe channelled through the 'ornament horizon'/Taunton metalworking of southern Britain led to the introduction of new metalworking techniques and a novel range of bronze and gold artifacts (Eogan 1964; 1994; Waddell 2010, 187–213). Bishopsland metalworking in Ireland produced specialised toolkits, with advances in bronze casting reflected in the use of clay moulds to make new object types such as the first bronze swords (Ballintober type). Novel types of gold ornament were also made, including a range of torcs, ear-rings, tress rings and bracelets. The appetite for fashion and innovation is clearly reflected in the great variety of bronze spearheads produced in the Middle Bronze Age.

With the beginning of the Late Bronze Age there was further intensification of bronze and gold production across Ireland, culminating in the metalworking of the Roscommon (*c*.1150–1000 BC) and Dowris (*c*.1000–700 BC) phases. Metalworking reached new heights in this period in terms of the scale of production, the great variety of metal products, and the technical accomplishment of the craft workers (Waddell 2010, 233–277). This was a time of conspicuous wealth in Ireland, most visibly expressed through large-scale metal production hoarding, and the use of prestige metalwork. A wide variety of bronze implements were produced, with evidence of specialised tools used in different craft activities. This is illustrated by the eponymous hoard from Co. Offaly that originally contained over 200 bronze objects, including many new types for Ireland. Among the items represented are socketed axeheads, hammers, gouges and spearheads, as well as punches, razors, knives, swords, chapes, spear-butts, horns, hollow-cast pendants (crotals), cauldrons and buckets (Eogan 1983). The Dowris Phase is also known for the excellence of goldworking. A great variety of personal ornaments and prestige objects were made from solid bar and sheet gold, as well as from gold wire and foil, including gorgets, dress fasteners, lock-rings, penannular rings and types of bracelet.

There was also a marked increase in the production of bronze weaponry during the Late Bronze Age. The first swords were introduced from southern England around the twelfth century BC. The earliest examples were the short Ballintober leaf-shaped type with organic handles riveted to projecting tangs (Eogan 1965; Waddell 2010). These were replaced by flange-hilted swords, imported or copied from Erbenheim and Hemigkofen swords on the Continent, coming in again through southern England. The use of these weapons in Ireland expanded significantly after 1000 BC, when a native form of the flange-hilted, leaf-shaped sword (Eogan's class 4), known in Britain as the Ewart Park type, was produced in large numbers during the Dowris phase to around the eighth century BC. There are innovations in spearhead design during the same period. The side-looped, basal-looped and protected-looped varieties of the Middle Bronze Age were gradually replaced after 1100 BC by lunate and riveted forms during the Roscommon and Dowris phases. These were the weapons of a militarised society of competitive regional hillfort chiefdoms, where warrior-aristocrats commanded the services of specialist metalworkers (O'Brien and O'Driscoll 2017). The production of prestige weaponry and ornaments reveals a concern with ostentatious display in that period, with cult practices involving votive deposition of metalwork.

The proliferation of new tool, weapon and ornament types shows diverse influences from southern and western Britain, from northern and central Europe, Atlantic Europe and the west Mediterranean. In addition to external stylistic and technological influences, Irish metalwork was also exchanged widely in Britain and on the Continent in this period (Eogan 1995). The high level of craft specialisation in bronze and gold, and in exotic materials such as amber, is evident in the technical quality of the finished objects. Advances in metal fabrication include the widespread use of clay moulds in casting, the working of sheet bronze to make buckets, cauldrons and shields, the use of joining techniques such as riveting and soldering, and new metal compositions, such as leaded bronze and gold alloying.

During the seventh century BC the first contacts were established with iron-using cultures in Britain and mainland Europe. Thus began a slow process of technological change, represented initially by Hallstatt C material in Ireland and culminating in the widespread adoption of iron metallurgy during a period of prolonged contact with La Tène groups from the third century BC (Raftery 1994). The processes by which iron was introduced to Ireland are much debated, as is the cultural context of this innovation. There is artifact evidence of Late Bronze Age metalworkers experimenting with iron in the centuries between 600–300 BC (Scott 1990). This experimentation occurred against a background of contact with southern and western Britain, and France. Copper alloy metalworking continues in Ireland during the Iron Age (600/300 BC–400 AD), used mostly for the production of personal ornaments and prestige metalwork (see Raftery 1984).

The supply of bronze

As already mentioned, the amount of metal in circulation in Ireland increased steadily during the second millennium BC. This is indicated by the large number of bronze and gold finds, and by an increase in metal hoarding, with around 160 deposits known from the Late Bronze Age, most from the Dowris phase (Eogan 1983; 1994). For individual object types, an estimated 700 flanged axeheads and 400 palstaves are recorded from Early to Middle Bronze Age transition (Ramsey 1995), with 2000 or so socketed axeheads from the Late Bronze Age (Eogan 2000). The amount of bronze in circulation is also indicated by the massive output of specialized weaponry in the Middle and Late Bronze Age. An estimated 733 bronze swords are recorded in Ireland, a density of 8.7 finds per 1000 km^2 one of the highest in Europe (Eogan 1965, revised by Colquhoun 2015). An estimated 1800 Middle and late Bronze Age spearheads are recorded in Ireland, including 45 end-looped, 827 side-looped, 182 basal-looped, 56 protected-looped, 29 lunate, 7 basal-looped/riveted and 639 riveted leaf-shaped forms (Lineen 2017).

Allowing for survival and recovery variables, these finds represent a fraction of the total number of weapons produced. Swords and spears were rarely committed to graves in Bronze Age Ireland, which added to the amount of weaponry available where these were passed on through the generations. There were also significant levels of loss, through the conduct of war, the recycling of broken items, and the removal of weapons through votive deposition (Becker 2013). Unfortunately, the majority of these bronze objects do not have secure archaeological contexts or dating, with many found in bogs, lakes and rivers. A further problem is the limited record of metallurgical activity from settlement contexts. Bronze workshops have been identified in settlements of Late Bronze Age date, but there is little site evidence for earlier periods (see Ó Faoláin 2004 for a summary of the evidence).

Returning to the question of where bronze came from, there is much evidence for trade in metal during the Middle to Late Bronze Age, including the acquisition of raw material and the exchange of finished objects. A lot of metal was sourced through recycling and foreign trade, with the discovery of scrap hoards suggesting this was a well-organised activity. Some primary (smelted) metal may have been imported from sources in Britain, where the only known copper mine in operation after 1400 BC is the Great Orme in north Wales. The circulation of copper from that mine is likely to have declined by 1000 BC (Williams 2019; Williams and Le Carlier de Veslud 2019). Trade links with the Continent led to new sources of copper (Northover 1982), with the most important supply possibly from the east Alpine mines in Austria. Irish metalwork was exchanged widely in Britain and the Continent during the Late Bronze Age, creating a network of contacts that supported the supply of metal.

The archaeological evidence for importation of metal to Ireland is weak, with no ingot finds or shipwrecks comparable to Langdon Bay, Kent, or Salcombe, Devon (Needham *et al*. 2013). The importation of bronze is indicated by new tool, weapon and ornament types with stylistic and technical connections to southern and western Britain, and farther afield into northern, central and Atlantic Europe. This also involved exports, as Irish metalwork was exchanged widely in Britain and on the Continent in this period (Eogan 1995). The interpretation of goods in transit ('merchant hoards') is problematic, though it is likely some hoards from the later Bronze Age were connected to supply networks. Metal analyses indicate a growing reliance on imported Continental metal during the Middle Bronze Age, with declining supply from British and Irish sources (Northover 1982, fig.7). It is likely that imported bronze from the Continent grew in importance during the Penard/Bishopsland phase, to eventually dominate copper supply during the Wilburton/Roscommon and Ewart Park/Dowris phases of the insular Late Bronze Age (*ibid*., figs. 11 and 13).

The identification of specific mine sources during this period is complicated by the uniformity of bronze composition, which itself is partly a consequence of widespread recycling (Northover 1988). This has important implications for source provenancing of metalwork using chemical or isotope analyses. It is likely that recycling made a significant contribution to metal circulation during the later Bronze Age in Ireland. That activity was well organised and included the use of secondary bronze from imported or older Irish sources. A number of scrap deposits ('founders hoard') containing broken/worn objects and/or ingots point to organised production and supply networks.

While imported stock and recycling made a significant contribution to metal supply in Ireland during the Middle and late Bronze Age, the possibility of primary copper production must also be considered. This requires a review of the evidence of prehistoric mining to identify potential sources of smelted copper for that period.

1.3 Prehistoric Copper Mining in South-west Ireland

Ireland has long been regarded as a significant producer of metal in the Bronze Age. This reflects the large quantities of Bronze Age metalwork in a part of Europe with abundant sources of copper. The Cork and Kerry region was an important centre of early copper production, with confirmed or likely prehistoric mines known at 15 locations (Figures 1.3 and 1.6; O'Brien 2015, 125). The earliest are those at Ross Island in Killarney, where Beaker culture groups produced arsenicated copper during the Chalcolithic and Early Bronze Age (*c*.2400–1900 BC). Farther south, there are seven copper mines dated to the Early-to-Middle Bronze Age (*c*.1800–1400 BC) in the peninsulas of west Cork. These, and other undated examples in West Cork and South Kerry, are known as Mount Gabriel-type mines, called after the largest concentration of such workings located on the eastern slopes of this mountain in the Mizen Peninsula of Co. Cork.

The study of these prehistoric mines began during the late eighteenth/early nineteenth centuries, when mineral prospecting led to the discovery of primitive workings at several locations in south-west Ireland. Described as 'Dane's Workings' or 'Danish Mines' in mining industry and antiquarian literature, these were associated with the use of fire-setting and stone hammers. Several examples were listed in 1929 by a geologist, Tom Duffy, who discovered the remarkable early mining landscape on Mount Gabriel (Duffy 1932). This was later mapped by another geologist, John Jackson, who brought the mountain to wider attention when he obtained a Bronze Age date from one of those workings (Jackson 1968), the first radiocarbon result obtained for a prehistoric copper mine in Europe. Jackson's subsequent reviews highlighted the importance of south-west Ireland as a centre of prehistoric mining, arguing the 'Danish Mines' in that region were Bronze Age on the basis of the Mount Gabriel evidence (Jackson 1979; 1980). This was vigorously disputed over many years by an archaeologist, Stephen Briggs, who argued that Mount Gabriel and other 'Danish Mines' in south-west Ireland, including the example at the centre of this study, are early modern in date (Briggs 1983a, 1983b, 1984; for reply, see Jackson 1984). While Briggs remains to be convinced (e.g. Briggs 2003; 2004), questions around chronology have mostly been resolved by archaeological excavation and scientific dating undertaken by the author over the past four decades at nine 'Danish Mine' sites in Cork and Kerry (O'Brien 1987b; 1994; 2003).

Ross Island

As mentioned previously, copper metallurgy was introduced to Ireland in the twenty fifth century BC, coinciding with the arrival of Beaker culture (Case 1966; Sheridan 1983). Those Beaker networks were critical in the transfer of mining expertise in Atlantic Europe, through coastal connections extending from northern Spain and western France to Ireland. The new technology was rapidly introduced, with a prolific output of axeheads, daggers and halberds over the following 400 years. These copper objects have distinctive arsenic content, connected to the mining of tennantite fahlore from one major source, Ross Island mine in Killarney, Co. Kerry. The extraction of fahlore copper began there around 2400 BC and continued through the Chalcolithic into the early centuries of the Bronze Age, ending around 1900 BC (O'Brien 1995).

The early workings at Ross Island consisted of large cave-like openings on mineralised rock exposures (Figure 1.7; see O'Brien 2004 for full publication of the Ross Island research). The full extent of underground mining is uncertain as the early workings are no longer accessible due to flooding and roof collapse, problems the prehistoric miners may have faced. The copper mineral was extracted to depths of 10–12m, using simple, but effective, techniques. These included fire-setting, which left distinctive profiles on the mine walls as well as charcoal residues in adjacent spoil heaps. The heat-shattered rock face was pounded with stone cobble hammers, both hafted and hand-held. Thousands of broken examples are recorded close to the mine workings. Other tools included the shoulder-blade bones of cattle used as scoops, while a range of wooden equipment is likely to have been used.

A miner's work camp was discovered adjacent to the early workings at Ross Island. This location was used for temporary habitation, with evidence of shelters, food consumption and the use of pottery. The foundation traces of several stake-built huts where the miners sheltered were identified. Food waste in the form of cattle and pig bones, and evidence of flint working, attest to other activities in the life of this mining camp. The animal bones indicate an important agricultural base supporting the mine operation, probably located within the environs of Killarney where copper and early bronze axes made with Ross Island metal have been found.

The Beaker mine camp at Ross Island was mainly used for activities connected to the production of metal. That began with the crushing and hand-sorting of mineralised rock (ore) using stone hammers and anvils to extract high-grade tennantite, which was then ground down using basin-shaped querns. The ore concentrate was then smelted in shallow pit furnaces fuelled by charcoal. The

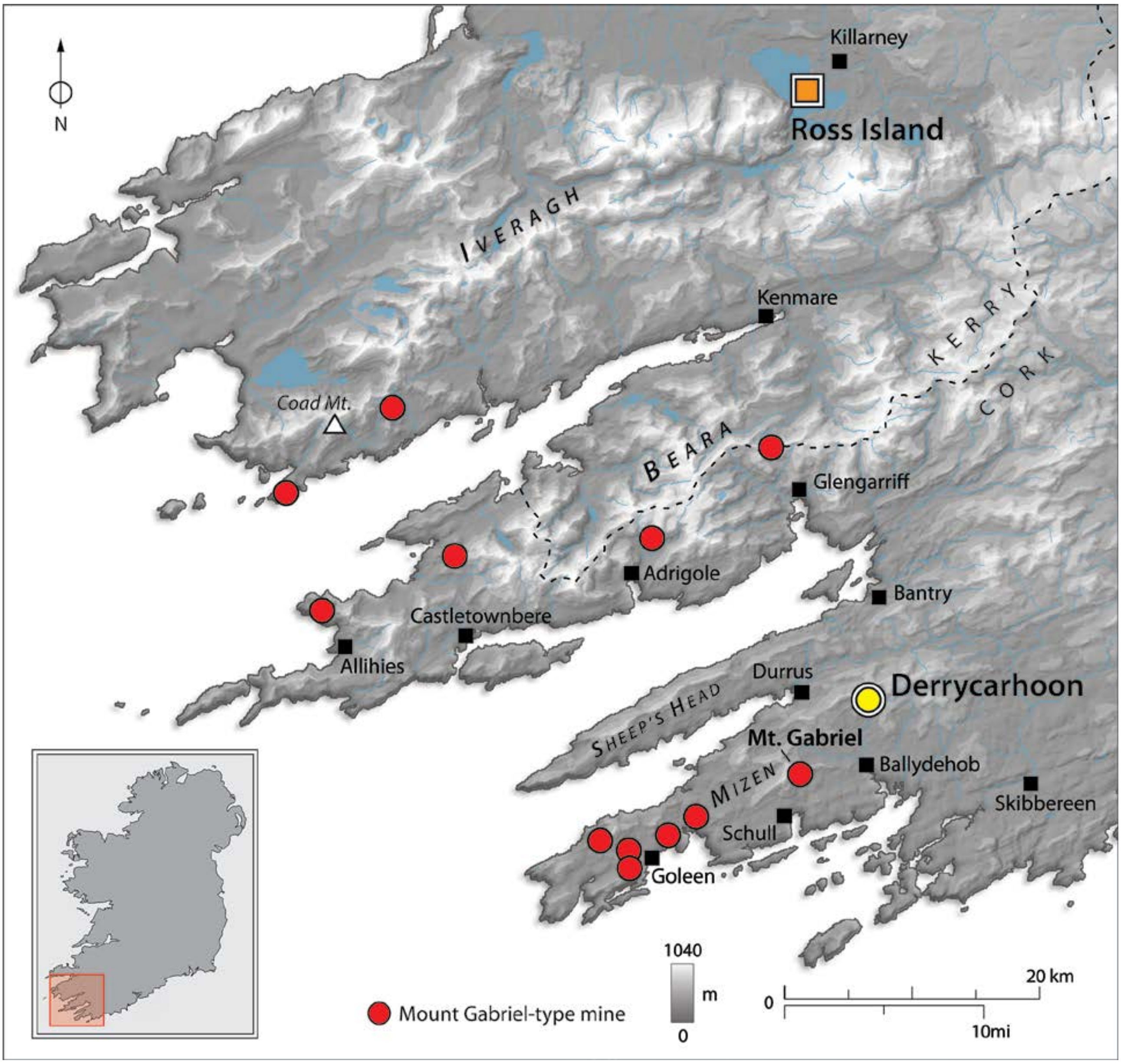


Figure 1.6 Prehistoric copper mines in south-west Ireland, showing location of Ross Island, Mount Gabriel and Derrycarhoon mines, together with distribution of Mount Gabriel-type workings in the Mizen, Beara and Iveragh peninsulas (drawing: Nick Hogan).

process was primitive, but effective, with a significant amount of copper produced over time. This was due to the large amounts of tennantite ore in the mine, which could be easily extracted and beneficiated using those hand-cobbing and smelting techniques. The tennantite has a high copper (40–45%) and low iron (<5%) content, with the major impurities (arsenic and sulphur) easily volatilised in low temperature smelting, in what was essentially a non-slagging technology.

Excavation confirms that copper droplets produced in these pit furnaces were re-melted and converted into small slab ingots, one of which was found in the mine area. These ingots were transported from the mine to settlements around Killarney, where the metal was cast into axeheads and blades in workshop settings. The arsenic content of this metal does not indicate deliberate admixture, but rather the use of a copper ore that is naturally rich in arsenic. The Ross Island tennantite typically contains around 20% arsenic, which was progressively reduced through oxidative reduction in smelting, ingot production and object casting processes to 1–5% arsenic, creating a distinctive impurity pattern (As>Sb>Ag) in the finished metalwork. Axeheads, daggers and other objects made with this arsenicated copper were widely exchanged across Ireland in the period 2400–1900 BC, with some products also reaching Britain (Northover 1982). The currency of this distinctive copper corresponds closely with a radiocarbon chronology for Ross Island, confirming that mine as the main source in Ireland. The same metal was recycled for several centuries following the closure of Ross Island mine, *c.* 1900–1800 BC (Bray and Pollard 2012).

Figure 1.7 Chalcolithic/Beaker culture copper mine at Ross Island, Killarney, Co. Kerry (photograph: William O'Brien).

The Ross Island mining was probably organised on a seasonal basis by miner/farmers, with the involvement of some full-time specialists. The food waste at the mine camp included cattle bone, which indicates contemporary farm settlement in Killarney, also confirmed in local pollen records. Excavation also uncovered approximately 450 sherds from at least 25 vessels of Beaker pottery. This ceramic can be directly associated with copper production in the mine during the period 2400–2000 BC. These well-made vessels, decorated with horizontal cord and comb impressions, were used as drinking cups by the miners. They were also employed in a washing process to extract prills of copper metal from the furnace pits. The discovery of this pottery is an important connection with the culture group that introduced copper metallurgy to Ireland at the end of the Neolithic.

On the basis of chronology and ore types, it is certain that Ross Island supplied arsenicated metal to make early copper axes in Ireland. The fact that the earliest axe forms (Castletownroche type) are made of the same type of copper places this mine close to the beginnings of Irish metallurgy. The background to this technology lies not in Britain but in mainland Europe, where the production of arsenicated copper from fahlore sources was part of a wider pattern of metal supply during the fourth and third millennia BC (Strahm 1994). The fahlore copper from Ross Island is likely to have been part of a Beaker metallurgical tradition that extended from Iberia and Atlantic France to Ireland in the mid-third millennium BC. The transmission of this knowledge to Ireland must have occurred along exchange networks established by Beaker culture groups in Atlantic Europe. The technological background to Ross Island may be sought in contemporary mining activity in southern France or northern Spain and in the use of arsenical copper in Atlantic Europe (Ambert 2001). The mining of tetrahedrite fahlore at Cabrières provides an obvious source of knowledge, as do some of the mines of northern Spain. The stone mining hammers from Ross Island have parallels in the Cantabrian mines of El Aramo and El Milagro (e.g. Blas Cortina and Suárez Fernández 2010, fig. 22). Whether the Ross Island miners came from northern Spain or western France is unclear, but it is likely the new technology was introduced to Ireland from Atlantic Europe during the later 25th century BC.

Mount Gabriel

Ross Island continued to supply copper into the early centuries of the technological Bronze Age. The decline of this mine *c.*1900–1800 BC was followed by a new type of copper mining over the next four centuries or so across the peninsulas of West Cork and south Kerry. That involved the extraction of low-grade oxidised ore, principally malachite, from small drift mines located on exposures of sedimentary copper-beds. These mines are concentrated in the hilly interior of the peninsulas, at elevations of 60–340m OD, usually within 5km of the coast. The largest concentration occurs on the eastern slopes of Mount Gabriel (408m OD) in the Mizen Peninsula, Co. Cork, where 32 individual workings are recorded (Figure 1.8). Copper mining on this mountain *c.*1700–1400 BC was associated with fire-setting and the use of stone hammers (O'Brien 1994 for full publication of the Mount Gabriel research).

Mount Gabriel is one of the best preserved Bronze Age mining landscapes in Europe, located in a blanket bog environment with minimal disturbance from later mining or other activities. The Bronze Age workings are dispersed across the eastern and southern slopes of the mountain at elevations of 150–340m OD. They occur within a Late Devonian sedimentary geology consisting of thick sequences of purple mudrock and fine-grained sandstone, interbedded with thin grey-green units of coarser sandstone. The copper mineralisation occurs within the grey-green strata of this red-bed sequence. They are mostly small inclined openings driven into vertical rock faces where the green sandstone beds are exposed. The latter contain disseminated copper minerals, visible when the outcrop exposure is stained green by the copper carbonate mineral, malachite. The distribution of workings indicates a careful search for these copper-beds, as well as an empirical understanding of the geological factors controlling their exposure. The miners only extracted rock that might contain copper minerals, moving to other exposures once a particular working was exhausted. Some workings were abandoned after less than one metre, with the largest archaeologically excavated examples worked to 11m (a few others may be deeper). The size of individual mines depended on the concentration of secondary copper minerals present and the difficulty of keeping inclined workings dry when fire-setting.

Evidence of the latter technology is visible on the mine walls, which generally have a smooth concave profile. This, together with the discovery of large quantities of roundwood fuel and charcoal within and close to the workings, confirms the use of fire-setting in rock extraction. In a typical daily cycle, fires were burnt against the mineralised rock face for many hours causing thermal fracture, at which point it was pounded with stone hammers. The miner's task was helped by micro-structures within the rock that allowed fragments to be prised out using fingers and wooden sticks. Experiments have shown that up to five centimetres of rock could be removed in this way before the next firing was necessary. On that basis, a single 10m deep mine on Mount Gabriel might have involved up to 200 fires over a period of several months. This would have consumed huge amounts of wood fuel. It is estimated that the extraction of approximately 4000 tonnes of rock from 32 recorded mines on the mountain required anything from 4000–14000 tonnes of roundwood fuel. The type of fuel used is confirmed by the discovery of a large quantity of branches in one of the waterlogged mines, many with axe tooling marks (O'Brien 1994, plates 37–9). Tree-ring analysis indicates organised collection to meet those enormous fuel requirements, while pollen

Figure 1.8 Bronze Age mining landscape on Mount Gabriel, Mizen Peninsula, Co. Cork. Inset: Mine 3, radiocarbon dated 1700–1660 BC (photograph: William O'Brien).

studies in the locality point to some form of woodland management (Mighall *et al*. 2000). Oak and hazel were mainly used, however species such as alder, ash, birch, pine and willow were also collected. Examples of wooden equipment include shovels carved from alder, twisted withies of hazel and willow for stone hammer handles, oak planks used as steps inside the mines, as well as splints of resinous pine used in torches.

Once rock was extracted, the next task was to separate the copper minerals to prepare an ore concentrate that could be smelted to metal. Ore beneficiation began with the coarse crushing of rock extract using stone hammers and anvil stones, with continuous hand-sorting of visibly mineralised fragments. This produced low mounds of crushed rock spoil near the mine entrances, containing large amounts of charcoal and broken stone hammers ('mauls'). The latter are rounded cobbles gathered from local beach deposits for use, either hand-held or hafted, at the mine face or in surface concentration of copper ore. They broke easily being of similar geology to the mine rock, which explains why many thousands of those implements were used over three centuries or so of mining on the mountain.

The Mount Gabriel mines were short-lived operations, probably undertaken on a seasonal basis due to the demands of the agricultural year. Mine flooding would have hindered fire-setting and may have caused the early abandonment of many workings. For that reason, it is likely individual mines were worked over a short period, with the extraction cycle at different outcrops overlapping to provide for continuous output during the mining season. This was probably organised around a diurnal fire-setting cycle, which allowed miners time to rest, process copper ore and engage in ancillary activities. Some individuals were engaged in underground rock extraction and surface ore concentration, while others supported the mining effort by collecting fuel from local woodland or hauling stone cobbles from beach sources up to 4km away. Food supply was probably organised from local farms where the miners lived. Those settlements have not been discovered, but their general location can be inferred from the occurrence of Bronze Age ritual monuments in the vicinity of the mountain.

On present evidence, the mining on Mount Gabriel concluded with the preparation of crushed ore concentrates ready for the smelting furnace. No evidence of smelting is recorded on the mountain, partly because those processes were non-slagging, with any furnace remains likely to be concealed by the later growth of blanket peat. The amount of copper ore extracted on Mount Gabriel was small, certainly when compared to the Ross Island mine. Current estimates suggest that these mines may have yielded as little as 15–20 kg of metal a year, enough to make 40–50 bronze axeheads for local needs and exchange into the wider region (O'Brien 1994, table 12).

Copper mining ended on Mount Gabriel around 1400 BC, probably when the supply of malachite from copper-bed exposures was exhausted. Similar mine workings of the same period, occurring either individually or in small clusters, are known from five other locations in the Mizen peninsula to the west of Mount Gabriel. One of these is on Ballyrisode Hill, Co. Cork, where in 1854 a hoard of twelve polished stone axes was discovered in a small fire-set working radiocarbon dated 1853–1619 BC. A Mount Gabriel-type stone hammer was discovered at infilled mine workings at nearby Toormore, an area where an important votive deposit of Early Bronze Age copper was discovered (O'Brien, Northover and Cameron 1989/90). Similar mines are also recorded at Boulysallagh in the Goleen area at the western end of the Mizen Peninsula, where 4–5 infilled workings and surface spoil containing stone hammers are visible today. This mine is radiocarbon dated 1883–1691 BC. Two other Mount Gabriel-type workings in the same area, Callaros Oughter and Carrigacat, are dated 1879–1531 BC and 2009–1693 BC respectively (O'Brien 2003).

Farther north, four Mount Gabriel-type copper mines have been identified in the Beara Peninsula of Co. Cork (Figure 1.6; O'Brien 2015, 134). They include an undated example at Tooreen in the mountains above Glengarriff, where there is a large cavernous opening with surface spoil deposits (Figure 1.9). Another example has been discovered at Canshanavoe in the mountains north of Adrigole village, Co. Cork. There are at least two areas of copper-bed extraction at this location, one of which contains three fire-set workings and a large spoil deposit with charcoal dated 1600–1430 BC. Other examples in this peninsula include Crumpane on the mountain ridge overlooking Eyeries, worked in the period 1700–1500 BC (O'Brien 2009), and an undated mine at Reentrusk in the Allihies area. Finally, there are two Mount Gabriel-type mines recorded on the southern side of the Iveragh Peninsula, Co. Kerry. The mines at Staigue near Sneem, and Lambs Head, Caherdaniel, are not dated, nor is a fire-set working ('St Crohane's Cave') on a quartz-sulphide vein on nearby Coad Mountain (O'Brien 1987a (vol. 2), 272–292).

Compared to Ross Island with its rich copper deposit, the Mount Gabriel-type mines represent a different approach to metal sourcing in the Bronze Age. The mining strategy was designed to maximise returns from low-grade mineralisation by extensive exploitation of small copper-bed exposures in the landscape. The proliferation of surface workings represents a limited investment of time and resources by small groups working on a seasonal or sporadic basis. That is indicative of the social context in which this small-scale mining was undertaken (O'Brien 2000).

What came next?

By 1400 BC primary copper production involving organised mining was declining in both Britain and Ireland. This is the picture presented by radiocarbon data from twenty or so early copper mines sampled in south-west

Figure 1.9 Bronze Age copper mine at Tooreen, Beara Peninsula, Co. Cork (photograph: William O'Brien).

Ireland, mid and north Wales and the English midlands (O'Brien 1994; 2003; 2004; Timberlake and Marshall 2019). The decline of copper mining in the later Bronze Age was a wider phenomenon across Atlantic Europe, coinciding with a growing demand for metal in societies with expanding trade connections.

Several theories can be advanced to explain the absence of insular copper mines during the later second millennium BC. One possibility is that mines did exist, but have not survived or cannot be easily recognised today. The former might be connected to a change in the type of ores extracted, possibly involving deeper mining of mineral deposits that were intensively worked in later periods. Against this, is the very notable absence in Ireland and Britain of slags connected to the smelting of copper-iron sulphide ores. This means that any indigenous mining after 1400 BC continued to rely on surface occurrences of oxidised mineralisation. The depletion of those accessible and easily smelted copper ores, combined with an inability to process copper-iron sulphides, may have been significant factors in the decline of mining during the Middle Bronze Age.

The destruction of mining evidence is certainly relevant, but is unlikely to be the entire explanation as Late Bronze Age mines are well known in other parts of Europe (O'Brien 2015). Archaeological visibility may be relevant, particularly if there were significant changes in mining technology. The replacement of fire-setting would remove distinctive wallrock patterns, while reducing the sample material available for radiocarbon dating. The use of large numbers of stone hammers in earlier copper mines is also relevant, as their replacement by specialised bronze tools would remove an important surface indicator of this activity. With no evidence the latter were used for mining in Atlantic Europe during the later Bronze Age, there may have been few options but to continue with the older technology.

The rise and fall of different mining regions can be understood in terms of boom/bust cycles, however the abandonment of established mines in the Bronze Age was not driven by economic forces alone. The closure of individual mines and a decline in mining at a regional level must also be understood in relation to the socio-political context of these ventures. This is a complex issue with many variables, such as technological constraints and alternatives to metal supply, such as recycling and long-distance trade. Some of these questions can be explored in relation to a recent discovery in south-west Ireland, which provides an insight into the final stages of copper mining there during the Bronze Age. The mine at Derrycarhoon provides the first evidence of continued supply of primary copper from an Irish mine during the Middle/Late Bronze Age transition.

1.4 Derrycarhoon Mine Project

This small copper mine lies in hilly terrain, 5km north of the village of Ballydehob on the north-east side of the Mizen Peninsula, Co. Cork (Figure 1.6). The discovery there in 1846 of 'Danish Mines', consisting of narrow trench workings '…smothered up by a growth of peat, over fourteen feet deep' (Kinahen 1886, 202), received much attention in antiquarian and mining circles in the late nineteenth century. Jackson (1980) interpreted this as representing six Mount Gabriel-type drift mines and a large open-cast, all of Bronze Age date. That interpretation was challenged by Briggs (1984) who rejected the possibility of Bronze Age mining at the site, proposing instead the 1846 discoveries are post-medieval in date. This was dismissed by Jackson (1984) on the basis of dates for the Mount Gabriel mines, which he argued were of similar type and technology to those at Derrycarhoon.

Around that time, the author reviewed those arguments and supporting historical information, but was unable to resolve the issue of Bronze Age copper mining (O'Brien 1989). No further research was undertaken at the site until 2007, with investigations of the Mount Gabriel and Ross Island mines pursued in the intervening years (O'Brien 1994; 2004). Work resumed at Derrycarhoon in 2007 with the first detailed survey of the archaeological area (O'Brien 2007a), undertaken to advise the National Monuments Service in advance of the felling of this forestry in 2014. In 2010 the author carried out sample excavation of surface spoil at Derrycarhoon, with one of the early trench mines excavated the following year (O'Brien 2010; 2011). Radiocarbon dates from both contexts confirmed copper mining at this location in the Middle to Late Bronze Age transition, *c.*1300–1000 BC. The results of this survey and excavation at Derrycarhoon were then published (O'Brien and Hogan 2012; O'Brien 2013; O'Brien 2019).

In 2018 a new stage of research began, with further survey and sampling at the site. The cultural landscape of the Bronze Age mine was explored at a local and regional level. The environmental setting and impact of this mining was examined through pollen analysis, details of which were recently published (Kearney and O'Brien 2021). Isotopic and chemical analysis was undertaken to examine whether the Derycarhoon ore deposit correlates with Middle and Late Bronze Age metalwork in the region and farther afield. The results of these and other studies are presented in this monograph.

Research design

This project has four broad aims, designed to examine the geological setting, mining history, technology, and wider context of Derrycarhoon mine. These aims and accompanying research objectives may be listed as follows:

Aim 1 (Geology)

Understand the physical setting of the mine, its bedrock geology, mineralisation and landform setting.

Objectives:

1a. Review published sources and mineral exploration data on the bedrock geology and mineralisation of the mine.

1b. Sampling of copper minerals for chemical and lead isotope analysis.

1c. Visualisation of surface features using ground and aerial survey methods, with geophysical imaging of the trench mines.

Aim 2 (Mining history)

Reconstruct the history and chronology of copper mining at Derrycarhoon.

Objectives:

2a. Review published and archival sources for the history of mining and mineral exploration at Derrycarhoon.

2b. Conduct excavation of an early mine working and surface spoil to obtain cultural material and stratified samples for radiocarbon dating.

2c. Carry out a detailed study of the 'Derrycarhoon Tube' using archival and other sources.

Aim 3 (Technology)

Examine the approach to mining and prospecting, and the technology in different periods.

Objectives:

3a. Archaeological and geophysical survey of surface workings and other mining features.

3b. Sample excavation to examine the size and form of the early trench mines.

3c. The recovery and analysis of mining tools used in the working of this mine.

Aim 4 (Environment)

Understand the palaeoecology and environmental impact of mining at Derrycarhoon

Objectives:

4a. Review historical records of peat growth at the mine site, with coring to identify surviving deposits.

4b. Conduct a new palynological study to reconstruct the vegetational history of Derrycarhoon

4c. Use pollen data to assess the environmental impact of Bronze Age mining at Derrycarhoon and other anthropogenic impacts on local vegetation in that period.

Aim 5 (Wider Context)

Explore the settlement background and cultural affinities of Derrycarhoon mine and its contribution to the circulation of metal in the Irish Bronze Age.

Objectives:

5a. Investigate Bronze Age archaeology within a 10km distance to identify settlement locales connected to the mine.

5b. Examine a possible connection between the Derrycarhoon miners and culture groups of the 'Stone Circle Complex' in the region.

5c. Conduct a pilot programme of chemical and lead isotope analysis of Middle and Late Bronze Age axeheads from the Cork region to assess the potential circulation of the copper produced at Derrycarhoon copper in that period.

Thanks to the support of Professor Johan Ling, the Derrycarhoon project was included in the 'Moving Metals' project based in the University of Gothenburg. That project examined the role of Bronze Age warrior elites in Scandinavia in trade networks across Atlantic Europe (Ling *et al*. 2013; 2014; 2019; Ling, Earle and Kristiansen 2018). Ore samples from Derrycarhoon and samples of contemporary metalwork were submitted to the project for lead isotope and chemical analysis. The aim was to examine the potential contribution this Irish mine made to the supply of copper in the Atlantic Bronze Age.

Finally, as already mentioned, this research began under a cloud of controversy concerning the chronology of Derrycarhoon mine. The project has been able to resolve that issue through historical research and scientific dating. This was the first geo-archaeological fieldwork undertaken at the site. While the scale of investigation is small, there is important new information on geological setting and palaeoenvironment, and on the mining strategies and technology employed in different periods. This provides a new understanding of the history of a small mining landscape from the Bronze Age to the present day. Through this research it is hoped to promote awareness and appreciation of that mining heritage, in an effort to protect the site from further damage caused by forestry and mineral exploration.

Layout of this book

Having introduced the subject matter, **Chapter 2** looks at the recent history of mining at Derrycarhoon, and the discovery in 1846 of 'Danish Mines' and primitive tools of which 'no previous tradition or suspicion had been entertained' (*Mining Journal* 1847, 70). This is supported by two appendices to the book that document those contemporary accounts. Later interpretations of the finds are examined, as well as recent commentary on their antiquity. **Chapter 3** examines the geology of Derrycarhoon and how the mining landscape was created. The surface evidence of mining is recorded by archaeological and geophysical survey, which also examines the extent to which this archaeology was damaged by recent conifer plantation and other activities.

Chapter 4 presents the results of archaeological excavation undertaken in 2010–11 at Derrycarhoon. This includes the sampling of surface spoil and the full excavation of an early mine working. The stratigraphic record is supported by details of early mine equipment and items of worked/unworked wood. The excavation recovered organic samples (wood, charcoal, antler and peat) from secure contexts for radiocarbon dating, the results of which are discussed in **Chapter 5**. The chapter also considers the 'Derrycarhoon Tube', a curved wooden object of later medieval date that has been the subject of much speculation since its discovery in 1846 at the mine. This study will advance a new interpretation of this object, which is now held in the collections of the Pitt-River Museum, Oxford, where it was not available for study in 2020–21 due to covid pandemic restrictions.

Chapter 6 presents the results of a palynological study at the mine undertaken for this project. This provides an important insight into the vegetation record and environmental impact of the Bronze Age mine in a local setting. **Chapter 7** explores the contemporary settlement landscape of the Bronze Age mine at Derrycarhoon. This involves analysis of all late prehistoric sites and artifact finds within a 10km distance of the mine. Particular attention is paid to monuments of the Stone Circle Complex, as proxy indicators of settlement in a Bronze Age landscape with generally low archaeological visibility and survival. This local study is expanded to consider the record of Middle to Late Bronze Age settlement in the Cork region.

Chapter 8 examines the technology and operation of the Bronze Age mine, from prospection to rock extraction and ore beneficiation. New data is presented on the chemistry and lead isotope signature of the copper mineralisation at Derrycarhoon, in relation to a pilot programme of metalwork analysis for the region. The objective there is to understand the circulation of metal from this mine during the later Bronze Age. The study concludes in **Chapter 9** by examining the significance of Derrycarhoon in the mining history of south-west Ireland, and the contribution it made to metal supply in Ireland and the wider Atlantic zone during the Middle and Late Bronze Age. Finally, the conservation of mining heritage at Derrycarhoon is considered in relation to the history of the site in the modern era and the lessons that might be learned.